Collection Systems

Grade 1 – 2

Course #1203

2021 Edition

Fleming Training Center
Your Partner in Clean Water

TN Department of Environment & Conservation

Fleming Training Center

Collection Systems Grade 1&2

Course #1203

March 1 - 5, 2021

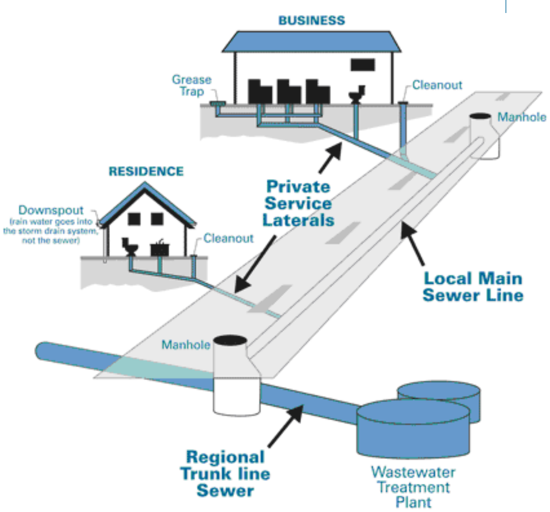

Diagram of a sanitary sewer system

<u>Monday, March 1:</u>

8:30 Exam References & NTK — Sara Terry
9:00 Wastewater Characteristics
10:00 Wastewater Collection Systems
12:00 LUNCH
1:00 Flow Measurement
2:00 Math—Solve for X, Dimensional Analysis

<u>Tuesday, March 2:</u>

8:30 Cross Connection Control — Ben Rodriquez
9:45 Safety & Trenching Safety
12:00 LUNCH
1:00 Pumps — Amanda Carter
2:30 Equipment Maintenance

<u>Wednesday, March 3:</u>

8:30 Pipe Materials — Ben Rodriquez
9:15 Pipe Installation
10:00 Trench Safety
12:00 LUNCH
1:00 Lift Stations
2:00 Inspections and Testing
2:00 Math—Circumference, Area, & Volume

<u>Thursday, March 4:</u>

8:30 Pipeline Cleaning and Maintenance — Ben Rodriquez
10:00 Underground Repair
12:00 LUNCH
1:00 TDEC Operator Rules
1:30 Sewer Renewal & Rehabilitation
2:00 TDEC Regulations
2:30 Math—Velocity & Flow

<u>Friday, March 5:</u>

8:30 Course Review — Sarah Terry
11:00 Course Evaluation and Exam

State of Tennessee

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Collection Systems

Section 1	Exam Need to Know & References	1
Section 2	Wastewater/Collections Systems Overview	7
Section 3	Flow Measurement	27
Section 4	Pipe Materials	39
Section 5	Pipe Installation	49
Section 6	Inspection and Testing	57
Section 7	Pipeline Cleaning and Maintenance	67
Section 8	Underground Repair	89
Section 9	Renewal and Rehabilitation	97
Section 10	Lift Stations	115
Section 11	Pumps	127
Section 12	Equipment Maintenance	149
Section 13	Safety and Trenching	163
Section 14	Cross Connection Control	199
Section 15	Math Review	223
Section 16	Rules and Regulations	259

Section 1

Collection Systems Operator Exam
Need to Know and References

Suggested Collection System Exam References

The following are approved as reference sources for the collection examinations. Operators should use the latest edition of these reference sources to prepare for the exam.

Textbooks

California State University, Sacramento (CSUS) Foundation, Office of Water Programs (www.owp.csus.edu)

- Operation of Wastewater Treatment Plants, Volume I and II
- Operation and Maintenance of Wastewater Collection Systems, Volume I and II
- Manage for Success

Water Environment Federation (www.wef.org)

- Operation of Municipal Wastewater Treatment Plants - Manual of Practice No. 11
- Existing Sewer Evaluation and Rehabilitation - Manual of Practice FD-6
- Wastewater Collection Systems Management - Manual of Practice No. 7

Regulations

- Code of Federal Regulations, Title 40 (www.gpo.gov).
- Design Criteria for Sewage Works, State of Tennessee, Department of Health and Environment, Division of Water Pollution Control, Nashville, 1995.
- Rules Governing Water and Wastewater Operator Certification, State of Tennessee, Department of Environment and Conservation, Board of Certification for Water and Wastewater Operators, Nashville, TN, December 2009, Section 1200-5-3.

Study Guides

- WEF/ABC Collection Systems Operator's Guide to Preparing for the Certification Examination, Water Environment Federation, (www.wef.org).
- Applied Math for Wastewater Plant Operators, Price, Joanne. 2000. Boca Raton, FL: CRC Press (www.crcpress.com).

Suggested Primary Collection System Exam References

The following are approved as reference sources for the ABC water treatment examinations. Operators should use the latest edition of these reference sources to prepare for the exam. These reference are not the only reference an operator should use in studying for the exam, however, these are the primary references used in developing the exam.

Collection 1

- ****CSUS Operation and Maintenance of Wastewater Collection Systems Volume I**
- ****CSUS Operation of Wastewater Treatment Plants Volume II**
- ***Design Criteria for Sewage Works State of Tennessee Department of Health and Environment Division of Water Pollution Control Nashville, Latest Revision***
- **CSUS Operation and Maintenance of Wastewater Collection Systems Volume II**
- **CSUS Operation of Wastewater Treatment Plants Volume I**
- **Price Joanne Kirkpatrick Applied Math for Wastewater Plant Operators Technomic Publishing Company Inc. Lancaster PA 1991**
- *Rules Governing Water and Wastewater Operator Certification, State of Tennessee, Department of Environment and Conservation, Board of Certification for Water and Wastewater Operators, Nashville, Latest Revision*

Collection 2

- ****CSUS Operation and Maintenance of Wastewater Collection Systems Volume I**
- ****CSUS Operation of Wastewater Treatment Plants Volume II**
- ****CSUS Operation and Maintenance of Wastewater Collection Systems Volume II**
- **CSUS Operation of Wastewater Treatment Plants Volume I**
- ***Design Criteria for Sewage Works State of Tennessee Department of Health and Environment Division of Water Pollution Control Nashville, Latest Revision***
- **CSUS Operation and Maintenance of Wastewater Collection Systems**
- *Rules Governing Water and Wastewater Operator Certification, State of Tennessee, Department of Environment and Conservation, Board of Certification for Water and Wastewater Operators, Nashville, Latest Revision*

There are 2-3 primary references for each of exam. The ** denotes that 20+ of the exam items are linked to the noted reference.

Bold items have at least three items linked to them. Any references that are not in bold, have only 1-2 items linked to them.

The Tennessee State references are included, however, there is a sixth reference if the sixth had at least three items linked to it; in some cases this was a tie of 2-3 references with just a few items each. State of Tennessee references are italicized.

Grade 2 Collection Systems Operator
Need-To-Know Criteria (Subject Areas)

The following list of categories suggests topics of information which are important to know in order to be a successful and proficient Grade 1 Collection Systems Operator. The list may not be all inclusive, and knowledge of additional topics may be of benefit to the operator.

Category of Information: Process

Gravity Sewers
- Describe
- Operation/maintenance
- Design/Construction

Pressure Sewers
- Describe
- Operation/maintenance
- Design/Construction

Vacuum Systems
- Describe
- Operation/maintenance
- Design/Construction

Sewer Equipment
- Application
- Maintenance
- Use/Procedure

Aeration
- Purpose
- Describe types

Chemical Additives
- Purpose
- Methods
- Equipment

Chlorination
- Purpose
- Methods
- Equipment

Corrosion Control
- Describe
- Methods

Infiltration/Inflow Devices
- Describe
- Methods of inspection and testing
- Concept of sewer rehabilitation

Lift Stations
- Operation/maintenance
- Design/Construction

Flow/Velocity Measurement
- Describe
- Purpose
- Flow regulators

Manholes
- Describe
- Purpose
- Design/Construction

Cross-Connection
- Definition
- Types of devices

Category of Information: Support Systems/Equipment

Motors
- Single phase
- Poly phase
- Variable speed

Drives
- Coupled
- Direct (Shaft; Gear)
- Speed Reducer (Fixed; Variable)
- Right angle

Blowers and Compressors
- Centrifugal
- Positive displacement (Rotary; Piston)

Generators – AC & DC

Engines – Gasoline, Diesel & Gas

Hydrants (Basic)

Pumps
- Air Lift
- Centrifugal
- Positive displacement
  - Piston plunger
  - Progressive cavity
  - Diaphragm
- Screw
- Turbine
- Metering
- Ejector

Joints
- Flanged
- Compression
- Dresser
- Victualic
- Fused
- Threaded

Category of Information: Support Systems/Equipment (continued)

Valves
- Ball
- Check
- Globe
- Gate
- Plug
- Petcock
- Pressure control
- Vacuum relief
- Mud
- Butterfly
- Multiport
- Telescoping
- Sluice Gate
- Air release
- Foot
- Altitude

Pipes
- Types
- Cleaning/maintenance
- Sewer rehabilitation

Fittings
- Coupling
- Union
- Plug/Caps
- Corporation (Ferrell; Cock)
- Curb Stop
- Special

Odor Control
- Biofilters
- Chemical Additives
- Scrubbers

Rolling Stock
- Service vehicles
- Fork lifts
- Trucks
- Tractors
- Trailers
- Lawn Mowers
- Loaders
- Portable pumps
- Generators

Chemical Feeders
- Solids
- Liquids
- Slurry

Measuring and Control
- Signal generators
  - Kennison nozzle
  - Magnetic flowmeter
  - Parshall flume
  - Proportional weir
  - Rectangular weir
  - Venturi
  - Propeller meter
  - Ultrasonic
  - Pitot tube
- Signal transmitters
  - Electric
  - Pneumatic
  - Hydraulic
  - Mechanical
  - Telemetry
- Signal receivers
  - Counters
  - Indicators
  - Log Scale Indicators
  - Totalizers
  - Recorders
  - Combination recorders
- Meters
  - Hydraulic – Rotameters
  - Electrical – Amp
  - Electrical – Watt
  - Electrical – Watt Hour
  - Electrical – Multi
  - Electrical – Multi – VOM
  - Electrical – Megger
  - Mechanical – RPM
- Alarms
- Controls
  - Pneumatic
  - Float
  - Hydraulic
  - Electrical
  - Telemetry
  - Timers

Transformers
- Step down
- Step up

Safety Equipment
- Personal protection gear
- Traffic control (Warning devices; Barricades)
- Hazard detection
- First Aid/Hygiene

Category of Information: Laboratory

Materials testing
- Concrete
- Piping

Category of Information: General Information/Knowledge

Units of expression
- Define units
- Convert units

Sources and characteristics
- Characterizing sources
- Quality/quantity
- Identify characteristics
- Describe effects

Electrical
- Basic concepts
- Math calculations

Hydraulics
- Basic concepts
- Math calculations

Maps/plans
- Interpretation and use
- Describe types

Section 2

Wastewater Characteristics & Collection Systems Overview

Wastewater Collection Systems

Wastewater Collection Systems

- A wastewater collection system gathers the used water from homes and businesses and conveys it to a wastewater treatment facility
- The used water comes from kitchens and bathrooms or different processes of homes, businesses and industries
- Additional water can also enter the collection system from groundwater, surface water, and stormwater

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Wastewater Collection Systems

- The system must be kept in good operating conditions because if it fails…
  - Blockages occur in the lines resulting in wastewater backups into homes and businesses
  - Raw wastewater can bypass the treatment facility resulting in contamination of surface waters and public health issues
  - Streets collapse – leaking sewer mains saturate the ground surrounding the pipe and eventually wash away the bedding materials leaving a void that can cause a collapse in the street above

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Wastewater Collection Systems

- Proper operation and maintenance of the collection system is a way to protect the capital investment the community has made in the system so that it performs its intended function and be used efficiently throughout the planned life of the system
- This is achieved by trained collection system operators who use manual and power operated equipment to install, inspect, and repair the system to keep it running

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Wastewater Collection Systems

*"The better collection systems operators are trained to do their jobs, the more effectively a wastewater treatment plant can do its intended job."**

* Operation and Maintenance of Wastewater Collection Systems – Vol. I, 7th Edition

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Intro to Wastewater Treatment

Why do we treat waste?

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Purpose of Wastewater Treatment

- To protect the environment and public health by:
  - Removing solids
  - Stabilizing organic matter
  - Removing pathogenic organisms

Disease causing

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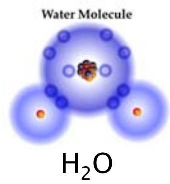
What is Pure Water?



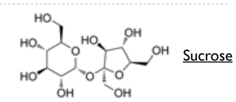
- Water is made up of two hydrogen atoms and one oxygen atom
- "Pure" water is manufactured in labs, even rain and distilled water contain other substances called impurities
- The majority of wastewater is just water, a much smaller portion are wastes

Waste Solids

- Total solids
- Dissolved solids
- Suspended solids
  - Settleable
  - Nonsettleable
- Floatable solids
- Organic and inorganic solids

Types of Waste

- Organic waste
  - Contains carbon
  - *Will use up oxygen in water*
  - *More food = More bugs = More oxygen used*

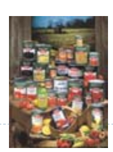


- Inorganic waste
  - Salts
  - Metals
  - Gravel
  - Sand

- Both may come from domestic or industrial waste
- Collection system job is to get <u>all</u> solids to WWTP

Organic Waste

- Domestic wastewater contains a large amount of organic waste
- Industries also contribute some amounts of organic wastes
- Some of these organic industrial wastes come from vegetable and fruit packing, dairy processing, meat packing, tanning and processing of poultry, oil, paper and fiber



Importance of Organic Matter

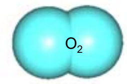
- Organic material consumes oxygen in water
  - Bacteria will "feed" on organic matter and most need oxygen to be able to do this
  - We want these bacteria to "feed" on the organic matter and use it up in the treatment plant and not in our receiving water
- High concentrations of organic material can cause taste and odor problems in recreational and drinking water
- Some material may be hazardous

Oxygen Depletion

- When organic wastes are discharged to a receiving stream bacteria begin to feed on it, these bacteria need oxygen for this process
  - As more organic waste is added to the receiving stream, the bacteria reproduce
  - As the bacteria reproduce, they use up more oxygen, faster than it can be replenished by natural diffusion from the atmosphere
  - This can potentially cause a fish kill and odors

Oxygen Depletion

- Most living creatures, including fish, need oxygen to survive
- In water this oxygen is present as dissolved oxygen
  - Most fish can survive with at least 5 mg/L DO



Dissolved Oxygen

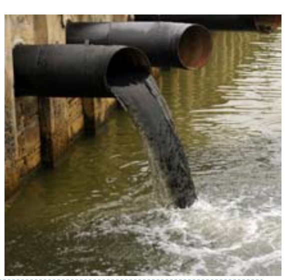
- There are two important factors that can influence the amount of dissolved oxygen present:
  - Water Temperature
    - Greater temperature → Less DO
    - Lower temperature → More DO
  - Organic matter
    - Organic material requires oxygen to decompose
    - More organic material requires more DO, and will tend to deplete water of DO

Oxygen Depletion

- One of the principal objectives of wastewater treatment is to prevent as much of this "oxygen-demanding" organic material as possible from entering the receiving water

Water Pollution

- Any condition caused by human activity that adversely affects the quality of stream, lake, ocean, or groundwater



NPDES Permit

- National Pollutant Discharge Elimination System
  - Required by the Federal Water Pollution Act Amendments of 1972 to help keep the nation's water suitable for swimming and for fish and other wildlife
  - Regulates discharges

Treatment

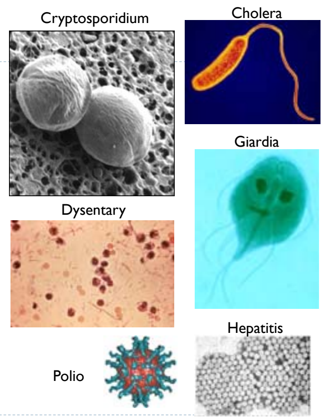
- The treatment plant actually removes the organic matter the same way a stream would in nature, but it works more efficiently by removing the wastes in secondary treatment
- The treatment plant is designed and operated to use natural organisms such as bacteria to stabilize and remove organic matter

Human Health

- Initial efforts for wastewater treatment came from preventing disease outbreaks
  - Most bacteria in wastewater are not harmful to humans
  - Humans who have a disease caused by bacteria or viruses can discharge some of these pathogens
  - Many serious outbreaks of communicable diseases have been traced back to contamination of drinking water or food from domestic wastewater
- ***Good personal hygiene is your best defense against infections and disease***

Diseases

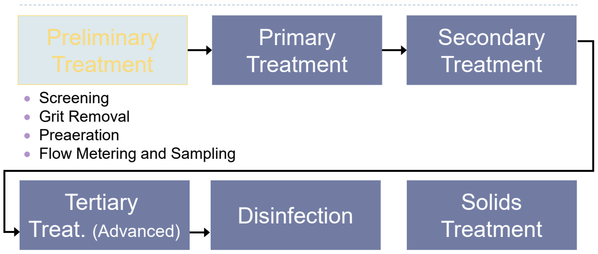
- Bacteria
  - Cholera
  - Dysentery
  - Shigella
  - Salmonella
  - Typhoid
- Viruses
  - Polio
  - Hepatitis (Jaundice)
- Protozoa
  - Giardia lamblia
  - Cryptosporidium parvum



Typical Wastewater Characteristics

- Fresh wastewater is usually a grey/dishwater color
  - Typically septic wastewater will have a black color
- Fresh domestic wastewater has a musty/earthy odor
  - If the wastewater is allowed to go septic, this will change significantly to a rotten egg odor associated with the production of hydrogen sulfide gas

Wastewater Treatment Processes



Preliminary Treatment

- The main goal of preliminary treatment is to remove as many solids as possible from the wastewater stream
- This is accomplished by passing the wastewater through screens to filter out large solids and then slowing the water down to settle out smaller solids
- Solids are removed and treated as solid waste and not treated with the dissolved solids in the wastewater

Solids

- Cause many problems in collection and treatment plant systems
  - Fill storage areas, clog ditches and channels
  - Interfere with mechanical systems
  - Associated with taste/color/clarity problems in drinking water

Preliminary Treatment

Solids Screening

- Variations: bar racks, mechanical rotating, rotary drum screen
- Must be cleaned regularly to prevent restriction of flow
- Failure to keep a bar screen clean can also result in a shockload
- Removes roots, rags, cans…

Preliminary Treatment

Muffin Monster

Solids Shredding

- Comminuter – device used to reduce the size of the solid materials in the wastewater by shredding
- Smaller solids can be settled out and cause less problems with pumps downstream
- Can help with clogging problems from rags and wipes
- Solids are not removed by a comminuter

Preliminary Treatment

Aerated Grit Chamber

- 1 ft/sec flow through grit chamber
- Used to remove grit – heavy, mainly inorganic solids (sand, egg shells, gravel, seeds, etc.)
- Aeration also freshens wastewater and helps remove floatables

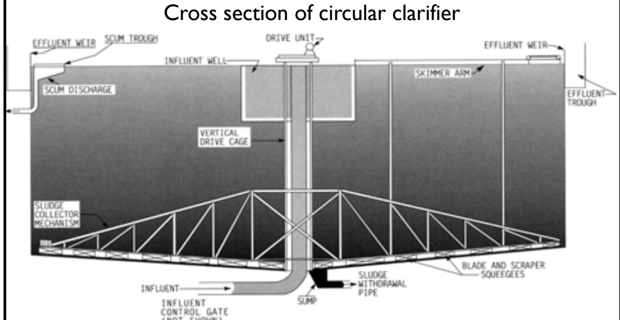
Wastewater Treatment Processes

Preliminary Treatment → Primary Treatment → Secondary Treatment → Tertiary Treat. (Advanced) → Disinfection → Solids Treatment

- Sedimentation and Flotation

Primary Clarifier

Cross section of circular clarifier



Primary Clarifier

- Goal of primary treatment is settle out more solids
- Velocity drops to < 1 fps
- Separates settleable and floatable solids
- Detention time ~ 1.5-2.0 hrs
- Raw water is gray

Wastewater Treatment Processes

- Preliminary Treatment → Primary Treatment → Secondary Treatment
  - Preliminary and Primary Treatment: Mechanical
  - Secondary Treatment:
    - Biological Treatment
    - Sedimentation
- Tertiary Treat. (Advanced) → Disinfection → Solids Treatment

Secondary Treatment

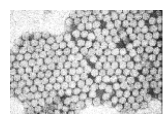
- The main goal of secondary treatment is to remove organic waste from the wastewater stream
- This is accomplished biologically by allowing the waste to come into contact and be consumed by a population of microorganisms
- The reduction of waste from the microorganisms occurs in some type of biological reactor

Biological Constituents

- Many are human pathogens
- Most occupy a role in the treatment process
- They are:
  - Bacteria
  - Archaea
  - Fungi/yeast
  - Protozoa
  - Rotifers
  - Algae
  - Viruses


Amoeba ingesting alga


Paramecia conjugating


Human hepatitis A virus

Biological Reactors

- There are different ways the "bugs" can come into contact with the waste
  - Fixed film reactors

Trickling Filter

Biological Reactors

- There are different ways the "bugs" can come into contact with the waste
  - Fixed film reactors

Rotating Biological Contactor

Biological Reactors

- There are different ways the "bugs" can come into contact with the waste
  - Mixed reactors


Oxidation Ditch


Sequencing Batch Reactor

Biological Reactors

- Secondary treatment requires a balance of organic waste and oxygen to maintain a healthy bug population for treatment


Fine bubble diffusers


Mechanical aeration

Biological Reactors

- A secondary clarifier is used settle out solids from the biological reactor to yield a treated effluent


Secondary Clarifier

Wastewater Treatment Processes

Preliminary Treatment → Primary Treatment → Secondary Treatment → Tertiary Treat. (Advanced) → Disinfection → Solids Treatment

- Chemical Nitrogen and Phosphorous Removal
- Biological Nutrient Removal
- Multimedia Filtration

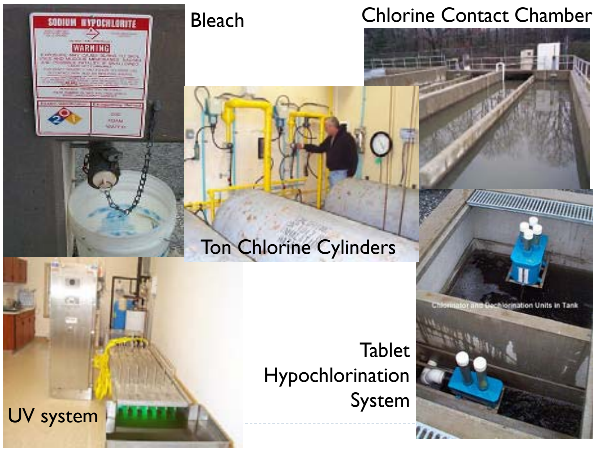
Wastewater Treatment Processes

Preliminary Treatment → Primary Treatment → Secondary Treatment → Tertiary Treat. (Advanced) → Disinfection → Solids Treatment

- Ultraviolet Irradiation
- Chlorine Gas
- Sodium Hypochlorite
- Calcium Hypochlorite

Disinfection

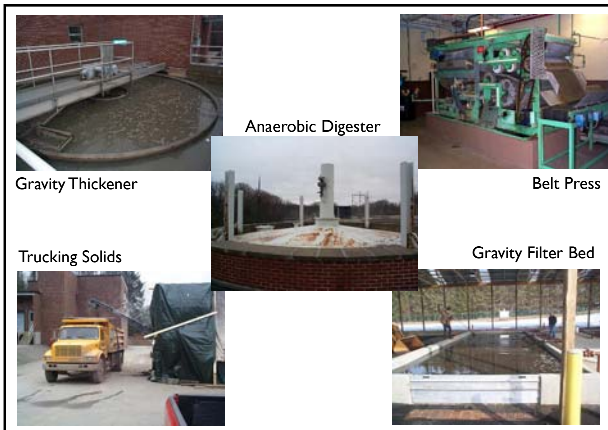
- Purpose is to kill pathogenic organisms still in wastewater
- Typically wastewater must contain 200 cfu/100mL for Fecal coliforms or 126 cfu/100mL for *E. coli* to be considered "disinfected"



Solids Treatment

Primary Treatment → Solids Treatment ← Secondary Treatment

- Digestion
- Dewatering
- Disposal



Effluent Discharge

- Most wastewater is discharged to a receiving stream, river, lake or ocean.
- Some is reclaimed or reused on golf courses, cemeteries, parks, etc.

Gravity
Small Diameter Gravity Systems (SDGS)
Pressure (STEP and Grinder Pump)
Vacuum

Wastewater Collection Systems

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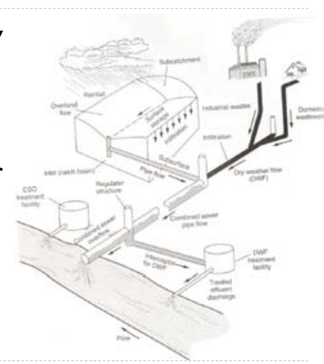
Wastewater

- Defined: water supply of a community or industry after it has been used
- Treatment: "onsite" or offsite ("centralized")
- Offsite treatment requires a "collection and conveyance" system



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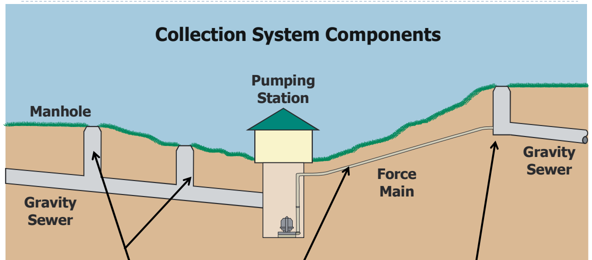
Wastewater Collection and Conveyance System



Manholes should be placed every 300-500 feet apart to provide access for inspections and cleaning

Minimum size is 4"

Constant minimum slope is required to provide a velocity of at least 2 fps to avoid solids depositing

Wastewater Collection and Conveyance System

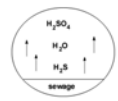
- Manholes are installed in lateral, main, trunk, and intercepting sewers for the purpose of placing persons, equipment, and materials into these sewers for inspection, maintenance, and the removal of solids from cleaning operations
- Manholes must be installed:
  - At the ends of any line 8" in diameter or larger line
  - Changes in grade, size of pipe or alignment
  - At intersections
  - And not greater than 400 ft on a 15" diameter and smaller sewers or 500 ft on 18-30" sewers

Wastewater Collection and Conveyance System

- Horizontal Separation – sewers should be laid with at least 10 feet of horizontal clearance from any existing or proposed water line
- Vertical Separation – when sewers must cross a water line, they should be laid 18" below the bottom of the water line

Wastewater Collection and Conveyance System

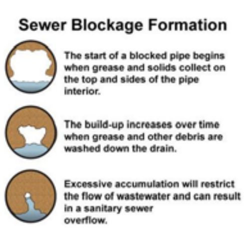
- Hydrogen sulfide is made in the collection system and can:
  - Make waste more difficult to treat
  - Damage concrete structures
  - Cause odor problems



- Biological activity in long, flat sewer lines will likely cause:
  - Hydrogen sulfide production
  - Oxygen deficiency in sewers, manholes or wet wells
  - Metal and concrete corrosion
- Chlorine can be used in the collection system or at the plant headworks to oxidize hydrogen sulfide

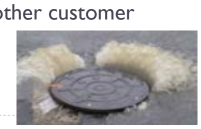
Oil and Grease

- Generally listed under one heading called FOG (fats, oils and greases) as it is often not important to know the exact make-up of this group of components.



O&M of Collection Systems

- The facilities should be kept in good operating condition
- What happens when collection systems fail due to lack of or improper operation and maintenance?
  - SSO – Sanitary Sewer Overflow
  - Blockages occurring in the sewer line that result in backups into homes, businesses and other customer facilities
  - Bypassing raw wastewater
  - Street collapse



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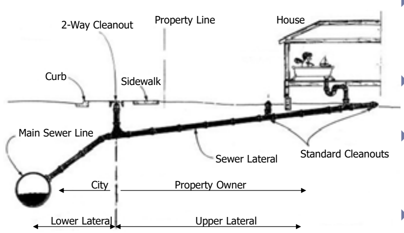
Building Service Lateral



Typical dwelling served by a main sewer in the street

- Connects internal plumbing to street sewer
- Usually homeowner is responsible
- Cleanout minimum **3 ft** from foundation
- Typically **4 inch** diameter
- Slope ¼ inch per foot minimum, 2%

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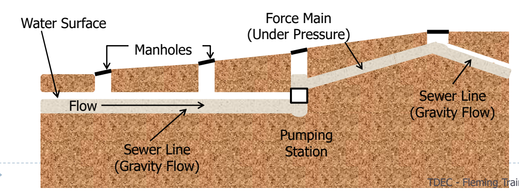
Conventional Gravity Sewer

- Uses natural slope of land to flow by gravity
- Manholes every 400-500 ft
  - State requirement: manhole at distance ≤ 400 ft for sewers 15 inches or less and 500 ft for sewers 18 to 30 inches
- Pump or lift station



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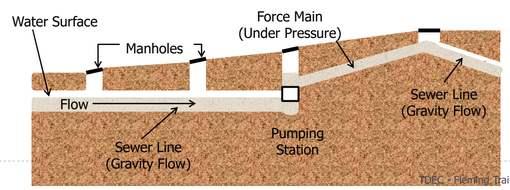
Conventional Gravity Sewer

- Scouring velocity- **2 ft/sec**
  - Flow < 2 ft/sec may lead to settling out of solids, stoppages, production of odors including toxic hydrogen sulfide, corrosive conditions
- Sewer not less than **2 ½ ft** deep



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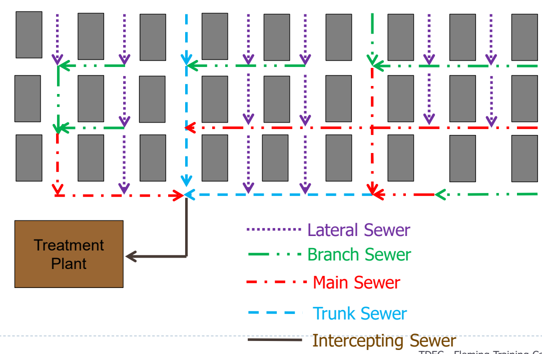
Gravity Collection Sewer



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Gravity Collection Sewer

- Building sewer – a gravity-flow pipeline connecting a building wastewater collection system to a lateral or branch sewer
  - The building sewer may begin at the outside of the building's foundation wall or some distance (2-10 ft) from the wall, depending on local sewer ordinances
  - Also called house connection or service connection
- Lateral sewer – a sewer that discharges into a branch or other sewer and has no other common sewer tributary to it
  - Sometimes called a "street sewer" because it collects wastewater from individual homes

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Gravity Collection Sewer

- Branch sewer – a sewer that receives wastewater from a relatively small area and discharges into a main sewer serving more than one branch sewer area
- Main sewer – a sewer line that receives wastewater from many tributary branches and sewer lines and serves as an outlet for a large tributary or is used to feed an intercepting sewer
- Trunk sewer – a sewer that receives wastewater from many tributary branches or sewers and serves a large territory and contributing population
- Intercepting sewer – a sewer that receives a flow from a number of other large sewers or outlets and conducts the waters to a point for treatment or disposal

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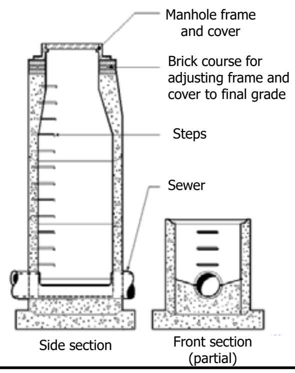
Sewer Manhole

- Place people, equipment and materials into sewer for inspection, maintenance and cleaning
- May not have steps since hazardous if corroded
- Minimum barrel diameter **48 inches**
- Inspected annually
- Reinforced concrete, brick, fiberglass



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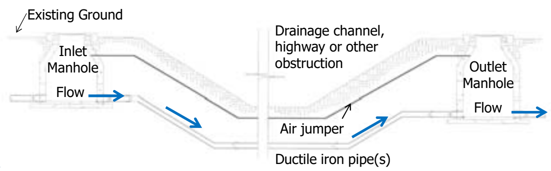
Inverted Siphon

- Sewer lines installed lower than the normal gradient of the sewer line to pass under obstructions such as watercourses and depressed roadways
- Wastewater is pushed through the siphon by the pressure resulting from the upstream sewer being higher than the downstream sewer



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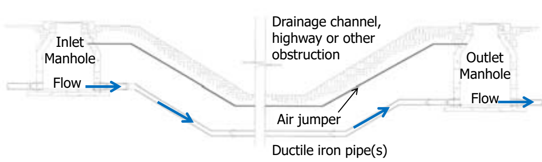
Air Jumper

- Air jumpers are sometimes constructed as part of an inverted siphon
- Since the siphon is completely filled with wastewater, a blockage in the flow of air in the sewer line occurs without an air jumper
- This blockage may cause a continuous release of toxic, odorous and corrosive hydrogen sulfide at the upstream siphon manhole
- Installation of jumpers prevents this from happening by providing the downstream flow of air that usually occurs above the wastewater in a partially filled sewer line



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Small Diameter Gravity Sewer (SDGS)

- Alternative wastewater collection system installed in areas where deep excavation is a concern, and in areas that are hilly or flat
- SDGS uses a smaller diameter pipe than conventional gravity sewers due to less solids
- Follows the surface contour of the land, reducing the amount of excavation and construction costs
- Septic tanks onsite discharge to small diameter gravity main
- Discharges effluent by gravity, pump or siphon
- **Minimum velocity 0.5 ft/sec**

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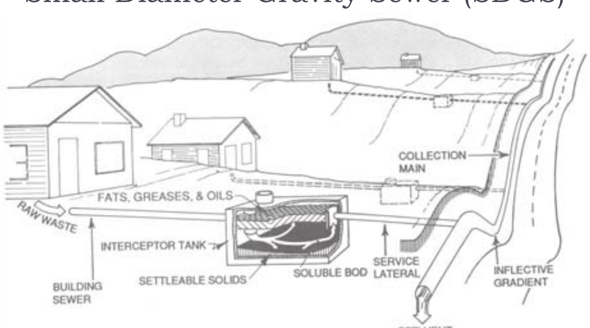
Small Diameter Gravity Sewer (SDGS)



Minimum velocity 0.5 ft/sec

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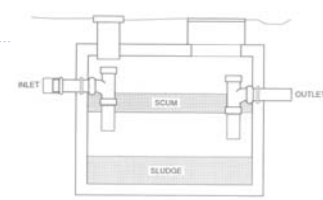
Interceptor Tank



Precast concrete, fiberglass, HDPE or coated steel common.

- Septic tank
- Removes floating and settleable solids
- Levels out flows
- Sludge solids decompose anaerobically
- Regular inspection to measure liquid level, depth of sludge & thickness of scum
- NO tank additive works

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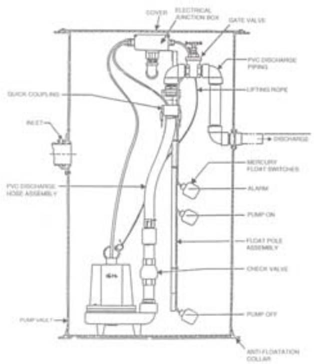
STEP – Septic Tank Effluent Pump Lift Station

- Simple reinforced concrete or fiberglass wet well after septic tank
- Submersible pump operated by mercury float switches
- Also on gravity mains to allow gravity flow at shallow depth



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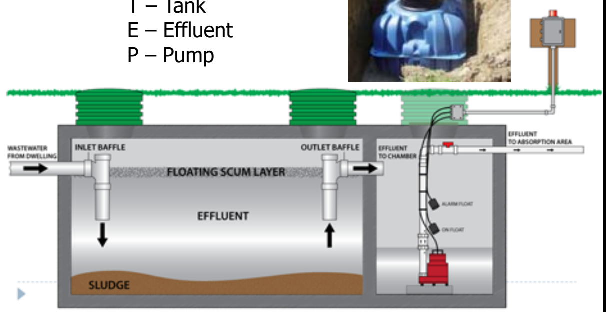
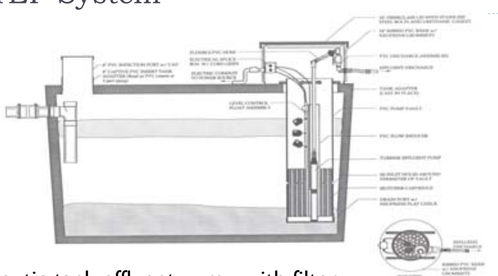
STEP System

S – Septic
T – Tank
E – Effluent
P – Pump



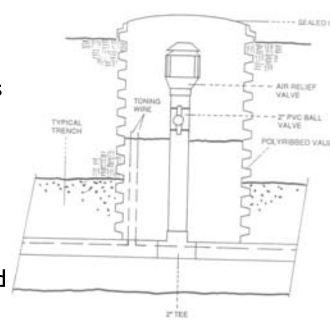
STEP System



- Septic tank effluent pump with filter
- Float activated mercury switch controls pump
- Keep OUT: eggshells, plastic, bones, grease

Vent & Air Release Valve

- Vent maintains flow in SDGS main
- Air release valve-vents air at high points in main that would restrict flow
- Gases vented from main often quite odorous- use activated carbon filter, soil bed masking agent



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Pressure Sewers

- Reasons:
  - Topography: Flat terrain or high slope
  - Rocky soil
  - High groundwater table

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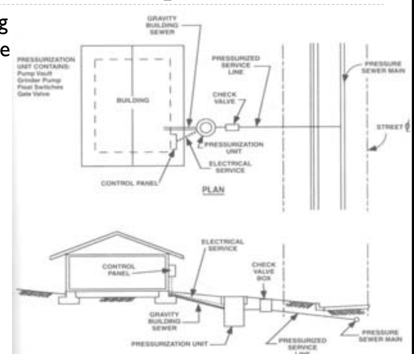
Pressure Sewers - Components

- 4" gravity building sewer at 2% slope
- Holding tank
- Grinder pump & controls
- Valves to isolate system
- Pressure main



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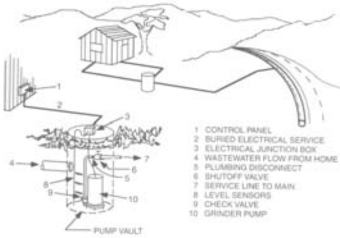
Grinder Pump System

- Submersible centrifugal pump with comminuting blade cuts and shreds solids in wastewater
- Pump unit acts to pressurize WW to move it through sewer
- WW flows from pump vault to pressurized main via a pressurized service line
- Grinder pump serving a home is usually 1-2 hp



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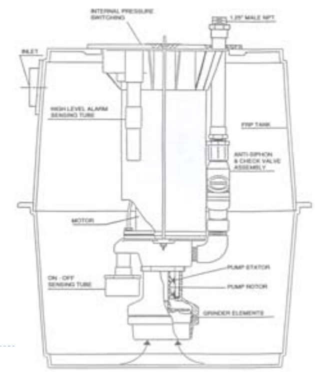
Progressive Cavity Grinder Pump

- Creates pressure that moves WW through sewer
- Reduces size of solids
- Pump, motor, grinder, pipes, valves, controls
- Pressure sensor measures liquid level



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Progressive Cavity Grinder Pump

- Check & gate valve on discharge prevent backflow
- Excavation not deep: 5-8 ft
- Uses small diameter pressure lines
- Odors associated with improper venting
- Maintenance: solids lodged in cutting blade
- Disadvantage: FOG is transported

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Pressure Sewer vs. Gravity Sewer

- Higher energy costs for pumping
- Greater costs for pumping facilities
- Deep trenches not necessary
- Inverted siphons not needed to cross roads and rivers
- Smaller pipes often needed
- Fewer stoppages (system pressurized)
- No I&I – no extra capacity needed
  - No root intrusion, air tight system

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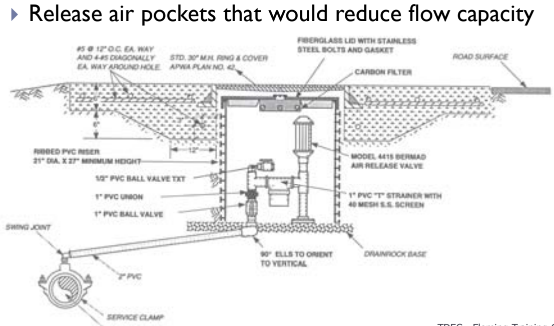
Automatic Air Release Assembly

- Located in high point of pressure sewer
- Release air pockets that would reduce flow capacity



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Pressure Sewer Cleaning

- Must have access for maintenance
- Manholes or access boxes must have valves and pipe spools that can be removed for cleaning the pipe
- Polyurethane pigs and swabs are slightly larger or the same size as the main to be cleaned
- Pigging typically done during low flow periods

Pipe with sludge before cleaning

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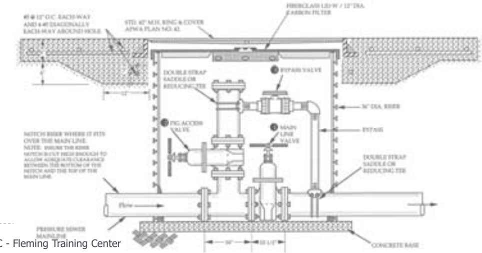
Pigging Port

- Installed to insert pig to clean inside sewer
- The poly pig is forced through the pipe under pressure
- Replaces manhole needed in gravity sewer
- Radio beacon device allows operator to track pig location



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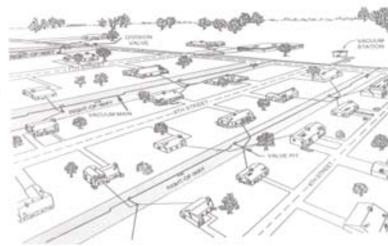
Vacuum Sewer Layout

- Applications: flat or rolling terrain, unstable soil, high water table, rocky terrain, urban development in rural areas
- 3 Components:
  - On-site valve pit
  - Vacuum collection piping
  - Central vacuum station



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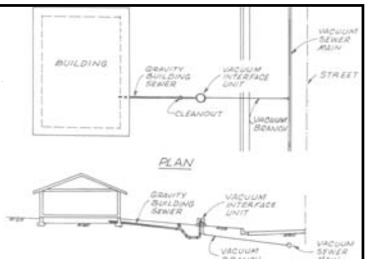
Vacuum Sewer Components



- **Gravity building sewer** to vacuum interface unit
- **Vacuum interface unit** seals vacuum service
  - Once 3 gal WW accumulate, valve opens to allow atmospheric air to force WW into vacuum branch
- **Vacuum main** sends WW to treatment facility
- Minimum slope vacuum main is 0.2 ft/sec

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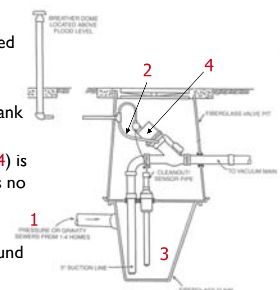
Typical Fiberglass Valve Pit With External Breather

- WW flows by gravity (1) into 30 gal holding tank
- As WW level rises, air is compressed in sensor tube connected to valve controller (2)
- Sensor signals valve to open until tank contents are evacuated (3)
- The spring-loaded interface valve (4) is controlled pneumatically and needs no electricity
- External breather is a 1 ¼ inch polyurethane pipe anchored in ground by concrete
- Breather pipe must be watertight and has domed cover to keep insects out



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Vacuum Sewer – How Does It Work?

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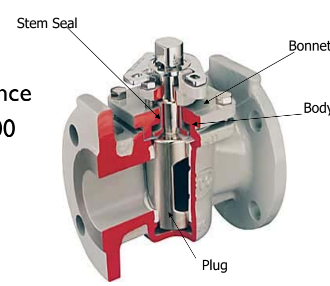
Isolation Valve

- Plug or gate valves isolate portions of vacuum sewer for repairs and maintenance
- Typical interval is 1500 to 2000 ft
- Also located at both sides of a bridge crossing and at both sides of an area of unstable soil



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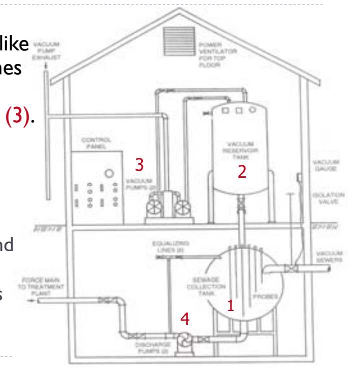
Typical Vacuum Station

- Steel or fiberglass collection tank (1) acts like wet well. Vacuum switches on reservoir tank (2) regulate vacuum pumps (3). Level control probes in collection tank regulate the WW pumps (4).
- Daily operating tasks:
  - Visual check of gages and charts
  - Record pump run times
  - Check oil & block temperature



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Typical Vacuum Station

- 1 station serves 200-300 customers
- Vacuum pumps operate 3-5 hrs/day
- Pumps are typically 20 hp

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Vacuum Sewer Advantages

- Small pipe sizes, typically 3, 4, 6, 8 and 10 in
- Easy to avoid underground obstacles
- Shallow installation (2 to 4 ft) eliminates need for wide deep trenches reducing excavation costs and environmental impact
- High scouring velocity reduces blockages and keeps wastewater aerated and mixed
- No infiltration - leaks easily noted
  - Reduced infiltration leads to reduced size and cost of treatment plant
- No manholes
- Only power source at vacuum station

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Vacuum Sewer O & M

- No odor problems
  - System is sealed; large air input with flow
- No corrosion problems
  - Corrosion resistant PVC, ABS, rubber, stainless steel
- Malfunctions:
  - Break in vacuum line
  - Valve malfunction
  - Closed isolation valve
- O&M of vacuum systems are more difficult than a low pressure system because it is harder to maintain a vacuum due to the number of inlets and valves to the system

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Collection Systems Vocabulary

______1. Alignment
______2. Barrel
______3. Bedding
______4. Building Sewer
______5. Check Valve
______6. Combined Sewer
______7. Exfiltration
______8. Force Main
______9. Grit
______10. Infiltration
______11. Inflow
______12. Lift Station
______13. Manhole
______14. Pneumatic Ejector
______15. Sanitary Sewer
______16. Slope
______17. Storm Sewer
______18. Weir

A. A special valve with a hinged disc or flap that opens in the direction of normal flow and is forced shut when flows attempt to go in the reverse or opposite direction of normal flows.
B. An opening in a sewer provided for the purpose of permitting operators or equipment to enter or leave a sewer. Sometimes called an "access hole" or "maintenance hole."
C. The heavy mineral material present in wastewater such as sand, coffee grounds, eggshells, gravel and cinders. This tends to settle out at flow velocities below 2 ft/sec and accumulate in the invert or bottoms of the pipelines.
D. (1) The cylindrical part of a pipe that may have a bell on one end. (2) The cylindrical part of a manhole between the cone at the top and the shelf at the bottom.
E. A pipe or conduit (sewer) intended to carry wastewater or waterborne wastes from homes, businesses and industries to the POTW (Publicly Owned Treatment Works). Storm water runoff or unpolluted water should be collected and transported in a separate system of pipes or conduits (storm sewers) to natural watercourses.
F. A sewer designed to carry both sanitary wastewaters and storm or surface water runoff.
G. A separate pipe, conduit or open channel (sewer) that carries runoff from storms, surface drainage and street wash, but does not include domestic and industrial wastes. They are often the recipients of hazardous or toxic substances due to the illegal dumping of hazardous wastes or spills created by accidents involving vehicles and trains transporting these substances.
H. A gravity-flow pipeline connecting a building wastewater collection system to a lateral or branch sewer. The pipeline may begin at the outside of the building's foundation wall or some distance (such as 2 to 10 feet) from the wall, depending on local sewer ordinances.
I. A device for raising wastewater, sludge or other liquid by compressed air. The liquid is alternately admitted through an inward-swinging check valve into the bottom of an airtight pot. When the pot is filled, compressed air is applied to the top of the liquid. The compressed air forces the inlet valve closed and forces the liquid in the pot through an outward-swinging check valve, thus emptying the pot.

J. The seepage of groundwater into a sewer system, including service connections. Seepage frequently occurs through defective or cracked pipes, pipe joints, connections or manhole walls.
K. The prepared base or bottom of a trench or excavation where a pipe or other underground structure is supported.
L. A wastewater pumping station that lifts the wastewater to a higher elevation when continuing the sewer at reasonable slopes would involve excessive depths of trench. Also, an installation of pumps that raise wastewater from areas too low to drain into available sewers. These situations may be equipped with air-operated ejectors or centrifugal pumps. Sometimes called a pump station, but this term is usually reserved for a similar type of facility that is discharging into a long force main, while this has a discharge line or force main only up to the downstream gravity sewer.
M. A pipe that carries wastewater under pressure from the discharge side of a pump to a point of gravity flow downstream.
N. The inclination or a sewer trench excavation is the ratio of the vertical distance to the horizontal distance or "rise over run."
O. The proper positioning of parts in a system. This refers to the location and direction of a pipeline or other line.
P. Water discharged into a sewer system and service connections from such sources as, but not limited to, roof leaders, cellars, yard and area drains, foundation drains, cooling water discharges, drains from springs and swampy area, around manhole covers or through holes in the covers, cross connections from storm and combined sewer systems, catch basins, storm waters, surface runoff, street wash waters or drainage. This differs from infiltration in that it is a direct discharge into the sewer rather than a leak in the sewer itself.
Q. Liquid wastes and liquid-carried wastes that unintentionally leak out of a sewer pipe system and into the environment.
R. A wall or plate placed in an open channel and used to measure the flow of water. The depth of the flow over this can be used to calculate the flow rate, or a chart or conversion table may be used to convert depth to flow.

Collection Systems Questions

1. What is the <u>purpose</u> of a wastewater collection system?

2. List the <u>principal</u> components of a low pressure collection system.

3. List the <u>principal</u> components of a vacuum collection system.

4. What is the <u>purpose</u> of a backflow preventer?

5. What factors control the width of a sewer trench?

6. List the problems that can be caused by poor sewer pipe joints.

7. Some agencies prohibit manhole steps and use ladders instead to
   a. Eliminate hazards of corroded steps.
   b. Increase speed of operators entering manholes.
   c. Protect operators from splashing or falling wastewater.
   d. Save on cost of steps.

8. Experience has shown that the <u>minimum scouring velocity</u> in a sewer should be greater than:
   a. 2 ft/sec
   b. 3 ft/sec
   c. 4 ft/sec
   d. 5 ft/sec

9. The amount of wastewater that a collection system conveys is determined by quantities of:
    a. Commercial wastewaters
    b. Domestic wastewaters
    c. Groundwater infiltration
    d. Sludge produced by wastewater treatment plant
    e. Surface water inflow

10. Construction materials for sewers are selected for their:
    a. Ability to minimize infiltration and exfiltration
    b. Cost of materials
    c. Cost of installation
    d. Resistance to deterioration
    e. Resistance to root intrusion

Answers to Vocabulary and Questions

Vocabulary:

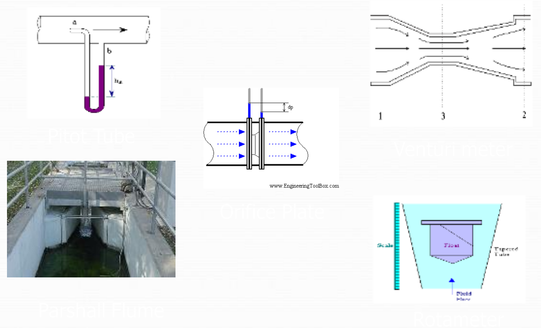
1. O	7. Q	13. B
2. D	8. M	14. I
3. k	9. C	15. E
4. H	10. J	16. N
5. A	11. P	17. G
6. F	12. L	18. R

Questions:

1. The purpose of a wastewater collection system is to collect the wastewater from a community's homes and industries and convey it at an appropriate velocity to a wastewater treatment plant.
2. The principal components of a low-pressure collection system include gravity sewers, holding tanks, grinder pumps and pressure mains.
3. The principal components of a vacuum collection system include gravity sewers, holding tanks, vacuum valves, vacuum mains and vacuum pumps.
4. Backflow preventers are used to stop the accidental backflow or reverse flow of wastewater into buildings from the sewer.
5. The width of a sewer trench is controlled by the diameter of the sewer pipe, clearance for pipe laying, soil stability for safety during excavation and the excavation procedures.
6. Poor sewer pipe joints can lead to problems caused by roots, infiltration & exfiltration.
7. a
8. a
9. a, b, c and e
10. All are correct

Section 3

Flow Measurement



Wastewater Flows and Flow Measurement

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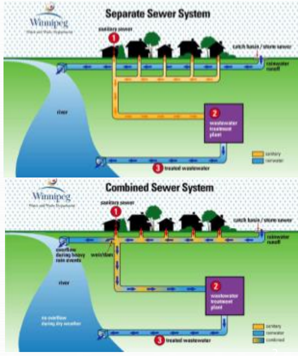
What are the Wastewater Flows?

- Sanitary Sewer:
  - Domestic and industrial waste
- Storm water:
  - Snow melt, street wash, etc.
- Combined sewer:
  - Sanitary plus storm
  - Example: Nashville
- Infiltration/Inflow



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I/I

- Inflow – Water discharged into a sewer system and service connections from such sources as, but not limited to, roof leaders, cellars, yard and area drains, foundation drains, cooling water discharges, drains from springs and swampy areas, around manhole covers or through holes in the covers, cross connections from storm and combined sewer systems, catch basins, storm waters, surface runoff, street wash waters or drainage
  - Inflow differs from infiltration in that it is a direct discharge into a sewer rather than a leak in the sewer itself

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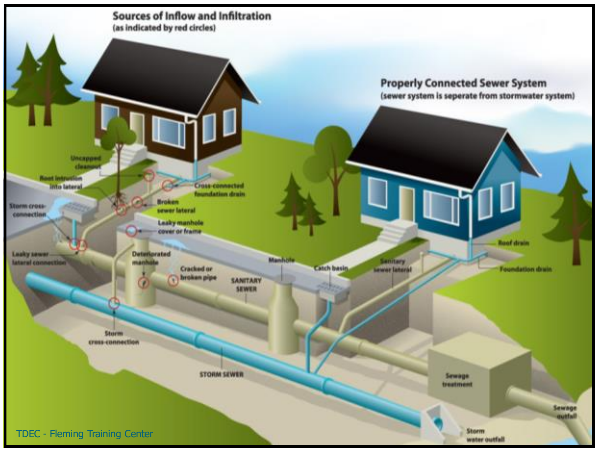

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I/I

- Infiltration – the seepage of groundwater into a sewer system, including service connections.
  - Seepage frequently occurs through defective or cracked pipes, pipe joints, connections or manhole walls
  - Due to age and condition of system and portion of system submerged in groundwater
- Exfiltration – liquid wastes and liquid-carried wastes that unintentionally leak out of a sewer pipe system and into the environment

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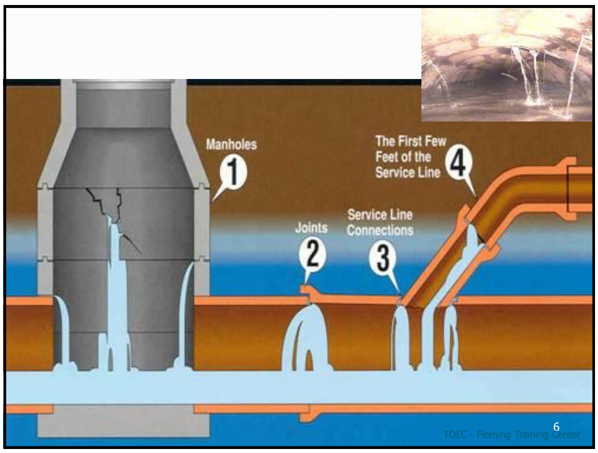

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Wastewater flows: Why do we care?

- Collection and conveyance system design
  - Are they getting shorter or longer as the years go on?
  - Getting longer and further away from the treatment plant means the water spends more time in the system, which also means water easily becomes septic
- Treatment system design
  - Hydraulic criteria: must be able to pass peak flows
  - Treatment criteria: meeting treatment standards often depends on "hydraulic residence time"
    - e.g. MG / MGD = days = residence time
  - Growth projections (population, development)

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Wastewater flow rates

- The average flow rate generated per person (per capita) per day is called the population equivalent
  - Typical units are gallons per capita per day (GPCD)
  - Typically estimated as 70% of the drinking water consumption during the wet season
  - Used as a quick way to estimate the amount of wastewater that could be generated by a community
- Rule of thumb:
  - US domestic is about 70-100 gpd/person
  - Developing countries: 5 to 50 gpd/capita
  - Other: depends on facility (industry, commercial, etc.)
  - I/I can be significant

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Factors Effecting Flow Rates

- Geographical location & socioeconomic conditions
- Type of development – residential, industrial
- Season (I/I)
- Climate (I/I)
- Time of Day

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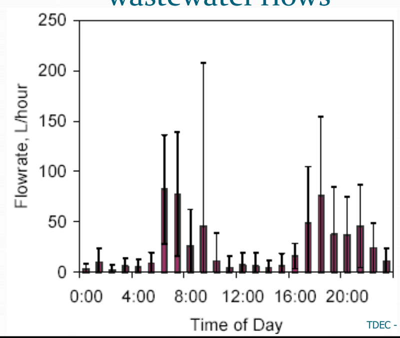
"Diurnal variations" in domestic wastewater flows



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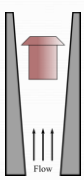
Flow Measurement

- Basics of Flow Measurement
- Open Channel Flow Measurement
  - Primary Elements
  - Secondary Elements
- Closed Pipe Flow Measurement
  - Differential Pressure
  - Mechanical Devices
- Flow Equalization



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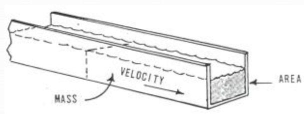
Flow is …

- Amount of water going past a reference point over a certain time
- Units: volume per unit time
  - (ft3/sec, gal/min, MGD)
- Calculated by the equation: $Q = AV$



Q = quantity of flow

A = cross-sectional area of flow

V = velocity of flow

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Sewer System Evaluations

- Flow monitoring is primary tool for identifying high inflow/infiltration (I/I)
- System problems:
  - Back flooding into private property due to surcharging of sewer mains
  - Bypassing of untreated wastewater to environment
  - Reduced system capacity

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Flow Measurement & Wastewater Treatment

- Unit processes are designed for specific flow levels
- Pumping rates, aeration rates, chemical feed rates, etc. based on current flow
- Accurate flow measurement is key to identify, correct and prevent operational problems

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Wastewater Loads

- Treatment is to decrease chemical constituents, but quantity to be treated depends on:
  - Concentration (mg/L)
  - Flow rate (gpd or MGD)
- Loading Rate (lbs/day)
  - Lbs/day = (Flow, MGD)(Concentration, mg/L)(8.34 lbs/gal)

- *Applied Math*: If total suspended solids (TSS) in a wastewater sample at the treatment plant influent is 100 mg/L, and the flow rate of the wastewater is 10 MGD, what is the loading rate to the treatment plant in lbs/day?

