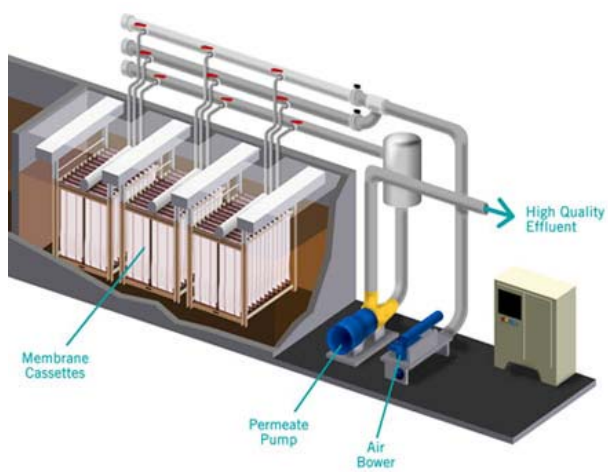
Advanced Water Treatment

Course # 3110



TENNESSEE DEPARTMENT OF ENVIRONMENT AND CONSERVATION

Fleming Training Center
March 4 – 8, 2013

http://www.tn.gov/environment/fleming/

Fleming Training Center

2022 Blanton Dr.
Murfreesboro, TN 37129

Phone: 615-898-6507
Fax: 615-898-8064
E-mail: Amanda.Carter@tn.gov

Fleming Training Center
Your Partner in Clean Water
http://tn.gov/environment/fleming

Advanced Water Treatment

Course # 3110

March 4-8, 2013

Monday, March 4:

8:30	Filters - Optimization and Performance	Amanda Carter
11:00	LUNCH	
12:15	Filters - Troubleshooting and Math	Amanda

Tuesday, March 5:

8:30	Pumps	Amanda
9:00	Part Identification	Amanda
10:30	Preventative Maintenance	Amanda
12:00	LUNCH	
1:15	Bacteriological Sampling and Plans	Amanda
2:30	Algae Identification	Amanda

Wednesday, March 6:

8:30	Membrane Filtration	Amanda
11:00	LUNCH	
1:30	Tour- Duck River WTP	

Thursday, March 7:

8:30	Fluoridation	Amanda
12:00	Lunch	
1:15	EOP	Amanda

Friday, March 8:

8:30	Safety	Amanda
9:45	Review for Exam	Amanda
11:00	LUNCH	
12:15	Exam and Course Evaluation	Amanda

Advanced Water Treatment

Section 1

Pumps
Part Identification
Preventive Maintenance
Predictive Maintenance

Pump Review

1

Pump Types

- There are two main types used in water treatment:
  - Positive displacement
    - Used for small volumes
    - More accurate
    - Chemical feeders
  - Centrifugal
    - Used for big flows

2

Centrifugal Pumps

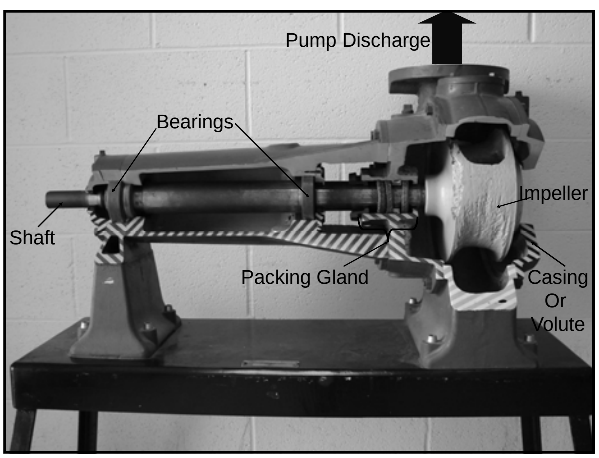
- Centrifugal pumps are velocity type pumps
- Most common type of pump found in water utilities
- Vary in size, shape and width of impeller
- Vary in a wide range of flows and pressures

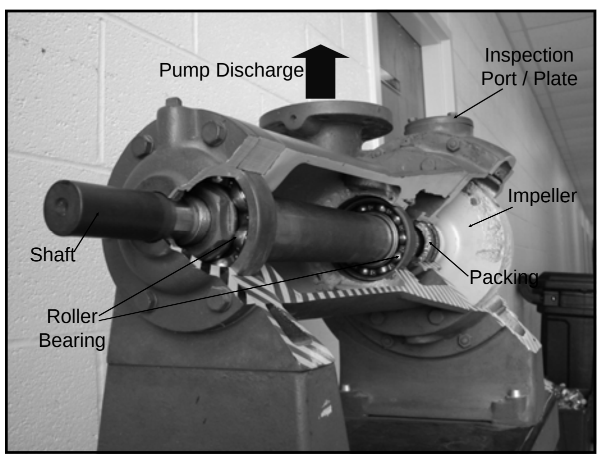
3

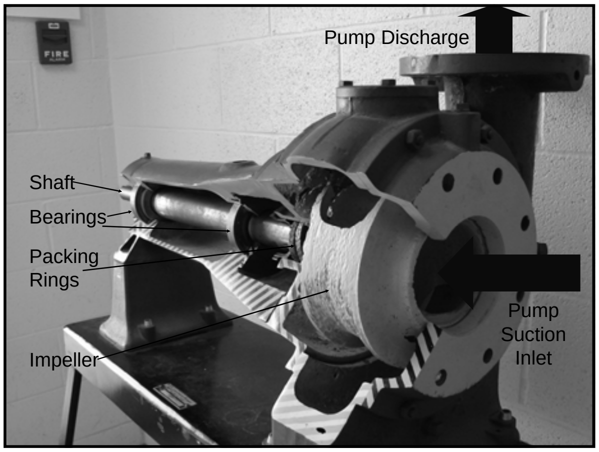
Centrifugal Pump Parts

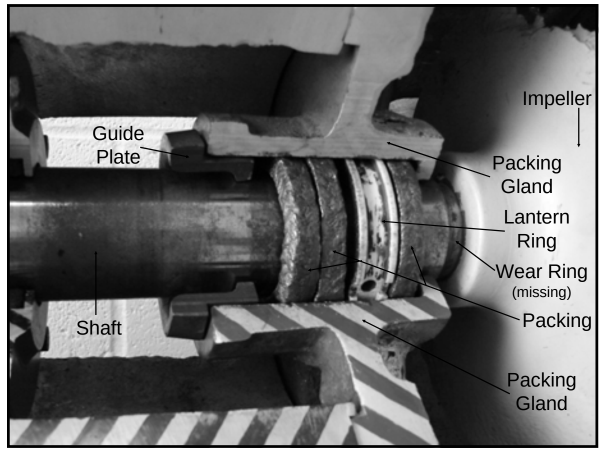
- Centrifugal pumps consist of many rotating parts
- Three designs for impellers
  - Axial
  - Radial
  - Mixed

4



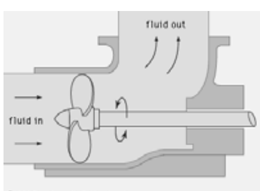


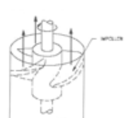




Axial Flow Design

- Propeller shaped impeller and adds head by lifting action on vanes

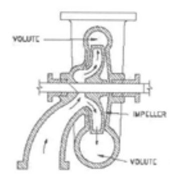




9

Radial Flow Design

- Flow from impeller is thrown outward
- Water enters from eye or center of impeller



10

Mixed Flow Design

- Impeller has both axial and radial flow design features combined

11

Mechanical Parts of Centrifugal Pumps

- Volute: the case or housing holding the impeller
  - Usually made of cast iron and spiral shape

12

Mechanical Parts of Centrifugal Pumps

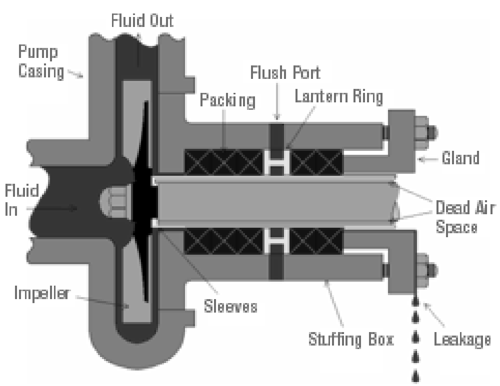
- Foot valve: a check valve placed in the bottom of the suction pipe which allows water to enter the casing to hold prime

13

Mechanical Parts

- Bearings: roller bearings support the pump shaft to guide rotation
- Packing: rings of graphite materials used to control leakage along the shaft
- Wear Rings: rings made of brass place on the impeller to control leakage of water from the the sides of the impeller

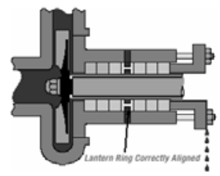
14

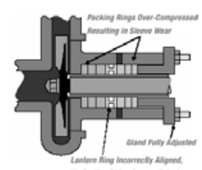


15

Mechanicals Parts

- Lantern Ring: a small perforated ring placed around the shaft to form a liquid seal that lubricates the packing

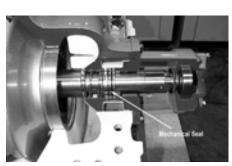




16

Mechanicals Parts

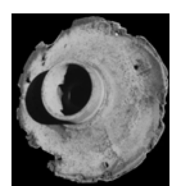
- Mechanical Seal: a seal placed on the pump shaft to prevent leakage along the shaft and leak proof
  - Also prevent air from entering the pump



17

Pump Operation

- Cavitation: a condition where a partial vacuum forms near the impeller blade and the pump case causing a pinging sound to implode against the impeller
  - Will damage the impeller causing the pitting condition of the metal



Pump Conditions

- Water Hammer: the potential damage occurred from closing water valves to quickly
  - The sudden change in water direction or water velocity creates great water pressure

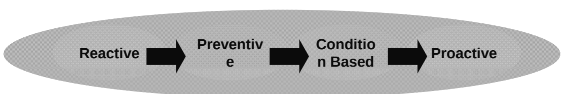
19

Pump Maintenance

Preventive and Predictive Maintenance

20

Operating Equipment Lifetime Management



"Fix it when it breaks"
•Costly
•Risky

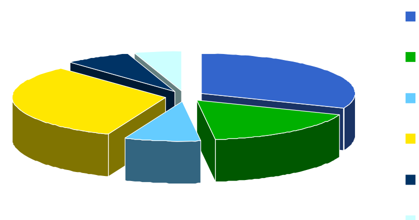
Scheduled
•Reduced failures
•Costly
•May cause damage

Determined by an objective measure of need
•More effective
•Safely eliminates PM
•Reduces capital

Preemptive action to optimize reliability, eliminate defects & avoid failure
•Most effective
•Minimizes failures
•Reduces capital

21

Lifetime Maintenance Costs



Over 60% of equipment lifetime maintenance cost were caused by preventable errors during design, procurement, installation, operation and maintenance.

22

Definitions

- Preventive maintenance is a schedule of maintenance activities aimed at the preventing of pump breakdowns and failures.
  - It is designed to preserve and enhance equipment operations by equipment checks, system overhauls, oil checks and other detailed maintenance checks on equipment.

23

Long Term Benefits of P/M

- Improved equipment reliability and longevity.
- Decrease in cost and replacement of parts.
- Decrease in down time of equipment.

24

Breakdown Maintenance

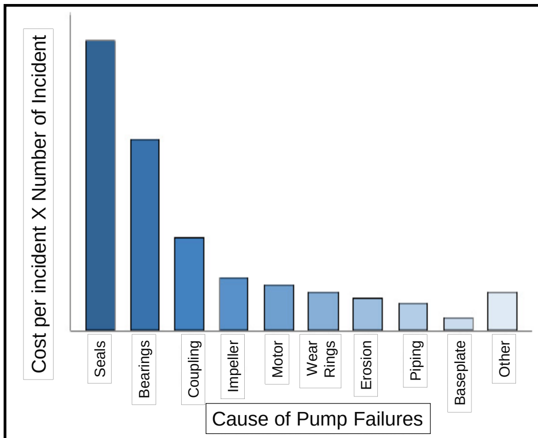
- Definition: includes the failure of equipment due to no Preventive maintenance measures
- Reasons for failures:
  - – No planning of servicing equipment
  - – No preventive measures, checks, service and monitors

25

Breakdown Maintenance

- Cost of breakdowns
  - – Loss time of the equipment
  - – Dollar cost of parts repair or replacement
  - – Customer service

26



Breakdown Maintenance

Avoid the breakdown failure mode
- – Bad operation habits
- – Run to fail
- – No P/M inspections
- – No equipment checks by operators

28

Goals of Preventive Maintenance

- Define P/M maintenance in your plant and establish some set goals of performance of equipment
- Locate equipment needs
  - – Look at a workable goal, start with something that can be achieved

29

Goals of Preventive Maintenance

- Describe and assign P/M functions
  - – Activities by operators
  - – Activities by maintenance personnel
- Describe the P/M function of equipment
  - – Perform P/M or SOP's
    - frequency of checks goals: week, month, year

30

Goals of P/M

- Define the scope of work and define the needs of maintenance or electrical work
- Establish the operations check on equipment operation
- Establish clear work goals. Focus on the frequency of equipment checks and historical trends of equipment
- Look at cost savings, increase run times
- Savings on parts and energy cost

31

Establish P/M Program

- Define the inspection check plan on equipment
- Define the frequency of inspection to a weekly or monthly inspection
- Define all the equipment involved or types of pumps, chlorine, feeders, chemicals, clarifiers, valves, water tanks, hydrants, meters

32

Establish P/M

- Locate equipment info on pump labels and tags

33

Establish P/M

- Locate OEM (Original Equipment Manuals), catalogs and web sites
- Locate operations SOP's on equipment
- Establish preventive maintenance SOP on each equipment or pump
- Train personnel, operators and staff on P/M schedules

34

P/M

- Record all P/m data, records on equipment and CMMS (Computer Management Maintenance Systems) files
- Create parts inventory listing
- Start a monthly list of P/M work orders to check equipment
- Start a weekly out of service inventory sheet for equipment, list causes and date to return to service

35

Check List

36

Preventive Maintenance Inspections

- Plan and schedule the work orders and seek your data on equipment
- Establish data recording levels of equipment settings, such as temperature and pressure settings
- Set equipment parameters for data
- Establish parameters for oil measures and temperatures and other settings

37

Inspections

- Establish run times of equipment
- Decide weekly or monthly check and frequency
- Record data and historic trends of equipment
- After 6 months establish less breakdowns
- Last phase, trend equipment toward predictive maintenance and consult with vibration analysis, oils analysis or thermal inspection

38

Predictive Maintenance

- Predictive maintenance will analyze equipment operations with a proactive predictive analysis of real time data of equipment operations and assessing the measurement technology available on equipment operations

Not to be done by operator.
Trained professionals are needed.

39

Predictive Maintenance

- Predictive processes include:
  - Vibration analysis
  - Laser alignment
  - Ultrasonic test
  - Heat thermography
  - Oil analysis
- Predictive maintenance uses technology to predict equipment operations and maintenance schedules.

40

Predictive Processes

- All pump and motors are tested for wear and run times of equipment for bearing wear
  - Laser alignment of pumps and motors for vibration analysis
  - Lubrication wear is tested for mineral deposits of bearing failure

41

Predictive Processes

- Down time failures are predicted and avoided
- Equipment conditioning to record on time telemetry of equipment run times and on line monitors
- Cost benefits of predictive maintenance to improve plant maintenance reduced failures and no downtimes
- Predictive processes can save money

42

Vibration Analysis

- Vibration analysis can identify defects such as:
  - Rotor unbalance,
  - Coupling misalignment,
  - Identify bearing frequency,
  - Mechanical looseness
- Vibration looks at frequency and severity of defects along with data trials.

43

Laser Alignment

- The balance of rotating assemblies with laser alignment and shaft balance.
- Shaft balance is measured at every 90 degree intervals.
- Also a post and return balance of equipment is required along with P/M records of equipment balance and wear indicators.

44

Heat Thermography

- Thermography is a predictive tool in electrical insulation of wear and damage
- On pumps, thermal indicators can predict:
  - Bearing heat and wear as an increase in shaft temps
  - And can predict failures or leakage
- More thermal testing of equipment is vital for needed predictive testing and base-lines of pumps and electrical equipment

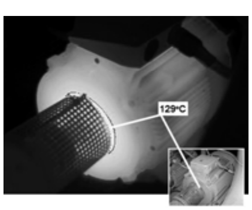
45

Heat Thermography

- Heat is one of the greatest wear indications of equipment and bearings and seals.
- Heat and temperature sensors on equipment are essential for proper operations.
- The use of thermal imaging on equipment is a key factor in location of hot spots on equipment.

46

Heat Thermography

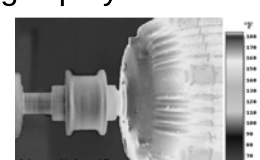


- Thermography uses a camera which produces an image of temperature variations on equipment with color intensity.
- Hot spots glow in yellow and red colors on the camera.

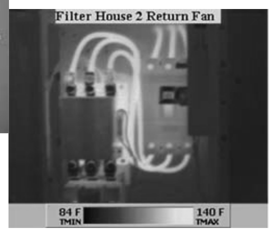
47

Heat Thermography

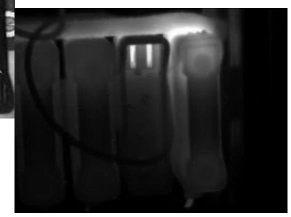
- Heat thermography is used to locate:
  - Loose electrical connections
  - Friable electrical insulation on wiring
  - Hot spots on electrical panels
  - Worn equipment and circuits



Heat Thermography

Heat Thermography

Shock Pulse and Ultrasonic Testing

- Shock Pulse and Ultrasonic testing of equipment continue to test the vibration frequency patterns of roller bearings and establish a base line of shaft operation to base a defective bearing against.

51

Ultrasonic Testing

- Ultrasonic testing can register audible sounds on headphones such as lifters on cams or valve actions and closings.

52

Oil Analysis

- Establish an need for an oil analysis of plant motors and pumps
- Locate current lubrication needs and types of oils and grease
- Schedule of lubrication inspect weekly or monthly

53

Oil Analysis

- What kinds of wear indicators are showing
- Used oil indicators and inspect for contamination
- Oil consumption indicators of seal failures

54

Oil Analysis

- Lubrication system rating of extended oil life
- Oil viscosity and rating
- Quality of my oils and grease or the cheapest grades
- Chemical oil testing of breakdowns due to heat,metals,sulfurs or moisture
- Oil filters include better filtration of impurities and clean equipment
- Keep records of oil schedules and results

55

Oil Analysis

- Establish the need for adequate lubrication of equipment
- Lubrication of equipment covers the selection of lubricants related to oil, grease, filters, rating viscosity, oil analysis and the handling or storage of oils

56

Lubricants

- Oil selection is based on OEM (Original Equipment Manufacturer) recommendations and design.
- Lube schedules and frequency establish along with system checks.
- Oil analysis of oils can use data of wear times and breakdown of oils and factors.

57

Oil Breakdowns

- Lubricants can be the cause to equipment failures
- Equipment or bearing wear due to fatigue
- Oil breakdown due to excessive heat on equipment
- Water or moisture leakage or contaminants in the oil such as dust or metals contamination

58

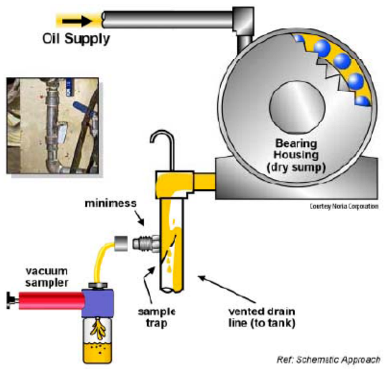
Oil Testing

- Oil inspection and proper sampling of equipment is needed
- Lab testing of oils inspect for:
  - Water
  - Dust
  - Metal content
  - Viscosity
  - Other contaminants and wear factors
- Oil temperature is key to life of oil usage

59

Metal shavings found in oil testing

60



61

Oil Longevity

- Wear indicators of oil require inspecting all equipment for moisture, leaks, leaking oil seals and filter replacements.
- Several P/M maintenance checks can locate oil leaks of pumps, seals and other maintenance needs.

62

Oil Schedules

- Plan oil schedules and lube records
- Plan all oil checks and changes
- Use index cards on oiling schedules Use data cards and sheets for each pump
- Indicate oil locations and types of oils

63

Oil Schedule – Recycle

- A good environmental response is always recycle spent oils
- Have a plan with local recycler and vendor

RECYCLE USED OIL

64

Oil Schedule – Recycle

- Have a spill protection plan
- Store all used oils to be recycle
- Use berms and soil dry
- Always recycle oil

65

Oil Schedule – Recycle

- Never pollute water ways or land areas

66

Cost Savings

- Providing results and proof of cost savings of predictive maintenance
- Less down time of equipment
- Operations of equipment are improved and less failures

67

CMMS

- Computer Maintenance Management System
  - CMMS is a computer driven maintenance management system of planned and work order driven maintenance reports and inspections.

68

CMMS

- Computer program of workorders
  - Predict time schedules and trend work maintenance of equipment
- Able to keep cost work times, parts and overtime
- Can keep parts inventory of all equipment
- Provide monthly summary reports of cost and work
- Also can contract out work service contracts

69

CMMS

- CMMS will generate a planned maintenance schedule of equipment services and work orders of scheduled work.
- CMMS will generate planned work schedules and inventory of work orders and data.

70

CMMS

- Produce cost summary and work time generation for maintenance cost.
- Produce yearly cost projections of maintenance cost and projections for failures
- Keep inventory of parts and service contracts
- Also complete inventory of tools and equipment or track chemical cost and usage.

71

End Results

- Complete process improvement of P/M
- Improved operations and less downtime
- Less equipment failures and reduced cost
- Conditioned equipment for complete life cycle
- A complete road map for plant maintenance.
- Start with training plant operators toward preventive maintenance.

72

Lasting Thoughts

- Plant maintenance has to be planned to operate and service equipment.Preventive measures have to be provided in timely schedules to prevent equipment failures.
- A planned preventative and predictive maintenance program will save you money and downtime of equipment and make plant operations more efficient.

73

FACILITY NAME:	MACHINE TYPE:	DATE (MM/DD/YY) (first working day of week):
FACILITY ID:	MACHINE ID:	

OPERATIONS AND MAINTENANCE CHECKLIST

DAILY ITEMS

CHECK THE FOLLOWING ITEMS DAILY
Check button trap and button trap screen AT LEAST once a day (more often if necessary). Place debris in sealed container.
Clean lint trap as often as required to avoid clogging fans and condensers. Place lint in sealed container.
Clean strainer in pre-lint filter (if applicable). Clean pump strainer. Place debris in sealed container.
Check all pressure gauges. Ensure proper operation pressures (refer to equipment operation manuals for specific requirements).
Empty wastewater collector into closed containers or wastewater processor (atomizer or evaporator).
Perform a visual leak inspection. This is a quick inspection – a thorough inspection should be accomplished weekly using the leak inspection checklist and a leak detector.
Check back pressure on cartridge filters, replace when manufacturer's recommended back pressure is reached. Drain filters for 24 hours (standard) or 48 hours (adsorptive), then place cartridges in sealed containers.
Check the still to ensure it does not exceed 75 percent of capacity (N/A for continuous stills).

WEEKLY CHECKLIST ITEMS

CHECK THE FOLLOWING ITEMS WEEKLY. CHECK-OFF AND INITIAL THE APPROPRIATE BOXES.					
WEEK	1	2	3	4	5
USE THE FIVE BOXES TO THE RIGHT TO ANNOTATE INSPECTION DATES					
INSPECTOR INITIALS					
Check pump for proper lubrication, flow rate and operation (refer to equipment owner's manual).					
Check air relief and diverter valves to ensure proper operation and closure.					
Check water separator for debris: empty into still and clean if necessary.					
Inspect and clean the still.					
Check the operation of waste eater treatment unit (if applicable). Replace carbon according to manufacturer's recommended frequency.					
Check to ensure the air-vapor stream downstream of the condenser is $\leq$ 45 deg F (7.2 deg C).					
Monitor carbon adsorber (if applicable) according to AQMD specifications.					

OTHER*

CHECK THESE ITEMS USING THE SUGGESTED FREQUENCY BELOW	DATE	INITIAL
Check the drive belts for proper tension and condition (Semi-Annually).		
Clean evaporative water towers to remove dirt and scale (Semi-Annually).		
Inspect cooling coils (condenser) for lint buildup and proper operating temperatures (Annually).		
Inspect cooling coils (still) for leaks, corrosion, and buildup (Annually).		
Check steam coils (heating) for lint buildup and proper drying temperatures (Annually).		
Check and clean all other machine areas (e.g., steam traps, fan blades, and air ducts).that may collect lint and affect proper operation (Annually).		
Check disk filters for damage and dry clean them (Annually).		
Change inductive door fan carbon (if applicable) (per manufacturer's recommendation).		
Lubricate (grease) fittings (per manufacturer's recommendation).		
Clean and inspect base solvent tanks (per manufacturer's recommendation).		

*This is a suggested frequency. Follow manufacturer's operating manual in cases where more frequent schedules are recommended.

Revised 4/17/96.

"Where Quality Is Measured and Certified"

PREVENTIVE MAINTENANCE FORM - VACUUM PUMP

CUSTOMER **SAMPLE REPORT**		PM SCHEDULE [ ] Annual [ ] Semi [X] Quarterly [ ] Monthly [ ] Other	**Document - PMF_VP2.2** Page 1 of 1
ADDRESS			
EQUIPMENT Vacuum Pump	MFG	DATE __/__/__	PM STATUS C - Completed; CA - Completed - Add'l parts/labor req'd; I - Incomplete - Add'l parts/labor req'd; X - Not Applicable
S/N	ID	DUE DATE __/__/__	

Check List	Status	Comments
Drain oil from reservoir, place into oil drain bucket.	C	Oil was low.
Remove oil filter & replace.	C	
Remove oil sight glass & clean as needed.	C	
Add approximately 7 quarts of vacuum oil.	C	
Remove exhaust filter cover plates & remove filter.	C	
Inspect exhaust chamber for excess oil, wipe out if needed.	C	
Check exhaust chamber; oil return line for clogging; clean if needed.	C	Cleaned return line.
Reinstall exhaust filter.	C	
Replace exhaust filter.	C	Next PM.
Re-install exhaust chamber cover.	C	
Inspect vacuum inlet filter.	C	
Wipe out interior of filter housing.	C	
Wipe exterior surfaces of pump free of debris & oil.	C	
Clean excess oil from floor.	C	
Remove & clean vacuum diverter valve, replace with new if needed.	C	
Reconnect vacuum pump to press.	C	

Pump Maintenance Checklist

Description	Comment	Maintenance Frequency			
		Daily	Weekly	Monthly	Annually
Pump use and sequencing	Turn off or sequence unnecessary motors.	X			
Overall visual inspection	Complete overall visual inspection to be sure all equipment is operating and safety systems are in place.	X			
Check lubrication	Assure that all bearings are lubricated per the manufacturer's recommendation.			X	
Check packing	Check packing for wear and repack as necessary. Consider replacing packing with mechanical seals.			X	
Motor and pump alignment	Align the pump/motor coupling to allow for efficient torque transfer to the pump.			X	
Check mountings	Check and secure all pump mountings.			X	
Check bearings	Inspect bearings and drive belts for wear. Adjust, repair, or replace as necessary.				X
Motor condition	Check the condition of the motor through temperature or vibration analysis to assure long life.				X

http://www1.eere.energy.gov/femp/operations_maintenance/printable_versions/om_pumpchecklist.html

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.

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.

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. Positive displacement pumps are rarely used for water distribution because:
    a. They require too much maintenance
    b. They are no longer manufactured
    c. They require constant observation
    d. Centrifugal pumps are much more efficient

13. Another name for double-suction pump is
    a. Double-jet pump
    b. Reciprocating pump
    c. Horizontal split-case pump
    d. Double-displacement pump

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

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

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

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

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

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

20. 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?

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Answers:

1. B
2. C
3. C
4. A
5. C
6. D
7. B
8. E
9. B
10. C
11. A
12. D
13. C
14. A
15. 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.
16. Volute casing and diffuser vanes.
17. Mixed-flow pump (the design used for most vertical turbine pumps)
18. 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.
19. 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.
20. Shaft-type and submersible-type vertical turbines.
21. A close-coupled vertical turbine with an integral sump or pot.
22. The jet pump consists of a centrifugal pump at the ground surface and an ejector nozzle below the water level.
23. Positive-displacement pumps are generally used in water plants to feed chemical into the water supply.
24. The foot valve prevents water from draining when the pump is stopped, so the pump will be primed when restarted.
25. The bolts holding the two halves of the casing together are removed and the top half is lifted off.
26. 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.
27. (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.
28. The pump impeller is mounted directly on the shaft of the motor.
29. 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.
30. 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.
31. During start-up.
32. (1) Increase system efficiency; (2) spread the pumping load more evenly throughout the day; (3) reduce power-factor charges
33. The bearings may run hot, and excess grease or oil could run out and reach the motor windings, causing the insulation to deteriorate.
34. The abrasive material on emery cloth is electrically conductive and could contaminate electrical components.
35. Imbalance of the rotating elements, bad bearings and misalignment
36. A condition called single-phasing can occur, causing the motor windings to overheat and eventually fail.

37. gasoline, propane, methane, natural gas and diesel oil (diesel fuel)
38. make, model, capacity, type, date and location installed, and other information for both the driver (motor) and the driven unit (pump)
39. 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 2

Filters

Optimizing and Performance
Troubleshooting
Math

Filter Evaluations

For Granular Media Filters

TDEC - Fleming Training Center 1

Preventive Maintenance

- Think of filter evaluation as preventive maintenance for your filters
  - Unfortunately filters have been evaluated due to a problem or "run to fail" attitude

TDEC - Fleming Training Center 2

Review Filter Design

- Before you begin, you need to know:
  - Type of media used
  - Different media depths for each grain size
  - Designed backflow rates
  - Effective size and uniformity coefficients of media
  - Appropriate backwash bed expansion

TDEC - Fleming Training Center 3

Review Water Quality

- Don't just look at the water quality being produced by the filter
- Look at the water quality leaving the sedimentation basins too

TDEC - Fleming Training Center 4

Water from Sed Basins

- Good rule of thumb
  - If your raw water turbidity is less than 10 NTU most of the time, then you should have about 1 NTU coming in from sedimentation basins
  - If your raw water turbidity is greater than 10 NTU most of the time, then you should have about 2 NTU coming in from sedimentation basins

TDEC - Fleming Training Center 5

Organization

- Remember organization is the key to good data
  - Each filter should have its own file or notebook

TDEC - Fleming Training Center 6

Equipment Needed

- Before starting the filter evaluation you must:
  - Read carefully each procedure
  - Gather all necessary equipment

TDEC - Fleming Training Center

Safety

- Remember, a filter bay is a considered a confined space, please take all necessary precautions before entering into filter bay
  - Use a ladder to enter the filter
  - Allow no more than one team member on the ladder at a time
  - Provide a source of forced air to the team members in the filter
  - Troughs can be walked down but not used to jump into the filter
  - No team member should enter the filter alone, practice the buddy system

TDEC - Fleming Training Center 8

Safety cont.

- Never walk directly on filter media
  - Use 2'x2' plywood boards
- Make sure filter is completely drained before entering

Safety cont.

- While fluidizing the media AND a person HAS to be in the filter bay, it is recommended that they should be attached to an emergency extraction harness and rope
  - NEVER fluidize the media while a person is standing on the surface of the media; they will disappear quickly into the filter media

Scheduling the Evaluation

- Inspections should be performed on a frequent basis
  - Annual is sufficient
- However, if a problem arises, then an evaluation should be performed more frequently
- Remember, filter will be out of service for at least a day, if not more

Review of Filtration Rules

Chapter 0400-45-01

Public Water System Rules

http://www.tn.gov/sos/rules_all/2012/0400-45-01.20121030.pdf

0400-45-1-.31(4)(c)

- The turbidity in the combined filter effluent must:
  - Be less than or equal to 0.3 NTU in at least 95% of measurements taken each month
  - And at no time exceed 1 NTU

TDEC - Fleming Training Center 13

Notes from Field Office

- Having a filter exceedance is not a violation
- The violation occurs when the water system fails to submit the filter exceedance report of denote a filter exceedance on the Filter Performance Report
  - It would be in the water system's best interest to go ahead and submit a filter exceedance report when in doubt rather than not submit a report at all

TDEC - Fleming Training Center 14

Notes from Field Office continued

- It may also be helpful for water systems to have a flow meter and be able to chart the flow of the effluent water going to the clear well against the turbidity

TDEC - Fleming Training Center 15

Notes from Field Office continued

- Also, the way the rules is written any measured turbidity level greater than 0.5 NTU in two consecutive readings 15 minutes apart requires a filter profile or obvious reason
  - This means if someone knocks the turbidimeter and the reading is elevated above 0.5 NTU for fifteen minutes or longer, they would technically need to report the filter exceedance
  - The obvious reason being someone bumped the turbidimeter

TDEC - Fleming Training Center 16

Notes from Field Office continued

- One example from the Field Office is that one water system had an elevated turbidity reading because a water system personnel sprayed the pipe gallery while cleaning
  - This would be an obvious reason as well

TDEC - Fleming Training Center 17

Notes from Field Office continued

- It may also be helpful for water systems to know that they use the filter data recorded on the back of the MOR to check plant operations, such as turbidity readings
- So it would be in their best interest to ensure the filter data section accurately reflects the daily operations of the filters

TDEC - Fleming Training Center 18

Notes from Field Office continued

- An example is if a system has eight filters and they know that two of the filters are out of service for two weeks
  - Then they would expect that the filter data would reflect this and not show that all eight filters were being used the entire month
  - This goes for the filter run time and could even be the amount of backwash water used

TDEC - Fleming Training Center 19

Levels Exceeded

- Depending on the exceedance level, the system must:
  - Produce a filter profile
  - Conduct a self-assessment and/or
  - Must arrange for the conduct of a comprehensive performance evaluation by the State or a 3rd party approved by the State

TDEC - Fleming Training Center 20

Filter Profile

- Is defined as a graphical representation of individual filter performance, based on continuous turbidity measurements or total particle counts versus time for an entire filter run, from startup to backwash inclusively, that includes an assessment of filter performance while another filter is being backwashed

TDEC - Fleming Training Center 21

Filter Profile continued

- A filter profile is basically a strip chart of the problem filter with the time of the filter backwashes for the filter and other filters denoted on the chart

TDEC - Fleming Training Center 22

Filter Profile continued

- For any individual filter that has a measured turbidity level of greater than 1.0 NTU in two consecutive measurements taken 15 minutes apart
- For any individual filter that has a measured turbidity level of greater than 0.5 NTU in two consecutive measurements taken 15 minutes apart at the end of the first four hours of continuous filter operation after the filter has been backwashed or otherwise taken offline

TDEC - Fleming Training Center 23

Filter Profile continued

- The system must either:
  - Produce a filter profile for the filter within 7 days of the exceedance
    - if the system is not able to identify an obvious reason for the abnormal filter performance
  - and report that the profile has been produced
    - Or report the obvious reason for the exceedance

TDEC - Fleming Training Center 24

FILTER PROFILE REPORT FOR INDIVIDUAL FILTERS

FOR PUBLIC WATER SYSTEMS THAT ARE USING SURFACE WATER SOURCES OR GROUND WATER SOURCES UNDER THE INFLUENCE OF SURFACE WATER THAT ARE REQUIRED TO CONDUCT ADDITIONAL INDIVIDUAL FILTER MONITORING

PUBLIC WATER SYSTEM NAME:	**TCEQ WSC**	**PLANT NAME OR NUMBER:**	**PDWS Water Treatment Plant**
PWS ID No.:	**1234567**	**Month:**	**February** **Year:** **2002**

OBVIOUS REASONS

	FILTER NO.: 1	**FILTER NO.:** 1	**FILTER NO.:** 5
	DATE: 02-04-02	**DATE:** 02-04-02	**DATE:** 02-04-02
	TIME: 10:00 AM	**TIME:** 4:15 PM	**TIME:** 11:45 AM
	DURATION: 45.00	**DURATION:** 15.00	**DURATION:** 15.00
	TURBIDITY: 1.32	**TURBIDITY:** 0.57	**TURBIDITY:** 1.05
***OBVIOUS REASONS* (Check all that apply)**			
NONE IDENTIFIED - *A Filter Profile must be submitted*	☐ *(See Profile No. ____)*	☐ *(See Profile No. ____)*	☐ *(See Profile No. ____)*
Filter Problems			
Post-Backwash Turbidity Spike	☐	☑	☐
Prolonged Filter Run Time	☑	☐	☐
Excessive Filter-Loading Rate	☐	☐	☐
Rate-of-Flow Control Valve Failure	☐	☐	☐
Media Defects (insufficient depth, mudballs, etc.)	☐	☐	☐
Inadequate Surface Wash or Backwash Facilities	☐	☐	☐
Backwash Artifact	☐	☐	☑
Turbidimeter Errors			
Incorrect Calibration	☐	☐	☐
Air Bubble	☐	☐	☐
Debris	☐	☐	☐
Chemical Feed Equipment Failure			
Coagulant	☐	☐	☐
Coagulant Aid	☐	☐	☐
Filter Aid	☐	☐	☐
Poor Raw Water Quality	☐	☐	☐
Other Major Unit Process Failures/Maintenance Activities	☐	☐	☐
Specify:			Backwash Filter No. 1

OBVIOUS REASONS

	FILTER NO.: 5	**FILTER NO.:**	**FILTER NO.:**
	DATE: 02-13-02	**DATE:**	**DATE:**
	TIME: 2:15 PM	**TIME:**	**TIME:**
	DURATION: 15.00	**DURATION:**	**DURATION:**
	TURBIDITY: 1.24	**TURBIDITY:**	**TURBIDITY:**
***OBVIOUS REASONS* (Check all that apply)**			
NONE IDENTIFIED - *A Filter Profile must be submitted*	☑ *(See Profile No. 1)*	☐ *(See Profile No. ____)*	☐ *(See Profile No. ____)*
Filter Problems			
Post-Backwash Turbidity Spike	☐	☐	☐
Prolonged Filter Run Time	☐	☐	☐
Excessive Filter-Loading Rate	☐	☐	☐
Rate-of-Flow Control Valve Failure	☐	☐	☐
Media Defects (insufficient depth, mudballs, etc.)	☐	☐	☐
Inadequate Surface Wash or Backwash Facilities	☐	☐	☐
Backwash Artifact	☐	☐	☐
Turbidimeter Errors			
Incorrect Calibration	☐	☐	☐
Air Bubble	☐	☐	☐
Debris	☐	☐	☐
Chemical Feed Equipment Failure			
Coagulant	☐	☐	☐
Coagulant Aid	☐	☐	☐
Filter Aid	☐	☐	☐
Poor Raw Water Quality	☐	☐	☐
Other Major Unit Process Failures/Maintenance Activities	☐	☐	☐
Specify:			

SUBMITTED BY: Hardy Worker **Certificate No. and Grade:** **123-45-6789, BSW** **Date:** **24-Feb-02**

TCEQ - 10276 (10-02-00) **PAGE 1** **FPR**

Filter Self-Assessment

- For any individual filter that has a measured turbidity level of greater than 1.0 NTU in two consecutive measurements taken 15 minutes apart at any time in each of three consecutive months

TDEC - Fleming Training Center 26

Filter Self-Assessment continued

- Self-assessment must be conducted within 14 days of the exceedance
- Report that the self-assessment was conducted

TDEC - Fleming Training Center 27

Filter Self-Assessment continued

- Must consist of at least the following components:
  - Assessment of filter performance
  - Development of a filter profile
  - Identification and prioritization of factors limiting filter performance
  - Assessment of the applicability of corrections
  - Preparation of a filter self-assessment report

TDEC - Fleming Training Center 28

FILTER ASSESSMENT REPORT FOR INDIVIDUAL FILTERS

FOR PUBLIC WATER SYSTEMS THAT ARE USING SURFACE WATER SOURCES OR GROUND WATER SOURCES UNDER THE INFLUENCE OF SURFACE WATER THAT ARE REQUIRED TO CONDUCT AN INDIVIDUAL FILTER ASSSESSMENT

PUBLIC WATER SYSTEM NAME: ______________________ **PLANT NAME OR NUMBER:** ______________

PWS ID No.: ______________________ **FILTER NUMBER:** ______________

DESIGN SPECIFICATIONS

FILTER TYPE		OPERATING MODE	

	Diameter (ft)	Length (ft)	Width (ft)	Surface Area (ft^2)	Freeboard (ft)	Max Head Loss (ft)
MEDIA BED DIMENSIONS						

MEDIA TYPE						
MEDIA SPECS	Material	Depth (inches)	Min. Size (mm)	Max. Size (mm)	UC	Specific Gravity
Layer 1 Material						
Layer 2 Material						
Layer 3 Material						
Layer 4 Material						
TOTAL DEPTH (inches)						
L/D RATIO						

UNDERDRAIN TYPE				
	No. of Grades	Min. Size (in)	Max. Size (in)	Total Depth (in)
SUPPORT GRAVEL				

TROUGHS		SUPPL. BACKWASH	
Number.			
Separation (inches)		FILTER-TO-WASTE	

	Regulatory Std	Design	Typical	During Backwash	Maximum	App'd Exception
FILTER FLOW RATE (gpm)						
LOADING RATE (gpm/ft^2)						
BW FLOW RATE (gpm)						
BW LOADING RATE (gpm/ft^2)						

	Source	Controller	Meter	Turbidimeter	LOHG
FILTER INFLUENT					
FILTER EFFLUENT					
BACKWASH WATER					

ADDITIONAL REMARKS:

OPERATING PROCEDURES

CALIBRATION	Flow Meter	Backwash Meter	Mech. ROFC	NTU (Primary)	NTU (Secondary)
Method					
Frequency					
Date of Last					

BACKWASH	Turbidity (NTU)	LOH (ft)	Run Time (hr)	Run Volume (gal)	Filtration Rate
Criteria					
Monitoring Interval					

WRITTEN SOPs	
Plant Start-up	
Filter Start-up	
Plant Shutdown	
Filter Shutdown	
Filter Backwash	
Filter Inspection	

ADDITIONAL REMARKS:

I certify that I am familiar with the information contained in this report and that, to the best of my knowledge, the information is true, complete, and accurate.

Operator's Signature: ______________________

Operator's Name (printed): ______________________

Certificate No. and Class: ______________________ **Date:** ______________

Submit Report to TCEQ/WP&RM Division/Public Drinking Water Section(MC-155), ATTN: Monthly Reports, P.O. Box 13087, Austin, TX 78711-3087
The report is due the 10th of the following month

TCEQ - 10277 (10-02-00) **PAGE 1** **Filter Assessment Report**

FILTER ASSESSMENT REPORT FOR INDIVIDUAL FILTERS

FOR PUBLIC WATER SYSTEMS THAT ARE USING SURFACE WATER SOURCES OR GROUND WATER SOURCES UNDER THE INFLUENCE OF SURFACE WATER THAT ARE REQUIRED TO CONDUCT AN INDIVIDUAL FILTER ASSSESSMENT

PUBLIC WATER SYSTEM NAME: ______________________ **PLANT NAME OR NUMBER:** ______________

PWS ID No.: ______________________ **FILTER NUMBER:** ______________

CURRENT CONDITIONS

DATE	TIME	TURBIDITY (NTU)	LOH (ft)	FLOW RATE (gpm)	RUN TIME (hr)	RUN VOLUME (gal)

PHYSICAL CONDITION	
Walls	
Troughs	
Suppl. Backwash	
Flow Meter	
ROFC	
Flow Control Valve	
Turbidimeter	
LOHG	

ADDITIONAL REMARKS:

MEDIA SURFACE CONDITIONS

	Before BW	After BW
MOUNDS		
Number		
Length (inches)		
Width (inches)		
Height (inches)		
DEPRESSIONS		
Number		
Length (inches)		
Width (inches)		
Depth (inches)		
ACCUMULATED FLOC		
Thickness (inches)		
Distribution		

	Before BW	After BW
RETRACTION		
Number		
Length (inches)		
Width (inches)		
Depth (inches)		
CRACKS		
Number		
Length (inches)		
Width (inches)		
Depth (inches)		
MUDBALLS		
No. per ft^2		
Size (inches)		
Distribution		

ADDITIONAL REMARKS:

BACKWASH CONDITIONS

BW FLOW RATE (gpm)	
RISE RATE (inches/minute)	
LOADING RATE (gpm/ft^2)	
DURATION (minutes)	
TOTAL VOLUME (gallons)	
TROUGHS	
Levelness	
Flooding	
SUPPL. BACKWASH	
Duration (minutes)	
Effectiveness	
JETTING	
No. of Sites	
Severity	
BW WATER DISTRIBUTION	
SPENT BWW TURBIDITY	
EXPANSION (inches)	
EXPANSION (percent)	
YIELD (percent)	

ADDITIONAL REMARKS:

Submitted by: ______________________ **Date:** ______________

TCEQ - 10277 (10-02-00) **PAGE 2** **Filter Assessment Report**

FILTER ASSESSMENT REPORT FOR INDIVIDUAL FILTERS

FOR PUBLIC WATER SYSTEMS THAT ARE USING SURFACE WATER SOURCES OR GROUND WATER SOURCES UNDER THE INFLUENCE OF SURFACE WATER THAT ARE REQUIRED TO CONDUCT AN INDIVIDUAL FILTER ASSSESSMENT

PUBLIC WATER SYSTEM NAME: ____________________ **PLANT NAME OR NUMBER:** ____________________

PWS ID No.: ____________________ **FILTER NUMBER:** ____________________

FILTER PROBE

NUMBER OF SITES	
MEDIA	
Max. Thickness (inches)	
Min. Thickness (inches)	
Typ. Thickness (inches)	
SUPPORT MATERIAL	
Max. Elevation	
Min. Elevation	
Typ. Elevation	

ADDITIONAL REMARKS:

FILTER EXCAVATION

	REFERENCE	SITE 2	SITE 3	SITE 4	SITE 5	SITE 6
SITE CHARACTERISTIC	Normal					
LAYER 1 (Top Layer)						
INTERFACE 1						
LAYER 2						
INTERFACE 2						
LAYER 3						
INTERFACE 3						
LAYER 4						
MUDBALLS						
Max. Size (inches)						
Min. Size (inches)						
Max. Depth (inches)						

	SITE 7	SITE 8	SITE 9	SITE 10	SITE 11	SITE 12
SITE CHARACTERISTIC						
LAYER 1 (Top Layer)						
INTERFACE 1						
LAYER 2						
INTERFACE 2						
LAYER 3						
INTERFACE 3						
LAYER 4						
MUDBALLS						
Max. Size (inches)						
Min. Size (inches)						
Max. Depth (inches)						

MEDIA CONDITION	
Sharpness	
Encrustation	
Uniformity	

ADDITIONAL REMARKS:

ADDITIONAL STUDIES

FILTER PROFILE ATTACHED?	

Note: A Filter Profile must be attached to this report.

PERCENT MUDBALLS	
Media Volume (ml)	
Mudball Volume (ml)	
% Mudballs	

ADDITIONAL REMARKS:

CONCLUSIONS

CONCLUSIONS:

CORRECTIVE ACTION PLAN ATTACHED?
WOULD YOU LIKE SOME TECHNICAL ASSISTANCE FROM THE TCEQ?

Submitted by: ____________________ **Date:** ____________________

TCEQ - 10277 (10-02-00) **PAGE 3** **Filter Assessment Report**

FILTER ASSESSMENT REPORT FOR INDIVIDUAL FILTERS

FOR PUBLIC WATER SYSTEMS THAT ARE USING SURFACE WATER SOURCES OR GROUND WATER SOURCES UNDER THE INFLUENCE OF SURFACE WATER THAT ARE REQUIRED TO CONDUCT AN INDIVIDUAL FILTER ASSSESSMENT

PUBLIC WATER SYSTEM NAME: ____________________ **PLANT NAME OR NUMBER:** ____________________

PWS ID No.: ____________________ **FILTER NUMBER:** ____________________

FILTER SCHEMATIC

PREPARE A SIMPLE FILTER SCHEMATIC SHOWING THE LOCATION OF BACKWASH WATER TROUGHS, OBSERVED ANOMOLIES, AND EXCAVATION SITES.

Submitted by: ____________________ **Date:** ____________________

TCEQ - 10277 (10-02-00) **PAGE 4** **Filter Assessment Report**

Comprehensive Performance Evaluation

- For any individual filter that has a measured turbidity level of greater than 2.0 NTU in two consecutive measurements taken 15 minutes apart at any time in each of two consecutive months
- Must be conducted by the State or a third party approved by the State

TDEC - Fleming Training Center 30

Comprehensive Performance Evaluation continued

- System has to arrange for this to be done no later than 30 days following exceedance
- The evaluation completed and submitted to the State no later than 90 days following the exceedance

TDEC - Fleming Training Center 31

Factors affecting filtration

- Physical condition of filter bed
- Physical condition of filter media
  - Depends on how frequently filter is backwashed
  - Media rubs together and eventually wears down
- Filtration rate
- Backwash procedures
  - Need SOP, everyone needs to backwash the same
- Backwash conditions and/or rates

TDEC - Fleming Training Center 32

Filtration Rate

- Filtration rate = (Filtration Velocity) (Area Available for Flow)

$$Q = V \times A$$

Q = Filtration Rate, is constant
V = Filtration Velocity
A = Area Available for Flow between Media Grains

TDEC - Fleming Training Center 33

Filtration Rate

- As Particles are Stored in a Filter Bed, "A" becomes Smaller

$$Q = V \times A$$

Q = Filtration Rate, is constant
V = Filtration Velocity
A = Area Available for Flow between Media Grains

TDEC - Fleming Training Center 34

Filtration Rate

- As "A" becomes Smaller, "V" becomes Larger

$$Q = V \times A$$

Q = Filtration Rate, is constant
V = Filtration Velocity
A = Area Available for Flow between Media Grains

TDEC - Fleming Training Center 35

Filtration Rate

- And, if "V" becomes too Large
  - Particles stored in a filter bed by:
    - Strained particles can be driven deeper into the filter bed
    - Particles stuck to the filter media can be detached from the media surface
    - Then both types of particles will go through the bottom of the filter resulting in turbidity breakthrough

TDEC - Fleming Training Center 36

Filter Run Hour Analysis

- Compares filters to each other throughout the facility
  - Allows the operator to see how many hours the filters are operated through the year, which determines if one is used more than others

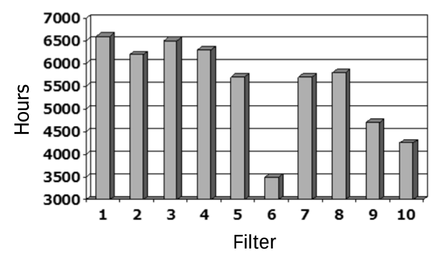
TDEC - Fleming Training Center 37

Filter Run Hour Analysis continued

- Procedure
  - Count the number of hours each filter is in service monthly
  - Put together an annual total filter run hours in a graph format

TDEC - Fleming Training Center 38

Filter Run Hour Analysis continued

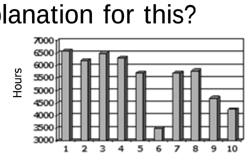


TDEC - Fleming Training Center 39

TDEC - Fleming Training Center

Filter Run Hour Analysis continued

- Filter 6 may have been out of service for maintenance for most of the year
- Filter 9 and 10 were not used as much as the others either, what would be the explanation for this?



40

Physical Condition of Bed

TDEC - Fleming Training Center 41

Physical Condition of Filter Bed

- Mounding
- Craters
- Mud/silt on top of filter
- Cracks in filter bed
- Sand separating from walls
- Algae
- Structural defects in filter
  - Blown tiles and/or grout
- Media in troughs
  - Backwash rate too high?
- Levelness of troughs
  - Length and width
  - Between troughs

Visual Observations

- This is your first line of defense in filter monitoring and evaluation
- Look for easy to recognize issues:
  - Media boils
  - Uneven wash distribution
  - Uneven overflow into backwash water troughs
  - Craters
  - Mudballs
- Create a map of any issues found

Media Depth

- Single-media filter
  - Must be 30 inches of sand
- Dual-media filter
  - Must be 30 inches of dual media
    - 10-12 inches of sand
    - 18-20 inches of anthracite
- Take 10-12 core samples and measure
  - Near wall and near center
  - Random

Media Depth continued

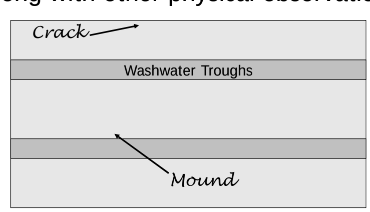
- Determine average media depth
  - First, backwash filter and then drain
  - You will be standing in the filter, have plywood down so you are not standing on the media

Media Depth continued

- Determine average media depth continued
  - Poke 5-ft ruler or steel rod into filter media at random spots until you reach support gravel or underdrains
    - Determined by feel or the sound of a “crunch” once you hit gravel
    - If you are using a steel rod, pinch at surface and carefully pull it out, tape at that point then measure distance
  - Determine average media depth by repeating about 10 times randomly around filter bed

Media Depth continued

- Draw picture of filter and write down depths where the measurement was taken along with other physical observations



TDEC - Fleming Training Center

Media Depth continued

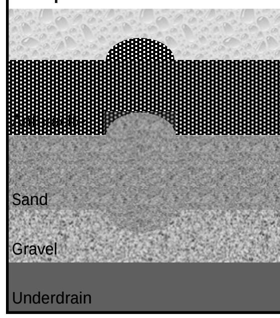
Support gravel extremely disrupted

	2 ft	4 ft	6 ft	8 ft	10 ft
2 ft	41	40.75	41	41	41
4 ft	40.75	40.5	41	41	40.75
6 ft	41	41.25	40.75	41	41
8 ft	40.75	41	41	40.75	40.75
10 ft	41	41	40.5	40.5	40.75
12 ft	41	46	46.5	41	41
14 ft	40.75	46	46.25	39	40.75
16 ft	41	39	38.75	37	40.75
18 ft	40.75	41.25	40.75	41	41

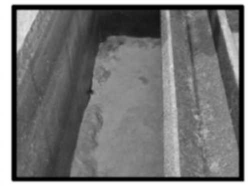
48

TDEC - Fleming Training Center

Mounding

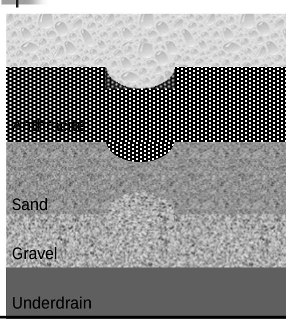


- Mounding suggests possible gravel displacement that allows more backwash water through



TDEC - Fleming Training Center

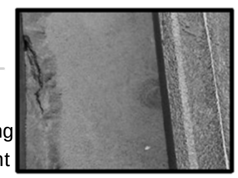
Craters



- Craters suggests underdrain damage or displacement of gravel
  - Allows less backwash water through this area
  - Loss of media can occur

50

Other Physical Conditions



- Cracks
  - Media binding is occurring
  - Backwash is not sufficient
  - Water passes through cracks and is not filtered
- Separation from walls
  - Suggests media is retaining mud causing a crack along the wall
  - Too much gravel was installed and the backwash is less than desired

TDEC - Fleming Training Center 51

Other Physical Conditions continued

- Algae
  - Algae can clog the filter and needs to be removed
- Structural
  - Make notes of structural defects to the walls, washwater troughs and/or piping:
    - Chipped concrete
    - Exposed rebar
    - Walls or washwater troughs rusting
  - Need to be fixed before it continues to worsen

TDEC - Fleming Training Center 52

Other Physical Conditions continued

- Media in troughs
  - Indicates backwash flow rate is too high
- Levelness of washwater troughs
  - Check the levelness
    - Across the width
    - Down the length
    - Between two troughs next to each other

TDEC - Fleming Training Center 53

Other Physical Conditions continued

- Freeboard measurement
  - This is the measurement between the top of the washwater troughs and the top of the media surface
  - Take measurements when and where level readings were taken

TDEC - Fleming Training Center 54

Backwash Analysis

TDEC - Fleming Training Center 55

Backwash Procedure

- Every plant needs an SOP
  - Everyone needs to backwash the same way every time
  - Variable rate of backwashing
    - Wide open and shut is not good
    - Ramp up: 25%, 50%, 75% then 100% and back down when finished
  - Rewash
  - Time
    - Not too clean nor left too dirty
  - How often
    - Hours run, effluent turbidity, head loss

TDEC - Fleming Training Center 56

Conditions of Backwash

- Intensity
- Time
- Efficiency

TDEC - Fleming Training Center 57

Backwash Intensity

- Measured by:
  - Backwash flow rate
    - ~15-20 gpm/ft^2
    - Design Criteria requires a minimum rate of 18.75 gpm/ft^2 for sand filter
  - Filter bed expansion
    - ~20-30%
    - Design Criteria recommends 50%
      - 4.2.1 K(1)

TDEC - Fleming Training Center 58

Length of Backwash

- Do not wash the filter too much
- Wash until water coming through the bed is about 10 NTU

TDEC - Fleming Training Center 59

Backwash Observations

- Media boils
  - Look for these toward the end of the backwash, you must be able to see the media
- Uneven backwash water distribution
  - Check for areas that are not moving, these areas are not being sufficiently washed and normally have mudballs in that area

TDEC - Fleming Training Center 60

Backwash Observations continued

- Media carryover
  - Can be several issues going on for media carryover
    - Backwash water jetting under trough
    - Too much media expansion near the bottom of the trough
    - Too high a backwash rate

TDEC - Fleming Training Center 61

Backwash Bed Expansion

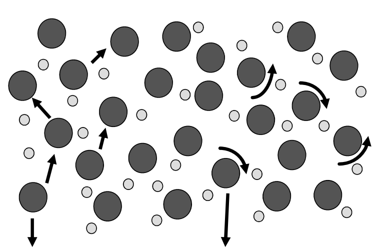
TDEC - Fleming Training Center 62

Backwash Bed Expansion

- Backwash rate needs to be high enough to completely suspend the filter media in the water
  - To clean the filter bed, the media grains need to be moved and bumped into each other.
  - This creates a scrubbing action that releases the floc from the media

TDEC - Fleming Training Center 63

Backwash Bed Expansion continued



TDEC - Fleming Training Center 64

Backwash Bed Expansion continued

- Inadequate bed expansion may lead an operator to believe filter is clean due to backwash water looking "clean"
  - If media is not expanded enough to rub together and knock loose the dirt, backwash water will look clean

TDEC - Fleming Training Center 65

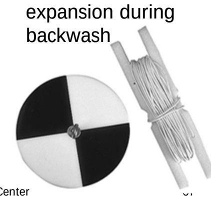
Backwash Bed Expansion continued

- If the filter is not sufficiently expanded during backwash, it will not be sufficiently cleaned
- This can lead to numerous problems:
  - Poor post-backwash recovery
  - Sensitivity to hydraulic surges during flow changes
  - Shortened filter run times
  - Mudball formation

TDEC - Fleming Training Center 66

Backwash Bed Expansion continued

- Equipment needed:
  - Secchi Disc or other apparatus to measure bed expansion during backwash



TDEC - Fleming Training Center

Backwash Bed Expansion continued

- Steps
  - Determine average media depth
    - Poke 5-ft ruler or steel rod into filter media at random spots until you reach support gravel or underdrains
      - Determined by feel or the sound of a "crunch" once you hit gravel
      - If you are using a steel rod, pinch at surface and carefully pull it out, tape at that point then measure distance
    - Determine average media depth

TDEC - Fleming Training Center 68

Backwash Bed Expansion continued

- Steps
  - Determine bed expansion using a Secchi disk
    - Using a Secchi disk on a rope, lower the disk into the water until you reach the top of the filter
    - Place piece of tape on rope at handrail level
    - Remove the Secchi disk
    - Start backwash

TDEC - Fleming Training Center 69

Backwash Bed Expansion continued

- Steps
  - Determine bed expansion using a Secchi disk
    - Once water clears, lower Secchi disk back down into filter until small amounts of filter cover the disc
      - If it becomes completely submerged, raise and slowly lower again
    - Place piece of tape on rope at handrail level
    - Measure distance between two pieces of tape

TDEC - Fleming Training Center 70

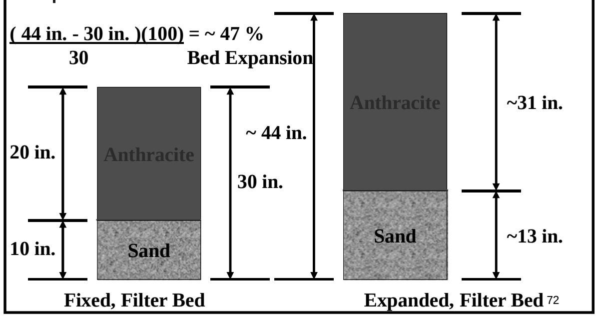
Backwash Bed Expansion continued

- Steps
  - Determine bed expansion using a Secchi disk
    - The distance between the two pieces of tape is your bed expansion in inches

$$\text{Bed expansion, \%} = \frac{(\text{Bed expansion, in})(100)}{\text{Media depth, in}}$$

TDEC - Fleming Training Center 71

Backwash Expansion Dual-Media Filter



Low Bed Expansion

- Media may have become encrusted with carbonate or “cemented”
  - Therefore, media has become heavier and will not allow bed to expand normally

Water Temp vs. Backwash Rates

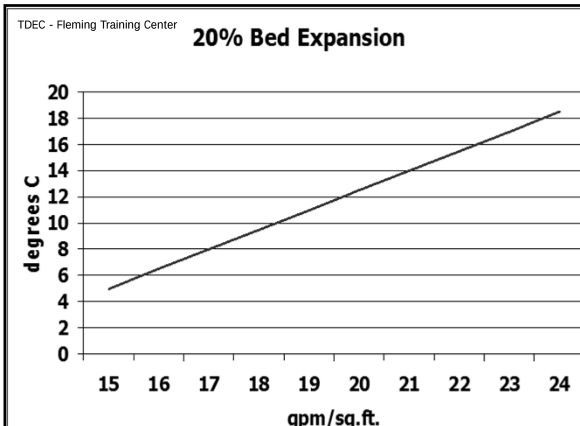
- Changes in water temperature will affect your backwash rates
- Cold water is more viscous than warm water
- Imagine dropping filter media into cold maple syrup and warm maple syrup
  - Media will stay suspended for a longer period of time in the cold maple syrup
  - Same goes for filter media in cold water versus warm water

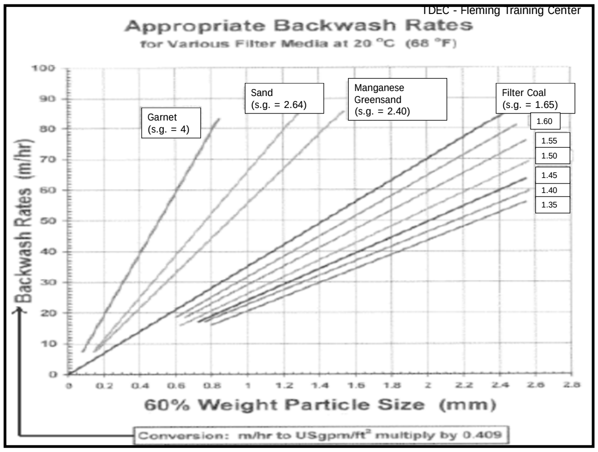
Water Temp vs. Backwash Rates cont.