(100 mg/L)(10 MGD)(8.34 lbs/gal) = 8340 lbs/day influent TSS

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Flow Metering Equipment Commonly Used in Wastewater Treatment Plants

Type	Accuracy	Advantages	Disadvantages
Open-Channel Flume	5-7%	Low headloss, self-cleaning	Requires careful construction, susceptible to flooding
Open-Channel Weir	5-7%	Low cost, ease of installation	High headloss, requires a well-developed flow profile, cleaning required
Full-Pipe Electro-magnetic	1-3%	No headloss, bi-directional	Minimum conductivity required, expensive, well-developed velocity profile required
Full-Pipe Doppler	2-5%	No headloss, low cost, not affected by air bubbles	Not suitable for some pipe material, well-developed velocity profile required
Full-Pipe Venturi	1-3%	Low headloss, high accuracy	Expensive, well-developed velocity profile required

MOP No. 11 – Operation of Municipal Wastewater Treatment Plants

Types of Flow Meters

- Different types of flow measuring devices include constant differential, head area, velocity meter, differential head and displacement.
- All flow measurement devices should be calibrated and maintained to ensure the accuracy of the measurement is ± 10% of the true flow.
- Methods that can be used to check the performance of a flow meter are:
  - Measure the area and velocity of an open channel
  - Measure how many minutes it takes to fill a 55-gallon drum
  - Measure how long it takes to fill a tank of a known volume

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Open Channel Flow Primary Elements

- Creates conditions that produce known relationship between flow and depth
- Channel width is known, but velocity is not needed
- Primary devices:
  - Weirs
  - Flumes

- Secondary element senses depth at measurement point, converting this to flow
- A detailed discussion of different types of weir and flume configurations used in North America is presented in the *Isco Open Channel Flow Measurement Handbook*

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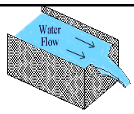
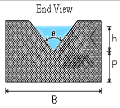
Weir



- Overflow structure; rectangular or V-notch
- Discharge rate determined by measuring vertical distance from crest of overflow to surface of upstream pool
- Disadvantage: Organic solids collect behind weir, causing odors & inaccurate measurements
- Measures liquid flow in partially full channels or basins
- Blocks the flow in the channel
- Depth of water proportional to amount of flow

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Weir

- Used in open channels and is placed across the channel, weirs are made of thin materials and may have either a rectangle or V-notch opening.
- The flow over the weir is determined by the depth of flow going through the opening.
- A disadvantage in using a weir at the influent of the plant is that solids may settle upstream of the weir and cause odors and unsightliness.
- Can provide final aeration/oxygenation

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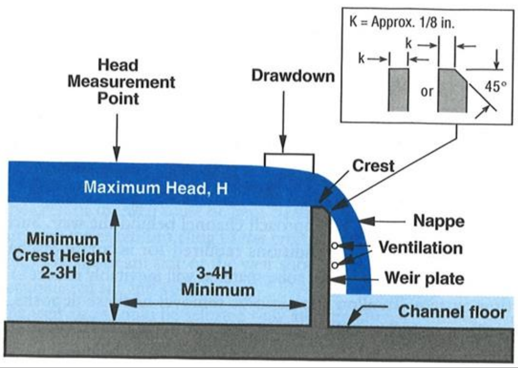
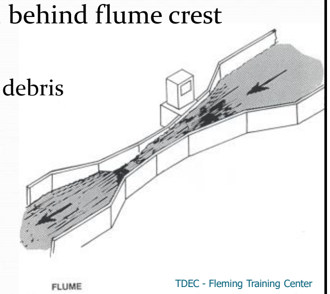
Weir



Flume

- Entrance, Throat, Discharge
- Depth is measured behind flume crest
- Best for:
  - Flow with solids or debris
  - Large Flows
  - Variable flows



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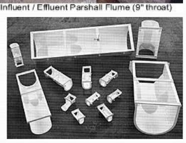
Flumes

- Specially shaped open channel section with entrance, throat & discharge sections
- Constriction causes change in head which can be converted to flow rates
- Used where head loss is a concern, for larger flows or flows with solids or debris



Influent / Effluent Parshall Flume (9" throat)


Palmer-Bowlus flumes
measures flow in existing sewers

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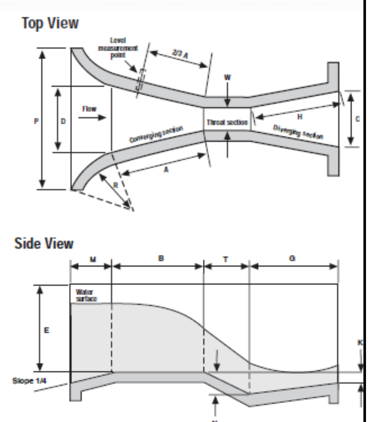
Flumes

- Measurement point is 1/3 of the way into the converging section in front of the throat for a Parshall flume



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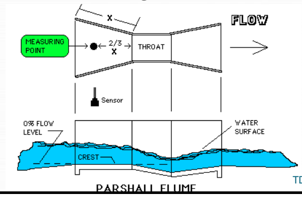
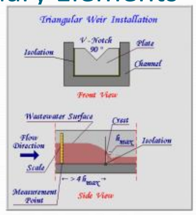
Parshall Flume

- Parshall flume is one of the most common measuring devices.
- It is a narrow place in a open channel which allows the quantity of wastewater flow to be determined by measuring the depth of flow with ultra sonic device, floats or manually with measuring device.



Open Channel Flow Secondary Elements

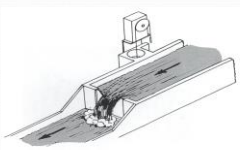
- Measures or indicates liquid level in primary device
- Used with instruments to convert head to flow
- Selection based on location, type of information required & cost
- **Staff gauge** in stilling well
- **Floats** in stilling well
- **Bubblers**
- **Ultrasonic devices**



Staff gauge

Secondary Elements

- Measure the water level in the Primary Device (weir or flume)
- Example 1 – Float
  - Simple, Inexpensive
  - Grease, solids may interfere



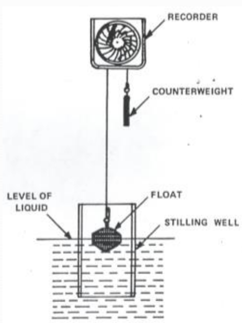


Fig. 6.12 A float is used to measure liquid level and convert the level reading to a flow measurement

Secondary Elements

- Types of float controls
  - Rod-attached floats
  - Steel tape, cable or rope attached floats
  - Mercury switch floats
  - Ultrasonic
  - Pressure transducers

Secondary Elements

- Ultrasonic Meter
  - Sound pulse
  - No direct contact with wastewater
  - Limit – Cannot measure less than 3 inches

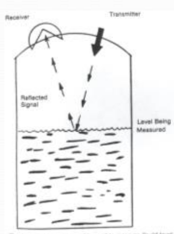
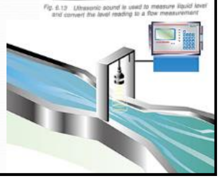
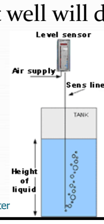


Fig. 6.13 Ultrasonic sound is used to measure liquid level and convert the level reading to a flow measurement



Secondary Elements

- Bubbler Tube
  - Constant flow of air
  - Depth determined by air pressure
  - Generally operate at 5 psi, the depth of the water in the wet well will determine the pressure required.



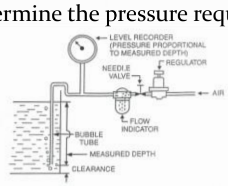


Fig. 6.14 A bubbler tube is used to measure liquid level and convert the depth reading to a flow measurement

Closed Pipe Flow Measurement

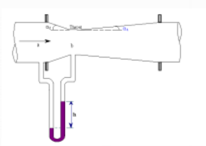
- Differential Producers
  - Venturi meter
  - Orifice plate
- Velocity Meters
  - Propeller-type
  - Pitot tube
  - Magnetic meter
- Constant Differential
  - Rotameter

Closed Pipe Flow Measurement: Differential Producers

- Venturi system
  - Pipe diameter gradually reduces at the throat and returns to original diameter
  - Low pressure is created in throat
  - Difference in pressure indicates amount of flow
  - Simple and inexpensive
  - Need straight runs of pipe before and after
  - Excellent for gases and liquids (not sludge)

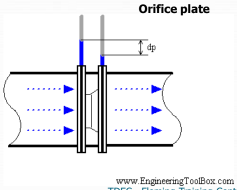
Closed Pipe Flow Measurement: Differential Producers

- Measure velocity directly or convert velocity head to pressure head by restricting flow in pipe
- Gases & liquids in closed pipes



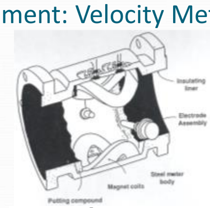
Venturi meter: liquid passes through reduced throat section & velocity increases. Pressure differential then measured using **manometer**.

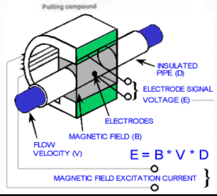
Orifice plate



Closed Pipe Flow Measurement: Velocity Meters

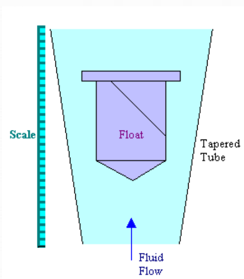
- Magnetic Flow Meter
  - Creates magnetic field in water stream
  - Conductor (water) moving through magnetic field produces electric current
  - Measure of electricity indicates amount of flow
  - Very accurate, Low maintenance
  - Can be expensive (esp. for larger diameters)





Closed Pipe Flow Measurement: Constant Differential

- Chemical Feed Systems
- Rotameter
  - Float or ball in vertical tube
  - Increased flow causes float to ride higher
  - Simple, accurate, easy
  - Must keep tube and float clean



Maintenance of Flow Measuring Devices

- Clean devices regularly
  - Grease build up on floats & magnetic meter coils
  - Weir plate clogged with debris
- Periodically inspect devices for damage & deterioration
  - Pneumatic lines may have air leaks
  - Electrical parts may short out
- Recalibrate secondary devices regularly

Flow Equalization

- Smoothes out fluctuations in flow volume and pollutant concentrations
- Provides for constant flow with less variations in loading
- Improves performance of downstream processes
- TN Design Criteria says you must maintain a 1.0 mg/L DO throughout the EQ tank

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Flow Equalization

- Types:
  - Surge – prevents flows above max. hydraulic capacity
  - Diurnal – reduces the magnitude of daily flow variations
  - Complete – eliminates flow variations
- Two Schemes
  - In-line equalization
  - Side-line equalization

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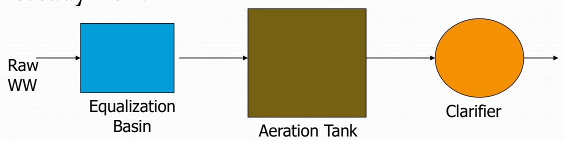
Flow Equalization: In-Line

- All flow enters equalization basin before entering STP.
- Flow is stored as required and later released as steady flow.



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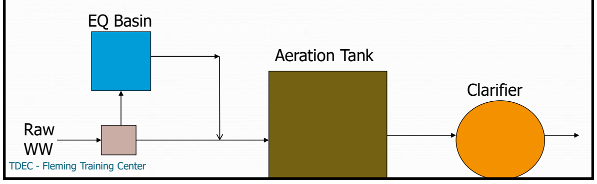
Flow Equalization: Side-Line

- Equalization basin in collection system or at STP.
- Only flow greater than daily average is diverted to basin.
- Can occur after screening and grit removal, eliminating major grit and settleable solids problems.



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Flow Equalization

- Requires mechanical or diffused air mixing, pumps & flow measurement
- Blend entire tank contents
- Benefits:
  - Increased DO
  - Better grease separation
  - Better settling in primary
  - Better settling in final
  - 10% - 20% BOD reduction
  - Improved response to shock loads

Landsdale, PA 2.5 MG equalization basin

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Flow Measurement Vocabulary

______1. Analog
______2. Composite
______3. Conductivity
______4. Density
______5. Digital Readout
______6. Head
______7. Head Loss
______8. Manometer
______9. Orifice
______10. Primary Element
______11. Secondary Element
______12. Sensor
______13. Surcharge
______14. Totalizer
______15. Venturi Meter

A. An opening (hole) in a plate, wall or partition. An orifice flange or plate placed in a pipe consists of a slot or a calibrated circular hole smaller than the pipe diameter. The difference in pressure in the pipe above and at the orifice may be used to determine the flow in the pipe.
B. A measure of the ability of a solution (water) to carry an electric current.
C. The secondary measuring device or Flowmeter used with a primary measuring device (element) to measure the rate of liquid flow. In open channels bubblers and floats are secondary elements. Different pressure measuring devices are the secondary elements in pipes or pressure conduits.
D. The readout of an instrument by a pointer (or other indicating means) against a dial or scale. Also the continuously variable signal type sent to an analog instrument.
E. An indirect measure of loss of energy or pressure. Flowing water will lose some of its energy when it passes through a pipe, bar screen, Comminutor, filter or other obstruction. This is measured as the difference in elevation between the upstream water surface and the downstream water surface and may be expressed in feet or meters. Flow measuring devices like venturi tubes and orifice plates use it.
F. The supply of water to be carried is greater than the capacity of the pipes to carry the flow. The surface of the wastewater in manholes rises above the top of the sewer pipe, and the sewer is under pressure or a head, rather than at atmospheric pressure.
G. The vertical distance (in feet) equal to the pressure (in psi) at a specific point. The pressure head is equal to the pressure in psi times 2.31 ft/psi.
H. A measure of how heavy a substance (solid, liquid or gas) is for its size. It is expressed in terms of weight per unit volume, which is grams per cubic centimeter or pounds per cubic foot. The density of water (at 4° C or 39° F) is 1.0 gram per cubic centimeter or about 62.4 pounds per cubic foot.
I. A device or meter that continuously measures and calculates a process rate variable in cumulative fashion.
J. An instrument for measuring pressure. Usually it is a glass tube filled with a liquid that is used to measure the difference in pressure across a flow-measuring device such as an orifice or a Venturi meter.
K. A collection of individual samples obtained at regular intervals, usually every one or two hours during a 24-hour time span. Each individual sample is combined with the

others in proportion to the rate of flow when the sample was collected. The resulting mixture forms a representative sample and is analyzed to determine the average conditions during the sampling period.

L. A flow-measuring device placed in a pipe. The device consists of a tube whose diameter gradually decreases to a throat and then gradually expands to the diameter of the pipe. The flow is determined on the basis of the difference in pressure (caused by different velocity heads) between the entrance and throat of the device.

M. The use of numbers to indicate the value or measurement of a variable. The readout of an instrument by a direct, numerical reading of the measured value.

N. A device that measures a physical condition or variable of interest. Floats and thermocouples are examples of these.

O. The hydraulic structure used to measure flows. In open channels weirs and flumes are primary elements or devices. Venturi meters and orifice plates are the primary elements in pipes or pressure conduits.

Flow Measurement Questions

1. When do open channel flow conditions occur?

2. What are the commonly used methods of measuring plant flows?

3. Where are flumes used instead of weirs to measure flows?

4. What are the two basic types of flow systems?

5. What are the three different sections of a flume?

6. What are the advantages of an electromagnetic/magnetic flow meter?

7. Why measure flows before and after an equalization basin?

Answers to Vocabulary and Questions

Vocabulary:

1. D	6. G	11. C
2. K	7. E	12. N
3. B	8. J	13. F
4. H	9. A	14. I
5. M	10. O	15. L

Questions:

1. When the flow upstream has a free or unconfined surface that is open to the air.
2. Velocity area and use of a hydraulic structure.
3. Where head loss is a concern, larger flows or flows with debris.
4. open channel flow and closed channel (or closed pipe)
5. ① the entrance section (converging section), ② throat section and ③ discharge (diverging) section
6. an obstruction less design, high accuracy and an output signal that is directly proportional to the flow rate
7. in order to control the basin's operation and optimize its effectiveness

Section 4

Pipe Materials

Sewer Pipe Materials

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Selection Considerations

- Pipe material selection is important since sewer systems are expected to have an economical life of at least 30 years and most are in service for a much longer period
- Pipe materials are selected for their strength to withstand earth and surface loads and resistance to deterioration by the wastewaters they carry and the surrounding soil

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Selection Considerations

- Other considerations include:
  - Pressure – gravity or force main
  - Physical properties – crush strength, shear loading strength, flexural strength
  - Flow and capacity
  - Resistance to root intrusion
  - Trench conditions
  - Corrosion resistance – both from wastewater and surrounding soil
  - Abrasive wastewater
  - Safety requirements for handling and installation
  - Cost

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Specification Standards

- Set by American Society of Testing Materials (ASTM) & American National Standards Institute (ANSI)
- Specify:
  - Internal diameter
  - Loadings (classes)
  - Wall thickness (schedule)

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Key Pipe Characteristics

- Pipe must be resistant to corrosion from wastewater and surrounding soil
- Leak tightness: resistance to root intrusion and minimize infiltration and exfiltration
- Scouring factor
- Hydraulic characteristics

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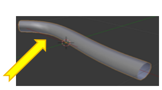
Key Pipe Characteristics

- Tensile strength – resistance to longitudinal (lengthwise) pull before material fails

- Flexural strength – ability of pipe material to bend or flex without breaking



- When either of these strengths are exceeded then pipe breakage occurs

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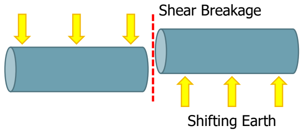
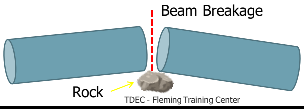
Key Pipe Characteristics

- Shear breakage occurs when the earth shifts



- Beam breakage occurs when a pipe is unevenly supported along its length



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Key Pipe Characteristics

- Pipe material used will produce either a flexible or rigid pipe with specific characteristics
- A flexible pipe will bend or bulge from its usual shape when subjected to a load without being adequately supported, but will not crack under most loads and will return nearly to its original shape when the load is removed

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Pipe Materials

- Flexible Pipe
  - Ductile Iron Pipe (DIP)
  - Steel Pipe
  - Thermoplastic Pipe
    - Acrylonitrile Butadiene Styrene (ABS)
    - Acrylonitrile Butadiene Styrene Composite Pipe
    - Polyethylene Pipe (PE)
    - Polyvinyl Chloride Pipe (PVC)
  - Thermoset Plastic Pipe
    - Reinforced Thermosetting Resin (RTR)
    - Reinforced Plastic Mortar (RPM)

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Ductile Iron Pipe (DIP)

- Flexible pipe
- Used for both gravity and pressure sewers
- DIP is manufactured by adding cerium or magnesium to cast (gray) iron just prior to the pipe casting process
- 3-54 inch diameters and length of 20 ft available
- Often used for stream crossings, inverted siphons and in high traffic area.
- Polyethylene, epoxy or cement mortar linings may be specified

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Ductile Iron Pipe

- Advantages
  - Long laying lengths (in some situations)
  - High pressure and load bearing capacity
  - High impact strength

- Disadvantages
  - Subject to corrosion where acids are present
  - Subject to chemical attack in corrosive soils
  - High weight
  - Expensive

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Steel Pipe

- Flexible pipe
- Rarely used for gravity sewers but common for force mains
- Usually has interior protective coatings or linings (polymeric, bituminous, asbestos)
- 8-120 inch diameters with lengths up to 40 feet

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Steel Pipe

- Advantages
  - Light weight
  - Long laying lengths (in some situations)

- Disadvantages
  - Subject to corrosion where acids are present
  - Subject to chemical attack in corrosive soils
  - Subject to excessive deflection when improperly bedded
  - Subject to turbulence abrasion

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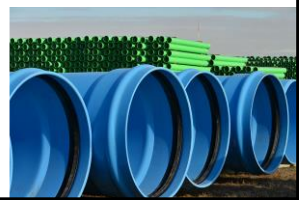
Thermoplastic Pipe

- Includes a wide variety of plastics that can be repeatedly softened by heating and hardened by cooling through a temperature range characteristic for each specific plastic
  - ABS
  - ABS Composite
  - HDPE
  - PVC



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Acrylonitrile Butadiene Styrene

- Lightweight black plastic flexible pipe
- Used for both gravity and pressure sewers
- Long laying lengths
- Ease in field cutting
- Rather brittle: subject to environmental stress cracking
- Subject to attack by some organic chemicals
- Susceptible to damage by sunlight
- Elastomeric seal gasket joints or solvent cemented joints

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Acrylonitrile Butadiene Styrene Composite

- Flexible pipe
- Produced by extrusion of ABS plastic material to create two concentric thermoplastic tubes integrally braced with truss beams and the annular space filled with Portland cement concrete
- Used for both gravity sewers
- Light weight and long laying lengths
- Ease in field cutting
- Subject to environmental stress cracking or attach by certain organic chemicals
- Susceptible to damage by sunlight

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HDPE Pipe

- High Density Polyethylene
- Flexible pipe
- Inert - not subject to chemical attack
- Resists corrosion from hydrogen sulfide
- Easily handled
- Longer laying length vs. heavier pipe
  - Gives long-term maintenance advantage of fewer joints and fewer root intrusions
- Nonporous
  - Although groundwater may infiltrate through poorly made joints or taps, but it won't seep through the walls
- Commonly used with pipe bursting & sliplining

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Polyvinyl Chloride (PVC)

- Most widely used plastic pipe
- Flexible pipe
- Non-pourous
- Inert - not subject to chemical attack
- Easily handled, lighter weight vs rigid pipe
- Longer laying length vs. heavier pipe (10-20 ft)
- Subject to excessive deflection when improperly bedded

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Polyvinyl Chloride (PVC)

- Needs to be protected from freezing temperatures and sunlight until installed
- Least susceptible to corrosion by acids formed from gases generated in sewers

Thermoset Plastic Pipe

- Include a broad variety of plastics that, after having been cured by heat or other means, are substantially infusible and insoluble

- Flexible pipe
- Two categories:
  - Reinforced Thermosetting Resin
  - Reinforced Plastic Mortar

Thermoset Plastic Pipe

- Reinforced Thermosetting Resin pipe contains fibrous reinforcement materials, such as fiberglass, imbedded in or surrounded by cured thermosetting resin
- Reinforced Plastic Mortar pipe contains fibrous reinforcements such as fiberglass and aggregates such as sand embedded in or surrounded by cured thermosetting resin

Thermoset Plastic Pipe

- Advantages
  - Light weight
  - Long laying lengths

- Disadvantages
  - Subject to strain corrosion in some environments
  - Subject to attack by certain organic chemicals
  - Subject to excessive deflection when improperly bedded
  - Subject to surface change from long-term ultraviolet exposure

Key Pipe Characteristics

- A rigid pipe will requires less support, however it will crack when the combination of a load on the pipe and its support causes a stress that exceeds the strength of the pipe
- Rigid pipe will not return to its original shape when the load is removed

Pipe Materials

- Rigid Pipe
  - Asbestos-Cement Pipe (ACP)
  - Cast-Iron Pipe (CIP)
  - Concrete Pipe
    - Reinforced Concrete Pipe (RCP)
    - Prestressed Concrete Pressure Pipe (PCPP)
  - Vitrified Clay Pipe (VCP)

Asbestos-Cement Pipe (ACP)

- Rigid pipe
- No longer manufactured
- It was used frequently for gravity and pressure sewers from 4 - 42 in
- Still found in many sanitary sewer systems throughout the US

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Asbestos-Cement Pipe

- Advantages
  - Long laying lengths
  - Availability of a wide range of strength classifications
  - Availability of a wide range of fittings
  - Resistant to abrasion
- Disadvantages
  - Subject to corrosion where acids are present
  - Subject to shear and beam breakage when improperly bedded
  - Low beam strength
  - Restrictions by OSHA due to asbestos content (precautions need to be taken when repairing AC pipe)

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Cast-Iron Pipe (CIP)

- Rigid pipe
- CIP (gray iron) is used for both gravity and pressure sewers in diameters from 2 – 48 inches
- A cement mortar lining with an asphaltic seal coating may be specified on the interior of the pipe for protection from corrosion
- Very resistant to crushing and is often used for creek and river crossings, shallow trench locations, and under heavy traffic load areas

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Cast-Iron Pipe

- Advantages
  - Long laying lengths (in some situations)
  - High pressure and load bearing capacity
- Disadvantages
  - Subject to corrosion where acids are present
  - Subject to chemical attack in corrosive soils
  - Subject to shear and beam breakage when improperly bedded
  - High weight
  - High cost

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Concrete Pipe

- Rigid pipe
- Reinforced (RCP) and non-reinforced concrete pipe are used for gravity sanitary sewers
- Reinforced concrete pressure pipe and prestressed concrete pressure pipe (PCPP) are used for pressure as well as gravity flow sanitary sewers
- Rigid; heavy
- Rubber gasket joints

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Concrete Pipe

- Prestressed pipe is reinforced with wire strands under tension to give the pipe an active resistance to loads or pressures on it

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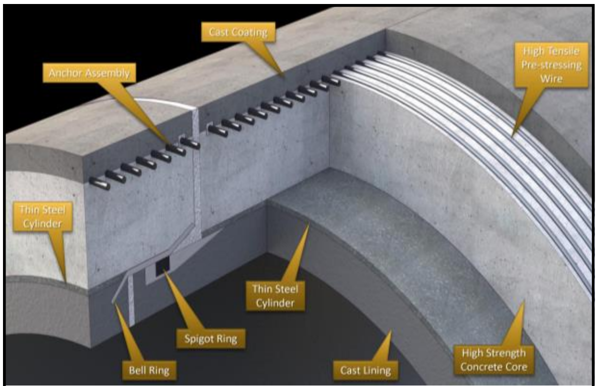

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Concrete Pipe

- Advantages
  - Wide range of structural and pressure strengths
  - Wide range of nominal diameters
    - Non-reinforced – 4-36 inches
    - Reinforced - 12-200 inches
  - Wide range of laying lengths – 4-24 feet
- Disadvantages
  - High weight
  - Subject to corrosion where acids are present (if not coated)
  - Subject to shear and beam breakage when improperly bedded
  - Special field repair methods and special fittings may be required for PCPP

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Vitrified Clay Pipe

- Rigid pipe
- Used for gravity sewers with laying lengths of 4-10 ft
- Manufactured from clay and shales
- Made non-porous (vitrified) by heating it at a high enough temperature to fuse the clay mineral particles
- 3-36 inch diameters are available, up to 42 in some areas
- Compression jointed
- Brittle: requires careful installation (shear & beam breakage possible)
- Heat resistant

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Vitrified Clay Pipe

- Advantages
  - High resistance to chemical corrosion
  - High resistance to abrasion
  - Wide range of fittings available
- Disadvantages
  - Joints susceptible to chemical attack
  - Limited range of sizes available
  - High weight
  - Subject to shear and beam breakage when improperly bedded

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Pipe Joints

- One of the most critical components of the sewer piping system are the pipe joints
- Joints must be effective to control groundwater infiltration, wastewater exfiltration, and root intrusion which leads to increased damage to the system
- An effective pipe joint must be:
  - Watertight
  - Root resistant
  - Flexible
  - Durable

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Pipe Joints

- There are many types of gasket (elastomeric seal) pipe joints that provide a reliable, tight seal against leakage
- Gasketed pipe joints create a seal through the compression of an elastomeric seal or ring
- Two main types of gasket-type pipe joints
  - Push-on
  - Mechanical compression

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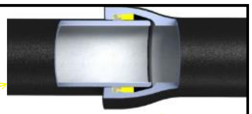
Pipe Joints



- Push-on pipe joints use a continuous elastomeric ring gasket, which is compressed into the annular space formed by the pipe, fitting, or coupler socket and the spigot end of the pipe (Bell and spigot)
  - Gasket provides a positive seal when the pipe spigot is pushed into the socket
  - When this type of joint is used in pressure sewers, thrust restraint may be required to prevent joint separation

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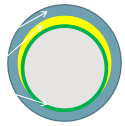
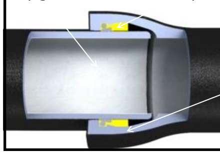
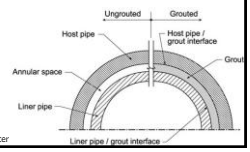
Pipe Joints

- The annular space is the ring-shaped space located between two circular objects
  - Examples: bell and spigot joints, pipe liner and the inside of the pipe







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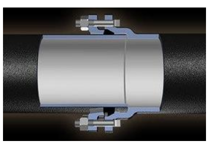
Pipe Joints

- Mechanical compression pipe joints use a continuous elastomeric ring gasket, which provides a positive seal when the gasket is compressed by means of a mechanical device
  - Flanged pipe joints
  - Push-on bell and spigot mechanical joint with gland-type follower



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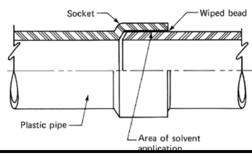
Pipe Joints

- Solvent cement pipe joints involves bonding a sewer pipe spigot into a bell or coupler using a solvent cement
  - Can be used on thermoplastic pipe – ABS, ABS composite, and PVC
  - Safety precautions should be taken to ensure adequate trench ventilation for operators



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Pipe Joints

- PVC pipe that is schedule 80 and heavier wall thicknesses may be threaded
  - Threading not recommended for polyethylene (PE) and polybutylene (PB)
- For PE and PB heat fusion pipe joints are commonly used
  - Involves butt fusion of the pipe lengths
  - Ends of two lengths of pipe are trimmed and softened to a melted state with heated metal plates then forced together to the point of butt fusion
  - Provides a positive seal that does not require thrust restraint in pressure applications

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Pipe Joints – Butt Fusion

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Pipe Joints

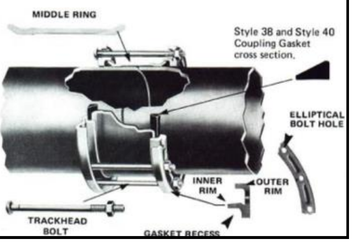
- Welded joints are typically found on steel pipe used for force mains and are very strong and leak tight
- Elastomeric sealing compound pipe joints can be used on concrete pipe that has been sandblasted and primed to provide a positive seal
- Mastic pipe joints are used for non-round shapes of concrete gravity sewer pipe which are not adaptable to gasket joints

Pipe Joints - Couplings

- Couplings can be used to join plain pipe ends and can consist of gaskets, solvent cement or welded ends
- Rubber couplings with compression bands can also be applied to join plain pipe ends

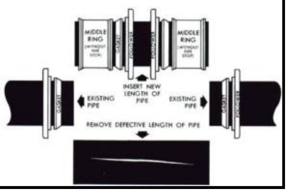
Pipe Joints - Couplings

- Dresser couplings consist of a cylindrical middle ring, two follower rings, two resilient gaskets made up of a special Dresser compound and a set of steel track head bolts



Pipe Joints - Couplings

- The middle ring of the Dresser coupling is placed over the ends of pipe to be connected and the follower rings compress the beveled gasket to achieve a durable seal and a flexible joint
  - Gaskets absorb vibrations and pipe movement and allow for moderate deflection

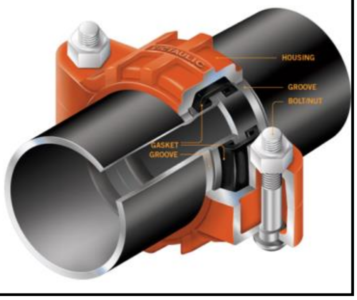


Pipe Joints - Couplings

- Victaulic (groove and shoulder) couplings join ends of a pipe that each have a machined groove that receives the sides of a trough-shaped metal housing in which there is a similarly shaped rubber gasket

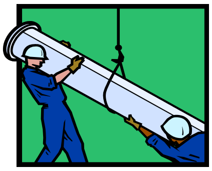
Pipe Joints - Couplings

- The housing encases the gasket and engages the groove providing a leak-tight seal in a self-restrained joint
  - Not designed for use with plastic pipe
  - Disadvantage: groove weakens the pipe wall



Section 5

Pipe Installation



PIPE INSTALLATION AND MAINTENANCE

Pipe Shipping and Unloading

- Can be shipped via truck, railroad or barge
- Pipes must be handled carefully to prevent damage when it is loaded, transported, and unloaded
- Pipe should be inspected upon arrival and again before installation
- Handle carefully
- Inspect lining and coating

Pipe Shipping and Unloading

- Plastic pipe must be inspected closely if arriving in cold weather
- Always use the proper equipment to unload

Stacking Pipe

- If pipe is to be stacked and stored - ensure it is stored off the ground
- Secure pipe to prevent rolling
- Secure the storage area
- Protect plastic pipe from sunlight - but allow air circulation

Stringing Pipe

- Lay pipe as near to the trench as possible to minimize handling
- String pipe on side opposite of spoil pile
- Place bells in direction of installation
- Secure each section to prevent rolling into trench
- String only enough for one days work to prevent vandalism
- May need to cover ends to keep dirt out and prevent contamination

Construction Equipment

- Backhoes
  - Most common equipment used for trench excavations with vertical or sloped sides
  - Cable sling can be added for lowering pipe into trenches
  - Can be used to excavate through rocky and unstable soils

Construction Equipment

- Backhoes
  - Wheeled backhoes – easy to maneuver, can be used as a loader
  - Tracked excavators – used to install heavy pipe, place pipe bedding, and move shoring and other heavy items

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Construction Equipment

- Mini-excavators – smaller, rubber-tired or tracked, used for shallow and restricted excavations
- Front-end loaders – used to place bedding and backfill material and to load excess material into dump trucks for hauling away from the site

IMPORTANT:
ONLY TRAINED PROFESSIONAL OPERATORS SHOULD OPERATE HEAVY EQUIPMENT

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Construction Equipment

- Skid steer loader – small, equipped with lift arms that can be outfitted with buckets or other tools
- Bulldozers – continuous-tracked, with metal blades that move soil, and excavated material
- Hydro-excavators – chassis-mounted, combined high pressure water and air vacuum systems used to cut through and break up soil, and to lift slurry from the excavation area

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Excavation

- Plans are prepared by project engineer and submitted for State approval
- Plans should show location and depth of line, manholes, etc.
- Plans should show location and depth of water and gas pipes, buried telephone lines, electric and cable lines
- Ensure selection of proper sized excavation equipment

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Excavation

- Water and Sewer lines separation at least 18 inches between the bottom of the water main and top of the sewer line
- Sewers should be at least 10 feet horizontally from any water line
- Notify the public about the work

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Trenching

- Most expensive part of pipe installation
- Minimize width and depth as much as possible without compromising safety
- Width should be no more than 1-2 feet more than pipe diameter, wider around curves
- Trench depth depends on maximum depth of frost penetration, minimum of 2.5 feet
- Minimum distance from trench to spoil pile is 2 feet

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Trenching

- Must have a egress if 4 feet or deeper - stairway, ladders, etc
- Trench must be shored or sloped at 5 feet or deeper
- If 20 feet or deeper must be designed by an engineer
- Left open as short a time as possible
- Mark with barricades, warning tape, lights, etc to prevent accidents

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Pipe Laying Procedures

- Inspect before laying and placing in trench
- Check for damage to the spigot end and lining
- Keep gaskets clean and dry

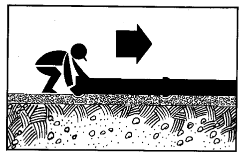

FIG. 19

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Pipe Laying Procedures

- Use a sling or pipe tong to place into trench- never roll
- Cover pipe with plug at the end of each work day
- Ensure pipe bedding is level and compacted
- Compact the backfill beneath the pipe curvature (Haunching)

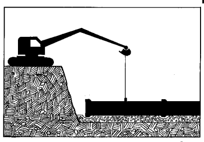

FIG. 21

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Pipe Joints

- Ensure gasket and spigot clean before being attached
- Bell holes or recesses in bedding dug to allow for joint installation
- Spigot end must be inserted to the painted line
- Full-length pipes are beveled at end to facilitate connection
- Level pipe for cutting
- Insert pipe straight

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Thrust Restraints In Pipe Installation

- Water under pressure and water in motion exerts tremendous pressure inside a pipeline and is highest when water flow changes direction
- All tees and bends should be restrained or blocked
- A thrust block prevents the separation of joints and pipe movement by transferring the resultant thrust force at a bend to the undisturbed soil behind the block

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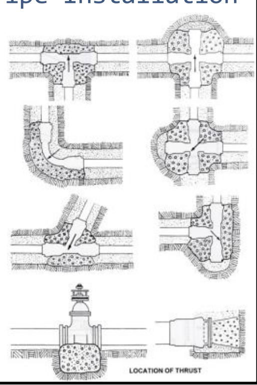
Thrust Restraints In Pipe Installation

- Thrust blocks are made of concrete or other permanent material
- Cast in place between fittings and undisturbed soil in the trench



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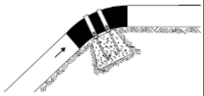
Thrust Restraints In Pipe Installation

- Thrust anchors can be used when there is no undisturbed solid to block against
- Tie rods are used to restrain mechanical joint fittings
- Steel rods hold the pipe and are attached to a block of concrete
- Restraining fittings use clamps and anchor screws



Bend in vertical plane anchorage

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Purpose Of Backfilling

- Provide for pipe and fitting support
- Provides lateral stability between pipe and trench walls
- Carries and transfers surface loads

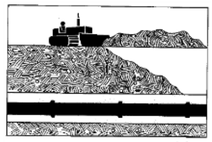

FIG. 24

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Placing Backfill

- Only clean sand or selected soil should be used for first layer
- Moist enough for compaction
- Should not contain peat, rocks, debris or frozen material

HDPE pipe installation

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Placing Backfill

- First layer placed equally on both sides of pipe, up to center, and compacted
- Do by hand or pneumatic tamper
- Second layer should be good quality backfill material
- Remaining backfill can be excavated spoils

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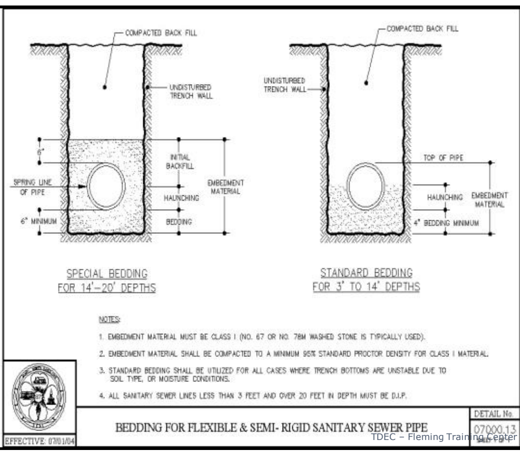

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Compacting

- Trench backfill should be well compacted to avoid later settling
- Water compaction: jetting trench backfill with water
  - Not suitable for all soil types
  - Wide variation in results
  - Backfill must dry out before restoration or paving

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Compacting

- Mechanical compaction: hand-held air tampers, plate vibrators, vibrating rollers
  - Excessive impact can damage pipe
  - Maintenance of shoring during compaction in lifts

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Testing

- Air testing (air compressor):
  - Test sewer pipes at air pressure of 3-5 psi above any outside water pressure on pipe
  - Air test pressure too high can blow out pipe joints or plugs, can injure personnel, or damage system
  - Better in steep terrain because of excessive water pressure at lower end of sewer pipe

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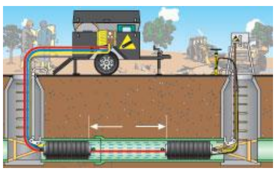
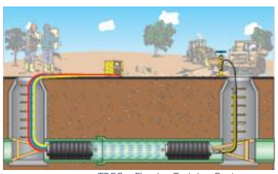
Low Pressure Air Testing

- Leak test accomplished by stringing the sewer line.
- Then, a winch cable pulls in 2 plugs which are attached with an interconnecting hose, through in 20 ft intervals.
- Air is fed between plugs until test fails.
- Leak is isolated by moving the plugs back and forth.





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Water Testing

- Water exfiltration test indicates new sewer's ability to convey wastewater without excessive leakage & to resist groundwater infiltration
- Infiltration test: groundwater entering pipe is monitored through use of weir.
- Can't determine location of leak.

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Mandrel Testing

- After placing and compacting trench backfill, but before site restoration, all new installation of flexible pipe should be tested with a mandrel to measure for deflection and offset joints

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Mandrel Testing

- The mandrel is a rigid, cylindrical plug with nine arms that is tapered at both ends and fitted with pulling rings to which pulling and tag lines are attached
  - Mandrel diameter is 95% of the average diameter of the pipe
  - Pulling and tag lines are marked so that the distance the mandrel has been pulled into the sewer can be determined

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Mandrel Testing

- As the mandrel is pulled through the new section of pipe it will not pass through if:
  1. A flexible pipe has deflected beyond 5% of its diameter
  2. A rigid pipe has been crushed
  3. A joint is offset more than 5% of the pipe diameter
  4. A building sewer connection is protruding into the main line

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Site Restoration

- Restored to original condition as soon as possible
- Grass restored, curbs replaced, pavement repaired
- Check drainage ditches for debris which would facilitate flooding
- Private property must be returned to original condition

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Section 6

Inspection and Testing

Inspection & Testing Collection Systems

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Reasons for Inspecting & Testing

- Wastewater collection systems are designed to be a reliable method to convey all wastewater to a treatment facility
- In order to accomplish this new and existing systems must be inspected and tested to gather information for the development of operation and maintenance programs
- The two main purposes of inspection and testing are to prevent leaks from developing in the system and to identify existing leaks so they can be corrected
  - The location and elimination of leaks is one of the major concerns of system operators

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Reasons for Inspecting & Testing

Inspection and testing accomplishes:

- Identifying existing and potential problem areas
- Evaluating the seriousness of detected problems
- Determining the exact location of facilities and problems
- Providing detailed information to supervisors regarding problems

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Why are leaks a problem?

- When sewer lines are below the water table infiltration occupies valuable capacity in the sewer and downstream treatment plant
- Sewers above the water table can exfiltrate raw wastewater polluting soil, groundwater and surface water
- Leaks also attract root intrusion into sewers causing damage and stoppages

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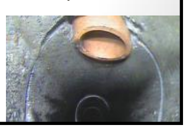
Types of Collection System Problems

- Design related deficiencies – ability of soil to support pipe and manhole weights, shifting soils, and vibrating or crushing forces from traffic
- Improper installation – improper line, grade, and joint installation or shortcuts in bedding, connections and backfilling
- Inadequate sewer use ordinances
- Improper inspection and enforcement of tap-ins or service connections



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Types of Collection System Problems

- Population shifts or changing patterns of activities can result in surcharging sections of the system
  - Surcharge – the supply of wastewater to be carried exceeds the pipe capacity
- Problems of a recurrent nature – grease, debris, and trash from specific dischargers resulting stoppages or restrictions
- Problems characteristic of that region resulting in rapid deterioration – climate, high sulfate content, high soil or wastewater temperatures

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Types of Collection System Problems

- Poor coordination and cooperation between local agencies – street construction and repair, existing utilities, handling illegal dumping into sewers
- Disaster or contingency situations – explosions, earthquakes, or subsidence
  - Subsidence – the settling of underground utilities after the removal of excess water from an aquifer
- Problems related to old or neglected collection systems

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Why control Infiltration & Inflow?

- Infiltration and Inflow (I/I) is recognized as a major cause of operational problem which can lead to poor performance or system failure
- Hydraulic overloads in a collection system lead to surcharged manholes, overflowing manholes, exposure of the public to the pathogens found in raw wastewater, and negative environmental effects
  - Sanitary Sewer Overflow (SSO)
  - Capacity Assurance, Management, Operation, and Maintenance (CMOM) – program proposed by the EPA specifically to control SSOs, reduce system degradation, avoid hydraulic overloading, SSO response, and protect the public's investment

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Why control Infiltration & Inflow?

- Hydraulic pressure resulting from overloading can lead to pipe failure because it is not designed as a pressure pipe
- Overloading can lead to exfiltration which can wash away the bedding material and soil creating voids that can lead to subsidence
- Wastewater treatment plants can exceed their hydraulic capacity which can overload the treatment processes and result in inadequate treatment

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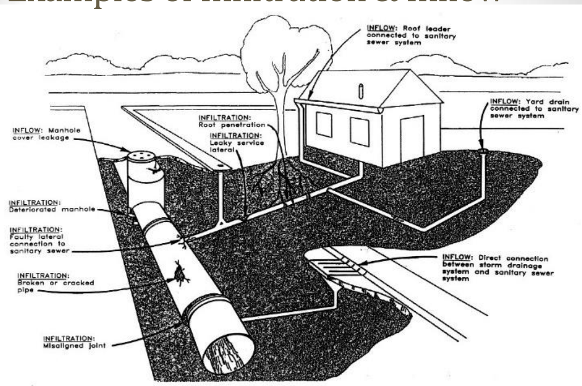
Examples of Infiltration & Inflow



Inflow

Inflow is water that is not polluted and should be in a stormwater drainage system, not a wastewater collection system

- Enters from deliberate illegal connections or by deliberate drainage of flooded areas
- Detection requires flow studies and inspections by smoke or dye testing of surrounding residential and commercial buildings or private property
- Corrections require sewer use ordinance
- Storm water inflow from pick holes in cover, poor seal between cover & casting

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Infiltration

- Created by high levels groundwater
- Through deteriorated or broken pipes, joints, manholes
- Detected by metering flows during low flow periods
- Once located, conduct field verification using visual inspection, CCTV inspection and/or smoke or dye testing

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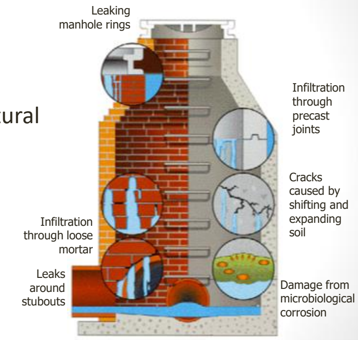
Exfiltration

- Leakage of wastewater out of CS through broken or damaged pipes or manholes
- May contaminate shallow wells or ditches where children and pets play
- Detected by CCTV inspection or smoke testing

Manhole Inspection: Objectives

- Lid elevation
- Ensure lid isn't buried
- Examine structural integrity
- Performing its intended job



Manhole Inspection: Objectives

- Some agencies prohibit manhole steps and use ladders instead to eliminate hazards of corroded steps
- Manhole pressure tests are typically negative-pressure (vacuum) tests

Examining Manhole Surface

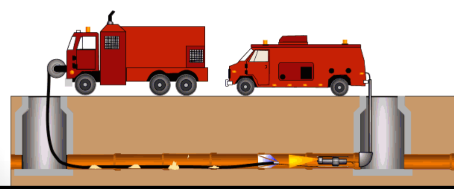
- Cracks or breaks
- Infiltration
- Joints
- Offsets
- Root intrusions
- Grease
- Gravel or debris
- Turbulence
- Grout bed of frame
- Shelf
- Flow
- Corrosion

CCTV Inspections

- Inspect conditions and determine problem areas
- Look for damage due to paving, building construction, nearby utility work, etc.
- Positively ID sewer stoppages caused by roots
- Search for illegal taps
- Locate I/I sources and amounts
- Evaluate effectiveness of maintenance work
- Locate buried or lost manholes

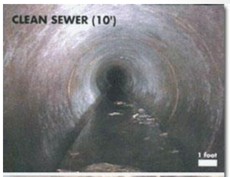
CCTV Inspections

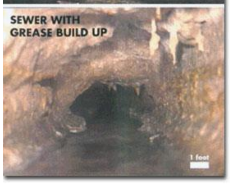
- "Pull type" CCTV inspection assembly requires at least two manholes be open.
- Pipe should be cleaned prior to inspection (high-velocity cleaning, power rodders, balling, bucket machines, water-jet vacuum trucks) to remove grit, grease, roots, sludge, etc.



Logging & Recording CCTV Inspections

- Written log/inspection report
- Still photographs
- Videotape recordings





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Logging & Recording CCTV Inspections

- Example of what camera may see:
  - CCTV inspection shows one section flowing ½ full, but upstream and downstream are only ¼ full, why?
  - There may be a sag in the pipe

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Purpose of Smoke Testing

- Sources of entry of surface water to CS
- Proof buildings are connected to CS
- Location of illegal or faulty connections
- Location broken sewers
- Location lost manholes


Smoke Testing Equipment

- Smoke blower unit
- Pipe plugs
- Smoke bombs



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Smoke Testing Preparations

- Warn public in advance when and where smoke testing is planned
- Involve local fire and police departments
- Train all operators how to handle persons who discover smoke in their homes
- Prepare operators to respect property and privacy of customers
- Inspect area to be tested

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Dye Testing

- Used to:
  - Determine if facilities or fixtures are connected to sewer
  - Estimate velocity of WW in sewer
  - Test for infiltration and exfiltration
- Equipment: manhole hook & dye (tablet vs. powder)


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Dye Testing

- Tracer dyes are also effective for estimating sewer velocities
- Start with downstream section and work upstream
- Insert the dye in the upstream manhole and record the time until it is first seen in the downstream manhole (t1) and when the dye can no longer be seen (t2)

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Inspecting & Testing Vocabulary

______1. Corrosion
______2. Offset
______3. Pre-Cleaning
______4. Saddle Connection
______5. Sewer Gas
______6. Subsidence
______7. Surcharge
______8. Tag Line
______9. Water Table

A. A building service connection made to a sewer main with a device called a saddle.
B. A pipe joint that has lost its bedding support and one of the pipe sections has dropped or slipped, thus creating a condition where the pipes no longer line up properly.
C. A line, rope or cable that follows equipment through a sewer so that equipment can be pulled back out if it encounters an obstruction or becomes stuck. Equipment is pulled forward with a pull line.
D. The dropping or lowering of the ground surface as a result of removing excess water (overdraft or over pumping) from an aquifer. After excess water has been removed, the soil will settle, become compacted and the ground surface will drop and can cause the settling of underground utilities.
E. The gradual decomposition or destruction of a material due to chemical action, often due to an electrochemical reaction.
F. The upper surface of the zone of saturation of groundwater in an unconfined aquifer.
G. Gas in collection lines (sewers) that result from the decomposition of organic matter in the wastewater. When testing for gases found in sewers, test for lack of oxygen and also for explosive and toxic gases.
H. Sewers are surcharged when the supply of water to be carried is greater than the capacity of the pipes to carry the flow. The surface of the wastewater in the manholes rises above the top of the sewer pipe, and the sewer is under pressure or a head, rather than at atmospheric pressure.
I. Sewer line cleaning, commonly done by high-velocity cleaners, that is done prior to the TV inspection of a pipeline to remove grease, slime and grit to allow for a clearer and more accurate identification of defects and problems.

Inspecting & Testing Questions

1. Why must inflow and infiltration be controlled?

2. What are the sources of inflow?

3. How can sources of infiltration be located?

4. How can infiltration problems be corrected or eliminated?

5. Why should exfiltration be controlled?

6. Why should manholes be inspected?

7. How often should a manhole be inspected?

8. Why must testing and inspecting collection systems be done thoroughly and on a regular basis?

9. Why should the TV camera always be pulled from the upstream manhole to the downstream manhole?

10. What is the purpose of smoke testing?

11. Where should observers look for smoke?

12. What is the purpose of dye testing?

13. What is the purpose of pipeline lamping?

Answers to Video, Vocabulary and Questions

Guardians of Health Video:

1. a. Explosive or flammable; b. Toxic; c. Oxygen deficient
2. 1-5years
3. a. i) Rain or storm water; ii) Street or surface wash water
   b. i) Roof leaders or down spouts, iii) Industrial drains
4. Low
5. a. Smoke blower unit; b. Pipe plugs; c. Smoke bombs
6. Establish that a section of pipe is straight and open or that it is not.

Vocabulary:

1. E	4. A	7. H
2. B	5. G	8. C
3. I	6. D	9. F

Questions:

1. Inflow and infiltration must be controlled to prevent hydraulic overload on the collection system or the wastewater treatment plant.
2. The source of inflow includes deliberate connections and surface drainage.
3. Sources of infiltration can be identified by the use of closed-circuit television, flow metering devices, smoke testing, dye testing and visual inspection.
4. Infiltration problems can be corrected or eliminated by sealing using pressure grouting, digging up and replacing pipe or inserting a plastic or fiber liner.
5. Exfiltration must be controlled because it can cause pollution of groundwaters.
6. Manholes should be inspected to be sure the lid is at the proper elevation, the manhole is structurally sound and the manhole is performing its intended job.
7. Every 1-5 years with those in heavy traffic areas being inspected more often.
8. To reduce the number of stoppages and failures.
9. The TV camera should always be pulled from the upstream manhole to the downstream manhole for the sake of consistency. Also there is a lesser chance of the camera becoming stuck in older lines. Pulling the camera toward the downstream manhole also helps to prevent a buildup of rages and debris in front of the lens.
10. To determine: sources of entry to the collection system of surface waters, proof that buildings or residences are connected to a wastewater collection system, location of illegal connections, location of broken sewers, location of lost manholes and diversion points.
11. Look for smoke from: roof vents, building foundations (especially where the house sewer passes under the foundation), yard drains, rain gutters and inside buildings.
12. To determine if certain facilities or fixtures are connected to the wastewater collection system, such as buildings that don’t show smoke from vents during smoke tests and yard drains or storm drains.
13. The purpose of pipeline lamping is to determine whether or not a section of pipe is straight and open.

Section 7

Pipeline Cleaning & Maintenance

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High velocity cleaner with vacuum device to remove grit & debris

Flushing operation

PIPELINE CLEANING & MAINTENANCE

Purpose

- Operate and maintain collection system to function as intended
- Primary purpose is to maintain the capacity of the sewer
- Potential problems can be found during routine cleaning and maintenance
- Minimize the number of
  - Stoppages per mile
  - Odor complaints
  - Lift station failures

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Stoppages

- Stoppages are caused by obstructions such as:
  - Roots
  - Debris
  - Grease
  - Broken pipe
  - Joint failure
  - Improper taps
  - Sticks

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Stoppages

- Debris found when removing stoppages includes:
  - Solidified grease
  - Detergents
  - Sticks
  - Rags
  - Plastic bags
  - Broken pipe
  - Brick
  - Rock
  - Sand
  - Silt
  - Egg shells

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Factors Effecting Sewer Cleaning Methods

- Wastewater characteristics
- Fluctuations in flow
- Sewer diameter or configuration
- Alignment or sewer grade
- Pipe materials
- Physical condition of sewer
- Location and accessibility of the pipe and records of previous cleaning

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Solids

- Solids which settle out in sewers lead to
  - Corrosive conditions
  - Odors
  - Stoppages
  - Toxic hydrogen sulfide gas
- Numerous odor complaints often indicates that a sewer needs to be cleaned

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Hydraulic Cleaning

- Using water pressure to clean sewers dates back over 100 years, but has recently undergone vast improvements with the development of self-propelling, high velocity cleaners (HVCs)
  - Also called jetters, hydraulic cleaners, hydro jets, flushers and jet trucks
- Water under pressure to produce high water velocities
  - High velocity cleaner
  - Ball or kite
  - Scooter
  - Flushing

High Velocity Cleaner - HVC

- HVCs force high pressure water through the nozzle at the end of the hose to scour the pipe walls
- The water pressure is also used to advance the nozzle head through the pipe
- The head cleans the invert and the walls of the pipe and moves the debris downstream where it can be captured and removed at a manhole

High Velocity Cleaner - HVC

- Effectively removes light grease and detergents, roots, sand, sludge and other light debris
  - Not as effective as power rodding machines for removing heavy roots and hardened grease
  - Not as effective as power bucket machines in removing packed debris in large diameter pipes
- HVCs operate most effectively in pipes ranging from 4 to 20 inches in diameter
- In pipes larger than 20 inches in diameter the cleaning effectiveness decreases as the pipe diameter increases
- Most commonly used as a preventive maintenance tool to keep sewers clear

High Velocity Cleaner - Equipment

- Equipment: Water tank, high pressure water pump, pump power source, hose reel with 500 or more feet and flushing nozzles
  - Trailer mounted system – ¾ inch diameter hose, delivers water flows from 25-40 GPM and operates at pressure ratings from 1500-2000 psi
  - Truck mounted system – 1 inch diameter hose delivering 50-100 GPM and pressure ratings up to 3000 psi
- The first 10 feet of hose behind the nozzle will be the first to wear from the impact of materials, to provide maximum protection a braided, steel-reinforced leader hose should be installed on the nozzle end

High Velocity Cleaner - Equipment

- Flushing nozzle: the selection of the nozzle is based on the work to be performed as the different designs accomplish different functions
- The angle of discharge from the nozzle is given in degrees, most common are 15, 35 and 45 degrees
  - The lower degrees provide better thrust, but higher degrees provide better cleaning capabilities
- Weekly nozzle inspection should be performed to ensure proper operation
- Drain the pump daily in cold weather

High Velocity Cleaner - Equipment

- 5 basic categories of nozzles:
  - Basic drilled nozzles – used for breaking blockages and cleaning debris
  - Rotational or spinning nozzles – best at cleaning grease and clearing light to medium roots (Brand names – Warthog and Bulldog)
  - Bottom or floor cleaners – remove heavy solids that have settled in the pipe invert
  - Specialty nozzles – designed for a single purpose (Ex. hydraulic root cutters)
  - High performance – engineered to provide a more powerful stream of water using less power with less maintenance

High Velocity Cleaner - Equipment

- Regardless of the nozzle chosen a finned nozzle extension should be used (attaches between the nozzle and the hose)
- The finned extension accomplishes two goals:
  - Helps to protect the nozzle from wear resulting from running on the rough surface of the pipe
  - Helps prevent the nozzle from turning up a lateral or service connection or turning around in the pipe

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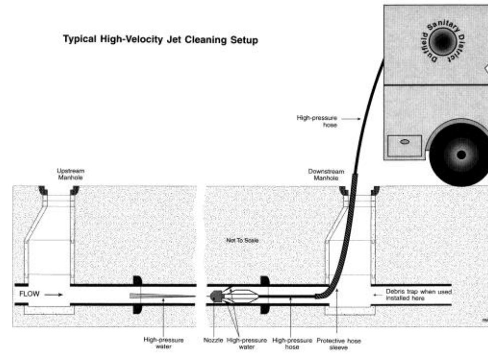
High Velocity Cleaner - HVC



High Velocity Cleaner - Operation

- HVCs water tank filled from a fire hydrant nearby
- When using a hydrant a special hydrant wrench must be used to operate the main hydrant valve
  - Never use a pipe wrench on a hydrant valve because the valve nut is brass and is easily damaged
  - Never use a cheater bar on the hydrant wrench
- A gate valve should be installed on the hydrant to regulate the flow of water and eliminate the need to open and close the hydrant's main valve repeatedly which could cause damage to the valve or cause water to discharge from the hydrant weep hole that could undermine the hydrant

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High Velocity Cleaner - Operation

- Once the gate valve is installed and in the closed position, fully open the hydrant's valve and then open the gate valve to allow water to run
  - Continue flushing until the water is clear from any rust
- Once the water is running clear, close the gate valve slowly to avoid water hammer in the water main
- Fill the water tank by slowly opening the gate valve to avoid disturbing any rust
  - A properly installed air gap must be used to prevent a cross connection between the HVC tank and the water system

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High Velocity Cleaner - Operation

- A flushing nozzle is installed at the end of the hose and is lowered into the downstream manhole of the section of sewer to be cleaned
- The rear facing jets on the nozzle allow the flushing nozzle and hose to be pushed forward through the line to the next manhole (usually not more than 300 ft away)
- As the nozzle travels through the line the high velocity water dislodges sediment, roots, grease, sand, silt and sludge and back-flushes it to the downstream manhole
- A debris trap in the downstream manhole is used to catch and remove the debris

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High Velocity Cleaner - Operation

- When cleaning a large diameter sewer pipe a sand trap is placed in the downstream pipe of the manhole to prevent large amounts of debris from accumulating downstream
- Water and debris entering the manhole builds up in the manhole and the water drains over the top of the trap while the solids settle out and remain in the manhole
  - Debris shovels, grabbers or vacuums can be used to remove the debris

Debris grabber

Sand trap

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High Velocity Cleaner - Operation

- Continue sending the nozzle end up the line and bring it back to the downstream manhole enough times to reach the upstream manhole and return without bringing back debris
- Keep the nozzle moving and the pump operating at all times to avoid creating stoppages, especially in smaller diameter lines
  - If you travel too far up the line enough debris could be dislodged that the nozzle can't move downstream fast enough resulting in a stoppage

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High Velocity Cleaner - Operation

- The exact distance the cleaning nozzle has moved forward must be known at all times
- Regularly check to ensure that the nozzle is threaded securely onto the skid or leader hose
  - If the nozzle detaches there will be an immediate drop in the water pressure
- While using an HVC to clear a stoppage once the nozzle reaches the stoppage pull the hose back a few feet by hand and let go
  - The nozzle will shoot forward quickly and give a pounding effect on the stoppage

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High Velocity Cleaner - Safety

- Use extreme caution when operating forward spraying nozzles
  - The pressure of a forward spraying nozzle can propel itself out of the line and cause serious operator injury
- If fresh soil or broken parts of the sewer pipe are washed into the downstream manhole stop the operation
  - Continued cleaning could result in a large hole developing under the street which could lead to street collapse
- A bend in the line will prevent you from pulling the nozzle back under full pressure, reduce the pressure until you pass the bend

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High Velocity Cleaner - Safety

- When clearing stoppages with an HVC avoid using the surcharged upstream manhole as it is difficult to know that the nozzle is secure in the invert and will not exit the manhole under high pressure and endanger operators and possibly damage the machine
  - Always use the dry downstream manhole to clear stoppages
- Always be aware of what the nozzle is doing in the pipe and be on guard for it to turn around in large diameter pipes
  - Debris or pieces of pipe can cause a nozzle to flip over backward and move back toward the operator

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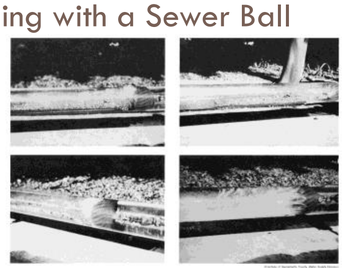
Cleaning with a Sewer Ball



- Preventive maintenance
- Spinning ball and high velocity water move debris downstream
- Effectively removes grease, sand, grit and other debris

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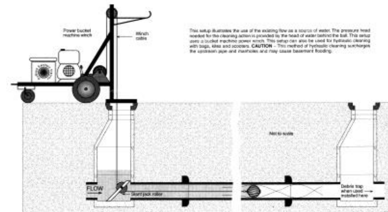
Cleaning with a Sewer Ball



- Don't use in areas with steep grade hills (basement flooding)
- Large sewers use kite, tire, or scooter instead of ball
- Cannot be use in areas with protruding taps or sewers with badly offset joints

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Cleaning with Kites and Bags

- Force mains and other larger diameter sewers, where HVCs are not effective, require the use of kites and bags
- Both are capable of washing ahead of themselves a full pipe of deposits
- Head pressure is built up upstream of the kite or bag and the velocity of water flowing around the outside of the bag or through the outlet of the kite will create sufficient cleansing velocity
- Equipment: water tank truck, dump truck and a power drum winch machine

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Sewer Scooter

- The scooter is a self-propelled tool the uses water pressure to effectively clean sewers at a cost that is considerably less than other cleaning methods
- The scooter is a framework on small wheels with a circular metal shield at one end that is rimmed with a rubber flange
- The top half of the shield is hinged and controlled by a chain-spring system while the lower half is fastened with bolts to the front of the frame
- Head pressure is created upstream of the scooter and the flow of water around the device creates hydraulic cleaning action while being controlled by the upper half of the shield

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Sewer Scooter

- Most effective in cleaning larger lines over 18 inches in diameter
- Effectively removes grease, grit, bricks, and rock
- Available in sizes from 6 - 96 inches
- Equipment: Tank truck, debris traps, control lines, control cable guide, power drum winch, scooter
  - Sewer up to 12 inches in diameter – hand winch
  - Sewers 15 inches and larger require a power drum winch and steel cable due to the tremendous pressure of water behind the head shield

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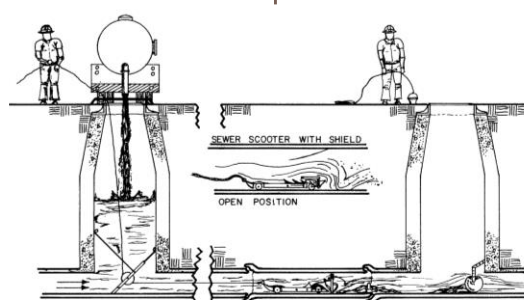
Sewer Scooter - Operation



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Sewer Scooter - Operation

- A control rope or cable is fastened to the control chain of the scooter and the scooter is lowered into the upstream manhole
- After the head shield is inserted into the pipe, install the lower manhole jack or control cable guide and secure firmly
  - This allows the control cable to take the strain without rubbing on the sharp edge of the pipe during the cleaning operation
- With the scooter inserted in the pipe and the head shield raised it will act as a plug and a head of water will begin building up in the manhole
- The water level in the manhole is controlled by pulling firmly on the control line to lower the head shield and allow water to pass

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Sewer Scooter - Operation

- At the start of the operation test the folding mechanism by giving the control line a short, smooth pull back 2 or 3 ft
  - If the buildup of water in the manhole in the upstream manhole starts to go down you know the folding mechanism is working
- Allow the scooter to work its way downstream, keeping steady tension on the control line to maintain a continuous flow of water and a smooth cleaning operation
- Attention must be given to the amount of water in the manhole above the invert, the best cleaning action results when the depth of water in the manhole is three times the pipe diameter

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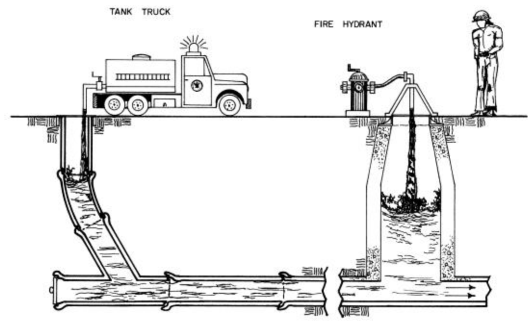
Sewer Scooter - Operation

- Scooter cleaning efficiency increases as the pipe diameter increases due to the increase in head pressure which increases the high velocity flow around the head shield
  - If the flow in the sewer is insufficient for effective cleaning then additional water can be added from a tank or hydrant
- If the scooter slows or stops during the operation this is usually due to a build up of material in front of the scooter
  - To clear the material give the control line a short, smooth pull back of 4 or 5 feet allowing the top half of the shield to fold back and a surge of water will be released to flush the accumulated material downstream

Flushing Operation

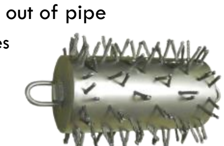


Flushing Operation

- May control odors at beginning of sewer where low flows may lead to solids accumulation
- May also control insects and rodents in sewer
- Also used with mechanical cleaning (bucket machines & power rodders)
- Air gap device needed if hydrant used as water source
- Safety considerations:
  - Traffic
  - Atmosphere in manholes (toxic & explosive gases)
  - Avoid flooding of houses & businesses

Mechanical Cleaning

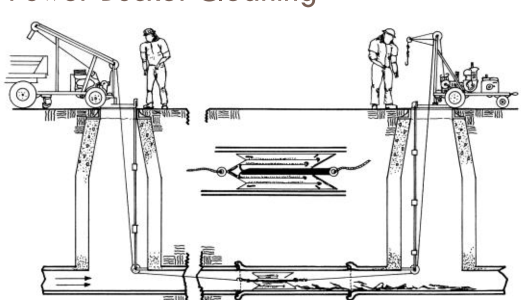
- Mechanical equipment that scrapes, cuts, pulls, or pushes material out of pipe
  - Bucket machines
  - Power rodders
  - Hand rodders
  - Porcupines
  - Swabs



Porcupines are used to scour pipe walls of hardened debris, roots, & grease

Swabs or poly pigs

Power Bucket Cleaning



Power Bucket Cleaning

- Provides means to clean larger sewers
- Final cleanup using porcupine to scrub sewer line
- May require hydraulic cleaning afterwards to remove smaller debris (sand, grit)
- Working machine located at the upstream manhole when cleaning debris from large lines
- Always pull porcupine downstream to avoid sealing off the line and causing the sewer to back up

Power Bucket Cleaning

- Power bucket machines are an excellent maintenance tool for removing large amounts of debris from the sewer, especially in large lines
- In smaller sewers with lower flows, the working machine is usually located at the downstream manhole
  - Working from this manhole reduces the possibility of a stoppage developing in the sewer below the work area
- Often the working machine is located at the upstream manhole when clearing debris from larger lines

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Bucket Machine Maintenance

- Proper lubrication cable scroll and level wind system
- Inspect belt and chain tensions
- Inspect gear clearance
- Watch for frayed cable
- Watch for loose cable clamps

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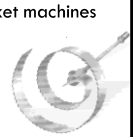
Power Rodder

- Power rodding machines use a steel rod to push or pull various clearing tools through sewers
- Used for:
  - Routine preventive maintenance
  - Scheduled clearing of grease deposits, roots and debris accumulations in flat lines
  - Threading cable for CCTV inspection and bucket machines
  - Emergency use for clearing stoppages
- One of the most widely used methods for clearing collection systems



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Power Rodder

- Can perform tasks that are difficult with hydraulic cleaning methods such as heavy root removal, grease and grit deposit removal and stoppage relief
  - Power rodders do not remove silt, sand and sludge as effectively as hydraulic cleaning methods
  - After clearing a sewer with a power rodder it should be cleaned hydraulically to restore the line to full capacity
- Due to the tendency for rods to bend or coil in large diameter pipes they are most effective in pipes that are 15 inches in diameter or smaller

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Power Rodder

- Power rodders are typically classified as either sectional or continuous type machines
- Both types of machines are effective in clearing sewer lines up to 15 inches in diameter and up to distances of 750-1000 feet depending on the diameter of the rod

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Power Rodder - Sectional

- Sectional power rodder is designed to use sections of rod that are mechanically attached to each other
  - Industry standard refer to sectional rod diameter sizes in fractions
  - Rod size can be either a 5/16 or 3/8 inch diameter
  - Available in lengths of 36 inches, 39 inches and 48 inches
  - Capable of clearing lines effectively in diameters up to 12 inches and distances up to approximately 750 feet

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Power Rodder – Continuous

- Continuous power rodders are designed to use a single continuous rod
  - Continuous rod diameters given in decimal form
  - Most common rod diameter sizes are 0.312 inch, 0.375 inch and 0.401 inch
  - Rod storage is usually between 1000 and 1500 feet

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Power Rodder Type Differences

- Continuous rodding machines are quickly and easily loaded, while loading a full sectional reel may require several hours of coupling all of the sections together
- Sectional rods are pushed through the drive head by a positive drive, but continuous rods are pushed by roller that can slip and cause wear
- Continuous rodders cover longer distances and are less likely to break than sectional rodders due to the transfer of torque down the continuous length of the rod
  - Sectional rod couplings and nuts can work loose or increase friction

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Power Rodder Type Differences

- Continuous rods must be cleaned as it passed through the drive rollers to prevent damage and wear, but sectional rods are more forgiving
  - Both types should be cleaned as they are being retrieved to prevent grit from entering the roller system
- Repairs to a broken sectional rod can be made quickly in the field, but a continuous rod break is difficult to repair and the broken section must be discarded resulting in a reduction in the operating length

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Power Rodder Type Differences

- The broken end of the continuous rod cannot be reused and the remaining portion on the reel may be too short to use effectively resulting in the replacement of the entire reel
- A broken continuous rod is also more difficult to retrieve than a broken sectional rod because there are no couplings for the pick-up tool to grab

Pick-up tool

Sectional steel rod
Used to push or pull various cleaning tools through the sewer

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Power Rodding Tools

Square bar corkscrew
Primarily used to relieve stoppages in pipes over 6 inches in diameter. An effective stoppage tool due to the open structure of the blade that allows materials to pass through the tool.

Auger
Used to pilot a hole through roots, grease and other solids in the pipe. Primarily used in conjunction with other tools to open a path in the line so that another tool, such as a root saw, can be used more easily. Effective in cleaning misaligned pipes because the direction of rotation can be reversed to navigate bad joints to travel to blockages.

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*Tool descriptions from *Operation and Maintenance of Wastewater Collections Systems Vol. 1, Eight Edition* – Figure 5.11

Power Rodding Tools

Double point corkscrew
Used to engage and retrieve root masses, cans, plastic bottles, fabrics and other solid debris from a pipe. The double points allow the tool to bite into material and retrieve it.

Spring blade cutter
Used as a finishing or pull-back tool after a root saw or auger has removed the bulk of roots or grease from the line. The tool is installed at the manhole away from the rodding machine and is slowly pulled backward through the pipe at a high rotation speed. The blades are designed to scour the pipe walls to remove the balance of materials left behind. This tool should be operated only while being pulled.

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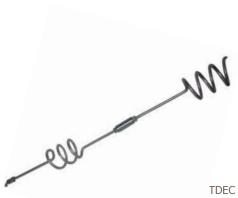
*Tool descriptions from *Operation and Maintenance of Wastewater Collections Systems Vol. 1, Eight Edition* – Figure 5.11

Power Rodding Tools

Sand leader
Used to rotate and remain above sand and other built-up deposits to thread a line with cable or attach a different tool from the next manhole or access point.



Sand corkscrew
Used in pipes where sand has plugged the line. The first screw portion pilots the tool into the sediments; the second screw portion further enlarges the access point and allows water to enter the material to loosen it.

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*Tool descriptions from *Operation and Maintenance of Wastewater Collections Systems Vol. 1, Eight Edition* – Figure 5.11

Power Rodding Tools

Root saw
Used exclusively to cut through root masses in the pipe after the auger has piloted a hole in the line. Available in many different configurations for different kinds of root cutting from small curtain or "veil" roots to large root intrusions.

Spearheads or boring tools
Used to break up stubborn stoppages, break glass, pierce cans and break up packed silt, sand or industrial debris.

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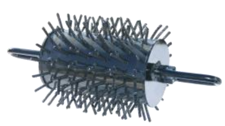
*Tool descriptions from *Operation and Maintenance of Wastewater Collections Systems Vol. 1, Eight Edition* – Figure 5.11

Power Rodding Tools

Porcupine
Used as a finishing tool to scour the pipe after cleaning operations. This tool should be operated only while being pulled, and it requires a winch and tag line for safety.



Pilot bullet
Used primarily on the end of the string of a rod to guide the rod easily through the rod guide hose. Installed after the line has been clean and the rod is pulled back into the machine. This tool also can be used for stoppages and threading a cable into a pipe.

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*Tool descriptions from *Operation and Maintenance of Wastewater Collections Systems Vol. 1, Eight Edition* – Figure 5.11

Power Rodding Tools

Pick-up tool
Used to retrieve sectional rods that have broken in a sewer line. Tool slowly turns and locks on the rod coupling, allowing the string of rod to be removed.

Assembly wrench
Used on the coupling nut to install and change tools or to change sectional rod sizes.

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*Tool descriptions from *Operation and Maintenance of Wastewater Collections Systems Vol. 1, Eight Edition* – Figure 5.11

Power Rodding Tools

Assembly turning handle
Used to provide a firm, safe hold on the rod coupling so that the assembly wrench can turn the coupling nut.

Swivel
Used when towing a cable through a pipe. The swivel action allows the cable or rod to twist independently and prevents knotting of the cable.

Sectional rod coupling
Used to attach steel rods to each other.

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*Tool descriptions from *Operation and Maintenance of Wastewater Collections Systems Vol. 1, Eight Edition* – Figure 5.11

Power Rodding Tools

Rod guide hose
Used on all power rodders to protect and support the rod as it travels from the machine to the bottom of the manhole.

Lower manhole brace
Used with the rod guide hose to prevent the bell end of the hose from pushing back out of the pipe when an obstruction is encountered. This brace attaches to the guide hose bell and, when placed against the opposite wall of the manhole, prevents the guide hose from pushing out of the pipe invert.

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*Tool descriptions from *Operation and Maintenance of Wastewater Collections Systems Vol. 1, Eight Edition* – Figure 5.11

Power Rodding Tools

- Tools for the rodding machine are designed to be rotated clockwise in the pipe to clear material
  - Corkscrew, boring tools and augers can be rotated counter-clockwise to back them out of the accumulated material or to travel over misaligned joints
- Corkscrew and boring tools should be rotated slowly at about 25 RPM
- Root saws need to rotate faster at 25-50 RPM
- Finishing or pull back tools need to rotate at about 55-60 RPM as they are being slowly pulled back

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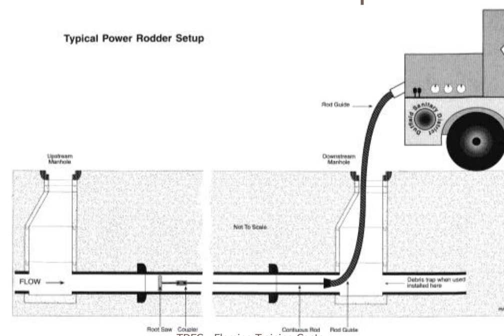
Power Rodder Machine Operation



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Power Rodder Machine Operation

- Start at the top of the system when clearing a long section of the system
  - Any debris lost downstream during the operation will be going into a pipe section that you will clear next
- ***Always test the manhole atmosphere for explosive gases before rodding operation because sparks from the rodding could cause an explosion***
- Install a lower manhole rod guide in the manhole being used and a debris trap in the downstream manhole

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Power Rodder Machine Operation

- If the rodding machine is being set up to clear a stoppage use a square bar corkscrew from the dry manhole, after material has broken loose examine it to determine which tool would work best to completely clear the stoppage
- It is usually better to change a tool from the far manhole which will save the time of removing the rod guide hose from the machine manhole
  - Pull the end of the rod out of the manhole, shut off power to the rodding machine before handling, replace the tool, wait until the new tool reaches the invert before turning power back on

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Power Rodder Machine Operation

To remove roots: auger ➔ root saw ➔ finishing tool

- Select an auger that is one size smaller than the pipe and run it upstream to the far manhole
- The root saw can be the same size as the pipe and is slowly pulled downstream at a high RPM
- Run the saw back up to the upstream manhole and change to the finishing tool (Ex. spring blade cutter) and slowly pull it back downstream at a high RPM

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Power Rodder Machine Operation

To remove grease: small auger ➔ pipe sized auger

- Select an auger that is one size smaller than the pipe and run it upstream to the far manhole
- At the upstream manhole change to an auger that is the same size as the pipe and pull it back to the machine
  - You could run the rod back to the upstream manhole and switch to a finishing tool to pull back through for a final cleaning
- A good practice is to flush the line after grease removal by using either an HVC or flush from an upstream hydrant

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Power Rodder Machine Operation

- Properly place the rodding machine so that there are no bends in the guide hose
  - When a rod is forced to stay in one place in a severe bend it will heat up as it is rotated, when the hot metal reaches the cool water it can be damaged resulting in likely spot for the rod to break
- The forward pressure on the rod should be limited to 350 pounds
  - Too much pressure may make the rod bend in the pipe and break or reverse itself causing a tangle

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Power Rodder Machine Operation

- The tool will usually stop rotating when it engages material and if you do not back off the rod will twist into a loop and continue to coil, this is called overtorque

Never handle a rod when it is under tension

Twisted rods are very dangerous and need to be treated carefully

- To increase the effectiveness of a clearing operation in areas of low flow, add additional flow from the upstream manhole
  - Flow in the section of sewer being cleared is essential for cooling the rotating tool and flushing removed debris

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Recovering Broken Rods

- When a rod breaks begin recovery by measuring the amount of rod pulled back to determine the approximate location of the broken rod
- For sectional rods remove the broken half at the coupling and install the pick-up tool to recover the rod remaining in the line, then couple the two rods together again
- Continuous rod breaks are far more difficult because the tool coupling is also lost in the line and a new one will need to be fashioned, then the pick-up tool can be used

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Poly Pig

- Poly pigs, also called pigs or swabs, are a common method of cleaning force mains
- A poly pig is inserted into the main and pushed through the pipe by pressurizing behind the pig
  - Poly pigs are available in various densities and surface coatings for different kinds of cleaning
  - Ice is also currently being used – Ice pigging

Types of swabs and pigs

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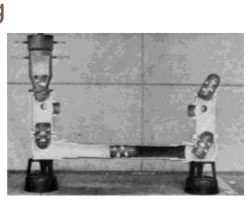
Poly Pig



- The capacity in a force main is reduced when slime builds up on the walls of the pipe or when solids settle in the invert
- As the poly pig is forced through the main it scours the pipe wall clean to regain full capacity

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Poly Pig

- A launching or entry point must be available to insert the poly pig and an access point at the end of the force main is needed to retrieve the poly pig after the operation
- Poly pigs are flexible enough that they can usually negotiate around corners and bends
  - Obstructions in the force main such as a butterfly valve will cause the pig to become stuck
  - Carefully review as-built drawings of the line to clean to avoid any obstructions
  - Poly pigs can be equipped with a radio beacon device which allows operators to track it's progress through the pipe

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Chemical Application

- Chemicals can be useful aids for cleaning and maintaining collection systems
- Chemicals can be used to control roots, grease, rodents, insects, odors and corrosion
  - Chemicals will not immediately clear stoppages

Review the SDS First!
Do not mix unknown chemicals



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Root Control

- Roots are drawn to sewer lines by vapor trails that escape into the soil through very small cracks in the pipe
  - Tiny roots enter the sewer line one cell at a time and quickly grow by feeding on the nutrient rich environment inside
  - As the roots grow they expand the cracks leading to breaks and fill the pipe creating stoppages
  - Roots that grow from the top of the pipe are called "veils" and catch passing grease and debris creating a blockage

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Root Control

- Power rodders are most effective method to remove roots using root saw
- Chemical root control agents applied by flooding or foaming destroy existing roots in sewers and can prevent regrowth for periods of 3-5 years
  - First ingredient is a fumigant that penetrates the cell walls of existing roots causing decay
  - Second ingredient is a growth inhibitor that chemically attaches itself to the interior of the pipe
  - Both are needed for good root control

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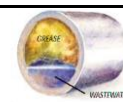
Grease



- Fats, Oils and Greases (FOG) and soaps cool, solidify and form a coating or deposit on the walls of a sewer creating a reduction in capacity and can lead to stoppages
- Sources: restaurants, hospitals, industries and homes with garbage disposals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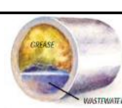
Grease



- Rate of buildup depends on amount in the wastewater, flow, velocity and sewer size
  - Sewers > 18 in typically have fewer grease problems
- Solutions: grease-eating bacteria, power rodders, high velocity cleaning (HVC)
- Inspect & clean grease traps as needed
- Ultimate solution is to educate sewer users about the problems created by soap and FOG discharge into sewers

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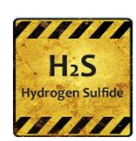
Odors

- Odors from the collection systems are primarily from the production of hydrogen sulfide (H_2S) and most odor control programs focus on reducing or eliminating H_2S production in the system
- The production of H_2S can be due to low-velocity flows, long sewer lines, high temperatures or poorly maintained collection systems



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Why Control Hydrogen Sulfide?

- Paralysis of respiratory system may lead to death of collection system operators
- Corrosion which could lead to possible collapse of the sewer, structures and equipment
- Loss of system capacity
- Creates a flammable and explosive atmosphere under certain circumstances
- Most common source of odor complaints
  - H_2S has a rotten-egg odor from the sulfur

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Hydrogen Sulfide Production

- H_2S is produced under anaerobic conditions by bacteria in the slime layer below the water line that convert sulfate to sulfide
  - Anaerobic – no free oxygen available for organisms to use
- The sulfide is dissolved in the wastewater until disturbed and is then released as H_2S gas which is highly dangerous to operators and creates an explosive environment
  - H_2S LEL (lower explosive limit) is 4.3% and UEL (upper explosive limit) is 46%
- The H_2S gas is used by bacteria above the water line to produce sulfuric acid (H_2SO_4) can cause severe corrosion
  - H_2SO_4 is corrosive to concrete, Fe, Cu, Zn, Pb, Cd

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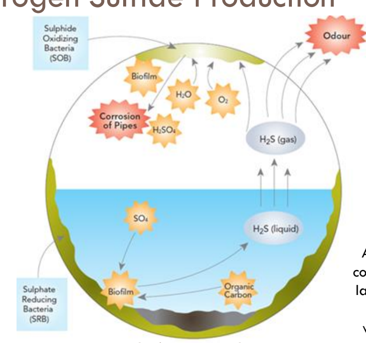
Hydrogen Sulfide Production



Anatomy of corrosive slime layer within a typical wastewater system pipe

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Factors that Contribute to Hydrogen Sulfide Production

- Sulfate concentration
- Concentration of organic matter
- Oxygen
  - Critical DO is 0.1 to 1.0 mg/L
- Amount of slime on pipe walls
  - Sulfide production is faster in warmer wastewater temperatures
- Lower stream velocity leads to thicker slime layer
- Temperature
- pH

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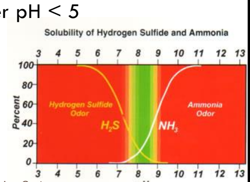
More on Hydrogen Sulfide

- Exposure for 2 min at 0.01% impairs sense of smell- *olfactory fatigue*
- Specific gravity 1.19
- Maximum safe 15-minute exposure: 20 ppm (OSHA)
- Greatest problem at wastewater pH < 5
- A concentration of 1 ppm in turbulent wastewater can produce a concentration of 300 ppm in the atmosphere



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Controlling Odors

- Many collection system municipalities are developing and implementing odor control plans which incorporate measures to reduce the generation and release of odors
- Odor control plans include:
  - Odor complaint response and investigation
  - Routine sewer maintenance
  - Chemical addition
  - Air withdrawal and treatment from the collection system
  - Sewer construction and repair
  - Ongoing monitoring of sewer air pressure and odor conc.

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Complaint Response & Investigation

- After receiving an odor complaint operators need to investigate and identify the source
  - Some odor complaints are non-sewer related such as standing water, stormwater catch basins or owner plumbing problems
- Once identified determine and implement necessary actions to eliminate the odor which could include sewer cleaning, sealing maintenance holes and inspecting trap maintenance holes for structural integrity and functionality
- Document the complaint and response, then inform the complaining customer according to your procedure

Routine Sewer Maintenance

- Routine maintenance is necessary to allow wastewater to flow freely in the system
- Obstructions slow the flow and cause to debris to settle out resulting in the production of H_2S
- Preventive maintenance includes
  - Sewer cleaning and root control
  - Trap manhole inspection and cleaning
  - Siphon inspection and cleaning
  - Sealing manholes

Chemical Odor Control Technologies

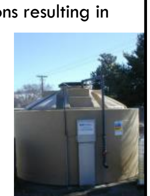
- Chemical or "liquid phase" control technologies limit the production of H_2S by preventing sulfide from forming in the wastewater in the system
- Aeration
  - Pure oxygen can be injected into force mains
  - Injection of compressed air
  - Oxidizes existing sulfides in water
  - Prevents downstream sulfide formation (keeps water aerobic)
  - Cheapest chemical available - it's free

Chemical Methods of Odor Control

- Hydrogen peroxide (H_2O_2) addition keeps the wastewater aerobic and oxidizes H_2S
- Requires a conditioning program because the slimes are not directly affected by normal doses of H_2O_2
  - Dose with sodium hydroxide (NaOH) also called caustic soda or calcium hydroxide ($Ca(OH)_2$) also called lime
  - Lime dosage at about 8000 mg/L over 1 hour will kill the slimes over periods of 1–14 days
- H_2O_2 Dose:
  - 35% conc. 13-15 mg/L per mg/L H_2S
  - 50% conc. 11-13 mg/L per mg/L H_2S

Chemical Methods of Odor Control

- Nitrate addition
  - Calcium nitrate ($Ca(NO_2)_2$) or Bioxide® adds nitrate to the wastewater stream and makes it available to the bacteria
  - Bacteria use the nitrate as an oxygen source before sulfate in anaerobic or anoxic water conditions resulting in less H_2S being produced
- Masking agents
  - Overpower the odor
  - Do not correct the problem



Chemical Methods of Odor Control

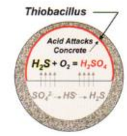
- Chlorine is the most widely used chemical for hydrogen sulfide control and lift stations are often used for injection sites
- Chlorine gas (Cl_2), Calcium hypochlorite ($Ca(OCl)_2$ solid; HTH) or Sodium hypochlorite (NaOCl; liquid bleach) can be used
- Chlorine doses of 10-20 mg/L are effective in controlling the production of H_2S
  - Toxic to most organisms in the wastewater resulting in less oxygen being consumed keeping it aerobic and directly eliminating the bacteria that produce H_2S

Chemical Methods of Odor Control

- Sodium hydroxide (NaOH)
  - Periodic treatment to inactivate bioslime
  - Increase pH to > 12.5 for 30 min
  - Safety considerations while handling
  - NaOH concentration is typically 3-6 % and care must be taken not to overfeed
- Iron salts
  - React with dissolved sulfide to form metal precipitate to prevent release of H_2S to air
  - Corrosive acid solution
    - Storage tanks for iron salts must be fiberglass or steel lined with rubber
    - Pipes must be PVC
    - Pumps must be plastic or rubber-lined to prevent corrosion

Chemical Methods of Odor Control

- Magnesium hydroxide (Thioguard®)
  - Raises WW pH>8, so sulfide is not produced
  - Binds up sulfide in solution forming magnesium polysulfide
  - Adds alkalinity
  - Non hazardous & environmentally safe
- Improves treatment plant performance
  - Controls odors
  - Addition of alkalinity aids nitrification
  - Cationic-improves sludge settleability and removal of TSS and BOD

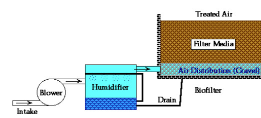


Magnesium hydroxide also sprayed on crown to stop corrosion

Air Treatment and Air Flow Control

- Conventional carbon adsorption system, scrubbers
  - Odorous air is directed through a vessel containing activated carbon
  - Hydrogen sulfide, other reduced sulfur compounds and volatile organic compounds (VOCs) are attracted to and adhere to the pore structure of the carbon and are removed from the air stream
  - Relieves the air pressure in the system while preventing the release of odors

Air Treatment and Air Flow Control



- Air is introduced into a bed of compost or peat (media)
- Bacteria living in media biologically oxidize odors
- Other odors captured by media are chemically oxidized
- Left: Biofilters can treat odors in air vented from sewer
- Right: Manhole insert can treat odors at one manhole

Cleaning & Maintenance Vocabulary

______1. Air Gap
______2. BOD
______3. Balling
______4. Bucket
______5. Flushing
______6. High-Velocity Cleaner
______7. Hydraulic Cleaning
______8. Insecticide
______9. Kite
______10. Mechanical Cleaning
______11. Pesticide
______12. Porcupine
______13. Rod
______14. Rodenticide
______15. Scooter
______16. Sewer Ball
______17. Swab

A. A machine designed to remove grease and debris from the smaller diameter sewer pipes with high-velocity jets of water.
B. Clearing pipe by using equipment that scrapes, cuts, pulls or pushes the material out of the pipe. These include bucket machines, power rodders and hand rods.
C. A sewer cleaning tool the same diameter as the pipe being cleaned. The tool is a steel cylinder having solid ends with eyes cast in them where a cable can be attached and pulled by a winch. Many short pieces of cable or bristles protrude from the cylinder to form a round brush.
D. A method of hydraulically cleaning a sewer or storm drain by using the pressure of a water head to create a high cleansing velocity of water around the ball.
E. Any substance or chemical formulated to kill or control insects.
F. A sewer cleaning tool whose cleansing action depends on the development of high water velocity around the outside edge of a circular shield. The metal shield is rimmed with a rubber coating and is attached to a framework on wheels. The angle of the shield is controlled by a chain-spring system that regulates the head of water behind it and thus the cleansing velocity of the water flowing around the shield.
G. A special device designed to be pulled along a sewer for the removal of debris from the sewer. It has one end open with the opposite end having a set of jaws.
H. A spirally grooved, inflatable, semi-hard rubber ball designed for hydraulic cleaning of sewer pipes.
I. Any substance or chemical designed or formulated to kill or control animal pests.
J. A circular sewer cleaning tool almost the same diameter as the pipe being cleaned. As a final cleaning procedure after a sewer line has been cleaned with a porcupine, this is pulled through the sewer and the flushing action of water flowing around the tool cleans the line.
K. An open vertical drop, or vertical empty space, between a drinking (potable) water supply and the point of use. This gap prevents backsiphonage because there is no way wastewater can reach the drinking water.
L. Any substance or chemical used to kill or control rodents.

M. Cleaning pipe with water under enough pressure to produce high water velocities using: a high-velocity cleaner; a ball, kite or similar sewer cleaning device; a scooter; or flushing.
N. A device for hydraulically cleaning sewer lines. Resembling an airport windsock and constructed of canvas-type material, it increases the velocity of a flow at its outlet to wash debris ahead of it.
O. The removal of deposits of material that have lodged in sewers because of inadequately velocity of flows. Water is discharged into the sewers at such high rates that the larger flow and higher velocities are sufficient to remove the material.
P. A light metal rod, three to five feet long with a coupling at each end. They are joined and pushed into a sewer to dislodge obstructions.
Q. Biochemical Oxygen Demand. The rate that organisms use the oxygen in water or wastewater while stabilizing decomposable organic matter under aerobic conditions.

Cleaning & Maintenance Questions

1. What are the <u>major</u> causes of stoppages?

2. What is the <u>most effective</u> method of removing grease buildups?

3. How can a stoppage caused by roots be cleared?

4. List three sewer line hydraulic cleaning methods.

5. What kinds of deposits in sewers can be removed by balling?

6. Where is the additional water obtained to provide the necessary head for a balling operation when flows in the sewer are low?

7. What are the uses of high-velocity cleaning machines?

8. Where should you start to clean the sewers in a given area or subdivision?

9. Which direction does the nozzle travel in the sewer?

10. Scooters can be used to remove what kinds of material from sewers?

11. How are force mains often cleaned?

12. Identify two sewer line mechanical clearing techniques.

13. What is the purpose of the porcupine tool?

14. Chemicals can be used to control what types of problems in wastewater collection systems?

15. What are the causes or sources of grease problems?

16. What problems are created by the presence of hydrogen sulfide?

17. What are the sources of hydrogen sulfide?

18. What are <u>three</u> potential methods of chemical control of sulfide?

Answers to Video, Vocabulary and Questions

Way Makers Video:

1. Large	5. Rubber/latex	9. Hydrogen
2. Downstream	6. Roots, insects, odors	10. 13; 30
3. Upstream	7. MSDS	
4. Porcupine	8. USEPA	

Vocabulary:

1. K	5. O	9. N	13. P	17. J
2. Q	6. A	10. B	14. L	
3. D	7. M	11. I	15. F	
4. G	8. E	12. C	16. H	

Questions:

1. Major causes of stoppages include obstructions such as roots, grease, debris, broken pipe or joint failures. Vandals, construction work, forces of nature and intersecting flows can also cause stoppages.
2. High-velocity cleaners are effective tools for removing grease buildups in sewers up to 15 inches in diameter. A parachute or bag may be a better method for larger diameter sewers.
3. A stoppage caused by roots can be cleared by either a power rodder or a hand rodder. A high-velocity cleaner is also effective with a special head and proper operation.
4. Balling, high-velocity cleaner, flushing, sewer scooter, kites, tires and poly pigs
5. Deposits of grit and grease
6. Fire hydrants or water truck
7. Open stoppages, remove grease, clean lines of debris and wash manholes and wet wells
8. Start at the top or highest point in the collection system.
9. Direct nozzle upstream
10. Large objects such as brick, sand, gravel and rocks
11. Poly pigs are frequently used
12. Bucket machines, power rodders and hand rods

13. Final cleanup since the bristles produce a scrubbing action.
14. Chemicals can be used to control roots, grease, odors, corrosion, rodents and insects.
15. Restaurants, industries and homes with garbage disposals
16. Paralysis of the respiratory center and death of operators; rotten egg odor; corrosion and possible collapse of sewers, structures and equipment; loss of capacity of the sewer
17. Hydrogen sulfide comes from the reduction of sulfate to sulfide by bacteria in the slimes on sewers under anaerobic conditions.
18. Chlorine compounds, hydrogen peroxide, iron salts, air, sodium hydroxide, magnesium hydroxide, nitrates.

Section 8

Underground Repair

Underground Repair of Sewers

- Safety Considerations
- Sources of Damages & Stoppages
- Grouting
- Manhole Problems

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Safety Considerations

- Cave-ins
  - Underground repair to replace damaged pipe or remove obstruction may require use of trench shield
- Dangerous gases & fumes, explosive conditions, lack of oxygen
- Traffic
  - Repairs in roadways require traffic control.
- Injury
- Public & private property
- Public from injury

Atmospheric Alarm

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Types of Underground Work

- Correct damage
- Remove obstructions preventing proper functioning of sewer
- Retrieve equipment stuck in the line

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Sources of Damages & Stoppages

- Roots
- Improper taps
- Damage by public (illegal taps or vandalism)
- Other underground construction

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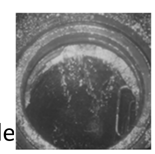
Grout Sealing



- Area unsuitable for excavation
- Infiltrating or exfiltrating through le cracks or small holes
- New construction to pass test acceptance

- Grout is commonly used to seal leaking joints and circumferential cracks, not collapsed pipe sections or broken pipes.

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Universal Grouting Applications

- Mainlines and Pipe Joints
- Lateral Sealing
- Manholes, Wet Wells and Lift Stations
- Soil Stabilization

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Grouting Materials

- Hydrophilic foams
- Hydrophilic gels
- Hydrophobic foams
- Chemically activated gels
- Epoxies
- Acrylamide
- Acrylate
- Urethane
- Cementitious

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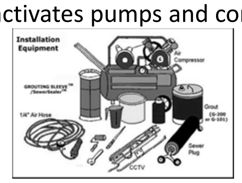
Basic Grouting Equipment

- Air compressor- operates pumps and inflates packer
- Chemical pump
- Water pump
- Control panel- activates pumps and controls packer
- Sleeve packer



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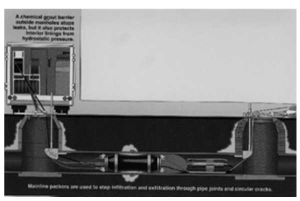
Sealing Process

- TV camera faces packer to observe operation.
- TV camera downstream of packer.
- Roots in sewer and joints killed & removed prior to using root control chemicals.



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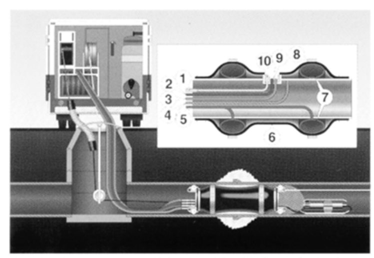
Detail of Sleeve Packer



Modern injection packers are very sophisticated, consisting of; (1) Pressure Sensing Line, (2) Chemical "A" Line, (3) Chemical "B" and Air Pressure Line, (4) Sleeve Air Line, (5) End Seal Air Line, (6) Sleeve, (7) End Seal Elements, (8) Sealing Pads, (9) Chemical Injection Ports, (10) Pressure Sensor Element.

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Grouting

TDEC - Fleming Training Center 11

Desirable Grout Characteristics

- Resistant to organic solvents, mild acids and alkalis
- Returns to shape after deformation
- Nontoxic when cured
- Not rigid or brittle when exposed to freeze-thaw or dry conditions
- Non corrosive; no neurotoxin ingredients

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Grout Limitations

- Not a structural repair
- Must thoroughly clean pipe/manhole first
- Packer won't seal properly in badly corroded pipe
- Not permanent
- Some dehydrate & shrink if groundwater level drops

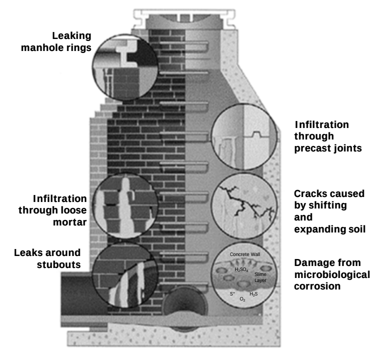
Factors that Effect Grout Performance

- Temperature
- pH
- Entrained oxygen in solution
- Contact with metals
- UV light
- Velocity of groundwater flows
- Mineral salts
- Proper use of equipment & process

Chemical Grout Additives

- Latex/emulsion/reinforcing agent: increases compression and tensile strength
- Accelerators: speeds up gel time (urethanes)
- Dichlobenil: inhibits root growth
- Tracer dye: illustrates proper mixing and travel
- Ethylene glycol: protects against freezing or drying out
- KFe Potassium Ferricynaide: extends gel time (acrylamide & acrylate)

Manhole Problems



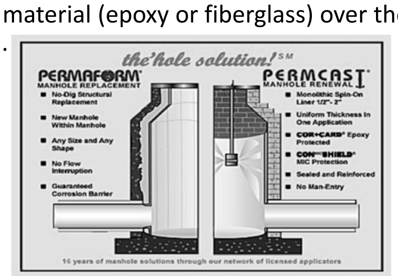
Repair Leaking Barrels

- Patching using fast dry cement.
- Grouting by hand or with sprays.
- Lining with spray-on epoxy or fiberglass or insert liner.

Grout is pumped into the soil outside the manhole. This keeps water from entering at the damaged area.

Manhole Liner

- Lining manhole by inserting liner or spraying a lining material (epoxy or fiberglass) over the barrel.



Manhole Liner

- Badly corroded brick manhole.
  - Prior to lining, surface must be cleaned with high pressure water to remove grease, sludge, mineral deposits, and loose brick and mortar.

- For larger manholes or wet wells, liner may be sprayed on by operator in the structure rather than from ground level.

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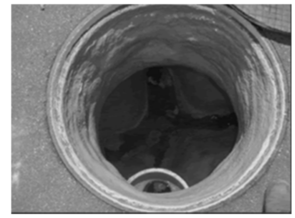
Manhole Liner

Before

After



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Air Testing

- The main reason for using low-pressure air testing for testing sewers is that pressurized air exerts the same pressure in all directions on the pipe during a specific moment in time
- The fact that air can leak through a smaller crack than wastewater helps find vapor leaks that may attract roots.
- Also, air could leak out of a small crack that could become a large crack in the future

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Water Testing

- Where conditions are appropriate, a water exfiltration test will provide an accurate test of a new sewer line’s ability to convey wastewater without excess leakage and to resist groundwater infiltration
  - Any building sewer connections must be plugged

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Underground Repair Vocabulary

______1. Angle of Repose	______6. Hydrophobic
______2. Annular	______7. Sheeting
______3. Cross Braces	______8. Spoil
______4. Gunite	______9. Stringers
______5. Hydrophilic	______10. Vacuum Test

A. Having a strong affinity (liking) to water.
B. Solid material, such as wooden 2-inch planks or $1^1/_8$ –inch plywood sheets or metal plates, used to hold back soil and prevent cave-ins.
C. The angle between a horizontal line and the slope or surface of unsupported material such as gravel, sand or loose soil. Also called the “natural slope.”
D. Horizontal shoring members, usually square, rough cut timber, that are used to hold solid sheeting, braces or vertical shoring members in place. Also called wallers.
E. Shoring members placed across a trench to hold other horizontal and vertical shoring members in place.
F. Excavated material such as soil from the trench of a sewer.
G. Having a strong aversion (dislike) for water.
H. A testing procedure that places a manhole under a vacuum to test the structural integrity of the manhole.
I. A ring-shaped space located between two circular objects. For example, the space between the outside of a pipe liner and the inside of a pipe.
J. A mixture of sand and cement applied pneumatically that forms a high-density, resistance concrete.

Underground Repair Questions

1. Why might a sewer line have to be dug up?

2. Why should other utility companies be notified before any excavation?

3. Why are sewer repairs sometimes necessary?

Answers to Vocabulary and Questions

Vocabulary:

1.	C	5.	A	9.	D
2.	I	6.	G	10.	H
3.	E	7.	B		
4.	J	8.	F		

Questions:

1. Sewer lines may have to be dug up because they are damaged, blocked, or to retrieve equipment stuck in the line.
2. All utilities in an area should be contacted before excavation so other underground utilities will not be damaged and possibly cause a serious injury (from electric shock or a gas explosion) to operators, the public or property.
3. Wastewater collection system repairs are necessary to correct damage to sewer.

Section 9

Sewer Renewal/Rehab

HDPE pipe sliplining job shown

Sewer Pipeline Rehabilitation

- Sewer System Evaluation
- Excavate and Replace
- Grouting
- Sliplining
- Cured in Place Pipe (CIPP)
- Fold and Form
- Pipe Bursting

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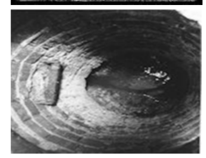
Why Rehabilitate?

- Restore structural integrity:
  - Corrosion
  - Deterioration
  - Damage from stress & live loads
- Control excess I/I during rainfall or high groundwater



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Sewer System Evaluation

- Helps reduce hydraulic load to sewer and treatment facility. I/I causes:
  - Increased treatment costs
  - Bypassing of untreated wastewater
  - Structural failure weakened collection system
- Primary tool for identifying high I/I: flow monitoring

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Techniques to Determine Sewer Condition

- CCTV: most effective method to identify & quantify defects
- Pipe flow tests
- Computer flow models
- Visual inspection
  - Smoke tests- quick, inexpensive
  - Dye testing
  - Lamping

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Excavate and Replace

- Oldest and most common method
- Corrects misalignment of pipe
- Sometimes only method if defect is severe.
- Should be considered on every job.
- Exfiltration may contaminate groundwater used as drinking water source.

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Excavate and Replace

- Same problems apply as with all new construction.
- Increases hydraulic capacity
- Repair bad service connections
- Eliminate sources of stormwater entry
- Removal incidental I/I
- Stop exfiltration

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Common Construction Problems

- Traffic disruption much longer than with other methods.
- Restoration includes paving, driveways, sidewalks, fences, landscaping.
- Often more expensive, too.
- Other issues:
  - Shoring
  - Excavation dewatering
  - Noise

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Internal Sealing

- Internal sealing is effective when the sewer line to be repaired has cracks and leaking joints

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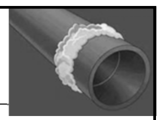
Chemical Grouting



- Most widely used method to seal leaking joints and circumferential cracks
- Remove roots and grease first
- Dig up joint or do low pressure air test to determine success of chemical grouting

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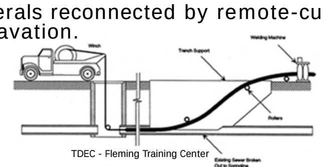
Sliplining

- New liner of smaller diameter placed inside existing pipe.
- Not completely trenchless as insertion pit must be dug.
- Continuous (shown): 40 ft sections butt-fusion welded.
  - Also segmental and spiral wound.
- Laterals reconnected by remote-cutter or excavation.



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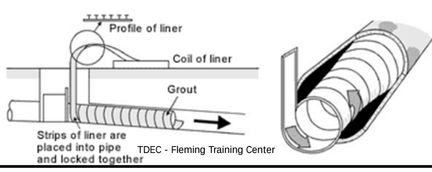
Spiral Wound Sliplining Process

- Annular space is grouted to prevent leaks and provide structural integrity
- Spiral wound pipe with interlocking edges to connect segments.



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Sliplining Features

- Insertion pit required
- Reduced pipe diameter
- Not well suited for small diameter pipes
- Requires little technical skill
- Excellent corrosion resistance

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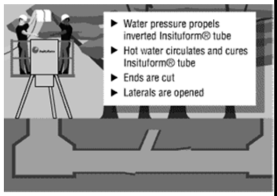
Cured-in-Place Pipe (CIPP)

- Pipe is cleaned and CCTV inspection is done
- Custom made felt tube is impregnated with thermosetting resin
- Weight of water pushes tube into damaged pipe & turns it inside out
- Laterals are cut internally



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Cured-in-Place Pipe (CIPP)

- Flexible fabric liner coated with thermosetting resin.
  - Each sock is custom made for specific job.
  - Keep ≤ 40°F and out of direct sunlight.
    - Heat may cause resin to react and begin to harden.
    - UV light deteriorates material.

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Cured-in-Place Pipe (CIPP)

- Pipe inverted with water (shown) or air.
- Laterals are reconnected with robotic cutter positioned and controlled by operator watching TV monitor
  - Laterals easily found since line was televised after cleaning and prior to start of rehab project.


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CIPP Features

- No grouting or excavation required
- New pipe has no joints or seams
- Bypass or diversion of flow required
- Must allow adequate curing time
- Small decrease in pipe diameter, but improved flow capacity due to smooth surface
- Proprietary

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Fold and Formed Pipe

- HDPE or PVC pipe is deformed in shape & inserted into host pipe
- Liner is pulled through existing line, heated and pressurized to original shape
- Bypass or diversion of flow required
- Laterals reconnected internally
- No grouting or excavation
- No joints or seams

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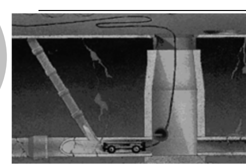
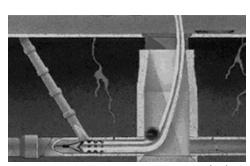
U-Liner® Installation

- Host pipe is thoroughly cleaned and inspected with CCTV.
- Pipe is uncoiled into upstream manhole and pulled through host pipe via cable from downstream manhole. Pipe is cut to the appropriate length and manifolds are attached at both ends.

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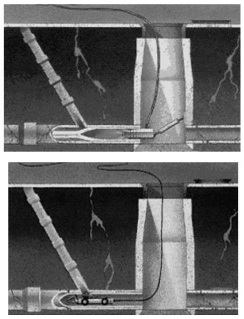
U-Liner® Installation



- Heat and pressure are applied to conform new pipe to host pipe.
- Individual service connections are restored with internal cutter. Device is remote-controlled, video monitored, and cuts precisely.

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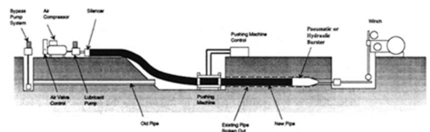
Pipe Bursting

- Insertion pit is excavated.
- Deteriorated host pipe is broken outward by means of an expansion tool and new pipe (black) is towed behind the bursting machine.
- Laterals reconnected by excavation after job is done.



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Bursting Heads

- Pneumatic (static) head has no moving internal parts and expands existing pipe through pulling.
- This model features a cutter to aid in shattering the host pipe.

Hydraulic head pulsates as the bursting device is pulled through the pipe.

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Pipe Bursting Features

- New pipe is PE, PP, PVC or GFR
- No reduction in capacity; can often upsize the new pipe
- Bypass or diversion of flow
- Insertion pit required
- Not suitable for all materials: can replace vitrified clay, cast iron, unreinforced concrete, & some PVC

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Questions???

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Sewer Renewal Vocabulary

______1. Annular
______2. Flow Isolation
______3. Infiltration
______4. Inflow
______5. Piezometer
______6. Surcharge

A. The seepage of groundwater into a sewer system, including service connections. Seepage frequently occurs through defective or cracked pipes, pipe joints, connection or manhole walls.
B. A ring-shaped space located between two circular objects. For example, the space between the outside of a pipe liner and the inside of a pipe.
C. The supply of water to be carried is greater than the capacity of the pipes to carry the flow. The surface of the wastewater in manholes rises above the top of the sewer pipe and the sewer is under pressure or a head, rather than at atmospheric pressure.
D. Water discharged into a sewer system and service connections from such sources as, but not limited to, roof leaders, cellars, yard and area drains, foundation drains, cooling water discharges, drains from springs and swampy areas, around manhole covers or through holes in the covers, cross connections from storm and combined sewer systems, catch basins, storm waters, surface runoff, street wash waters or drainage.
E. A procedure used to measure inflow and infiltration (I/I). A section of sewer is blocked off or isolated and the flow from the section is measured.
F. An instrument used to measure the pressure head in a pipe, tank or soil.

Sewer Renewal Questions

1. What causes sewers to lose their structural integrity?

2. What problems are common to all types of sewer construction?

3. Why should a lateral be lined?

4. What is the oldest and most common method of sewer rehabilitation?

5. What is the most common method of sealing leaking pipe joints and circumferential cracks?

True-False

6. Flows greater than the expected base flow can be considered to come from inflow and infiltration sources.
   True
   False

7. Smoke testing is a slow and expensive method of detecting illegal I/I sources in a sewer system.
   True
   False

Multiple Choice

8. The <u>first step</u> in defining a sewer rehabilitation program is to:
   a. Analyze condition of the system
   b. Collect flow measurement data
   c. Conduct an inventory of the system
   d. Set goals of rehabilitation program

9. Exfiltration can be a serious problem in areas where exfiltration flow can:
   a. Cause flooding of surface water
   b. Contaminate groundwater used for public drinking water supply
   c. Overload lift stations
   d. Reduce scouring velocities in sewers

10. The CIPP saturated liner should be kept:
    a. At ambient temperature until installation
    b. At or below 40° F (4° C)
    c. Out of direct sunlight
    d. Dry until installation
    e. B and C

11. When a service connection has suffered total collapse and is in a crushed condition, the service connection is restored by:
    a. Chemical grout
    b. Cured-in-place pipe
    c. Excavation and replacement
    d. Sliplining

12. When manhole walls have suffered deterioration due to hydrogen sulfide attack, they can be repaired with:
    a. Coating processes
    b. Excavation and replacement
    c. Grout
    d. Paint
    e. Sliplining

Answers to Vocabulary and Questions

Vocabulary:

1. B
2. E
3. A
4. D
5. F
6. C

Questions:

1. Due to corrosion and deterioration, damage also results from undue stress and live loads placed on sewers.
2. Traffic disruption, disruption to properties, paving damage, shoring requirements, excavation dewatering, noise, flow control and restoration
3. Laterals are lined if infiltration, exfiltration or root intrusion is a problem.
4. Excavation and replacement
5. Chemical grouting
6. True
7. False
8. C
9. B
10. E
11. C
12. A

United States Environmental Protection Agency | Office of Water Washington, D.C. | EPA 832-F-99-032 September 1999

Collection Systems O&M Fact Sheet
Trenchless Sewer Rehabilitation

DESCRIPTION

As the infrastructure in the United States ages, increasing importance is being placed on rehabilitating the nation's wastewater treatment collection systems. Cracks, settling, tree root intrusion, and other disturbances that develop over time deteriorate pipe lines and other conveyance structures that comprise wastewater collection systems. These deteriorating conditions can increase the amount of inflow and infiltration (I/I) entering the system, especially during periods of wet weather. Increased I/I levels create an additional hydraulic load on the system and thereby decrease its overall capacity. In addition to I/I flow, storm water may enter the wastewater collection system through illegal connections such as down spouts and sump pumps. If the combination of wastewater, infiltration, and illegal storm water connections entering the wastewater treatment plant exceeds the capacity of the system at any point, untreated wastewater may be released into the receiving water. This bypass of untreated wastewater, known as a Sanitary Sewer Overflow (SSO), may adversely affect human health as well as impair the usage and degrade the water quality of the receiving water.

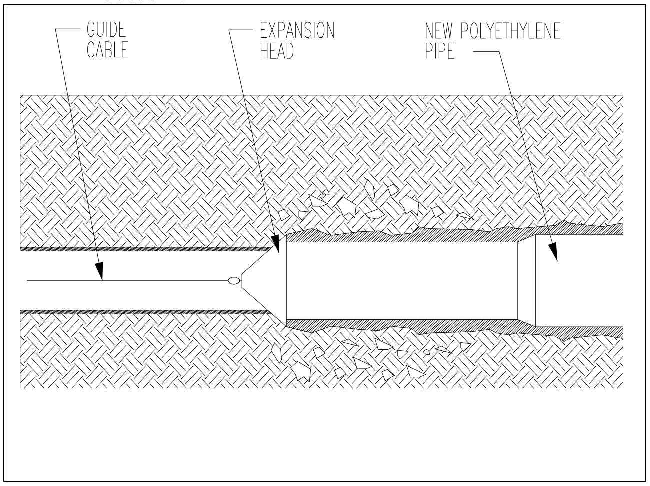
Under the traditional method of sewer relief, a replacement or additional parallel sewer line is constructed by digging along the entire length of the existing pipeline. While these traditional methods of sewer rehabilitation require unearthing and replacing the deficient pipe (the dig-and-replace method), trenchless methods of rehabilitation use the existing pipe as a host for a new pipe or liner. Trenchless sewer rehabilitation techniques offer a method of correcting pipe deficiencies that requires less restoration and causes less disturbance and environmental degradation than the traditional dig-and-replace method. Trenchless sewer rehabilitation methods include:

- Pipe Bursting, or In-Line Expansion;
- Sliplining;
- Cured-In-Place Pipe; and
- Modified Cross Section Liner.

These alternative techniques must be fully understood before they are applied. These four sewer rehabilitation methods are described further in the following sections.

Pipe Bursting or In-Line Expansion

Pipe bursting, or in-line expansion, is a method by which the existing pipe is forced outward and opened by a bursting tool. The Pipebursting™ method, patented by the British Gas Company in 1980, was successfully applied by the gas pipelines industry before its applicability was identified by other underground utility agencies. Over the last two decades, other methods of in-line expansion have been patented as well. During in-line expansion, the existing pipe is used as a guide for inserting the expansion head (part of the bursting tool). The expansion head, typically pulled by a cable rod and winch, increases the area available for the new pipe by pushing the existing pipe radially outward until it cracks. The bursting device pulls the new pipeline behind itself. The pipe bursting process is illustrated in Figure 1. Various types of expansion heads, categorized as static or dynamic, can be used on the bursting tool to expand the existing pipeline. Static heads, which have no



Source: Created by Parsons Engineering Science, Inc., 1999.

FIGURE 1 THE PIPE BURSTING PROCESS

moving internal parts, expand the existing pipe only through the pulling action of the bursting tool. Unlike static heads, dynamic heads provide additional pneumatic or hydraulic forces at the point of impact. Pneumatic heads pulsate internal air pressure within the bursting tool, while hydraulic heads expand and collapse the head. While the dynamic head pulsates or expands and contracts, the bursting device is pulled through the existing pipeline and breaks up the existing pipe, replacing it with the new pipe directly behind it. Dynamic heads are often required to penetrate difficult pipe materials and soils. However, because dynamic heads can cause movement of the surrounding soils-resulting in additional pressure and ground settlement-static heads are preferred where pipe and soil conditions permit.

During the pipe bursting process, the rehabilitated pipe segment must be taken out of service by re-routing flows around it. After the pipe bursting is completed, laterals are re-connected, typically with robotic cutting devices.

Sliplining

Sliplining is a well-established method of trenchless rehabilitation. During the sliplining process, a new liner of smaller diameter is placed inside the existing pipe. The annulur space, or area between the existing pipe and the new pipe, is typically grouted to prevent leaks and to provide structural integrity. If the annulus between the sections is not grouted, the liner is not considered a structural liner. Continuous grouting of the annular space provides a seal. Grouting only the end-of-pipe sections can cause failures and leaks.

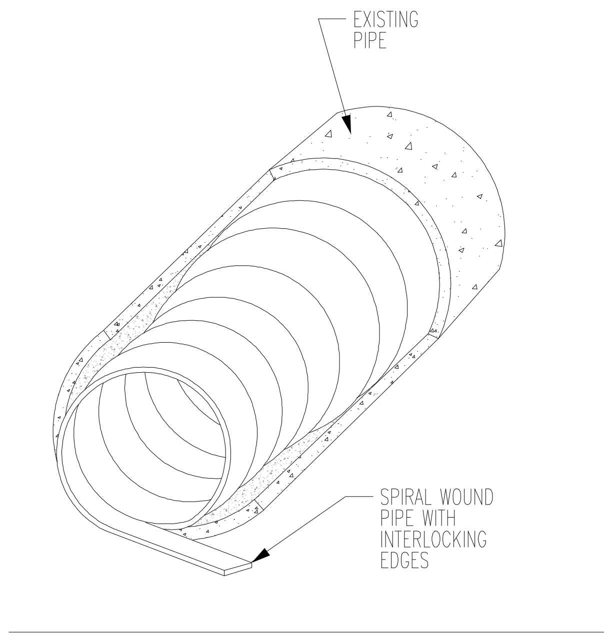
In most sliplining applications, manholes cannot function as proper access points to perform the rehabilitation. In these situations, an insertion pit must be dug for each pipeline segment. Because of this requirement, in most applications, sliplining is not a completely trenchless technique. However, the excavation required is considerably less than that for the traditional dig-and-replace method. System and site conditions will dictate the amount of excavation spared.

Methods of sliplining include continuous, segmental and spiral wound. All three methods require laterals to be re-connected by excavation or by a remote-cutter. In continuous sliplining, the new pipe, joined to form a continuous segment, is inserted into the host pipe at strategic locations. The installation access point, such as a manhole or insertion pit, must be able to handle the bending of the continuous pipe section.

Installation by the segmental method involves assembling pipe segments at the access point. Sliplining by the segment method can be accomplished without rerouting the existing flow. In many applications, the existing flow reduces frictional resistance and thereby aids in the installation process. Spiral wound sliplining is performed within a manhole or access point by using interlocking edges on the ends of the pipe segments to connect the segments. The spiral wound pipe is then inserted into the existing pipe as illustrated in Figure 2.

Cured-In-Place Pipe

During the cured-in-place pipe (CIPP) renewal process, a flexible fabric liner, coated with a thermosetting resin, is inserted into the existing pipeline and cured to form a new liner. The liner is typically inserted into the existing pipe through an existing manhole. The fabric tube holds the resin in place until the tube is inserted in the pipe and ready to be cured. Commonly manufactured resins include unsaturated polyester, vinyl ester, and



Source: Created by Parsons Engineering Science, Inc., 1999.

FIGURE 2. SPIRAL WOUND SLIPLINING PROCESS

epoxy, with each having distinct chemical resistance to domestic wastewater.

The CIPP method can be applied to rehabilitate pipe lines with defects such as cracks, offset joints, and structurally deficient segments. The thermosetting resin material bonds with the existing pipe materials to form a tighter seal than most other trenchless techniques. The two primary methods of installing CIPP are winch-in-place and invert-in-place. These methods are used during installation to feed the tube through the pipe. The winch-in-place method uses a winch to pull the tube through the existing pipeline. After being pulled through the pipeline, the tube is inflated to push the liner against the existing pipe walls. The more typically applied inversion-in-place method uses gravity and either water or air pressure to force the tube through the pipe and invert it, or turn the tube inside out. This process of inversion presses the resin- coated tube against the walls of the existing pipe. During both the winch-in-place and inversion-in-place methods, heat is then circulated through the tube to cure the resin to form a strong bond between the tube and the existing pipe. A typical CIPP process by the water-inversion method is illustrated is Figure 3.

Under both CIPP methods, as the liner expands to fit the new pipe, dimples occur in the line where the laterals exist. Dimples in the line can be found by TV inspection or robotic equipment. In some applications, a Tee is placed at the junction before rehabilitation begins. Tee's enable junctions to be easily identified and modified after the pipeline has been re-lined. Laterals are typically reinstated with robotic cutting devices, or, for large-diameter pipes, by manually cutting the liner.

Modified Cross Section Lining

The modified cross section lining methods include deformed and reformed methods, swagelining™, and rolldown. These methods either modify the pipe's cross sectional profile or reduce its cross-sectional area so that the liner can be extruded through the existing pipe. The liner is subsequently expanded to conform to the existing pipe's size.

During deformed and reformed pipeline renewal, a new flexible pipe is deformed in shape and inserted into the host pipe. While the method of deforming the flexible pipe varies by manufacturer, with many processes referred to as fold and form methods, a typical approach is to fold the new liner into a "U" shape, reducing the pipe's diameter by about 30 percent. After the liner is pulled through the existing line, the liner is heated and pressurized to conform to the original pipe shape. A typical deformed and reformed cross-section is illustrated in Figure 4.