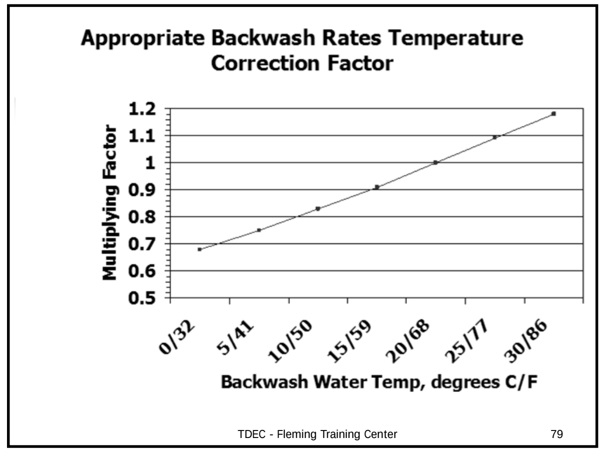
- If backwash flow rates stay the same, year-round, you will get a higher bed expansion during colder water temps than warmer water temps
  - If rates are not changed during summer and winter months
    - Mudballs may occur during the summer
    - Media loss may occur during the winter
  - Colder water temps need lower backwash rates
  - Warmer water temps need higher backwash rates

Water Temp vs. Backwash Rates cont.

- Check bed expansion seasonally
  - Chart water temperature and backwash rate that allows a 20% bed expansion throughout the year
  - If you have different filter designs, do one for each design




TDEC - Fleming Training Center
Appropriate Backwash Rates
for Various Filter Media at 20 °C (68 °F)
Garnet (s.g. = 4)
Sand (s.g. = 2.64)
Manganese Greensand (s.g. = 2.40)
Filter Coal (s.g. = 1.65)
1.60
1.55
1.50
1.45
1.40
1.35
Backwash Rates (m/hr)
60% Weight Particle Size (mm)
Conversion: m/hr to USgpm/ft² multiply by 0.409


Appropriate Backwash Rates Temperature Correction Factor
Multiplying Factor
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0/32
5/41
10/50
15/59
20/68
25/77
30/86
Backwash Water Temp, degrees C/F
TDEC - Fleming Training Center
79

Filter Bed Expansion Worksheet

Filter Media Depth Measurements			
Measurements	Media Depth, in	Measurements	Media Depth, in
1		11	
2		12	
3		13	
4		14	
5		15	
6		16	
7		17	
8		18	
9		19	
10		20	
Sum of Measurements		Sum of Measurements	
Total Depth = Add the sums of the two columns of measurements			
Average Depth = Divide the total depth by the number of measurements			
Bed Expansion, in			
Bed Expansion, % = $\frac{\text{(Bed Expansion, in)(100)}}{\text{Average Media Depth, in}}$			
Water Temperature, °C			
Backwash Control Valve, % Open			
Is this the desirable 20-30%			

Filter Number: ___________ Tester: ______________________________

Date: ___________________ Time: _______________________________

Bed Expansion Math

1. While evaluating a filter, a bed expansion test was performed. During the backwash the filter bed rose 4 ¼ inches. The average media depth was 30 inches. Calculate the bed expansion in percent.

2. While evaluating a filter, a bed expansion test was performed. During the backwash the filter bed rose 6 ½ inches. The average media depth was 31 inches. Calculate the bed expansion in percent.

3. While evaluating a filter, a bed expansion test was performed. During the backwash the filter bed rose 8 inches. The average media depth was 36 inches. Calculate the bed expansion in percent.

4. Filter 5 at a water plant has an average media depth of 29 inches. The bed expanded by 8 inches during backwash. What is the bed expansion in percent?

5. Filter 2 at a water plant has an average media depth of 28 inches. The bed expanded by 4 inches during backwash. What is the bed expansion in percent?

6. Filter 16 at a water plant has an average media depth of 32 inches. The bed expanded by 10 inches during backwash. What is the bed expansion in percent?

7. Calculate the filter bed expansion if the average media depth is 33 inches and the bed expansion is 5.5 inches.

8. Calculate the filter bed expansion if the average media depth is 34 ½ inches and the bed expansion is 7 inches.

9. Calculate the filter bed expansion if the average media depth is 28 inches and the bed expansion is 9 inches.

10. Calculate the filter bed expansion if the average media depth is 31 inches and the bed expansion is 5 inches.

Answers:

1. 14%
2. 21%
3. 22%
4. 28%
5. 14%
6. 31%
7. 17%
8. 20%
9. 32%
10. 16%

Backwash Rise Rate Analysis

Backwash Flow Rate Analysis

- Also known as rise test
- Determines actual backwash rate in gpm/ft^2 and gpm
- Backwash flow meters can become inaccurate and may need calibration
  - Determines meter accuracy

Backwash Flow Rate Analysis

- Equipment needed:
  - Hook gauge – two hooks 6 inches apart
  - Stop watch
  - Tape measure
  - Calculator

Backwash Flow Rate Analysis
continued

- Recommended backwash rates:
  - Single media filters = 18.75 gpm/ft^2
  - Dual media filters = 20 gpm/ft^2

Backwash Flow Rate Analysis
continued

- Steps
  - Measure the length and width of the filter bed and basin
  - Place hook gauge in filter with the top hook well below the washwater troughs
    - Make sure the hook gauge is level front to back and side to side
  - Drain the filter

TDEC - Fleming Training Center 85

Backwash Flow Rate Analysis
continued

- Steps
  - Begin backwash
  - Start the timer when the water reaches the top of the bottom hook
  - Stop the timer when the water reaches the top of the top hook
  - Record time
  - Drop water below bottom nail and repeat two more times

TDEC - Fleming Training Center 86

Backwash Flow Rate Analysis
continued

- Number Crunch
  - Calculate the volume of the water that rose in the filter

$$\text{volume, gal} = (\text{filter bed length, ft})(\text{filter bed width, ft})(0.5\text{ ft depth})(7.48\text{ gal/ }ft^3)$$

  - Calculate the average time in minutes

$$\text{avg. time, min} = \frac{(Time_1 + Time_2 + Time_3)}{(3)(60\text{ sec/ min})}$$

TDEC - Fleming Training Center 87

Backwash Flow Rate Analysis
continued

- Number Crunch
  - Calculate the filter bed area

$$\text{filter bed area, } ft^2 = (\text{bed length, ft})(\text{bed width, ft})$$

  - Calculate backwash rate in gpm

$$\text{backwash rate, gpm} = \frac{\text{volume, gal}}{(\text{avg. time, min})}$$

TDEC - Fleming Training Center 88

Backwash Flow Rate Analysis
continued

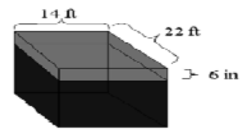
- Number Crunch
  - Calculate the backwash rate in gpm/ft^2

$$\text{backwash rate, gpm}/ft^2 = \frac{\text{backwash rate, gpm}}{(\text{filter bed area}, ft^2)}$$

TDEC - Fleming Training Center 89

Backwash Flow Rate Analysis
continued

- A filter measures 22 ft by 14 ft. The backwash cycle was started. The water level rose 6 inches in 11 sec, 10 sec and 12 sec during three tests. What is the backwash rate in gpm, gpm/ft^2 and how many gallons were used if it were backwashed for 12 minutes?

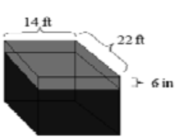


TDEC - Fleming Training Center

Volume, gal

$V=(l, ft)(w, ft)(d, ft)(7.48 \text{ gal}/ft^3)$

$V=(22 \text{ ft})(14 \text{ ft})(0.5 \text{ ft})(7.48 \text{ gal}/ft^3)$



V= 1151.9 gal

TDEC - Fleming Training Center 91

Average Time, min

11 sec, 10 sec and 12 sec

$$\text{Avg time, min} = \frac{sec_1 + sec_2 + sec_3}{(3)(60 \text{ sec/min})}$$

$$\text{Avg Time, min} = \frac{11 + 10 + 12}{(3)(60 \text{ sec/min})}$$

Avg Time, min = 0.1833 min

TDEC - Fleming Training Center 92

Sand Bed Area

A filter measures 22 ft by 14 ft.

Sand Area, ft^2 =(length, ft)(width, ft)

Sand Area, ft^2 = (22 ft)(14 ft)

Sand Area, ft^2 = 308 ft^2

TDEC - Fleming Training Center 93

Volume, gal = 1151.9 gal
Time, min = 0.1833 min
Area, ft^2 = 308 ft^2

Backwash Rate, gpm/ft^2

Filter rate, gpm = $\frac{\text{volume, gal}}{\text{average time, min}}$

Filter rate, gpm = $\frac{1151.9 \text{ gal}}{0.1833 \text{ min}}$

Filter rate, gpm = 6284 gpm

TDEC - Fleming Training Center 94

Backwash Rate, gpm = 6284 gpm
Volume, gal = 1151.9 gal
Time, min = 0.1833 min
Area, ft^2 = 308 ft^2

Backwash Rate, gpm/ft^2

Filter rate gpm/ft^2 = $\frac{\text{filter rate, gpm}}{\text{sand area, ft}^2}$

Filter rate, gpm/ft^2 = $\frac{6284 \text{ gpm}}{308 \text{ ft}^2}$

Filter rate, gpm/ft^2 = 20.4 gpm/ft^2

TDEC - Fleming Training Center 95

Backwash Gallons Used

Backwash Vol., gal = (Backwash Rate, gpm/ft^2)(Sand Area, ft^2)(time, min)

Backwash Vol., gal = (20.4 gpm/ft^2)(308 ft^2)(12 min)

Backwash Vol., gal = 75,398.4 gallons

TDEC - Fleming Training Center 96

TDEC - Fleming Training Center

Backwash Flow Rate	Bed Expan., %	Action Needed
Low	<20%	↑ backwash flow rate and repeat bed expan. analysis
Low	20-30%	↑ backwash flow rate and repeat bed expan. analysis
Low	>30%	Check water temp
Correct	<20%	"cementing" of filter?
Correct	20-30%	None
Correct	>30%	Check effective size and uniformity coefficient
High	<20%	"cementing" of filter?
High	20-30%	"cementing" of filter?
High	>30%	↓ backwash flow rate and repeat bed expan. analysis

Backwash Rate Analysis Worksheet

Filter Bay Dimensions			
Length	ft	Width	ft
Filter Bed Dimensions			
Length	ft	Width	ft
Time to Drop 6 inches			
$Time_1$	sec		
$Time_2$	sec		
$Time_3$	sec		

Backwash Volume	
$vol, gal = (bed\ length, ft)(bed\ width, ft)(0.5\ ft\ rise)(7.48\ gal/ft^3)$	
$average\ time, min = \frac{Time_1 + Time_2 + Time_3}{(3)(60\ sec/min)}$	
$filter\ bed\ area, ft^2 = (bed\ length, ft)(bed\ width, ft)$	
$backwash\ rate, gpm = \frac{vol, gal}{(avg.\ time, \text{min})}$	
$backwash\ rate, gpm/ft^2 = \frac{backwash\ rate, gpm}{filter\ bed\ area, ft^2}$	
$backwash\ water\ vol., gal = (backwash\ rate, gpm)(time\ backwashed, min)$	
Is this sufficient backwash rate for your media to achieve at least 20% expansion?	

Filter Number: ___________ Tester: ______________________________

Date: ___________________ Time: _______________________________

Backwash Math

1. A filter measures 28 feet by 20 feet. The backwash cycle is started and the water rises 6” in 12, 13, and 13 seconds. What is the backwash rate in gallons per minute per square foot (gpm/ft^2)?

2. The Randyville Water Plant treats an average of 5.18 MGD. The water is split equally to each of the 8 filters. Each filter basin measures 12 feet wide by 16 feet long and by 24 feet deep. Each filter bed measures 12 feet by 14 feet by 11 feet deep. Filter 6 is taken offline to backwash. Using a hook gauge and a stopwatch, it is noted that the water level in the filter rises 6 inches in 14, 16, and 15 seconds. What is the backwash rate in gallons per minute per square foot (gpm/ft^2) and how many gallons were used if the filter was backwashed for 9 minutes?

3. The Chrisburg Water Plant treats an average of 7.2 MGD. The water is split equally to each of 8 filters. Each filter basin measures 12.5 feet wide by 16.5 feet long by 24 feet deep. Each filter bed measures 12.5 feet by 14 feet by 10 feet deep. Filter 6 is taken offline to backwash. Using a hook gauge and a stopwatch, it is noted that the water level in the filter rises 6 inches in 12 seconds on test 1, 6 inches in 11 seconds on test 2 and 6 inches in 14 seconds on test 3. What is the backwash rate in gallons per minute per square foot (gpm/ft^2)?

4. Determine the backwash rate in gpm/ft^2 for a filter with a surface of 28 feet by 20 feet. The backwash cycle started and the water rose 6 inches in 15, 16, and 16 seconds.

5. Determine the backwash rate in gpm/ft^2 for a filter bay that is 10 by 14 feet and the filter bed is 10 by 12 feet. The test was run three times. The backwash cycle started and the water rose 6 inches in 17, 16, and 16 seconds.

6. Determine the backwash rate in gpm/ft^2 for a filter bay that is 15 by 22 feet and the filter bed is 15 by 20 feet. The test was run three times. The backwash cycle started and the water rose 6 inches in 18, 17, and 20 seconds

7. Determine the backwash rate in gpm/ft^2 for a filter bay that is 16 by 18 feet and the filter bed is 16 by 16 feet. The test was run three times. The backwash cycle started and the water rose 6 inches in 11, 10, and 9 seconds

8. Determine the backwash rate in gpm/ft^2 and the amount of water used if they backwashed for 12 minutes for a filter bay that is 14 by 18 feet and the filter bed is 14 by 16 feet. The test was run three times. The backwash cycle started and the water rose 6 inches in 18, 17, and 20 seconds

9. Determine the backwash rate in gpm/ft^2 and the amount of water used if they backwashed for 14 minutes for a filter bay that is 20 by 32 feet and the filter bed is 20 by 30 feet. The test was run three times. The times required for the water to rose 6 inches were 13, 12 and 15 seconds.

10. Determine the backwash rate in gpm/ft^2 and the amount of water used if they backwashed for 9 minutes for a filter bay that is 24 by 36 feet and the filter bed is 24 by 34 feet. The test was run three times. The times required for the water to rose 6 inches were 14, 15 and 16 seconds.

Answers:

1. 17.72 gpm/ft^2
2. 14.96 gpm/ft^2, 22,619.5 gal
3. 18.19 gpm/ft^2
4. 14.32 gpm/ft^2
5. 13.74 gpm/ft^2
6. 12.24 gpm/ft^2
7. 22.44 gpm/ft^2
8. 12.24 gpm/ft^2, 32,901 gal
9. 16.83 gpm/ft^2, 141,372 gal
10. 14.96 gpm/ft^2, 109,866 gal

Backwash Water Turbidity Analysis

Backwash Water Turbidity

- Used to determine adequate backwashing duration
- Desired backwash time is determined by the amount of time to drop the backwash water turbidity in the range of 10-15 NTU
  - AWWA recommends 10 NTU as the cutoff for backwashing
- Target time is 6-8 minutes

Backwash Water Turbidity cont.

- The Interim Enhanced Surface Water Treatment Rule (IESWTR) requires filters to produce water with <0.3 NTU within 30 minutes of the start of the filter run
- Extending backwash until water runs clear may be causing some spikes after backwash
  - The filter may become too clean and needs longer time to "ripen"

Backwash Water Turbidity cont.

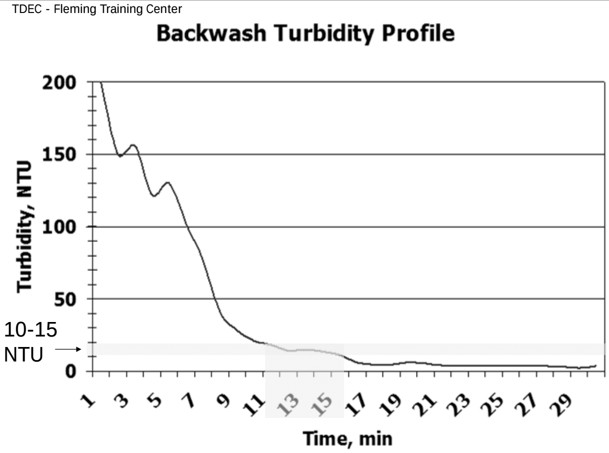
- Equipment needed:
  - Stop watch
  - Sampler for grabbing samples of backwash water
  - Turbidimeter
  - 30 100-mL sample bottles marked in one-minute intervals

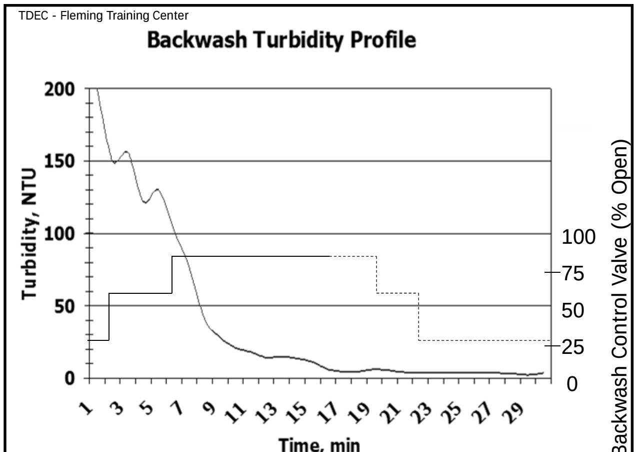
Backwash Water Turbidity cont.

- Procedure:
  - Place all bottles in order
  - One person needed to keep time with stopwatch and another person needed to collect samples
  - Start normal backwash cycle and stopwatch
  - Collect samples of backwash water in trough near discharge end (so it is well mixed) at one-minute intervals with sampler

Backwash Water Turbidity cont.

- Procedure:
  - Fill 100-mL sample bottles to the line and dump remainder back into filter
  - Repeat this procedure every minute until backwash is complete, extend normal backwash time about 3-5 minutes
  - Take each sample to turbidimeter
  - Mix samples thoroughly and read on turbidimeter
  - Plot readings on graph paper





AWWA Filter Surveillance Workshop, Nov. 1999

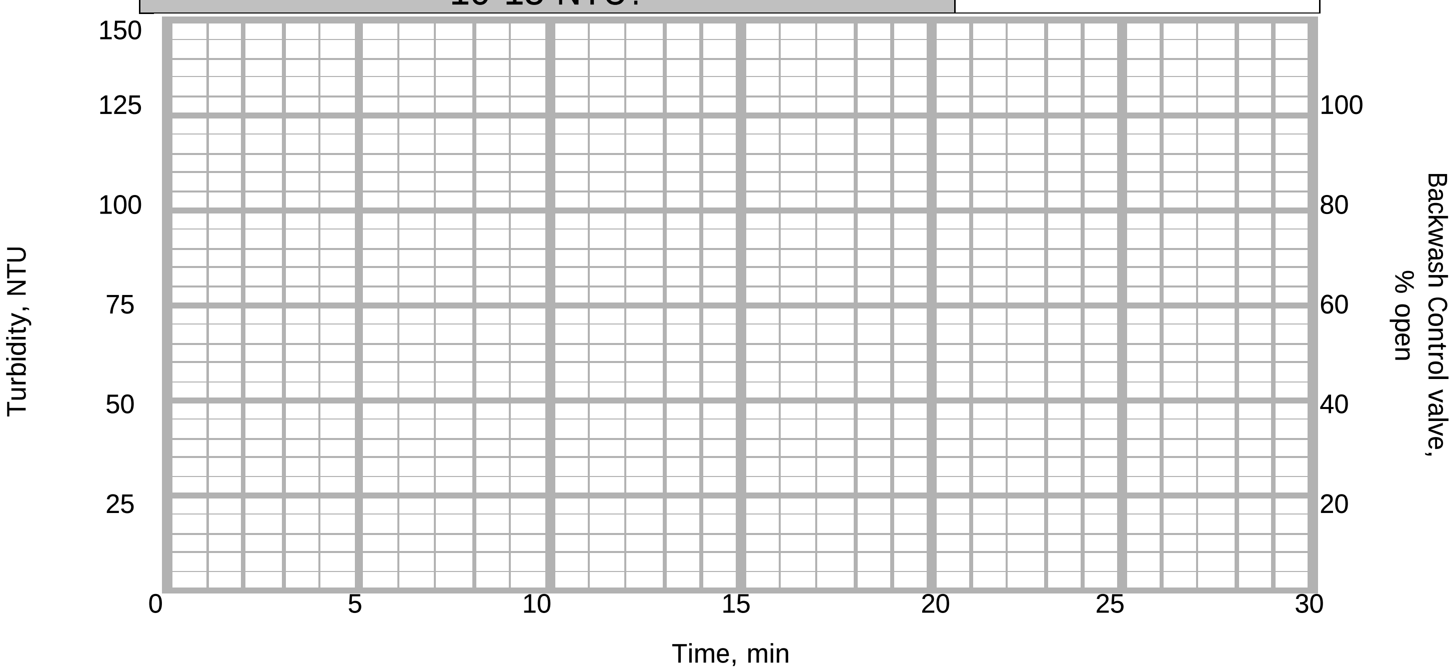
Backwash Water Turbidity cont.

- Troubleshooting:
  - Water clears up after about 2-3 minutes of backwashing?
    - You may be only cleaning the top layer of anthracite
    - To fix this problem, raise backwash flow rate
  - Takes a long time to drop to 10-15 NTU range?
    - Filter may have been dirty for a long time and you are finally cleaning the filter

TDEC - Fleming Training Center 107

Backwash Water Turbidity Analysis

Time, min	Backwash Water Turbidity	Time, min	Backwash Water Turbidity
1		16	
2		17	
3		18	
4		19	
5		20	
6		21	
7		22	
8		23	
9		24	
10		25	
11		26	
12		27	
13		28	
14		29	
15		30	
What time did the backwash water fall between 10-15 NTU?			



Filter Number: ___________ Tester: ______________________________

Date: ___________________ Time: _______________________________

Gravel-layer Analysis

Gravel-layer Problems

- Indicators:
  - Dead areas
  - Boils
  - Excessive mud in one location
  - Media separation from the wall

Gravel-layer Analysis

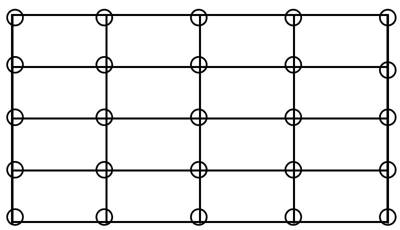
- Equipment needed:
  - 5-ft ruler or steel rod
- This can be done at the same time you are getting media depths

Gravel-layer Analysis continued

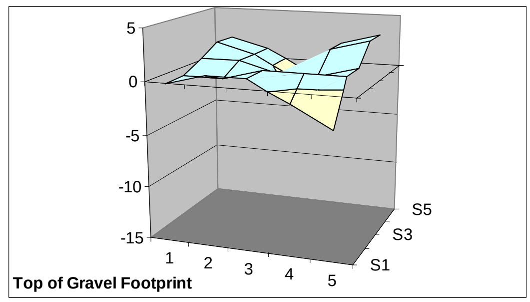
- Procedure:
  - Filter bed dimensions need to be determined, draw a layout of filter bed
    - Divide filter in half length-wise
    - Divide those halves in half
    - Divide filter in half width-wise
    - Divide those halves in half also
  - Where the lines cross are your sampling areas, along with where the lines touch the sides and the corners

Gravel-layer Analysis continued

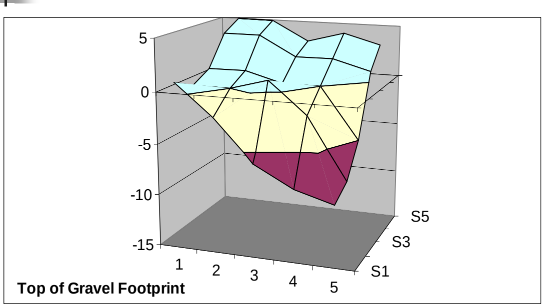
- 25 sampling points



Gravel-layer Analysis continued



Gravel-layer Analysis continued



Filtration Rate Analysis

Filtration Rates Allowed in TN

- Rapid Sand Filters
  - 2.0 gpm/ft^2 for turbidity removal
  - 3.0 gpm/ft^2 for iron removal
- High Rate Filters
  - 4.0 gpm/ft^2 for turbidity and iron removal

State Design Criteria 4.2.1 a. 1 & 2

TDEC - Fleming Training Center 117

Filtration Rate Analysis

- Also known as Hook Gauge
- Determines actual filtration rate in gpm/ft^2
- Determines the accuracy of the filtration rate flow meter
- Equipment needed:
  - Hook gauge – two hooks 6 inches apart
  - Stop watch
  - Tape measure
  - Calculator

TDEC - Fleming Training Center 118

Filtration Rate Analysis continued

- Steps
  - Measure the length and width of the filter bed and basin
  - Place hook gauge in filter with the top hook well below the surface of the water
    - Make sure the hook gauge is level front to back and side to side
  - Close the influent valve, leaving the effluent valve open
    - Record meter's flow

TDEC - Fleming Training Center 119

Filtration Rate Analysis continued

- Steps
  - Start the timer when the water breaks the surface of the first hook
  - Stop timer when the water breaks the surface of the second hook
  - Record time
  - Refill basin and repeat two more times

TDEC - Fleming Training Center 120

Filtration Rate Analysis continued

- Number Crunch
  - Calculate the volume of the water that passed through the filter

$$\text{volume, gal} = (\text{filter bay length, ft})(\text{filter bay width, ft})(0.5\text{ ft depth})(7.48\text{ gal/ ft}^3)$$

  - Calculate the average time in minutes

$$\text{avg. time, min} = \frac{(Time_1 + Time_2 + Time_3)}{(3)(60\text{ sec/ min})}$$

Filtration Rate Analysis continued

- Number Crunch
  - Calculate the filter bed area

$$\text{filter bed area, ft}^2 = (\text{bed length, ft})(\text{bed width, ft})$$

  - Calculate filtration rate in gpm

$$\text{filtration rate, gal/min} = \frac{\text{volume, gal}}{\text{avg. time, min}}$$

Filtration Rate Analysis continued

- Number Crunch
  - Calculate filtration rate in gpm/ft^2

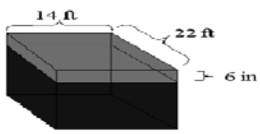
$$\text{filtration rate, gpm/ ft}^2 = \frac{\text{filtration rate, gal/min}}{\text{filter bed area, ft}^2}$$

Filtration Rate Analysis continued

- Is the calculated flow rate greater than the State's allowable rate?
  - Slow down the filtration rate
- Is the calculated flow rate equal to the flow meter?
  - If not, re-do hook gauge
  - If it is still off, the flow meter needs to be calibrated

Filter Rate (Hook Gauge)

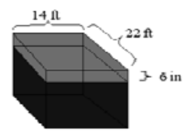
- A filter measures 22 ft by 14 ft. The influent is closed and the effluent is opened. The water level drops 6 inches in 120 sec, 124 sec and 128 sec during three tests. What is the filter rate in gpm/ft^2?



Volume, gal

V=(l, ft)(w, ft)(d, ft)(7.48 gal/ft^3)

V=(22 ft)(14 ft)(0.5 ft)(7.48 gal/ft^3)



V= 1151.9 gal

Average Time, min

120 sec, 124 sec and 128 sec

$$\text{Avg time, min} = \frac{sec_1 + sec_2 + sec_3}{(3)(60\ sec/min)}$$

$$\text{Avg Time, min} = \frac{120+124+128}{(3)(60\ sec/min)}$$

Avg Time, min = 2.0667 min

Sand Bed Area

A filter measures 22 ft by 14 ft.

Sand Area, ft^2 =(length, ft)(width, ft)

Sand Area, ft^2 = (22 ft)(14 ft)

Sand Area, ft^2 = 308 ft^2

Volume, gal = 1151.9 gal
Time, min = 2.0667 min
Area, ft^2 = 308 ft^2

Filter Rate, gpm/ft^2

$$\text{Filter rate, gpm (Hook Gauge)} = \frac{\text{volume, gal}}{\text{average time, min}}$$

$$\text{Filter rate, gpm} = \frac{1151.9 \text{ gal}}{2.0667 \text{ min}}$$

Filter rate, gpm = 557.4 gpm

Filtration Rate, gpm = 557.4 gpm
Volume, gal = 1151.9 gal
Time, min = 2.0667 min
Area, ft^2 = 308 ft^2

Filter Rate, gpm/ft^2

$$\text{Filter rate gpm/ft}^2 = \frac{\text{filter rate, gpm}}{\text{sand area, ft}^2}$$

$$\text{Filter rate, gpm/ft}^2 = \frac{557.4 \text{ gpm}}{308 \text{ ft}^2}$$

Filter rate, gpm/ft^2 = 1.8 gpm/ft^2

Filtration Rate Analysis Worksheet

Filter Bay Dimensions			
Length	ft	Width	ft
Filter Bed Dimensions			
Length	ft	Width	ft
Time to Drop 6 inches			
$Time_1$	sec		
$Time_2$	sec		
$Time_3$	sec		
Filtered Volume			
$vol, gal = (bay\ length, ft)(bay\ width, ft)(0.5\ ft\ drop)(7.48\ gal/\ ft^3)$			
$average\ time, min = \frac{Time_1 + Time_2 + Time_3}{(3)(60\ sec/min)}$			
$filter\ bed\ area, ft^2 = (bed\ length, ft)(bed\ width, ft)$			
$filtration\ rate, gpm/\ ft^2 = \frac{vol, gal}{(avg.\ time, \text{min})(filter\ bed\ area, ft^2)}$			
Is this the allowable filtration rate for the State of TN?			

Rapid Sand Filters	
2.0 gpm/ft^2 for turbidity removal	3.0 gpm/ft^2 for iron removal
High Rate Filters	
4.0 gpm/ft^2 for iron and turbidity removal	

Filter Number: ___________ Tester: ______________________________

Date: __________________ Time: ______________________________

Filtration Math

1. A filter measures 28 feet by 20 feet. The influent is closed and the effluent is opened and the water drains down 6" in 120, 125, and 113 seconds. What is the filter-loading rate in gallons per minute per square foot (gpm/ft^2)?

2. The Randyville Water Plant treats an average of 5.18 MGD. The water is split equally to each of the 8 filters. Each filter basin measures 12 feet wide by 16 feet long and by 24 feet deep. Each filter bed measures 12 feet by 14 feet by 11 feet deep. The influent line to Filter 6 is closed while the effluent remains open. Using a hook gauge and a stopwatch, it is noted that the water level in the filter drops 6 inches in 80, 86, and 89 seconds. What is the filtration rate in gallons per minute per square foot (gpm/ft^2)?

3. The Chrisburg Water Plant treats an average of 7.2 MGD. The water is split equally to each of 8 filters. Each filter basin measures 12.5 feet wide by 16.5 feet long by 24 feet deep. Each filter bed measures 12.5 feet by 14 feet by 10 feet deep. The influent line to Filter 6 is closed while the effluent remains open. Using a hook gauge and a stopwatch, it is noted that the water level in the filter drops 6 inches in 69 seconds on test 1, 6 inches in 67 seconds on test 2 and 6 inches in 70 seconds on test 3. What is the filtration rate in gallons per minute per square foot (gpm/ft^2)?

4. Determine the filtration rate in gpm/ft^2 for a filter with a surface of 28 feet by 20 feet. With the influent valve closed, the water above the filter dropped 6 inches in 57, 56, and 60 seconds.

5. Determine the filtration rate in gpm/ft^2 for a filter bay that is 10 by 14 feet and the filter bed is 10 by 12 feet. The test was run three times. The times required for the water to drop 6 inches were 135, 132 and 129 seconds.

6. Determine the filtration rate in gpm/ft^2 for a filter bay that is 15 by 22 feet and the filter bed is 15 by 20 feet. The test was run three times. The times required for the water to drop 6 inches were 79, 85 and 80 seconds.

7. Determine the filtration rate in gpm/ft^2 for a filter bay that is 16 by 18 feet and the filter bed is 16 by 16 feet. The test was run three times. The times required for the water to drop 6 inches were 65, 62 and 64 seconds.

8. Determine the filtration rate in gpm/ft^2 for a filter bay that is 14 by 18 feet and the filter bed is 14 by 16 feet. The test was run three times. The times required for the water to drop 6 inches were 72, 75 and 76 seconds.

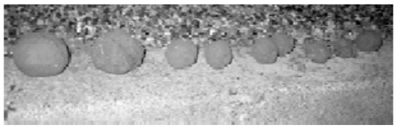
9. Determine the filtration rate in gpm/ft^2 for a filter bay that is 20 by 32 feet and the filter bed is 20 by 30 feet. The test was run three times. The times required for the water to drop 6 inches were 61, 59 and 58 seconds.

10. Determine the filtration rate in gpm/ft^2 for a filter bay that is 24 by 36 feet and the filter bed is 24 by 34 feet. The test was run three times. The times required for the water to drop 6 inches were 62, 60 and 59 seconds.

Answers:

1. 1.88 gpm/ft^2
2. 3.02 gpm/ft^2
3. 3.85 gpm/ft^2
4. 3.89 gpm/ft^2
5. 1.98 gpm/ft^2
6. 3.03 gpm/ft^2
7. 3.97 gpm/ft^2
8. 3.40 gpm/ft^2
9. 4.03 gpm/ft^2
10. 3.94 gpm/ft^2

Mudball Analysis



Mudballs

- Caused by grains of filter media covered with sticky floc material
  - If not effectively removed by backwashing, the grains clump together to form mudballs
- As they become larger, they sink into the filter bed and clog areas where they settle
- These areas become inactive, causing higher-than-optimal filtration rates in the remaining active areas and unequal distribution of backwash water

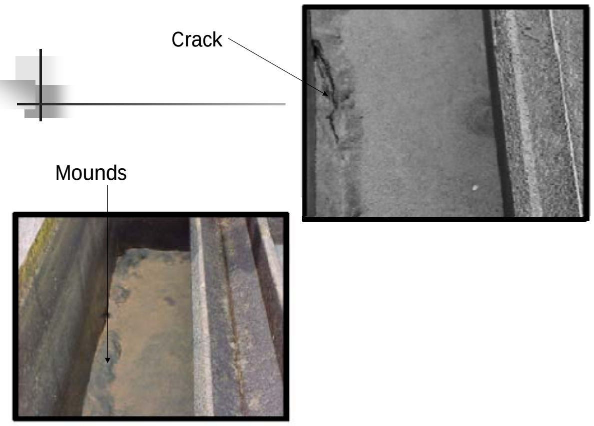
Mudballs continued

Two large mudballs

- Small, light mudballs usually consist of chemicals and feel "spongy"
- Heavy, dense mudballs consist normally of clay particles and are more rigid to the touch

Mudball Analysis

- Drain and isolate the filter
  - Good time to do this is when you are going to do core samples
  - Visually check filter media for mounds, cracks and separation from the wall
    - Due to mud retention from either poor backwash or surface wash not getting edges



Mudball Analysis By Hand

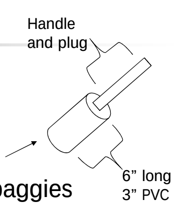
- Lay plywood boards down on top of filter media
  - To avoid stepping onto media
- Pick a location and start digging with your hands
  - This creates a smaller hole as opposed to digging with a shovel
- Gently sift through media with your hands searching for mudballs

Mudball Analysis By Hand cont.

- As you are digging, look for separation of sand and anthracite
  - Measure depth of each separate media and make note of these depths
- Removal:
  - Manually
  - Soak the media in acidic water
- Backwash procedures will have to be modified to prevent accumulation of mudballs in the future

Mudball Analysis

- Equipment Needed:
  - No. 12 sieve (10 mesh)
  - Mudball sampling device
  - 1-gal resealable plastic baggies
  - 5-gal bucket
  - 250-mL graduated cylinder
    - 500-1,000-mL graduate cylinder may be needed if large mudballs are present

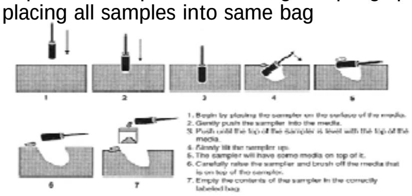


Mudball Analysis cont.

- Backwash filter
- Drain the water from the filter to a point below the media surface
- Select five sampling points at random
- Beginning with the first sampling point, push the mudball sampler 6 inches into the media

Mudball Analysis cont.

- Tilt the mudball sampler back until it is horizontal with the filter bed
- Lift the mudball sampler, keeping it horizontal
- Empty into a baggie
- Repeat this steps for remaining sampling spots, placing all samples into same bag



Mudball Analysis cont.

- Put water in 5-gal bucket until about half-full
- Lower the No. 12 sieve into the water until nearly submerged
- Put sampled media into sieve, handful at a time
- Carefully raise and lower the sieve into the water to wash media through the mesh

Mudball Analysis cont.

- Continue placing handfuls of media, lowering and raising sieve until all media has been sieved
- Gently wash any mudballs collected to one side of the sieve

Mudball Analysis cont.

- Fill 250-mL graduated cylinder to the 200-mL mark
  - May need 500 to 1000-mL graduated cylinder if you have large mudballs
- Gently transfer the mudballs from the sieve to the graduated cylinder
- Read and record new volume

TDEC - Fleming Training Center 144

Mudball Analysis cont.

- Number crunch:

$$Media\ Sample\ Vol,\ mL = \frac{(0.785)(D^2)(H)(N)(3{,}785\,mL/gal)}{231\,in^3/gal}$$

Where:
D = diameter, in
H = height of sampler, in
N = number of samples taken

$$Media\ Sample\ Vol,\ mL = \frac{(0.785)(3^2)(6)(5)(3{,}785\,mL/gal)}{231\,in^3/gal} = 3472.6\,mL$$

TDEC - Fleming Training Center 145

Mudball Analysis cont.

- Number crunch:

$$Mudball\ Volume,\ mL = Final\ Cylinder\ Vol,\ mL - Initial\ Cylinder\ Vol,\ mL$$

$$\%\ Mudballs = \frac{(Mudball\ Vol,\ mL)(100)}{Media\ Sample\ Vol,\ mL}$$

TDEC - Fleming Training Center 146

Mudball Analysis cont.

% Mudballs	Filter Bed Condition
0.0 – 0.1	Excellent
0.1 – 0.2	Very good
0.2 – 0.5	Good
0.5 – 1.0	Fair
1.0 – 2.5	Fairly bad
2.5 – 5.0	Bad
Greater than 5.0	Very bad

TDEC - Fleming Training Center 147

Mudball Analysis cont.

- Easy mudball removal
  - Use of strainer basket during a low-rate backwash
  - Break up of mudballs by using a rake
  - Passing media through large sieves that will let media less than 1 inch pass through

Mudball Analysis cont.

- More difficult mudball removal
  - Injection of high-pressure air or water into media to bring mudballs to the surface
  - Chemical addition to break up mudballs
  - Removal of media and cleaning or replacing it
    - Replacing does not fix the problem, backwash procedures need to be re-evaluated

Mudball Analysis Worksheet

Coring Device Diameter	in	Coring Device Depth	in

Mudball Volume	
Initial Cylinder Reading (V1)	mL
Final Cylinder Reading (V2)	mL
Mudball Volume (V1 – V2)	mL
$Media\ Sample\ Vol,\ mL = \frac{(0.785)(D^2)(H)(N)(3{,}785\,mL / gal)}{231\,in^3 / gal}$ Where: D = diameter, in H = height of sampler, in N = number of samples taken	mL
$\%\,\text{Mudballs} = \frac{(\text{Mudball Vol., mL})(100)}{\text{Media Sample Vol., mL}}$	%

Circle the range that corresponds to the value you got

0.0– 0.1 Excellent	0.1 – 0.2 Very Good	0.2 – 0.5 Good	0.5 – 1.0 Fair	1.0 – 2.5 Fairly Bad	2.5 – 5.0 Bad	Greater than 5.0 Very Bad

Filter Number: ___________ Tester: ______________________________

Date: ___________________ Time: _______________________________

Mudball Math

1. Mudball samples were taken with a sampler that has a 3 in diameter and is 6 inches deep. The 250-mL graduated cylinder was filled up to the 200-mL mark with water. The mudballs were placed in the graduated cylinder and the water rose to the 235 mL mark. What is the percent of mudballs if 5 samples were taken?

2. Mudball samples were taken with a sampler that has a 3 in diameter and is 6 inches deep. The 500-mL graduated cylinder was filled up to the 300-mL mark with water. The mudballs were placed in the graduated cylinder and the water rose to the 425 mL mark. What is the percent of mudballs if 5 samples were taken?

3. Mudball samples were taken with a sampler that has a 3 in diameter and is 6 inches deep. The 250-mL graduated cylinder was filled up to the 200-mL mark with water. The mudballs were placed in the graduated cylinder and the water rose to the 247 mL mark. What is the percent of mudballs if 5 samples were taken?

Answers:

1. 1.0%
2. 3.6%
3. 1.4%

Acid-Soluble Mineral Analysis

Also known as Carbonate Precipitation Analysis

Presence of Acid-Soluble Minerals

- Calcium carbonate or manganese dioxide may "cement" the filter particles together
  - Increases media weight
  - Decreases bed expansion
  - Reduces filter effectiveness
- Can use muriatic acid to dissolve calcium carbonate, but it may also damage concrete filter bay
  - Have example from a water plant on procedure

Presence of Acid-Soluble Minerals continued

- Equipment needed
  - Balance
  - Drying oven
  - Dessicator
- Sample can be what is left in 5 gallon bucket from mudball analysis

Presence of Acid-Soluble Minerals continued

- AWWA B100-01 outlines analysis
  - Performed by immersing a known weight of filter media in 1:1 hydrochloric acid until the acid-soluble materials are dissolved, then determining the weight loss

Presence of Acid-Soluble Minerals continued

- 5.3.1 Acid solubility test
  - Wash sample with distilled water and dry at 110 ± 5°C to a constant weight
  - Cool in dessicator no more than 30 minutes
  - Weigh 200 grams dried sample to nearest 0.1 % of weight of sample
  - Place sample in beaker and add enough 1:1 HCl to immerse sample, but not less than volume indicated on next slide

Presence of Acid-Soluble Minerals continued

Max. Particle Size in Sample		Min. Sample Wt	Min. 1:1 HCl vol.
mm	in	gram	mL
63.0	2 ½	4,000	7,000
37.5	1 ½	250	800
25.4	1	250	800
19.0	¾	250	800
12.5	½	250	800
9.5	$^{3}/_{8}$ and smaller	100	320

Presence of Acid-Soluble Minerals continued

- 5.3.1 Acid solubility test
  - Allow to stand in 1:1 HCl at room temperature for at least 30 minutes after fizzing stops
  - Wash sample with distilled water several times and dry at 110 ± 5°C to a constant weight
  - Cool in dessicator no more than 30 minutes
  - Weigh dried sample to nearest 0.1 % of weight of sample
  - Report loss in weight as acid-soluble material

Acid-Soluble Mineral Analysis Worksheet

Weigh Measurements			
Initial Sample Weight	grams	Final Sample Weight	grams
Calculations			
Carbonate Weight = Initial Weight, grams - Final Weight, grams			grams
Percent Carbonate $= \frac{\text{(Carbonate Weight, grams)(100)}}{\text{Initial Weight, grams}}$			grams
Additional Comments			

Filter Number: ___________ Tester: ______________________________

Date: ___________________ Time: _______________________________

Sieve Testing Procedure

Effective Size &
Uniformity Coefficient

Uniformity Coefficient and Effective Size

- From the design specifications, find out what the uniformity coefficient and effective size was supposed to be for each type of media
  - Gravel
  - Sand
  - Coal

Uniformity Coefficient

- The lower the uniformity coefficient, the more uniform the size of the media
- The more uniform the media size, the slower the head loss buildup of a filter
- Sand
  - Not greater than 1.7
- Anthracite
  - Not greater than 1.85

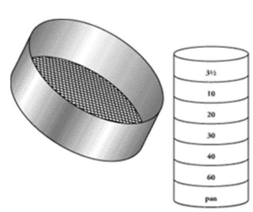
Uniformity Coefficient continued

- Time consuming test
  - Takes 2-3 days
- The ratio of particle diameters as determined by sieve analysis
- It is a measure of how well or poorly sorted the sediment is

Effective Size

- The smaller the media, the lower the effluent turbidity
- But less run time as well
- Sand
  - 0.35 mm to 0.55 mm
- Anthracite
  - 0.8 mm to 1.2 mm

Determination of Uniformity Coefficient & Effective Size



- Apparatus needed:
  - No. 200 sieve
  - Set of sieves
    - Numbers 3½, 10, 20, 30, 40, 60, lid and receiver
  - Drying oven
    - Set at a controlled temperature of 105-110°C
  - Set of metal pans for drying and weighing samples
  - A balance of 250 gram capacity and accurate to 0.01 gram

Determination of Uniformity Coefficient & Effective Size cont.

- Drain and isolate filter
- Determine sampling sites
  - 3-4 sites for a representative sample
- Enter filter and stand on plywood
- Place coring device (metal pipe ~1.5 inches in diameter) into media and push down until you come to resistance or hear the crunch of gravel
- Place hand on top of coring device to provide suction

TDEC - Fleming Training Center 165

Determination of Uniformity Coefficient & Effective Size cont.

- Slowly raise coring device out of media, still with hand on top to provide suction
- Lay aluminum foil sheet down on plywood
- Gently tip the end of the coring device so the contents are slowly emptied across the length of the aluminum foil
- Separate the sand and anthracite at the interface

TDEC - Fleming Training Center 166

Determination of Uniformity Coefficient & Effective Size cont.

- Repeat these steps for the next samples
- Label two bags, one for sand and one for anthracite

TDEC - Fleming Training Center 167

Determination of Uniformity Coefficient & Effective Size cont.

- Begin with about a 100-gram sample of sand
  - Repeat for anthracite as well
- Dry in 105-110ºC oven for two hours
- Weigh dry sand sample (WD)
- Label and weigh metal sample pans, and set aside

TDEC - Fleming Training Center 168

Determination of Uniformity Coefficient & Effective Size cont.

- Fill sand sample container with tap water, shake and decant wash water through No. 200 sieve
- Wash material retained on sieve back into sample container
- Repeat several times until wash water is clear

TDEC - Fleming Training Center 169

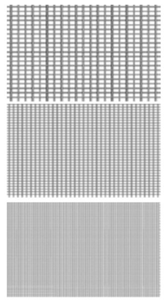
Determination of Uniformity Coefficient & Effective Size cont.

- Dry sand again in 105-110oC oven for two hours
- Weigh dry washed sand (WDS) and subtract from dry weight to determine weight of fines
- Wt. of fines = WD - WDS

TDEC - Fleming Training Center 170

Determination of Uniformity Coefficient & Effective Size cont.

- Arrange a set of sieves from largest opening to smallest
- Shake stacked sieves, vibrating, jogging, and jolting them to keep the sand in continuous motion for two minutes
- Shake each sieve individually over a clean tray to make sure all the sand has passed through and is distributed by size



Determination of Uniformity Coefficient & Effective Size cont.

- Pour the sand off each sieve into labeled, weighed pans
- Weigh and determine the sample weight (WS) by subtracting the weight of the pan
- Determine the percent passing for each sieve by:
  - % of material retained on the sieve = $\frac{WS \times 100\%}{WDS}$

Determination of Uniformity Coefficient & Effective Size cont.

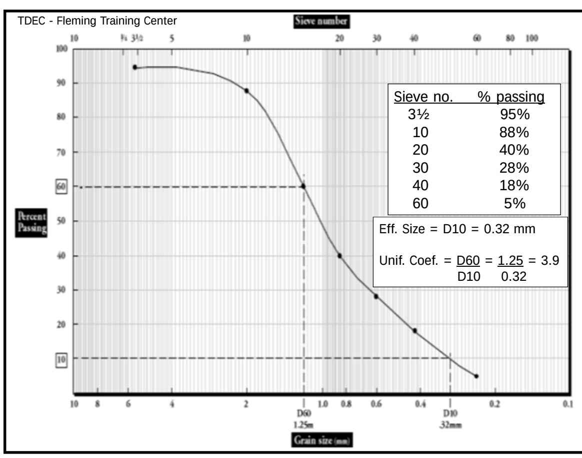
- % passing = % passing the next largest on sieve - % retained sieve
- An example calculation of percent passing each sieve for a 120 gram sample is summarized on the next slide

Sand Particle Size Analysis: Calculating Percent Passing Selected Sieves

Sieve number	Sieve size	Sample weight	% retained	% passing	% passing next larger sieve
3.5	5.6	6.0	5	95	100
10	2.0	8.4	7	88	95
20	0.85	57.6	48	40	88
30	0.425	14.4	12	28	40
40	0.425	12.0	10	18	28
60	0.25	15.6	13	5	18
Pan	-----	6.0	5	-----	5
Total Weight	-----	120.0			

Determination of Uniformity Coefficient & Effective Size cont.

- Graph the percent passing results on semi-log paper
- From the graph, find the Effective Size as D10, where only 10% of the sample is a smaller size
- Also from the graph, find D60, where 60% of the sample is a smaller size
- The Uniformity Coefficient is D60/D10



Floc Retention Analysis

Retained Floc

- Some retained floc should remain
  - Too clean – turbidity spikes
  - Too dirty – mudball formation will occur
  - Just enough – very few turbidity spikes will occur
- All depths of the media should retain a turbidity value of 30-60 NTU

Floc Retention Analysis

- Some “dirt” should remain in filter
  - This floc retention profile is a way to determine how much “dirt” stays in the filter and at what depths
- AWWA video says to do this annually, but you should do this quarterly to see if seasonal changes affect your filters

Floc Retention Analysis cont.

- Equipment Needed:
  - 24-36 1-gallon resealable plastic bags
  - Coring device
  - 100-mL graduated cylinder
  - Pint jar – “mason” or “jelly” jar
  - 50-mL beaker
  - Turbidimeter
  - 1-liter Erlenmeyer flask

Floc Retention Analysis cont.

- Performed twice on a filter
  - Once before backwashing and
  - Once after backwashing

Floc Retention Analysis cont.

- Procedure
  - Prepare 2 sets of plastic bags
    - 7 with “Before Backwash”
    - 7 with “After Backwash”
    - Each set needs media depths written on them as well:
      - 0-2 inches
      - 2-6 inches
      - 6-12 inches
      - 12-18 inches
      - 18-24 inches
      - 24-30 inches
      - 30-36 inches, just in case

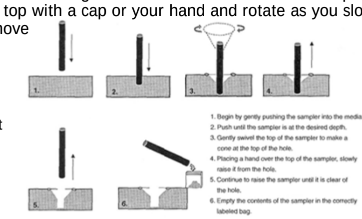
Floc Retention Analysis cont.

- Sample Collection Procedure
  - Select at least three sampling sites
    - Not in the same area
    - Try to get a good composite
  - Completely drain the filter
  - Lay down plywood and enter the filter

Floc Retention Analysis cont.

- Sample Collection Procedure
  - Push the coring device down into the filter, turning as you push down to the desired depth
  - Once the coring device has reached the desired depth seal the top with a cap or your hand and rotate as you slowly remove

Rotating it widens the hole so that it won't cave in



Floc Retention Analysis cont.

- Sample Collection Procedure
  - Break the seal and deposit the media into the appropriate bag for that depth
  - Repeat this process in the same hole for each sample depths
  - Then repeat this whole process in at least two other areas
    - You should have 3 areas sampled at depth of 0-2 inches in one bag, 2-6 inches, etc.

Floc Retention Analysis cont.

- Sample Collection Procedure
  - Backwash the filter
  - Repeat again, except this time place core samples in bags labeled "After Backwash"

Floc Retention Analysis cont.

- Sample Analysis Procedure
  - Mix each bag thoroughly and then arrange in order of depth with before and after backwash separated
  - Weigh out approximately 50 grams of media
    - Approximately 50-mL
  - Place into "jelly" jar

Floc Retention Analysis cont.

- Sample Analysis Procedure
  - Add 100-mL of tap water
    - Use same 50-mL beaker, filled twice to get 2:1
  - Cap and shake vigorously for 1 minute
  - Decant the turbid water into a 1000-mL flask
  - Repeat the steps of adding 100-mL tap water, shaking and decanting until you have a total of 500-mL

Floc Retention Analysis cont.

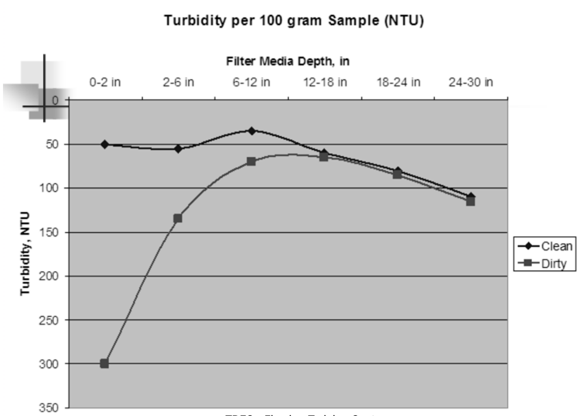
- Sample Analysis Procedure
  - Thoroughly mix the 500-mL of turbid water and take a turbidity reading
  - Multiply the reading by 2 in order to calculate the turbidity reading for a 100 gram sample
  - Repeat this procedure for each sample for both sets of before and after backwash at each depth
  - Record and plot results

TDEC - Fleming Training Center 189

Floc Retention Analysis cont.

Turbidity	Filter Bed Condition
0-30 NTU	Media too clean, not well ripened
30-60 NTU	Media clean, slightly ripened; optimal filter performance
60-120 NTU	Slightly dirty media, well ripened, should perform well
120-300 NTU	Dirty media, well ripened; re-evaluate backwash procedure
300-600 NTU	Dirty media, possible mudballs
600-1200 NTU	Very dirty media, many mudballs
> 1200 NTU	Extremely dirty; chemical cleaning of media or replacement

TDEC - Fleming Training Center 190

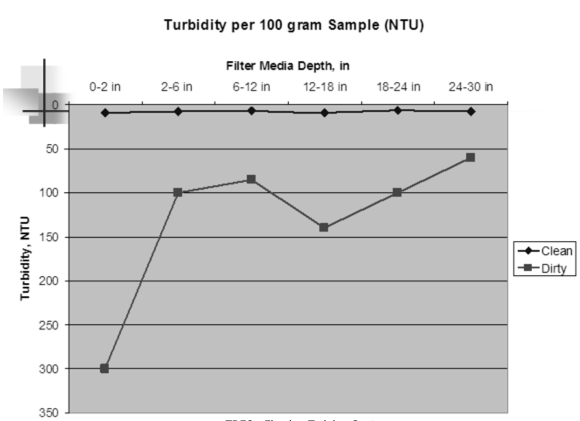


TDEC - Fleming Training Center 191

Floc Retention Analysis cont.

- From the previous graph
  - It appears the top couple of inches is catching the most particles
  - Most of the filtration occurred in the anthracite layer
  - Sand layer was not cleaned well during backwash

TDEC - Fleming Training Center 192

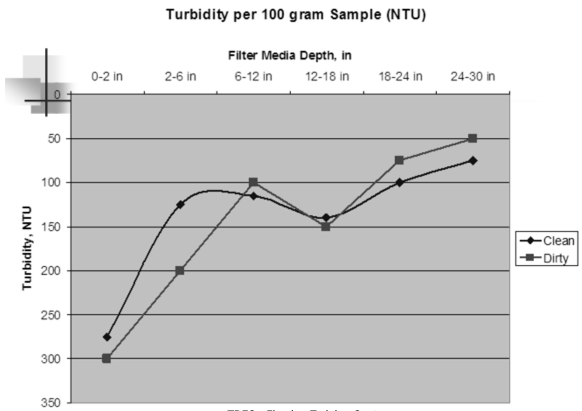


TDEC - Fleming Training Center 193

Floc Retention Analysis cont.

- From the previous graph
  - Operator over-washed the filter
  - Common problem

TDEC - Fleming Training Center 194



Floc Retention Analysis cont.

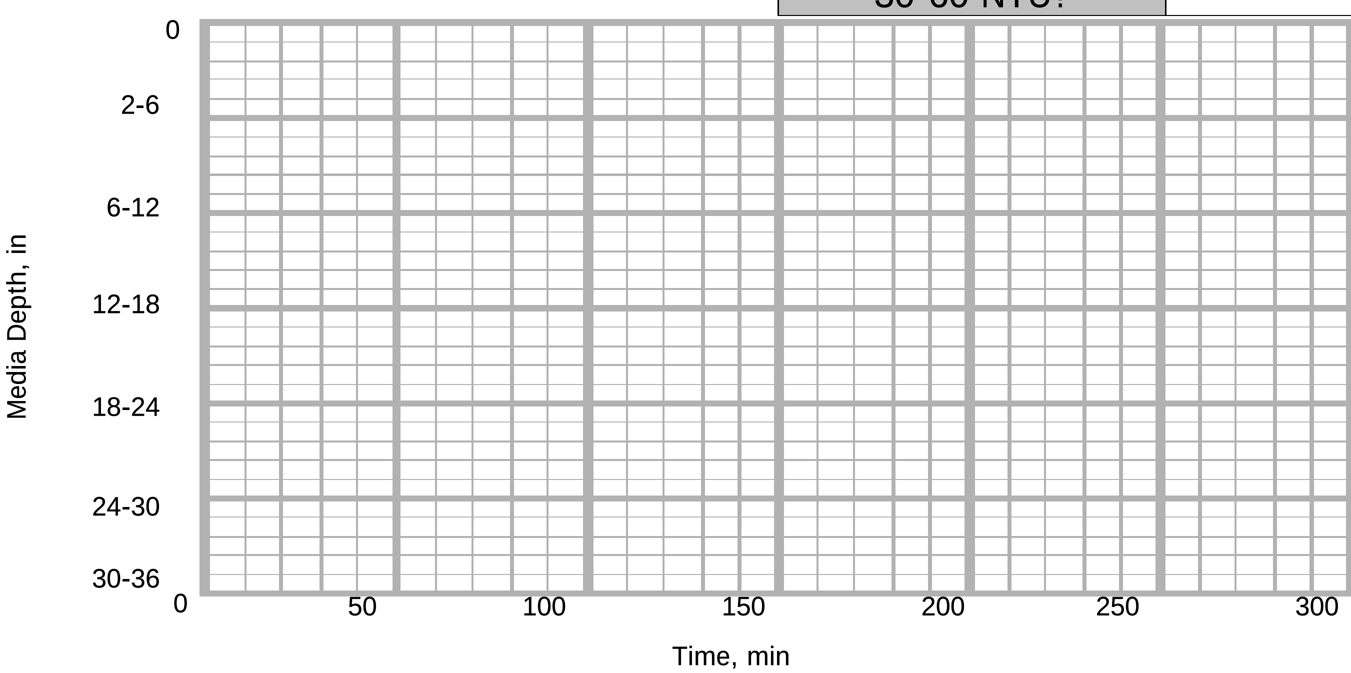
- From the previous graph
  - Poor backwash

Floc Retention Analysis cont.

- You want most of your particles removed during backwash
  - Filter should be cleaned and ripened
  - Filter can be too clean or too dirty with improper backwash

Floc Retention Profile

Before Backwash				After Backwash			
Core Sampler Depth, in	Turbidity	X	Floc Retention, NTU	Core Sampler Depth, in	Turbidity	X	Floc Retention, NTU
0-2		2		0-2		2	
2-6		2		2-6		2	
6-12		2		6-12		2	
12-18		2		12-18		2	
18-24		2		18-24		2	
24-30		2		24-30		2	
30-36		2		30-36		2	
Total Retained Floc				Total Retained Floc			
Average Retained Floc				Average Retained Floc			
				Is this in the range of 30-60 NTU?			



Filter Number: ___________	Tester: ______________________________
Date: ___________________	Time: _______________________________

Disinfection

- Once filter surface is broken, filter bed must be disinfected
- If filter is dosed at 50 mg/L and let sit for 12-24 hours, it will remove mudballs, mud deposits, bacterial growth, iron and manganese deposits on filter walls and within media itself

Disinfection cont.

- AWWA Standard C653-03
  - This applies to disinfection of filter basins and gravel, silica sand, anthracite and other mixed media materials ***except*** granular activated carbon (GAC)
  - If GAC is part of the filter media, special care should be taken to protect the GAC from contamination

Disinfection cont.

- AWWA Standard C653-03
  - The entire filter basin should be filled up to the maximum water level and disinfected by one of two methods:
    - Chlorine injected into backwash water
    - Chlorine injected into filter influent while filtering to waste

Disinfection cont.

- AWWA Standard C653-03
  - Chlorine injected into backwash water
    - Enough chlorine injected to produce at least 25 mg/L free chlorine residual throughout entire filter
    - Chlorinated water shall be allowed to stand in the filter for at least 12 hours
    - Collect samples at the end of 12 hours, free residual chlorine shall not fall below 15 mg/L or else disinfection needs to be repeated

Disinfection cont.

- AWWA Standard C653-03
  - Chlorine injected into filter influent while filtering to waste
    - Enough chlorine injected to produce at least 25 mg/L free chlorine residual throughout entire filter
      - Turn on filter to waste to get through filter
    - When water with at least 25 mg/L free chlorine residual chlorine reaches the filter-to-waste, the flow of water shall be stopped
    - Filter shall be held for at least 12 hours

TDEC - Fleming Training Center 203

Disinfection cont.

- AWWA Standard C653-03
  - After 12 hour contact time
    - Samples should be collected from the top and bottom of the unit to ensure the free chlorine residual readings measure the lowest chlorine level existing in the unit at the end of the 12-hour period
      - May have to dose at 50-100 mg/L to get residual of 15 mg/L after 12 hours
    - If satisfactory levels of chlorine residuals are obtained, the filter shall be run to waste or backwashed thoroughly to remove highly chlorinated water

TDEC - Fleming Training Center 204

Disinfection cont.

- AWWA Standard C653-03
  - Bacteriological sampling
    - After chlorination and before filter placed back into service, two or more samples shall be taken from the unit not less than 30 minutes apart and shall be tested for the presence of coliform
      - 50% have to be negative, therefore take at least 3 samples, if one is positive, then more than 50% were negative

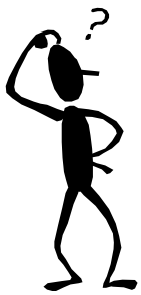
TDEC - Fleming Training Center 205

Disinfection cont.

- AWWA Standard C653-03
  - Bacteriological sampling
    - If none of the samples show the presence of coliform, the unit may be placed back into service
    - If positive, take repeat at least 24 hours apart until consecutive samples are negative
    - Or disinfect again and resample

TDEC - Fleming Training Center 206

Now What?