Another method of obtaining a close fit between the new lining and existing pipe is to temporarily compress the new liner before it is drawn through the existing pipeline. The swagelining™ and rolldown processes use chemical and mechanical means, respectively, to reduce the cross-sectional area of the new liner.

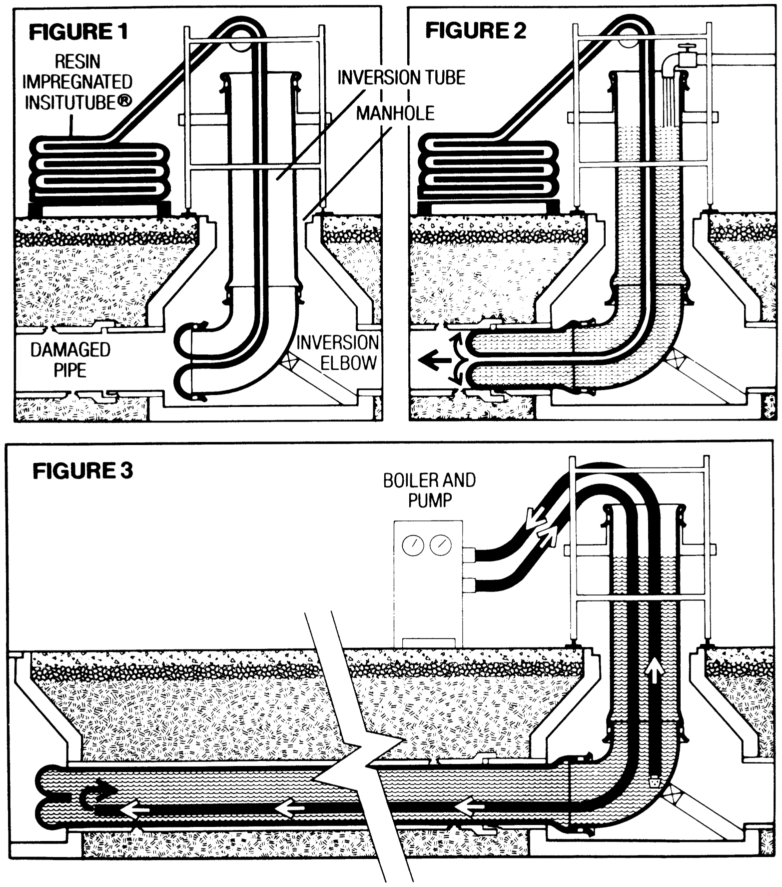
During swagelining™, a typical drawdown process, the new liner is heated and subsequently passed through a reducing die. A chemical reaction between the die and liner material temporarily reduces the liner's diameter by 7 percent to 15

How Insituform® is installed

Figure 1. A special needled felt reconstruction tube, Insitutube®, coated on the outside, is custom engineered and manufactured to fit the damaged pipe exactly. It is impregnated with a liquid thermosetting resin and lowered into a manhole through an inversion tube. One end of the Insitutube is firmly attached to the lower end of the inversion tube elbow.

Figure 2. The inversion tube is then filled with water. The weight of the water pushes the Insitutube into the damaged pipe and turns it inside out, while pressing the resin impregnated side firmly against the inside walls of the old pipe. The smooth coated side of the Insitutube becomes the new interior surface of the pipe.

Figure 3. After the Insitutube is inverted through the old pipe to the desired length, the water is circulated through a boiler. The hot water causes the thermosetting resin to cure within a few hours, changing the pliable Insitutube into a hard, structurally sound, pipe-within-a-pipe, Insitupipe™. It has no joints or seams and is usually stronger than the pipe it replaced. The ends are cut off and the inversion tube and scaffolding are removed. Normally, there are no messy excavation repairs to be made since most work is done without digging or disruption.



Source: Iseley and Najafi, 1995 (from Insituform®)

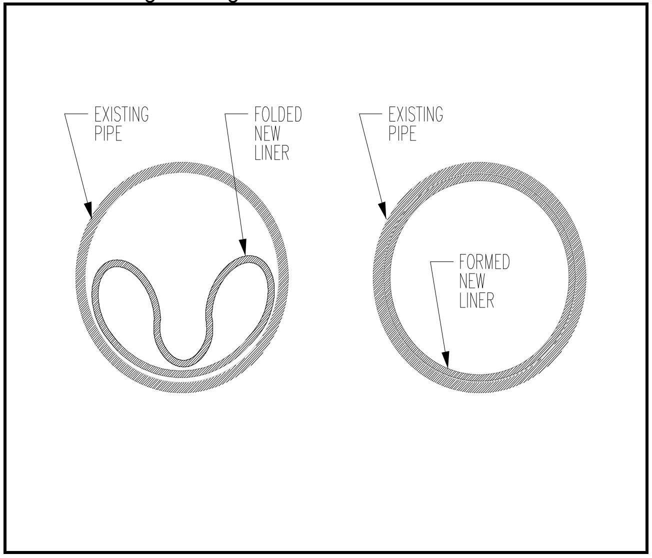
FIGURE 3 A TYPICAL CURED-IN-PLACE PIPE INSTALLATION PROCEDURE

percent and allows the liner to be pulled through the existing pipe. As the new liner cools, it expands to its original diameter. The rolldown process uses a series of rollers to reduce the pipe liner's diameter. As in deform-and-reform methods, heat and pressure are applied to the expand the liner to its original pipe diameter after it has been pulled through the existing pipe.

Unlike CIPP, modified cross section methods do not make use of resins to secure the liner in-place. Lacking resin-coated lining, these methods do not have the curing time requirement of CIPP. A tight fit is obtained when the folded pipe expands to the host pipe's inside diameter under applied heat and pressure. As with the CIPP method, dimples are formed at lateral junctions and similar methods of reconnecting the laterals can be employed. Materials typically used for modified cross section linings include Polyvinyl Chloride (PVC) and High Density Polyethylene (HDPE).

Trenchless sewer rehabilitation methods are now routinely applied to wastewater collection system improvement projects in the United States and many other countries. Trenchless sewer rehabilitation has been successfully applied by both large municipalities such as New York, NY; Los Angeles, CA; Boston, MA; Miami, FL; and Houston, TX; and smaller municipalities such as Baton Rouge, LA; Madison, WI; and Amarillo, TX. Kramer and Thomson (1997) estimate that the market value for sewer and pressure pipe rehabilitation projects will be $5 billion dollars world-wide in the year 2000.

In many municipalities, sewer rehabilitation projects are an essential part of operation and



Source: Created by Parsons Engineering Science, Inc., 1999.

FIGURE 4 DEFORMED AND REFORMED LINERS

maintenance (O&M) programs for the collection system. For example, as part of an O&M program focused on pro-active maintenance, Fairfax County, Virginia, has identified two older sewersheds for rehabilitation. All trunk and main lines within each sewershed are television inspected. Results of the TV inspection are used to prioritize cleaning needs and to help determine appropriate rehabilitation measures. Projects within the targeted sewersheds have utilized the CIPP and fold-and-form rehabilitation methods.

In an effort to monitor the effectiveness of the rehabilitation efforts, the department installed permanent and temporary meters in these two sewersheds. Fairfax County's focused approach to maintenance has reduced average flows to the wastewater treatment plant (WWTP) despite several years of above- normal rainfall.

APPLICABILITY

While trenchless techniques may be applied to rehabilitate existing pipelines in a variety of conditions, they are particularly valuable in urban environments where construction impacts are particularly disruptive to businesses, homeowners, and automotive and pedestrian traffic. Other underground utilities and existing infrastructure are an obstacle in the traditional dig and replace method, and trenchless techniques are widely applied where these are present. Most trenchless techniques are applicable to both gravity and pressure pipelines. Many trenchless methods are capable of performing spot repairs as well as manhole to manhole lining.

For most applications, trenchless sewer rehabilitation techniques require less installation time-and therefore less pump-around time- than traditional dig-and-replace methods. Installation time can be critical in deciding between trenchless sewer rehabilitation methods and dig- and-replace methods. For example, when considering sewer repair or replacement options for a critical force main crossing the Elbe River in Heidenau, Germany, city officials determined that the line could not be out of service for more than 12 days (Saccogna, 1998). As a result of this time constraint, as well as reduced disruption to riverboat traffic, city officials chose to rehabilitate the sewer using the swagelining™ process. The successfully rehabilitated sewer was out of service only eight days.

Trenchless sewer rehabilitation can be performed to increase the hydraulic capacity of the collection system. While pipe bursting typically yields the largest increase in hydraulic capacity, rehabilitation by other trenchless methods may also increase hydraulic capacity, by reducing friction. A hydraulic analysis of the pre- and post-rehabilitation conditions can be performed to evaluate the impact on collection system capacity. In general, the hydraulic analysis is performed by municipal engineers and/or consultants who prepare specifications for contractors.

Each of the trenchless rehabilitation methods described has been used for various applications over a range of pipe sizes and lengths. A comparison of trenchless techniques is shown in Table 1.

ADVANTAGES AND DISADVANTAGES

By reducing I/I levels in the collection system, trenchless rehabilitation projects can assist communities in complying with the EPA's Clean Water Act and thereby protect the aquatic integrity of receiving water-bodies from potentially high

TABLE 1 A COMPARISON OF VARIOUS SEWER REHABILITATION TECHNIQUES

Method:		Diameter Range (mm)	Maximum Installation (m)	Liner Material
In-Line Expansion	Pipe Bursting	100-600 (4-24 in.)	230 (750 ft.)	PE, PP, PVC, GRP
Sliplining	Segmental	100 - 4000 (4-158 in.)	300 (1,000 ft.)	PE, PP, PVC, GRP (-EP & -UP)
	Continuous	100 -1600 (4-63 in.)	300 (1,000 ft.)	PE, PP, PE/EPDM, PVC
	Spiral Wound	150 -2500 (6-100 in.)	300 (1,000 ft.)	PE, PVC, PP, PVDF
Cured-In-Place Product Linings	Inverted-In-Place	100-2700 (4-108 in.)	900 (3,000 ft.)	Theromoset Resin/Fabric Composite
	Winched-In-Place	100 -1400 (4-54 in.)	150 (500 ft.)	Theromoset Resin/Fabric Composite
	Spray-on-Linings	76-4500 (3-180 in.)	150 (500 ft.)	Epoxy Resins/Cement Mortar
Modified Cross-Section Methods	Fold and Form	100-400 (4-15 in.)	210 (700 ft.)	PVC (thermoplastics)
	Deformed/Reformed	100-400 (4-15 in.)	800 (2,500 ft.)	HDPE (thermoplastics)
	Drawdown	62-600 (3-24 in.)	300 (1,000 ft.)	HDPE, MDPE
	Rolldown	62-600 (3-24 in.)	300 (1,000 ft.)	HDPE, MDPE
	Thin-walled lining	500-1,100 (20-46 in.)	960 (3,000 ft.)	HDPE
Internal Point Repair	Robotic Repair	200-760 (8-30 in.)	N/A	Exopy Resins Cement Mortar
	Grouting/Sealing & Spray-on	N/A	N/A	Chemical Grouting
	Link Seal	100-600 (4-24 in.)	N/A	Special Sleeves
	Point CIPP	100-600 (4-24 in.)	15 (50 ft.)	Fiberglass/Polyester, etc.

Note: Spiral wound slipling, robotic repair, and point CIPP can only be used only with gravity pipeline. All other methods can be used with both gravity and pressure pipeline.

EPDM = Ethylene Polypelene Diene Monomer
GRP = Glassfiber Reinforced Polyester
HDPE = High Density Polyethylene
MDPE= Medium Density Polyethylene
PE = Polyethylene
PP = Polypropylene
PVC = Poly Vinyl Chloride
PVDF = Poly Vinylidene Chloride

Source: Iseley and Najafi (1995)

pollutant concentrations by reducing SSOs. In addition to potential improvements in receiving water-bodies, trenchless sewer rehabilitation requires substantially less construction work than traditional dig-and-replace methods. In wetland areas and areas with established vegetation, construction influences can be especially harmful to the plant and aquatic habitat. Underground utility construction can disrupt citizens living and working in areas near the construction zone. Trenchless sewer rehabilitation, with the potential to reduce surface disturbance over traditional dig- and-replace methods, can reduce the number of traffic and pedestrian detours, spare tree removal, decrease construction noise, and reduce air pollution from construction equipment. In addition to these benefits, reducing the amount of underground construction labor and surface construction zone area confines work zones to a limited number of access points, reducing the area where safety concerns must be identified and secured. Rehabilitation techniques should be selected based on site constraints, system characteristics, and project objectives. A comparison of economic, cultural and social costs of sewer rehabilitation with those of traditional dig-and-replace methods can help determine whether or not a trenchless sewer rehabilitation is suitable and economically feasible for a particular site. Because some digging may be required for point repairs, construction limitations should be evaluated when deciding whether trenchless sewer rehabilitation techniques can be applied. If there are major changes in cross section between manholes or if the existing alignment, slope, or pipe bedding material must be changed, each line must be rehabilitated as an independent segment, necessitating even more digging. Specific limitations of each trenchless rehabilitation method are listed in Table 2. As seen, the sliplining, deform-and- reform methods, and CIPP methods will reduce the pipe diameter tending to decrease the hydraulic capacity of the sewer. The rehabilitated pipeline, however, may be less rough than the original. The roughness coefficient depending on the liner material. New high performance plastic materials tend to reduce pipe roughness against aged concrete materials. Additionally, the hydraulic capacity may be modified during rehabilitation as groundwater intrusion is inadvertently redirected to unlined side sewers. An evaluation may be performed to determine whether the change in pipe friction and

TABLE 2 LIMITATIONS OF TRENCHLESS SEWER REHABILITATION

Method	Limitations
Pipe Bursting	Bypass or diversion of flow required Insertion pit required Percussive action can cause significant ground movement May not be suitable for all materials
Sliplining	Insertion pit required Reduces pipe diameter Not well suited for small diameter pipes
CIPP	Bypass or diversion of flow required Curing can be difficult for long pipe segments Must allow adequate curing time Defective installation may be difficult to rectify Resin may clump together on bottom of pipe Reduces pipe diameter
Modified Cross Section	Bypass or diversion of flow required The cross section may shrink or unfold after expansion Reduces pipe diameter Infiltration may occur between liner and host pipe unless sealed Liner may not provide adequate structural support

groundwater redirection will offset the decrease in pipe diameter and meet project objectives for an increase in peak flow and/or reduction in SSOs. Most trenchless rehabilitation applications require laterals to be shut down for a 24 hour period. Coordinating shut-downs with property owners can be a difficult and unpopular task. Unforseen conditions can increase construction time and increase the risk and responsibility to the client and contractor. For example, during a rehabilitation project in Norfolk, Virginia, pipe bursting had to be coordinated with the relocation of a nearby electrical substation and the rerouting of flow from a sanitary force main found in a manhole where an insertion pit was to be located (Small, Gidley, and Riley, 1997). In addition to these issues, numerous abandoned underground utilities which were not indicated on city or private utility records were encountered during the project. Such underground conditions are found in many other urban environments around the United States. When trenchless rehabilitation is planned, public works projects and utility work by other agencies should be coordinated with sewer rehabilitation projects.

PERFORMANCE

The performance of trenchless techniques in reducing I/I can be determined through flow measurements taken before and after the rehabilitation. Effectiveness is typically calculated by correlating flow measurements with precipitation data to determine the peak rate and volume of I/I entering the collection system. Another method of calculating I/I is to isolate the rehabilitated line and measure flows both before and after the rehabilitation.

The performance of sewer rehabilitation projects in three Northeastern Illinois communities was documented by Goumas (1995). Results of pre- and post-monitoring within these three communities indicate that I/I reductions of 49 percent, 65 percent and 82 percent were achieved. The Washington Suburban Sanitary Commission (WSSC) uses the isolation and measurement method to assess the performance of rehabilitation projects. An analysis of 98 sewer mains rehabilitated between 1989 and 1995 indicates that I/I flow was reduced by 70 percent in the rehabilitated sewers (WSSC, 1998).

The Miami-Dade Water and Sewer Department (MDWASD) is completing one of the country's largest I/I reduction programs. The program, aimed at reducing I/I thoughout the system, utilizes the fold and form, CIPP, pipe bursting, and sliplining rehabilitation techniques in conjunction with point and robotic repairs. MDWASD has already experienced success with this program; an average I/I reduction of 19 percent (20 MGD) has been achieved between January 1995 and May 1998 based on comparing plant flow and billed flow (MDWASD, 1998)

In Fairfax County, VA, between June 1994 and June 1998, wet weather flows were significantly reduced within the two sewer sheds identified in the County’s focused rehabilitation program even though the program addresses only main and trunk sewer lines and does not address I/I from private laterals (Fairfax County, 1998).

These studies should only be used as an indicator of potential I/I removal. Removal rates will vary depending on the material and condition of the pipe, local soil type, groundwater flow, and other site-specific conditions.

COSTS

Cost ranges for trenchless rehabilitation of a typical size sewer main are provided in Table 3. These costs include a standard cleaning of the sewer line (major blockages and point repairs increase the cost) and inspection of the sewer line before and after the sewer is rehabilitated. Sewer rehabilitation by both trenchless and traditional dig- and-replace methods can reduce treatment and O&M costs at the receiving treatment plant by potentially eliminating I/I flows to the plant. In addition to treatment cost savings, energy costs for transporting flows to the treatment plant could also be reduced due to the reduced flow volume.

A cost comparison of trenchless and traditional sewer rehabilitation methods must consider the condition and site characteristics of the existing

TABLE 3 TYPICAL COST RANGE FOR SMALL SEWER MAINS

Technique	Pipe Diameter, mm (in.)	Cost Range, per linear meter (ft.)
Pipe Bursting	203 (8)	$130-$260 ($40-$80)
Sliplining	457 (21)	$260-$550 ($80-$170)
CIPP	203 (8)	$80-$215 ($25-$65)
Modified Cross Section	203 (8)	$58-$162 ($18-$50)

Sources: Kung'u (1998), Burkhard (1998), Cost in 1998 dollars.
These costs are an indicator of some project costs but each project cost is site-specific.

pipeline. Factors influencing the cost of a trenchless sewer rehabilitation project include:

- the diameter of the pipe;
- the amount of pipe to be rehabilitated;
- specific defects in the pipe (such as joint offsets, root intrusions, severe cracking or other defects);
- the depth of the pipe to be replaced, and changes in grade over the pipe length;
- the locations of access manholes;
- the number of additional access points that need to be excavated;
- the location of other utilities that have to be avoided during construction;
- provisions for flow by-pass;
- the number of service connections that need to be reinstated; and
- the number of directional changes at access manholes.

In general, the less the amount of excavation required for a rehabilitation operation, the more cost-effective trenchless sewer rehabilitation becomes as compared with the traditional dig-and-replace method. In addition to excavation and installation costs, sewer cleaning and inspection are typically required before sewer rehabilitation

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MUNICIPAL TECHNOLOGY BRANCH

Section 10

Lift Stations

Wastewater Lift Stations

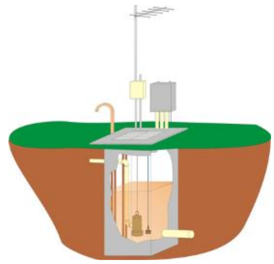
1

PURPOSE
TYPES
COMPONENTS
OPERATION
SAFETY

Purpose of Lift Stations

2

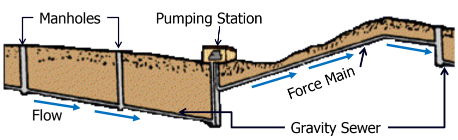
- Lift or raise wastewater or storm water from a lower to a higher elevation



Location

3

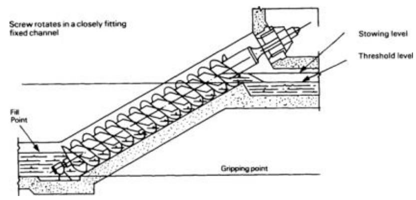
- Excavation costs to keep gravity flow become excessive
- Poor soil stability
  - If soil is too unstable for trenching, pump station may be necessary.
- Groundwater table too high to install deep sewers
- Present flow insufficient to justify extension of large trunk sewers



Screw Pumps

4

- Screw carries wastewater up to discharge point.
- Handle large solids & rags without clogging.
- Screw supported by 2 bearings-must lubricate.
- Daily inspection: bent flights, unusual noises, general operation.



Screw Pumps

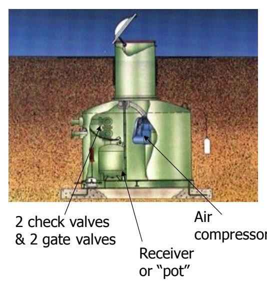
5

- Archimedes screw pumps at Memphis STP.
- Each is 8 feet in diameter and can lift 19,900 gpm (28.6 MGD).
- May be covered to control flies, odors and spread of wastewater in air.

Pneumatic Ejector

6

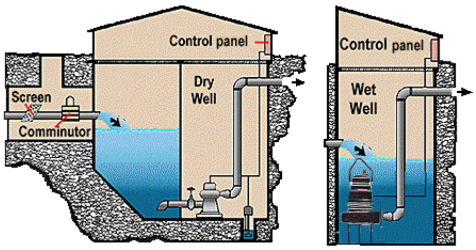
- Uses compressed air to eject wastewater.
- Handles low flows with low to medium heads with large solids.
- Maintenance: clean grease from tank; inspect valves, air lines, & electrical controls.
- During routine maintenance, observe several cycles of the ejector.



Installations

7

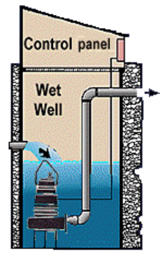
- Wet well/dry well vs. submersible pump station



Submersible Pump Station

8

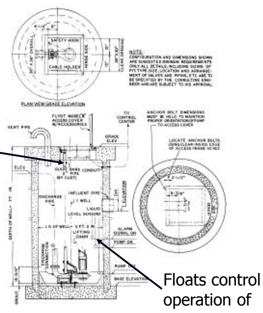
- Pump is in wet well
- Low flows & higher heads (pumping against a large change in elevation)



Submersible Pumping Station

9

- Pump-motor unit, electrical & mechanical controls, piping, wet well, access frame & cover
- Guide bars of 2" pipe allow removal of pump from top of the manhole.
- Check & isolation valves & flow meter installed in separate valve pit.
- Operator does not have to enter the wet well to remove or install the pump.

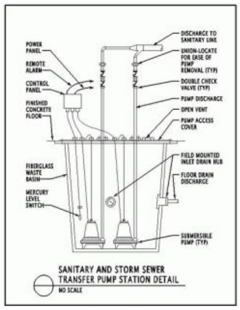


Floats control operation of pumps

Duplex Submersible Pumping Station

10

- Two pumps (duplex)
- Completely submerged in WW
- Waterproof motor
- Second pump provides continuous operation if 1 pump fails or needs repairs.
- When mechanical seal starts leaking, WW can enter the motor and cause motor to burn out
- Mechanical seals keep wastewater out
  - Check motor with megger monthly
  - Replace mechanical seals regularly
  - Clean grit out of wet well regularly



Submersible Lift Stations

11

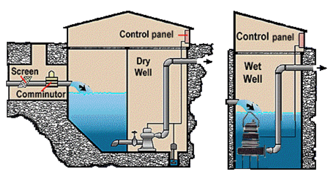
- Submersible lift stations are designed to blend readily with natural surroundings, since there is no pump house and there is a minimum of above-ground equipment.
- Other advantages to below-ground installations are noise reductions and less safety-hazard concerns.

- This submersible wastewater pump is being lowered into a lift station on a guide rail system.
- All that is needed is a hoist; there is no need for a person to go into the pit.
- By using a guide rail system, pump maintenance and installation is easier because the piping system does not need to be disconnected.

Wet Well/Dry Well

12

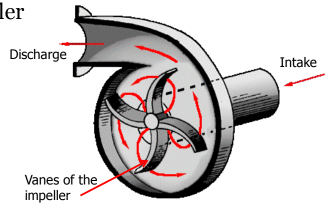
- Dry well houses pumps, motors, electrical controls, & auxiliary equipment.
- Typically for higher flows because has higher initial cost.
- Equipment in wet well is minimized.



Centrifugal Pumps

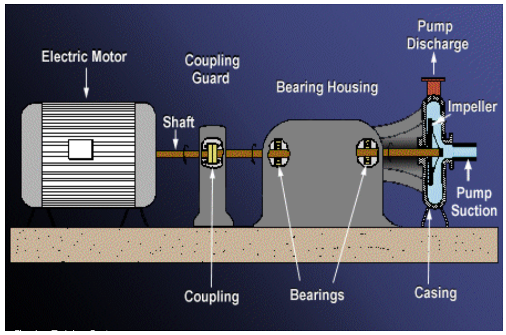
13

- Most common wastewater lift station pump
- Impeller: rotating vanes pump wastewater; large opening prevent clogging
- Volute: spiral-shaped casing collects water discharged by impeller



Horizontally Mounted Centrifugal Pump

14



Pump Operation

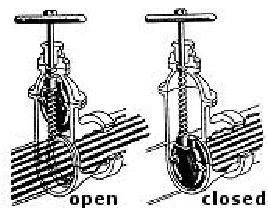
15

- Frequent starts & stops:
  - Cause excessive motor wear
  - Cause surges in wastewater flow
  - Increase power costs
- Draw more power starting than during normal operation because motor & pump have to start turning

Gate Valves

16

- Needed in lift station to permit proper flow of wastewater and permit maintenance to occur
- Immediately before & after pump to isolate it from wet well & force main
- Operate inactive valves to prevent sticking
- Always "back off" half turn when fully opening or closing to avoid "freezing"



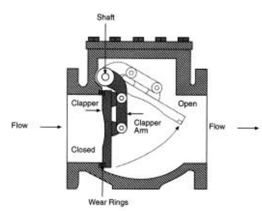
Gate Valves

17

- More susceptible to plugging than plug valves
- Better than plug valves:
  - Some can be slammed shut by backflow, breaking the valve body & injuring operator from water hammer due to sudden stoppage of flowing water
  - Plug valves have a restriction which can become clogged with rags & sticks

Check Valve

18

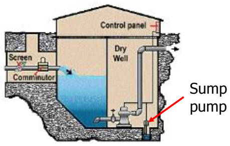


- Installed in discharge of each pump to prevent the force main from drawing back into the wet well.
- Swinging check valve has valve body with clapper arm that open when pump comes on & closes when pump shuts off.
- Must close before flow reverses to prevent water hammer

Auxiliary Equipment

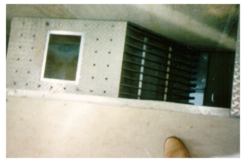
19

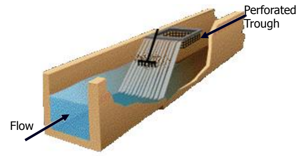
- Screens & comminutors installed prior to pumps to prevent large debris from entering & plugging pipes.
  - Protects pumps downstream
- Sump pump in dry well removes accumulated moisture.
- Ventilation system with sensors & alarms.
- Lights sufficient in number & right location to avoid glare & shadows.



Manually Cleaned Bar Screen/Rack

20



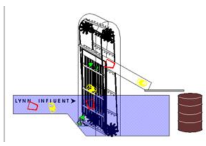


- Bar screens or racks collect leaves, sticks, cans, and trash.
- Must be cleaned frequently so flow to the pumps is not restricted.
- Screenings can cause odors and attract rats and flies.
- Screening disposal in landfill.
- Safety
  - Be careful not to trip or fall into the wastewater.
  - Back injuries and muscle strains can occur when pulling heavy water-logged debris.

Mechanically Cleaned Bar Screen

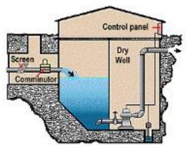
21

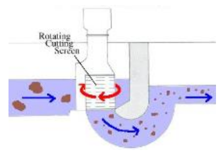
- In larger installations, mechanically cleaned bar screens are installed.
- To reduce wear, controls clean the screen only when debris has accumulated and head loss reaches a preset level.
- Maintenance:
  - Keep well lubricated and adjusted
  - Hose down with water to prevent slime growth and odors/flies it generates



Comminutor

22





- Shreds solids, but leaves them in the wastewater.
- Safety: never attempt to unjam cutter blades without first bypassing unit, turning off power, locking out breaker & placing tag on breaker.
- Advantages vs. bar screens: eliminates screening disposal; eliminates problems from flies and odors.
- Disadvantages: plastic and wood may be rejected and must be removed manually.

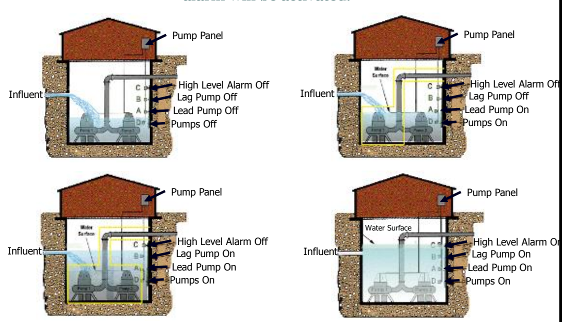
[Muffin Monster Video]

Level Controllers

23

- Float controllers:
  - Grease & debris can hinder movement
  - Float attachment line breakage
  - May develop leaks
  - Sensitive to level changes

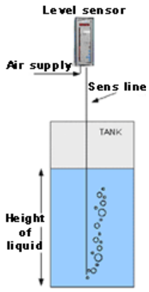
No pump will run until the water rises to level A or higher. As the water rises a pump will automatically turn on. If the water continues to rise, a 2nd pump will turn on. With both pumps running, if water level continues to rise, an alarm will be activated.



Level Controllers

25

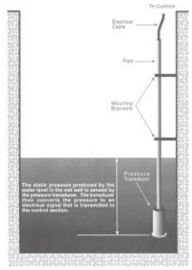
- Air bubblers:
  - Constant low volume, low pressure air fed through vertically mounted pipe in wet well
  - Water level determined by force required to displace water in the pipe



Level Controllers

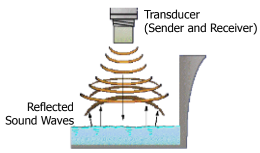
26

- Pressure transducer:
  - Submerged
  - Pressure created by static head of water level sensed by flexible membrane.
  - Converted to electrical signal in control system.
  - Rags & debris foul unit
  - Grease may cover unit



Level Controllers

27

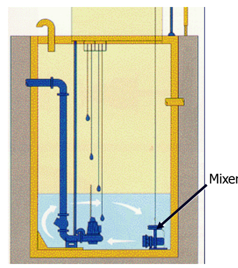


- Ultrasonic transducer:
  - Ultrasonic pulses hit the water surface & bounce back.
  - Pulse travel time is converted to electrical signal in control system.

Grit

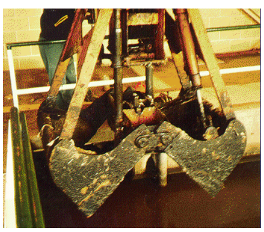
28

- Pump down the wet well to the lowest possible level and then flush the grit to the pump's suction with high pressure hoses.
- Grit accumulation leads to reduced flow to pumps and loss of wet well capacity.
- A mixer may re-suspended material in the bottom of the wet well.



Grit Removal

29



- Removed by flushing, bucket machine or vacuum truck.

Grease & Scum in Wet Well

30

- Causes odors & impairs functioning of equipment
- Removal:
  - Manual
  - Chemical/biological treatment of FOG

Lift Station Problems

31

- Power
- Control system (flooded wet well)
- Pumping system (stuck check valve; air-bound pump)
- Structure (ventilation fan burned out)

Lift Station Safety

32

- Confined space
- Hazardous atmospheres
- Slippery ladders or stairs
- Mechanical & electrical hazards
- Insects, snakes & rodents
- Infections & diseases
- Drowning

Lift Stations Vocabulary

______1. Cavitation	______9. Lift Station
______2. Comminutor	______10. Pneumatic Ejector
______3. Discharge Head	______11. Suction Head
______4. Dry Well	______12. Volute
______5. Entrain	______13. Water Hammer
______6. Force Main	______14. Wet Well
______7. Head	
______8. Impeller	

A. A pipe that carries wastewater under pressure from the discharge side of a pump to a point of gravity flow downstream.

B. A wastewater pumping station that lifts the wastewater to a higher elevation when continuing the sewer at reasonable slopes would involve excessive depths of trench. These stations may be equipped with air-operated ejectors or centrifugal pumps. Sometimes called a pump station.

C. A device used to reduce the size of the solids chunks in wastewater by shredding. The shredding action is like many scissors cutting to shreds all the large solids in the wastewater.

D. The spiral-shaped casing that surrounds a pump, blower or turbine impeller and collects the liquid or gas discharged by the impeller.

E. The vertical distance, height or energy of water above a point. This may be measured in either height (feet) or pressure (pounds per square in or psi).

F. A device for raising wastewater sludge or other liquid by compressed air.

G. The formation and collapse of a gas pocket or bubble on the blade of an impeller or the gate of a valve. It is accompanied by a loud noise that sounds like someone is pounding on the impeller or gate with a hammer.

H. The sound like someone hammering on a pipe that occurs when a valve is opened or closed very rapidly. When a valve position is changed quickly, the water pressure in a pipe will increase and decrease back and forth very quickly. This rise and fall in pressures can cause serious damage to the system.

I. A rotating set of vanes in a pump designed to pump or lift water.

J. The pressure (in pounds per square inch or psi) measured at the centerline of a pump discharge and very close to the discharge flange, converted to feet. The pressure is measured from the centerline of the pump to the hydraulic grade line of the water in the discharge pipe.

K. The positive pressure (in feet or pounds per square inch or psi) on the suction side of a pump. The pressure can be measured from the centerline of the pump up to the elevation of the hydraulic grade line on the suction side of the pump.

L. To trap bubbles in water either mechanically through turbulence or chemically through a reaction.

M. Dry room or compartment in a lift station, near or below the water level, where the pumps are located.
N. Compartment or tank in which wastewater is collected.

Lift Stations Questions

1. What is the purpose of a lift station?

2. Why does a pump require more energy (draw more power) to start than it does during normal operating conditions?

3. What are the advantages and limitations of having bar racks/screens in wet wells?

4. Why should isolation valves in lift stations be gate valves instead of plug valves?

5. Why must lift stations have adequate ventilation?

6. What kind of problems or failures can occur in lift stations?

7. Why should air release valves be installed at high points in force mains?

8. Which type of pump is most commonly used in raw wastewater lift stations?

9. Why should lift stations be equipped with at least two pumps?

True-False

10. Equipment located in the wet well should be minimized.
    True
    False

11. Power to electrode controllers must be turned off and properly tagged before performing any maintenance on the equipment.
    True
    False

12. Gate valves are less susceptible to plugging than plug valves.
    True
    False

Multiple Choice

13. Lifting of wastewater in a lift station is accomplished by:
    a. Air lift pumps
    b. Centrifugal pumps
    c. Piston pumps
    d. Turbine pumps

14. Accumulated air in force mains is blown off by:
    a. Air release valves
    b. Altitude control valves
    c. Blowers
    d. Check valves

15. A sump pump is used to pump drainage out of a:
    a. Dry well sump
    b. Full wet well
    c. Manhole
    d. Wet well sump

16. The purpose of a check valve is to:
    a. Adjust the discharge flows from the pump
    b. Isolate the pump from the system
    c. Prevent the force main from draining back into the wet well
    d. Prevent plugging of pumps

17. Pumps draw more power starting than during normal operating conditions because:
    a. Gate valves have to be pushed open
    b. Pipe friction losses are greater
    c. The motor and pump have to start turning
    d. The total dynamic head is greater

18. <u>Advantages</u> of float control systems include:
    a. Capacity to completely drain the wet well
    b. May be reset manually or by remote control
    c. Sensitivity to water level changes
    d. Simple design eliminates fouling by grease or debris

19. <u>Limitations</u> of electrode controllers include:
    a. Grease or slime can cover electrodes
    b. If not properly maintained, pumps may not start and stop when desired
    c. Rags and debris can foul electrodes
    d. There are none
    e. A, B and C

Answers to Vocabulary and Questions

Vocabulary:

1. G
2. C
3. J
4. M
5. L
6. A
7. E
8. I
9. B
10. F
11. K
12. D
13. H
14. N

Questions:

1. To lift or raise wastewater or storm water from a lower elevation to a higher elevation
2. The energy required to start a pump is greater than the total dynamic head (TDH) during normal operating conditions because additional energy is required to start the motor and the pump to start the water flowing through the pipes, the check valves and the pump.
3. Advantages: Prevent any large debris from entering and plugging or damaging the pump. Limitations: Must be cleaned frequently so there is no substantial restriction of wastewater flow to the pumps.
4. Isolation valves in lift stations should be gate valves instead of plug valves because some types of plug valves can be slammed shut by wastewater backflow and possibly injure you and break the valves body or a portion of the pipe system from the water hammer due to the sudden stoppage of the flowing water. Also plug valves have a restriction that can be clogged with rags or sticks.
5. To provide a safe atmosphere for operation and maintenance operators
6. Power, control systems, pumping systems, structures
7. to prevent accumulation of air and other gases; trapped pockets of air reduce the carrying capacity of the pipe, increase pumping costs, contribute to damage by water hammer and may create negative pressures strong enough to collapse pipes
8. centrifugal pumps
9. to provide continuous operation if one pump fails or needs repairs
10. True
11. True
12. False
13. B
14. A
15. A
16. C
17. C
18. C
19. E

Section 11

Pumps

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PUMPS

California State University: Sacramento

Updated 12-2017

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Necessity Of Pumps

- Pumps are required when gravity cannot supply water with sufficient pressure to all parts of the distribution system
- Pumps account for the largest energy cost for a water supply operation

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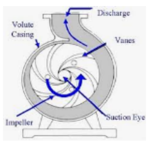
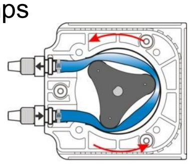
Types of Pumps

- Velocity Pumps



- Positive-Displacement Pumps



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Types of Pumps

- Positive-Displacement Pumps
  - Metering pumps
    - sometimes used to feed chemicals
  - Piston pump
  - Screw pump
- Velocity Pumps
  - Vertical turbine
  - Centrifugal

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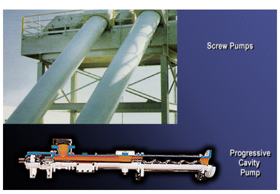
Positive-Displacement Pumps

- Chemical feed pumps
- Delivers a constant volume with each stroke
- Less efficient than centrifugal pumps
- **Cannot operate against a closed discharge valve**
- Types: piston, diaphragm, gear, or screw pump



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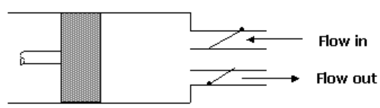
Positive-Displacement Pumps

- Reciprocating (piston) pump - piston moves back and forth in cylinder, liquid enters and leaves through check valves



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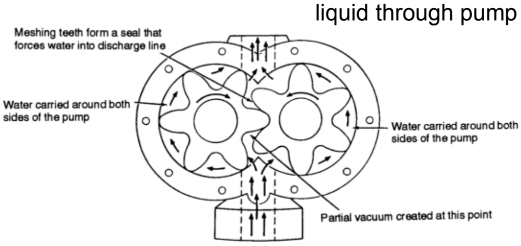
Positive-Displacement Pumps

- Rotary pump - Use lobes or gears to move liquid through pump



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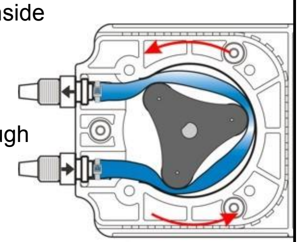
Positive Displacement Pumps

- Peristaltic Pump
  - Fluid to be pumped flows through flexible tube inside a pump casing
  - Rotor inside turns and compresses the tube
  - Rotor forces fluid through tube



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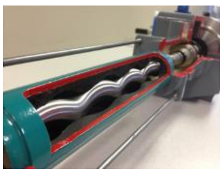
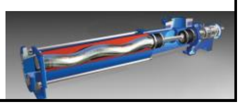
Screw Pumps

Incline screw pumps handle large solids without plugging

- Aka progressive cavity pumps
- Screw pumps are used to lift wastewater to a higher elevation
- This pump consists of a screw operating at a constant speed within a housing or trough
- The screw has a pitch and is set at a specific angle
- When revolving, it carries wastewater up the trough to a discharge point





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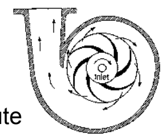
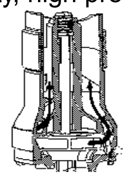
Velocity Pumps

- Spinning impeller or propeller accelerates water to high velocity in pump casing (or volute)
- High velocity, low pressure water is converted to low velocity, high pressure water



Volute



Diffuser

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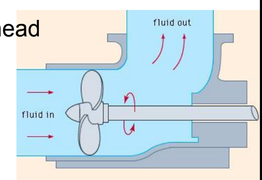
Velocity Pump Design Characteristics

- Axial - flow designs
  - Propeller shaped impeller adds head by lifting action on vanes
  - Water moves parallel to pump instead of being thrown outward
  - High volume, but limited head
  - Not self-priming



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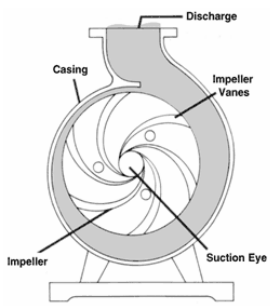
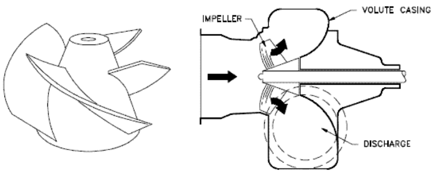
Velocity Pump Design Characteristics

- Radial flow designs
  - Water comes in through center (eye) of impeller
  - Water thrown outward from impeller to diffusers that convert velocity to pressure
  - The discharge is perpendicular to the pump shaft



Velocity Pump Design Characteristics

- Mixed - flow designs
  - Has features of axial and radial flow
  - Works well for water with solids



Centrifugal Pump

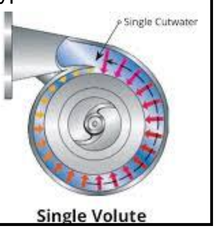
- Basically a very simple device: an impeller rotating in a casing
- The impeller is supported on a shaft, which in turn, is supported by bearings
- Liquid coming in at the center (eye) of the impeller is picked up by the vanes and by the rotation of the impeller and then is thrown out by centrifugal force into the discharge

Centrifugal Pumps

- Volute-casing type most commonly used in water utilities
- Impeller rotates in casing - radial flow
- Single or multi-stage
- By varying size, shape, and width of impeller, a wide range of flows and pressures can be achieved

Advantages of Centrifugal Pumps

- Wide range of capacities
- Uniform flow at a constant speed and head
- Low cost
- Ability to be adapted to various types of drivers
- Moderate to high efficiency
- No need for internal lubrication



Disadvantages of Centrifugal Pumps

- Efficiency is limited to very narrow ranges of flow and head
- Flow capacity greatly depends on discharge pressure
- Generally no self-priming ability
- Can run backwards if check valve fails and sticks open
- Potential impeller damage if pumping abrasive water

Let's Build a Centrifugal Pump

- First we need a device to spin liquid at high speeds – an impeller
  - As the impeller spins, liquid between the blades is impelled outward by centrifugal force
  - As liquid in the impeller moves outward, it will suck more liquid behind it through this eye

#1: If there is any danger that foreign material may be sucked into the pump, clogging or wearing of the impeller unduly, provide the intake end of the suction piping with a suitable screen

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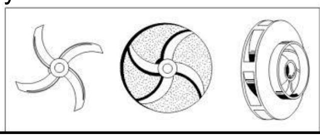
Impeller

- Bronze or stainless steel
- Closed; some single-suction have semi-open; open designs
- Inspect regularly
- As the impeller wears on a pump, the pump efficiency will decrease



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Let's Build a Centrifugal Pump

- Now we need a shaft to support and turn the impeller
  - It must maintain the impeller in precisely the right place
  - But that ruggedness does not protect the shaft from the corrosive or abrasive effects of the liquid pumped, so we must protect it with sleeves slid on from either end

#2: Never pump a liquid for which the pump was not designed

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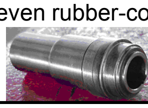
Shaft and Sleeves

- Shaft
  - Connects impeller to pump; steel or stainless steel
  - Should be repaired/replaced if grooves or scores appear on the shaft
- Shaft Sleeves
  - Protect shaft from wear from packing rings
  - Generally they are bronze, but various other alloys, ceramics, glass or even rubber-coating are sometimes required.



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Let's Build a Centrifugal Pump

- We mount the shaft on sleeve, ball or roller bearings
  - If bearings supporting the turning shaft and impeller are allowed to wear excessively and lower the turning units within a pump's closely fitted mechanism, the life and efficiency of that pump will be seriously threatened.

#3: Keep the right amount of the right lubricant in bearings at all times.

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Bearings

- Anti-friction devices for supporting and guiding pump and motor shafts
- Get noisy as they wear out
- If pump bearings are over lubricated, the bearings will overheat and can be damaged or fail
  - Tiny indentations high on the shoulder of a bearing or race is called brinelling
  - When greasing a bearing on an electric motor, the relief plug should be removed and replaced after the motor has run for a few minutes. This prevents you from damaging the seals of the bearing.
- Types: ball, roller, sleeve

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Let's Build a Centrifugal Pump

- To connect with the motor, we add a coupling flange
  - Our pump is driven by a separate motor, and we attach a flange to one end of the shaft through which bolts will connect with the motor flange
  - If shafts are met at an angle, every rotation throws tremendous extra load on bearings of both pump and the motor

#4: See that pump and motor flanges are parallel and vertical and that they stay that way.

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Couplings

- Connect pump and motor shafts
- Lubricated require greasing at 6 month intervals
- Dry has rubber or elastomeric membrane
- Calipers and thickness gauges can be used to check alignment on flexible couplings

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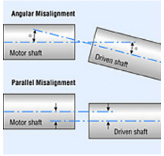
Misalignment of Pump & Motor



- Excessive bearing loading
- Shaft bending
- Premature bearing failure
- Shaft damage
- Checking alignment should be a regular procedure in pump maintenance.
  - Foundations can settle unevenly
  - Piping can change pump position
  - Bolts can loosen
  - Misalignment is a major cause of pump and coupling wear.

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Common Pump & Motor Connections

- Direct coupling
- Angle drive
- Belt or chain
- Flexible coupling
- Close-coupled

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Let's Build a Centrifugal Pump

- Now we need a "straw" through which liquid can be sucked
  - The horizontal pipe slopes upward toward the pump so that air pockets won't be drawn into the pump and cause loss of suction

#5: Any down-sloping toward the pump in suction piping should be corrected

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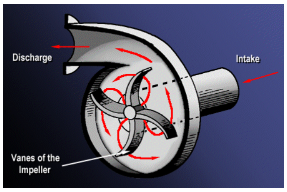
Let's Build a Centrifugal Pump

- We contain and direct the spinning liquid with a casing
  - Designed to minimize friction loss as water is thrown outward from impeller
  - Usually made of cast iron, spiral shape



#6: See that piping puts absolutely no strain on the pump casing.

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Mechanical Details of Centrifugal Pumps

- Casing
  - Housing surrounding the impeller; also called the volute
  - Designed to minimize friction loss as water is thrown outward from impeller
  - Usually made of cast iron, spiral shape

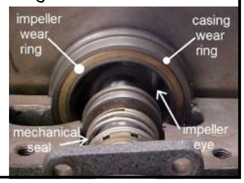
Let's Build a Centrifugal Pump

- Now our pump is almost complete, but it would leak like a sieve
  - As water is drawn into the spinning impeller, centrifugal force causes it to flow outward, building up high pressure at the outside of the pump (which will force water out) and creating low pressure at the center of the pump (which will draw water in)
    - Water tends to be drawn back from pressure to suction through the space between the impeller and casing – this needs to be plugged

Let's Build a Centrifugal Pump

- So we add wear rings to plug internal liquid leakage
  - Wear rings fill the gaps without having to move the parts of the pump closer together

#7: Never allow a pump to run dry. Water is a lubricant between the rings and impeller.



Wear Rings

- Restrict flow between impeller discharge and suction
- Leakage reduces pump efficiency
- Installed to protect the impeller and pump casing from excessive wear
- Provides a replaceable wearing surface
- Inspect regularly

#8: Examine wearing rings at regular intervals. When seriously worn, their replacement with greatly improve pump efficiency.

Let's Build a Centrifugal Pump

- To keep air from being drawn in, we use stuffing boxes
  - We have two good reasons for wanting to keep air out of our pump
    - We want to pump water, not air
    - Air leakage is apt to cause our pump to lose suction
  - Each stuffing box we use consists of a casing, rings of packing and a gland at the outside end
    - A mechanical seal may be used instead

Stuffing Box

#9 – Packing should be replace periodically. Forcing in a ring or two of new packing instead of replacing worn packing is bad practice. It is apt to dislodge the seal cage.

#10 - Never tighten a gland more than necessary as excessive pressure will wear shaft sleeves unduly.

#11 – If shaft sleeves are badly scored, replace them immediately.

Let's Build a Centrifugal Pump

- To make packing more airtight, we add water seal piping
  - In the center of each stuffing box is a "seal cage"
  - This liquid acts both to block out air intake and to lubricate the packing
  - To control liquid flow, draw up the packing gland just tight enough to allow approximately one drop/second flow from the box

#12 – If the liquid being pumped contains grit, a separate source of sealing liquid should be obtained.

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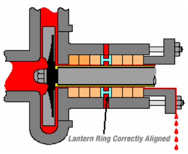
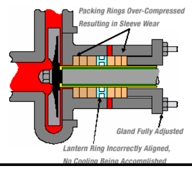
Lantern Rings

- Perforated ring placed in stuffing box
- A spacer ring in the packing gland that forms seal around shaft, helps keep air from entering the pump and lubricates packing





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Packing Rings

- Asbestos or metal ring lubricated with Teflon or graphite
- Provides a seal where the shaft passes through the pump casing in order to keep air form being drawn or sucked into the pump and/or the water being pumped from coming out

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Packing Rings

- If new packing leaks, stop the motor and repack the pump
- Pumps need new packing when the gland or follower is pulled all the way down
- The packing around the shaft should be tightened slowly, over a period of **several hours** to just enough to allow an occasional drop of liquid (**20-60 drops per minute** is desired)
  - Leakage acts as a lubricant
- Stagger joints 180º if only 2 rings are in stuffing box, space at 120º for 3 rings or **90º if 4 rings or more are in set**

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Packing Rings

- If packing is not maintained properly, the following troubles can arise:
  - **Loss of suction** due to air being allowed to enter pump
  - **Shaft or shaft sleeve damage**
  - Water or wastewater **contaminating bearings**
  - **Flooding** of pump station
  - Rust corrosion and unsightliness of pump and area

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Mechanical Seals

- Located in stuffing box
- Prevents water from leaking along shaft; keeps air out of pump
- **Should not leak**
- Consists of a rotating ring and stationary element
- The operating temperature on a mechanical seal should never exceed 160ºF (71ºC)
- Mechanical seals are always flushed in some manner to lubricate the seal faces and minimize wear
  - The flushing water pressure in a water-lubricated wastewater pump should be **3-5 psi higher** than the pump discharge pressure.

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Mechanical Seals

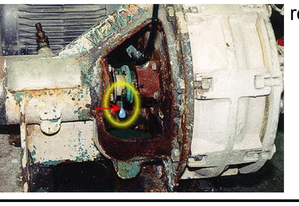
- Required instead of packing rings for suction head greater than 60 psi
- Prevents water from leaking along shaft, keeps air out of pump
  - Should not leak any water

Packing vs. Mechanical Seals

- If a pump has packing, water should drip slowly
- If it has a mechanical seal, no leakage should occur

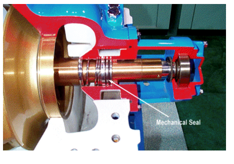
Packing Rings vs. Mechanical Seal

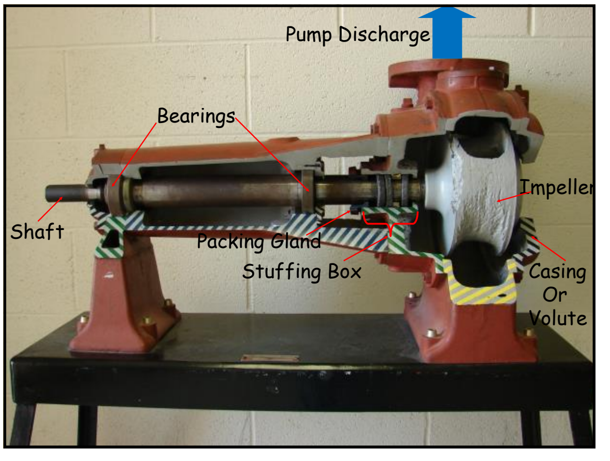
- Advantages
  - Less expensive, short term
  - Can accommodate some looseness
- Disadvantages
  - Increased wear on shaft or shaft sleeve
  - Increased labor required for adjustment and replacement

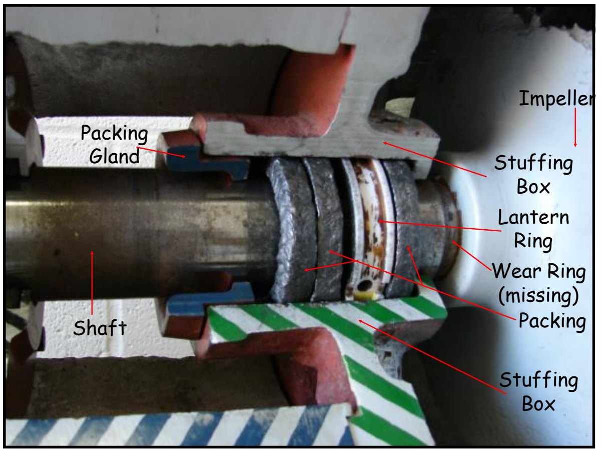


Mechanical Seal vs. Packing Rings

- Advantages
  - **Last 3-4 years**, which can be a savings in labor
  - Usually there is **no damage to shaft sleeve**
  - **Continual adjusting, cleaning or repacking is not required**
  - Possibility of flooding lift station because a pump has thrown its packing is eliminated; however mechanical seals can fail and lift stations can be flooded
- Disadvantages
  - **High initial cost**
  - **Great skill and care needed to replace**
  - When they fail, the pump must be shut down
  - **Pump must be dismantled to repair**







Centrifugal Pump Operation

- Pump Starting -
  - Impeller must be submerged for a pump to start
    - Should never be run empty, except momentarily, because parts lubricated by water would be damaged
  - Foot valve helps hold prime
  - Discharge valve should open slowly to control water hammer
  - In small pumps, a check valve closes immediately when pump stops to prevent flow reversal
  - In large pumps, discharge valve may close before pump stops

Centrifugal Pump Operation

- Pump shut down for extended period of time -
  - Close the valve in the suction line
  - Close the valve in the discharge line
  - Drain the pump casing

Flow Control

- Flow usually controlled by starting and stopping pumps
- Throttling flow should be avoided - wastes energy
- Variable speed drives or motor are best way to vary flow
  - Variable speed pumping equipment can be adjusted to match the inflow rate

Monitoring Operational Variables

- Pump and motor should be tested and complete test results recorded as a baseline for the measurement of performance within the first 30 days of operation

Monitoring Operational Variables

- Suction and Discharge Heads
  - Pressure gauges
- Bearing and Motor Temperature
  - Temp indicators can shut down pump if temp gets too high
  - Check temp of motor by feel

Monitoring Operational Variables

- Vibration
  - Detectors can sense malfunctions causing excess vibration
  - Operators can learn to distinguish between normal and abnormal sounds

Monitoring Operational Variables

- Likely causes of vibration
  - Bad bearings or bearing failure
  - Imbalance of rotating elements, damage to impeller
  - Misalignment from shifts in underlying foundation
  - Improper motor to pump alignment

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Monitoring Operational Variables

- Speed
  - Cavitation can occur at low and high speeds
  - Creation of vapor bubbles due to partial vacuum created by incomplete filling of the pump

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Monitoring Operational Variables

- Cavitation is a noise coming from a centrifugal pump that sounds like marbles trapped in the volute
- A condition where small bubbles of vapor form and explode against the impeller, causing a pinging sound
- Best method to prevent it from occurring is to reduce the suction lift

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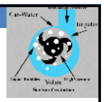
Suction Cavitation



- Suction Cavitation occurs when the pump suction is under a low pressure/high vacuum condition where the liquid turns into a vapor at the eye of the pump impeller.
- This vapor is carried over to the discharge side of the pump where it no longer sees vacuum and is compressed back into a liquid by the discharge pressure.
- This imploding action occurs violently and attacks the face of the impeller.
- An impeller that has been operating under a suction cavitation condition has large chunks of material removed from its face causing premature failure of the pump.

Information from http://www.pumpworld.com/Cavitation_discharge.htm

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Discharge Cavitation

- Discharge Cavitation occurs when the pump discharge is extremely high.
- It normally occurs in a pump that is running at less than 10% of its best efficiency point.
- The high discharge pressure causes the majority of the fluid to circulate inside the pump instead of being allowed to flow out the discharge.
- As the liquid flows around the impeller it must pass through the small clearance between the impeller and the pump cutwater at extremely high velocity.

Information from http://www.pumpworld.com/Cavitation_discharge.htm

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Discharge Cavitation

- This velocity causes a vacuum to develop at the cutwater similar to what occurs in a venturi and turns the liquid into a vapor.
- A pump that has been operating under these conditions shows premature wear of the impeller vane tips and the pump cutwater.
- In addition due to the high pressure condition premature failure of the pump mechanical seal and bearings can be expected and under extreme conditions will break the impeller shaft.

Information from http://www.pumpworld.com/Cavitation_discharge.htm

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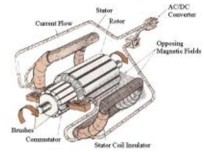
Inspection and Maintenance

- Inspection and maintenance prolongs life of pumps
  - Checking operating temperature of bearings
  - Checking packing glands
  - Operating two or more pumps of the same size alternatively to equalize wear
  - Check parallel and angular alignment of the coupling on the pump and motor
    - A feeler gauge, dial indicator calipers are tools that can be used to check proper alignment
- Necessary for warranty
- Keep records of all maintenance on each pump
- Keep log of operating hours

Inspection: Impellers

- Wear on impeller and volute
- Cavitation marks
- Chips, broken tips, corrosion, unusual wear
- Tightness on shaft
- Clearances
- Tears or bubbles (if rubber coated)

Pump Won't Start?



- Incorrect power supply
- No power supply
- Incorrectly connected
- Fuse out, loose or open connection
- Rotating parts of motor jammed mechanically
- Internal circuitry open

Pump Safety

- Machinery should always be turned off and locked out/tagged out before any work is performed on it
- Make sure all moving parts are free to move and all guards in place before restarting
- Machinery creating excessive noise shall be equipped with mufflers.

Pump Safety: Wet Wells

- Confined spaces
- Corrosion of ladder rungs
- Explosive atmospheres
- Hydrogen sulfide accumulation
- Slippery surfaces

Pump Vocabulary

1. Axial-Flow Pump – a pump in which a propeller-like impeller forces water out in the direction parallel to the shaft. Also called a propeller pump.
2. Bearing – anti-friction device used to support and guide a pump and motor shafts.
3. Casing – the enclosure surrounding a pump impeller, into which the suction and discharge ports are machined.
4. Cavitation – a condition that can occur when pumps are run too fast or water is forced to change direction quickly. A partial vacuum forms near the pipe wall or impeller blade causing potentially rapid pitting of the metal.
5. Centrifugal Pumps – a pump consisting of an impeller on a rotating shaft enclosed by a casing having suction and discharge connections. The spinning impeller throws water outward at high velocity, and the casing shape converts this velocity to pressure.
6. Closed-Coupled Pump – a pump assembly where the impeller is mounted on the shaft of the motor that drives the pump.
7. Diffuser Vanes – vanes installed within a pump casing on diffuser centrifugal pumps to change velocity head to pressure head.
8. Double-Suction Pump – a centrifugal pump in which the water enters from both sides of the impeller. Also called a split-case pump.
9. Foot Valve – a check valve placed in the bottom of the suction pipe of a pump, which opens to allow water to enter the suction pipe but closes to prevent water from passing out of it at the bottom end. Keeps prime.
10. Frame-Mounted Pump – a centrifugal pump in which the pump shaft is connected to the motor shaft with a coupling.
11. Impeller – the rotating set of vanes that forces water through the pump.
12. Jet Pump – a device that pumps fluid by converting the energy of a high-pressure fluid into that of a high-velocity fluid.
13. Lantern Ring – a perforated ring placed around the pump shaft in the stuffing box. Water from the pump discharge is piped to this ring. The water forms a liquid seal around the shaft and lubricates the packing.
14. Mechanical Seal – a seal placed on the pump shaft to prevent water from leaking from the pump along the shaft; the seal also prevents air from entering the pump.
15. Mixed-Flow Pump – a pump that imparts both radial and axial flow to the water.
16. Packing – rings of graphite-impregnated cotton, flax, or synthetic materials, used to control leakage along a valve stem or a pump shaft.
17. Packing Gland – a follower ring that compressed the packing in the stuffing box.
18. Positive Displacement Pump – a pump that delivers a precise volume of liquid for each stroke of the piston or rotation of the shaft.

19. Prime Mover – a source of power, such as an internal combustion engine or an electric motor, designed to supply force and motion to drive machinery, such as a pump.
20. Radial-Flow Pump – a pump that moves water by centrifugal force, spinning the water radially outward from the center of the impeller.
21. Reciprocating Pump – a type of positive-displacement pump consisting of a closed cylinder containing a piston or plunger to draw liquid into the cylinder through an inlet valve and forces it out through an outlet valve.
22. Rotary Pump – a type of positive-displacement pump consisting of elements resembling gears that rotate in a close-fitting pump case. The rotation of these elements alternately draws in and discharges the water being pumped.
23. Single-Suction Pump – a centrifugal pump in which the water enters from only one side of the impeller. Also called an end-suction pump.
24. Stuffing Box – a portion of the pump casing through which the shaft extends and in which packing or a mechanical seal is placed to prevent leakage.
25. Submersible Pump – a vertical-turbine pump with the motor placed below the impellers. The motor is designed to be submersed in water.
26. Suction Lift – the condition existing when the source of water supply is below the centerline of the pump.
27. Velocity Pump – the general class of pumps that use a rapidly turning impeller to impart kinetic energy or velocity to fluids. The pump casing then converts this velocity head, in part, to pressure head. Also known as kinetic pumps.
28. Vertical Turbine Pump – a centrifugal pump, commonly of the multistage, diffuser type, in which the pump shaft is mounted vertically.
29. Volute – the expanding section of pump casing (in a volute centrifugal pump), which converts velocity head to pressure head..
30. Water Hammer – the potentially damaging slam that occurs in a pipe when a sudden change in water velocity (usually as a result of too-rapidly starting a pump or operating a valve) creates a great increase in water pressure.
31. Wear Rings – rings made of brass or bronze placed on the impeller and/or casing of a centrifugal pump to control the amount of water that is allowed to leak from the discharge to the suction side of the pump.

Pump and Motor Facts

Pump Facts

High-service pump – discharges water under pressure to the distribution system.

Booster pump – used to increase pressure in the distribution system and to fill elevated storage tanks.

Impeller or centrifugal pump used to move water.

Likely causes of vibration in an existing pump/motor installation:

1. bad bearings
2. imbalance of rotating elements
3. misalignment from shifts in underlying foundation

Pump and motor should be tested and complete test results recorded as a baseline for the measurement of performance within the first 30 days of operations.

Calipers and thickness gauges can be used to check alignment on flexible couplings.

Packing/Seals Facts

If new packing leaks, stop the motor and repack the pump.

Pumps need new packing when the gland or follower is pulled all the way down.

The packing around the shaft should be tightened just enough to allow an occasional drop of liquid for cooling.

Joints of packing should be staggered at least 90°.

Mechanical seals consist of a rotating ring and stationary element.

The operating temperature on a mechanical seal should never exceed 160°F or 71°C.

Motor Facts

Motors pull the most current on start up.

In order to prevent damage, turn the circuit off immediately if the fuse on one of the legs of a three-phase circuit blows.

An electric motor changes electrical energy into mechanical energy.

Power factors on motors can be improved by:
1. changing the motor loading
2. changing the motor type
3. using capacitors

Routing cleaning of pump motors includes:
1. checking alignment and balance
2. checking brushes
3. removing dirt and moisture
4. removal of obstructions that prevent air circulation

Cool air extends the useful life of motors.

A motor (electrical or internal combustion) used to drive a pump is called a prime mover.

The speed at which the magnetic field rotates is called the motor synchronous speed and is expressed in rpm.

If a variable speed belt drive is not to be used for 30 days or more, shift the unit to minimum speed setting.

Emory cloth should not be used on electric motor components because it is electrically conductive and may contaminate parts.

Ohmmeters used to test a fuse in a motor starter circuit.

The most likely cause of a three-phase motor not coming to speed after starting – the motor has lost power to one or more phases.

Transformer Facts

Transformers are used to convert high voltage to low voltage.

High voltage is 440 volts or higher.

Standby engines should be run weekly to ensure that it is working properly.

Relays are used to protect electric motors.

Pump and Motor Review Questions

1. Leakage of water around the packing on a centrifugal pump is important because it acts as a (n):
   a. Adhesive
   b. Lubricant
   c. Absorbent
   d. Backflow preventer

2. What is the purpose of wear rings in a pump?
   a. Hold the shaft in place
   b. Hold the impeller in place
   c. Control amount of water leaking from discharge to suction side
   d. Prevent oil from getting into the casing of the pump

3. Which of the following does a lantern ring accomplish?
   a. Lubricates the packing
   b. Helps keep air from entering the pump
   c. Both (a.) and (b.)

4. Closed, open and semi-open are types of what pump part?
   a. Impeller
   b. Shaft sleeve
   c. Casing
   d. Coupling

5. When tightening the packing on a centrifugal pump, which of the following applies?
   a. Tighten hand tight, never use a wrench
   b. Tighten to 20 foot pounds of pressure
   c. Tighten slowly, over a period of several hours
   d. Tighten until no leakage can be seen from the shaft

6. Excessive vibrations in a pump can be caused by:
   a. Bearing failure
   b. Damage to the impeller
   c. Misalignment of the pump shaft and motor
   d. All of the above

7. What component can be installed on a pump to hold the prime?
   a. Toe valve
   b. Foot valve
   c. Prime valve
   d. Casing valve

8. The operating temperature of a mechanical seal should not exceed:
   a. 60°C
   b. 150°F
   c. 160°F
   d. 71°C
   e. c and d

9. What is the term for the condition where small bubbles of vapor form and explode against the impeller, causing a pinging sound?
   a. Corrosion
   b. Cavitation
   c. Aeration
   d. Combustion

10. The first thing that should be done before any work is begun on a pump or electrical motor is:
    a. Notify the state
    b. Put on safety goggles
    c. Lock out the power source and tag it
    d. Have a competent person to supervise the work

11. Under what operating condition do electric motors pull the most current?
    a. At start up
    b. At full operating speed
    c. At shut down
    d. When locked out

12. As the impeller on a pump becomes worn, the pump efficiency will:
    a. Decrease
    b. Increase
    c. Stay the same

13. How do the two basic parts of a velocity pump operate?

14. What are two designs used to change high velocity to high pressure in a pump?

15. In what type of pump are centrifugal force and the lifting action of the impeller vanes combined to develop the total dynamic head?

16. Identify one unique safety advantage that velocity pumps have over positive-displacement pumps.

17. What is the multistage centrifugal pump? What effects does the design have on discharge pressure and flow volume?

18. What are two types of vertical turbine pump, as distinguished by pump and motor arrangement, which are commonly used to pump ground water from wells?

19. What type of vertical turbine pump is commonly used as an inline booster pump?

20. Describe the two main parts of a jet pump.

21. What is the most common used of positive-displacement pumps in water plants today?

22. What is the purpose of the foot valve on a centrifugal pump?

23. How is the casing of a double-suction pump disassembled?

24. What is the function of wear rings in centrifugal pumps of the closed-impeller design? What is the function of the lantern rings?

25. Describe the two common types of seals used to control leakage between the pump shaft and the casing.

26. What feature distinguishes a close-coupled pump and motor?

27. What is the value of listening to a pump or laying a hand on the unit as it operates?

28. Define the term “racking” as applied to pump and motor control.

29. When do most electric motors take the most current?

30. What are three major ways of reducing power costs where electric motors are used?

31. What effect could over lubrication of motor bearings have?

32. Why should emery cloth not be used around electrical machines?

33. What are the most likely causes of vibration in an existing pump installation?

34. What can happen when a fuse blows on a single leg of a three-phase circuit?

35. Name at least three common fuels for internal-combustion engines.

36. List the type of information that should be recorded on a basic data card for pumping equipment.

37. What is the first rule of safety when repairing electrical devices?

Answers:

1. B	4. A	7. B	10. C
2. C	5. C	8. E	11. A
3. C	6. D	9. B	12. A

13. A spinning impeller accelerates water to a high velocity within a casing, which changes the high-velocity, low-pressure water to a low-velocity, high-pressure discharge.
14. Volute casing and diffuser vanes.
15. Mixed-flow pump (the design used for most vertical turbine pumps)
16. If a valve is closed in the discharge line, the pump impeller can continue to rotate for a time without pumping water or damaging the pump.

17. A multistage centrifugal pump is made up of a series of impellers and casings (housings) arranged in layers, or stages. This increases the pressure at the discharge outlet, but does not increase flow volume.
18. Shaft-type and submersible-type vertical turbines.
19. A close-coupled vertical turbine with an integral sump or pot.
20. The jet pump consists of a centrifugal pump at the ground surface and an ejector nozzle below the water level.
21. Positive-displacement pumps are generally used in water plants to feed chemical into the water supply.
22. The foot valve prevents water from draining when the pump is stopped, so the pump will be primed when restarted.
23. The bolts holding the two halves of the casing together are removed and the top half is lifted off.
24. Wear rings prevent excessive circulation of water between the impeller discharge and suction area. Lantern rings allow sealing water to be fed into the stuffing box.
25. (1) Packing rings are made of graphite-impregnated cotton, flax, or synthetic materials. They are inserted in the stuffing box and held snuggly against the shaft by an adjustable packing gland. (2) Mechanical seals consist of two machined and polished surfaces. One is attached to the shaft, the other to the casing. Spring pressure maintains contact between the two surfaces.
26. The pump impeller is mounted directly on the shaft of the motor.
27. An experienced operator can often detect unusual vibration by simply listening or touching. Vibration, especially changes in vibration level, are viewed as symptoms or indicators of other underlying problems in foundation, alignment and/or pump wear.
28. Racking refers to erratic operation that may result from pressure surges when the pump starts; it is often a problem when the pressure sensor for the pump control is located too close to the pump station.
29. During start-up.
30. (1) Increase system efficiency; (2) spread the pumping load more evenly throughout the day; (3) reduce power-factor charges
31. The bearings may run hot, and excess grease or oil could run out and reach the motor windings, causing the insulation to deteriorate.
32. The abrasive material on emery cloth is electrically conductive and could contaminate electrical components.
33. Imbalance of the rotating elements, bad bearings and misalignment
34. A condition called single-phasing can occur, causing the motor windings to overheat and eventually fail.
35. gasoline, propane, methane, natural gas and diesel oil (diesel fuel)
36. make, model, capacity, type, date and location installed, and other information for both the driver (motor) and the driven unit (pump)
37. Make sure the power to the device is disconnected. This is critical since rubber gloves, insulated tools and other protective gear are not guarantees against electrical shock.

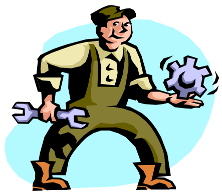
Section 12

Equipment Maintenance

Maintenance

California State University, Sacramento

Water Treatment Plant Operations Vol. II



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System Maintenance

- A good maintenance program is a must in order to maintain successful operation of a water plant
- Should include everything from mechanical equipment to the care of the plant grounds, buildings and structures
- Mechanical maintenance is of prime importance as the equipment must be kept in good operating condition in order for the plant to maintain peak performance

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Preventive Maintenance Records

- Preventive maintenance programs keep equipment in good working condition and correct small malfunctions before they turn into big problems
- A good record keeping system tells when maintenance is due and shows equipment performance
- Equipment service cards and service record cards should be filled out for each piece of equipment in the plant

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Equipment Service Card

- Tells what should be done and when
- Should include equipment name
  - e.g. raw water intake pump No. 1
- List each required maintenance service with an item number
- List maintenance services in order of frequency of performance
- Describe each type of service under work to be done

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EQUIPMENT SERVICE CARD
Equipment: #1 Raw Water Intake Pump

Item No.	Work to be done	Frequency	Time
1	Check water seal and packing gland	Daily	
2	Listen for unusual noises	Daily	
3	Operate pump alternately	Weekly	Monday
4	Inspect pump assembly	Weekly	Wednesday
5	Inspect and lube bearings	Quarterly	1, 4, 7, 10
6	Check operating temperature of bearings	Quarterly	1, 4, 7, 10
7	Check alignment of pump and motor	Semi-annually	4, 10
8	Inspect and service pump	Semi-annually	4, 10
9	Drain pump before shutdown		

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Service Record Card

- Tells what was done and when it was done
- Should have date and work done, listed by item number and signed by the operator who performed the service

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SERVICE RECORD CARD
Equipment: #1 Raw Water Intake Pump

Date	Work Done (Item No.)	Signed
1-6-13	1-2-3	J.D.
1-7-13	1-2	J.D.
1-8-13	1-2-4-5-6	P. K.

Date	Work Done (Item No.)	Signed

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Electrical Equipment

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Beware of Electricity

- Do not attempt to install, troubleshoot, maintain, repair, or replace electrical equipment, panels, controls, wiring, or circuits unless
  - You know what you are doing
  - You are qualified
  - You are authorized

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Volts

- Also known as electromotive force (EMF)
- The electrical pressure available to cause a flow of current (amperage) when a circuit is closed
- Voltage (E) is the force that is necessary to push electricity or electric current through a wire
- Two types:
  - Direct current (DC)
  - Alternating current (AC)

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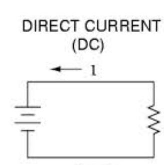
Direct Current (DC)

- Flow in one direction and is essentially free from pulsation
- Used exclusively in automotive equipment, certain types of welding equipment, and a variety of portable equipment
- Found in various voltages
  - 6, 12, 24, 48, and 110 volts
- All batteries are DC



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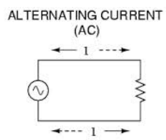
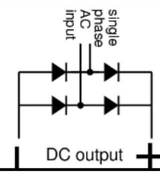
Alternating Current (AC)

- Voltage and current periodically change direction and amplitude
- Current goes from zero to maximum strength, back to zero, and to the same strength in the opposite direction
- Hertz describes the frequency of cycles completed per second
- Classified as
  - Single phase
  - Two phase
  - Three phase or polyphase



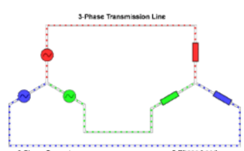
Alternating Current – Single Phase

- Found in lighting systems, small pump motors, various portable tools, and throughout homes
- Usually 120 volts and sometimes 240 volts
- Only one phase of power is supplied to the main electrical panel



Alternating Current – Three Phase

- Generally used with motors and transformers
- Usually is 208, 220, 240 volts, or 440, 460, 480, and 550 volts
- Used when high power requirements or larger motors are used
- Efficiency is higher and less maintenance is required
- Generally, all motors with > 2 HP are three phase



Alternating Current – Circuit Breakers

- Used to protect electric circuits from overloads
- Metal conductors that de-energize the main circuit is overheated by too much current passing through

Amps

- The measurement of current or electron flow and is an indication of work being done or "how hard the electricity is working"
- The practical unit of electrical current

Watts (W) and Kilowatts(kW)

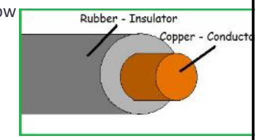
- The units of measurement of the rate at which power is being used or generated
- In DC circuits, watts equal the voltage times the current

  Watts = (volts)(amps)
- In AC polyphase circuits, you have to include the power factor and the √3

  Watts = (volts)(amps)(power factor)(1.73)
- Power factor is the ratio of actual power passing through a circuit to the apparent power
  - Usually somewhere near 0.9

Conductors and Insulators

- Conductor - a material that allows the flow of electric current e.g. copper
- Insulator - a material that will not allow the flow of electricity e.g. rubber
  - Insulation commonly used to prevent the loss of electrical flow by two conductors coming into contact with each other



Tools, Meters and Testers

Voltage Testing

- Multimeter used for checking voltage
- Use meter that has sufficient range to measure voltage you would expect to find
- Tells if AC or DC and intensity or voltage
- Used to test for open circuits, blown fuses, single phasing of motors, grounds, etc.

Ammeter

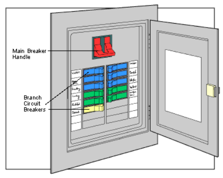
- Records the current or “amps” flowing in the circuit
- Two common types:
  - Clamp-on type – used for testing
    - Clamped around a wire supplying a motor
  - In-line type – installed in a panel or piece of equipment
    - Connected in line with the power lead or leads

Megger

- Used for checking the insulation resistance on motors, feeders, bus bar systems, grounds, and branch circuit wiring
- Connected to a motor terminal at the starter
- Test results show if the insulation is deteriorating or cut
- Three types
  - Crank operated
  - Battery operated
  - Instrument

Ohmmeters

- Used to measure the resistance in a circuit
- Also called circuit testers
- Electrical circuit must be OFF to use ohmmeter
- Ohmmeter supplies own power



Equipment Protective Devices

Fuses

- A protective device having a strip or wire of fusible metal that will melt and break the electrical circuit when subjected to excessive temperature
- Common types:
  - Current-limiting fuses – used to protect power distribution circuits
  - Dual-element fuses – used for motor protection circuits
- Be sure to replace fuses with proper size and type indicated for that circuit

Fuses

Circuit Breakers

- A protective device consisting of a switch that opens automatically when the current of the voltage exceeds or falls below a certain limit
- Can be reset unlike a fuse
- Can be visually inspected to find out if it has been tripped

Overload Relays

- Heater strips open on current rise (overheating) and open the control circuit
  - This opens the power control circuit which de-energizes the start and stops power to the motor
- Also known as heaters or “thermal overloads”
- Range form 100-110 of the motor nameplate ratings
- Should never exceed 125% of the motor rating
- Never increase the rating of the overload relay
  - Find the problem that is causing it to trip and repair it
- Ground – an electrical connection to earth or a large conductor that is at the earth’s potential or neutral voltage

Overload Relays

Auxiliary Electrical Power

- Standby power generation – three types
  - Engine driven generator
  - Batteries
  - Alternate power source
- Emergency lighting
- Batteries

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Compressors

- A device used to increase the pressure of air or gas
- Consists of a suction pipe with a filter and a discharge pipe that connects to an air receiver
- Can be simple diaphragm type or complex rotary, piston, or sliding vane type

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Compressor Maintenance

- Inspect the suction filter of the compressor monthly
  - Clean or replace filter every 3-6 months
- Lubrication must be inspected daily
  - Oil should be replaced every 3 months
- Cylinder or casing fins should be cleaned weekly
- Inspect unloader
  - If not working properly, compressor will not start, stall, or burn off belts if belt driven
- Test the safety valves weekly

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Compressor Maintenance

- Drain the condensate from air receiver daily
  - If has automatic drain, inspect periodically
- Inspect belt tension on compressor
  - Should be able to press the belt down, in the center, with your hand approximately ¾ inch
- Examine operating controls
  - Make sure compressor is starting and stopping at the proper settings
- Ensure portable compressors have oil in tool oiler reservoir
- Clean thoroughly each month

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Valves

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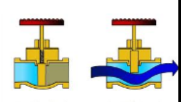
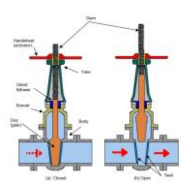
Gate Valves



- Basic parts: operator (handle), shaft packing assembly, bonnet, valve body with seats, stem, and disc
- Valve disc is raised/lowered by a threaded shaft
- Disc is screwed down until it wedges itself between two machined valve seats
- Not used to control flows
- Either rising stem or non-rising stem type



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Gate Valves – O & M

- 1. Open valve fully
- 2. Operate all large valves at least yearly to ensure proper operation
- 3. Inspect valve stem packing for leaks
- 4. If the valve has a rising stem, keep stem threads clean and lubricated
- 5. Close valves slowly in pressure lines to prevent water hammer
- 6. If a valve will not close by using the handwheel, check for the cause; Using a “cheater” bar will only aggravate the problem

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Gate Valves - Maintenance

Frequency	Service
Annually	**Replace packing:** Remove all old packing from stuffing box. Insert new split ring packing while staggering the ring splits.
Semi-annually	**Operate valve:** Operate inactive gate valves to prevent sticking
Annually	**Lubricate gearing:** Lubricate gate valves as recommended by manufacturer
Semi-annually	**Lubricate rising stem threads:** Clean threads on rising stem gate valves and lubricate with grease
Annually	**Reface leaky gate valve seats:** Remove bonnet and clean examine disc body thoroughly. Check and service all parts of valve completely. Remove all old packing a clean out stiffing box. Do not salvage old gasket. After cleaning and examining all parts, determine whether valve can be repaired or must be replaced. Test repaired valve before putting back in line.

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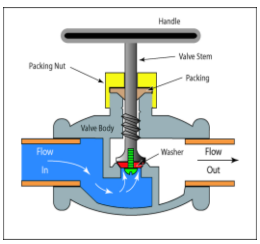
Globe Valves

- Use a circular disc to make a flat surface contact with a ground-fitted valve seat
- Internal design enables valve to be used in a controlling /throttling mode
- Can be of rising or nonrising stem type
- O & M similar to gate valve



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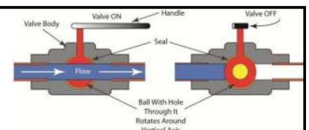
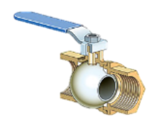
Ball Valves



- A valve consisting of a ball resting in a cylindrical seat
- A hole is bored through the ball to allow water to flow when the valve is open
- When the valve is rotated 90°, the valve is closed
- Should be operated fully open or fully closed
  - Throttling can lead to damage to the seal



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Eccentric Valves

- Uses a cam shaped plug to match an eccentric valve seat
- As the valve is closed, the plug throttles the flow yet maintains a smooth flow rate
- Excellent for controlling the flows of slurries and sludges

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Butterfly Valves

- Used primarily as a control valve
- Uses a machined disc that can be opened to 90º to allow full flow through valve
- Closed valve is forced against the continuous rubber seat

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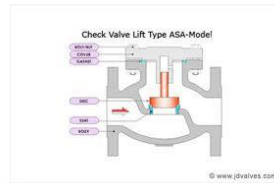
Check Valves

- Allows water to flow in only one direction
- Three types:
  - Swing check – a movable disc (clapper) rests at a right angle to the flow an seats against a ground seat
  - Wafer check – a circular disc that hinges in the center of the disc. Flow collapses the disc and flow stoppage allows the disc to return to its circular form
  - Lift check – uses a vertical lift disc or ball. Flow lifts the disc/ball and allows water to flow through.
    - Foot valves are nearly always vertical lift valves

Lift Check Valve



Swing Check Valve

Wafer Check Valve

Check Valves - Maintenance

Frequency	Service
Annually	**Inspect disc facing**: Open valves to observe condition of facing on swing check valves
Annually	**Check pin wear:** Check pin wear on balanced check valve, since disc must be accurately positioned in seat to prevent leakage

Equipment Maintenance Vocabulary

______1. Amperage	______7. Fuse
______2. Brinelling	______8. Jogging
______3. Cavitation	______9. Mandrel
______4. Circuit	______10. Megger
______5. Circuit Breaker	______11. Resistance
______6. Current	______12. Voltage

A. A safety device in an electric circuit that automatically shuts off the circuit when it becomes overloaded. The device can be manually reset.
B. Tiny indentations (dents) high on the shoulder of the bearing race or bearing. A type of bearing failure.
C. A special tool used to push bearing in or to pull sleeves out. Also can be a gage used to measure for excessive deflection in a flexible conduit.
D. A protective device having a strip or wire of fusible metal that, when placed in a circuit, will melt and break the electric circuit if heated too much. High temperatures will develop in the fuse when a current flows through the fuse in excess of that which the circuit will carry safely.
E. The formation and collapse of a gas pocket or bubble on the blade of an impeller or the gate of a valve. The collapse of this gas pocket or bubble drives water into the impeller or gate with a terrific force that can cause pitting on the impeller or gate surface. This is accompanied by loud noises that sound like someone is pounding on the impeller or gate with a hammer.
F. The electrical pressure available to cause a flow of current (amperage) when an electric circuit is closed.
G. The frequent starting and stopping of an electric motor.
H. A movement or flow of electricity.
I. An instrument used for checking the insulation resistance on motors, feeders, bus bar systems, grounds and branch circuit wiring.
J. The strength of an electric current measured in amperes. The amount of electric current flow, similar to the flow of water in gallons per minute.
K. That property of a conductor or wire that opposes the passage of a current, thus causing electrical energy to be transformed into heat.
L. The complete path of en electric current, including the generating apparatus or other source; or, a specific segment or section of the complete path.

Equipment Maintenance Questions

1. What are some of the uses of a voltage tester?

2. How often should motors and wirings be megged?

3. An ohmmeter is used to check the ohms of resistance in what control circuit components?

4. What are the two types of safety devices found in main electrical panels or control units?

5. What is the most common pump driver used in lift stations?

6. Why should inexperienced, unqualified or unauthorized persons and even qualified and authorized persons be extremely careful around electrical panels, circuits, wiring and equipment?

7. Under what conditions would you recommend the installation of a screw pump?

8. What are the advantages of a pneumatic ejector?

9. What is the purpose of packing?

10. What is the purpose of the lantern ring?

11. How often should impellers be inspected for wear?

12. What is the <u>purpose</u> of wear rings?

13. What causes cavitation?

14. How often should the suction filter of a compressor be cleaned?

15. How often should the condensate from the air receiver be drained?

16. What is the <u>purpose</u> of lubrication?

17. What precautions must be taken before oiling or greasing equipment?

18. If an ammeter reads higher than expected, the high current could produce
    a. "Freezing" of motor windings
    b. Irregular meter readings
    c. Lower than expected output horsepower
    d. Overheating and damage equipment

19. The <u>greatest cause</u> of electric motor failures is
    a. Bearing failures
    b. Contaminants
    c. Overload (thermal)
    d. Single phasing

20. Flexible shafting is used where the pump and driver are
    a. Coupled with belts
    b. Difficult to keep properly aligned
    c. Located relatively far apart
    d. Required to be coupled with universal joints

21. Never operate a compressor without the suction filter because dirt and foreign materials will cause
    a. Deterioration of lubricants
    b. Effluent contamination
    c. Excessive water
    d. Plugging of the rotors, pistons or blades

Answers to Vocabulary and Questions

Vocabulary:

1. J
2. B
3. E
4. L
5. A
6. H
7. D
8. G
9. C
10. I
11. K
12. F

Questions:

1. A voltage tester can be used to test for voltage, open circuits, blown fuses, single phasing of motors and grounds.
2. At least once a year and twice a year if possible
3. Coils, fuses, relays, resistors and switches
4. Fuses and circuit breakers
5. A.C. induction motor
6. You can seriously injure yourself or damage costly equipment.
7. To pump fluctuating flows with large solids and rags.
8. They can handle limited flows with relatively large solids. Maintenance is not as complicated as the maintenance on most pumps; however, maintenance must be performed when scheduled.
9. To keep air from leaking in and water leaking out where the shaft passes through the casing

10. To allow outside water or grease to enter the packing for lubrication, flushing, and cooling and to prevent air from being sucked or drawn into the pump
11. Every 6 months or annually, depending on pumping conditions; if grit, sand or other abrasive material is being pumped, inspections should be more frequent
12. They protect the impeller and pump body from damage due to excessive wear.
13. Cavitation can be caused by a pump operating under different conditions than what it was designed for, such as off the design curve, poor suction conditions, high speed, air leaks into suction end and water hammer conditions.
14. The frequency of cleaning a suction filter on a compressor depends on the use of a compressor and the atmosphere around it. The filter should be inspected at least monthly and cleaned or replaced every three to six months. More frequent inspections, cleanings and replacements are required under dusty conditions such as operating a jackhammer on a street.
15. Daily
16. To reduce friction between two surfaces and to remove heat caused by friction
17. Shut it off, lock it out and tag it so it can't be started unexpectedly and injure you
18. D
19. C
20. C
21. C

Section 13

Safety & Trenching

Safety

Distribution and Collections Systems

Safety

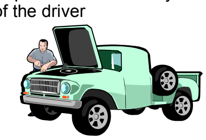
- An accident is caused by either an unsafe act or an unsafe environment.
- Personal cleanliness is the best means of protection against infection

General Duty Clause

- FEDERAL - 29 CFR 1903.1
- Worker Right to Know:
  - EMPLOYERS MUST: Furnish a place of employment free of recognized hazards that are causing or are likely to cause death or serious physical harm to employees. Employers must comply with occupational safety and health standards promulgated under the Williams-Steiger Occupational Safety and Health Act of 1970.

Before Leaving the Yard

- Work assignments
- Equipment needs
- Equipment inspection
- Vehicle inspection
  - When backing up a truck, one person should always be at the rear of the truck in view of the driver
  - Mirrors and windows
  - Lights and horn
  - Brakes
  - Tires
  - Trailer hitch/safety chain

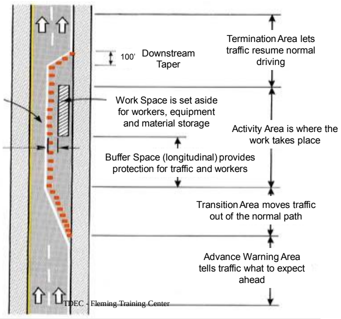


Traffic Safety

Traffic Control Zones

- Advanced warning area
- Transition area
- Buffer space
- Work area
- Termination area

Traffic Control Zones



Advanced warning area length:
Urban areas- 1 block
Roadways- 1500 ft
Freeways- ½ to 1 mile

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Advanced Warning Area

- This is where you communicate to the motorists that traffic is changing ahead
  - This area will hopefully put the drivers on alert
- Must be long enough to give motorists adequate time to respond to particular work area conditions

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Advanced Warning Area

- Typically ½ mile to one mile for highways
- 1500 feet for most other types of roads
- At least one block for urban streets

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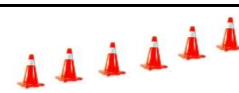
Transition Area



- Traffic is channelized from the normal highway lanes to the path required to move traffic around the work area
- Use of tapers
  - Channeling devices or pavement markings placed at an angle to direct traffic
- Not required if no lane or shoulder closure is involved

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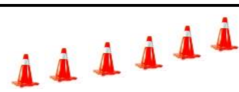
Transition Area



- Types of tapers used in traffic control zones:
  - Lane closure tapers – To slowly angle traffic out of a lane and eventually close it off to motorists
  - Two-way traffic tapers – To control two-way traffic where traffic is required to alternately use a single lane (One Lane Two-Way Closure or Flagger Closure)
  - Shoulder closure taper – to close off shoulder areas from motorists
  - Downstream taper – Installed after the work area to return/direct traffic back into its normal path

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Buffer Space

- The buffer space is the open, unoccupied space between the transition and work areas
- Provides margin of safety for both the motorists and the operators in the street
- If a driver does not see the advanced warning signs or fails to negotiate the transition, a buffer space provides room to stop before entering the work area
- Must be kept free of equipment, operators, materials, and vehicles

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Work Area

- The portion of the roadway which contains the work activity and is closed to traffic and set aside for exclusive use by operators, equipment, and construction materials
- Delineated by channelizing devices or shielded by barriers to exclude traffic and pedestrians
- Include a lateral buffer space between work activity and traffic if possible

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Work Area

- All work must be done within the safety of the work area – no operator should work outside of the work area, including the buffer space
- Avoid gaps in the traffic control that may falsely lead drivers to think they have passed through the work area
- Post **Road Construction Next ____ Miles** to inform drivers of the length of work area
  - Do Not set up sign until work begins

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Termination Area

- Provides short distance for traffic to clear work area and return to normal traffic lanes
- Downstream tapers are optional and may not be advisable when material trucks move into the work area by backing up from the downstream end of the work area
- End of Road Work sign can be used to clearly communicate to the motorists

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Traffic Signs

- Always use official signs
- Most permanent warning signs are diamond-shaped with black legends on yellow background
- Temporary signs have an orange background
- Best to use picture direction instead of wording

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Traffic Signs

- Signs should be 36 inches by 36 inches for low-speed applications and 48 inches by 48 inches for high-speed applications
- Minimum mounting height on fixed supports should be seven feet from the ground to the bottom of the sign in urban districts and five feet in rural
- Signs mounted on barricades or temporary supports may be installed lower but the bottom of the sign should not be less than one foot above the pavement elevation

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Traffic Signs

- All traffic control devices should be constructed to yield upon impact to minimize damage to a vehicle that strikes them and to minimize hazards to motorists and workers
- No traffic control devices should be weighted so heavily that it becomes hazardous to motorists and operators
- Approved ballast for devices is sandbags, but should never be suspended from the device

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Channelizing Devices

- Used to warn drivers and alert them to conditions created by work activities in roadway, to protect workers in the traffic control, and to guide drivers and pedestrians
- Include barricades, traffic cones and tubes, drums, and vertical panels
- Devices are not interchangeable because they have different effects on traffic
- Devices must be in acceptable condition

Channelizing Devices

- Barricades are commonly used to outline excavation or construction areas, close or restrict the right-of-way, mark hazards, or mount signs
- Have alternating orange and white stripes marked with reflectors that *slope down toward traffic*
- Classified as Type I, II, or III by the number of marked panels
- Type I and II are used in areas that traffic continues to move through, Type III are used to partially or completely close a roadway

Channelizing Devices

- Traffic cones and tubes are an effective method of channelizing traffic and best when used during daylight hours
- Can be easily moved by passing vehicles so must be monitored
- Cones are 18-36 inches high and orange in color
- Drums have higher visibility and can have the addition of lights
- Drums are 2 orange and 2 white stripes

Nighttime Traffic Control

- Additional modification to traffic control should be made for use at night
- Increased visibility of devices can be accomplished by use of lights on devices, use of larger devices such as drums, floodlighting for all flagging stations and work areas
- All traffic control devices used at night should have adequate retroreflective areas for high visibility
- All workers must have high visibility clothing approved for use at night – ANSI 107-2004 Class 3

Flaggers – MUTCD Sec. 6E.01

Because flaggers are responsible for public safety and make the greatest number of contacts with the public of all highway workers, they should be trained in safe traffic control practices and public contact techniques.

Flaggers – MUTCD Sec. 6E.01

Flaggers should be able to satisfactorily demonstrate the following abilities:

A. *Ability to receive and communicate specific instructions clearly, firmly, and courteously*
B. *Ability to move and maneuver quickly in order to avoid danger from errant vehicles*
C. *Ability to control signaling devices (such as paddles and flags) in order to provide clear and positive guidance to drivers approaching a TTC zone in frequently changing situations*
D. *Ability to understand and apply safe traffic control practices, sometimes in stressful or emergency situations*
E. *Ability to recognize dangerous traffic situations and warn workers in sufficient time to avoid injury*

Flaggers

- Flaggers shall wear high visibility safety apparel that meets the Class 2 or 3 requirements of the ANSI/ISEA 107-2004
- Apparel background color shall be fluorescent orange-red, fluorescent yellow-green, or a combination of the two
- The retroreflective material shall be orange, yellow, white, silver, yellow-green and shall be visible at a minimum distance of 1000 feet

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Flaggers

- The *STOP/SLOW* paddle should be the primary and preferred hand-signaling device, use of flags should be limited to emergency situations
- Paddle shall have an octagonal shape on a rigid handle, be at least 18 inches wide with letters at least 6 inches high
- Flagging station should be at least <u>100 feet</u> in front of the work space with a sign indicating that a flagger is ahead positioned as far in front of the flagger as practical – 500 feet minimum

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Flaggers

- Flaggers should:
  - Stand either on the shoulder adjacent to the road or in the closed lane adjacent to the through lane
  - Never stand in a through lane unless traffic has already been stopped
  - Be clearly visible to oncoming traffic at all times
  - Be positioned far enough in advance to warn workers of approaching danger
  - Have a line of sight to other flagger or a way to communicate with other flagger
  - Stand alone, away from others with no distractions (including cell phones!)

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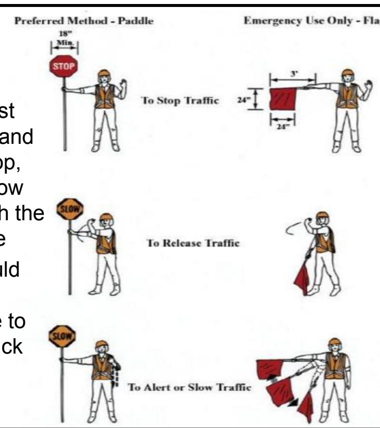
Flaggers

- Flaggers must use proper hand signals to stop, slow, and allow traffic through the traffic closure
- Flagger should identify an escape route to avoid be struck by an errant vehicle



Flaggers

<u>REMEMBER</u>

Flaggers are responsible for employee and public safety, they must have a sense of responsibility and they must receive appropriate training in traffic control practices

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Confined Space

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Manhole Hazards

- Atmospheric
- Physical injury
- Infection and disease
- Insects and biting animals
- Toxic exposure
- Drowning



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Confined Space Conditions

- Large enough and so configured that an employee can bodily enter and perform assigned work
- Limited or restricted means of entry or exit
- Not designed for continuous employee occupancy

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Confined Space Examples

- Storage tanks
- Manholes
- Hoppers
- Vaults
- Septic tanks
- Inside filters
- Basins
- Sewers


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Equipment Needed for Confined Spaces

- Safety harness with lifeline, tripod and winch
- Electrochemical sensors
- Ventilation blower with hose
  - Should have a capacity of no less than 750-850 cfm



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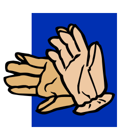
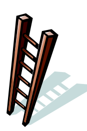
Equipment Needed for Confined Spaces

- PPE
- Ladder
- Rope
- Breathing Apparatus

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Permit Required Confined Space

- Contains or has potential to contain hazardous atmosphere
- Contains material with potential to engulf an entrant
- Entrant could be trapped or asphyxiated
- Positions required for entrance into a permit required confined space
  - Supervisor
  - Attendant – at least one person much be outside a permit required space
  - Entrant

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Atmospheric Hazards

- Need to have atmosphere monitored!!!
  - Explosive or flammable gas or vapor
    - These can develop in the collection system or sewer plant duel to legal, illegal or accidental sources
  - Toxic or suffocating gases
    - Comes from natural breakdown of organic matter in wastewater or toxic discharges
  - Depletion or elimination of breathable oxygen
    - Oxygen deficient atmosphere
    - Minimum oxygen level is 19.5%

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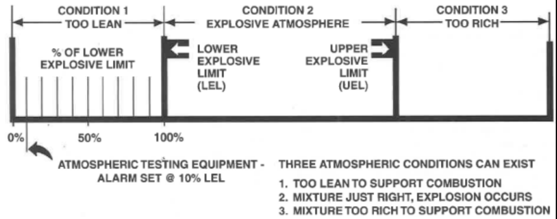
Atmospheric Hazards



- LEL is the lowest concentration of a gas or vapor below which a flame will not spread in the presence of an ignition source
- UEL is the highest concentration above which a flame will not spread due to not enough oxygen (displaced by the flammable gas)

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** Operation and Maintenance of Wastewater Collection Systems Vol. 1, Seventh Edition – Fig. 3.21, Pg 112*

Hydrogen Sulfide – H_2S

- Detected by the smell of rotten eggs
- Loss of ability to detect short exposures
  - Olfactory fatigue
- Not noticeable at high concentrations
- Poisonous, colorless, flammable, explosive and corrosive
- Exposures to 0.07% to 0.1% will cause acute poisoning and paralyze the respiratory center of the body
- At the above levels, death and/or rapid loss of consciousness occur
- S.G. = 1.19
- Alarm set point = 10 ppm (0.001%)

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Hydrogen Sulfide – H_2S

%	PPM	Hazard
46	460,000	Upper Explosive Limit (UEL)
4.3	43,000	Lower Explosive (LEL)
0.1	1,000	DEAD
0.07	700	Rapid loss of consciousness
0.01	100	IDLH
0.005	50	Eye tissue damage
0.002	20	Eye, nose irritant
0.001	10	Alarm set point

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Methane Gas – CH_4

- Product of anaerobic waste decomposition
- Leaks in natural gas pipelines
  - Odorless unless natural gas supplied through pipeline, has mercaptans added, but soil can strip the odor
- Explosive at a concentration of 5% or 50,000 ppm
- Spaces may contain concentrations above the Lower Explosive Limits (LEL) and still have oxygen above the 19.5% allowable
- Colorless, odorless, tasteless
- Acts as an asphyxiant – displaces oxygen
  - Coal miners used canaries as early alarms; if bird died, it was time to get out
- S.G.= 0.55
- Alarm set point is 10% LEL = 5000 ppm

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Methane Gas – CH_4

%	PPM	Hazard
85	850,000	Amount in natural gas
65	650,000	Amount in digester gas
15	150,000	Upper Explosive Limit (UEL)
5	50,000	Lower Explosive Limit (LEL)
0.5	5,000	Alarm set point (10% of LEL)

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Carbon Monoxide - CO

- Decreases amount oxygen present
  - Hazardous because it readily binds with hemoglobin in blood, starving the person's body of oxygen
- ALWAYS VENTILATE
- 0.15% (1500 ppm) → DEAD
- Will cause headaches at 0.02% in two hour period
- Maximum amount that can be tolerated is 0.04% in 60 minute period
- Colorless, odorless, tasteless, flammable and poisonous
- By-product of fuel gas
  - Can be hazard in home if using gas heat or gas appliances
- S. G. = 0.97
- Alarm set point at 35 ppm

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Carbon Monoxide - CO

%	PPM	Hazard
74	740,000	Upper Explosive Limit (UEL)
12.5	125,000	Lower Explosive (LEL)
0.2	2,000	Unconscious in 30 minutes
0.15	1,500	IDLH*
0.05	500	Sever headache
0.02	200	Headache after 2-3 hours
0.0035	35	8-hour exposure limit
0.0035	35	Alarm set point

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*IDLH – Immediately Dangerous to Life or Health

Oxygen – O_2

- ALWAYS ventilate – normal air contains ~ 21%
- Oxygen deficient atmosphere if less than **19.5%**
- Oxygen enriched at greater than **23.5%**
  - Speeds combustion
  - Could be from pure oxygen being used to oxidize hydrogen sulfide
- Leave area if oxygen concentrations approach 22%
- Early warning signs that an operator is not getting enough oxygen:
  - Shortness of breath
  - Chest heaving
  - Change from usual responses

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Oxygen – O_2

%	PPM	Hazard
23.5	235,000	Accelerates combustion
20.9	209,000	Oxygen content of normal air
19.5	195,000	Minimum permissible level
8	8,000	**DEAD** in 6 minutes
6	6,000	Coma in 40 seconds, then **DEAD**

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Oxygen – O_2

- When O_2 levels drop below 16%, a person experiences
  - Rapid fatigue
  - Inability to think clearly
  - Poor coordination
  - Difficulty breathing
  - Ringing in the ears
  - Also, a false sense of well-being may develop

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Oxygen – O_2

- In a confined space, the amount of oxygen in the atmosphere may be reduced by several factors
  - Oxygen consumption
    - During combustion of flammable substances
    - Welding, heating, cutting or even rust formation
  - Oxygen displacement
    - Carbon dioxide can displace oxygen
  - Bacterial action

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Atmospheric Alarm Units

- Continuously sample the atmosphere
- Test atmospheres from manhole areas prior to removing the cover if pick holes available
- Remove manhole covers with non sparking tools
- **Test for oxygen first**
- **Combustible gases second (methane at 5000 ppm)**
  - Atmospheric alarms with a catalytic element are used to test for explosive conditions.

Atmospheric Alarm Units

- Alarms set to read:
  - Flammable gasses exceeding 10% of the LEL
  - H_2S exceeds 10 ppm and/or
  - O_2 percentage drops below 19.5%
  - CO alarm set point is 35 ppm
- Calibrate unit before using
- Most desirable units: simultaneously sample, analyze and alarm all three atmospheric conditions

Atmospheric Alarm Units

- Some physical and environmental conditions that could affect the accuracy of gas detection instruments include:
  - Caustic gases
  - Temperature
  - Dirty air
  - Humidity
  - Air velocity
  - Vibration

Safety Procedures if Explosive Atmosphere Discovered

- Immediately notify supervisor
- Do not remove manhole cover
- Turn off running engines in area
- Route vehicles around area
- Inspect up and downstream of manhole
- Route traffic off the street
- Notify waste and or pretreatment facility
- Cautiously ventilate
- NO SMOKING IN AREA

Ventilation

- Blowers need to be placed upwind of manhole and at least 10 feet from opening
- Gas driven engine – exhaust must be downwind of manhole
- Air intake should be 2-5 feet above ground service

Infectious Disease Hazards

- Many diseases may be transmitted by wastewater: hepatitis A, cholera, bacterial dysentery, polio, typhoid, amoebic dysentery
- Ingestion (splashes); inhalation (aerosols); contact (cuts or burns)
- Wash hands frequently
- Avoid touching face
- Never eat, drink or smoke without first washing hands

Best method of protection is person cleanliness!

Written Entry System

- Employer shall document entry permits
- Entry supervisor sign permits
- Permit posted
- Shall not exceed time required
- Retain permits for at least 1 year

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Information on Permit Forms

- Space to be entered
- Purpose
- Date and authorized duration
- Attendant ID by name
- Authorized entrants ID by name
- Entry supervisor name and signature
- Hazards of permit space
- Measures to eliminate, isolate, or control the hazards
- Results of tests
- Rescue and emergency services
- Communications

56

Information on Equipment

- PPE (personal protective equipment)
- Testing equipment

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Duties Of Entrants

- Know signs, symptoms, and consequence of exposure
- Properly use equipment
- Alert attendant of warning signs, symptoms and other possible hazards
- Exit when ordered to evacuate by supervisor or attendant

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Duties of Confined Space Attendant

- Know signs, symptoms, and consequences of exposure
- Possible behavioral effects of hazards
- Maintain accurate count of entrants
- Remain outside permit space
- Communicate with entrants
- Summon rescue and emergency units

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Duties of Confined Space Attendant

- Warn unauthorized persons to stay away
- Perform non-entry rescue
- Do not perform any duties that may interfere with primary duty: <u>monitoring and protecting entrants</u>

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Duties of Supervisors and Managers

- Knowledge of signs, symptoms, and consequences of exposure
- Verify appropriate entries, procedure, tests and equipment
- Terminate entries and cancel permits if warranted
- Verify means for summoning rescue
- Ensure that acceptable conditions are maintained and operations remain consistent with entry permit

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Required Training

- Employer shall train all employees on hazards, procedures, and skills to perform their jobs safely
- Employees trained before first assigned duty
- Employer shall certify training of employees
- Maintain individual training records of employees

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Record Keeping

- Identification and Evaluation of all Hazardous areas in workplace
- Entrance permits filed
- Training Certification
- Written Confined Space Program

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General Requirements

- Identify, evaluate, and monitor hazards in permit-required confined spaces
- Post signs "Permit Required"
- Prevent unauthorized entries
- Re-evaluate areas
- Inform contractors
- Have a written program available for employees
- Have proper PPE on hand
- Annual Training (TOSHA requirements)

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Confined Space Requirements

- All electrodes removed and machines disconnected from power sources
- Gas supply shut off
- Gas cylinders outside work area
- All employees entering must undergo confined space training
- Ventilation used to keep toxic fumes, gases, and dusts below max levels

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Lockout / Tagout

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LOTO General Requirements

- Written program
- Utilize tagout system if energy isolating device not capable of being locked out
- Lockout/tagout hardware provided
- Devices used only for intended purposes
- Tagout shall warn **DO NOT START, DO NOT ENERGIZE, DO NOT OPERATE**
- Only trained employees shall perform lockout/tagout

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Requirements When Lockout of Equipment

- Before beginning work on any pump, the first thing to be done is to lock it out.
  - The person doing the work should have the ONLY key
- Notify employees
- Employees notified after completion of work and equipment re-energized

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Recommend Steps for Lockout/Tagout

- Notify employees that device locked and tagged out
- Turn off machine normally
- De-activate energy
- Use appropriate lockout/tagout equipment
- Release any stored energy
- Try to start machine by normal means

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Steps for Restoring Equipment

- Check area for equipment or tools
- Notify all employees in the area
- Verify controls are in neutral
- Remove lockout/tagout devices and re-energize device
- Notify employees maintenance and/or repairs are complete and equipment is operationally

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Training Requirements

- Employer shall train all employees
- All new employees trained
- Recognition of applicable hazardous energy
- Purpose of program
- Procedures
- Consequences
- ANNUAL REQUIREMENT

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Inspections

- Conduct periodic inspection at least annually
- Shall include review between the inspector and each authorized employee
- Recommendation: Frequent walk through of work areas and observation of Maintenance and Operation area

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Required Record Keeping

- Written Lockout/Tagout Program
- Training: Annual and New Employees
- Inspections: Annual including new equipment, inspection of devices, and procedures

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Most Frequently Citied Workplace Safety Violations 2015

- Fall protection (1926.501)
- Hazard communication (1910.1200)
- Scaffolding (1926.451)
- Respiratory protection (1910.134)
- Lockout/tagout (1910.14)
- Powered industrial trucks (1910.178)
- Ladders (1926.1053)
- Electrical – wiring methods (1910.305)
- Machine guarding (1910.212)

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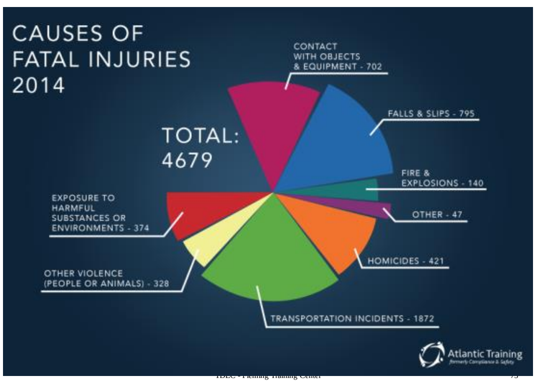
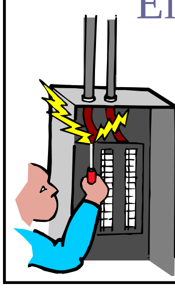


Electrical Safety



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OSHA Says

- Any electrical installations shall be done by a professionally trained electrician.
- Any employee who is in a work area where there is a danger of electric shock shall be trained.
- Employees working on electrical machinery shall be trained in lockout/tagout procedures

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Fire Protection

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Fire Protection Equipment

- Fire extinguishers shall be located where they are readily accessible.
- Shall be fully charged and operable at all times.
  - Charged after each use.
- All fire fighting equipment is to be inspected at least annually.
- Portable fire extinguishers inspected at least monthly and records kept.
- Hydrostatic testing on each extinguisher every five years.
- Fire detection systems tested monthly if batter operated.

Types of Fire Extinguishers

- Class A 
  - Used on combustible materials such as wood, paper or trash
  - Can be water based.
- Class B 
  - Used in areas where there is a presence of a flammable or combustible liquid
  - Shall not be water based
  - Example is dry chemical extinguisher
  - An existing system can be used but not refilled.

Types of Fire Extinguishers

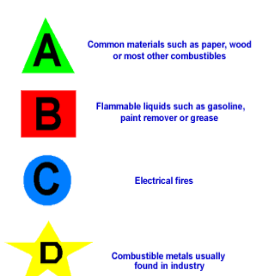
- Class C 
  - Use for areas electrical
  - Best is carbon dioxide extinguisher.
  - Using water to extinguish a class C fire risks electrical shock
- Class D
  - Used in areas with combustible metal hazards
  - Dry powder type
  - Use no other type for this fire.

Types of Fire Extinguishers

Class	Material	Method
A	Wood, paper	Water
B	Flammable liquids (oil, grease, paint)	Carbon dioxide, foam, dry chemical or Halon
C	Live electricity	Carbon dioxide, dry chemical, Halon
D	Metals	Carbon dioxide

Types of Fire Extinguishers

- Combination ABC are most common
- Have the types of extinguishers available depending upon analyses performed in each area



Fire Extinguishers

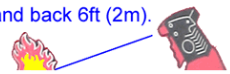
- To operate a fire extinguisher, remember the word PASS
  - **P**ull the pin. Hold the extinguisher with the nozzle pointing away from you
  - **A**im low. Point the extinguisher at the base of the fire.
  - **S**queeze the lever slowly and evenly.
  - **S**weep the nozzle from side-to-side.

Fire Extinguishers

Combo Extinguisher

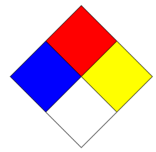
1. Pull pin.
Hold unit upright.

2. Aim at base of fire.
Stand back 6ft (2m).



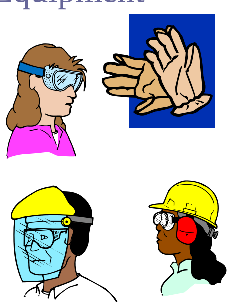
3. Press trigger.
Sweep side to side.

Chemical Safety



Personal Protective Equipment

- Gloves
- Coveralls / Overalls
- Face Shield / Goggles
- Respirator / SCBA
- Boots
- Ear Plugs / Muffs

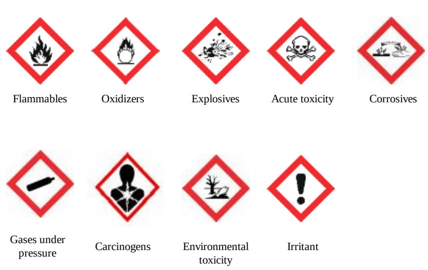


Minimum Info for SDS

- Product identification
- Hazard Identification
- Composition/info on ingredients
- First-aid measures
- Fire-fighting measures
- Accidental release measures
- Handling and storage
- Exposure controls
- Physical/chemical properties
- Stability & reactivity
- Toxicological information
- Ecological information*
- Disposal considerations*
- Transport information*
- Regulatory information*
- Other information (including date of SDS or last revision)*

* Non mandatory

OSHA Pictograms



NFPA

- National Fire Protection Association
- Chemical hazard label
  - Color coded
  - Numerical system
    - Health
    - Flammability
    - Reactivity
  - Special precautions
- Labels are required on all chemicals in the lab

RTK Labels

- "Right to Know"
  - In 1983, OSHA instituted Hazard Communication Standard 1910-1200, a rule that gives employees the right to know the hazards of chemicals to which they may be exposed in the workplace.

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Degrees of Hazard

- Each of the colored areas has a number in it regarding the degree of hazard
  - 4 → extreme
  - 3 → serious
  - 2 → moderate
  - 1 → slight
  - 0 → minimal
- This is opposite of GHS
  - 1 → highest hazard
  - 4 → lowest hazard

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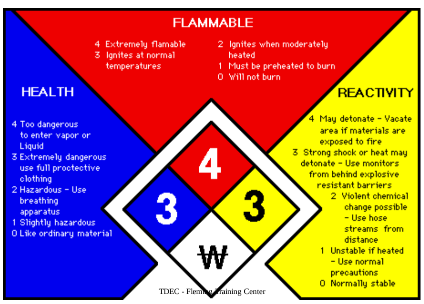
Chemical Label



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Terms

- Lower Explosive Level (LEL) – minimum concentration of flammable gas or vapor in air that supports combustion
- Upper Explosive Limit (UEL) – maximum concentration of flammable gas or vapor in air that will support combustion
- Teratogen – causes structural abnormality following fetal exposure during pregnancy
- Mutagen – capable of altering a cell's genetic makeup

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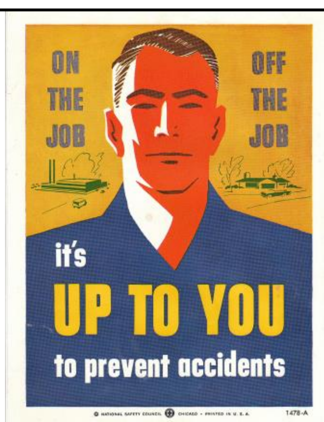

95

OSHA FACT Sheet

Lockout/Tagout

What is the OSHA standard for control of hazardous energy sources?

The OSHA standard for *The Control of Hazardous Energy (Lockout/Tagout), Title 29 Code of Federal Regulations* (*CFR*) Part 1910.147, addresses the practices and procedures necessary to disable machinery or equipment, thereby preventing the release of hazardous energy while employees perform servicing and maintenance activities. The standard outlines measures for controlling hazardous energies—electrical, mechanical, hydraulic, pneumatic, chemical, thermal, and other energy sources.

In addition, *29 CFR* 1910.333 sets forth requirements to protect employees working on electric circuits and equipment. This section requires workers to use safe work practices, including lockout and tagging procedures. These provisions apply when employees are exposed to electrical hazards while working on, near, or with conductors or systems that use electric energy.

Why is controlling hazardous energy sources important?

Employees servicing or maintaining machines or equipment may be exposed to serious physical harm or death if hazardous energy is not properly controlled. Craft workers, machine operators, and laborers are among the 3 million workers who service equipment and face the greatest risk. Compliance with the lockout/tagout standard prevents an estimated 120 fatalities and 50,000 injuries each year. Workers injured on the job from exposure to hazardous energy lose an average of 24 workdays for recuperation.

How can you protect workers?

The lockout/tagout standard establishes the employer's responsibility to protect employees from hazardous energy sources on machines and equipment during service and maintenance.

The standard gives each employer the flexibility to develop an energy control program suited to the needs of the particular workplace and the types of machines and equipment being maintained or serviced. This is generally done by affixing the appropriate lockout or tagout devices to energy-isolating devices and by deenergizing machines and equipment. The standard outlines the steps required to do this.

What do employees need to know?

Employees need to be trained to ensure that they know, understand, and follow the applicable provisions of the hazardous energy control procedures. The training must cover at least three areas: aspects of the employer's energy control program; elements of the energy control procedure relevant to the employee's duties or assignment; and the various requirements of the OSHA standards related to lockout/tagout.

What must employers do to protect employees?

The standards establish requirements that employers must follow when employees are exposed to hazardous energy while servicing and maintaining equipment and machinery. Some of the most critical requirements from these standards are outlined below:

- Develop, implement, and enforce an energy control program.
- Use lockout devices for equipment that can be locked out. Tagout devices may be used in lieu of lockout devices only if the tagout program provides employee protection equivalent to that provided through a lockout program.
- Ensure that new or overhauled equipment is capable of being locked out.
- Develop, implement, and enforce an effective tagout program if machines or equipment are not capable of being locked out.

Lockout/Tagout

- Develop, document, implement, and enforce energy control procedures. [See the note to *29 CFR* 1910.147(c)(4)(i) for an exception to the documentation requirements.]
- Use only lockout/tagout devices authorized for the particular equipment or machinery and ensure that they are durable, standardized, and substantial.
- Ensure that lockout/tagout devices identify the individual users.
- Establish a policy that permits only the employee who applied a lockout/tagout device to remove it. [See *29 CFR* 1910.147(e)(3) for exception.]
- Inspect energy control procedures at least annually.
- Provide effective training as mandated for all employees covered by the standard.
- Comply with the additional energy control provisions in OSHA standards when machines or equipment must be tested or repositioned, when outside contractors work at the site, in group lockout situations, and during shift or personnel changes.

How can you get more information?

OSHA has various publications, standards, technical assistance, and compliance tools to help you, and offers extensive assistance through its many safety and health programs: workplace consultation, voluntary protection programs, grants, strategic partnerships, state plans, training, and education. Guidance such as OSHA's *Safety and Health Management Program Guidelines* identify elements that are critical to the development of a successful safety and health management system. This and other information are available on OSHA's website at **www.osha.gov**.

- For a free copy of OSHA publications, send a self-addressed mailing label to this address: OSHA Publications Office, P.O. Box 37535, Washington, DC 20013-7535; or send a request to our fax at (202) 693-2498, or call us at (202) 693-1888.
- To file a complaint by phone, report an emergency, or get OSHA advice, assistance, or products, contact your nearest OSHA office under the "U.S. Department of Labor" listing in your phone book, or call us toll-free at **(800) 321-OSHA (6742)**. The tele-typewriter (TTY) number is (877) 889-5627.
- To file a complaint online or obtain more information on OSHA federal and state programs, visit OSHA's website.

U.S. Department of Labor
Occupational Safety and Health Administration

Trenching Safety

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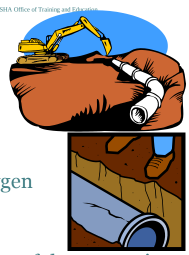
Trenching Safety

- Reduction of injury and illness rates.
- Daily exposure to job hazards by thousands of workers.
- Efficiency can be greatly improved.
- OSHA safety standards require:
  - Establishment of a "Safety" program
  - Training be conducted
  - Job hazards be assessed
  - Hazards and precautions be explained

OSHA Office of Training and Education

Excavation Hazards



- Cave-ins are the greatest risk
- Other hazards include:
  - Asphyxiation due to lack of oxygen
  - Inhalation of toxic materials
  - Fire
  - Moving machinery near the edge of the excavation can cause a collapse
  - Accidental severing of underground utility lines

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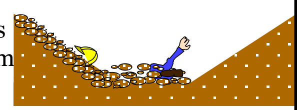
Cave-ins

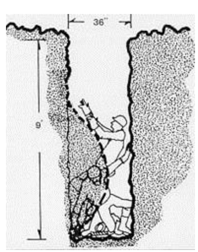
- Hundreds of workers killed annually from cave-ins
- Thousand of workers injured annually from cave-ins
- Fatality rate for trenching is twice the level for general construction



OSHA Office of Training and Education

Injury and Death

- Excavating is one of the most hazardous construction operations
- Most accidents occur in trenches 5-15 feet deep
- There is usually no warning before a cave-in



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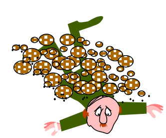
Asphyxiation

- Each time a breath is exhaled the weight of the load restricts inhalation of the next breath.
- Slow suffocation usually follows unless rescue is immediate.