- Many tests can be done
- What order should they be done?

TDEC - Fleming Training Center 207

Order of Tests

- Set up hook gauge
- Establish a fixed point for bed expansion measurements
- Take the initial bed measurement
- Wash plywood sheets with strong hypochlorite solution

TDEC - Fleming Training Center 208

Order of Tests cont.

- Drain filter
  - Run hook gauge (drop test)
  - Look for uneven drainage, cracks, mounding
  - Do not let filter dry out before next steps
- Set up ladders for safely entering and exiting the filter bay
- Lay down plywood to avoid standing on media

TDEC - Fleming Training Center 209

Order of Tests cont.

- Measure levelness of troughs
- Take media depth measurements randomly throughout filter bed
- Take "Before Backwash" core samples for floc retention analysis
- Remove all people and equipment
- Lower hook gauge below troughs

TDEC - Fleming Training Center 210

Order of Tests cont.

- Slowly start backwash to refill filter
  - Observe distribution of backwash water
  - Look for boils, mudballs

TDEC - Fleming Training Center 211

Order of Tests cont.

- While the filter is being backwash:
  - Take samples for backwash water turbidity analysis
  - Take second measurement for bed expansion
  - Perform rise test for backwash water flow rate
    - Afterward raise again to repeat drop test later

TDEC - Fleming Training Center 212

Order of Tests cont.

- After backwash, drain filter again
  - Run hook gauge (drop test)
  - Look for uneven drainage, cracks, mounding
  - Do not let filter dry out before next steps
- Set up ladders for safely entering and exiting the filter bay
- Lay down plywood to avoid standing on media

TDEC - Fleming Training Center 213

Order of Tests cont.

- Take “After Backwash” core samples for floc retention analysis
- Take samples for mudball analysis
- Remove all people and equipment
- Backwash again
- Disinfect
- Run samples in lab

TDEC - Fleming Training Center 214

References

- *Filter Evaluation Procedures for Granular Media*, 1st Edition. 2003. AWWA
- *AWWA Standard B100-01*
- *Filter Evaluation and Optimization*, TAUD – John Shadwick

Acid Washing and Disinfecting Dual Media Filters

Each filter shall be acid washed and disinfected annually for proper maintenance of filter media. Proper PPE should be worn while handling Hydrochloric acid, Hydrogen Peroxide, Calcium Hypochlorite and Sodium Hypochlorite (respirators, chemical resistant gloves and apron).

Acid Washing:

Note: Before any work on a filter begins, be sure to check that the effluent valve is in the closed position and is placed in the off position.

1. Follow the backwashing procedures for a Manual backwash, except when you ramp the wash water back down to zero open the rewash valve and let the filter level go back down to about 0.7 – 0.9 feet on top of the filter. **Collect media sample after initial backwash. Record time.**
2. While running the air sour to mix the acid with filter media add 15 to 20 gallons of 31% Hydrochloric acid or until the water on top of the filter reaches a pH of 1.8 to 1.9, document the results. Let the air scour mix the acid for 1 hour.
3. **Record beginning and end times.**
4. Wash the filter again so that the pH is elevated back up to normal (6.5 – 7.0) and document the results (pH prior to disinfection) and time spent in air scour acid wash.
5. Once pH is adjusted back around 7.00, drop the water level on top of the filter to 1.00 foot.
6. Add 12 pounds of 65% HTH (Calcium Hypochlorite) (**this number is not exact and should be adjusted accordingly with varying water levels on top of the filters**) or 10 gallons of 12.5% Sodium Hypochlorite to the filter to achieve 200ppm total chlorine residual.
7. Turn air scour back on.
8. Check the total chlorine residual in the filter then let the filter air scour for 30 minutes to disinfect. **Record total chlorine residual and start and end times for the disinfection.**
9. After 30-minute disinfection, wash the filter again until the chlorine residual is back down to normal and collect the bacteriological sample. **Record the chlorine residual before collecting the bacteriological sample.**
10. Put the filter into rewash until it seasons and turbidity reaches 0.20NTU. Record the total backwash water used for the entire process. Make note of the filter media depth in comparison to the red indicating tile on the filter bed wall. **Make sure all information is clearly stated on filter disinfection form.**

Acid Washing and Disinfecting Record

Acid Wash			
31% Hydrochloric Acid			
pH dropped to		pH prior to disinfection	
Air Scour for 1 hour			
Begin Time	AM PM	End Time	AM PM

Disinfection			
Slug Chlorination			
Required Chlorine Dose		ppm or mg/L	
Contact Time		hours	
Begin Time	AM PM	End Time	AM PM
Calculations			

$\text{Volume} = \frac{(\text{Filter Area, ft}^2)(3.5\text{ ft})(7.48\text{gal/ft}^3)}{1{,}000{,}000}$ *3.5 = Water + Filter Media Depth*	MG
$\text{HTH, lbs} = \frac{(\_\_\_\_\_\_\_\_\_\ \text{mg/L})(\_\_\_\_\_\_\_\_\_\_\ \text{MG})(8.34\text{ lbs/gal})}{(\_\_\_\_\_\_\_\_\_\_)\%\text{Chemical Purity, as decimal}}$	lbs
$\text{Bleach, gal} = \frac{(\_\_\_\_\_\_\_\_\_\ \text{mg/L})(\_\_\_\_\_\_\_\_\_\_\ \text{MG})}{(\_\_\_\_\_\_\_\_\_\_)\%\text{Chemical Purity, as decimal}}$	gal

Lab Results			
Actual chlorine content initial (after chlorine was added)			m/L
Chlorine residual prior to pulling Bac'T sample			m/L
Bac'T sample Results		Bac'T Sample Date & Time	AM PM
Total Backwash Water Used		Date & Time put back into service	AM PM

Filter Number: ___________ Tester: ______________________________

Date: ___________________ Time: ______________________________

Section 2

Bed Expansion Math

1. While evaluating a filter, a bed expansion test was performed. During the backwash the filter bed rose 4 ¼ inches. The average media depth was 30 inches. Calculate the bed expansion in percent.

$$\frac{(4.25)(100)}{30} = 14\%$$

2. While evaluating a filter, a bed expansion test was performed. During the backwash the filter bed rose 6 ½ inches. The average media depth was 31 inches. Calculate the bed expansion in percent.

$$\frac{(6.5)(100)}{31} = 21\%$$

3. While evaluating a filter, a bed expansion test was performed. During the backwash the filter bed rose 8 inches. The average media depth was 36 inches. Calculate the bed expansion in percent.

$$\frac{(8)(100)}{36} = 22\%$$

4. Filter 5 at a water plant has an average media depth of 29 inches. The bed expanded by 8 inches during backwash. What is the bed expansion in percent?

$$\frac{(8)(100)}{29} = 28\%$$

5. Filter 2 at a water plant has an average media depth of 28 inches. The bed expanded by 4 inches during backwash. What is the bed expansion in percent?

$$\frac{(4)(100)}{28} = 14\%$$

6. Filter 16 at a water plant has an average media depth of 32 inches. The bed expanded by 10 inches during backwash. What is the bed expansion in percent?

$$\frac{(10)(100)}{32} = 31\%$$

7. Calculate the filter bed expansion if the average media depth is 33 inches and the bed expansion is 5.5 inches.

$$\frac{(5.5)(100)}{33} = 17\%$$

8. Calculate the filter bed expansion if the average media depth is 34 ½ inches and the bed expansion is 7 inches.

$$\frac{(7)(100)}{34.5} = 20\%$$

9. Calculate the filter bed expansion if the average media depth is 28 inches and the bed expansion is 9 inches.

$$\frac{(9)(100)}{28} = 32\%$$

10. Calculate the filter bed expansion if the average media depth is 31 inches and the bed expansion is 5 inches.

$$\frac{(5)(100)}{31} = 16\%$$

Backwash Math

1. A filter measures 28 feet by 20 feet. The backwash cycle is started and the water rises 6" in 12, 13, and 13 seconds. What is the backwash rate in gallons per minute per square foot (gpm/ft^2)?

vol. = (28 ft)(20 ft)(0.5 ft)(7.48) = 2094.4 gal

time = $\frac{12s + 13s + 13s}{(3)(60)}$ = 0.2111 min

area = (28 ft)(20 ft) = 560 ft^2

gpm/ft^2 = $\frac{2094.4 \text{ gal}}{(0.2111 \text{ min})(560 \text{ ft}^2)}$ = **17.72 gpm/ft^2**

2. The Randyville Water Plant treats an average of 5.18 MGD. The water is split equally to each of the 8 filters. Each filter basin measures 12 feet wide by 16 feet long and by 24 feet deep. Each filter bed measures 12 feet by 14 feet by 11 feet deep. Filter 6 is taken offline to backwash. Using a hook gauge and a stopwatch, it is noted that the water level in the filter rises 6 inches in 14, 16, and 15 seconds. What is the backwash rate in gallons per minute per square foot (gpm/ft^2) and how many gallons were used if the filter was backwashed for 9 minutes?

vol. = (12 ft)(14 ft)(0.5 ft)(7.48) = 628.32 gal

time = $\frac{14s + 16s + 15s}{(3)(60)}$ = 0.25 min

area = (12 ft)(14 ft) = 168 ft^2

gpm/ft^2 = $\frac{628.32 \text{ gal}}{(0.25 \text{ min})(168 \text{ ft}^2)}$ = **14.96 gpm/ft^2**

vol. = (14.96 gpm/ft^2)(168 ft^2)(9 min) = **22,619.5 gal**

3. The Chrisburg Water Plant treats an average of 7.2 MGD. The water is split equally to each of 8 filters. Each filter basin measures 12.5 feet wide by 16.5 feet long by 24 feet deep. Each filter bed measures 12.5 feet by 14 feet by 10 feet deep. Filter 6 is taken offline to backwash. Using a hook gauge and a stopwatch, it is noted that the water level in the filter rises 6 inches in 12 seconds on test 1, 6 inches in 11 seconds on test 2 and 6 inches in 14 seconds on test 3. What is the backwash rate in gallons per minute per square foot (gpm/ft^2)?

vol. = (12.5 ft)(14 ft)(0.5 ft)(7.48) = 654.5 gal

time = $\frac{12s + 11s + 14s}{(3)(60)}$ = 0.2056 min

area = (12.5 ft)(14 ft) = 175 ft^2

gpm/ft^2 = $\frac{654.5 \text{ gal}}{(0.2056 \text{ min})(175 \text{ ft}^2)}$ = **18.19 gpm/ft^2**

4. Determine the backwash rate in gpm/ft^2 for a filter with a surface of 28 feet by 20 feet. The backwash cycle started and the water rose 6 inches in 15, 16, and 16 seconds.

vol. = (28 ft)(20 ft)(0.5 ft)(7.48) = 2094.4 gal

$$time = \frac{15s + 16s + 16s}{(3)(60)} = 0.2611\ min$$

area = (28 ft)(20 ft) = 560 ft^2

$$gpm/ft^2 = \frac{2094.4\ gal}{(0.2611\ min)(560\ ft^2)} = \boxed{14.32\ gpm/ft^2}$$

5. Determine the backwash rate in gpm/ft^2 for a filter bay that is 10 by 14 feet and the filter bed is 10 by 12 feet. The test was run three times. The backwash cycle started and the water rose 6 inches in 17, 16, and 16 seconds.

vol. = (10 ft)(12 ft)(0.5 ft)(7.48) = 448.8 gal

$$time = \frac{17s + 16s + 16s}{(3)(60)} = 0.2722\ min$$

area = (10 ft)(12 ft) = 120 ft^2

$$gpm/ft^2 = \frac{448.8\ gal}{(0.2722\ min)(120\ ft^2)} = \boxed{13.74\ gpm/ft^2}$$

6. Determine the backwash rate in gpm/ft^2 for a filter bay that is 15 by 22 feet and the filter bed is 15 by 20 feet. The test was run three times. The backwash cycle started and the water rose 6 inches in 18, 17, and 20 seconds

vol. = (15 ft)(20 ft)(0.5 ft)(7.48) = 1122 gal

$$time = \frac{18s + 17s + 20s}{(3)(60)} = 0.3056\ min$$

area = (15 ft)(20 ft) = 300 ft^2

$$gpm/ft^2 = \frac{1122\ gal}{(0.3056\ min)(300\ ft^2)} = \boxed{12.24\ gpm/ft^2}$$

7. Determine the backwash rate in gpm/ft^2 for a filter bay that is 16 by 18 feet and the filter bed is 16 by 16 feet. The test was run three times. The backwash cycle started and the water rose 6 inches in 11, 10, and 9 seconds

vol. = (16 ft)(16 ft)(0.5 ft)(7.48) = 957.44 gal

$$time = \frac{11s + 10s + 9s}{(3)(60)} = 0.1667\ min$$

area = (16 ft)(16 ft) = 256 ft^2

$$gpm/ft^2 = \frac{957.44\ gal}{(0.1667\ min)(256\ ft^2)} = \boxed{22.44\ gpm/ft^2}$$

8. Determine the backwash rate in gpm/ft^2 and the amount of water used if they backwashed for 12 minutes for a filter bay that is 14 by 18 feet and the filter bed is 14 by 16 feet. The test was run three times. The backwash cycle started and the water rose 6 inches in 18, 17, and 20 seconds

vol. = (14 ft)(16 ft)(0.5 ft)(7.48) = 837.76 gal

time = $\frac{18s + 17s + 20s}{(3)(60)}$ = 0.3056 min

area = (14 ft)(16 ft) = 224 ft^2

gpm/ft^2 = $\frac{837.76 \text{ gal}}{(0.3056 \text{ min})(224 \text{ ft}^2)}$ = **12.24 gpm/ft^2**

backwash vol. = (12.24 gpm/ft^2)(224 ft^2)(12 min) = **32,901 gal**

9. Determine the backwash rate in gpm/ft^2 and the amount of water used if they backwashed for 14 minutes for a filter bay that is 20 by 32 feet and the filter bed is 20 by 30 feet. The test was run three times. The times required for the water to rose 6 inches were 13, 12 and 15 seconds.

vol. = (20 ft)(30 ft)(0.5 ft)(7.48 gal) = 2244 gal

time = $\frac{13s + 12s + 15s}{(3)(60)}$ = 0.2222 min

area = (20 ft)(30 ft) = 600 ft^2

gpm/ft^2 = $\frac{2244 \text{ gal}}{(0.2222 \text{ min})(600 \text{ ft}^2)}$ = **16.83 gpm/ft^2**

backwash vol. = (16.83 gpm/ft^2)(600 ft^2)(14 min) = **141,372 gal**

10. Determine the backwash rate in gpm/ft^2 and the amount of water used if they backwashed for 9 minutes for a filter bay that is 24 by 36 feet and the filter bed is 24 by 34 feet. The test was run three times. The times required for the water to rose 6 inches were 14, 15 and 16 seconds.

vol. = (24 ft)(34 ft)(0.5 ft)(7.48) = 3051.84 gal

time = $\frac{14s + 15s + 16s}{(3)(60)}$ = 0.25 min

area = (24 ft)(34 ft) = 816 ft^2

gpm/ft^2 = $\frac{3051.84 \text{ gal}}{(0.25 \text{ min})(816 \text{ ft}^2)}$ = **14.96 gpm/ft^2**

backwash vol., gal = (14.96 gpm/ft^2)(816 ft^2)(9 min) = **109,866 gal**

Filtration Math

1. A filter measures 28 feet by 20 feet. The influent is closed and the effluent is opened and the water drains down 6" in 120, 125, and 113 seconds. What is the filter-loading rate in gallons per minute per square foot (gpm/ft^2)?

   $$\text{vol.} = (28\,ft)(20\,ft)(0.5\,ft)(7.48) = 2094.4\,gal$$

   $$\text{time} = \frac{120s + 125s + 113s}{(3)(60)} = 1.9889\,min$$

   $$\text{area} = (28\,ft)(20\,ft) = 560\,ft^2$$

   $$gpm/ft^2 = \frac{2094.4\,gal}{(1.9889\,min)(560\,ft^2)} = \boxed{1.88\,gpm/ft^2}$$

2. The Randyville Water Plant treats an average of 5.18 MGD. The water is split equally to each of the 8 filters. Each filter basin measures 12 feet wide by 16 feet long and by 24 feet deep. Each filter bed measures 12 feet by 14 feet by 11 feet deep. The influent line to Filter 6 is closed while the effluent remains open. Using a hook gauge and a stopwatch, it is noted that the water level in the filter drops 6 inches in 80, 86, and 89 seconds. What is the filtration rate in gallons per minute per square foot (gpm/ft^2)?

   $$\text{vol.} = (12\,ft)(16\,ft)(0.5\,ft)(7.48) = 718.08\,gal$$

   $$\text{time} = \frac{80s + 86s + 89s}{(3)(60)} = 1.4167\,min$$

   $$\text{area} = (12\,ft)(14\,ft) = 168\,ft^2$$

   $$gpm/ft^2 = \frac{718.08\,gal}{(1.4167\,min)(168\,ft^2)} = \boxed{3.02\,gpm/ft^2}$$

3. The Chrisburg Water Plant treats an average of 7.2 MGD. The water is split equally to each of 8 filters. Each filter basin measures 12.5 feet wide by 16.5 feet long by 24 feet deep. Each filter bed measures 12.5 feet by 14 feet by 10 feet deep. The influent line to Filter 6 is closed while the effluent remains open. Using a hook gauge and a stopwatch, it is noted that the water level in the filter drops 6 inches in 69 seconds on test 1, 6 inches in 67 seconds on test 2 and 6 inches in 70 seconds on test 3. What is the filtration rate in gallons per minute per square foot (gpm/ft^2)?

   $$\text{vol.} = (12.5\,ft)(16.5\,ft)(0.5\,ft)(7.48) = 771.375\,gal$$

   $$\text{time} = \frac{69s + 67s + 70s}{(3)(60)} = 1.1444\,min$$

   $$\text{area} = (12.5\,ft)(14\,ft) = 175\,ft^2$$

   $$gpm/ft^2 = \frac{771.375\,gal}{(1.1444\,min)(175\,ft^2)} = \boxed{3.85\,gpm/ft^2}$$

4. Determine the filtration rate in gpm/ft^2 for a filter with a surface of 28 feet by 20 feet. With the influent valve closed, the water above the filter dropped 6 inches in 57, 56, and 60 seconds.

$$vol = (20 ft)(28 ft)(0.5 ft)(7.48) = 2094.4 \text{ gal}$$

$$time = \frac{57s + 56s + 60s}{(3)(60)} = 0.9611 \text{ min}$$

$$area = (20 ft)(28 ft) = 560 ft^2$$

$$gpm/ft^2 = \frac{2094.4 \text{ gal}}{(0.9611 \text{ min})(560 ft^2)} = \boxed{3.89 \text{ gpm}/ft^2}$$

5. Determine the filtration rate in gpm/ft^2 for a filter bay that is 10 by 14 feet and the filter bed is 10 by 12 feet. The test was run three times. The times required for the water to drop 6 inches were 135, 132 and 129 seconds.

$$vol. = (10 ft)(14 ft)(0.5 ft)(7.48) = 523.6 \text{ gal}$$

$$time = \frac{135s + 132s + 129s}{(3)(60)} = 2.2 \text{ min}$$

$$area = (10 ft)(12 ft) = 120 ft^2$$

$$gpm/ft^2 = \frac{523.6 \text{ gal}}{(2.2 \text{ min})(120 ft^2)} = \boxed{1.98 \text{ gpm}/ft^2}$$

6. Determine the filtration rate in gpm/ft^2 for a filter bay that is 15 by 22 feet and the filter bed is 15 by 20 feet. The test was run three times. The times required for the water to drop 6 inches were 79, 85 and 80 seconds.

$$vol. = (15 ft)(22 ft)(0.5 ft)(7.48) = 1234.2 \text{ gal}$$

$$time = \frac{79s + 85s + 80s}{(3)(60)} = 1.3556 \text{ min}$$

$$area = (15 ft)(20 ft) = 300 ft^2$$

$$gpm/ft^2 = \frac{1234.2 \text{ gal}}{(1.3556 \text{ min})(300 ft^2)} = \boxed{3.03 \text{ gpm}/ft^2}$$

7. Determine the filtration rate in gpm/ft^2 for a filter bay that is 16 by 18 feet and the filter bed is 16 by 16 feet. The test was run three times. The times required for the water to drop 6 inches were 65, 62 and 64 seconds.

$$vol. = (16 ft)(18 ft)(0.5 ft)(7.48) = 1077.12 \text{ gal}$$

$$time = \frac{65s + 62s + 64s}{(3)(60)} = 1.0611 \text{ min}$$

$$area = (16 ft)(16 ft) = 256 ft^2$$

$$gpm/ft^2 = \frac{1077.12 \text{ gal}}{(1.0611 \text{ min})(256 ft^2)} = \boxed{3.97 \text{ gpm}/ft^2}$$

8. Determine the filtration rate in gpm/ft^2 for a filter bay that is 14 by 18 feet and the filter bed is 14 by 16 feet. The test was run three times. The times required for the water to drop 6 inches were 72, 75 and 76 seconds.

gal = (14 ft)(18 ft)(0.5 ft)(7.48) = 942.48 gal

$$\text{time} = \frac{72s + 75s + 76s}{(3)(60)} = 1.2389 \text{ min}$$

area = (14 ft)(16 ft) = 224 ft^2

$$\text{gpm/ft}^2 = \frac{942.48 \text{ gal}}{(1.2389 \text{ min})(224 \text{ ft}^2)} = \boxed{3.40 \text{ gpm/ft}^2}$$

9. Determine the filtration rate in gpm/ft^2 for a filter bay that is 20 by 32 feet and the filter bed is 20 by 30 feet. The test was run three times. The times required for the water to drop 6 inches were 61, 59 and 58 seconds.

gal = (20 ft)(32 ft)(0.5 ft)(7.48) = 2393.6 gal

$$\text{time} = \frac{61s + 59s + 58s}{(3)(60)} = 0.9889 \text{ min}$$

area = (20 ft)(30 ft) = 600 ft^2

$$\text{gpm/ft}^2 = \frac{2393.6 \text{ gal}}{(0.9889 \text{ min})(600 \text{ ft}^2)} = \boxed{4.03 \text{ gpm/ft}^2}$$

10. Determine the filtration rate in gpm/ft^2 for a filter bay that is 24 by 36 feet and the filter bed is 24 by 34 feet. The test was run three times. The times required for the water to drop 6 inches were 62, 60 and 59 seconds.

gal = (24 ft)(36 ft)(0.5 ft)(7.48) = 3231.36 gal

$$\text{time} = \frac{62s + 60s + 59s}{(3)(60)} = 1.0056 \text{ min}$$

area = (24 ft)(34 ft) = 816 ft^2

$$\text{gpm/ft}^2 = \frac{3231.36 \text{ gal}}{(1.0056 \text{ min})(816 \text{ ft}^2)} = \boxed{3.94 \text{ gpm/ft}^2}$$

Mudball Math

1. Mudball samples were taken with a sampler that has a 3 in diameter and is 6 inches deep. The 250-mL graduated cylinder was filled up to the 200-mL mark with water. The mudballs were placed in the graduated cylinder and the water rose to the 235 mL mark. What is the percent of mudballs?

Sampler Vol. $= \frac{(0.785)(3\text{ in})^2(6\text{ in})(5)(3785)}{231} = 3472.86\text{ mL}$

$235 - 200 = 35\text{ mL}$

$\frac{(35\text{ mL})(100)}{3472.86\text{ mL}} = 1.0\%$ fairly bad

2. Mudball samples were taken with a sampler that has a 3 in diameter and is 6 inches deep. The 500-mL graduated cylinder was filled up to the 300-mL mark with water. The mudballs were placed in the graduated cylinder and the water rose to the 425 mL mark. What is the percent of mudballs?

$425 - 300 = 125\text{ mL}$

$\frac{(125\text{ mL})(100)}{3472.86\text{ mL}} = 3.6\%$ bad

3. Mudball samples were taken with a sampler that has a 3 in diameter and is 6 inches deep. The 250-mL graduated cylinder was filled up to the 200-mL mark with water. The mudballs were placed in the graduated cylinder and the water rose to the 247 mL mark. What is the percent of mudballs?

$247 - 200 = 47\text{ mL}$

$\frac{(47\text{ mL})(100)}{3472.86\text{ mL}} = 1.4\%$ fairly bad

Answers:

1. 1.0%
2. 3.6%
3. 1.4%

Filter Math

Filter Dimensions:

Bay Length = 30 ft　　　　Bed Length = 28 ft.

Bay Width = 24 ft　　　　Bed Width = 24 ft

Media Depth Measurements:

28″	29″	28″
28″	30″	29″
31″	29″	29″
30″	28″	27″

} avg. media depth = 28.83 in

Bed Expansion: 4 inches

Drop Test Times = 72 sec, 70 sec, 73 sec avg. time = 1.1944 min

Rise Test Times = 18 sec, 20 sec, 21 sec avg. time = 0.3278 min

What is the percent bed expansion; filtration rate in gpm and gpm/ft^2; the backwash rate in gpm and gpm/ft^2 and the amount of water if backwashed for 12 minutes?

$$\% \text{ bed expansion} = \frac{(4)(100)}{28.83} = \boxed{13.87\%}$$

$$\text{filtration rate, gpm} = \frac{(30\text{ ft})(24\text{ ft})(0.5\text{ ft})(7.48)}{1.1944\text{ min}} = \boxed{2254.5\text{ gpm}}$$

$$\text{filtration rate, gpm/ft}^2 = \frac{2254.5\text{ gpm}}{(28\text{ ft})(24\text{ ft})} = \boxed{3.35\text{ gpm/ft}^2}$$

$$\text{backwash rate, gpm} = \frac{(28\text{ ft})(24\text{ ft})(0.5\text{ ft})(7.48)}{0.3278\text{ min}} = \boxed{7667.1\text{ gpm}}$$

$$\text{backwash rate, gpm/ft}^2 = \frac{7667.1\text{ gpm}}{(28\text{ ft})(24\text{ ft})} = \boxed{11.4\text{ gpm/ft}^2}$$

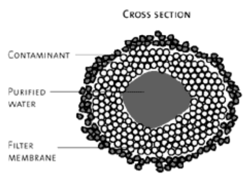
$$\text{backwash vol., gal} = (11.4\text{ gpm/ft}^2)(28\text{ ft})(24\text{ ft})(12\text{ min}) = \boxed{91{,}929.6\text{ gal}}$$

Section 3

Membrane Filtration

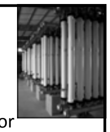
Science and Theory
Operations
Pilot Studies
Regulations

Membrane Technology



1

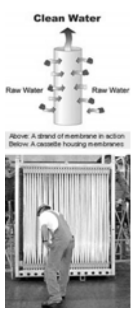
History



- Mid-late 1980's- membrane filtration used primarily for industrial applications such as the wine and juice industries.
- Companies such as Aquasource and Memcor began to market membrane technology for treatment of drinking water in the early 1990's.
- Small scale pilot studies at drinking water facilities showed membranes improved filtrate quality and reduced DBP's.
- First full scale microfiltration membrane facility, the Saratoga WTP in California, went online in 1993.
- In 1994 a Rice University study showed that low pressure membrane filtration would be cost-effective at capacities of 5 MGD.

2

History



Above: A strand of membrane in action. Below: A cassette housing membranes

- In 1997 a study showed that if membranes were installed downstream of conventional coagulation, flocculation and sedimentation that the membrane could be operated at a higher rate, making it cost effective for even 50 MGD capacity.
- The potential for large scale membrane facilities resulted in the formation of additional membrane manufacturers and improvements in membrane technology.
- Companies such as Pall, Zenon, and Koch began to develop new membrane technology
- The largest low pressure membrane filtration plant to date is in Singapore. It utilizes membrane technology developed by Zenon and treats 72 MGD.

3

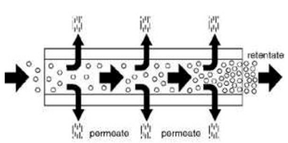
Why Membrane Technology?

- **Regulatory**- the SWTR requires a higher level of turbidity and particulate removal. Membranes can consistently obtain that level of turbidity removal.
- **Cost**- since the early 1990's the capital cost of membrane treatment has decreased. In addition, the implementation of innovative backwash and cleaning strategies had reduced the operational costs.
- **Operational flexibility**- low pressure membrane filtration processes are highly flexible and can be used in conjunction with other processes to achieve specific treatment objectives. In addition, membrane facilities can be easy to operate because the process is not dependent on water chemistry or flow.

4

Pressure forces the water through the pores in the membrane.

Raw water is passed through a membrane



The particles that are too large to pass through are collected, and wasted.

The pure water, or permeate, is collected on the other side of the membrane.

5

Membranes: Science and Theory

- Pure water transport across a clean porous membrane is affected most by the trans-membrane pressure and the viscosity of the water.
- **Trans-membrane pressure**: The force which drives liquid flow through a cross flow membrane. During filtration, the feed side of the membrane is under higher pressure than the permeate side. The pressure difference forces liquid through the membrane.

6

Flux

- The word *flux* comes from Latin: *fluxus* which means "flow".
- Volumetric flux describes the volume of flow across a unit of area.
- Typical units for membrane volumetric flux are gallons per square foot of membrane per day or liters per square meter of membrane per hour.

7

Temperature Effects

- Think about maple syrup, when maple syrup is cold it is very thick and viscous.
- If you put it in the microwave and warm it up it pours much more easily.

8

Temperature Effects

- Water behaves much like maple syrup.
- The viscosity or resistance to flow of water is dependent of temperature.
- The colder the water, the higher the viscosity.
- Viscosity will affect membrane performance by either reducing the flux or by requiring an increase in trans-membrane pressure to keep the flux constant.

9

Seasonal Effects

- Higher trans-membrane pressures may be required in the winter to offset the effect of temperature on the viscosity of the water.
- Membrane fouling may also change with season and temperature.
- Source water is variable, there is seasonal variation in the amounts of organics, metals, nitrates, etc.

10

Reductions in Membrane Productivity

Reductions in membrane productivity can result for a number of reasons including:

- Membrane Compaction
- Membrane Fouling
  - Inorganic fouling
  - Organic fouling
  - Biofouling

11

Membrane Compaction

- Membrane compaction is a physical compression of the membrane. This compression results in a decrease in flux. The rate of compaction is directly proportional to an increase in temperature and pressure.
- Compaction occurs naturally over time requiring a greater feed pressure.
- Compaction is permanent and can occur quickly in membranes if operated at higher pressures for any extended period of time.
- Usually membrane compaction results in a few percent flux decline, and has strongest effect during the initial operating period.

12

Fouling

- Fouling is defined as the reduction in flux at constant pressure resulting from the adsorption or deposition of suspended matter in the membrane pores or on the membrane surface.

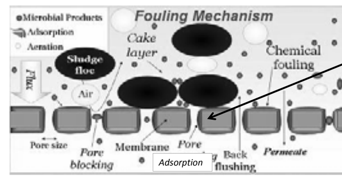
The three fouling mechanisms are:

- Pore adsorption
- Pore blocking
- Cake formation

13

Fouling

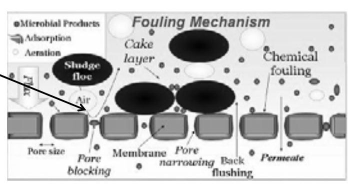
- **Pore adsorption:** occurs when particles smaller than the pore deposit themselves on the pore walls which reduces the effective size of the pores.



14

Fouling

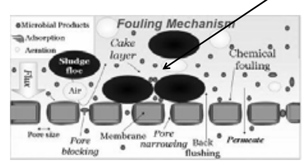
- **Pore blocking:** occurs when particles as large as the pore become lodged in the pore and block the passage. The effective number of pores is reduced.