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Cave-ins Result From

- Vibrations
- Adjacent structures
- Freezing and thawing
- Weight of the soil itself
- Addition or removal of water
- Reduction in frictional and cohesive capacities of soil

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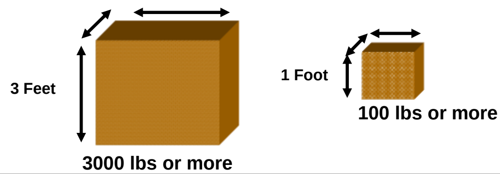
Density and Water Content

- One cubic yard weighs - 3000 lbs or more
- One cubic foot weighs - 100 lbs or more



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How do most deaths occur?

- Instantaneously
- Trenches 5 to 15 feet deep
- With absolutely no warning
- In seemingly safe conditions
- With workers in a bent or lying position

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Before you begin excavation:

- The site must be assessed
- Potential hazards must be determined
- Known hazards reduced or eliminated
- Emergency procedures established
- Periodic inspection intervals determined
- Utility locations must be staked or marked

- Regardless of the equipment used, a sewer trench must be kept as narrow as possible.

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Basic Safety Requirements

- Conduct inspections before each work shift
- Do not travel under elevated loads
- Do not work over unprotected employees
- Wear proper personal protective equipment
- Provide walkways or bridges over trenches

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Basic Safety Requirements

- Provide trench exits within 25 feet of workers in trenches more than four feet deep
  - For every 25 feet of trench there needs to be 1 ladder
- Ensure spoilage is at least 2 ft. from trench edges
- Provide protection for trenches 5 feet or deeper
  - Shores needed
- A registered professional engineer (RPE) must design protective systems for excavations deeper than 20 feet

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Emergency Procedures

- Immediately call 911, or the Emergency Response Team
- Report:
  - Exact Location
  - Number of Victims
  - Nature of Emergency
  - Trench Measurements
  - Special Hazards

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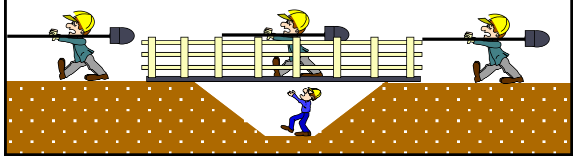
Structural Ramps: Access & Egress

- Used only by people
- Designed by a "competent person"
- Egress required every 25 feet
  - (lateral) ≥ 4ft



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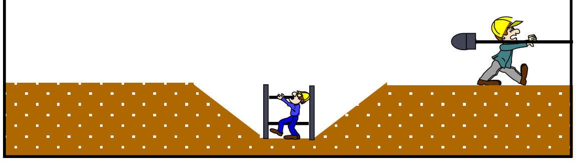
Trench Safety

- Trenches more than 5 feet deep
  - Require shoring
  - Or must have a stabilized slope
- In hazardous soil conditions
  - Trenches under 5 feet need protection



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Hazardous Atmospheres

- Testing and controls
  - Oxygen deficiency
  - Flammable atmospheres
  - Testing
- Emergency rescue equipment
  - Availability
  - Lifelines

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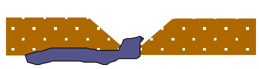
Hazards

- Adequate precautions must be taken when working in accumulated water
- Controlling water and water removal must be monitored by a competent person
- Ditches, dikes or comparable means should be used to prevent surface water from entering excavations



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Weather Factors - Mother Nature

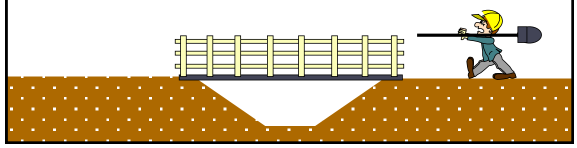
- Don't underestimate the effects weather can have
- Daily (or hourly) site inspections must be made
- Consider protection from:
  - Lightening
  - Flooding
  - Erosion
  - High winds
  - Hot or cold temperatures

Site Inspections

- Daily inspections must be made by a competent person
  - Excavations
  - Adjacent areas
  - Protective systems
- When evidence is found of a hazardous condition, the exposed employees must be immediately removed from the area

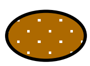
Fall Protection

- Guardrails must be provided for crossing over excavations if the trench is 6 feet or more in depth
- Barriers must be provided for remotely located excavations

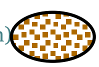


Soil Classification System

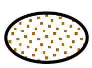
- Type A Soils
  - Clay
  - Silty Clay
  - Sandy Clay
  - Clay Loam



- Type B Soils
  - Granular Cohesionless Soils (Silt Loam)

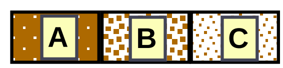


- Type C Soils
  - Gravel
  - Sand
  - Loamy Sand



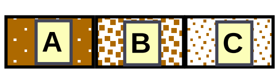
Soil Classification System

- Must be done by a competent person
- Visual test:
  - Check entire worksite
  - Fissured ground
  - Layered soil
  - Disturbed earth
  - Seepage
  - Vibration
  - Poor drainage



Soil Classification System

- Manual test
  - Plasticity
  - Dry strength
  - Thumb penetration
  - Pocket penetrameter
  - Hand operated shear vane



- Warning:
  - One soil inspection and classification may not be enough.
  - Outside disturbances during excavation may change even the best soil classification.
  - Inspect the soil after any change in conditions.

Requirements for Protective Systems

- Each employee must be protected from cave-ins by an adequately designed system.
- Exceptions are:
  - Excavation made in stable rock
  - Excavations less than 5 feet
- Protective systems must have the capacity to resist all loads that are expected to be applied to the system

25

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Materials and Equipment

- Must be free from damage or defects that might impair proper function
- Must be used and maintained in a manner that is consistent with the recommendations of the manufacturer
- Must be examined by a competent person if damage occurs

26

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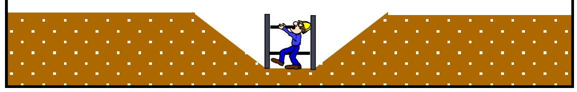
Installation and Removal of Support

- General requirements:
  - Support systems must be securely connected
  - Support systems must be installed and removed in a manner that protects from collapse
  - Support systems must not be subjected to loads exceeding design specifications



27

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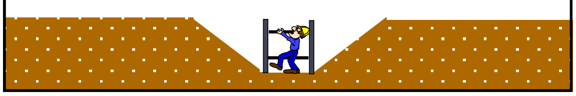
Installation and Removal of Support

- General requirements:
  - Additional precautions must be taken to ensure safety before temporary removal begins
  - Removal must begin at the bottom of the excavation
  - Backfilling must progress together with the removal of support systems from excavations



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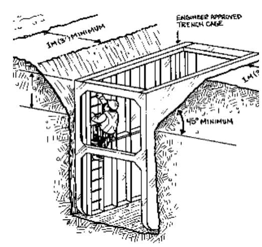
Protect Employees Exposed to Potential Cave-ins

- Slope or bench the sides of the excavation,
- Support the sides of the excavation, or
- Place a shield between the side of the excavation and the work area



29

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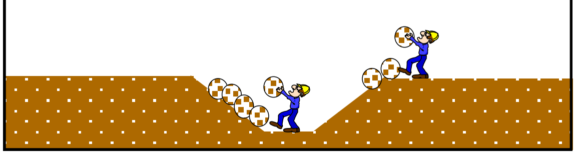
Sloping and Benching Systems

- Employees must not be permitted to work:
  - On the faces of sloped or benched excavations
  - At levels above other employees except when employees at the lower levels are adequately protected from the hazard of falling, rolling or sliding material or equipment



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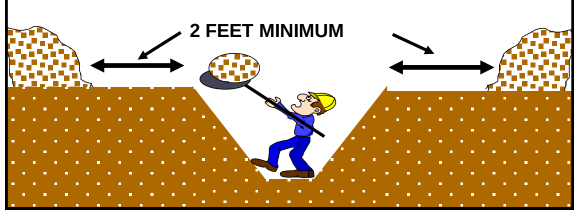
Sloping and Benching Systems

- Temporary spoil piles:



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Spoils

- Don't place spoils within 2 feet from edge of excavation
- Measure from nearest part of the spoil to the excavation edge
- Place spoils so rainwater runs away from the excavation
- Place spoil well away from the excavation

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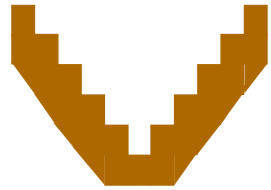
Sloping and Benching Systems

- Benching general requirements
  - Various slope angles are allowed by OSHA
  - Appendix B to 1926 Subpart P must be consulted
  - Evacuate the excavation if walls show signs of distress
  - If soil conditions change, re-inspect



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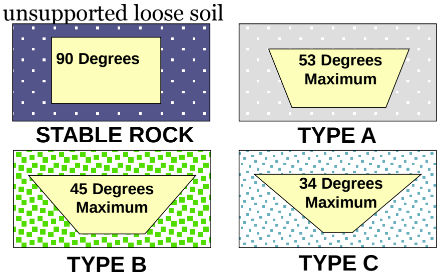
Sloping and Benching Systems

- The angle of repose is the angle of slope of the unsupported loose soil



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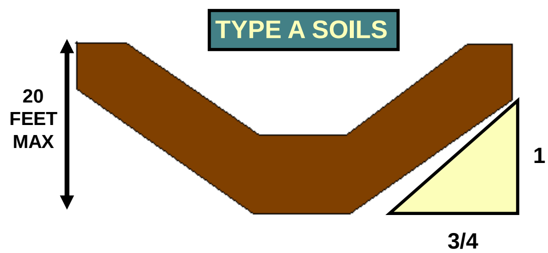
Sloping Example Type A Soils



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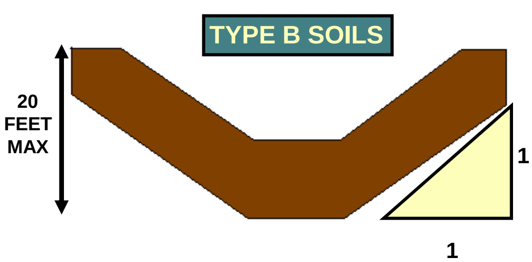
Sloping Example Type B Soils



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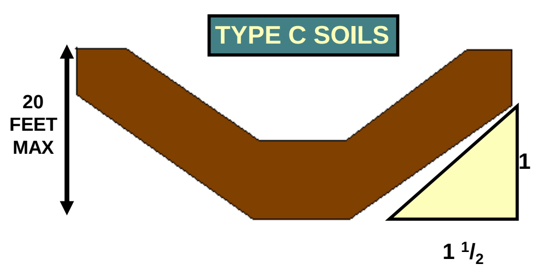
Sloping Example Type C Soils



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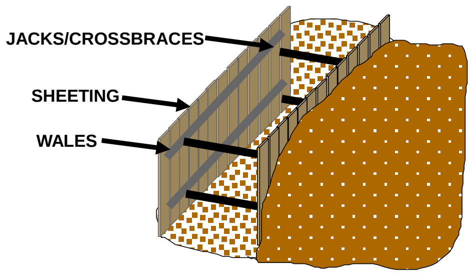
Shoring Systems



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Shoring

- General
  - Provides a framework to work in
  - Uses wales, cross braces and uprights
  - Supports excavation walls
- OSHA tables provide shoring data
  - Must know soil type
  - Must know depth and width of excavation
  - Must be familiar with the OSHA Tables

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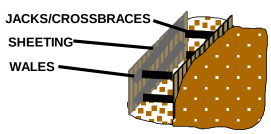
Shoring Systems

- Removal
  - Remove shoring from the bottom up
  - Pull sheeting out from above
  - Backfill immediately after removal of support system



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Hydraulic Trench Support

- Using hydraulic jacks the operator can easily drop the system into the hole
- Once in place, hydraulic pressure is increased to keep the forms in place
- Trench pins are installed in case of hydraulic failure

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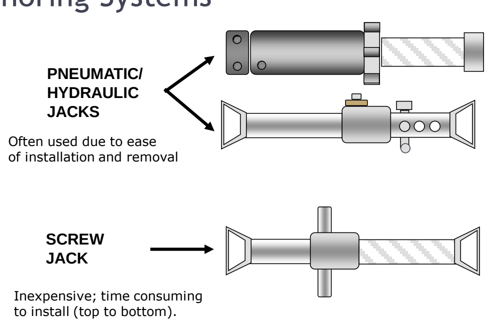
Shoring Systems



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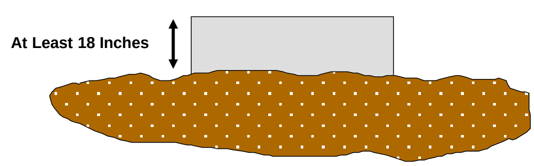
Shield Systems

- General
  - Shield systems must project at least 18 inches above the lowest point where the excavation face begins to slope

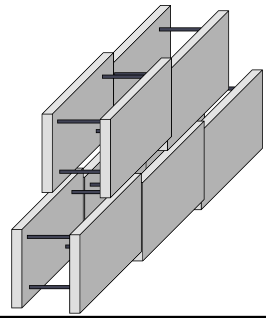


Shield Systems

- General
  - Shield systems must not be subjected to loads exceeding those which the system was designed to withstand
  - Shields must be installed to restrict hazardous movement
  - Employees must be protected from the hazard of cave-ins when entering or exiting the areas protected by shields
  - Employees must not be allowed in shields when shields are being installed, removed, or moved vertically

Shield Systems

- Systems may be connected
- Systems may be stacked
- Configuration must be consistent with the recommendations of the manufacturer
- Must be examined by a competent person if damage occurs

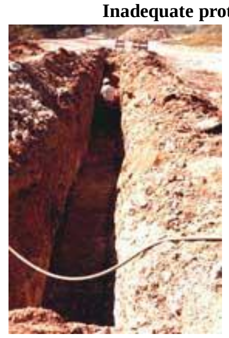


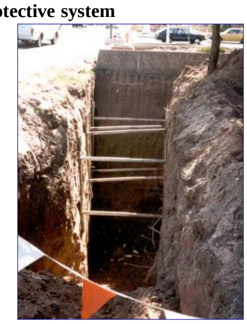
Trench Shield

A trench shield was built around this work area

Cave-in Hazard

Inadequate protective system



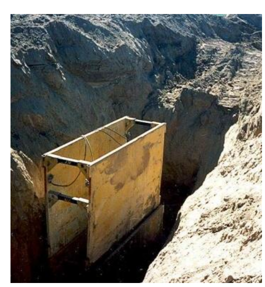


Hazardous Conditions

- The weight and vibrations of the crane make this a very hazardous condition.
- They should not be working under this crane.

Materials and Equipment

- Equipment used for protective systems must not have damage or defects that impair function.
- If equipment is damaged, the competent person must examine it to see if it is suitable for continued use.
- If not suitable, remove it from service until a professional engineer approves it for use.



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Protection from Vehicles

- Install barricades
- Hand/mechanical signals
- Stop logs
- Grade soil away from excavation
- Fence or barricade trenches left overnight

Trenching Summary

- Provide stairways, ladders, ramps or other safe means of access in all trenches **4 feet** or deeper
  - These devices must be located within **25 feet** of all workers
  - Ladders used in trenches shall protrude at least **3 feet** above the trench edge
  - Minimum diameter of rungs on a fixed steel ladder is **¾-inch**
  - Minimum clear length of rungs on a fixed steel ladder is **16 inches**

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Trenching Summary

- Trenches **5 feet** deep or greater require a protective system, which can be shielding, shoring or sloping
  - A registered engineer must approve all shielding and shoring
- Trenches **20 feet** deep or greater require that the protective system be designed by a registered professional engineer
- Keep excavated soil (spoils) and other materials at least **2 feet** from trench edges.
- The support or shield system must extend at least **18 inches** above the top of the vertical side.

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OSHA® FactSheet

Trenching and Excavation Safety

Two workers are killed every month in trench collapses. The employer must provide a workplace free of recognized hazards that may cause serious injury or death. The employer must comply with the trenching and excavation requirements of 29 CFR 1926.651 and 1926.652 or comparable OSHA-approved state plan requirements.

An excavation is any man-made cut, cavity, trench, or depression in an earth surface formed by earth removal.

Trench (Trench excavation) means a narrow excavation (in relation to its length) made below the surface of the ground. In general, the depth is greater than the width, but the width of a trench (measured at the bottom) is not greater than 15 feet (4.6 meters).

Dangers of Trenching and Excavation

Cave-ins pose the greatest risk and are much more likely than other excavation-related accidents to result in worker fatalities. Other potential hazards include falls, falling loads, hazardous atmospheres, and incidents involving mobile equipment. One cubic yard of soil can weigh as much as a car. An unprotected trench is an early grave. Do not enter an unprotected trench.

Trench Safety Measures

Trenches 5 feet (1.5 meters) deep or greater require a protective system unless the excavation is made entirely in stable rock. If less than 5 feet deep, a competent person may determine that a protective system is not required.

Trenches 20 feet (6.1 meters) deep or greater require that the protective system be designed by a registered professional engineer or be based on tabulated data prepared and/or approved by a registered professional engineer in accordance with 1926.652(b) and (c).

Competent Person

OSHA standards require that employers inspect trenches daily and as conditions change by a competent person before worker entry to ensure elimination of excavation hazards. A competent person is an individual who is capable of identifying existing and predictable hazards or working conditions that are hazardous, unsanitary, or dangerous to workers, soil types and protective systems required, and who is authorized to take prompt corrective measures to eliminate these hazards and conditions.

Access and Egress

OSHA standards require safe access and egress to all excavations, including ladders, steps, ramps, or other safe means of exit for employees working in trench excavations 4 feet (1.22 meters) or deeper. These devices must be located within 25 feet (7.6 meters) of all workers.

General Trenching and Excavation Rules

- Keep heavy equipment away from trench edges.
- Identify other sources that might affect trench stability.
- Keep excavated soil (spoils) and other materials at least 2 feet (0.6 meters) from trench edges.
- Know where underground utilities are located before digging.
- Test for atmospheric hazards such as low oxygen, hazardous fumes and toxic gases when > 4 feet deep.
- Inspect trenches at the start of each shift.
- Inspect trenches following a rainstorm or other water intrusion.
- Do not work under suspended or raised loads and materials.
- Inspect trenches after any occurrence that could have changed conditions in the trench.
- Ensure that personnel wear high visibility or other suitable clothing when exposed to vehicular traffic.

Protective Systems

There are different types of protective systems.

Benching means a method of protecting workers from cave-ins by excavating the sides of an excavation to form one or a series of horizontal levels or steps, usually with vertical or near-vertical surfaces between levels. *Benching cannot be done in Type C soil.*

Sloping involves cutting back the trench wall at an angle inclined away from the excavation.

Shoring requires installing aluminum hydraulic or other types of supports to prevent soil movement and cave-ins.

Shielding protects workers by using trench boxes or other types of supports to prevent soil cave-ins. Designing a protective system can be complex because you must consider many factors: soil classification, depth of cut, water content of soil, changes caused by weather or climate, surcharge loads (e.g., spoil, other materials to be used in the trench) and other operations in the vicinity.

Additional Information

Visit OSHA's Safety and Health Topics web page on trenching and excavation at
www.osha.gov/SLTC/trenchingexcavation/index.html
www.osha.gov/dcsp/statestandard.html

This is one in a series of informational fact sheets highlighting OSHA programs, policies or standards. It does not impose any new compliance requirements. For a comprehensive list of compliance requirements of OSHA standards or regulations, refer to Title 29 of the Code of Federal Regulations. This information will be made available to sensory-impaired individuals upon request. The voice phone is (202) 693-1999; teletypewriter (TTY) number: (877) 889-5627.

For assistance, contact us. We can help. It's confidential.

OSHA® **Occupational Safety and Health Administration**

U.S. Department of Labor
www.osha.gov (800) 321-OSHA (6742)

DOC FS-3476 9/2011

OSHA QUICK CARD™

Protect Yourself
Trench Safety

- **Do not enter an unprotected trench!**
- Trench collapses cause dozens of fatalities and hundreds of injuries each year.
- Trenches **5** feet deep or greater require a **protective system**.
- Trenches **20** feet deep or greater require that the protective system be **designed by a registered professional engineer**.

Protective Systems for Trenches

- **Sloping** protects workers by cutting back the trench wall at an angle inclined away from the excavation.
- **Shoring** protects workers by installing aluminum hydraulic or other types of supports to prevent soil movement.
- **Shielding** protects workers by using trench boxes or other types of supports to prevent soil cave-ins.

Competent Person

OSHA standards require that trenches be inspected daily and as conditions change by a competent person prior to worker entry to ensure elimination of excavation hazards.

Safety Tips

- Inspect trenches at the start of each shift, following a rainstorm or after any other hazardous event.
- Test for low oxygen, hazardous fumes and toxic gases before entering a trench.
- Keep heavy equipment and excavation spoils at least two feet away from the trench edge.
- Provide stairways, ladders, ramps or other safe means of access in all trenches 4 feet or deeper.

Think Safety!

For more complete information:

OSHA Occupational Safety and Health Administration
U.S. Department of Labor
www.osha.gov (800) 321-OSHA

OSHA 3197-04N-04

Sewer Safety Vocabulary

______1. Aerobic
______2. Ambient
______3. Anaerobic
______4. Competent Person
______5. Confined Space
______6. Confined Space, Non-Permit
______7. Confined Space, Permit-Required
______8. Decibel
______9. Engulfment
______10. Fit Test
______11. IDLH
______12. Mercaptans
______13. Olfactory Fatigue
______14. Oxygen Deficiency
______15. Oxygen Enrichment
______16. Septic
______17. Sewer Gas
______18. Spoil

A. A condition where atmospheric or dissolved molecular oxygen is not present in the aquatic (water) environment.
B. A unit for expressing the relative intensity of sounds on a scale from zero for the average least perceptible sound to about 130 for the average level where sound causes pain to humans. Abbreviated dB.
C. A space which is large enough and so configured that an employee can bodily enter and perform assigned work; has limited or restricted means for entry or exit and it not designed for continuous employee occupancy.
D. Compounds containing sulfur that have an extremely offensive skunk-like odor; also sometimes described as smelling like garlic or onions.
E. The use of a procedure to qualitatively or quantitatively evaluate the fit of a respirator on an individual.
F. An atmosphere containing oxygen at a concentration of less than 19.5% by volume.
G. A condition where atmospheric or dissolved molecular oxygen is present in the aquatic (water) environment.
H. A condition produced by anaerobic bacteria. If severe, the wastewater produces hydrogen sulfide, turns black, gives off foul odors, contains little or no dissolved oxygen and the wastewater has a high oxygen demand.
I. Immediately Dangerous to Life or Health. The atmospheric concentration of any toxic, corrosive or asphyxiant substance that poses an immediate threat to life or would cause irreversible or delayed adverse health effects or would interfere with an individual's ability to escape from a dangerous atmosphere.
J. Gas in collection lines (sewers) that result from the decomposition of organic matter in the wastewater. When testing for gases found in sewers, test for lack of oxygen and also for explosive and toxic gases.
K. A person capable of identifying existing and predictable hazards in the surroundings, or working conditions that are unsanitary, hazardous or dangerous to employees, and who has authorization to take prompt corrective measures to eliminate the hazards.
L. Excavated material such as soil from the trench of a sewer.

M. The surrounding and effective capture of a person by a liquid or finely divided (flowable) solid substance that can be aspirated to cause death by filling or plugging the respiratory system or that can exert enough force on the body to cause death by strangulation, constriction or crushing.
N. A condition where a person's nose, after exposure to certain odors, is no longer able to detect the odor.
O. A confined space that does not contain or, with respect to atmospheric hazards, have the potential to contain any hazard capable of causing death or serious physical harm.
P. An atmosphere containing oxygen at a concentration of more than 23.5% by volume.
Q. Surrounding. Ambient or surrounding atmosphere.
R. A confined space that has one or more of the following characteristics: contains or has the potential to contain a hazardous atmosphere; contains a material that has the potential for engulfing an entrant; has an internal configuration such that an entrant could be trapped or asphyxiated by inwardly converging walls or by a floor that slopes downward and tapers to a smaller cross section; or contains any other recognized serious safety of health hazard.

Safety Questions

1. How can traffic be warned of your presence in the street?

2. What is the <u>purpose</u> of the advance warning area?

3. List <u>six</u> types of traffic control devices.

4. How can explosive or flammable atmosphere develop in a collection system?

5. What types of hazardous atmospheres should an atmospheric test unit be able to detect in confined spaces?

6. If operators are scheduled to work in a manhole, when should the atmosphere in the manhole be tested?

7. When a blower is used to ventilate a manhole, where should the blower be located?

8. List the safety equipment recommended for use when operators are required to enter a confined space.

9. What are some early signs that an operator working in a manhole or other confined space is not getting enough oxygen?

10. How can collection system operators be protected from injury by the accidental discharge of stored energy?

11. How can collection system operators protect their hearing from loud noises?

12. How would you extinguish a fire?

Answers to Vocabulary and Questions

Vocabulary:

1. G	5. C	9. M	13. N	17. J
2. Q	6. O	10. E	14. F	18. L
3. A	7. R	11. I	15. P	
4. K	8. B	12. D	16. H	

Questions:

1. Traffic can be warned of your presence in a street by signs, flags or flashers and vehicles with rotating flashing lights. Vehicle-mounted traffic guides are also helpful. Flaggers can be used to alert drivers and to direct traffic around a work site.
2. The purpose of the advance warning area is to give drivers enough time to see what is happening ahead and adjust their driving patterns.
3. Types of traffic control devices include: signs, barricades, traffic cones, drums, vertical panels, lighting devices, advance warning arrow boards, flashing vehicle lights, high level warning devices and portable changeable message signs. Flaggers may also be used to control traffic.
4. Explosive or flammable atmospheres can develop at any time in the collection system. Flammable gases or vapors may enter a sewer or manhole from a variety of legal, illegal or accidental sources.
5. An atmospheric test unit should be able to detect flammable and explosive gases, toxic gases and oxygen deficiency.
6. If operators are scheduled to work in a manhole, the atmosphere in the manhole should be tested before anyone enters it, preferably before the cover is even removed, and atmospheric testing should continue for the entire time anyone is working in the manhole.
7. The blower used to ventilate a manhole should be located in an area upwind of the manhole and at least 10 feet from the manhole opening. If the blower has a gas-driven engine, the exhaust must be downwind from the manhole. The air intake to the blower should be 2-5 feet above the ground surface, depending on conditions (higher for dusty conditions).
8. SCBA (self-contained breathing apparatus); safety harness with lifeline, tripod and winch; portable atmospheric alarm unit; ventilation blower with hose; manhole enclosure (if entering a manhole); ladder or tripod with winch; ropes and buckets; hard hats; protective clothing; cones and barricades; firs-aid kit; soap, water, paper towels and a trash bag
9. The early warning signs that an operator is not getting enough oxygen include: labored breathing (shortness of breath), chest heaving and change from usual responses
10. Operators can be protected from injury due to the accidental discharge of stored energy by following prescribed lockout/ tagout procedures.
11. Collection system operators can protect their hearing from loud noises by use of approved earplugs, earmuffs and/or person protective equipment.
12. To extinguish a fire, first identify the material burning (class or category) and then use the appropriate method to put out the fire.

Section 14

Cross Connection Control

Cross-Connection Control

TN Department of Environment & Conservation

Outline

- Case studies of backflow incidents
- Basics of Cross-Connection Control
- Hydraulics
- Definitions
- Backflow Preventers
- Applications

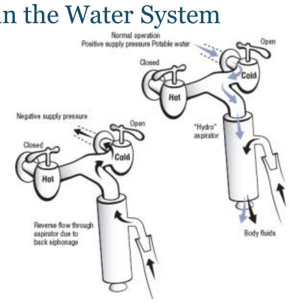
Backflow Case Study

Human Blood in the Water System

Blood observed in drinking fountains at a funeral home

Hydraulic aspirator used to drain body fluids during embalming

Contamination caused by low water pressure while aspirator was in use



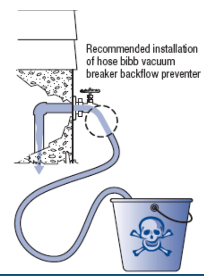
Backflow Case Study

Kool-Aid Laced with Chlordane

Exterminator submerged garden hoses in small buckets while mixing insecticide at the same time a water meter was being installed nearby

During a new water meter installation chlordane was backsiphoned into water lines and became mixed with Kool-Aid

A dozen children and three adults became sick



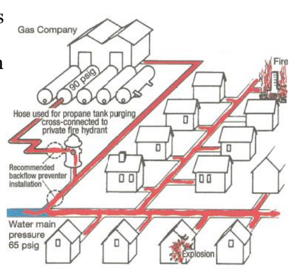
Backflow Case Study

Propane Gas in the Water Mains

Gas company initiated repairs on 30,000 gallon liquid propane tank by flushing with fire hydrant

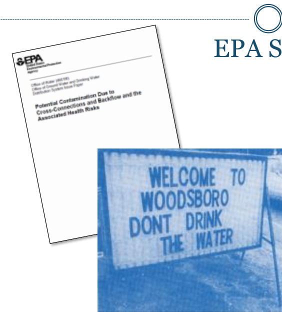
Vapor pressure of propane residual in the tank exceeded water main pressure

Hundreds evacuated, two homes caught fire, water supply contaminated



Backflow Case Study

EPA Study



EPA compiled backflow incident data from 1970 to 2001 and found:

459 incidents resulted in **12,093** illnesses

Backflow incidents can result in property damage, personal injury, and even death

Authority

- Federal
  - Federal Safe Drinking Water Act
- State
  - Tennessee Safe Drinking Water Act
  - Statute
  - Regulation
- Local
  - Ordinance (City) or Policy (Utility)
  - Plumbing Code
  - Cross Connection Control Plan

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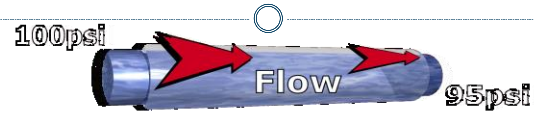
Hydraulics and Pressure



- Water can flow through a pipe in either direction
- The direction of flow will depend on the forces (pressures) acting on the water
- Water pressure naturally tends to equalize
- Therefore, water flows down a gradient from high pressure regions to low pressure regions

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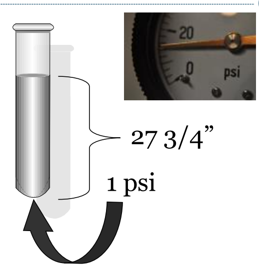
Head Pressure



27 ¾" = 2.31 Feet of Head

- 27 3/4" of water generates a pressure of one pound per square inch (psi)
- The pressure on the bottom of the container is generated by the weight of the water above it

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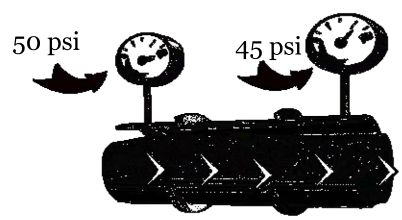
Normal Flow



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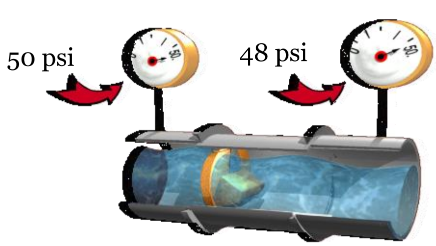
No Flow



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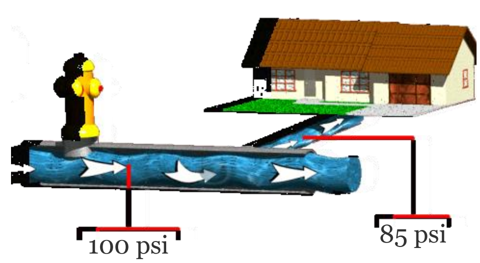
Normal Flow



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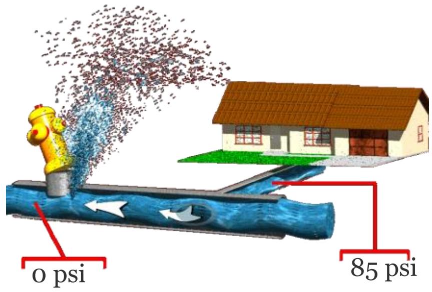
Reverse Flow - Backflow

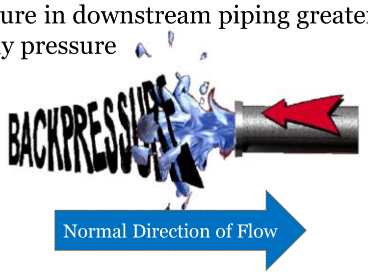


Backflow

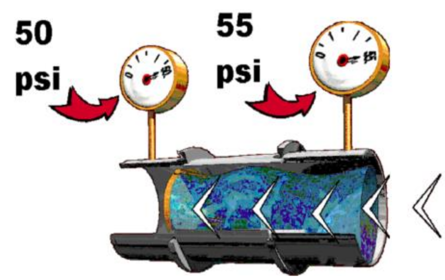
- The undesirable reversal of flow of water or other substances into the potable water distribution supply
- Occurs due to:
  - Backpressure
  - Backsiphonage

Backpressure

- Pressure in downstream piping greater than supply pressure

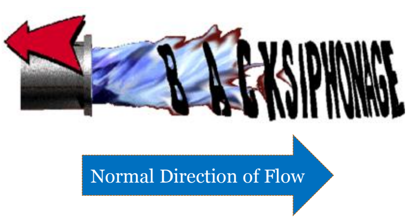


Backpressure



Backsiphonage

- Sub-atmospheric pressure in the water system



Backsiphonage

What is drawn into the water pipes if backsiphonage occurs?

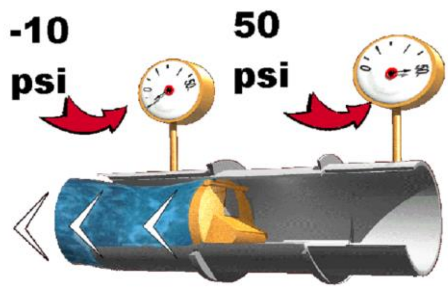
- As backsiphonage occurs air will be drawn up into the water pipes

Backsiphonage

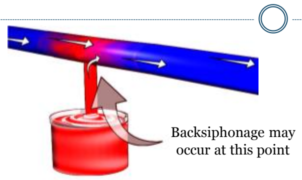
What is drawn into the water pipes if backsiphonage occurs?

- Whatever is in the barrel…

Backsiphonage



Aspirator Effect



- As water flows through a pipe, the pressure against the walls of the pipe decreases as the speed of the water increases
- If a second pipe is attached there could be a low pressure area created at the point of connection which could siphon water from the attached pipe into the flowing pipe - Backsiphonage

Cross-Connection

- An actual or potential connection between a potable water supply and any non-potable substance or source
- Cross-connection types:
  - Direct
  - Indirect

Direct Cross-Connection

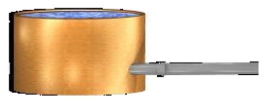
- A direct cross-connection is subject to backpressure or backsiphonage

Indirect Cross-Connection

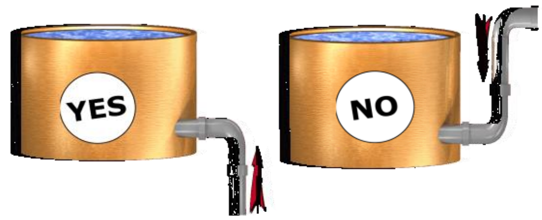
- An indirect cross-connection is subject to backsiphonage only

Submerged Inlet

Indirect Cross Connection

Submerged Inlet	Low Inlet
	

Low Inlet



Direct Cross Connection?

Degree of Hazard

- Non-Health Hazard
  - Low hazard
  - Will not cause illness or death
  - **Pollutant**

- Health Hazard
  - High hazard
  - Causes illness or death
  - **Contaminant**

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The Backflow Incident

For backflow to occur three conditions must be met:

1. There must be a cross-connection. A passage must exist between the potable water system and another source.
2. A hazard must exist in this other source to which the potable water is connected.
3. The hydraulic condition of either backsiphonage or backpressure must occur.

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Five Means of Preventing Backflow

- Air Gap Separation (AG) **Best Method**
- Reduced Pressure Principle Assembly (RPZ/RPBP/RP) **Best Device**
- Double Check Valve Assembly (DCVA)
- Pressure Vacuum Breaker (PVB)/ Spill-Resistant Vacuum Breaker
- Atmospheric Vacuum Breaker (AVB)

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Air Gap

- An air gap is the vertical separation between the water supply line outlet and the overflow rim of the non-pressurized receiving fixture or tank

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Air Gap

2 X ID,
not <1 inch

- An air gap is the *BEST* method of protection against backflow
- Approved air gap separation must have a vertical unobstructed distance of at least twice the internal diameter of the outlet pipe, but never less than 1 inch

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Air Gap Separation Limitations

- The air gap is the best method of backflow prevention, but it is easily defeated through modifications or being bypassed
- The air gap separation causes a loss of pressure in the system
- Sanitary control is lost - cannot be installed in an environment containing airborne contamination

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Approved Air Gap Separation

Backflow Protection Against:

- Backsiphonage
- Backpressure
- Contaminant (health hazard)
- Pollutant (non-health hazard)

BEST METHOD OF PROTECTION

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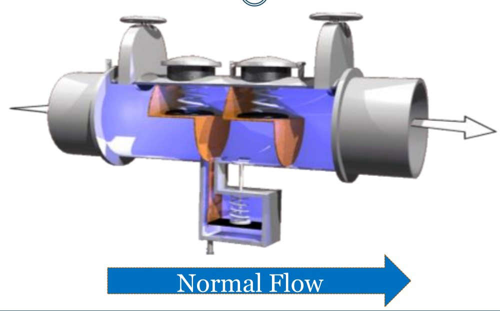
Reduced Pressure Principle Assembly



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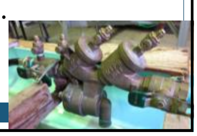
Reduced Pressure Principle Assembly

- The reduced pressure principle backflow prevention assembly (RP) consists of two independently operating check valves together with a hydraulically operating, mechanically independent, pressure differential relief valve located between the check valves, all located between two resilient seated shutoff valves and four properly located test cocks.
- *BEST* device to protect against backflow



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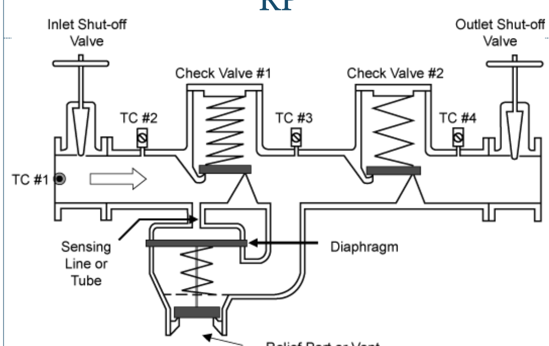
RP



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RP

- The two check valves loaded in the closed position mechanically keep the water flowing in one direction through the assembly
- The relief valve assembly is designed to maintain a lower pressure in the zone between the two checks than in the supply side of the unit which hydraulically keeps the water flowing in one direction through the assembly
  - Water always flows from high pressure to low pressure

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RP

<u>Backflow Protection Against</u>:

- Backsiphonage
- Backpressure
- Contaminant (health hazard)
- Pollutant (non-health hazard)

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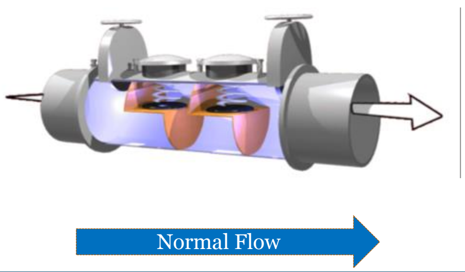
Double Check Valve Assembly (DC)



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Double Check Valve Assembly (DC)

- The double check valve backflow prevention assembly (DC) consists of two independently operating check valves installed between two tightly closing resilient seated shutoff valves and fitted with four properly located test cocks
- Similar to the RP, but has no relief port so it cannot maintain a lower pressure in the zone between the checks and nowhere for the water to go during a backflow incident or failure

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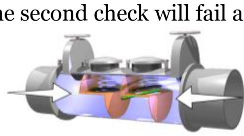
Double Check Valve Assembly (DC)

- Since the water in a DC cannot leave the system during a backflow event or assembly failure then it is a higher risk and therefore cannot be used in a high hazard (contaminant) application
- If one check fails the other will continue to protect, but given enough time the second check will fail and backflow will occur



Second check fouled during backpressure

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Double Check Valve Assembly (DC)

<u>Backflow Protection Against</u>:

- Backsiphonage
- Backpressure
- Pollutant <u>only</u>

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Proper Installation for DC and RP

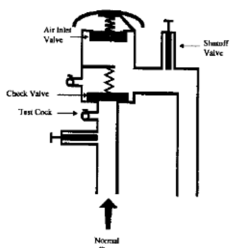
- Lowest part of the relief valve should be a minimum of 12 inches above either: the ground, the top of the opening of the enclosure wall, or the maximum flood level
  - Whichever is highest, in order to prevent any part of the assembly from becoming submerged
- Maximum 60" above grade to the center line of assembly, if higher then safe permanent access must be provided for testing and servicing

* Tennessee Cross-Connection Control Manual and Design Criteria for Cross-Connection Control Plans, Ordinances, and Policies (2008) – Appendix B

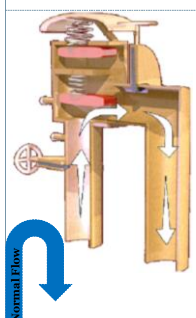
Proper Installation for DC and RP

- Assemblies should be installed in accordance with manufacturer's installations otherwise it voids the approval for the assembly
- Protected from vandalism and weather (if needed)
- RP requires adequate drainage – ***cannot*** be installed in a pit or meter box
- Must be accessible for testing and repair

Pressure Vacuum Breaker (PVB)

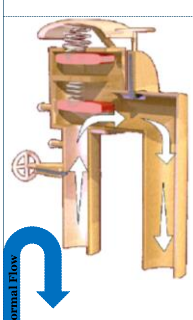


Pressure Vacuum Breaker (PVB)



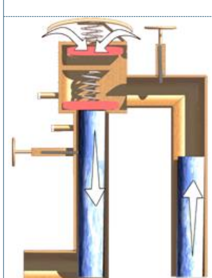
- The pressure vacuum breaker or spill resistant vacuum breaker consists of an independently operating check valve loaded in the closed position and an independently operating air inlet valve loaded in the open position and located on the discharge side of the check valve, with tightly closing shutoff valves on each side of the check valves, and properly located test cocks for valve testing

Pressure Vacuum Breaker (PVB)



- Incoming water pressure will compress the spring on the check and flow into the body
- As pressure builds up in the body it will compress the spring on the air valve and close it allowing water to travel downstream

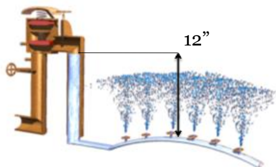
PVB Backsiphonage Condition



- In a backsiphonage condition there is a loss of supply pressure and the check valve is forced closed
- If the body loses pressure the air inlet valve is forced open allowing air into the body of the pressure vacuum breaker and breaking any siphon
- Only to be used to protect against backsiphonage

Installation of PVB

- PVB is not designed to protect against backpressure and cannot have any source of backpressure (including head pressure) downstream of the device
- Needs to be installed **12 inches** above the highest point downstream



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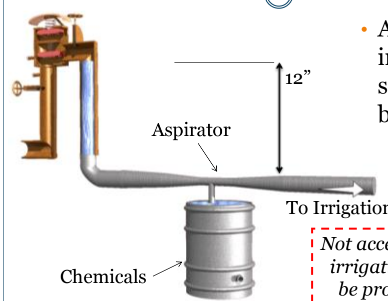
Pressure Vacuum Breaker



- Acceptable installation not subject to backpressure

Not acceptable in TN – all irrigation systems must be protected by an RP

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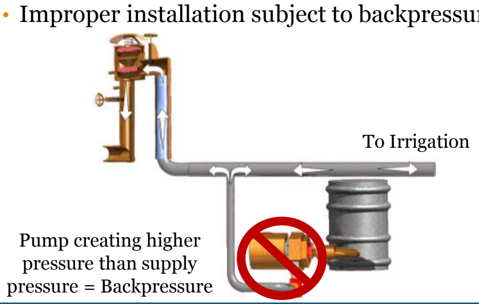
Pressure Vacuum Breaker

- Improper installation subject to backpressure



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Pressure Vacuum Breaker

Backflow Protection Against:

- Backsiphonage Only
- Contaminant (health hazard)
- Pollutant (non-health hazard)
- Elevation - at least 12” above downstream piping

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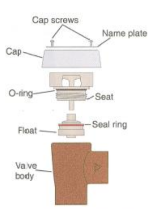
Atmospheric Vacuum Breaker (AVB)



Atmospheric Vacuum Breaker Exploded View

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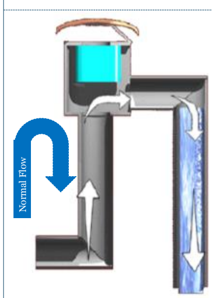
Atmospheric Vacuum Breaker (AVB)



- The atmospheric vacuum breaker is a device designed to prevent backsiphonage. It consists of a body, a single moving float that acts as a check valve when there is no flow and as a air-inlet valve when flow is present, and an air-inlet opening covered by a cap

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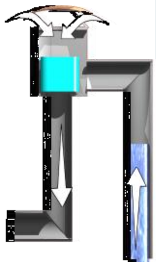
Atmospheric Vacuum Breaker (AVB)

- During a backsiphonage condition the float drops by gravity due to the loss of incoming pressure which automatically opens the air inlet, introducing air into the system to break any siphon that has formed



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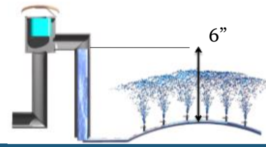
Installation of AVB

- AVB is not designed to protect against backpressure and cannot have any source of backpressure (including head pressure) downstream of the device
- Needs to be installed **6 inches** above the highest point downstream



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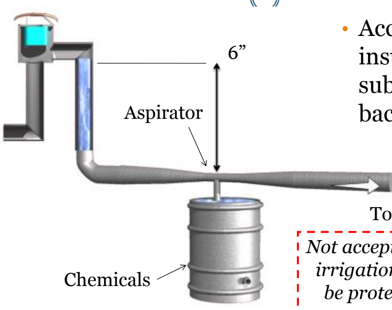
Atmospheric Vacuum Breaker



- Acceptable installation not subject to backpressure

Not acceptable in TN – all irrigation systems must be protected by an RP

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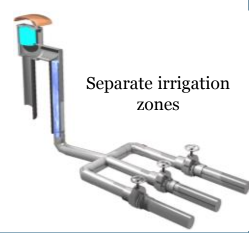
Atmospheric Vacuum Breaker

- Improper installation: downstream shutoff valves
- Shutoff valves downstream of an AVB can cause a continuous use situation
- The float of an AVB subjected to continuous use could begin to adhere to the air inlet and allow backflow



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Atmospheric Vacuum Breaker

Backflow Protection Against:

- Backsiphonage Only
- Contaminant (health hazard)
- Pollutant (non-health hazard)
- Elevation - at least 6”
- Non-Continuous Use

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	Indirect		Direct
	Backsiphonage Only		Backpressure and Backsiphonage
	Continuous Use	Non-Continuous Use	
Health Hazard	Air Gap	Air Gap	Air Gap
	RP	RP	RP
	PVB	PVB	
		AVB	
Non – Health Hazard	Air Gap	Air Gap	Air Gap
	RP	RP	RP
	DC	DC	DC
	PVB	PVB	
		AVB	

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Testing of Assemblies

- Assemblies must be tested when installed, after repair, and at least annually
- Assembly testing must be conducted by certified personnel
- TDEC issues a certification for all assembly testers
- Backflow tester certification courses are offered through the Fleming Training Center

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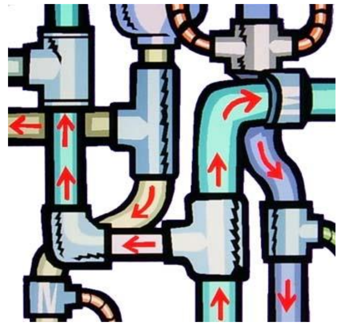


Vocabulary

Absolute Pressure – The total pressure; gauge pressure plus atmospheric pressure. Absolute pressure is generally measured in pounds per square inch (psi).

Air Gap – A physical separation between the free flowing discharge end of a potable water supply line and an open or non-pressurized receiving vessel. An air gap acts as a physical, unobstructed separation between the water distribution system and the wastewater collections system. An "approved air gap" must be twice the internal diameter of the supply pipe measured vertically above the overflow rim of the receiving vessel, but never less than 1 inch.

The air gap is the most effective method for preventing backflow.

Air Inlet – The opening in the body of a device (usually a vacuum breaker) which will allow free atmosphere into the liquid passageway of the device body, which will prevent downstream siphoning. (backsiphonage) -

Approved Backflow Prevention Assembly – An assembly that has been evaluated/tested and approved according to the authority having jurisdiction for use within the water system.

Aspirator Effect – The hydraulic effect of suction created by an aspirator or restricted area of flow. At this restricted area of flow the pressure drops to sub-atmospheric, creating suction. The effect can be increased with the use of a Venturi apparatus.

Atmospheric Pressure – The pressure exerted by the weight of the atmosphere (14.7 psi at sea level). As the elevation above sea increases, the atmospheric pressure decreases.

Atmospheric Vacuum Breaker (AVB) – A non-testable backflow device consisting of a body, a checking member (float), and an atmospheric opening. An AVB protects against backsiphonage only, not backpressure.

Auxiliary Water Supply – Any water supply on or available to the premises other than water supplied by the public water purveyor. These waters may be polluted or contaminated and constitute an unacceptable water source over which the water purveyor does not have sanitary control.

Backflow – The undesirable reversal of flow of contaminated water, other liquids or gases into the distribution system of a potable water supply.

Backflow Prevention Device (Backflow Preventer) – Any device, method or construction used to prevent the backward flow of liquids into a potable water supply.

Backpressure (Superior Pressure) – The hydraulic condition of increased pressure in a system above the supply pressure which results in backflow into the potable water supply.

Backsiphonage – The hydraulic condition resulting in backflow due to a reduction in system pressure, which causes a sub-atmospheric pressure (vacuum) to exist in the water system.

Bypass – Any arrangement of pipes, plumbing or hoses designed to divert the flow around an installed backflow device or assembly through which the flow normally passes.

Check Valve – A mechanical device designed to allow flow in one direction only.

Containment – A water purveyor's backflow prevention policy of installing a backflow prevention device commensurate with the degree of hazard after the termination of the distribution system (water meter) and prior to any branches in the system.

Contaminant – Any substance introduced into the public water system that will cause illness or death. (high hazard)

Continuous Pressure – A condition in which upstream pressure is applied for more than 12 hours in a 24-hour period to a device or assembly. Continuous pressure can cause mechanical parts within a device to freeze.

Cross Connection – Any physical arrangement whereby a public water system is connected, directly or indirectly, with any other water supply system, sewer, drain, conduit, pool, storage reservoir, plumbing fixture or other device which contains or may contain contaminated water, sewage, or other waste or liquid of unknown or unsafe quality which may be capable of contaminating the public water supply as a result of backflow.

Cross Connection Control – The use of assemblies, methods and procedures to prevent contamination of a potable water supply through cross connections.

Degree of Hazard – The danger posed by a particular substance or set of circumstances. Generally, a low degree of hazard (pollutant) is one that does not affect health, but may be aesthetically objectionable. A high degree of hazard (contaminant) is one that could cause serious illness or death.

Differential Pressure – The relative difference in pressure between two pressure sources.

Direct Cross-Connection – A continuous, enclosed interconnection to allow the flow of fluid from ones system to the other. A direct cross connection is subject to both backsiphonage and backpressure.

Distribution System – A system of conduits (pipes, laterals, fixtures) by which a potable water supply is distributed to consumers.

Double Check Detector Assembly – A specially designed assembly composed of line size approved double check valve assembly, with a bypass containing a water meter and approved double check valve assembly specifically designed for such application. The meter shall register accurately for very low rates of flow up to 2 gallons per minute and shall show a registration for all rates of flow. This assembly shall only be used to protect against non-health hazards and is designed primarily for uses on fire sprinkler systems.

Double Check Valve Assembly – A backflow prevention assembly consisting of two independently acting internally loaded check valves, four properly located test cocks, and two shutoff valves. Used to protect against non-health hazards (pollutants) only.

Dual Check – An untestable backflow prevention device consisting of two independently operating check valves, without any test cocks or shut-off valves.

Failed – The status of a backflow prevention assembly determined by a performance evaluation based on the failure to meet all minimums set forth by the approved testing procedure.

Feed Water – Water that is added to a commercial or industrial system and subsequently used by the system, such as water that is fed to a boiler to produce steam.

Flood-Level Rim – The top edge of a receptor from which water overflows.

Gauge Pressure – Pounds per square inch (psi) that are registered on a test gauge. Gauge pressure measures only the amount of pressure above (or below) atmospheric pressure.

Indirect Cross-Connection – A potential cross connection where the interconnection is not continuously enclosed and is subject to backsiphonage only.

Isolation – A water purveyor's backflow prevention policy of installing a backflow prevention device commensurate with the degree of hazard at each fixture or appliance outlet.

Liability – Legally responsible for or being obligated by law for the protection of the potable water supply.

Negative Pressure – Pressure that is less than atmospheric; negative pressure in a pipe can induce a partial vacuum that can siphon nonpotable liquids into the potable distribution system.

Nonpotable – Any liquid that is not considered safe for human consumption.

Parallel Installation (Dual Installation) – The installation of two or more backflow prevention assemblies of the same type having a common inlet, outlet, and direction of flow.

Passed – The status of a backflow prevention assembly determined by a performance evaluation in which the assembly meets all minimums set forth by the approved testing procedure.

Pathogen – A disease producing organism, such as a virus, bacterium, or other microorganism. Associated with high hazard (contaminant) conditions.

Performance Evaluation – An evaluation of an approved backflow prevention assembly using the latest approved testing procedures in determining the status of the assembly.

Plumbing – Any arrangement of pipes, fittings, fixtures or other devices for the purpose of moving liquids from one point to another, generally within a single structure.

Poison – A substance that can kill, injure or impair a living organism.

Pollutant – A substance that would constitute a non-health hazard and would be aesthetically objectionable if introduced into the potable water system.

Potable – Water (or other liquids) that are safe for human consumption.

Pressure – The weight (of air, water, etc.) exerted on a surface, generally expressed as pounds per square inch (psi).

Pressure Vacuum Breaker (PVB) – A backflow prevention assembly consisting of one or two independently operating spring loaded check valves and an independently operating spring loaded air inlet valve located on the discharge side of the check valve(s), with properly located test cocks, and tightly closing shutoff valves on each side of the check valves. A PVB is testable and protects against backsiphonage only, not backpressure.

Reduced Pressure Principle Assembly (RP) – A backflow prevention assembly consisting of two independently operating spring-loaded check valves together with a hydraulically operating, mechanically independent, pressure differential relief valve located between the check valves and below the first check valve. These units shall be located between two tightly closing shutoff valves with four properly located test cocks.

The RP is the best device for preventing backflow.

Reduced Pressure Principle Detector Assembly – A specially designed assembly composed of a line size approved reduced pressure principle backflow prevention assembly with a bypass containing a water meter and an approved reduced pressure principle backflow prevention assembly specifically designed for such application. The meter shall register accurately for very low flow rates of flows up to 2 gallons per minute and shall show registration of all flow rates. This assembly shall only be used to protect against non-health and health hazards and is designed primarily for uses on fire sprinkler systems.

Refusal of Service (Shutoff Policy) – A formal policy adopted by a governing board to enable a utility to refuse or discontinue service where a known hazard exists and corrective measures are not undertaken.

Regulating Agency – Any local, state or federal authority given the power to issue rules or regulations having the force of law for the purpose of providing uniformity in details and procedures.

Relief Valve – A device designed to release air from a pipeline, or introduce air into a line if the internal pressure drops below atmospheric pressure.

Submerged Inlet – The discharge of a piping system that is located below the flood level rim of a tank or vessel. This can result in an indirect cross connection with a potable drinking water supply.

Test Cock – An appurtenance on a device or valve used for testing the device.

Venturi – A specifically designed hydraulic structure designed to increase the velocity and thus decrease the pressure of a fluid through a constricted region creating suction.

Venturi Effect – A hydraulic principle that states that as the flow path is restricted, a fluid will exhibit a greater velocity and a reduced system pressure through the restriction. The Venturi effect can induce a vacuum in a distribution system.

Waterborne Disease – Any disease that is capable of being transmitted through water. Examples include typhoid, cholera, giardiasis.

Water Purveyor – An organization that is engaged in producing and/or distributing potable water for domestic use.

Cross-Connections Examples and Potential Hazards

Connected System	Hazard Level
Sewage pumps	High
Boilers	High
Cooling towers	High
Flush valve toilets	High
Garden hose (sil cocks)	Low to high
Auxiliary water supply	Low to high
Aspirators	High
Dishwashers	Moderate
Car wash	Moderate to high
Photographic developers	Moderate to high
Commercial food processors	Low to moderate
Sinks	High
Chlorinators	High
Solar energy systems	Low to high
Sterilizers	High
Sprinkler systems	High
Water systems	Low to high
Swimming pools	Moderate
Plating vats	High
Laboratory glassware or washing equipment	High
Pump primers	Moderate to high
Baptismal founts	Moderate
Access hole flush	High
Agricultural pesticide mixing tanks	High
Irrigation systems	Low to high
Watering troughs	Moderate
Autopsy tables	High

Cross Connection Vocabulary Review

______1. Air Gap
______2. Atmospheric Vacuum Breaker
______3. Auxiliary Supply
______4. Backflow
______5. Backpressure
______6. Backsiphonage
______7. Check Valve
______8. Cross Connection
______9. Feed Water
______10. Pollutant
______11. Overflow Rim
______12. Pressure Vacuum Breaker
______13. Reduced Pressure Principle Assembly
______14. Water Purveyor
______15. Differential Pressure

A. A valve designed to open in the direction of normal flow and close with the reversal of flow.
B. A hydraulic condition, caused by a difference in pressures, in which non-potable water or other fluids flow into a potable water system.
C. The test kit gauge measures this on the backflow prevention assemblies.
D. In plumbing, the unobstructed vertical distance through the free atmosphere between the lowest opening from any pipe or outlet supplying water to a tank, plumbing fixture or other container, and the overflow rim of that container.
E. A backflow condition in which the pressure in the distribution system is less than atmospheric pressure.
F. A substance that would constitute a non-health hazard and would be aesthetically objectionable if introduced into the potable water system.
G. A mechanical device consisting of two independently operating, spring-loaded check valves with a reduced pressure zone with relief valve between the check valves.
H. Any water source or system, other than potable water supply, that may be available in the building or premises.
I. Water that is added to a commercial or industrial system and subsequently used by the system, such as water that is fed to a boiler to produce steam.
J. A device designed to prevent backsiphonage, consisting of one or two independently operating spring-loaded check valves and an independently operating spring –loaded air-inlet valve.
K. A backflow condition in which a pump, elevated tank, boiler or other means results in a pressure greater than the supply pressure.
L. A physical arrangement that connects the potable water supply with any other non-potable water supply.
M. The top edge of an open receptacle over which water will flow.
N. A mechanical device consisting of a float check valve and an air-inlet port designed to prevent backsiphonage.
O. An organization that is engaged in producing and/or distributing potable water for domestic use.