15

Fouling

- **Cake formation:** this occurs when particles to large to enter the pores become deposited on the surface of the membrane. Cake formation results in a reduced flux across the membrane.



16

Inorganic Fouling

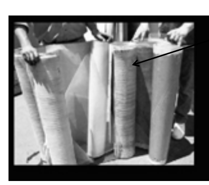
- Inorganic fouling can occur when inorganic particles such as silt, clay, iron, manganese, nitrates, etc are deposited on the surface of the membrane.

Membrane fouled with inorganic material.

17

Organic Fouling

- Organic fouling occurs when natural organic matter (NOM) in source water prevent flux across the membrane by plugging pores in the membrane.



A membrane severely fouled by organics

18

Biofouling

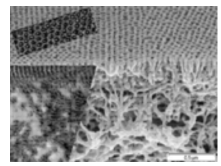
- Biofouling occurs when microorganisms adhere to the membrane surface and begin to grow colonies on or in the membrane. The microbes will eventually obstruct the flow through the membrane

Extreme biofouling of membrane.

19

Membrane Materials

- The most common membrane materials are either organic polymers or ceramic materials.
- The polymer membrane materials vary with resistance to fouling, operating temperature and pH ranges and resistance to oxidants.



20

Polymer Materials

Membrane material	Type	Oxidant tolerance	pH range	Resistance to fouling
PVDF	MF/UF	Very high	2-11	Excellent
Polypropylene(PP)	MF	Low	2-13	Acceptable
Polyethersulfone (PES)	UF	High	2-13	Very Good
Polysulfone (PS)	UF	Moderate	2-13	Good
Cellulose Acetate (CA)	UF	Moderate	5-8	Good

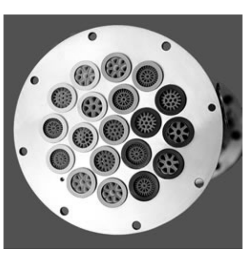
21

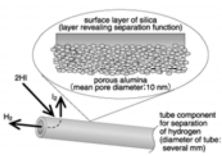
Ceramic Membranes

- Ceramic membranes are made by heating materials like aluminum oxide, titanium dioxide or carbon composites into a brittle clay like ceramic form.
- The ceramic membranes are thicker and have a greater resistance to water transport, so the trans-membrane pressures may need to be increased.
- The benefits of ceramic membranes include: that they are easier to clean and maintain than polymer membranes, and that they are able to with stand higher temperatures and pressures and can operate at a pH of 0-14.

22

Ceramic Membranes

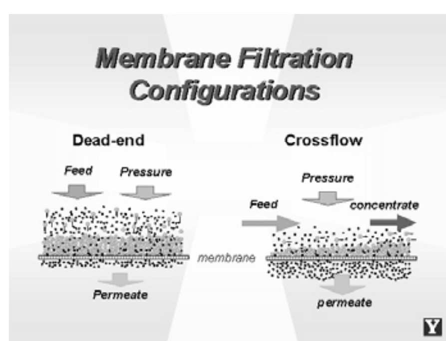




Ceramic Membrane Elements and Housings

23

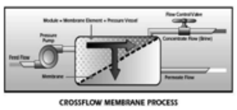
Membrane Configurations

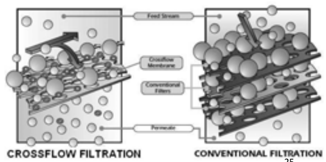


24

Crossflow Filtration

- In some cases crossflow filtration is used.
- The direction of the flow can help to prevent the deposition of materials on the membrane surface thereby reducing fouling.





25

Membrane Module Types

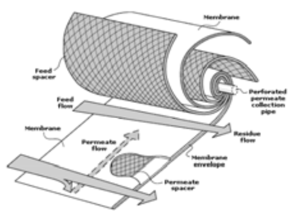
There are several commercially available membrane technologies including:

- Spiral wound
- Tubular
- Hollow fiber
- Plate and Frame
- Cassette

26

Spiral Wound Membrane

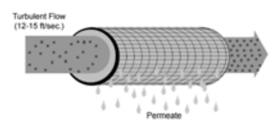
- Not commonly used for microfiltration or ultrafiltration.
- The flat sheet nature makes it difficult to keep clean.



27

Tubular Membrane Module

- Rather than a sheet of microfiltration membrane, the membrane is made in a tube fit into a module.
- The membrane is on the inside of the tube with a HDPE support tube.
- This arrangement allows the membrane to be backwashed which controls fouling.



28

Tubular Membrane Module

- The membranes which are composed of polymer or ceramic are placed inside plastic or stainless steel modules and sealed by a gasket or ring clamp.
- The tubular membranes have relatively large inner diameters (1-2.5 cm).
- The feed water which is under pressure flows through the inner lumen of the tube. The permeate is collected in the outer shell of the module

29

Tubular Membrane Module

Advantages

- Large diameter of channels allows for treatment of water with large particles or high solids.
- High cross flow velocities (up to 5 m per second) can be used to control fouling
- Easy to clean because of large diameter channels

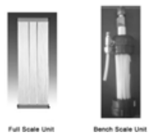
Disadvantages

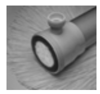
- Low surface area to volume ratio or “packing density” of membrane

30

Hollow Capillary Fiber Membrane

- Can be arranged in a tubular housing or as a cassette type module.
- Can be backwashed to prevent fouling.





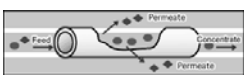
31

Hollow Fiber Membrane

- Consists of several hundred to several thousand fibers encased in a module.
- The fibers are bonded at each end with an epoxy or urethane resin.
- The inner lumens or internal fiber diameters are very small (0.4 to 1.5 mm).
- There are two different regimes in hollow fiber filtration: inside out, and outside in.

32

Inside- Out Filtration



- A high cross-flow velocity over the membrane surface prevents membrane fouling.
- Easier to backwash
- This makes inside-out filtration suitable for concentration and purification of highly concentrated solutions.

33

Outside -In Filtration

- Utilizing the lager area of the outer surface of the membrane fiber, the filtration load per unit area may be reduced.
- Lower head loss through the module.
- These features make this mode of operation well suited for high volume water clarification.
- It is more difficult to backwash and control flow to the membrane.
- Cleaning technique such as 'air-scrubbing' may be utilized.

34

Hollow Fiber Membrane

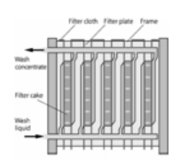
Advantages
- Low pressure drop across the module
- High surface to volume ratio or “packing density”.
- Low trans -membrane pressures 3-15 psi.
- Fibers can be backwashed.

Disadvantages
- Small tube diameter are susceptible to plugging
- The large number of fibers may cause difficulty in detecting the loss of membrane integrity.

35

Plate and Frame Type

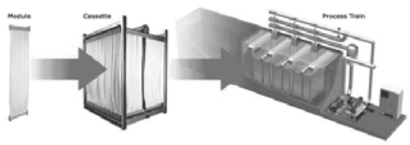
- Membrane filter plates: a flexible membrane is fixed to the support body.
- Materials for the membranes include Polypropylene, synthetic rubber (for example NBR, EPDM) or thermoplastic elastomer (TPE).
- The membrane is impermeable and serves to compress the cake within the chamber after the filtration process is complete.
- Most often used in industrial applications, or wastewater, not used in water treatment.



Filter cake washing in a plate and frame filter press

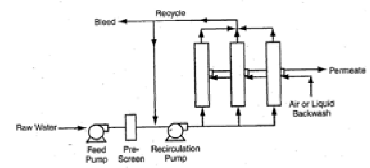
36

Cassette Type Membrane



37

System Configurations



Pressure driven system configuration with crossflow

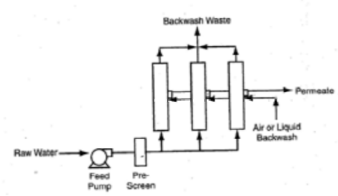
38

Crossflow

- Feed water is pumped with a crossflow tangential to the membrane.
- The water that does not pass through the membrane is recirculated as concentrate and blended with the feed water.
- Pressure on the concentrate side is conserved and deducted from the total head requirement.
- A bleed stream can be used to control the concentration of solids in the recirculation loop.
- Concentrate can be wasted at any time from the recirculation loop.

39

System Configuration



Pressure driven direct flow

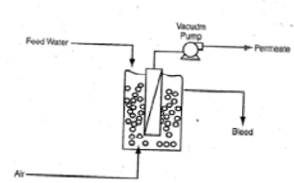
40

Direct Flow

- Also called dead-end or deposition mode.
- Water is applied directly to the membrane.
- All feed water passes through the membrane between backwashings.
- There is 100% recovery of this water, however, some must be used for backwashing.
- Considerable energy savings because recirculation is not required.

41

System Configuration



Direct flow submersible

42

Submersible

- Fibers are submerged in the feed water.
- A vacuum is applied to the inner lumen of the fibers to create a pressure differential necessary for filtration to occur.
- The outside of the fibers are scoured by air periodically or continuously.
- Backwashing with the permeate is conducted at regular intervals.

43

System Operations

The two primary operational concepts are:

- To operate at a constant pressure
  - To operate at a constant flux

44

Constant Pressure

Advantages:

- Feed pumps can be sized to maintain the constant pressure with simple on/off controls.
- Energy requirements are constant.

Disadvantages:

- Permeate flow will decrease over time due to membrane plugging prior to backwash.
- Output of plant is reduced.

45

Constant Flux

Advantages:

- No over-sizing of the system is needed.
- Out-put remains the same
- Most often used by full scale membrane plants

Disadvantages:

- Feed pressure must increase to maintain constant flux between backwashes
- Energy efficiency decreases with increased trans-membrane pressure.

46

Pump Requirements

- **Variable speed centrifugal:** used to deliver raw water to membranes at the required flow and pressure. (usually 20 -30 psi)
- **Permeate vacuum pump**: used for systems that operate under a vacuum, one dedicated to each membrane bank, sized to produce the permeate flow of each membrane bank.
- **Recirculation pump:** used for inside-out crossflow configurations, one dedicated for each membrane bank.
- **Backwash pump:** used for backwashing, may use liquid or gas medium.

47

Membrane Backwashing

- For most systems it is performed automatically.
- Can be set for a run time, usually every 30-120 minutes.
- Can also be set to backwash when a certain trans-membrane pressure is reached or when a certain amount of permeate has been produced.
- The duration of backwash lasts from 1 -5 minutes.

48

Backwashing

- The permeate collected in a reservoir is employed to backwash the membrane.
- A liquid stream under pressure from a backwash pump dislodges solids from the surface of the membrane
- For submerged systems, backwashing occurs for 30 seconds every 15 minutes to several hours.
- The backpulsing dislodges any deposition that has accumulated.

49

Pretreatment

- **Prefiltration:** may be required to remove large particles that could plug the inlet to the fibers.
- **pH adjustment:** may be required to keep feed water in the optimum range for the membrane polymer type.
- **Adsorption and Coagulation:** coagulants and PAC can be used to prevent fouling of the membrane.
- **Pre-oxidation:** used to oxidize metals such as iron and manganese so that they do not form in the membrane or the permeate.

50

Post Treatment

- Disinfection: required by State and Federal Regulations.

Optional:

- Fluoridation
- Corrosion Control

51

Cleaning

- When fouling materials can no longer be removed by backwashing, chemical cleaning is required.
- Considerations include the cleaning and rinse volumes, temperature of cleaning water, reuse and disposal of chemicals.
- Many different chemicals can be used including detergents, acids, bases, oxidizing agents and enzymes.
- Chlorine is often used on PVDF membranes in concentrations from 2- 2000 mg/L.
- Heating the cleaning solution to 35-40 C can enhance cleaning effectiveness.

52

Membrane Integrity Testing

- One of the most critical aspects of employing membrane technology is integrity testing.
- Integrity testing ensures that the membranes are an effective barrier between the feed water and the permeate being produced.

53

Integrity Testing

There are several methods that can be used to monitor membrane integrity including:

- Turbidity monitoring
- Particle counting
- Particle monitoring
- Biological monitoring
- Air pressure decay testing
- Diffusive air flow testing
- Water displacement testing
- Bubble testing
- Sonic wave sensing
- Visual inspection

54

Turbidity Monitoring

- Most commonly used method of measuring the performance of filtration systems.
- Most membrane systems can provide permeate with turbidities less than 0.1 NTU
- Use of turbidity as the sole method for determining membrane integrity does not provide adequate sensitivity to detection of small pinholes in membrane fibers

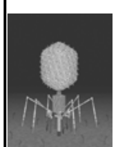
55

Particle Counting and Monitoring

- Multichannel particle counting is a standard particle counting method used in many water treatment plants.
- The advantage is that it is a continuous online measurement, however, several sensors are required to establish the sensitivity needed to detect loss of membrane integrity.
- Another method of measuring particles is particle monitoring which is based on dynamic light obscuration.
- Particle monitors are usually cheaper and easier to operate than particle counters, however, they also require multiple sensors for the sensitivity level of membranes.

56

Biological Monitoring



- One of the most sensitive methods for evaluating membrane integrity is viral seeding.
- Viruses at densities in the range of 106-107 PFU/mL are introduced into the effluent.
  - **Plaque:** an area of cells in a layer which display a cytopathic effect.
  - **Plaque-forming unit (PFU):** a virus or group of viruses which cause a plaque.

  At various times, samples are collected from the permeate to determine if those viruses have passed through the membrane.

  Often used for pilot- or bench scale studies, because you don't want to introduce viruses into water that is being consumed.

57

Air Pressure Decay Testing

- The membrane module is pressurized to approximately 15 psi from the feed side.
- Minimal loss of held pressure (usually less than 1 psi every 5 minutes) at the filtrate side indicates a passed test.
- A significant decrease of the held pressure indicates a failed test.

58

Diffusive Air Flow Testing

- The diffusive air flow test uses the same concept as the air pressure decay test but it is performed by monitoring the displaced liquid volume caused by leaking air from the compressed membrane fibers.
- This test is more sensitive than air pressure decay because it is easier to measure small changes in liquid volume than small changes in air pressure.

59

Bubble Testing

- Bubble testing can identify a fiber or seal location that is leaking in a membrane module.
- This test is usually run after the compromised module is identified by another monitoring method such as air pressure decay or a sonic sensor.
- Basically the module is submerged while air is passed through it, bubbles formed by escaping air identify the location of the leaking fiber.
- The leaking fiber is either sealed using epoxy glue or by inserting a pin of the same diameter into the inlet.

60

Sonic Wave Sensing

- Sonic sensor equipment consists of a sound wave sensor attached to a headphone.
- The headphones are manually placed at the top, middle, and bottom of the membrane module during the air pressure decay test.
- The headphones can detect sound waves produced by air escaping from a compromised membrane.
- This test has to be followed by the bubble test and visual inspection.

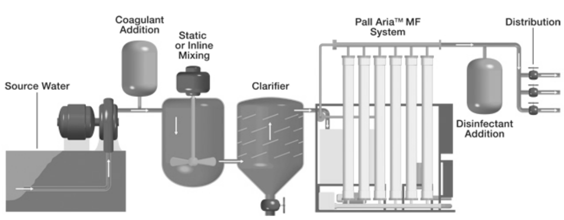
61

Visual Inspection

- If a pressure based integrity test is used, visual inspection can be conducted simultaneously by watching the fibers for bubbles escaping.
- Often the module may have to be removed from the housing so that visual inspection can be performed.

62

Membrane Manufacturers: Pall



63

Pall

- Pall membrane systems may be stand alone or in combination with pretreatment processes.
- The Microza PVDF membranes work well with the addition of coagulant or PAC.
- Large MF or UF systems consist of module racks supporting up to 100 Microza modules.
- The Microza systems operate in an outside-in mode.
- Feed water flows under pressure through the large openings at the bottom of the module to the outside of the fibers.
- Water permeates through the pores in the membrane and flows along the lumen to the discharge side of the module.

64

Pall

- Once every 15 to 30 min the MF systems are air scrubbed and backwashed to remove particles from the surface of the membrane.
- Clean in place (CIP) required when trans-membrane pressure(TMP) reaches 30-35 psi or every 3 to 6 weeks.
- The system is designed to recover CIP solution to minimize chemical use.
- System integrity is monitored by a pressure decay test, if failed a visual inspection, bubble test is used to isolate the affected fiber.

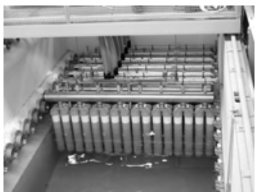
65

Pall

Characteristic	
Operating TMP	4-35 psi
Pore size	0.1 um
Ph tolerance	1-10
Coagulant tolerance	60 mg/L
Typical flux rate	55 gallons/ft2/day
Bacterial removal	7 log
Giardia and crypto removal	6 log

66

US Filter-Memcor



67

US Filter-Memcor

- The simple modular membrane system is available in two product lines ;
- Continuous Microfiltration(CMF)
- Continuous Microfiltration Submerged (CFMS)
- CMF systems has modules housed in pressure vessels connected to manifold assemblies that fit together in a grid.
- CFMS eliminates the module housing, the filters are submerged directly in the feed tank.

68

US Filter-Memcor

- Can be either polypropylene or PVDF
- Direct feed systems, crossflow is used only during back wash.
- 100% recovery of filtrate during the filtration cycle.
- Backwash and filtration cycle is automatically controlled.
- Integrity testing is in place pressure decay test and correlates with microbial removal.

69

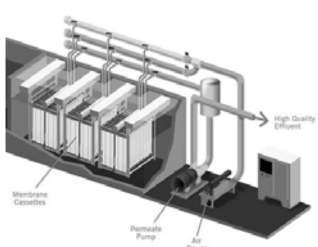
US Filter-Memcor

Characteristic	
Operating TMP	3-29 psi
Pore size	0.1 to 0.2 um
Ph tolerance	1.5 to 9.5

70

Zenon

Membrane Cassette



71

Zenon

- Zenon’s immersed membrane called ZeeWeed is a hollow fiber with filtration from the outside –in.
- The module is shell-less and is immersed directly in the feed water.
- The fibers are made of chlorine tolerant PVDF.
- UF membranes reject all suspended and colloidal solids including viruses.

72

Zenon

- Backwashing is by back pulsing with permeate.
- Air scour also aids in the prevention of membrane fouling.
- Integrity testing includes turbidity measurement, and air pressure decay testing.

73

Zenon

Characteristic	
Operating TMP	Vacuum -3 to -7 psi
Pore size	0.1 um
Ph tolerance	5-9.5
Coagulant tolerant	yes
permeability	15 gfd/psi

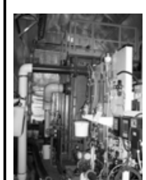
74

Plant Comparisons

Category	Pall	USF Memcor	Zenon
Plant name	Abilene, TX	Bendigo, Australia	Collingwood, ONTARIO
Year operational	2003	2002	2001
Capacity MGD	3	10.5	1.2
Type	MF	MF	UF
Filtration area	538 ft2	6 cells	400 ft2
Feed water	High TOC level	Less than 10 NTU	NTU from 2 to 50
Pre-treatment	Coagulation and flocculation	Coagulation and screen	Prechlorination
Backwash	Every 15 to 30 min for 1-5 min	Every 30 -60 min for 1-5 min	Every 30 -60 minutes for 60 sec
CIP	Every 30 days	Clean with citric acid.	1-2/year

75

Pilot Testing of Membrane Systems



- Pilot testing is a valuable tool in determining the appropriate design criteria of membrane systems prior to large scale installation.
- Pilot testing establishes the basis for evaluating operational parameters such as pathogen removal, efficiency, maintenance, and cost of operation.

76

Pilot Testing

Prior to the start of pilot testing, specific goals should be established including the following;

- To verify or establish the design criteria so that plant capacity requirements are met.
- To demonstrate critical system procedures, backwashing and integrity testing
- To verify that the finished water meets expected standards
- To produce a feed water profile with special attention to parameters that affect membrane performance (TOC, algae, ph, temperature)
- To provide hand on training for the plant operators on membrane processes

77

Pilot Testing

- Funds for conducting pilot investigations are often limited so it is important to research the different types of products available prior to pilot testing.
- Membrane system suppliers should have satisfactory experience and a good history of providing customer service for there products.

78

Pilot Testing

- Process integration
- Depending on the membrane selected, a high level of pre-treatment may be required to reduce membrane fouling.
- It is critical that pilot tests take into account any pretreatment that may have to be used in large scale production.

79

Pilot Testing

- Seasonal impact on water quality
- The initial pilot test period should take into account anticipated seasonal fluctuations in temperature, turbidity, total organic carbon, pesticides and taste and odors.
- Some state agencies require at least 12 months of membrane pilot testing.

80

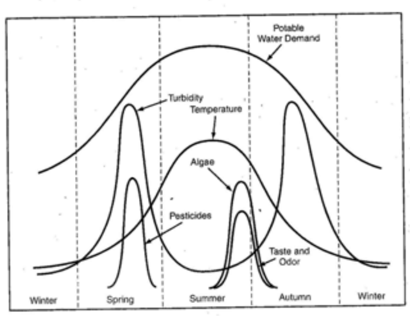


Figure 7-3 Seasonal impact on water quality for surface water

81

Pilot Testing

- Typical infrastucture requirements:

Category	
Feed water	25 gpm
Footprint	40-300 ft2
Power	480 volt, 20 to 60 amp
Residual disposal	For backwash and CIP waste, access to sanitary sewer or other means of treatment

82

Pilot Testing

- Water quality of the feed water and permeate should be monitored regularly.
- Ph, temperature, TOC, DOC, alkalinity, algae, turbidity, odor, TDS, hardness, and microbial counts should be monitored.
- Parameters such as the ph, TOC, DOC, and turbidity of the waste or (concentrate) should be monitored on a monthly basis.

83

Results of Pilot Studies

- The results should include a summary of hydraulic and water quality data collected through out the pilot study.

84

Results of Pilot Testing

Basis for design	Membrane A	Membrane B
Flux at 20 °C (gal/ft2/day)	3.58 gal/ft2/day	3.29 gal/ft2/day
Module surface area	15 ft2	55 ft2
Production per module	6.9 gpm	21.5 gpm
Downtime for backwash	2.5 min	1.5 min
Backwash frequency	30 min	20 min
CIP frequency	23 days	7 days
Total downtime percent	8.4 %	8.1 %

85

System Design

Considerations:

- Site specific issues: capacity and demand of the facility, raw water quality, finished water quality goals, space available for equipment (footprint).
- Membrane specific issues: factors unique to the membrane supplier including flux, backwash approach, cleaning and residual disposal.

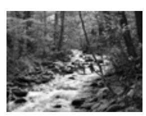
86

System Design

Raw Water quality parameters that may affect membrane system design.

Turbidity: generally if turbidity is less than 10 NTU the water may be applied directly to the membrane.

If turbidity is greater than 10 NTU it may be more economical to install pretreatment processes



87

System Design

- Membrane flux: should be measured from the feed side of the membrane.
- Varies with membrane material, pore size, the direction of flow (whether inside out or outside in) and the percentage of active membrane that is porous.
- The useful life of a UF or MF membrane is a function of the membrane material as well as the backwash and cleaning techniques employed.
- It may last from 5 to 20 years.

88

System Design

The major reason hollow fibers are used for most UF and MF processes is because:

- Hollow fibers have bi-directional strength and can be backwashed.
- Hollow fibers have higher membrane area per volume.

89

System Design

- Backwashing occurs more frequently in membranes than in conventional filters.
- Backwashing usually lasts for 1- 3 minutes.
- Total water lost from backwashing is usually low from 5 to 10%.
- Ideally the backwash will restore TMP pressure to the same value after each backwash, if not, cleaning may be required.

90

System Design

- The use of softened or de-mineralized water is highly desirable in some locations to get effective cleaning.
- Cleaning solution should be heated to 40 C or 105 F to enhance cleaning and reduce cleaning time.

91

Cleaning Chemicals

- **Acids**-citric acid is most commonly used, it works well on inorganic contaminants such as iron. Other acids such as hydrochloric or sulfuric may be used
- **Bases-** caustic soda is the most commonly used, also good on inorganics
- **Oxidants-** free chlorine is very effective at removing organic contaminants.
- **Surfactants-** release contaminants instead of dissolving them. Works well on PAC or if the membrane has a limited ph range.

92

Process Residuals

- Waste characteristics depend on the source water being treated.
- Waste usually contains inorganic and organic colloids, pathogens, and turbidity.
- If coagulants, PAC or other pretreatment chemicals are used the residual is similar to that produced by conventional treatment plants.
- Chemical cleaning waste has a different composition and usually a small volume compared with the concentrate and backwash residuals.

93

Process Residuals

Methods of disposal include:

- Surface Water Discharge
- Sewer Discharge
- Land Application
- Recycling

94

Process Residuals

Surface Water Discharge-

- Surface water discharge must meet the requirements of a site specific NPDES permit.
- May require treatment prior to surface water discharge.
- For most installations, a settling basin or lagoon will suffice.

95

Process Residuals

Sewer discharge-

- Most commonly used method of backwash waste disposal.
- Sewer disposal of backwash wastes is controlled by the receiving wastewater treatment plant's NPDES permit and available sewer capacity.
- May not be feasible at all locations.

96

Process Residuals

Land application-
- Includes percolation ponds or lagoons, spray irrigation and leach fields.
- May require chemical neutralization.
- Periodic removal of accumulated solids from lagoons may be required.

97

Process Residuals

Recycling-
- At large installations recycling is accompanied by some type of settling process to concentrate solids.
- Backwash water and cleaning water are sent to a clarifier or settling basin.
- The supernatant is collected off the surface of the settling basin and mixed with feed water.

98

Operations

Membrane Filtration
- Treatment is independent of pre-treatment conditions and raw water turbidity.
- Pore size in membranes forms an effective barrier to cyst sized particles.
- No need for a filter to waste step at the beginning of a filtration run.

Conventional Filtration
- Requires optimized chemical pretreatment (coagulation, flocculation, sedimentation).
- Operators must adjust treatment for changing water conditions.
- Giardia and Cryptosporidium may pass through filter.
- Must filter to waste prior to returning to the filtration cycle after backwashing.

99

Operations

Membrane Filtration
- Increased turbidity may have no effect on performance or it may cause a decline in flux or a decrease in time interval between backwashing and cleaning.
- Goal is to maintain finished water productivity, quality of the filtrate remains the same.

Conventional Filtration
- Increased turbidity will require additional coagulant to be added, or increased flocculation/settling, shorter filter runs, increased backwashing or may result in reduced finished water quality.
- Goal is to maintain finished water quality.

100

Operations

Modes of Operation
- Filtration
- Backwash
- Air scrub
- Chemically enhanced backwash (some systems)
- Chemical clean in place (CIP)
- Membrane Integrity Testing

101

Operations

Generally filtration, backwash and air scrubbing are automatically controlled by the system based on operator selected points such as:
- Trans-membrane pressure (TMP)
- Flux rate or volume filtered
- Filter run time

Clean in place is usually selected manually.

Integrity testing is conducted automatically or at operator selected intervals.

102

Operations

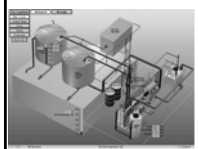
Data Collection- careful data collection and good recordkeeping are important to the successful long-term performance of membrane systems.

Data should be collected as soon as the unit begins service and should include:

- Flow of reed water, filtrate, and retentate
- Temperature
- Turbidity of feed and filtrate
- Results of integrity testing
- TMP

103

Operations



- Most data is collected automatically using a SCADA system.
- It is important to collect both pre and post cleaning data.

104

Troubleshooting

Condition	Ideas to consider
Failed Integrity Test	Verify readings
	Determine if membranes are fully wetted or have become hydroscopic
	Locate and isolate modules with flaws or leaking seals or O rings
	Conduct new integrity test with problem modules removed to make sure all the problems have been found
	Determine the nature of the failure
	Repair flawed module and return to service
	Conduct new integrity test to make sure the problem is resolved

105

Troubleshooting

Condition	Ideas to Consider
High turbidity in filtrate	Conduct integrity test
	If integrity test indicates no broken fibers or leaks, verify turbidity reading
	Measure turbidity in a grab sample
	Clean and calibrate turbidimeter, look from problems (air bubbles)

106

Troubleshooting

Condition	Ideas to consider
High rate of fiber breakage	Check pressures and water hammer potential being applied during operating cycles. Inaccurate pressure can result in damage during a backwash or integrity test.
	Check for exposure to highly concentrated chemicals, evaluate quality of CIP and CEB chemicals
	Check for exposure to extreme temperatures
	Consider the age of the membranes
	Have the integrity and strength of membranes evaluated by the manufacturer (membrane autopsy)
	If fibers are not old, consider a warranty claim
	Old or improperly operated membranes may become brittle, they need to be operated wet.

107

Troubleshooting

Condition	Ideas to Consider
Interval between cleanings is too short	Verify that the data are normalized for temperature, flux may be too high for the application
	Raw water quality may have changed
	Evaluate pretreatment processes, mishandled polymer can result in significant irreversible flux loss.
	Evaluate backwash and chemically enhanced backwash (CEB) procedures, and the chemicals used.
	Consider the effects of pH, may cause aluminum scale on membrane if alum is used in pretreatment
	Evaluate CIP procedures with manufacturer and engineers, compare with other utilities
	Chemically enhanced backwash if not already in use may increase the interval between CIPs.

108

Troubleshooting

Condition	Ideas to consider
CIP does not return unit to baseline	Check normalized clean water resistance and permeability values
	Evaluate CIP procedure, more aggressive cleaning may be needed (higher temp, stronger chemical concentration if compatible with membrane)
	Consider changing the order of chemicals 9acid before caustic, etc)
	Consider the effects of pH, may cause aluminum scale on membrane if alum is used in pretreatment
	Evaluate CIP procedures with manufacturer and engineers, compare with other utilities
	Consider using soft water for CIP solutions

109

Regulations

- Currently state primacy agencies award different log removal credits for MF/UF membrane systems.
- In 2003 USEPA proposed specific language relative to the use and application of membranes to meet requirements of the Long-Term 2 Enhanced Surface Water Treatment Rule (LT2SWTR).
- A draft of a guidance manual (Membrane Filtration Guidance Manual) is available to assist the drinking water community and regulatory agencies in permitting membrane systems.

110

TN Rules for Membranes

Systems receive LT 2 *Cryptosporidium* treatment credit for membrane filtration that meets the following criteria:

- The removal efficiency is demonstrated during challenge testing
- The maximum removal efficiency can be verified through direct integrity testing used with the membrane filtration process.
- The system must conduct continuous indirect integrity monitoring.

111

TN Rules for Membranes

Challenge Testing

- Challenge testing must be conducted on either a full-scale membrane module or a smaller-scale membrane module, identical in material and similar in construction to the full-scale module.
- Challenge testing must be conducted using *Cryptosporidium* oocysts or a surrogate that is removed no more efficiently than *Cryptosporidium* oocysts.
- The organism or surrogate used during challenge testing is referred to as the challenge particulate.
- The concentration of the challenge particulate, in both the feed and filtrate water, must be determined using a method capable of discretely quantifying the specific challenge particulate used in the test; gross measurements such as turbidity may not be used.

112

TN Rules for Membranes

Challenge Testing-

- The maximum feed water concentration that can be used during a challenge test is based on the detection limit of the challenge particulate in the filtrate and must be determined according to the following equation: Maximum Feed Concentration = 3.16 × 106 × (Filtrate Detection Limit)
- Challenge testing must be conducted under representative hydraulic conditions at the maximum design flux and maximum design process recovery specified by the manufacturer for the membrane module.

113

TN Rules for Membranes

Challenge Testing-

- Removal efficiency of a membrane module must be calculated from the challenge test results and expressed as a log removal value (LRV) according to the following equation: LRV = LOG10(Cf) × LOG10(Cp)
- Cf = the feed concentration measured during the challenge test; and Cp = the filtrate concentration measured during the challenge test

114

TN Rules for Membranes

Challenge Testing-

- The removal efficiency of a membrane filtration process demonstrated during challenge testing must be expressed as a log removal value (LRVCTest).
- If fewer than 20 modules are tested, then LRVC-Test is equal to the lowest of the representative LRVs among the modules tested. If 20 or more modules are tested, then LRVC-Test is equal to the 10th percentile of the representative LRVs among the modules tested.
- The challenge test must establish a quality control release value (QCRV) for a non-destructive performance test that demonstrates the *Cryptosporidium* removal capability of the membrane filtration module

115

TN Rules for Membranes

Direct Integrity Testing-

- Systems must conduct direct integrity testing in a manner that demonstrates a removal efficiency equal to or greater than the removal credit awarded to the membrane filtration process.
- A direct integrity test is defined as a physical test applied to a membrane unit in order to identify and isolate integrity breaches (*i.e.*, one or more leaks that could result in contamination of the filtrate).

116

TN Rules for Membranes

Direct Integrity Testing-

- The direct integrity method must have a resolution of 3 micrometers or less.
- The direct integrity test must have a sensitivity sufficient to verify the log treatment credit awarded to the membrane filtration process by the State.
- Systems must establish a control limit within the sensitivity limits of the direct integrity test that is indicative of an integral membrane unit capable of meeting the removal credit awarded by the State.
- If the result of a direct integrity test exceeds the control limit established, the system must remove the membrane unit from service.
- Systems must conduct a direct integrity test to verify any repairs, and may return the membrane unit to service only if the direct integrity test is within the established control limit.

117

TN Rules for Membranes

Direct Integrity Testing-

- Systems must conduct direct integrity testing on each membrane unit at a frequency of not less than once each day that the membrane unit is in operation. The State may approve less frequent testing, based on demonstrated process reliability, the use of multiple barriers effective for *Cryptosporidium*, or reliable process safeguards.

118

TN Rules for Membranes

Indirect Integrity Monitoring-

- Indirect integrity monitoring is defined as monitoring some aspect of filtrate water quality that is indicative of the removal of particulate matter.
- Unless the State approves an alternative parameter, continuous indirect integrity monitoring must include continuous filtrate turbidity monitoring.
- Continuous monitoring must be conducted at a frequency of no less than once every 15 minutes.
- Continuous monitoring must be separately conducted on each membrane unit.

119

TN Rules for Membranes

Indirect Integrity Monitoring-

- If indirect integrity monitoring includes turbidity and if the filtrate turbidity readings are above 0.15 NTU for a period greater than 15 minutes (i.e., two consecutive 15-minute readings above 0.15 NTU), then direct integrity testing must immediately be performed on the associated membrane unit.
- If indirect integrity monitoring includes a State-approved alternative parameter and if the alternative parameter exceeds a State- approved control limit for a period greater than 15 minutes, direct integrity testing must immediately be performed on the associated membrane units.

120

Helpful information

EPA's Membrane Filtration Guidance Manual
http://epa.gov/OGWDW/disinfection/lt2/pdfs/guide_lt2_membranefiltration_final.pdf

AWWA Manual of Water Supply Practices
M53 Microfiltration and Ultrafiltration Membranes for Drinking Water

121

Membrane Filtration Vocabulary

Asymmetric – Having a varying consistency throughout (e.g. a membrane that varies in density or porosity across its structure).

Backpulse – A very short-duration backwash.

Backwash – The intermittent waste stream from a microfiltration or ultrafiltration membrane system; also, a term for a cleaning operation that typically involves periodic reverse flow of clean water and/or air from the filtrate aide to the feed side to remove foulants accumulated at the membrane surface.

Bank – A group of pressure vessels that share common valving and that can be isolated as a group for testing, cleaning, or repair; synonymous with the terms train, skid, rack and membrane unit.

Biofouling – Membrane fouling that is attributed to the deposition and growth of microorganisms on the membrane surface and/or the adsorptive fouling of secretions of microorganisms.

Bleed – The continuous waste stream from a microfiltration or ultrafiltration system operated in a crossflow mode (synonymous with the terms reject and concentrate).

Cartridge – A type of module consisting of a disposable backwashable or nonbackwashable filter element contained in an external casing.

Chemical Cleaning (also, Clean-In-Place or CIP) – The periodic application of a chemical solution (or series of solutions) to a membrane unit for the intended purpose of removing accumulated foulants and thus restoring permeability and resistance to baseline levels; a commonly used term for in situ chemical cleaning.

Crossflow – The application of water at high velocity tangential to the surface of a membrane to maintain contaminants in suspension.

Differential Pressure – A pressure drop across a membrane module or unit form the feed inlet to concentrate outlet.

Fiber – A single hollow fiber or hollow fine fiber.

Filtrate – The water produced from a filtration process.

Flux – The throughput of a pressure-driven membrane filtration system, expressed as flow per unit of membrane area.

Foulant – Any substance that causes fouling.

Fouling – The gradual accumulation of contaminants on a membrane surface or within a porous membrane structure that inhibits the passage of water, therefore decreasing productivity.

Hydrophilic – The water-attracting property of membrane material.

Hydrophobic – The water-repelling property of membrane material.

Inside-out – A flow pattern associated with hollow fiber membranes in which the feedwater enters the inside of the fiber and is filtered as it passes through the lumen wall to the outside of the fiber.

Log Removal – The filtration removal efficiency for a target organisms, particulate, or surrogate expresses as $\log_{10}$.

Lumen – The center or bore of a hollow fiber membrane.

Microfiltration (MF) – A pressure-driven membrane filtration process that typically employs hollow fiber membranes with a pore size range of approximately 0.10 – 0.5 µm.

Nanofiltration (NF) – A pressure-driven membrane separation process that employs the principles of reverse osmosis to remove dissolved contaminants from water; typically applied for membrane softening or the removal of dissolved organic contaminants.

Outside-In – A flow pattern associated with hollow fiber membranes in which the feedwater is filtered through the lumen wall as it passes from the outside of the fiber to the inside where the filtrate is collected.

Reverse Osmosis (RO) – The reverse of the natural osmosis process, i.e. the passage of a solvent (e.g. water) through a semipermeable membrane from a solution of higher concentration to a solution of lower concentration against the concentration gradient, achieved by applying pressure greater than the osmotic pressure to the more concentrated solution; also, the pressure-driven membrane separation process that employs the principles of RO to remove dissolved contaminants from water.

Scaling – The precipitation or crystallization of salts on a surface (e.g. on the feed side of a membrane).

Ultrafiltration (UF) – A pressure-driven membrane filtration process that typically employs hollow fiber membranes with a pore size range of approximately 0.01-0.05 µm.

Section 4

Bacteriological Sampling & Plans

TDEC - Fleming Training Center

Bacteriological Sampling and Plans

1

TDEC - Fleming Training Center

Bacteriological Sampling Plan

- Developed to insure the water quality within the distribution system
- Major steps are:
  - Sample sites
  - Maps
  - Number of samples
  - Sampling procedures

2

TDEC - Fleming Training Center

Sampling Sites

- Sampling sites will include:
  - Residential areas
  - Dead end lines
  - Low use areas
  - Commercial areas
  - Areas near storage tanks

3

TDEC - Fleming Training Center

Sampling Sites cont.

- Samples will be distributed to ensure that no area served by the system is neglected during the year

4

TDEC - Fleming Training Center

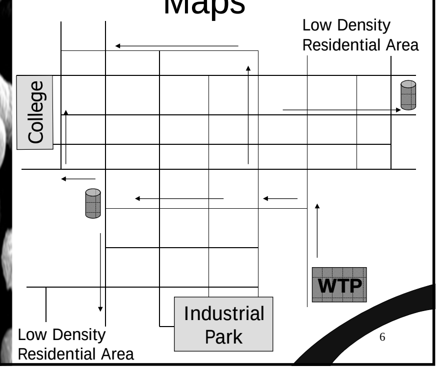
Sampling Sites cont.

- The reason for selecting sampling zones and specific sites is to aid the operators in:
  - Understanding the bacteriological quality of the water throughout the system
    - Zones should have the same water quality
  - Describing the quality of the water consumed by all the customers in the system

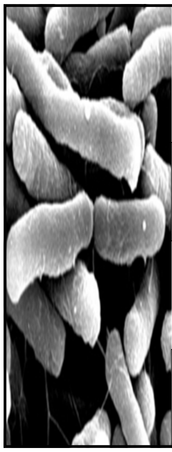
5

TDEC - Fleming Training Center

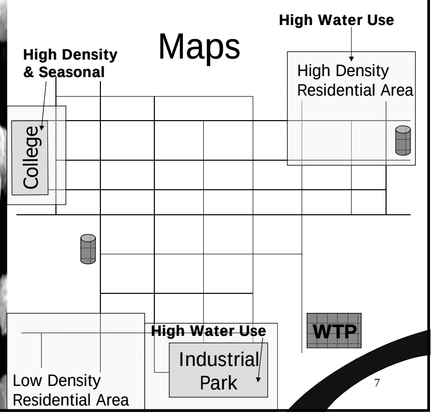
Maps

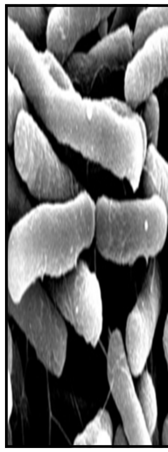


6



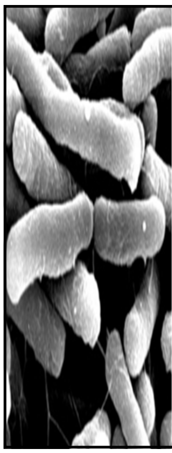
Maps





Maps cont.

- Maps need:
  - Street names
  - Pressure zones
    - Dead ends
    - Low usage
    - High usage
  - Sample sites numbered
  - Alternate sample sites



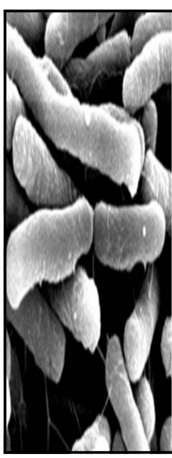
Number of Samples

- Number of samples to be taken monthly is determined by TN Department of Environment and Conservation, Division of Water Supply

Number of Samples cont.

1200-5-1-.07(1)(c)

- Coliform samples shall be taken at regular time intervals and in number proportional to the population served by the system during the reporting period as set forth



Total Coliform Monitoring Frequency for Community Water Systems

Population Served	Minimum Number of Samples Per Month
25 to 1,000	1
1,001 to 2,500	2
2,501 to 3,300	3
3,301 to 4,100	4
4,101 to 4,900	5
4,901 to 5,800	6
5,801 to 6,700	7
6,701 to 7,600	8
7,601 to 8,500	9
8,501 to 12,900	10
12,901 to 17,200	15
17,201 to 21,500	20
21,501 to 25,000	25
25,001 to33,000	30
33,001 to 41,000	40
41,001 to 50,000	50
50,001 to 59,000	60
59,001 to 70,000	70
70,001 to 83,000	80
83,001 to 96,000	90
96,001 to 130,000	100
130,001 to 220,000	120
220,001 to 320,000	150
320,001 to 450,000	180
450,001 to 600,000	210
600,001 to 780,000	240
780,001 to 970,000	270
970,001 to 1,230,000	300
1,230,001 to 1,520,000	330
1,520,001 to 1,850,000	360
1,850,001 to 2,270,000	390
2,270,001 to 3,020,000	420
3,020,001 to 3,960,000	450
3,960,001 or more	480

Coliform MCL

1200-5-1-.06(4)(a)(1)

- For a system that collects at least 40 samples per month, if no more than 5.0 % of samples collected during a month are total-coliform positive, the system is in compliance with the MCL
- For a system that collects fewer than 40 samples per month, if no more than one sample collected during a month are total-coliform positive, the system is in compliance with the MCL

Repeat Samples

1200-5-1-.07(2)(a)

- For systems that take only one routine sample per month, a set of no fewer than 4 repeat samples must be taken
- For systems that take more than one routine sample per month, a set of no fewer than 3 repeat samples must be taken

13

Repeat Samples cont.

- Routine samples should be taken on Mondays and Tuesdays to avoid problems with repeats
  – If repeats are needed, this should give time to resample, take to the lab and start test before weekend

14

Selecting Sampling Sites

- The system should take at least 30% of the required samples from residential areas
  – Residential areas are defined as locations in the distribution system which are served by the smallest distribution lines

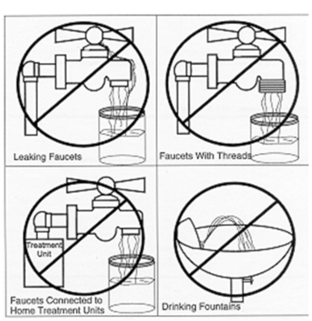
15

Selecting Sampling Sites cont.

- The plan must include maps of the distribution system that would allow the sanitary surveyor to determine if samples were collected at dead ends, low use areas, near storage tanks or other high probability areas for coliform

16

Sample Sites



17

Sample Sites cont.

- Avoid sampling from hydrants, taps from water softeners and leaking faucets
  – Very good chance for contamination
- Collect sample from a non-swivel faucet

Sample Sites cont.

- Mixing faucets should not be used because water passing through the "hot" waterside may not be representative of the water in the distribution system
  - Water in the hot water tank is more likely to grow bacteria because the warm water may promote growth

19

Sample Sites cont.

- Threaded taps should be avoided
  - Bacteria can grow in the grooves of the threads
  - Never take samples from taps that are clearly contaminated with scum or build up around faucet

20

Sample Sites cont.

- Avoid faucets close to the ground or sink bottom
  - Close to the ground can be contaminated with dirt
  - Close to the sink bottom may not allow room for bottle to be put under flow without touching the inside of the bottle

21

Sample Sites cont.

- Good sample sites:
  - Water tank
  - Dead end with sampling tap
  - Fire halls
  - Public buildings

22

Sampling Procedure cont.

- If a faucet has a strainer, aerator or any other attachment, remove before sampling

- Let the water run for several minutes (3-5 min) to insure fresh water from the main

23

Sampling Procedure cont.

- Take Free Chlorine Residual using DPD method and record

- Disinfect faucet with either a dilute bleach spray (~200 mg/L), rubbing alcohol (~25%) or flame it with a propane or butane torch
  - 200 mg/L equals 4 mL of 5% bleach into 1 L

24

Sampling Procedure cont.

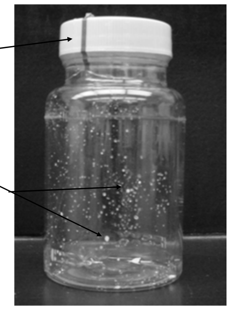
- Reopen the faucet and let the water run in a stream about the size of a pencil to prevent splashing during sampling
  - Remember the bottles are sterile
  - DO NOT rinse the bottle
  - If you feel you have contaminated the bottle, dispose & start with a new one
  - Use fresh bottles, old bottles left out in the sun may not eliminate chlorine as well

25

Sampling Procedure cont.

Sterile bottle, never been opened

Sodium Thiosulfate (white crystals)



Sampling Procedure cont.

- Hold the bottle in one hand near the bottom and with the other hand remove the top
  - Care should be taken in removing the lid so as not to touch the inside of the bottle or lid

27

Sampling Procedure cont.

- Hold the bottle under the faucet, allowing only a small, steady stream to flow from the faucet
  - When filling the bottle, hold the bottle so as to avoid water contacting the hand and running into the bottle
  - Collect 100 mL ± 2%
    - Meniscus needs to touch the 100 mL mark
  - Immediately remove bottle from underneath the faucet and replace the lid

28

Sampling Procedure cont.

- Document the required information from the sample site
  - Time and date collected
  - Location or address
  - Free chlorine residual
  - Collector's name
  - Sample type
    - Routine DS sample
    - Check sample
    - Raw or finished water sample
    - Repeat or confirmation sample
    - Other special purpose sample

29

Sample Label

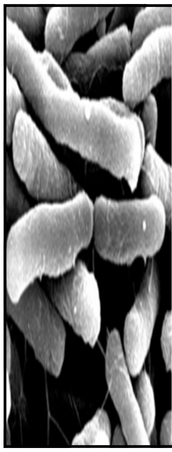
Site 196 E. Main Street Billieville, TN

Date / Time August 15, 2005 8:15 AM

Sampled by Billy Joe Smith

Comments grab sample, monthly Bac't
Residual chlorine = 2.1 mg/L

30

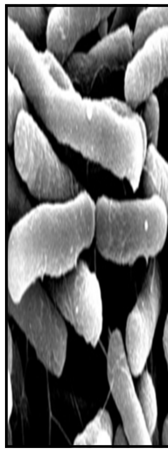


TDEC - Fleming Training Center

Sampling Procedure cont.

- Replace all attachments after sampling is completed
- All samples must be tested within 30 hours of collection

31



TDEC - Fleming Training Center

Positive Samples

- Repeat samples shall be collected within 24 hours of positive results
  - One repeat sample at original site of total coliform-positive sample
  - At least one at a tap within 5 service connections upstream
  - At least one at a tap within 5 service connections downstream

32

EPA Lab # _______________
TN Lab # ________________

Bacteriological Sample Analysis Report

Membrane Filter and/or Presence/Absence

Sample		Collected		Collected By	Free Cl Residual (mg/L)	Time Received in Lab	Time in Incubator		Analyst	Results Read		Results		Read By
Location	Type*	Date	Time				Date	Time		Date	Time	Total	E. coli	

*Sample Type: D = Distribution System
R = Repeat Sample
N = New Line
S = Special Sample

Section 5

Fluoride

Health Benefits
Regulations
Additives
Lab Analysis
Equipment

Water Fluoridation Principles and Practices For Water Facility Operators

Water Fluoridation

Health Benefits
Regulatory Perspective
Fluoride Additives
Equipment/Facilities
Laboratory Analysis
Personnel Safety
Operations

Who, What, Where, Why, How

- **Fluoridation is adjustment of water fluoride**
- **Used for optimum oral health benefits**
- **One of ten great public health achievements of the twentieth century (CDC)**
- **Water fluoridation has a 60-year history of success**

Who?

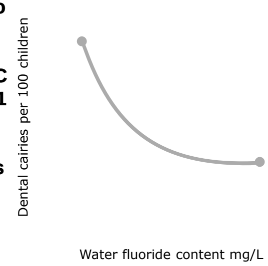
- **Dr. Frederick S. McKay initiated a study in 1908 of "Colorado Brown Stain" in Colorado Springs**
- **Important conclusions…**
  - Affected teeth more resistant to dental decay
  - Life-long residents had stained teeth, more recent residents did not
  - High fluoride content of water identified in 1931

Who? (continued)

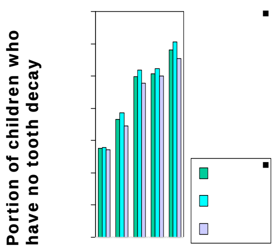
- **In 1930s, Dr. H. Trendley Dean conducted the "21 Cities Study"**
- **Important conclusions:**
  - Optimum levels of fluoride for enhancing oral health (natural breakpoint at 1 mg/L)
  - 1.0 mg/L provided best combination of reduction in tooth decay (caries) and low risk of fluorosis
  - Established community fluorosis index (increased incidence at 2 mg/L)

What?

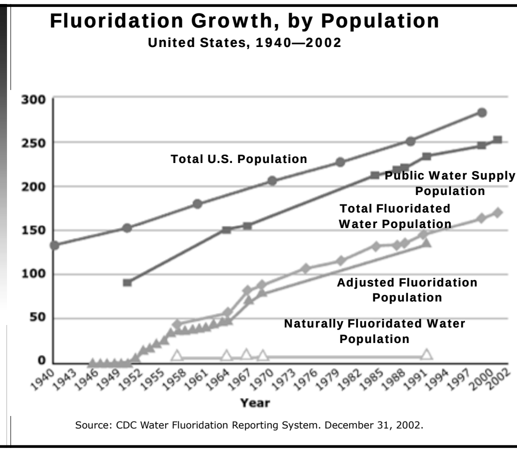
- **Adjustment of fluoride in water to an optimum range of 0.7-1.2 mg/L**
- **Recommended CDC control range is 0.1 below to 0.5 mg/L above optimum**
- **Decreased benefits below optimum**
- **No additional benefit and more severe fluorosis above 2 mg/L**

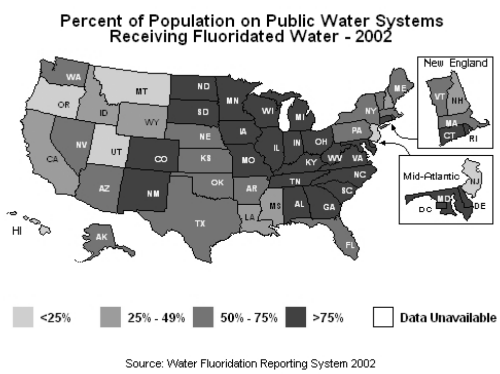


What?



- Fluoridation has contributed to a remarkable decline in the prevalence and severity of tooth decay
- Potable water industry professionals have been leaders





Halo Effect

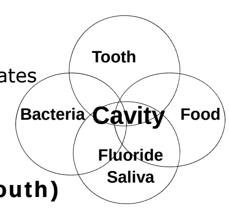
- Processed products shipped to non-fluoridated communities
- Fluoride in toothpaste and food chain
- Difference in caries now only 20%-40%

Why?

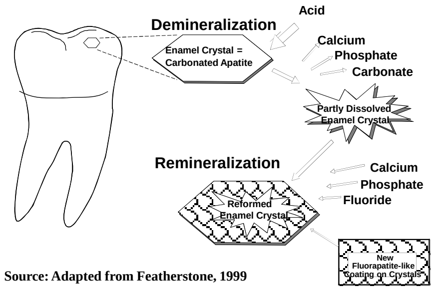
- Fluoridated communities have 20%-40% fewer caries (dental decay)
- Cost-effective results: every dollar spent on water fluoridation avoids $38 in dental care, while increase in drinking water costs to consumers is less than 1%
- Benefits all consumers across socio-economic status
- Benefits all age groups, from children to senior citizens

Risk Factors for Caries

- Diet
  - sugars and carbohydrates
- Oral hygiene
- Xerostomia (Dry Mouth)
  - fluoride
  - salivary flow and composition
- Bacteria Levels (especially mutans streptococci)



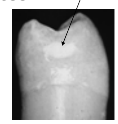
How Fluoride Works



Source: Adapted from Featherstone, 1999

Progression of Caries

- **First sign of a cavity is an increased microporosity of enamel**
  - demineralization of apatite crystallites
    - A "chalky" appearance of the enamel
  - demineralization is reversible
    - ***crystallites can regrow***



Remineralization -- Demineralization

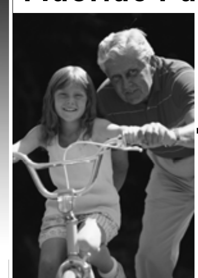
Sound → Decay

Histologic Evidence | Earliest Enamel Caries | Overt Enamel Caries | Overt Dentinal Caries | Indicated for Restoration

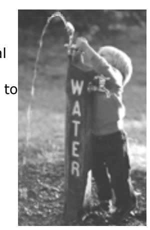
Fluoride Public Health Issues

- **Fluoridation has resulted in a remarkable decline in the prevalence and severity of tooth decay**
- **Despite this reduction, dental caries is still the most common preventable chronic disease in the U.S.**
  - 1 of 4 elementary school children
  - 2 of 3 adolescents
  - 9 of 10 adults

Fluoride Public Health Issues



- **Tooth decay uneven across the general population**
- **Populations with increased risk:**
  - Low SES
  - Low level of parental education
  - Little, if any, access to "dental care"



- **Water fluoridation benefits all people young, old, rich, and poor**

Fluoride Is Naturally Occurring

- **Surface water typically low, less than 0.2 mg/L**
- **Groundwaters can have fluoride from less than 0.1 mg/L to over 5 mg/L**
- **Ocean water is typically 0.8 to 1.4 mg/L**

Enamel Fluorosis

- **Occurs when children with developing teeth consume excessive fluoride (pea-sized toothpaste sufficient)**
- **Ingestion of high-fluoride toothpaste by children a major cause of fluorosis**
- **Potential for enamel fluorosis increases as water content exceeds 2 mg/L**
- **Excessively high fluoride levels, generally greater than 10 mg/L, may result in skeletal fluorosis**

Mild Fluorosis

Moderate Fluorosis with Stains

Alternatives to Fluoridated Water

- **Fluoridated water most common vehicle (various estimates of 220-300 million people worldwide)**
- **Fluoridated salt second most common vehicle (various estimates of 40-300 million people worldwide)**
- **Dietary fluoride supplements -- drops, tablets, or vitamins (60 million people-WHO 2003)**
- **Fluoridated milk used in a few places**

Challenges

- **Opponents of community water fluoridation have made claims that optimally fluoridated water can cause an array of health problems including:**
  - Cancer
  - Increased bone fractures
  - Effects on the renal, gastrointestinal, and immune systems
  - Lower IQ in children
  - Down's syndrome
  - Allergies
  - AIDS
  - Alzheimer's disease
  - Reproductive problems

Credible Scientific Evidence

- **Studies & Research**
  - For 60+ years, extensive investigations demonstrate safety and effectiveness
    - Solid design
    - Can be replicated

Alarming allegations can drive public policy

Credible Scientific Evidence

- **Occasional studies have suggested an association between fluoridation and one adverse effect or another; however, these individual studies typically have failed to account for confounding factors or have had other flaws, and the findings have not been replicated by other independent researchers**

Credible Scientific Evidence

- **Expert Committees and Task Forces**
  - Independent reviews
    - University of York, UK (2000)
    - U.S. Surgeon General's Report (2000)
    - CDC Fluoride Recommendations (2001)
    - U. S. Guide to Community Preventive Services (2001)
  - National Research Council Review completed in 1993, Update currently in review

Safe and Effective

- **Expert scientific panels, medical and professional organizations, and public health officials have concluded that water fluoridation is safe and effective**
- **Water fluoridation has been endorsed by the past five Surgeons Generals of the United States including the current one, Dr. Richard Carmona**

Public Policy on Fluoridation

- **Recognized by the American Dental Association, U.S. Public Health Service, American Medical Association, World Health Organization, American Water Works Association, and virtually every scientific and professional organization in the health field**

Fluoridation Facts

- **CDC web site at www.CDC.gov/OralHealth**
- **American Dental Association "Fluoridation Facts" available from www.ADA.org**
- **Your State Water Fluoridation Program and State Dental Director**

Impact on Water Bill

- **Average water and wastewater bill for a typical family is $41.95/month** (source 2004 AWWA Raftelis survey)
- **Average annual cost to fluoridate water supply for typical household of 2.4 people $4.25** (source Griffin; J.Public Health Dentistry, 1992 adjusted for inflation)
- **Results in equivalent cost to fluoridate typically less than 1 percent of annual utility bill**

Health Benefits

Questions?

Water Fluoridation

Health Benefits
Regulatory Perspective
Fluoride Additives
Equipment/Facilities
Laboratory Analysis
Personnel Safety
Operations

Safe Drinking Water Act (SDWA)

- **Passed by Congress December 16, 1974**
- **Reauthorized in 1986 and 1996**
- **Assures that drinking water supplied to the public is safe**
- **Administered and enforced by individual states when they adopt criteria equal or exceeding the federal standards**

National Primary Drinking Water Regulations

- **Contaminant**
  - Any physical, chemical, biological, or radiological substance or matter in water
  - Some contaminants are nutrients that promote good health at low concentrations including fluoride, copper, iron, and others

EPA and Water Fluoridation

- **EPA and the PHS were early partners in promoting water fluoridation**
  - **1962 and 1972 Engineering Manual was predecessor to AWWA MOP #4**
  - **Regional Fluoridation Engineers**
- **1974 SDWA defined water fluoridation as a state program, not an EPA program**

Water Additives Not Regulated by EPA

- **EPA focuses on safe water and contaminant levels that result in unfavorable health outcomes**
- **Other entities provide standards covering water additives (AWWA, NSF International)**
- **Water fluoridation is a state program, not a federal program**

National Primary Drinking Water Regulations

- **MCL**
  - Maximum Contaminant Level
  - The maximum permissible level of a contaminant in water which is delivered to any user of a public water system.
  - Assure no short-term or long-term health risk
  - Economically and technologically feasible
  - States can set stricter standards

National Primary Drinking Water Regulations

- **MCLG**
  - Maximum Contaminant Level Goal
  - Maximum level of a contaminant in drinking water at which no known or anticipated adverse effect on the health of persons would occur, and includes a margin of safety.
  - Non-enforceable health-based goal

National Primary Drinking Water Regulations

- **Maximum Fluoride Levels**
  - MCLG - 4.0 mg/L
  - MCL - 4.0 mg/L

National Secondary Drinking Water Regulations

- **Aesthetic Qualities of Water**
- **Not Federally Enforceable**
- **Intended as Guidelines for the States**

National Secondary Drinking Water Regulations

- **sMCL**
  - Secondary Maximum Contaminant Level
  - EPA website indicates that this was promulgated for naturally high fluoride waters
  - 2.0 mg/L

National Primary Drinking Water Regulations

- **Sampling**
  - Groundwater sources - 3 year
  - Surface water sources - Annual

National Primary Drinking Water Regulations

- **Public Notification – MCL**
  - Tier 2 notification requirements
  - Within 30 days of violation
  - Applies to all CWS's
  - Specific language
  - Description of CWS efforts to achieve compliance

National Primary Drinking Water Regulations

- **Public Notification – SMCL**
  - Any single exceedance of 2.0 mg/L SMCL triggers notification process
  - Tier 3 notification requirements
  - Within 12 months of exceedance
  - Applies to all CWS's
  - Specific language

State Water Fluoridation Program

- **Managed at the state level**
- **12 states have mandatory fluoridation requirements, other state programs promote implementation**
- **CDC provides technical assistance and support**

Regulatory Perspective

- **Water fluoridation programs managed at the state level to promote good health**
- **Optimal level**
- **Control range**
- **EPA has established regulatory levels that are considerably above the levels for optimal oral health benefits**
  - MCL 4.0 mg/L
  - MCLG 4.0 mg/L
  - SMCL 2.0 mg/L

Regulatory Perspective

Questions?

Water Fluoridation

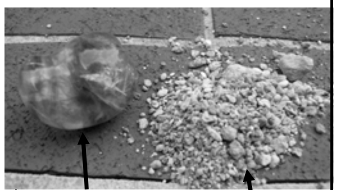
Health Benefits
Regulatory Perspective
Fluoride Additives
Equipment/Facilities
Laboratory Analysis
Personnel Safety
Operations

Fluoride Additives

- **Three Common Additives in U.S.**
  - Sodium fluoride (NaF)
  - Sodium fluorosilicate (Na_2SiF_6 or NaFS)
    - (sodium hexafluorosilicate, sodium silicofluoride, sodium sil)
  - Fluorosilicic acid (H_2SiF_6 or FSA)
    - (FSA, hydrofluoroslicic acid, HFS, hexafluorosilicic acid)

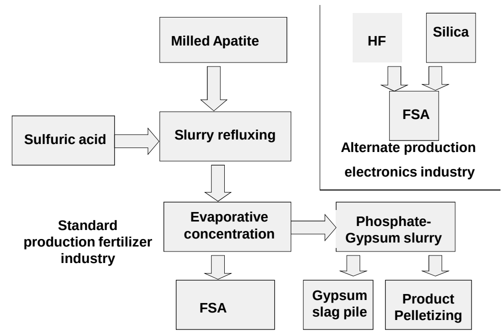
What additive is used at your facility?