Cross-Connections Review Questions

1. Define a cross-connection.

2. Explain what is meant by backsiphonage and backpressure.

3. List four situations that can cause negative pressure in a potable water supply.
   -
   -
   -
   -

4. List six waterborne diseases that are known to have occurred as a result of cross-connections.

   •
   •
   •
   •
   •
   •

5. What is the most reliable backflow-prevention method?

6. Is a single check valve position protection against backflow? Why or why not?

7. How often should a reduced-pressure-zone backflow preventer be tested?

8. In what position should an atmospheric vacuum breaker be installed relative to a shutoff valve? Why?

9. How does a vacuum breaker prevent backsiphonage?

10. List seven elements that are essential to implement and operate a cross-connection control program successfully?

-
-
-
-
-
-
-

Vocabulary Answers:

1. D
2. N
3. H
4. B
5. K
6. E
7. A
8. L
9. I
10. F
11. M
12. J
13. G
14. O
15. C

Review Question Answers:

1. A cross-connection is any connection or structural arrangement between a potable water system and a nonpotable system through which backflow can occur.
2. Backsiphonage is a condition in which the pressure in the distribution system is less than atmospheric pressure. In more common terms, there is a partial vacuum on the potable system.
   Backpressure is a condition in which a substance is forced into a water system because that substance is under a higher pressure than system pressure.
3.
   - fire demand
   - a broken water main or exceptionally heavy water use at a lower elevation than the cross-connection
   - a booster pump used on a system
   - undersized piping
4.
   - typhoid fever
   - dysentery and gastroenteritis
   - salmonellosis
   - polio
   - hepatitis
   - brucellosis

5. The most reliable backflow prevention method is an air gap.
6. A single check valve is not considered positive protection against backflow. A check valve can easily be held partially open by debris, corrosion products or scale deposits.
7. Reduced-pressure-zone backflow preventers should be tested at least annually.
8. An atmospheric vacuum breaker must be installed downstream from the last shutoff valve. If it is placed where there will be continuing backpressure, the valve will be forced to remain open, even under backflow conditions.
9. When water stops flowing forward, a check valve drops, closing the water inlet and opening an atmospheric vent. This lets water in the breaker body drain out, breaking the partial vacuum in that part of the system.
10.
    - an adequate cross-connection control ordinance
    - an adequate organization with authority
    - a systematic surveillance program
    - follow-up procedures for compliance
    - provisions for backflow-prevention device approvals, inspection and maintenance
    - public awareness and information programs

Section 15

Math Review

Math Problem Strategies

Use these rules of operation to approach math problems (*especially when working with formulas*):

1) Work from left to right.
2) Do all the work inside the parentheses first.
3) Do all the multiplication/division above the line (numerator) and below the line (denominator).
4) Then do all the addition and subtraction above and below the line.
5) Perform the division (divided the numerator by the denominator).

Strategy for solving word problems:

1) Read the problem, disregard the numbers (What type of problem is it? What am I asked to find?)
2) Refer to the diagram, if provided. If there isn't one, draw your own.
3) What information do I need to solve the problem, and how is it given in the statement of the problem?
4) Work it out.
5) Does it make sense?

It might be helpful to write out everything that is known in one column and the unknown (what am I asked to find?) in another column. Identify the correct formula and write it in the middle, plug in the numbers and solve.

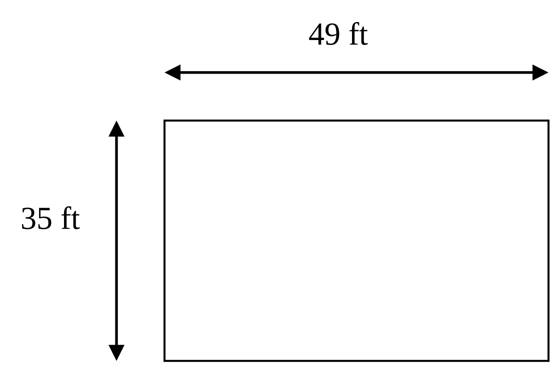
Known **Unknown**

Length = 35 ft
Width = 49 ft

Area = ?

A = (l)(w)

A = (35 ft)(49 ft)
A = 1715 ft^2

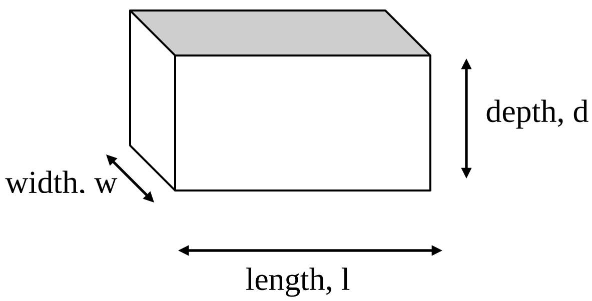


***Remember: make sure measurements agree; if diameter of pipe is in inches then change to feet; if flow is in MGD and you need feet or feet/sec then change to ft^3/sec before you plug values into formula.**

mega (M)	..	kilo (k)	hecto (h)	deka (da)	no prefix	deci (d)	centi (c)	milli (m)	..	micro (μ)
1,000,000		1,000	100	10	1	$^{1}/_{10}$	$^{1}/_{100}$	$^{1}/_{1,000}$		$^{1}/_{1,000,000}$

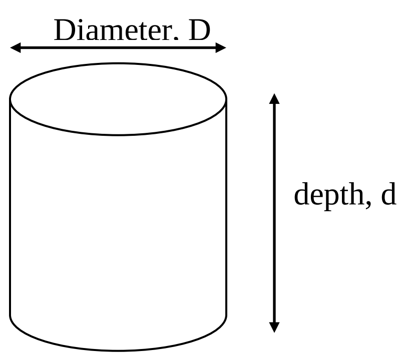
Tank Volume Calculations: Most tank volumes calculations are for tanks that are either rectangular or cylindrical in shape.

Rectangular Tank



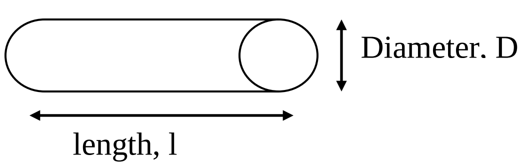
Volume = (l)(w)(d)

Cylindrical Tank



Volume = (0.785) (D)^2 (d)

Portion of a Pipeline



Volume = (0.785) (D)^2 (l)

Basic Math Concepts

For Water and Wastewater Plant Operators
by Joanne Kirkpatrick Price

Suggested Strategy

- Disregarding all numbers, what type of problem is it?
- What diagram, if any, is associated with the concept identified?
- What information is required to solve the problem and how is it expressed in the problem?
- What is the final answer?
- Does the answer make sense?

Solving for the Unknown Value (X)

Solving for X

- Solve for X

$$(4)(1.5)(x) = 1100$$

  - X must be by itself on one side of equal sign
    - 4 and 1.5 must be moved away from X

$$x = \frac{1100}{(4)(1.5)}$$

$$x = 183.3$$

    - How was this accomplished?

Movement of Terms

- To understand how we move the numbers, we will need to consider more closely the math concepts associated with moving the terms.
- An equation is a mathematical statement in which the terms or calculation on one side equals the terms or calculation on the other side.

Movement of Terms

- To preserve this equality, anything done to one side of the equation must be done to the other side as well.

$$3x = 14$$

- Since X is multiplied by 3, you can get rid of the 3 by using the opposite process: division.

Movement of Terms

- To preserve the equation, you must divide the other side of the equation as well.

$$\frac{3x}{3} = \frac{14}{3}$$

$$x = \frac{14}{3}$$

- Since both sides of the equation are divided by the same number, the value of the equation remains unchanged.

Example 1

$$730 = \frac{x}{3847}$$

What you do to one side of the equation, must be done to the other side.

$$730 = \frac{x}{3847} \times \frac{3847}{1}$$

$$\frac{3847}{1} \times 730 = \frac{x}{3847} \times \frac{3847}{1}$$

$$3847 \times 730 = x$$

$$2{,}808{,}310 = x$$

Example 2

$$0.5 = \frac{(165)(3)(8.34)}{x}$$

Simplify

$$0.5 = \frac{4128.3}{x}$$

What you do to one side of the equation, must be done to the other side.

$$0.5 = \frac{4128.3}{x} \times \frac{x}{1}$$

$$\frac{x}{1} \times 0.5 = \frac{4128.3}{x} \times \frac{x}{1}$$

$$(x)(0.5) = 4128.3$$

$$\frac{(x)(0.5)}{0.5} = \frac{4128.3}{0.5}$$

$$x = \frac{4128.3}{0.5}$$

$$x = 8256.6$$

Solving for X when squared

- Follow same procedure as solving for X
- Then take the square root

$$x^2 = 15{,}625$$

$$\sqrt{x^2} = \sqrt{15{,}625}$$

$$x = 125$$

Example 3

$$(0.785)(x^2) = 2826$$

$$\frac{(0.785)(x^2)}{0.785} = \frac{2826}{0.785}$$

$$x^2 = \frac{2826}{0.785}$$

$$x^2 = 3600$$

$$\sqrt{x^2} = \sqrt{3600}$$

$$x = 60$$

Fractions and Percents

Converting Decimals and Fractions

- To convert a fraction to a decimal
  - Simply divide the numerator by the denominator

$$\frac{1}{2} = 1 \div 2 = 0.5$$

$$\frac{10}{13} = 10 \div 13 = 0.7692$$

Percents and Decimals

- To convert from a decimal to a percent
  - Simply move the decimal point two places to the right

0.46. ⟶ 46.0%

- To convert from a percent to a decimal
  - Simply move the decimal two points to the left

.79.5% ⟶ 0.795

- Remember:

You CANNOT have a percent in an equation!!

Writing Equations

- Key words
  - **Of** means "multiply"
  - **Is** means "equal to"
- Calculate 25% of 595,000

$$25\% \times 595{,}000$$

$$0.25 \times 595{,}000$$

$$148{,}750$$

Example 5

448 is what percent of 560?

$$448 = x\% \times 560$$

$$\frac{448}{560} = \frac{x\% \times 560}{560}$$

$$0.80 = x\%$$

$$80\% = x$$

Solving for the Unknown

Basics – finding x

1. $8.1 = (3)(x)(1.5)$

2. $(0.785)(0.33)(0.33)(x) = 0.49$

3. $\frac{233}{x} = 44$

4. $940 = \frac{x}{(0.785)(90)(90)}$

5. $x = \frac{(165)(3)(8.34)}{0.5}$

6. $56.5 = \frac{3800}{(x)(8.34)}$

7. $114 = \frac{(230)(1.15)(8.34)}{(0.785)(70)(70)(x)}$

8. $2 = \frac{x}{180}$

9. $46 = \frac{(105)(x)(8.34)}{(0.785)(100)(100)(4)}$

10. $2.4 = \frac{(0.785)(5)(5)(4)(7.48)}{x}$

11. $19{,}747 = (20)(12)(x)(7.48)$

12. $\frac{(15)(12)(1.25)(7.48)}{x} = 337$

13. $\frac{x}{(4.5)(8.34)} = 213$

14. $\frac{x}{246} = 2.4$

15. $6 = \frac{(x)(0.18)(8.34)}{(65)(1.3)(8.34)}$

16. $\frac{(3000)(3.6)(8.34)}{(0.785)(x)} = 23.4$

17. $109 = \frac{x}{(0.785)(80)(80)}$

18. $(x)(3.7)(8.34) = 3620$

19. $2.5 = \frac{1{,}270{,}000}{x}$

20. $0.59 = \frac{(170)(2.42)(8.34)}{(1980)(x)(8.34)}$

Finding x^2

21. $(0.785)(D^2) = 5024$

22. $(x^2)(10)(7.48) = 10{,}771.2$

23. $51 = \frac{64{,}000}{(0.785)(D^2)}$

24. $(0.785)(D^2) = 0.54$

25. $2.1 = \frac{(0.785)(D^2)(15)(7.48)}{(0.785)(80)(80)}$

Percent Practice Problems

Convert the following fractions to decimals:

1. $\frac{3}{4}$
2. $\frac{5}{8}$
3. $\frac{1}{4}$
4. $\frac{1}{2}$

Convert the following percents to decimals:

5. 35%
6. 99%
7. 0.5%
8. 30.6%

Convert the following decimals to percents:

9. 0.65
10. 0.125
11. 1.0
12. 0.05

Calculate the following:

13. 15% of 125
14. 22% of 450
15. 473 is what % of 2365?
16. 1.3 is what % of 6.5?

Answers for Solving for the Unknown

Basics – Finding x

1.	1.8	8.	360	15.	2817
2.	5.7	9.	1649	16.	4903
3.	5.3	10.	244.7	17.	547,616
4.	5,976,990	11.	11	18.	117
5.	8256.6	12.	5	19.	508,000
6.	8.1	13.	7994	20.	0.35
7.	0.005	14.	590.4		

Finding x^2

21.	80	23.	40	25.	10.9
22.	12	24.	0.83		

Percent Practice Problems

1.	0.75	7.	0.005	13.	18.75
2.	0.625	8.	0.306	14.	99
3.	0.25	9.	65%	15.	20%
4.	0.5	10.	12.5%	16.	20%
5.	0.35	11.	100%		
6.	0.99	12.	5%		

DIMENSIONAL ANALYSIS

MATHEMATICS MANUAL FOR WATER AND WASTEWATER TREATMENT PLANT OPERATORS
BY FRANK R. SPELLMAN

DIMENSIONAL ANALYSIS

- Used to check if a problem is set up correctly
- Work with the units of measure, not the numbers
- Step 1:
  - Express fraction in a vertical format

$$gal/ft^3 \text{ to } \frac{gal}{ft^3}$$

- Step 2:
  - Be able to divide a fraction

$$\frac{\frac{lb}{day}}{\frac{min}{day}} \text{ becomes } \frac{lb}{day} \times \frac{day}{min}$$

DIMENSIONAL ANALYSIS

- Step 3:
  - Know how to divide terms in the numerator and denominator
  - Like terms can cancel each other out
    - For every term that is canceled in the numerator, a similar term must be canceled in the denominator

$$\frac{lb}{\cancel{day}} \times \frac{\cancel{day}}{min} =$$

- Units with exponents should be written in expanded form

$$ft^3 = (ft)(ft)(ft)$$

EXAMPLE 1

- Convert 1800 ft^3 into gallons.
- We need the conversion factor that connects the two units
- This is a ratio, so it can be written two different ways
- We want to use the version that allows us to cancel out units

EXAMPLE 1

$$\left(\frac{1800\ ft^3}{1}\right)$$

- Will anything cancel out?

NO

- Let's try the other version
- Will anything cancel out?

YES

Metric System & Temperature

For Water and Wastewater Plant Operators
by Joanne Kirkpatrick Price

Metric Units

Primary Unit

mega	....	kilo	hecto	deka	no prefix	deci	centi	milli	....	micro
(M)		(k)	(h)	(da)		(d)	(c)	(m)		(μ)
1,000,000		1,000	100	10	1	$^1/_{10}$	$^1/_{100}$	$^1/_{1,000}$		$^1/_{1,000,000}$

↓

meter – linear measurement
liter – volume measurement
gram – weight measurement

King Henry Died By Drinking Chocolate Milk

Metric Units

Kilo	Hecto	Deca	Basic Unit	Deci	Centi	Milli
King	Henry	Died	By	Drinking	Chocolate	Milk
1000X larger	100X larger	10X larger	Meter Liter Gram ***1 unit***	10X smaller	100X smaller	1000X smaller

MULTIPLY numbers by 10 if you are getting smaller →

← **DIVIDE** number by 10 if you are getting bigger

Problem 1

- Convert 2500 milliliters to liters

Primary Unit

kilo	hecto	deka	no prefix	deci	centi	milli
(k)	(h)	(da)		(d)	(c)	(m)

- Converting milliliters to liters requires a move of three place values to the left
- Therefore, move the decimal point 3 places to the left

2 5 0 0. =
3 2 1

Problem 2

- Convert 0.75 km into cm

Primary Unit

kilo	hecto	deka	no prefix	deci	centi	milli
(k)	(h)	(da)		(d)	(c)	(m)
1,000	100	10	1	$^1/_{10}$	$^1/_{100}$	$^1/_{1,000}$

- From kilometers to centimeters there is a move of 5 value places to the right

0. 7 5 =
1 2 3 4 5

General Conversions

1. 325 ft^3 = gal

2. 2512 kg = lb

3. 2.5 miles = ft

4. 1500 hp = kW

5. 2.2 ac-ft = gal

6. 2100 ft^2 = ac

7. 92.6 ft^3 = lb

8. 17,260 ft^3 = MG

9. 0.6% = mg/L

10. 30 gal = ft^3

11. A screening pit must have a capacity of 400 ft^3. How many lbs is this?

12. A reservoir contains 50 ac-ft of water. How many gallons of water does it contain?

13. 3.6 cfs = gpm

14. 1820 gpm = gpd

15. 45 gps = cfs

16. 8.6 MGD= gpm

17. 2.92 MGD = lb/min

18. 385 cfm = gpd

19. 1,662 gpm = lb/day

20. 3.77 cfs = MGD

21. The flow through a pipeline is 8.4 cfs. What is the flow in gpd?

22. A treatment plant receives a flow of 6.31 MGD. What is the flow in cfm?

Basic Conversions Extra Problems

1. How many seconds are in a minute?

2. How many minutes are in an hour?

3. How many hours in a day?

4. How many minutes in a day?

5. How many inches in a foot?

6. How many feet in a mile?

7. How many feet in a meter?

8. How many meters in a mile?

9. How much does one gallon of water weigh?

10. How much does one cubic foot of water weigh?

11. Express a flow of 5 cfs in terms of gpm.

12. What is 38 gps expressed as gpd?

13. What is 0.7 cfs expressed as gpd?

14. What is 9164 gpm expressed as cfs?

15. What is 1.2 cfs expressed as MGD?

16. Convert 65 gpm into lbs/day.

17. Convert 345 lbs/day into gpm.

18. Convert 0.9 MGD to cfm.

19. Convert 1.2 MGD to ft^3/hour.

20. Convert a flow of 4,270,000 gpd to cfm.

21. What is 5.6 MGD expressed as cfs?

22. Express 423,690 cfd as gpm.

23. Convert 2730 gpm to gpd.

24. Convert 1440 gpm to MGD.

25. Convert 45 gps to ft^3/day.

Volume and Flow Conversions

1. 2,431 gal
2. 5,533 lb
3. 13,200 ft
4. 1,119 kW
5. 717,200 gal
6. 0.05 ac
7. 5,778.24 lb
8. 0.13 MG
9. 6,000 mg/L
10. 4.01 ft^3
11. 24,960 lb
12. 16,300,000 gal
13. 1,615.68 gal/min
14. 2,620,800 gal/day
15. 6.02 ft^3/sec
16. 5,968.4 gpm
17. 16,911.67 lb/min
18. 4,146,912 gal/day
19. 19,959,955.2 lb/day
20. 2.43 MGD
21. 5,428,684.8 gal/day
22. 585.82 ft^3/min

Basic Conversions Extra Problems

1. 60 sec
2. 60 min
3. 24 hr
4. 1440 min
5. 12 in
6. 5280 ft
7. 3.28 ft
8. 1610 m
9. 8.34 lbs
10. 62.4 lbs
11. 2244 gpm
12. 3,283,200 gpd
13. 452,390 gpd
14. 20.42 cfs
15. 0.78 MGD
16. 780,624 lbs/day
17. 0.03 gpm
18. 83.56 ft^3/min
19. 6684.49 ft^3/hr
20. 396.43 ft^3/min
21. 8.67 cfs
22. 2200.83 gpm
23. 3,931,200 gpd
24. 2.07 MGD
25. 519,786.10 ft^3/day

LINEAR MEASUREMENT
CIRCUMFERENCE & PERIMETER

Basic Math Concepts for Water and Wastewater Plant Operators
by Joanne Kirkpatrick Price

Suggested Strategy to Solving Word Problems

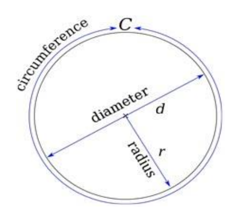
- Disregarding all numbers, what type of problem is it?
- What diagram is associated with the concept identified? If there is not one provided draw one yourself.
- What information is required to solve the problem and how is it expressed in the problem?
- What is the final answer?
- Does the answer make sense?

Linear Measurement

- Linear measurement is simply the measurement along a line and expressed in units of length (ft, m, in, yd, mi, km)
- Many collections system calculations require tank or channel dimensions, pipe lengths and diameters, traffic control zone measurements
- One particular type of length measurement is the distance around the outside edge of an area or object – the perimeter and circumference

Parts of a Circle

- Diameter is the distance across the center of circle
- Radius is the distance from circle's center to the edge and is half of the diameter
- Circumference is the distance around a circle or a circular object



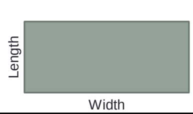
Circumference & Perimeter

- Circumference of a Circle

$$Circumference = (3.14)(Diameter)$$

- Perimeter is obtained by adding the lengths of the four sides of a square or rectangle

$$Perimeter = 2(length) + 2(width)$$



Example 1

- Find the circumference in inches of a 6 inch diameter pipe.

$$Circumference = (3.14)(diameter)$$
$$C = (3.14)(6\ inches)$$
$$C = 18.85\ inches$$

- Find the perimeter of a trench that is 15 ft by 22 ft.

$$Perimeter = 2(length) + 2(width)$$
$$P = 2(15\ ft) + 2(22\ ft)$$
$$P = 30\ ft + 44\ ft$$
$$P = 74\ ft$$

To add the units must be the same

AREA

Area

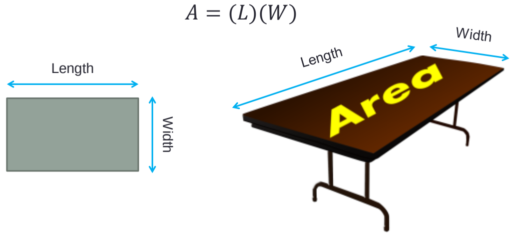
- Area is the measurement of the amount of space on the surface of an object
- Two dimensional measurement
- Measured in: in^2, ft^2, m^2, acres, etc.

Area

- Area of Rectangle

$$Area = (length)(width)$$

$$A = (L)(W)$$



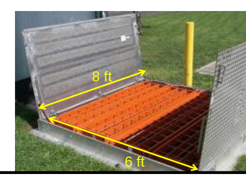
Example 1

- Find the area in ft^2 of a rectangular access hatch door that is 8 feet long and 6 feet wide.

$$A = (L)(W)$$

$$A = (8ft)(6ft)$$

$$A = 48ft^2$$

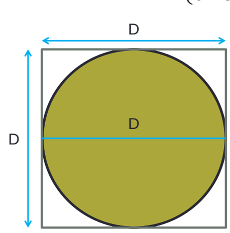


Area

- Area of Circle

$$Area = (0.785)\ (Diameter)^2$$

$$A = (0.785)(D)^2$$



The circle takes up 78.5% of a square

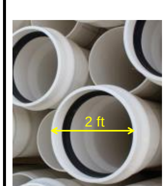
Example 2

- Find the area of the cross section of a pipe in ft^2 that has a diameter of 2 feet.

$$Area = (0.785)(D)^2$$

$$A = (0.785)(2ft)(2ft)$$

$$A = 3.14\ ft^2$$

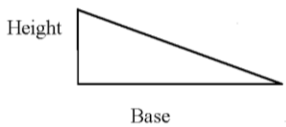


Area

- Area of Right Triangle

$$Area = \frac{(base)(height)}{2}$$

$$A = \frac{(b)(h)}{2}$$

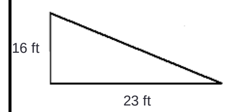


Example 3

- Determine the area in ft² of a right triangle where the base is 23 feet long with a height of 16 feet.

$$A = \frac{(b)(h)}{2}$$

$$A = \frac{(23ft)(16ft)}{2}$$



$$A = \frac{368ft^2}{2}$$

$$A = 184ft^2$$

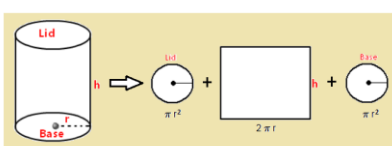
Area

- Area of Cylinder (total exterior surface area)

$$Area = [End\ \#1\ SA] + [End\ \#2\ SA] + [(3.14)(D)(h)]$$

$$Where\ SA = surface\ area$$

$$A = A_1 + A_2 + [(3.14)(D)(h)]$$



Example 4

- Find the total surface area in ft² of a drum that is 2 ft in diameter and 4 ft tall.

$$A = A_1 + A_2 + [(3.14)(D)(h)]$$

$$A_1 = (0.785)(D)^2$$

$$A_1 = (0.785)(2ft)(2ft)$$

$$A_1 = 3.14ft^2 \qquad A_1 = A_2$$

$$A = 3.14ft^2 + 3.14ft^2 + [(3.14)(2ft)(4ft)]$$

$$A = 3.14ft^2 + 3.14ft^2 + 25.12ft^2$$

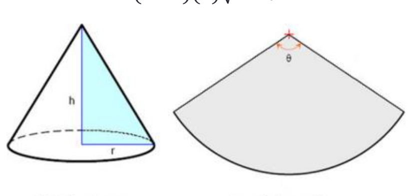
$$A = 31.40\ ft^2$$

Area

- Area of Cone (lateral area)

$$Area = (3.14)(radius)\sqrt{radius^2 + height^2}$$

$$A = (3.14)(r)\sqrt{r^2 + h^2}$$



Example 5

- Find the lateral area (in²) of a conical funnel that is 7 inches tall and has a radius of 9 inches.

$$A = (3.14)(r)\sqrt{r^2 + h^2}$$

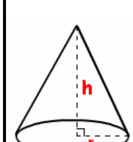
$$A = (3.14)(9in)\sqrt{(9in)(9in) + (7in)(7in)}$$

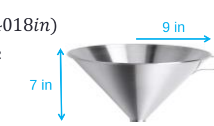
$$A = (3.14)(9in)\sqrt{81in^2 + 49in^2}$$

$$A = (3.14)(9in)\sqrt{130in^2}$$

$$A = (3.14)(9in)(11.4018in)$$

$$A = 322.21in^2$$



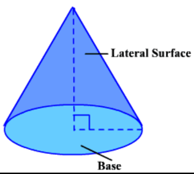


Area

- Area of Cone (total surface area)

$$Area = (3.14)(radius)(radius + \sqrt{radius^2 + height^2})$$

$$A = (3.14)(r)(r + \sqrt{r^2 + h^2})$$



Example 6

- Find the total surface area in ft^2 of a cone that is 4.5 feet deep with a diameter of 6 feet.

$$A = (3.14)(r)(r + \sqrt{r^2 + h^2})$$

$$A = (3.14)(3ft)(3ft + \sqrt{(3ft)(3ft) + (4.5ft)(4.5ft)})$$

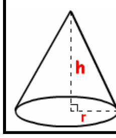
$$A = (3.14)(3ft)(3ft + \sqrt{9ft^2 + 20.25ft^2})$$

$$A = (3.14)(3ft)(3ft + \sqrt{29.25ft^2})$$

$$A = (3.14)(3ft)(3ft + 5.4083ft)$$

$$A = (3.14)(3ft)(8.4083ft)$$

$$A = 79.21ft^2$$



Radius = (1/2)D
r = (1/2)(6ft)
r = 3ft

VOLUME

Volume

- Volume is the capacity of a unit or how much it will hold
- General types of collection systems volume calculations are:
  - Tank Volume
  - Channel or Pipeline Volume
  - Pit, Trench or Pond Volume

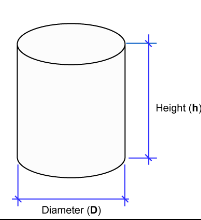
Volume

- Volume calculations are measured in:
  - cubic units (ft^3, m^3, yd^3)
  - liquid volume units (gallons, liters, MG)
- Calculated volumes will always be in cubic units and must be converted to liquid measurement units if they are desired

Volume of a Cylinder

$$Volume = (0.785)(Diameter^2)(height)$$

$$Vol = (0.785)(D^2)(h)$$



Example 1

- Determine the volume in ft^3 for a tank that is 20 feet long with a diameter of 7.5 ft.

$$Vol = (0.785)(D)^2(h)$$

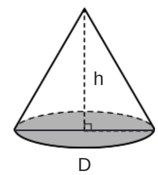
$$Vol = (0.785)(7.5ft)(7.5ft)(20ft)$$

$$Vol = 883.13\ ft^3$$

Volume of a Cone

$$Volume = (^1/_3)(0.785)(Diameter^2)(height)$$

$$Vol = (^1/_3)(0.785)(D^2)(h)$$



Example 2

- Determine the volume in gallons of a conical tank that is 8 feet wide and 15 feet tall.

$$Vol = (^1/_3)(0.785)(D^2)(h)$$

$$Vol = (^1/_3)(0.785)(8ft)(8ft)(15ft)$$

$$Vol = (0.3333)(753.6\ ft^3)$$

$$Vol = 251.1749\ ft^3$$ ← *Not done yet!*

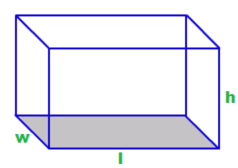
$$Vol, gal = (251.1749\ \cancel{ft^3})(7.48\ \frac{gal}{\cancel{ft^3}})$$

$$Vol, gal = 1878.79\ gallons$$

Volume of a Rectangle

$$Volume = (length)(width)(height)$$

$$Vol = (l)(w)(h)$$



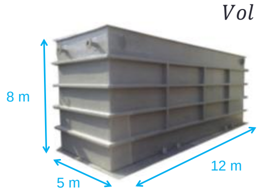
Example 3

- Determine the volume in m^3 for a tank that measures 12 meters by 8 meters by 5 meters.

$$Vol = (l)(w)(h)$$

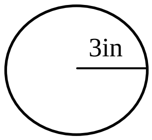
$$Vol = (12m)(8m)(5m)$$

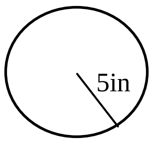
$$Vol = 480m^3$$

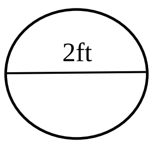


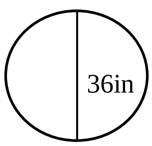
Basic Math for Water and Wastewater
CIRCUMFERENCE, AREA, AND VOLUME

<u>Circumference</u>

1. 

2. 

3. 

4. 

5. A chemical holding tank has a diameter of 24 feet. What is the circumference of the tank in feet?

6. An influent pipe inlet opening has a diameter of 4 feet. What is the circumference of the inlet opening in inches?

7. What is the length (in feet) around the top of a circular clarifier that has a diameter of 32 feet?

Area

1. A basin has a length of 45 feet and a width of 12 feet. Calculate the area in ft^2.

2. If the diameter of a circle is 10 inches, what is the cross-sectional area in square feet?

3. Calculate the surface area (in ft^2) of the top of basin which is 90 feet long, 25 feet wide, and 10 feet deep.

4. Calculate the area (in ft^2) for a 2 ft diameter main that has just been laid.

5. What is the area of the rectangle that is 3 feet by 9 feet?

6. Calculate the area (in ft^2) for an 18" main that has just been laid.

Volume

1. Calculate the volume (in ft^3) for a tank that measures 10 feet by 10 feet by 10 feet.

2. Calculate the volume (in gallons) for a basin that measures 22 feet by 11 feet by 5 feet.

3. Calculate the volume of water in a tank (in gallons), which measures 12 feet long, 6 feet wide, 5 feet deep, and contains 8 inches of water.

4. Calculate the volume (in ft^3) of a cone shaped chemical hopper with a diameter of 12 feet and a depth of 18 feet.

5. A new water main needs to be disinfected. The main is 30" in diameter and has a length of 0.25 miles. How many gallons of water will it hold?

6. A 3 million gallon water tank needs to be disinfected. The method you will use requires you to calculate 5% of the tank volume. How many gallons will this be?

DON'T THINK TOO HARD ON THIS ONE…

7. If you double the size of a pipe, does it double the volume that can be carried? For example, if you have 1000 feet of 12 inch line and you replace it with a 24 inch line, does your volume double?

ANSWERS:

Circumference

1. 18.85 in
2. 31.42 in
3. 6.28 ft
4. 113.10 in
5. 75.40 ft
6. 150.80 in
7. 100.53 ft

Area

1. 540 ft^2
2. 0.55 ft^2
3. 2250 ft^2
4. 3.14 ft^2
5. 27 ft^2
6. 1.77 ft^2

Volume

1. 1000 ft^3
2. 9050.8 gal
3. 359.04 gal
4. 678.58 ft^3
5. 48442.35 gal
6. 150,000 gal
7. 446671.14 gal
8. No, it quadruples it (4X)

Velocity & Flow

Velocity

- The speed at which something is moving
- Measured in
  - $^{ft}/_{min}$ $^{ft}/_{sec}$ $^{miles}/_{hr}$ etc

$$Velocity = \frac{distance}{time}$$

Example 1

- Blue dye is placed in a sewer line at a manhole. Three (3) minutes later, the dye appears in a manhole 125 feet down stream. What is the velocity of the flow in ft/min?

$$Velocity = \frac{distance}{time}$$

$$Vel = \frac{125\ ft}{3\ min}$$

$$Vel = 41.67\ ^{ft}/_{min}$$

Flow

- The volume of water that flows over a period of time
- Measured in
  - $^{ft^3}/_{sec}$ $^{ft^3}/_{min}$ $^{gal}/_{day}$ $^{MG}/_{D}$

$$Flow = (Area)(Velocity)$$

$$Q = AV$$

Example 2

- Water is flowing at velocity 3 ft/sec through a channel that is 2 feet wide and 1.5 feet deep. What is the flow in cubic feet per second?

$$Q = AV$$

$$Q = (l)(w)(velocity)$$

$$Q = (2ft)(1.5ft)\left(3\ ^{ft}/_{sec}\right)$$

$$Q = 9\ ^{ft^3}/_{sec}$$

Example 3

- Determine the flow in ft^3/sec through a 6 inch pipe that is flowing full at a velocity of 4.5 ft/sec.

$D = (6\ in)(\frac{1\ ft}{12\ in})$

$D = 0.5\ ft$

$$Q = AV$$

$$Q = (0.785)(D^2)\ (vel)$$

$$Q = (0.785)(0.5\ ft)(0.5\ ft)\left(4.5\ ^{ft}/_{sec}\right)$$

$$Q = 0.88\ ^{ft^3}/_{sec}$$

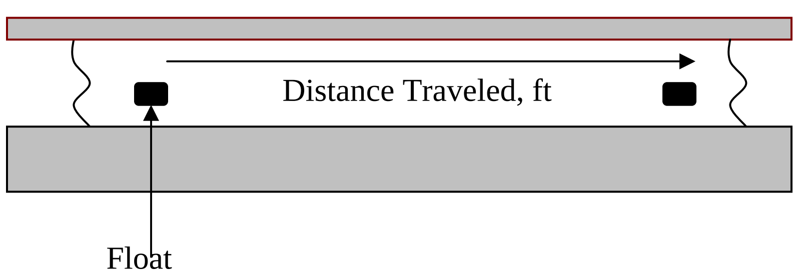
Basic Math for Water and Wastewater
Flow and Velocity

<u>Velocity</u>

1. A cork is placed in a channel and travels 370 feet in 2 minutes. What is the velocity of the wastewater in the channel, ft/min?

2. A float travels 300 feet in a channel in 2 minutes and 14 seconds. What is the velocity in the channel, ft/sec?

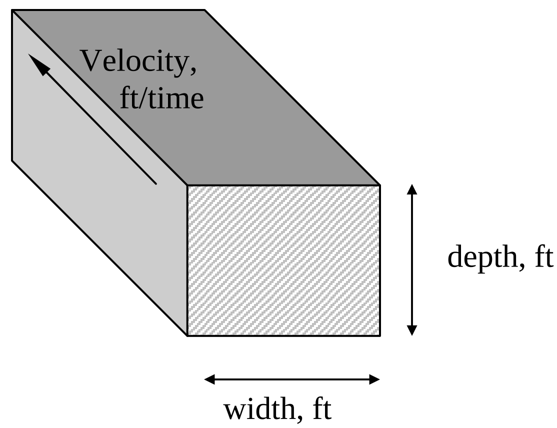
3. The distance between manhole #1 and manhole #2 is 105 feet. A fishing bobber is dropped into manhole #1 and enters manhole #2 in 30 seconds. What is the velocity of the wastewater in the sewer in ft/min?



$$\text{Velocity} = \frac{\text{Distance Traveled, ft}}{\text{Duration of Test, min}}$$

$$= \text{ft/min}$$

1.) 185 ft/min 2.) 2.2 ft/sec 3.) 210 ft/min



$$\underset{ft^3/time}{Q} = \underset{(ft)(ft)}{(A)} \; \underset{(ft/time)}{(V)}$$

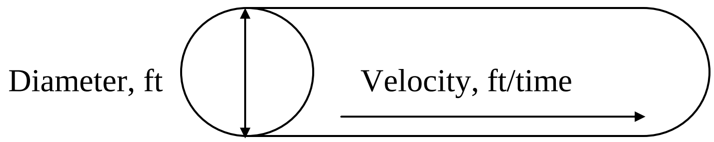
<u>Flow in a channel</u>

4. A channel 48 inches wide has water flowing to a depth of 1.5 feet. If the velocity of the water is 2.8 ft/sec, what is the flow in the channel in cu ft/sec?

5. A channel 3 feet wide has water flowing to a depth of 2.5 feet. If the velocity through the channel is 120 feet/min, what is the flow rate in cu ft/min? in MGD?

6. A channel is 3 feet wide and has water flowing at a velocity of 1.5 ft/sec. If the flow through the channel is 8.1 ft^3/sec, what is the depth of the water in the channel in feet?

4.) 16.8 ft^3/sec 5.) 900ft^3/min; 9.7 MGD 6.) 1.8 ft



$$\underset{ft^3/time}{Q} = \underset{ft^2}{(A)}\ \underset{(ft/time)}{(V)}$$

$$\underset{ft^3/time}{Q} = (0.785)\ \underset{(ft)(ft)}{(D)^2}\ \underset{(ft/time)}{(vel)}$$

<u>Flow through a full pipe</u>

7. The flow through a 2 ft diameter pipeline is moving at a velocity of 3.2 ft/sec. What is the flow rate in cu ft/sec?

8. The flow through a 6 inch diameter pipeline is moving at a velocity of 3 ft/sec. What is the flow rate in ft^3/sec?

9. The flow through a pipe is 0.7 ft^3/sec. If the velocity of the flow is 3.6 ft/sec, and the pipe is flowing full, what is the diameter of the pipe in inches?

10. An 8 inch diameter pipeline has water flowing at a velocity of 3.4 ft/sec. What is the flow rate in gpm?

7.) 10.05 ft3/sec 8.) 0.59 ft3/sec 9.) 6 in 10.) 532.4 gpm

Basic Math for Water and Wastewater
FLOW RATE

Q = AV

1. A channel is 3 feet wide with water flowing to a depth of 2 feet. If the velocity in the channel is found to be 1.8 fps, what is the cubic feet per second flow rate in the channel?

2. A 12-inch diameter pipe is flowing full. What is the cubic feet per minute flow rate in the pipe if the velocity is 110 feet/min?

3. A water main with a diameter of 18 inches is determined to have a velocity of 182 feet per minute. What is the flow rate in gpm?

4. A 24-inch main has a velocity of 212 feet/min. What is the gpd flow rate for the pipe?

5. What would be the gpd flow rate for a 6” line flowing at 2 feet/second?

6. A 36” water main has just been installed. According to the Design Criteria for the State of Tennessee, the minimum flushing velocity is 2 ft/sec. If the main is flushed at 2.5 ft/second, how many gallons/minute should be flushed from the hydrant?

7. A 36” water main has just been installed. If the main is flows at 2 ft/second, how many MGD will the pipe deliver?

8. A certain pipe has a diameter of 18 inches. If the pipe is flowing full, and the water is known to flow a distance of 830 yards in 5 minutes, what is the MGD flow rate for the pipe?

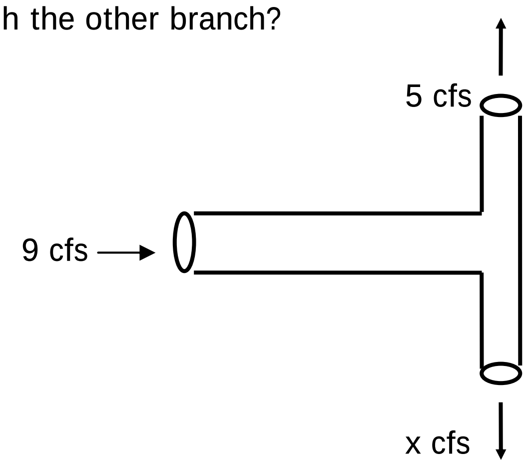
9. A float is placed in a channel. It takes 2.5 minutes to travel 300 feet. What is the velocity in feet per minute in the channel? (Assume that float is traveling at the average velocity of the water.)

10. A cork placed in a channel travels 30 feet in 20 seconds. What is the velocity of the cork in feet per second?

11. A channel is 4 feet wide with water flowing to a depth of 2.3 feet. If a float placed in the channel takes 3 minutes to travel a distance of 500 feet, what is the cubic-feet-per-minute flow rate in the channel?

12. The average velocity in a full-flowing pipe is measured and known to be 2.9 fps. The pipe is a 24” main. Assuming that the pipe flows 18 hours per day and that the month in question contains 31 days, what is the total flow for the pipe in MG for that month?

13. The flow entering the leg of a tee connection is 9 cfs. If the flow through one branch of the tee is 5 cfs, what is the flow through the other branch?



ANSWERS:

1. 10.8 ft^3/sec
2. 86.35 ft^3/min
3. 2,404.50 gpm
4. 7,170,172.42 gpd
5. 253,661.76 gpd
6. 7,926.93 gpm
7. 9.13 MGD
8. 9.47 MGD
9. 120 ft/min
10. 1.5 ft/sec
11. 1,533.33 ft^3/min
12. 136.83 MG
13. 4 ft^3/sec

Section 16

Rules and Regulations

Design Criteria for Sewage Works

Revised March 1, 2016

State of Tennessee
Department of Environment and Conservation
Division of Water Pollution Control
http://tn.gov/environment/wpc/

CHAPTER 2

Sewers and Wastewater Pumping Stations

2.1 General Requirements for Collection Systems

2.1.1 Construction Approval
2.1.2 Ownership
2.1.3 Design
2.1.4 Overflows
2.1.5 Calculations

2.2 Design Considerations

2.2.1 Design Period
2.2.2 Basis of Design
2.2.3 Design Factors

2.3 Design and Construction Details

2.3.1 Gravity sewers
2.3.2 Materials
2.3.3 Pipe Bedding
2.3.4 Joints
2.3.5 Leakage Testing
2.3.6 Visual Inspection
2.3.7 Low Pressure Systems
2.3.8 Manholes

2.4 Special Details

2.4.1 Protection of Water Supplies
2.4.2 Backflow Preventers
2.4.3 Sewers in Relation to Streams
2.4.4 I inverted Siphons

2.5 General Requirements for Wastewater Pumping stations

2.5.1 Location and Flood Protection
2.5.2 Pumping Rate and Number of Units
2.5.3 Grit and Clogging Protection
2.5.4 Pumping Units
2.5.5 Flow Measurement
2.5.6 Alarm System
2.5.7 Overflows and/or Bypasses

2.6 Special Details

2.6.1 General
2.6.2 Wet Well - Dry Well Stations
2.6.3 Suction Lift Stations
2.6.4 Submersible Pumps
2.6.5 Grinder and Effluent Pumps

2.7 Operability and Reliability

2.7.1 Objective
2.7.2 Backup Units
2.7.3 Power Outages
2.7.4 Emergency Power Supply (for Treatment Plants as well as Pumping stations)
2.7.5 Storage

2.8 Force Mains

2.8.1 Size
2.8.2 Velocity
2.8.3 Air Release Valve
2.8.4 Termination
2.8.5 Materials of Construction
2.8.6 Pressure Tests
2.8.7 Anchorage
2.8.8 Friction Losses
2.8.9 Water Hammer
2.8.10 Isolation and Valving

APPENDIX

Appendix 2-A: Design Basis for Wastewater Flow and Loadings

2.1 General Requirements for Collection Systems

2.1.1 Construction Approval

In general, construction of new sewer systems or extensions of existing systems must ensure that the downstream conveyance system and the receiving wastewater treatment plant are either:

a. Capable of adequately conveying or processing the added hydraulic and organic load, or

b. Capable of providing adequate conveyance or treatment facilities on a time schedule acceptable to the Division

2.1.2 Ownership

Sewer systems including pumping stations integral to gravity sewer and low-pressure sewer designs require ownership by a responsible party, such as a public entity, for operation and maintenance.

2.1.3 Design

The design and construction of new sewer systems must achieve total containment of sanitary wastes and exclusion of infiltration and inflow (I/I). This includes installing pipe with watertight joints, watertight connections to manholes, and watertight connections to service laterals or service lateral stubs and trench design that minimizes the potential for migration of water along the trench. However, the new sewer system and appurtenances must be able to convey the wastewater load, including existing I/I, from upstream areas as appropriate.

2.1.4 Overflows

The Division of Water Resources (Division) will not permit overflows in separate sanitary sewers or new overflows in existing combined sewers. The Division will not permit overflows in new interceptor sewers intercepting existing combined sewers. An alarm system to signal existing overflow conditions and procedures for reporting overflows may be required.

2.1.5 Calculations

The Division requires the submittal of all computations and other data used for design of the sewer system.

2.2 Design Considerations

2.2.1 Design Period

2.2.1.1 Collection sewers (Laterals and Submains)

The Division requires collection sewers for the ultimate development of the tributary areas.

2.2.1.2 Main, Trunk, and Interceptor Sewers

The Division requires certain design factors for trunk sewers:

a. Possible solids deposition, odor, and pipe corrosion that might occur at initial flows
b. Population and economic growth projections and the accuracy of the projections
c. Comparative costs of staged construction alternatives
d. Effect of sewer sizing on land use and development

2.2.2 Basis of Design

The Division's design requirements for new sewer systems are on the basis of per capita flows or alternative methods.

2.2.2.1 Per Capita Flow

The Division requires the use of Appendix 2-A. Substitutions or additions to the information presented in this table are acceptable if better or more accurate data is available.

The Division requires the following:

a. Lateral and Submains: Minimum peak design flow should be not less than 400 percent of the average design flow.

   "Lateral" - a sewer that has no other common sewers discharging into it.

   "Submain" is defined as a sewer that receives flow from one or more lateral sewers.

b. Main, Trunk, and Interceptor sewers: Minimum peak design flow should be not less 250 percent of the average design flow.

   "Main" or "trunk" is defined as a sewer that receives flow from one or more submains.

   "Interceptor" - a sewer that receives flow from a number of main or trunk sewers, force mains, etc.

2.2.2.2 Alternative Methods

The Division allows alternative methods other than on the basis of per capita flow rates. Alternative methods may include the use of peaking factors of the contributing area, allowances for future commercial and industrial areas, separation of infiltration and inflow from the normal sanitary flow (for new sewers serving existing upstream sewers), and modification of per capita flow rates (based on specific data). There should be no allowance for infiltration or inflow into newly constructed or proposed sewers.

2.2.3 Design Factors

The Division requires consideration of the following factors:

a. Peak wastewater flows from residential, commercial, institutional, and industrial sources
b. Potential for groundwater infiltration from existing upstream sewers
c. Topography and depth of excavation
d. Treatment plant location
e. Soils conditions
f. Pumping requirements
g. Maintenance, including manpower and budget
h. Existing sewers
i. Existing and future surface improvements
j. Controlling service connection elevations
k. Proximity to surface streams, including minimizing the potential for draining or diversion of stream water into the pipe trench
l. Watertight and exclude groundwater and surface water.

2.3 Design and Construction Details

2.3.1 Gravity Sewers

The Division requires gravity sewers to be approximately one-half full when conveying the anticipated peak daily dry weather flow and does not surcharge when conveying the anticipated peak wet weather flow.

2.3.1.1 Minimum Size

The minimum size of new public sewers should be 8 inches (nominal) in diameter.

2.3.1.2 Depth

Generally, sewers should not be less than 2 ½ feet deep but should be sufficiently deep to prevent freezing and physical damage.

2.3.1.3 Roughness Coefficient

The Division requires that a roughness coefficient “n” value of 0.013 be used in Manning’s formula for the design of all sewer facilities unless a roughness coefficient specific to the given pipe material is available. The roughness coefficient selected must consider the long-term condition of the sewer. However, the Division requires an “n” value equal to or greater than 0.011.

2.3.1.4 Slope

Sewers must be self-cleansing and capable of transporting most solids to the desired point, usually a treatment facility. Two methods are approved for design in the State of Tennessee: 1) Tractive Force and 2) Traditional (Ten-State Standards). For reasons of economical design and long-term maintenance, the Division prefers the Tractive Force Method.

Tractive Force Method:

ASCE and WEF (WEF Manual of Practice No. FD-5 *Gravity Sanitary Sewer Design and Construction*, 2007, Section 5.6) now advocates a transition to the tractive force approach for self-cleansing design. "Tractive Force (TF) design is a major improvement over traditional methods to achieve self-cleansing in gravity sewers. This approach results in a self-cleansing pipe slope value (S_{min}) for the design minimum flow rate (Q_{min}) in each sewer reach. Q_{min} is the predicted largest 1-hour flow rate in the reach during the lowest flow week over the sewer design life. Past design practices seldom included accurate estimation of Q_{min} values, but good estimates of Q_{min} are crucial for TF design. The engineer should show in the engineering report the calculations for Q_{min} for new sewer pipe projects. As compared to traditional minimum slopes, S_{min} slopes via the TF method are flatter for sewers carrying typical to larger Q_{min} values and steeper for sewers carrying smaller Q_{min} values." (Merritt, LaVere B., *Tractive Force Design for Sanitary Sewer Self-Cleansing*, ASCE, May 2009)

Once a good estimate has been developed for Q_{min}, then Table 2-1 (WEF, 2007, Table 5.5, page 148) for calculating minimum slopes for a typical condition in sewers is provided to assist designers with applying TF principles.

Table 2-1 Tractive Force Equations for Minimum Slope

Sewer Size (inches)	When n is Variable* value of S_{min} = (Q in cfs)
8	$0.000848\ Q_{min}^{-0.5707}$
10	$0.000887\ Q_{min}^{-0.5721}$
12	$0.000921\ Q_{min}^{-0.5731}$
15	$0.000966\ Q_{min}^{-0.5744}$
18	$0.001004\ Q_{min}^{-0.5754}$
21	$0.001038\ Q_{min}^{-0.5761}$
24	$0.001069\ Q_{min}^{-0.5768}$
27	$0.001097\ Q_{min}^{-0.5774}$
30	$0.001123\ Q_{min}^{-0.5778}$
36	$0.001169\ Q_{min}^{-0.5787}$
42	$0.001212\ Q_{min}^{-0.5812}$

3Based on Darcy-Weisbach

Traditional Method:

The Traditional Method for conventional gravity sewers requires mean velocities, when flowing full, of not less than 2.0 feet per second. Table 2-2 provides minimum slopes when using the traditional method; however, slopes greater than these are desirable.

Table 2-2 Minimum Slope from Traditional Method

Sewer Size (inches)	Minimum Slope* (feet per 100 feet)
8	0.40
10	0.28
12	0.22
15	0.15
18	0.12
21	0.10
24	0.08
27	0.067
30	0.058
36	0.05 **
42	0.042***

* Great Lakes Upper Mississippi River Board, 1997.
** Recommended steeper – to give velocity of 2.1 ft/sec (WEF, 2007)
*** Recommended steeper – to give velocity of 2.3 ft/sec (WEF, 2007)

Under special condition, the using the Traditional Method, the Division may allow slopes slightly less than those required for the 2.0 feet-per-second velocity when flowing full may be permitted. Such decreased slopes will only be considered where the depth of flow will be 0.3 of the diameter or greater for design average flow. Whenever such decreased slopes are proposed, the design engineer should furnish with his report his computations of the depths of flow in such pipes at minimum, average, and daily or hourly rates of flow. The maintaining wastewater agency must recognize and accept in writing the problems of additional maintenance caused by decreased slopes.

Uniform slope between manholes is required.

A minimum of 5 feet of horizontal separation between gas mains is required.

Anchors are required for sewers on 20 percent slope or greater. Secure anchors will have a minimum two-foot thick tightly compacted clay collar or equal. Suggested minimum anchorage spacing is as follows:

a. Not over 36 feet center to center on grades 20 percent and up to 35 percent.

b. Not over 24 feet center to center on grades 35 percent and up to 50 percent.

c. Not over 16 feet center to center on grades 50 percent and over.

2.3.1.5 Alignment

Straight alignment between manholes is required for gravity sewers. However, curved sewers may be approved where circumstances warrant but only in large (i.e., 24" and larger) diameter segments.

2.3.1.6 Increasing Size

When a smaller sewer joins a larger one, the Division requires the alignment to maintain the same energy gradient. An approximate method for securing these results is to match the crowns of the sewers entering/ exiting the manhole or junction structure.

2.3.1.7 High-Velocity Protection

Where velocities greater than 15 feet per second are expected, the Division requires protective measures against internal erosion or displacement by shock.

2.3.2 Materials

The Division will consider any generally accepted material for sewers. The material selected should be adapted to local conditions such as character of industrial wastes, possibility of septicity, soil characteristics, abrasion and similar problems. The Division requires careful consider of pipes and compression joint materials subjected to corrosive or solvent wastes. Chemical/stress failure and stability in the presence of common household chemicals such as cooking oils, detergents and drain cleaners are factors.

The specifications should stipulate need to keep clean the pipe interior, sealing surfaces, fittings and other accessories. Pipe bundles should be stored on flat surfaces with uniform support. The protection of stored pipe is required. Pipe with prolonged exposure (six months or more) to sunlight requires a suitable covering (canvas or other opaque material). The Division requires care be given to gaskets. Ensure that gasket not be exposed to oil, grease, ozone (produced by electric motors), excessive heat and direct sunlight. Consult with the manufacturers for specific storage and handling recommendations.

2.3.2.1 Rigid Pipe

Rigid pipe includes, but is not be limited to, concrete pipe. Any rigid pipe should have a minimum crushing strength of 2000 pounds per lineal foot. All pipes should meet the appropriate ASTM and/or ANSI specifications.

2.3.2.2 Semi-rigid Pipe

Semi-rigid pipe includes, but is not be limited to, ductile iron. All pipes should meet the appropriate ASTM and/or ANSI specifications.

2.3.2.3 Flexible Pipe

Flexible pipe includes, but is not be limited to, ABS solid wall pipe, polyvinyl chloride pipe (PVC), polyethylene pipe (PE), fiberglass composite pipe, reinforced plastic mortar pipe (RPM) and reinforced thermosetting resin pipe (RTR). PVC pipe should have a minimum Standard Dimension Ratio (SDR) of 35. The Division requires that all other flexible pipe have the same calculated minimum deflection under identical conditions as the SDR 35 PVC pipe.

To calculate the flexible pipe deflection under earth loading use the formula presented in the ASCE/WPCF publication, Design and Construction of Sanitary and Storm Sewers.

All pipes should meet appropriate ASTM and/or ANSI specifications. ASTM D-3033 and D-3034 PVC pipes differ in wall thickness and have non-interchangeable fittings.

2.3.3 Pipe Bedding and Backfilling

The Division requires that all sewers designs provide protection from damage from superimposed loads. The width and depth of the trench require allowances be made for loads on the sewer. Backfill material up to three feet above the top of the pipe should not exceed 6 inches in diameter at its greater dimension.

The Division requires ductile iron pipe in roadways where cover is less than 4 feet. In such cases, a minimum cover of six inches is required.

The Division requires ductile iron pipe or relocation when the top of the sewer is less than 18 inches below the bottom of a culvert or conduit.

2.3.3.1 Rigid Pipe

Bedding Classes A, B, or C as described in ASTM C-12 or WPCF MOP No. 9 (ASCE MOP No. 37) should be used for all rigid pipe, provided the proper strength pipe is used with the specified bedding to support the anticipated load. The Division requires the use of ASTM-C-12 (placement of bedding and backfill).

2.3.3.2 Semi-Rigid Pipe

The Division requires the use of Bedding Classes I, II, III, or IV (ML and CL only) as described in ASTM D-2321 for all semi-rigid pipe provided with the specified bedding to support the anticipated load.

The Division requires ASTM-A-746 be used to install ductile iron pipe.

2.3.3.3 Flexible Pipe

The Division requires the use of Bedding Classes I, II, or III as described in ASTM D-2321 for all flexible pipe. The Division requires the proper strength pipe with the specified bedding to support the anticipated load.

The Division requires ASTM-D-2321 for bedding, haunching, initial backfill, and backfill.

The Division requires Class I bedding material for bedding, haunching, and initial backfill as described in 2.3.3.4. (polyethylene pipe).

2.3.3.4 Alternate Bedding Option

The Division will allow all sewers bedded and backfilled with a minimum of 12 inches of Class I material over the top and below the invert of the pipe--an alternative to sub-sections 2.3.3.1, 2.3.3.2 and 2.3.3.3.

2.3.3.5 Deflection Testing

The Division requires deflection testing of all flexible pipes. The Division requires backfill testing after it has been in place at least 24 hours.

No pipe should exceed a deflection of 5%.

The test should be run with a rigid ball or an engineer approved 9-arm mandrel having a diameter equal to 95% of the inside diameter of the pipe. The test requires manually pulling the test device through the line.

2.3.4 Joints

The Division requires the specification to include the method of making joints and the materials used. The Division requires that sewer joints eliminate infiltration and prevent the entrance of roots.

Elastomeric gaskets, other types of pre-molded (factory made) joints, and ABS solvent-cement welded joints are required. The Division requires the use of ASTM-F2620 for butt fusion joining technique with polyethylene pipe. The Division requires the removal of internal beads for butt fusion joints on pipelines with slopes less than one percent. Cement mortar joints are not acceptable. Field solvent welds for PVC and PE pipe and fittings are not acceptable.

2.3.5 Leakage Testing

The Division requires the use of ASTM-C-828 for low-pressure air testing for all pipes. The time required for the pressure to drop from the stabilized 3.5 psig to 2.5 psig should be greater than or equal to the minimum calculated test time (the Division requires that air loss rate be part of the test criteria).
The testing method should take into consideration the range in groundwater elevations projected and the situation during the test. The height of the groundwater should be measured from the top of the invert (one foot of H_20 = 0.433 psi).

Table 2-3 provides the minimum test times and allowable air loss values for various pipe size per 100 ft.

Table 2-3 Leakage Test Parameters

Pipe Size (inches)	**Time**, T (sec/100 ft)	**Allowable Air Loss**, Q (ft^3/min)
6	42	2.0
8	72	2.0
10	90	2.5
12	108	3.0
15	126	4.0
18	144	5.0
21	180	5.5
24	216	6.0
27	252	6.5
30	288	7.0

2.3.6 Visual Inspection

The Division requires that new sewers be video inspected to confirm proper installation and to provide a visual record of the condition of the newly constructed sewer for future reference.

2.3.7 Low Pressure Systems

2.3.7.1 Application

The Division requires the consideration of low-pressure systems for situations in which gravity sewers are extremely costly or impractical, such as rock or high groundwater table.

2.3.7.2 Grinder Pumps

The Division requires all the collection and transport of raw wastewater from individual buildings/dwellings to the pressure system by appropriately sized grinder pumps.

Grinder pumps do not require a septic tank.

All pumps should have operating curves that do not allow backflow under maximum head conditions.

Pumps should be watertight and located above the seasonal groundwater table were possible where possible.

2.3.7.3 Septic Tank Effluent Pump (STEP) system

All STEP installations require careful attention to the following design details and construction techniques:

a. All STEPs preceded by a watertight septic tank. Retrofitting a STEP to an existing septic tank will require a visual inspection of the tank.

   Replacement of all defective septic tanks.

b. STEPs retrofitted to an existing septic tank and drain field must provide a positive means of preventing groundwater from backing up through the drain field to the STEP.

c. The STEP should be located as close as possible to the septic tank.

d. Electrical power supplied through the main circuit box. Electricity furnished to a separate circuit box installed on the exterior wall of the building, near the STEP.

2.3.7.4 Hydraulic

Hydraulic calculations are of extreme importance. Head losses within the low-pressure system will change with each pump activation.

2.3.7.5 Minimum Velocity

The recommended minimum operating velocity in a pressure system should be 2 feet per second (fps).

2.3.7.6 Flushing

There should be a means of cleaning the system, particularly to clear any settleable solids or grease accumulation.

2.3.7.7 Pressure Testing

There should be means for isolating and pressurizing sections of the system to detect and locate leaks.

2.3.7.8 Alarms

There should be an external visual warning system to indicate the malfunction of the pump. The high-level (in storage tank) warning system should be a dual audio / visual system.

2.3.7.9 Cleanouts

The Division requires cleanouts at a maximum of 400-foot intervals.

2.3.7.10 Ventilation

Ventilation of the pumping station should be provided via house vents where allowable or through a separate system.

2.3.8 Manholes

2.3.8.1 Location

The Division requires manholes at the end of each 8-inch diameter sewer or greater. The Division will waive this requirement if a stub-out is installed (assumes line will be extended in near future).

The Division requires manholes at all changes in grade, size, or alignment; at all intersections; and at distances not greater than 400 feet for sewers 15 inches or less. The Division requires manholes at 500 feet for sewer 18 inches to 30 inches. The Division may allow greater spacing in larger sewers and in those carrying a settled effluent.

2.3.8.2 Drop Connection

The Division requires a drop connection for a sewer entering a manhole at an elevation of 24 inches or more above the manhole invert. Where the difference in elevation between the incoming sewer and the manhole invert is less than 24 inches, a filleted invert will prevent solids deposition.

2.3.8.3 Diameter

The minimum diameter of manholes should be 48 inches; larger diameters are preferable. The minimum clear opening in the manhole frame shall meet current OSHA standards.

2.3.8.4 Flow Channels

Flow channels in manholes should be of such shape and slope to provide smooth transition between inlet and outlet sewers and to minimize turbulence. Channeling height should be to the crowns of the sewers. Benches should be sloped from the manhole wall toward the channel to prevent accumulation of solids.

2.3.8.5 Water tightness

The Division requires watertight manhole covers wherever the manhole tops may be flooded. Manholes of brick or segmented block are not appropriate materials for manhole construction where groundwater conditions are unfavorable. In pre-cast concrete manholes, the Division requires plastic gaskets, pre-molded rubber gaskets or flexible, plastic gaskets.

2.3.8.6 Connections

The Division requires special attention be paid to the connection between the manhole wall and the sewer pipe in order to minimize long-term infiltration into the system. The Division requires flexible joints for line connections directly to the manholes, or to short stubs integral with the manholes. Flexible joints are joints that permit the manholes to settle without destroying the watertight integrity of the line connections.

2.3.8.7 Ventilation

The Division requires consideration of ventilation of gravity sewer systems where continuous watertight sections are greater than 1,000 feet in length. Vent height and construction must consider flood conditions.

2.3.8.8 Frames, Covers, and Steps

Frames, covers, and steps, if utilized, should be of suitable material and designed to accommodate prevailing site conditions and to provide for a safe installation.
Materials used for manhole steps should be highly corrosion-resistant. The Division requires aluminum or plastic with reinforcing bar.

2.3.8.9 Vacuum Testing

New manholes should be vacuum tested after construction to verify they will not be new sources of infiltration or inflow. The Division requires the test to include the manhole frame. The Division considers the test acceptable if the vacuum remains at 10 inches of mercury or drops to no less than 9 inches of mercury within one minute. The Division may allow alternative testing methods--if demonstrated to be equal of better than vacuum testing.

2.4 Special Details

2.4.1 Protection of Water Supplies

2.4.1.1 Water Supply Interconnections

There shall be no physical connection between a public or private potable water supply system and a sewer or appurtenance thereto.

2.4.1.2 Relation to Water Mains

Horizontal Separation: Whenever possible, the Division requires at least 10 feet horizontal separation of the sewer from any existing or proposed water main. Should local conditions prevent a lateral separation of 10 feet, the Division may allow the sewer closer than 10 feet to a water main if in a separate trench and if the elevation of the top (crown) of the sewer is at least 18 inches below the bottom (invert) of the water main.

Vertical Separation: Whenever sewers must cross under water mains, the Division requires the sewer at such elevation that the top of the sewer is at least 18 inches below the bottom of the water main. The Division will consider other alternatives if the sewer evaluation cannot be varied.

When it is impossible to obtain proper horizontal and vertical separation as stipulated above, the sewer should be designed and constructed equal to the water main pipe and should be pressure-tested to assure water-tightness (see drinking water criteria) or the joints of the sewer pipe should be encased in concrete to inhibit infiltration/exfiltration. Details of the encasement should be clear and extend the necessary distance to achieve design goals. The designer should consider the temperature differential between the

pipe and the surrounding materials in their determination if reinforcement is necessary. Such arrangements are discouraged.
The Division requires the designer's evaluation, calculations, and conclusions in the project record and provided to all interested parties upon request.

2.4.2 Backflow Preventers

State approved reduced pressure backflow prevention devices are required on all potable water mains serving the wastewater treatment plant or pumping station. The Division can provide a list of approved backflow preventers.

2.4.3 Sewers in Relation to Streams

2.4.3.1 Site Characterizations for Sewers in Proximity to Streams

For new sewers or existing sewers replaced in the same trench that cross or have an alignment within 50 feet of the bank of a surface stream, upon notification of the potential route of the proposed sewer, the Division will perform a site characterization to determine the potential for stream capture. (See Section 1.2.4.1 of Chapter 1) If the Division determines there is potential for stream capture, a site-specific Aquatic Resource Alteration Permit (ARAP) is required, and obtaining this permit will require the design engineer to provide a plan to prevent stream capture. This may require additional study of the characteristics of the stream, including soil classification data, rock depth (if present), recommendations for controlling seepage, cut and fill recommendations, a trench dewatering plan, and other site specific data.

2.4.3.2 Location of Sewers in Streams

Open trench sewers located along streams should be located outside of the streambed and sufficiently removed there from to minimize disturbance or root damage to streamside trees and vegetation.

Sewer outfalls, headwalls, manholes, gate boxes or other structures should be located so they do not interfere with the free discharge of flood flows of the stream.

The Division requires open trench sewer crossings of streams to cross the stream as nearly perpendicular to the stream flow as possible and be free from change in grade.

2.4.3.3 Construction

Sewers entering or crossing streams should be ductile iron pipe from manhole to manhole, wrapped in plastic and encased in high strength flowable fill. (Note: This provision is subject to a case-by-case review. In this case, the Division requires an impermeable barrier that might be flowable fill, concrete, liners, casing pipe or a combination. The best practice may be different depending upon stream flow, local soils, topography and geology).

The sewer should be free of alignment or grade changes. The Division requires sewer systems designs to minimize the number of stream crossings. The Division requires the stream returned as nearly as possible to its original condition upon completion of construction. The Division requires the stream banks to be seeded or other erosion prevention methods employed to prevent erosion. Stream banks should be sodded, if necessary, to prevent erosion. The consulting engineer should specify the method or methods in the construction of the sewers in or near the stream to control siltation.

With regard to prohibitions on the contractor, the Division requires that the specifications contain the following clauses:

- unnecessarily disturbing or uprooting trees and vegetation along the stream bank and in the vicinity of the stream,
- dumping of soil and debris into streams and/or on banks of streams,
- changing course of the stream without encroachment permit,
- leaving cofferdams in streams,
- leaving temporary stream crossings for equipment,
- operating equipment in the stream, or
- pumping silt-laden water into the stream.

The Division requires provisions in the specifications to:

- retard the rate of runoff from the construction site,
- control disposal of runoff,
- liberal use of silt fencing to trap sediment resulting from construction in temporary or permanent silt-holding basins,
- pump discharges resulting from dewatering operations;
- deposit out of the flood plain area all material and debris removed from the streambed.

Specifications should require that cleanup, grading, seeding, planting or restoration of the work area should be carried out as early as practical as the construction proceeds. The Division requires the specifications mandate a trench-dewatering plan for new sewer alignments that cross a stream or are within 50 feet of the bank of the stream defined in Section 1.2.4.1.

2.4.3.4 Special Construction Requirements

The Division requires the employment of special design requirements to prevent stream drainage from sinking at the crossing and following along the sewer pipe bedding. The Division requires an in trench impounding structure of compacted clay or concrete check dams. The Division will consider other proposals.

2.4.3.5 Aerial Crossings

The Division may allow sewers that lay on piers across ravines or streams if no other practical alternative exists or, in the design engineer's judgment, other methods will not be as reliable.

The Division requires support for all joints. All supports designs must prevent frost heave, overturning or settlement. The Division requires precautions against freezing, such as insulation or increased slope and expansion joints between aboveground and belowground sewers. The Division requires deigns to consider the impact of floodwaters and debris. The design should consider maintenance of an adequate waterway for the 100-year flood flows. The design engineer should analyze the impact of the proposed aerial crossing(s) on flooding, including hydraulic modeling, such as Hydrologic Engineering Center-River Analysis System (HEC-RAS) modeling, as necessary.

2.4.3.6 Permits

It is the owner's responsibility to obtain all necessary permits along streams or rivers; i.e., Corps of Engineers, TVA, or the Natural Resources Section of the Division of Water Resources.

2.4.4 Inverted Siphons

Under normal conditions, the Division will not allow inverted siphons. However, if they are, the Division requires that the following:

- Minimum of two barrels,
- Minimum pipe size of six inches--provided with necessary appurtenances for convenient flushing and maintenance,
- Manholes with adequate clearances for rodding,
- Sufficient head and pipe sizes to secure velocities of at least 3.0 feet per second for average flows,
- Inlet and outlet details arranged so that the normal flow is diverted to one barrel, and so that either barrel may be cut out of service for cleaning,
- Design engineer furnishes hydraulic calculations with the plans,
- Proper access maintained.

2.5 General Requirements for Wastewater Pumping Stations

2.5.1 Location and Flood Protection

The Division requires wastewater pumping stations located as far as practicable from present or proposed built-up residential areas, with an all-weather road and noise control, odor control, and station architectural design taken into consideration. Sites for stations should be of sufficient size for future expansion or addition, if applicable. The Division requires security for the pumping station and controls.

The Division requires protection from the 100-year flood for the station's operational components.

Where the wet well is at a depth greater than the water table elevation, special provisions should be made to ensure watertight construction of the wet well. The Division requires connections to the pumping station at an elevation higher than the maximum water table elevation, where possible.

2.5.2 Pumping Rate and Number of Units

At least two pump units should be provided, each capable of handling the expected maximum flow. The Division requires the submittal of pump head and system head curves.

For three or more units the Division requires a design to fit actual flow conditions and must be of such capacity that, with any one unit out of services, the remaining units will have capacity to handle the maximum wastewater flow.

A station expected to operate at a flow rate less than one-half the average design flow for an extended period may create septic conditions due to long holding times in the wet well. The design should consider the need for additional measures to prevent the formation of odors.

The design should the use of variable-speed or multiple staged pumps, particularly when the pumping station delivers flow directly to a treatment plant. The design allows delivery of the wastewater at approximately the same rate as received at the pumping station.

2.5.3 Grit and Clogging Protection

Where it may be necessary to pump wastewater prior to grit removal, the design of the wet well should receive special attention, and the design of the discharge piping should be to prevent grit settling in pump discharge lines of pumps not operating.

Design of the pumping station should consider the protection of the pump from damage caused by grit and debris, where warranted. To accomplish this--maintain minimum pump operational speeds, through the installation of bar screens with a grinder or comminutor, or similar devices. For the larger or deeper stations, duplicate protection units, each sized at full capacity, are preferred.

2.5.4 Pumping Units

2.5.4.1 Pump Openings

The Division requires pumps be capable of passing a 3-inch compressible solid. The Division requires pump suction and discharge openings to be at least 4 inches in diameter unless it is a pump with chopping or grinding capabilities.

2.5.4.2 Priming

The Division requires the placement of pumps so that under normal operating conditions they will operate under a positive suction head (except for suction lift pumps).

2.5.4.3 Intake

Each pump should have an individual intake. Wet well design should be such as to avoid turbulence near the intake.

2.5.4.4 Controls

The location of controls should ensure that the flows entering the wet well to not affect them, by the suction of the pumps, or by proximity to wet well walls. Controls must be able to activate additional pumps if the water in the wet well continues to rise. Controls can be float switches, air-operated pneumatic, radar, ultrasonic or capacitance probe types. Provisions should be made to automatically alternate the pumps in use. Pumping stations with motors and/or controls below grade should be equipped with a secure external disconnect switch. The Division requires consideration of an "intrinsically safe" power source if float switches are used.

The Division requires consideration of redundant controls and/or remote monitoring to assist in preventing overflows.

2.5.5 Flow Measurement

At pumping stations with flow capacity greater than 0.5 million gallons per day (mgd), the Division recommends providing suitable devices for measuring flow.

2.5.6 Alarm System

The Division recommends an alarm system for all pumping stations such as, telemetry alarm to 24-hour monitoring stations or telephone alarms to duty personnel (when reliability classification or property damage warrants it). The Division requires an audiovisual device at the station for external observation when telemetry is not used.

The Division requires alarms for high wet well and power failure, as a minimum, for all pumping stations. For larger stations, the Division requires alarms signalizing pump and other component failures or malfunctions.

The Division requires a backup power supply, such as a battery pack with an automatic switchover feature, for the alarm system, such that a failure of the primary power source will not disable the alarm system. The alarm system must be tested and verified that it is in good working order.

2.5.7 Overflows and/or Bypasses

Pumping stations should be designed and built without any type of overflow or bypass structure.

2.6 Special Details

2.6.1 General

2.6.1.1 Materials

Materials must not contain hydrogen sulfide and other corrosive gases, greases, oils, and other constituents frequently present in wastewater. The Division recommends the use of concrete additives or protective coatings to prevent deterioration caused by corrosive gases.

2.6.1.2 Electrical Equipment

Electrical systems and components (e.g., motors, lights, cables, conduits, switchboxes, and control circuits) in enclosed or partially enclosed spaces where flammable mixtures occasionally may be present (including raw wastewater wet wells) should comply with the National Electrical Code requirements for Class I Division 1 locations.

2.6.1.3 Water Supply

There should be no physical connection between any potable water supply and a wastewater pumping station that under any conditions might cause contamination of the potable water supply. A potable water supply must comply with conditions stipulated in section 2.4.2.

2.6.1.4 Lighting

Adequate lighting is required for the entire pumping station.

2.6.1.5 Pump and Motor Removal

The Division requires the removal of pumps, motors, and other equipment, without interruption of system service.

2.6.1.6 Safety

The Division requires suitable and safe means of access to equipment requiring inspection or maintenance and that stairways and ladders satisfy all OSHA requirements.

2.6.1.7 Valves and Piping

The Division requires suitable shutoff valves on suction and discharge lines of each pump for normal pump isolation and a check valve on each discharge line between the shutoff valve and the pump. Pump suction and discharge piping should not be less than 4 inches in diameter except where design of special equipment allows. The velocity in the suction line should not exceed 6 feet per second and, in the discharge piping, 8 feet per second. A separate shutoff valve is desirable on the common line leaving the pumping station.

2.6.1.8 Ventilation

The Division requires ventilation for all pumping stations during all periods when the station is manned. Portable ventilation equipment is acceptable for small pumping stations. Mechanical ventilation is required if screens or mechanical equipment, which might require periodic maintenance and inspection, are located in the wet well. In pits over 15 feet deep, multiple inlets and outlets are desirable. The Division requires that dampers not be used on exhaust or fresh air ducts, and fine screens or other obstructions in air ducts should be avoided to prevent clogging.

2.6.2 Wet Well - Dry Well Stations

2.6.2.1 Separation

The Division requires complete separation of wet and dry wells, including their superstructures.

The Division recommends dividing the wet well into two sections, properly interconnected, to facilitate repairs and cleaning where continuity of pumping station operation is necessary.

2.6.2.2 Wet Well Size and Design

Provide an evaluation of the effective capacity of the wet well based on pumping requirements and reliability classifications.

Wet well design should consider approaches for minimizing solids deposition.

2.6.2.3 Dry Well Dewatering

The Division requires a separate sump pump in the dry wells to remove leakage or drainage with the discharge above the high water level of the wet well. The Division will not approve water ejectors connected to a potable water supply. All floor and walkway surfaces should have an adequate slope to a point of drainage.

2.6.3 Suction Lift Stations

2.6.3.1 Priming

Conventional suction-lift pumps should be of the self-priming type, as demonstrated by a reliable record of satisfactory operation. The maximum recommended lift for a suction lift pumping station is 15 feet, using pumps of 200 gallons per minute (gpm) capacity or less.

2.6.3.2 Capacity

The capacity of suction lift pumping stations should be limited by the net positive suction head and specific speed requirements, as stated on the manufacturer's pump curve, for the most severe operating conditions.

2.6.3.3 Air Relief

a. Air Relief Lines
An air relief line on the pump discharge piping is required for all suction lift pumps. This line should be located at the maximum elevation between the pump discharge flange and the discharge check valve to ensure the maximum bleed-off of entrapped air. The air relief line should terminate in the wet well or suitable sump and be open to the atmosphere.

b. Air Relief Valves
The Division requires air relief valves in air relief lines on pumps not discharging to gravity sewer collection systems. The air relief valve should be located as close as practical to the discharge side of the pump.

2.6.3.4 Pump Location

For standard designs, suction lift pumps are mounted on the wet well but not within the wet well.

2.6.3.5 Access to Wet Well

Access to the wet well should not be through the dry well, and the dry well should have a gastight seal when mounted directly above the wet well.

2.6.4 Submersible Pumps

2.6.4.1 Pump Removal

Submersible pumps should be readily removable and replaceable without dewatering the wet well or requiring personnel to enter the wet well.

The Division recommends a hoist or crane system for removing the pumps from the wet well either through a permanent installation at the site or a mobile system that could be utilized at multiple sites.

2.6.4.2 Controls

The control panel should be located outside the wet well and suitably protected from weather, humidity, vandalism, and gases migrating from the wet well.

2.6.4.3 Valves

The Division recommends all control valves on the discharge line for each pump in a convenient location outside the wet well in separate pits and protected from weather and vandalism.

2.6.4.4 Submergence

Positive provision, such as backup controls, is required to assure submergence of the pumping units.

2.6.5 Grinder and Effluent Pumps

The requirements for grinder pumps are included in Section 2.3.6.

2.7 Operability and Reliability

2.7.1 Objective

The objective of reliability is to prevent the discharge of raw or partially treated wastewater to any waters and to protect public health by preventing backup of wastewater and subsequent discharge to basements, streets, and other public and private property.

2.7.2 Backup Units

A minimum of two pumps or pneumatic ejectors are required in each station in accordance with section 2.5.2.

2.7.3 Power Outages

An emergency power source or auxiliary power is required for all pumping stations larger than 1 MGD to ensure continuous operability unless experience has shown the frequency and duration of outages to be low and the pumping station and/or sewers provide storage sufficient for expected interruptions in power service.

2.7.4 Emergency Power Supply (for Treatment Plants as well as Pumping stations)

2.7.4.1 General

The Division requires provision of an emergency power supply for pumping stations (and treatment plants) to at least two independent public utility sources, or by provision of portable or in-place internal combustion engine equipment that will generate electrical or mechanical energy, or by the provision of portable pumping equipment. Emergency power must be provided for all stations which are 1 MGD or larger, or as determined by the reliability classification.

Emergency power should be provided that, alone or combined with storage, will prevent overflows from occurring during any power outage that is equal to the maximum outage in the immediate area during the last 10 years. If available data were less than 10 years, an evaluation of a similar area served by the power utility for 10 years would be appropriate.

2.7.4.2 In -Place Equipment

The utilization of in-place internal combustion equipment requires the following guidelines:

a. Placement: bolted in place. Facilities for unit removal for purposes of major repair or routine maintenance.
b. Controls: automatic and manual startup and cut-in.
c. Size: adequate to provide power for lighting and ventilation systems and such further systems that affect capability and safety as well as the pumps.
d. Engine Location: located above grade, with suitable and adequate ventilation of exhaust gases.
e. Underground Fuel Storage Tank: design and construction must conform to the applicable requirements of Federal Regulations 40 CFR 280 and 281. Contact the Tennessee Division of Superfund, Underground Storage Tank Program, for guidance.

2.7.4.3 Portable Equipment

The utilization of portable equipment requires the following guidelines:

Pumping units have connections to operate between the wet well and the discharge side of station and the station provided with permanent fixtures that will facilitate rapid and easy connection of lines.

2.7.5 Storage

The Division requires wet well and tributary main capacity above the high-level alarm sufficient to hold the peak flow expected during the maximum power outage duration during the last 10 years.

2.8 Force Mains

2.8.1 Size

Minimum size force mains required to be not less than 4 inches in diameter, except for grinder pumps or septic tank effluent applications

2.8.2 Velocity

At pumping capacity, a minimum self-scouring velocity of 3 feet per second (fps) should be maintained unless flushing facilities are provided. Velocity should not exceed 8 fps.

2.8.3 Air/Vacuum Relief Valve

An air relief valve is required at the necessary high points in the force main to relieve air locking. Vacuum relief values may be necessary to relieve negative pressures on force mains to protect against pipe collapse.

2.8.4 Termination

The force main should enter the receiving manhole with its centerline horizontal and with an invert elevation that will ensure a smooth flow transition to the gravity flow section; but in no case should the force main enter the gravity sewer system at a point more than 1 foot above the flow line of the receiving manhole. The design should minimize turbulence at the point of discharge.

The Division requires the use of inert materials or protective coatings for the receiving manhole to prevent deterioration because of hydrogen sulfide or other chemicals where such chemicals are present or suspected to be present because of industrial discharges or long force mains.

2.8.5 Materials of Construction

The pipe material should be adapted to local conditions, such as character of industrial wastes, soil characteristics, exceptionally heavy external loadings, internal erosion, corrosion, and similar problems.

Installation specification should contain appropriate requirements based on the criteria, standards, and requirements established by the industry in its technical publications. Requirements should be set forth in the specifications for the pipe and methods of bedding and backfilling thereof so as not to damage the pipe or its joints, impede cleaning operations, not create excessive side fill pressures or ovality of the pipe, nor seriously impair flow capacity.

The Division requires that the design of all pipes prevent damage from superimposed loads. Proper design allowance for loads on the pipe because of the width and depth of trench is required.

2.8.6 Pressure Tests

The Division requires testing, before backfilling, of all force mains at a minimum pressure of at least 50 percent above the design operating pressure for at least 30 minutes. Leakage should not exceed the amount given by the following formula:

$$\mathbf{L = ND\ (P)}^{.5}\ /7{,}400$$

Where **L** is allowable leakage in gallons per hour
N is the number of pipe joints
D is the pipe diameter in inches
P is the test pressure in psi

2.8.7 Anchorage

The Division requires sufficient anchorage of force mains within the pumping station and throughout the line length to include, thrust blocks, restrained joints, and/or tie rods.

2.8.8 Friction Losses

The Division requires the use of a C factor that will take into consideration the conditions of the force main at its design usage. For example, a grease-coated pipe after several years will not have the same C factor as a new pipe.

2.8.9 Water Hammer

The force main design should investigate the potential for the existence of water hammer.

2.8.10 Isolation and Valving

The Division recommends the installation of isolation valves at strategic locations along the force main to facilitate maintenance of the system.

<u>APPENDIX 2-A</u>

Design Basis for Wastewater Flow and Loadings

Table 2-A.1. Typical Wastewater Flow Rates from Commercial Sources
(Source: Crites and Tchobanoglous, 1998)

FACILITY	UNIT	Flow, gallons/unit/day	
		Range	Typical
Airport	Passenger	2 - 4	3
Apartment House	Person	40 - 80	50
Automobile Service Station	Vehicle served	8 - 15	12
	Employee	9 - 15	13
Bar	Customer	1 - 5	3
	Employee	10 - 16	13
Boarding House	Person	25 - 60	40
Department Store	Toilet Room	400 - 600	500
	Employee	8 - 15	10
Hotel	Guest	40 - 60	50
	Employee	8 - 13	10
Industrial Building (Sanitary waste only)	Employee	7 - 16	13
Laundry (self-service)	Machine	450 - 650	550
	Wash	45 - 55	50
Office	Employee	7 - 16	13
Public Lavatory	User	3 - 6	5
Restaurant (with toilet)	Meal	2 - 4	3
Conventional	Customer	8 - 10	9
Short order	Customer	3 - 8	6
Bar/cocktail lounge	Customer	2 - 4	3
Shopping Center	Employee	7 - 13	10
	Parking Space	1 - 3	2
Theater	Seat	2 - 4	3

Table 2-A.2. Typical Wastewater Flow Rates from Institutional Sources
(Source: Crites and Tchobanoglous, 1998)

FACILITY	UNIT	Flow, gallons/unit/day	
		Range	Typical
Assembly Hall	Seat	2 - 4	3
Hospital, Medical	Bed	125 -240	165
	Employee	5 - 15	10
Hospital, Mental	Bed	75 - 140	100
	Employee	5 - 15	10
Prison	Inmate	80 - 150	120
	Employee	5 - 15	10
Rest Home	Resident	50 - 120	90
	Employee	5 - 15	10
School, day-only:			
With cafeteria, gym, showers	Student	15 - 30	25
With cafeteria only	Student	10 - 20	15
Without cafeteria, gym, or showers	Student	5 - 17	11
School, boarding	Student	50 - 100	75

Table 2-A.3. Typical Wastewater Flow Rates from Commercial Sources
(Source: Crites and Tchobanoglous, 1998**)**

FACILITY	UNIT	Flow, gallons/unit/day	
		Range	Typical
Apartment, resort	Person	50 - 70	60
Bowling Alley	Alley	150 - 250	200
Cabin, resort	Person	8 - 50	40
Cafeteria	Customer	1 - 3	2
	Employee	8 - 12	10
Camps:			
Pioneer Type	Person	15 - 30	25
Children's, with central toilet/bath	Person	35 - 50	45
Day, with meals	Person	10 - 20	15
Day, without meals	Person	10 - 15	13
Luxury, private bath	Person	75 - 100	90
Trailer Camp	Person	75 - 125	125
Campground-developed	Person	20 - 40	30
Cocktail Lounge	Seat	12 - 25	20
Coffee Shop	Customer	4 - 8	6
	Employee	8 - 12	10
Country Club	Guests on-site	60 - 130	100
	Employee	10 -15	13
Dining Hall	Meal Served	4 - 10	7
Dormitory/bunkhouse	Person	20 - 50	40
Fairground	Visitor	1 - 2	2
Hotel, resort	Person	40 - 60	50
Picnic park, flush toilets	Visitor	5 - 10	8
Store, resort	Customer	1 - 4	3
	Employee	8 - 12	10
Swimming Pool	Customer	5 - 12	10
	Employee	8 - 12	10
Theater	Seat	2 - 4	3
Visitor Center	Visitor	4 - 8	5

CHAPTER 13

Plant Flow Measurement and Sampling

13.1 Purpose

13.2 Flow Measurement

13.2.1 General Considerations
13.2.2 Parshall Flumes
13.2.3 Sharp Crested Weirs
13.2.4 Venturi and Modified Flow Tube Meters
13.2.5 Other Flow Metering Devices
13.2.6 Hydrograph Controlled Release (HCR) Systems

13.3 Sampling

13.3.1 Automatic Sampling Equipment
13.3.2 Manual Sampling
13.3.3 Long Outfall Lines
13.3.4 Sampling Schedules

PLANT FLOW MEASUREMENT AND SAMPLING

13.1 Purpose

Complete and accurate flow measuring and sampling are essential in the proper treatment of wastewater. Compliance with discharge limits requires proper flow measurement and sampling. They provide the operator with the information to optimize process control and operational costs, as well as providing an accurate data base of flows and process performance which can be used to analyze changes in operational strategy or assist future plant design.

13.2 Flow Measurement

13.2.1 General Considerations

13.2.1.1 Facilities for measuring the volume of sewage flows should be provided at all treatment works.

13.2.1.2 Plants with a capacity equal to or less than 100,000 gallons per day (gpd) shall be equipped, as a minimum, with a primary metering device such as: a Parshall flume having a separate float well and staff gauge, a weir box having plate and staff gauge, or other approved devices. Continuous recording devices may be required where circumstances warrant.

13.2.1.3 Plants having a capacity of greater than 100,000 gpd shall be provided with indicating, recording, and totalizing equipment using strip or circular charts and with flow charts for periods of 1 or 7 days. The chart size shall be sufficient to accurately record and depict the flow measured.

13.2.1.4 Flows passed through the plant and flows bypassed shall be measured in a manner which will allow them to be distinguished and separately reported.

13.2.1.5 Measuring equipment shall be provided which is accurate under all expected flow conditions (minimum initial flow and maximum design peak flow). The accuracy of the total flow monitoring system (primary device, transmitter, and indicator) must be acceptable. The effect of such factors as ambient temperature, power source voltage, electronic interference, and humidity should be considered. Surges must be eliminated to provide accurate measurement.
Two primary devices and flow charts may be required in some cases.

13.2.1.6 Metering devices within a sewage works shall be located so that recycle flow streams do not inadvertently affect the flow measurement. In some cases, measurement of the total flow (influent plus recycle) may be desirable.

13.2.1.7 All clarifiers must be provided with a means for accurate flow measurement of sludge wasting and sludge return lines so that solids handling can be controlled. Sludge digesters, thickeners, and holding tanks should be provided with some way to determine the volume of sludge added or removed. This can be accomplished by a sidewall depth scale or graduation in batch operations.

13.2.1.8 Flow meter and indicator selection should be justified considering factors such as probable flow range, acceptable headloss, required accuracy, and fouling ability of the water to be measured. For more detailed information the consultant is encouraged to read the EPA Design Information Report "Flow Measurement Instrumentation"; Journal WPCF, Volume 58, Number 10, pp. 1005-1009. This report offers many installation details and considerations for different types of flow monitoring equipment.

13.2.1.9 Flow splitter boxes shall be constructed so that they are reliable, easily controllable, and accessible for maintenance purposes.

13.2.1.10 Where influent and effluent flow-proportional composite sampling is required, separate influent and effluent flow measuring equipment is required.

13.2.1.11 Consideration should be given to providing some types of flow meters with bypass piping and valving for cleaning and maintenance purposes.

13.2.2 Parshall Flumes

Parshall Flumes are ideal for measuring flows of raw sewage and primary effluents because clogging problems are usually minimal.

The properly sized flume should be selected for the flow range to be encountered. All Parshall Flumes must be designed to the specified dimensions of an acceptable reference.

The following requirements must be met when designing a Parshall Flume.

13.2.2.1 Flow should be evenly distributed across the width of the channel.

13.2.2.2 The crest must have a smooth, definite edge. If a liner is used, all screws and bolts should be countersunk.

13.2.2.3 Longitudinal and lateral axes of the crest floor must be level.

13.2.2.4 The location of the head measuring points (stilling well) must be two-thirds the length of the converging sidewall upstream from the crest. Sonar-type devices are only acceptable when foaming or turbulance is not a problem.

13.2.2.5 The pressure tap to the stilling well must be at right angles to the wall of the converging section.

13.2.2.6 The invert (i.e., inside bottom) of the pressure tap must be at the same elevation as the crest.

13.2.2.7 The tap should be flush with the flume side wall and have square, sharp corners free from burrs or other projections.

13.2.2.8 The tap pipe should be 2 inches in size and be horizontal or slope downward to the stilling well.

13.2.2.9 Free-flow conditions shall be maintained under all flow rates to be encountered by providing low enough elevations downstream of the flume. No constrictions (i.e., sharp bends or decrease in pipe size) should be placed after the flume as this might cause submergence under high flow conditions.

13.2.2.10 The volume of the stilling well should be determined by the conditions of flow. For flows that vary rapidly, the volume should be small so that the instrument float can respond quickly to the changes in rate. For relatively steady flows, a large-volume stilling well is acceptable. Consideration should be given to protecting the stilling well from freezing.

13.2.2.11 Drain and shut-off valves shall be provided to empty and clean the stilling well.

13.2.2.12 Means shall be provided for accurately maintaining a level in the stilling well at the same elevation as the crest in the flume, to permit adjusting the instrument to zero flow conditions.

13.2.2.13 The flume must be located where a uniform channel width is maintained ahead of the flume for a distance equal to or greater than fifteen (15) channel widths.
The approach channel must be straight and the approaching flow must not be turbulent, surging, or unbalanced. Flow -lines should be essentially parallel to the centerline of the flume.

13.2.3 Sharp Crested Weirs

The following criteria are for V-notch weirs, rectangular weirs with and without end contractions, and Cipolletti weirs. The following details must be met when designing a sharp crested weir:

13.2.3.1 The weir must be installed so that it is perpendicular to the axis of flow. The upstream face of the bulkhead must be smooth.

13.2.3.2 The thickness of the weir crest should be less than 0.1 inch or the downstream edge of the crest must be relieved by chamfering at a 45° angle so that the horizontal (unchamfered) thickness of the weir is less than 0.1 inch.

13.2.3.3 The sides of rectangular contracted weirs must be truly vertical. Angles of V-notch weirs must be cut precisely. All corners must be machined or filed perpendicular to the upstream face so that the weir will be free of burrs or scratches.

13.2.3.4 The distance from the weir crest to the bottom of the approach channel must be greater than twice the maximum weir head and is never to be less than one foot.

13.2.3.5 The distance from the sides of the weir to the side of the approach channel must be greater than twice the maximum weir head and is never to be less than one foot (except for rectangular weirs without end contractions.

13.2.3.6 The nappe (overflow sheet) must touch only the upstream edges of the weir crest or notch. If properly designed, air should circulate freely under and on both sides of the nappe. For suppressed rectangular weirs (i.e., no contractions), the enclosed space under the nappe must be adequately ventilated to maintain accurate head and discharge relationships.

13.2.3.7 The measurement of head on the weir must be taken at a point at least four (4) times the maximum head on the crest upstream from the weir.

13.2.3.8 The cross - sectional area of the approach channel must be at least eight (8) times that of the nappe at the crest for a distance upstream of 15-20 times the maximum head on the crest in order to minimize the approach velocity.
The approach channel must be straight and uniform upstream of the weir for the same distance, with the exception of weirs with end contractions where a uniform cross section is not needed.

13.2.3.9 The head on the weir must have at least three (3) inches of free fall at the maximum downstream water surface to ensure free fall and aeration of the nappe.

13.2.3.10 All of the flow must pass over the weir and no leakage at the weir plate edges or bottom is permissable.

13.2.3.11 The weir plate is to be constructed of a material equal to or more resistant than 304 Stainless Steel.

13.2.4 Venturi and Modified Flow Tube Meters

The following requirements should be observed for application of venturi meters:

13.2.4.1 The range of flows, hydraulic gradient, and space available for installation must be suitable for a venturi meter and are very important in selecting the mode of transmission to the indicator, recorder, or totalizer.

13.2.4.2 Venturi meters shall not be used where the range of flows is too great or where the liquid may not be under a positive head at all times.

13.2.4.3 Cleanouts or handholes are desirable, particularly on units handling raw sewage or sludge.

13.2.4.4 Units used to measure air delivered by positive - displacement blowers should be located as far as possible from the blowers, or means should be provided to dampen blower pulsations.

13.2.4.5 The velocity and direction of the flow in the pipe ahead of the meter can have a detrimental effect on accuracy. There should be no bends or other fittings for 6 pipe diameters upstream of the venturi meter, unless treated effluent is being measured when straightening vanes are provided.

13.2.4.6 Other design guidelines as provided by manufacturers of venturi meters should also be considered.

13.2.5 Other Flow Metering Devices

Flow meters, such as propeller meters, magnetic flow meters, orifice meters, pitot tubes, and other devices, should only be used in applications in accordance with the manufacturer's recommendations and design guidelines.

RULES
OF
THE TENNESSEE DEPARTMENT OF ENVIRONMENT AND CONSERVATION
BOARD OF WATER AND WASTEWATER OPERATOR CERTIFICATION

CHAPTER 0400-49-01
RULES GOVERNING WATER AND WASTEWATER OPERATOR CERTIFICATION

TABLE OF CONTENTS

0400-49-01-.01	Application for Certificate
0400-49-01-.02	Examinations
0400-49-01-.03	Fees
0400-49-01-.04	General
0400-49-01-.05	Definitions
0400-49-01-.06	Classifications of Water Treatment Plants and Water Distribution Systems
0400-49-01-.07	Classifications and Qualifications of Water Treatment Plant Operators and Water Distribution System Operators
0400-49-01-.08	Classification of Wastewater Treatment Plants and Wastewater Collection Systems
0400-49-01-.09	Classifications and Qualifications of Wastewater Treatment Plant Operators and Wastewater Collection System Operators
0400-49-01-.10	Continuing Education
0400-49-01-.11	Summary Suspension and Revocation of Certificate
0400-49-01-.12	Civil Penalties

0400-49-01-.01 APPLICATION FOR CERTIFICATE.

(1) Application for certification by examination.

(a) A separate application for each certification shall be made on an original form approved by the Board for that purpose and available upon request from the Secretary of the Board.

(b) An application for certification must be submitted to the Secretary of the Board and include the following items:

1. A sworn application signed by the applicant.

2. Payment of a non-refundable $100 fee for each application for examination.

3. A copy of any verifying document in support of an application must be submitted with the application unless the applicant has previously provided such documentation to the Secretary of the Board. This includes, but is not limited to, proof of high school education or equivalent of the applicant. College transcripts, if needed to document experience credit, must be submitted directly from the college and/or university to the Secretary to the Board. Credit for enrollment in special training courses and programs will only be granted to an applicant upon verification that he/she satisfactorily completed all course or program requirements. If training credit is requested, a copy of a course attendance card, a class roster, or a certificate of completion must be submitted to the Secretary. Verification of work experience must be provided in a written document signed by a certified operator of a similar or higher classification, familiar with the applicant's work experience. However, if no such person is available, it may be documented by a person in authority with the system. The Board may exempt applicants from the verification of work experience requirement where there are unusual circumstances.

(c) A complete application must be received by the Secretary sixty (60) days or more in advance of the scheduled examination date for consideration. Applications received less than sixty (60) days prior to an examination date will be reviewed for the next examination. Upon written request by an applicant, the Board may choose to review,

(Rule 0400-49-01-.02, continued)

(5) An applicant shall be notified in writing whether his/her examination score was satisfactory for the issuance of a certificate.

(6) An applicant who fails to achieve a satisfactory score may reapply for the next examination by submitting an abbreviated application for examination with fees, but he/she shall not be eligible to take another examination for the particular operator classification which he/she failed until five months have elapsed from the date that examination was taken.

(7) All examinations shall be administered by the Board or its authorized representatives who are empowered to maintain the integrity of all examinations.

(8) (a) An applicant shall be guilty of cheating upon a written examination who does an act including, but not limited to, the following:

1. violates paragraph (2) of this rule; or

2. without express authorization from examination officials,

(i) removes examination materials furnished by the Board or the written examination itself, in whole or in part, from the examination room, or

(ii) aids another applicant in answering examination questions during a written examination; or

3. violates the examination rules.

(b) Upon a determination by the Commissioner that an applicant is guilty of cheating upon a written examination for a particular operator classification, the applicant shall not be issued an initial certificate of competency for that classification.

(c) An applicant shall be ineligible to again apply for certification in that same operator classification for one year from the date the determination of cheating becomes final.

Authority: *T.C.A. §§ 4-5-201 et seq. and 68-221-901 et seq.* ***Administrative History:*** *Original rule filed May 21, 2014; effective August 19, 2014. Rule renumbered from 1200-05-03. Amendments filed January 18, 2017; effective April 18, 2017.*

0400-49-01-.03 FEES.

(1) Fees for Certification

(a) Fees for certification shall be required of each applicant and paid in advance as follows:

1. Application fee for each operator examination or reciprocity request applied for ……………………………………………………………………………………$100

2. Discount annual renewal fee for each operator certificate:
(Payment prior to February 1)………………………………………………………………$50

3. Standard annual renewal fee for each operator certificate:
(Payment from February 1 through June 30.)…………………………………………$100

(b) No application fee will be returned.

(Rule 0400-49-01-.03, continued)

(c) Upon payment of an application fee and approval by the Board, an applicant may take any one scheduled examination during the following twelve (12) months. If an applicant chooses not to take or fails to appear for, the first examination offered after receiving approval, the applicant must register on a form approved by the Board to be scheduled for a subsequent exam within the established time. The registration must occur sixty (60) days in advance of the examination he/she wishes to take. If an applicant does not take the examination within twelve (12) months of the Board's approval, he/she must reapply by submitting a new application with fees in order to be considered to take a subsequent examination.

(d) Each year a certified operator shall submit to the Board for the following year a completed certificate renewal application and a fee for the renewal of each operator certificate he/she possesses. Applications received prior to February 1 of each year shall be subject to discount renewal fees. Applications received February 1 through June 30 of each year shall be subject to standard renewal fees. Any person failing to meet the June 30 deadline may, within sixty (60) days of the deadline, request that the Board grant a variance. A variance may be granted when the delay was caused by Board or staff error, Board action, or documented postal error. A completed certificate renewal application or appropriate annual renewal fee for an expired certificate not received by the Board by June 30 shall preclude the recertification of the operator in his/her expired classification until he/she shall have fulfilled all the requirements for the issuance of an initial certificate in that classification, including the satisfactory completion of a written examination. When an operator classification is upgraded, the certificate he/she was upgraded from becomes void; and no additional fee payment is necessary until renewal.

(2) Fees for Cross Connection Control Training Registration

(a) Fees for Cross Connection Control Training registration shall be required of each person and paid in advance as follows:

1. Registration fee for a Cross Connection Control Basic Class (full time employees of public water systems as defined in T.C.A. § 68-221-703 and Department employees who assist with cross connection control training or testing classes are exempt)......... …………………………………………………………………..$275

2. Registration fee for a Cross Connection Control Renewal Class (full time employees of public water systems as defined in T.C.A. § 68-221-703 and Department employees who assist with cross connection control training or testing classes are exempt).……………………………………………………... $110

(b) No registration fee will be returned.

(c) The registration fee must be received thirty (30) days in advance of the class he/she wishes to take.

(3) Fees for Cross Connection Control Testing Application

(a) Fees for Cross Connection Control Testing Application shall be required of each person and paid in advance as follows:

1. Application for a Cross Connection Control Basic Test (Department employees who assist with cross connection control training or testing are exempt)…...........................….............................…....................................$60

(Rule 0400-49-01-.03, continued)

2. Application fee for Cross Connection Control Renewal Test (Department employees who assist with cross connection control training or testing are exempt)...................... ....$60

(b) Application fees are not refundable or transferable.

(c) The application for testing conducted by the Department must be received a minimum of thirty (30) days in advance of the test he/she wishes to take, however, applications from private institutions may be received the day the test materials are submitted to the Fleming Training Center.

(d) Prior to sitting for a test, an applicant must present proof of completion of training accepted by the Department for the appropriate test. Basic training may be accepted by the Department if it has a minimum class length of 480 minutes (300 minutes minimum in classroom), including but not limited to the following topics: hydraulic and backflow principles, theory of backflow and cross connection, codes and regulations of a cross connection control program, responsibilities and actions in a cross connection control program and mechanical equipment for cross connection control. Acceptable training must also provide a minimum of one working practice station and test kit for each three students. Renewal training may be accepted by the Department if it has a minimum class length of 300 minutes (180 minutes minimum in classroom) including but not limited to the following topics: hydraulic and backflow principles, theory of backflow and cross connection, codes and regulations of a cross connection control program, responsibilities and actions in a cross connection control program and mechanical equipment for cross connection control. Acceptable training must also provide a minimum of one working station and test kit for each three students.

(e) An applicant must take the test within twelve (12) months of receipt of the training certificate.

Authority: *T.C.A. §§ 4-5-201 et seq., 68-203-101 et seq., 68-221-901 et seq.* ***Administrative History:*** *Original rule filed May 21, 2014; effective August 19, 2014. Rule renumbered from 1200-05-03. Amendments filed January 18, 2017; effective April 18, 2017.*

0400-49-01-.04 GENERAL.

(1) Certification under T.C.A. §§ 68-221-901 et seq., being the “Water and Wastewater Operator Certification Act,” is available to any operator of a water treatment plant, a wastewater treatment plant, a water distribution system, or a wastewater collection system who meets the minimum qualifications of a given classification.

(2) Each person in direct charge at a water treatment plant, a wastewater treatment plant, a water distribution system, or a wastewater collection system shall hold a certificate in a grade equal to or higher than the grade of the treatment plant, distribution system, or collection system he/she operates. The grade of a facility will be established by the criteria set forth in this chapter of rules.

(3) All operating personnel making process control/system integrity decisions about water quality or quantity that affect public health must be certified. A designated certified operator must be available for each operating shift.

(4) Each water supply system and wastewater system required to have a certified operator shall, no later than the first day of August annually, inform the Board, through its designated agent, the Division of Water Resources, in writing of the name of each person who is a certified operator in direct charge of any water treatment plant, wastewater treatment plant, water

(Rule 0400-49-01-.04, continued)

distribution system or wastewater collection system it operates. A system shall notify the Division of Water Resources in writing within thirty (30) days of its loss of the services of a certified operator in direct charge.

(5) A certified operator shall be responsible for keeping the Board Secretary informed of his/her current address.

Authority: *T.C.A. §§ 4-5-201 et seq. and 68-221-901 et seq.* ***Administrative History:*** *Original rule filed May 21, 2014; effective August 19, 2014. Rule renumbered from 1200-05-03.*

0400-49-01-.05 DEFINITIONS.

(1) "Available" means that a certified operator must be on site or able to be contacted as needed to initiate the appropriate action in a timely manner, based on system size, complexity and the quality of either the source water or the receiving stream.

(2) "Board" means the board of certification as described in T.C.A. § 68-221-905.

(3) "Commissioner" and "Department" mean the Commissioner of the Tennessee Department of Environment and Conservation or his/her duly authorized representative.

(4) "Operating Shift" is that period of time during which operator decisions that affect public health are necessary for proper operation of the system.

(5) "Process control/system integrity decisions" means decisions regarding the manipulation of equipment, chemicals or processes that determine the quality and quantity of the water supplied by a water treatment plant or a water distribution system, or the quality of the effluent from a wastewater treatment plant or the integrity of a wastewater collection system.

(6) "Person in direct charge" as used in these rules means the person or persons expressly designated to be in direct charge and so named in writing to the Board's authorized representative by each water supply system and wastewater system, whose decisions and directions to system personnel control the manipulation of equipment and thereby determine the quality and quantity of the water supplied by a water treatment plant or a water distribution system, or the quality of the effluent from a wastewater treatment plant or the integrity of a wastewater collection system.

Authority: *T.C.A. §§ 4-5-201 et seq. and 68-221-901 et seq.* ***Administrative History:*** *Original rule filed May 21, 2014; effective August 19, 2014. Rule renumbered from 1200-05-03.*

0400-49-01-.06 CLASSIFICATION OF WATER TREATMENT PLANTS AND WATER DISTRIBUTION SYSTEMS.

(1) Water treatment plants shall be classified by the Board or its authorized representative into one of five groups, designated either as Small Water, Grade I, II, III, or IV. These classifications shall be made according to the number of population served, the type of treatment plant, and the complexity of treatment required for a particular water.

(2) The classification of a water treatment plant or a water distribution system may be changed by the Board or its authorized representative because of changes in the conditions or the circumstances upon which the original classification was based. Notice of such a classification change shall be given to the management officers of the plant or system.

(3) Types of Water Systems:

(Rule 0400-49-01-.08, continued)

Push-button or visual methods for simple tests such as pH, settleable solids ...…………………………………………………………….. 3 pts.
Additional procedures such as DO, COD, BOD, gas analysis, titrations, solids, volatile content …………………………………………….. 5 pts.
More advanced determinations such as specific nutrients, total oils, phenols, etc …………………………………………………………... 7 pts.
Highly sophisticated instrumentation such as atomic absorption and gas chromatography ……………………………………………………10 pts.

These terms describe the minimum level of effluent quality attainable for treated wastewater under standard design conditions in terms of the arithmetic mean of the values for effluent samples collected in a period of thirty (30) consecutive days for the following parameters: five-day biochemical oxygen demand (BOD_5); total suspended solids (TSS); and acidity/alkalinity (pH).

1. "Equivalent to secondary wastewater treatment" means the 30-day average for BOD_5 does not exceed 45 mg/l and there is no ammonia limit.

2. "Secondary wastewater treatment" means the 30-day average for BOD_5 does not exceed 30 mg/l and there is no ammonia limit.

3. "Advanced secondary wastewater treatment" means that the biochemical oxygen demand is expressed as the carbonaceous form ($CBOD_5$) that is equal to or greater than 10 mg/l and is equal to or less than 25 mg/l; and there is an ammonia limit.

4. "Tertiary wastewater treatment" means that the $CBOD_5$ is less than 10 mg/l and there is an ammonia limit.

(b) Grade I Collection System. This classification is for a wastewater collection system that uses collector and/or transmission lines to transport wastewater to a treatment plant and which serves no more than five thousand (5,000) service connections.

(c) Grade II Collection System. This classification is for a wastewater collection system that uses collector and/or transmission lines to transport wastewater to a treatment plant and which serves more than five thousand (5,000) service connections.

Authority: *T.C.A. §§ 4-5-201 et seq. and 68-221-901 et seq.* ***Administrative History:*** *Original rule filed May 21, 2014; effective August 19, 2014. Rule renumbered from 1200-05-03.*

0400-49-01-.09 CLASSIFICATIONS AND QUALIFICATIONS OF WASTEWATER TREATMENT PLANT OPERATORS AND WASTEWATER COLLECTION SYSTEM OPERATORS.

(1) (a) Grade IV Wastewater Treatment Plant Operator

Certification as an operator in this classification will be made only upon the satisfactory completion by the applicant of the requirements of either parts 1 or 2 of this subparagraph.

1. An applicant must have a bachelor degree in engineering, chemistry or a related science from an accredited college or university, must have twelve (12) months of operating experience at a Grade III or a Grade IV Wastewater Treatment plant, and must satisfactorily complete a written examination.

(Rule 0400-49-01-.09, continued)

Pumps
Lift stations
Valves
Lines and equipment
Pipeline installation
Service connection installation
Leak detection
TV crew activities
Line repairs
Line cleaning
Manhole maintenance
Pretreatment

(5) Summary of Wastewater Treatment Plant and Collection System Operator Education and Experience

Wastewater Treatment Plant Operators

Classification	Experience			Maximum Training or College Classwork Substitution	Maximum Related Work Substitution
	Experience needed with:	HS Education	BS Degree		
Grade IV	Gained at a Grade III or IV Wastewater Plant	*60 months	12 Months	36 Months	24 Months
*Regardless of the substitution allowances, a minimum of 1 year of actual work experience is required					
Grade III	Gained at a Grade II or III Wastewater Plant	12 Months		3 Months	
Grade II	Gained at a Grade I or II Wastewater Plant	12 Months		3 Months	
Grade I	Gained at a Grade I Wastewater Plant	12 Months		3 Months	
	Gained at Biological/Natural and Grade I Wastewater Plant	12 Months 6 Months			
Grade BNS	Gained at a BNS Wastewater Plant	12 Months		3 Months	

COLLECTION SYSTEM OPERATORS

Classification	Experience		Maximum Training or College Classwork Substitution	Maximum Related Work Substitution
	Experience needed with:	HS Education		
Grade II	Gained at a Collection I or II System	12 Months	3 Months	
Grade I	Gained at a Collection I or II System	12 Months	3 Months	

Authority: *T.C.A. §§ 4-5-201 et seq. and 68-221-901 et seq.* ***Administrative History:*** *Original rule filed May 21, 2014; effective August 19, 2014. Rule renumbered from 1200-05-03.*

0400-49-01-.10 CONTINUING EDUCATION.

At least once during every continuing education period each certified operator shall satisfactorily complete the required number of continuing education hours approved by the Board for the particular type of certificate he/she holds. The continuing education period for a certified operator shall begin either with the date the certified operator obtained his/her certificate or the date the certified operator last satisfactorily completed the required number of continuing education hours and shall end at the conclusion of the annual continuing education term three (3) calendar years thereafter. An annual continuing education

(Rule 0400-49-01-.10, continued)
term shall begin each year on October 1 and shall end on September 30 of the following year. The failure of an operator to satisfactorily complete the required number of continuing education hours approved by the Board Secretary during his/her continuing education period shall be grounds for the denial of his/her application for the renewal of his/her certificate. An operator shall notify the Board Secretary upon his/her satisfactory completion of the continuing education requirement by furnishing appropriate documentation of course completion. Notification by the operator is not necessary in those cases where an agency notifies the Board Secretary of such activity. An operator that fails to satisfactorily complete the required number of continuing education hours during his/her continuing education period due to an unusual event such as an incapacitating illness or similar unavoidable circumstances may make a written request to the Board for an extension of time to do so. All requests by an operator for an extension of time to meet the continuing education requirement must be made in writing to the Board either within two (2) months of the elapsed continuing education period or by the date of return of the operator to active employment, whichever is later. All such requests must be accompanied by complete supporting documentation of the circumstances causing the failure to meet the continuing education requirement.

Authority: *T.C.A. §§ 4-5-201 et seq. and 68-221-901 et seq.* ***Administrative History:*** *Original rule filed May 21, 2014; effective August 19, 2014. Rule renumbered from 1200-05-03.*

0400-49-01-.11 SUMMARY SUSPENSION AND REVOCATION OF CERTIFICATE.

(1) An operator's certificate may be revoked when:

(a) In accordance with paragraph (2) of this rule, an operator has not used reasonable care, judgment, or the application of his/her knowledge in the performance of his/her duties as a certified operator, or

(b) In accordance with paragraph (3) of this rule, an operator is incompetent to perform those duties properly; or

(c) In accordance with paragraph (4) of this rule, an operator has practiced fraud or deception.

(2) An operator shall be deemed to have not used reasonable care, judgment, or the application of his/her knowledge in the performance of his/her duties if he/she does not comply with the laws, rules, permit requirements, or orders of any governmental agency or court which govern the water supply system or the wastewater system he/she operates. Such acts of noncompliance include but are not limited to the following:

(a) The intentional or the negligent failure by the operator or persons under his/her supervision to act that results in a water supply system facility or a wastewater system facility not operating in the manner in which it is capable of being operated for the performance of its designed function.

(b) The intentional or the negligent failure by the operator or persons under his/her supervision to comply with the monitoring, sampling, analysis, or reporting requirements for a water supply system facility or a wastewater system facility.

(c) The intentional or the negligent unlawful discharge of wastes from a water supply system facility or a wastewater system facility.

(d) The intentional or the negligent failure by the operator or persons under his/her supervision to notify the Department of conditions: which may affect the quantity or quality of water being supplied to the customers of a water supply system; which cause the pollution of the waters of the State of Tennessee; or, which are violative of a standard of water quality promulgated by any governmental agency.

(Rule 0400-49-01-.11, continued)

(3) An operator shall be deemed to be incompetent to perform his/her duties properly when he/she does not possess the basic skills and knowledge necessary to operate a water supply system facility or a wastewater system facility including laboratory functions or if he/she fails to have a system of verification and oversight of employees under his/her charge. Incompetency shall be determined by examining the technical skills of the operator in operating the type of facility of which he/she is in direct charge.

(4) An operator shall be deemed to have practiced fraud or deception as follows:

(a) Obtained his/her certificate through fraud, deceit, or the submission of inaccurate data regarding his/her qualifications upon his/her application for a certificate.;

(b) Has practiced fraud or deception during the performance of his/her duties as a certified operator; or

(c) Has prepared and/or signed reports of laboratory analysis results for the system that:

1. Contain inaccurate data and are known or should be known by the operator to be false; or,

2. Contain inaccurate data because the operator has not used reasonable care, judgment, or the application of his/her knowledge either in the performance of the laboratory analysis or in the preparation of the laboratory analytical reports.

(5) Revocation

(a) The Commissioner may initiate the process to revoke a certificate when he/she believes an operator has engaged in any of the activities set forth in paragraph (1) of this rule.

(b) The Commissioner shall give notice by mail to the affected operator of facts or conduct that warrants revocation of the certificate and give the affected operator an opportunity to show compliance with these rules by conducting an informal hearing as provided in T.C.A. § 4-5-320(c).

(c) After the T.C.A. § 4-5-320(c) informal hearing, if the Commissioner determines that the affected operator has failed to demonstrate compliance, the Commissioner shall issue a notice of hearing for revocation and include a recommendation to the Board to revoke and reinstate or not to reinstate the certificate. Any recommendation of reinstatement of the certificate shall include terms for such reinstatement.

(d) The notice of hearing for revocation shall contain the information required by part 1 of this subparagraph and be served in accordance with part 2 of this subparagraph.

1. The notice shall include:

(i) A statement of the time, place, nature of the hearing, and the right to be represented by counsel;

(ii) A statement of the legal authority and jurisdiction under which the hearing is to be held, including a reference to the particular sections of the statute and rules involved; and

(Rule 0400-49-01-.11, continued)

(iii) A short and plain statement of the facts or conduct that warrant a revocation. (If the Commissioner is unable to state the matters in detail at the time the notice is served, the initial notice may be limited to a statement of the issues involved. Thereafter, upon timely, written application a more definite and detailed statement shall be furnished ten (10) days prior to the time set the hearing.)

2. A copy of the notice of hearing shall be:

(i) Served upon the operator no later than thirty (30) days prior to the hearing date; and

(ii) Served by personal service, return receipt mail or equivalent carrier with a return receipt,

A person making personal service on the operator affected shall return a statement indicating the time and place of service, and a return receipt must be signed by the operator affected. However, if the affected operator evades or attempts to evade service, service may be made by leaving the notice or a copy of the notice at the affected operator's dwelling house or usual place of abode with some person of suitable age and discretion residing therein, whose name shall appear on the proof of service or return receipt card. Service may also be made by delivering the notice or copy to an agent authorized by appointment or by law to receive service on behalf of the affected operator, or by any other method allowed by law in judicial proceedings.

(6) Summary Suspension and Revocation

(a) The Commissioner may initiate the process of summary suspension and revocation of the certificate when the Commissioner believes that an emergency action is needed to protect the public health, safety or welfare.

(b) The Commissioner shall give a notice to the affected operator by any reasonable means and shall inform the affected operator of the intended action, the acts or conduct that warrants summary suspension and revocation of the certificate and hold an informal hearing, as provided in T.C.A. § 4-5-320(d), to give the operator an opportunity to address the issue of whether there is an emergency.

(c) The Commissioner shall appoint a hearing officer to conduct this T.C.A. § 4-5-320(d) hearing and the hearing shall be recorded and transcribed.

(d) After the informal hearing as provided in T.C.A. § 4-5-320(d), if the Commissioner determines that an emergency action is warranted, the Commissioner shall issue an Order of Summary Suspension and a notice of hearing for revocation and include a recommendation to the Board to reinstate or not to reinstate the certificate. Any recommendation of reinstatement of the certificate shall include terms for such reinstatement.

(e) The Order of Summary Suspension and the notice for revocation shall contain the information required by part (5)(d)1 of this rule and be served in accordance with part (5)(d)2 of this rule.

(f) When the Commissioner has issued an Order of Summary Suspension and Notice of Revocation, the Board shall conduct its revocation hearing and render a decision within ninety (90) days of the operator's summary suspension. In the event the Board does

(Rule 0400-49-01-.11, continued)

not render its decision within ninety (90) days of the operator's summary suspension, the Order of Summary Suspension shall expire and no longer be in force or effect. However, the Commissioner may reissue an Order of Summary Suspension in accordance with this paragraph, for a period not to exceed ninety (90) days.

(7) The revocation hearing before the Board shall be held in accordance with T.C.A. §§ 4-5-301 et seq. and Rule Chapter 1360-04-01 Uniform Rules of Procedure for Hearing Contested Cases Before State Administrative Agencies.

(8) The Board may revoke the certificate of an operator when it is found that the operator has practiced fraud or deception; that reasonable care, judgment or the application of such operator's knowledge was not used in performance of such operator's duties; or that the operator is incompetent to properly perform such operator's duties. If the certificate is revoked and is to be reinstated, the Board shall determine the timing, terms and conditions for reinstatement.

(9) An operator who receives an order of the Board for the revocation of his/her certificate may appeal the order to the Chancery Court of Davidson County within sixty (60) days.

(10) An operator whose certificate is revoked for failure to use reasonable care, judgment or the application of operator knowledge in performing the operator's duties or for incompetency shall be ineligible to again apply for certification as an operator for a minimum of one (1) year. An operator whose certificate is revoked for practicing fraud or deception, willfully violating regulations or permit conditions, or falsifying records and reports shall be ineligible to again apply for certification as an operator for a minimum of five years. When an operator whose certificate has been revoked has applied for a certificate after the minimum time has passed, the Board shall determine whether the operator has taken appropriate action to address the circumstances that were the cause of the revocation. The Board may request records and review his/her experience, education, training and past performance. The Board may request the former operator's presence at a meeting of the Board and interview him/her to assess the potential of future violations. After the reviews, the Board shall decide to accept or refuse the application.

Authority: *T.C.A. §§ 4-5-201 et seq. and 68-221-901 et seq.* ***Administrative History:*** *Original rule filed May 21, 2014; effective August 19, 2014. Rule renumbered from 1200-05-03.*

0400-49-01-.12 CIVIL PENALTIES.

(1) The Commissioner may assess the civil penalty authorized by law against a municipality, utility district, corporation, or any person operating a water supply system or a wastewater system if the competency of the person in direct charge of a system facility has not first been certified in accordance with these rules.

(2) A certified operator may be assessed the civil penalty authorized by law for the same acts and omissions that would constitute grounds for the revocation of his/her certificate by the Board.

(3) Prior to issuing an order that assess a civil penalty, in accordance with paragraphs (1) and (2) of this rule the Commissioner may hold a show cause meeting with the person or entity to whom the order is proposed to be issued.

Authority: *T.C.A. §§ 4-5-201 et seq. and 68-221-901 et seq.* ***Administrative History:*** *Original rule filed May 21, 2014; effective August 19, 2014. Rule renumbered from 1200-05-03.*

Continuing Education Requirements

The following hours of Continuing Education are required to maintain certification.

Certification Title	Number of Continuing Education Hours Needed
Biological/Natural Systems	6 hours every 3 years
Collection 1	6 hours every 3 years
Collection 2	6 hours every 3 years
Distribution 1	6 hours every 3 years
Distribution 2	6 hours every 3 years
Small Water System	6 hours every 3 years
Water Treatment 1	6 hours every 3 years
Water Treatment 2	6 hours every 3 years
Water Treatment 3	12 hours every 3 years
Water Treatment 4	12 hours every 3 years
Wastewater Treatment 1	6 hours every 3 years
Wastewater Treatment 2	6 hours every 3 years
Wastewater Treatment 3	12 hours every 3 years
Wastewater Treatment 4	12 hours every 3 years

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Beginning October 1, 2002