Apatite



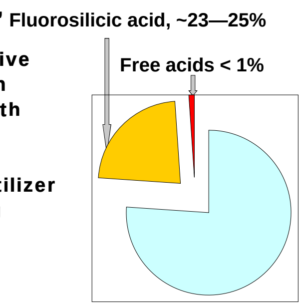
- Mixture of calcium compounds
  - Calcium phosphate
  - Calcium carbonates
  - Calcium fluorides (Contains 3 to 7% Fluoride)
- Primary source for fluoridation additives
- Raw material for phosphate fertilizer
- US largest world production; Florida principal location

Fluorosilicic Acid (FSA)



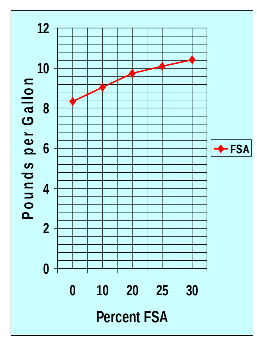
Fluorosilicic Acid (H_2SiF_6) FSA

- Straw-colored, transparent
- Fuming corrosive acid – FSA is in equilibrium with volatile HF
- Derived from phosphate fertilizer manufacturing



Fluorosilicic Acid (FSA)

- 22 to 26% FSA (as weight basis in water solution)
- Solution pH 1.2
- Density (25%) 10.1 pounds per gallon
- Avoid dilution range of 10:1 to 20:1 (precipitation of silica is a potential problem)



Sodium Fluorosilicate (NaFS)

- Old name: "Sodium Silicofluoride"
- White odorless crystalline powder
- Produced by neutralizing fluorosilicic acid with sodium carbonate or sodium chloride
- Solubility varies with temperature
- Solution pH 3.0 to 4.0
- 14.0 pounds per million gallons to provide 1.1 mg/L F-

Sodium Fluoride (NaF)

- First to be used
- White odorless salt
  - powder or crystalline
- Produced by neutralizing fluorosilicic acid with caustic soda (NaOH)
- Relatively constant solubility of 4%
- Ideal for fluoride saturators
- Solution pH 7.6
- 1.8 pounds per MG to provide 1.1 mg/L F-

Fluoride Additives Standards

- **American Water Works Association specifies manufacturing and quality**
  - AWWA B701-06 – Sodium Fluoride
  - AWWA B702-06 – Sodium Fluorosilicate
  - AWWA B703-06 – Fluorosilicic Acid
- **NSF International – ANSI/NSF 60-2002 specifies distribution and purity**
  - Key concept is additive must contribute less than 10 % of the MAL for any contaminant

AWWA Verification Tests

FSA	NaFS	NaF
• Fluoride content - specific gravity	• Fluoride content -specific ion	• Fluoride content -specific ion
• Fluoride content - titration	• Moisture content	• Moisture content
• Free acid	• Size (sieve)	• Size (sieve)
• Heavy metals	• Insoluble matter	• Insoluble matter
	• Heavy metals	• Heavy metals
		• Saturated solution turbidity

Additive Availability

- **Shortages occur mostly at the local level**
- **Problems with phosphate fertilizer production affect national supply**
- **Dry additives can be imported, FSA also from Mexico**
- **Plan to maintain 2 to 3 month inventory, coordinate with supplier**

FSA Delivery

- **Rail tank cars (20,000 gallons)**
- **Truck tank cars (4,000–6,000 gals)**
- **Tote tanks (300 or 400 gallons)**
- **55-gallon drums**
- **13-gallon carboys**

FSA Delivery Issues

- **Most problems occurs after shipment leaves manufacturing location or depot**
- **Typical problems**
  - Breakdown and release from transfer hoses
  - Delivery in damaged containers
  - Improperly or inadequately equipped delivery personnel
  - Attempted delivery to wrong storage area
  - Transport related trash including black particles attributed to breakdown of vehicle tank liners, plastic bags, other trash

FSA Storage

- **Preferred storage location is inside building**
- **Keep sealed with air vent (HF) to outside**
- **Ensure storage area has adequate ventilation or air changes per hour**
- **Seal all electrical and other conduits**
- **Spill containment for 110 percent volume (double-wall tank or barrier)**
- **FSA is aggressive – use corrosion resistant materials**
- **Bulk storage container should never be used for additive feed supply…include day-tank**

Fluoridation Unrelated to Pipe Corrosion or Lead Levels

- Some operators may think that since HF gas released from concentrated H_2SiF_6 storage results in corrosion, water fluoridation will corrode pipes
- EPA and University of Michigan (Ann Arbor) researchers have proven that at temperatures and concentrations for water fluoridation, FSA achieves complete dissociation to fluoride, hydrogen, and silica and cannot produce HF
- Silicates are actually used as a stabilizer for water corrosion

FSA 55-Gallon Drum

CORRECT Outside vent

IMPROPER

300 to 400 Gallon Tote Tank

Up to 10,000 Gallon HDPE

- Polyethylene tanks available from 10 to 10,000 gallons
- Gangs of multiple tanks can increase storage volume

Depressed floor provides containment for spills

Fiberglass Storage to 20,000 Gal

Vent to atmosphere

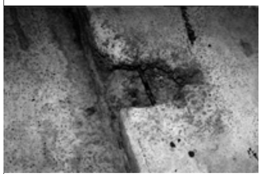
- Fiberglass tanks have been used for storage, but may be susceptible to glass-fiber attack
- Verify that resins and coatings are suitable for hydrogen fluoride

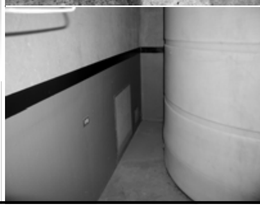
Concrete barrier provides containment for spills

Vent to Outside Structure

IMPROPER VENT

FSA Is Aggressive





- FSA will damage concrete surfaces
- A dual application of epoxy undercoat with urethane topcoat provides corrosion resistance
- Consult with coating manufacturer for acceptable products

Dry Additive Containers

- **Sizes**
  - 50-pound bags
  - 100-pound bags
  - 125 to 400-pound fiber drums
  - 2,500-pound supersacks
- **Handling**
  - Use knife to slit bag
  - Secured disposal to avoid personnel exposure

Dry Additive Delivery Issues

- **Most problems occurred after shipment leaves manufacturing location or depot**
- **Typical problems**
  - Delivery in damaged packaging
  - Improperly or inadequately equipped delivery personnel
  - Attempted delivery to wrong storage area
  - Mixing with other chemicals
  - Degradation of product during transport

Dry Additive Storage

- **Separate room**
  - do not mix additives
  - secured access
- **Convenient to feed location**
- **Good ventilation**
- **Elevated platform**
  - keep dry additives on pallets
- **Limit stacks to 6 bags**
- **Protected from elements**
  - additives cake when compressed and exposed to moisture

2,500 lbs Supersack Delivery

Dry Spills

- **Sweep and place in secure container**
- **Typically, supplier will agree to pick up for disposal**
- **Check Codes and Regulations**
  - State hazardous waste agency
  - Local Fire Marshall

Liquid Spills

- **Ensure that storage tank is in spill containment barrier or on containment pallets**
- **Use spill control pillows or dams that adsorb acid to contain liquid from spreading**
- **Neutralize and then consult with authorities on disposal requirements**
- **Avoid "flushing" to public sewer or on-site septage (septic tank) system**

Liquid Spills

Neutralization – Lime

$$H_2SiF_6 + Ca(OH)_2 \rightarrow CaSiF_6 + 2H_2O$$

$$CaSiF_6 + 2Ca(OH)_2 \rightarrow 3CaF_2 + SiO_2 + 2H_2O$$

Calcium fluoride and silica (sand) are considered non-hazardous and accepted at most landfills

0.39 pound of lime is required to neutralize one pound of acid for an acid strength of 25%

Liquid Spills

- **Caustic soda or soda ash can be used for FSA spills**
- **Use of these agents will result in either sodium fluorosilicate or sodium fluoride**
  - Both are hazardous materials
  - Special caution is required to clean up the residue, and disposal may involve special licensing

Fluoride Additives

- **Three additives**
  - Fluorosilicic acid
  - Sodium fluorosilicate
  - Sodium fluoride
- **AWWA and NSF International Standards**
- **Delivery and storage considerations**
- **Clean up of spills/neutralization**

Fluoride Additives

Questions?

Water Fluoridation

Health Benefits
Regulatory Perspective
Fluoride Additives
Equipment/Facilities
Laboratory Analysis
Personnel Safety
Operations

Fluoride System Selection

- **There is no one specific type of system or equipment that is best**
- **Historically**
  - Large city - FSA
  - Medium system – FSA, dry feeder
  - Small system – FSA, dry feeder or saturator

How Many Fluoridation Systems?

- **Surface water system may have one treatment plant with one fluoride feed point**
- **Groundwater system may have multiple wells (or well fields) in locations scattered throughout their distribution system**
  - Each location may require a separate feed system

Fluoride Additive Selection

- **Fluoride Products Availability**
- **Existing Facilities**
  - Compatibility with water system
  - Availability of space
  - Number of treatment sites (fluoride injection points)
- **Characteristics of the Water**
  - Natural fluoride level
  - Type of flow (variable or steady state)
  - Pressure (discharge)

Fluoride Additive Selection (continued)

- **Estimated overall cost**
  - Capital (initial)
  - Operation and Maintenance (O&M)
  - Chemicals
- **State rules, regulations, and preferences**

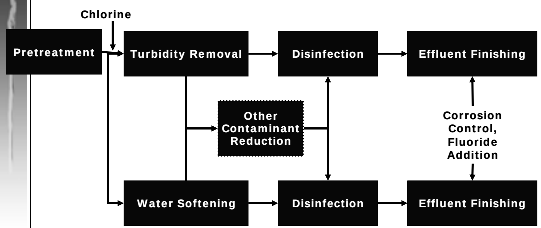
Context of Fluoridation to Water Treatment

- **Must be compatible with other processes**
- **Must not contribute to water quality violations**
- **Different from other water treatment processes in being routinely unrelated to safe drinking water standards**
- **Similar to fire fighting in that it promotes a community benefit**
- **EPA's perspective is that fluoride is like copper: beneficial nutrient levels are close to levels that result in undesirable cosmetic results**

Objectives of Water Treatment

- **Disinfection to protect against pathogenic organisms**
- **Reduction of contaminants for health effects**
- **Oxidation of undesirable reduced compounds**
- **Aesthetics – taste, odor, and color**
- **Not treatment, but a community benefit is fire fighting , which is the original reason for many community water systems**

Simplified Water Treatment



Fluoridation Design Basics

- Basic design principles for fluoridation same as for other water treatment processes
- Equipment and process design same as for other standard water treatment processes

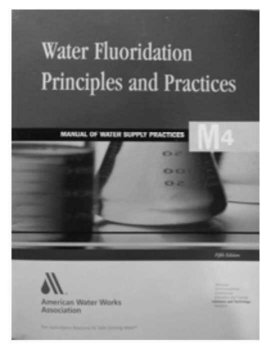
It's Really Very Simple

…You need a tank to hold the FSA or solution formed from the dry additive, and a pump…

…but the devil is in the details….

Standard Reference Guidance

- American Water Works Association Manual of Practice (MOP) No. 4 – Water Fluoridation Principles and Practices (fifth edition 2004)



Experience Builds Knowledge

"In theory, there is no difference between theory and practice…in practice, there is."
-Yogi Berra

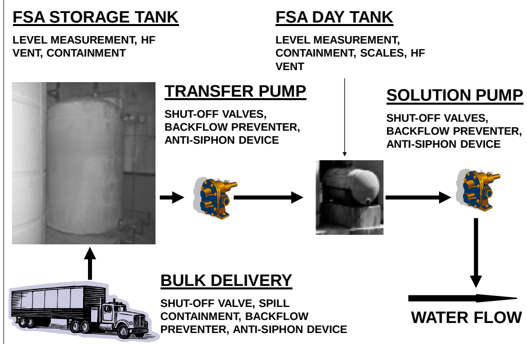
Fluoride Additive Feed Equipment Requirements

- Precise Delivery
- Small Quantities/Capacities
- Reliable
- Corrosion Resistance
- Safety in Handling Hazardous Products

Fluoride Feed Equipment

- **FSA Fed With Small Metering Pump**
- **Saturated Solutions of NaF**
- **Unsaturated solutions of NaF or NaFS**

FSA Schematic Process Diagram



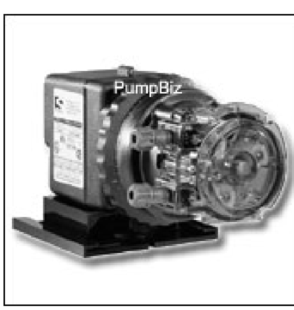
Metering Pump Classification

- **Centrifugal**
  - hydraulic vortex induces pressure delivery
- **Positive displacement**
  - Hydraulic vortex induces pressure delivery

Positive Displacement Pumps

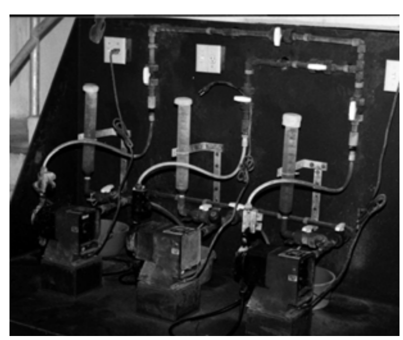
- **Peristaltic**
  - Also known as hose pump or tube pump
- **Diaphragm**
- **Piston**
- **Other (not used in fluoridation)**
  - Progressive cavity
  - Screw
  - Rotary lobe or gear

Peristaltic Pumps



Rotating element squeezes replaceable hose

Solution Feed Pumps



Diaphragm Pump

Replaceable diaphragm

Fluorosilicic Acid Feed

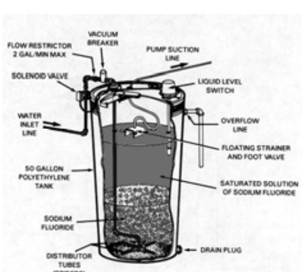
Dry Additive Feeders

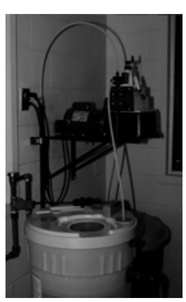
- **Fluoride Saturators**
  - Upflow: most common
  - Downflow: rarely used in United States
  - Venturi: rarely used except in large installations
- **Dry Feeders**
  - Volumetric
  - Gravimetric

Fluoride Saturators

- **Operating Procedure**
  - Generally uses sodium fluoride
  - Consistent fluoride additive bed maintained in tank
  - Water flows through bed
  - Water becomes saturated
  - Saturated solution injected

Typical Upflow Saturator





Water Softener With Saturator

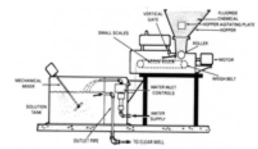
- **In areas with high hardness, a water softener is often needed to minimize the potential for calcium fluoride scale formation**

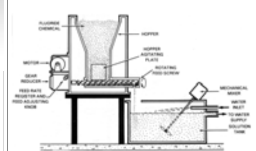
Dry Additive Feeders

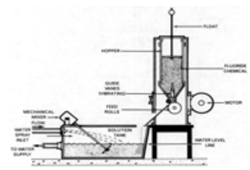
- **Dry Volumetric Feeders**
  - Delivers a constant volume of fluoride additive
  - Generally sodium fluorosilicate, but also used with sodium fluoride

Dry Additive Volumetric Feeders

- rotating disk
- oscillating pan
- vibratory pan
- roll
- rotating screw







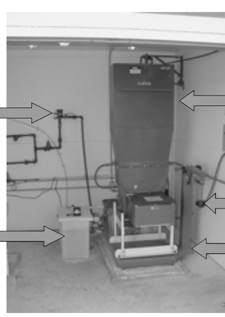
Dry Feeder Solution Mixing

- **Minimum 5 minutes to fully dissolve NaFS**
- **Hard water, colder temperatures (less than 60oF), and crystalline form of additive can increase the required time to fully dissolve NaFS**

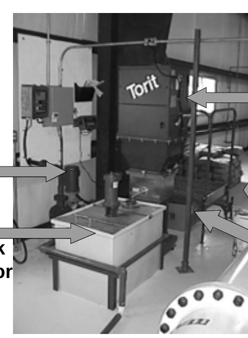
Dry Feeder Solution Mixing Continued

- **Failure to produce a clear, homogeneous solution indicates:**
- **Dissolving chamber too small**
- **Detention time inadequate**
- **Dilution water insufficient**
- **Agitation insufficient**
- **Short-circuiting**

Volumetric Feeder Installation



Volumetric Feeder Installation



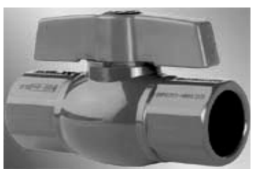
Types of Auxiliary Equipment

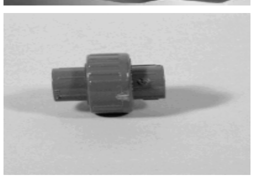
- Water Meters
- Pacing Meters
- Vacuum Breakers
- Anti-Siphon Valves
- Day Tanks
- Mixers
- Scales
- Continuous analyzers

Types of Auxiliary Equipment

- Unions
- Valves
- Strainers
- Timers
- Alarms
- Flow Switches
- Pressure Switches
- Hauling Equipment

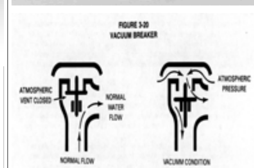
Piping Considerations





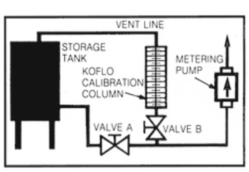
- Use fluoride compatible materials such as PVC, HDPE
- Include numerous shut-off valves and unions at key locations to facilitate pipe repairs
- Identify the pipe

Backflow and Air-Relief Valves



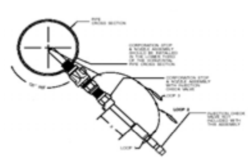
- Include backflow prevention and air-relief valves in key locations so that tanks do not siphon or drain in the event of a line break

Calibration Cylinders



- Calibration cylinders allow verification of pump discharge rates

Injector

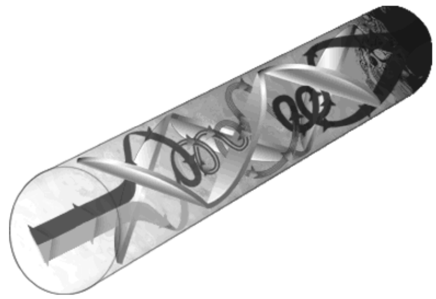


- When solution is added to a pipe, an injector should be used to ensure good mixing with the water flow
- The injector should be placed in the lower third of the pipe and extend into the pipe approximately one-third of the pipe's diameter

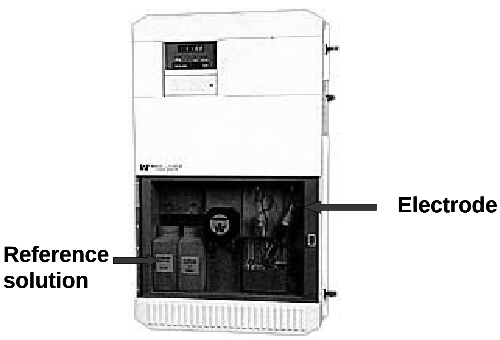
Injector

- Some contractors will install the injector into the crown (top) of the pipe due to easy access, but this will result in poor mixing.
- The fluorosilicic acid solution is denser (heavier) than water, so if the injector is pointed down towards the lower portion of the pipe, then the solution will sink to the bottom of the pipe and the solution plume will be poorly mixed.

Static In-line Mixer

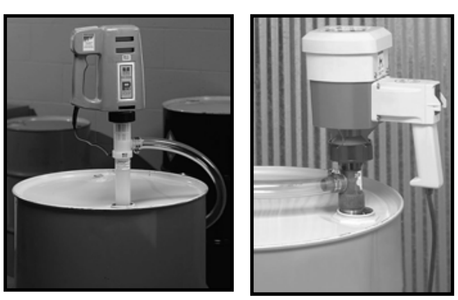


Continuous Analyzers

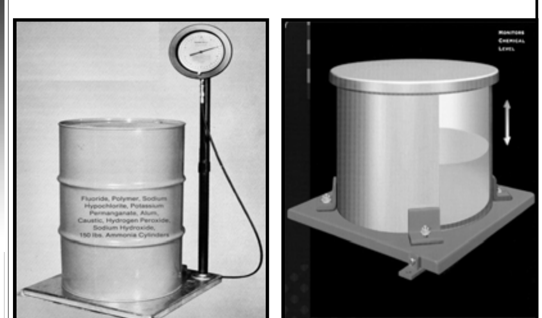


Drum Pump - Hand

Drum Pump - Electric

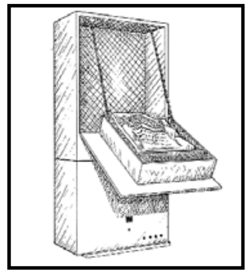


Drum or Tank Scale



Containment Pallets

Bag Loading Hopper



Storage of Fluoride Products

- **Storage of additive**
  - CDC recommends 3 months (annual average basis)
- **Consult with vendors on product availability / reliability to determine appropriate storage requirements**

Size / Capacity of Equipment

- **Day tank sized for 1 to 3-day holding capacity of solution depending on regulations**
- **Saturator can be appropriately sized if also used as daytank**
- **Pumps provide maximum delivery equal to water capacity…do not provide excess fluoride solution delivery capability**

Design Modifications

- **Many states require review and approval of proposed modifications or additions prior to implementation. Know your state requirements.**

Equipment / Facilities

Questions?

Water Fluoridation

Health Benefits
Regulatory Perspective
Fluoride Additives
Equipment/Facilities
Laboratory Analysis
Personnel Safety
Operations

Fluoride Testing Methods

- **Three Principal Methods**
  - Colorimetric
  - Specific Ion Electrode
  - Inductively Coupled Plasma Spectroscopy (ICP-MS)

Increasing Accuracy
Increasing skill and ability

Fluoride Testing Methods

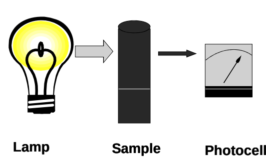
- **Colorimetric**
  - Compares reduction of indicator solution color influenced by ions
- **Specific Ion Electrode**
  - Measures ionic activity as a relative indicator
- **(ICP-MS)**
  - measures the number of ions in a fixed volume on basis of mass to charge ratio

Method Selection

- **Speed**
- **Economy**
- **Test Purpose**
- **Interferences**

Colorimetric Elements

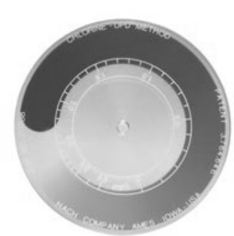
- **Source of Radiant Energy (lamp)**
- **Absorption Body**
- **Energy Detector**



Visual Determinations

"Do YOU See What I See?"

- **Color Perception**
- **Anomalous Trichromatism**
  - Difficulty in matching colors
- **Confuse Reds & Greens**



Chlorine DPD Color Wheel

Absorbance Measurement

- **Two types of Instruments**
  - Filter Photometer (Colorimeter)
  - Spectrophotometer
    - More accurate than a colorimeter

SPADNS Method

The colorimetric method relies on a reagent with color. For fluoride, this is

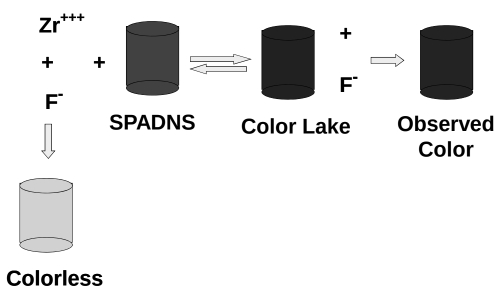
SPADNS

- **Sodium 2-(parasulfophenylazo)-1,8-dihydroxy-3,6-naphlene disulfonate**

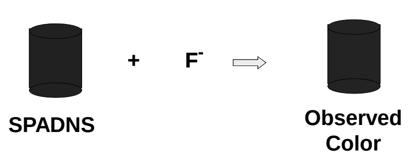
SPADNS Method

HACH AccuVac Ampules

Zirconium SPANS Complex



Zirconium SPANS Complex



- **The observed reduction in color is an indication of the amount of fluoride in the solution**
- **A deep red color indicates an absence of fluoride, and a light red color indicates a high fluoride concentration**

Colorimetric Analysis Sources of Error

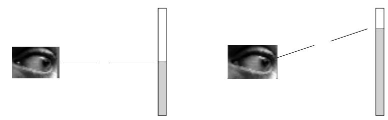
- **Sample collection**
- **Sample handling**
- **Testing cell**
- **Standards**
- **Electronic**
- **Calibration**
- **Interfering substances**

Sample Collection

- **Is solution fully mixed?**
- **Is container used for collection clean?**
  - Was glassware cleaned with phosphate based detergent?
- **Is person introducing contamination?**
- **Is chlorine a contaminate?**
  - Sodium arsenite removes chlorine interference

Sample Handling

- **Skill in using a pipette**
- **Bulb or pipette may be contaminated**
- **Parallax in measurement**



Testing Cell (cuvette)

- **Cell might be dirty or smeared**
- **Residuals could interfere**
- **Consistent optical clarity between cells**
- **Chips or scratches**

Standards

- **Use fresh standards**
- **Appropriate calibration of test**
- **Use true deionized water (zero fluoride)**

Electronics

- **Weak batteries**
- **Leaking batteries**
- **Deterioration of electronics**

Verification

- **Correct instrument verification**
- **Background color or turbidity**
- **Temperature differences**

SPADNS Interferences

Concentration of substance (mg/L) req. to cause error of plus or minus 0.1 mg at 1.0 mg/L fluoride		
Interfering Substance	**SPADNS**	**Electrode**
Alkalinity	5,000 (-)	7,000 (+)
Aluminum	0.1 (-)	3.0 (-)
Chloride	7,000 (+)	20,000 (-)
Iron	10 (-)	200 (-)
Hexametaphosphate	1.0 (+)	50,000
Phosphate	16 (+)	50,000
Sulfate	200 (+)	50,000 (-)

SPADNS Interferences

Concentration of substance (mg/L) req. to cause error of plus or minus 0.1 mg at 1.0 mg/L fluoride		
Interfering Substance	**SPADNS**	**Electrode**
Chlorine	Must be completely removed with arsenite*	5,000
Color & Turbidity	Must be removed or compensated for	___

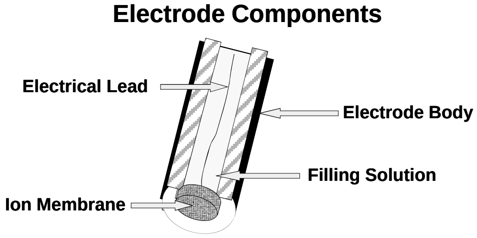
*Most suppliers (Hach is one of them) have arsenite in their SPADNS to remove up to 5.0mg/L free chlorine

HACH Pocket Colorimeter

Hach DR 4000

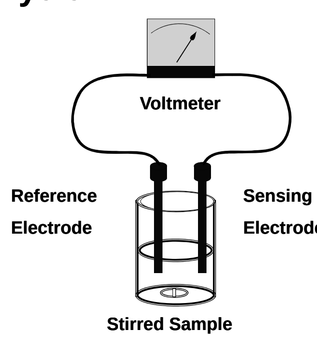
Specific Ion Electrode Analysis

Electrode Components



Measures Fluoride Ion Activity
LaF Crystal "Membrane"

Specific Ion Electrode Analysis



Specific Ion Electrode Analysis

- **Advantages**
  - Greater Range, 0.1 – 10.0 mg/L
  - Fewer Interfering Substances
  - Less Susceptible to Technique Errors
- **Disadvantages**
  - Expensive

Specific Ion Electrode Analysis

- **Total Ionic Strength Adjusting Buffer**
  - Adjusts pH 5 – 5.5 to Optimize Fluoride Ion Availability
  - Adjusts Total Ionic Strength by Swamping Background
  - Complexes Iron & Aluminum

Total Ionic Strength Adjusting Buffer

- **TISAB II**
  - Equal parts TISAB & Sample
  - Complexes up to 5 mg/L Aluminum or Iron

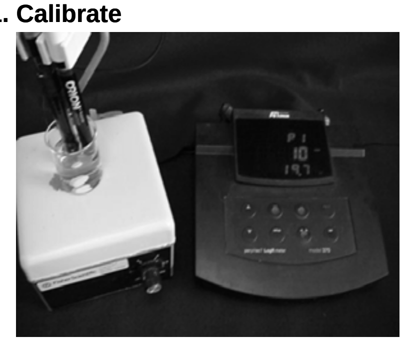
Total Ionic Strength Adjusting Buffer

- **TISAB III**
  - CDTA
  - 5.0 – 5.5 pH
  - Up to 5.0 mg/L Aluminum or Iron
  - Concentrated
- **TISAB IV**
  - Tartrate
  - 8.5 pH
  - Up to 100 mg/L Aluminum or Iron
  - Complexes Lanthanum

Specific Ion Electrode Analysis

Specific Ion Electrode Analysis

1. Calibrate

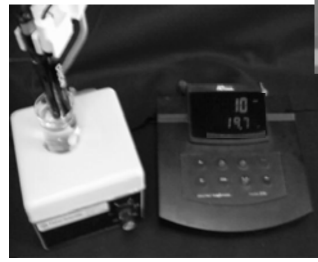


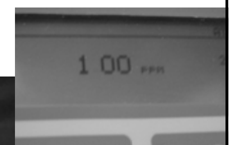
Specific Ion Electrode Analysis

2. Prevent carryover

Specific Ion Electrode Analysis

3. Read





Specific Ion Analysis Sources of Error

- Sample collection
- Sample handling
- Standards
- Electronic
- Element
- Interfering substances

Sample Collection

- Is solution fully mixed?
- Is container used for collection clean?
- Is person introducing contamination?

Sample Handling or Method Related

- Parallax in measurement
- Improper stirring
- Bubble
- Complexation (TISAB)
- Concentration out of range

Standards

- Use fresh standards
- Appropriate calibration of test
- Use true deionized water (zero fluoride)

Electronics

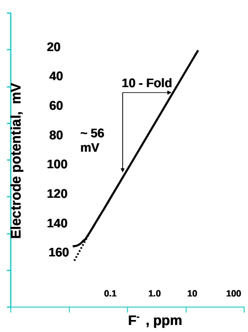
- **Weak batteries**
- **Leaking batteries**
- **Deterioration of electronics**
- **Instrument drift**
  - Batteries
  - Temperature

Fluoride Electrode Element

- **Broken Lead**
- **Leaking**
- **Filling solution**
  - Correct Type
  - Correct Amount
- **Crystallized / plugged membrane**
- **Correct reference electrode**

Suspect the Fluoride Electrode?

- **Check the Slope**
- **Pair Reference Electrode with a pH Electrode & Perform a pH Calibration**



Specific Ion Interfering Substances

Concentrations Causing 0.1 mg / L Error

	mg/L	Effect
Aluminum	3.0	⬇
Iron	200	⬇
Hexametaphosphate	>50,000	
Phosphate	>50,000	
Sulfate	>50,000	
Chlorine	5,000	

A negative effect means that the indicated value is lower than the actual Fluoride concentration, and vice versa.

Storing the Electrodes

- **Fluoride Single Junction** ⇨ **DRY!!**
- **Fluoride Combination** ⇨ **Filling Solution**
- **Reference** ⇨ **Filling Solution**

Laboratory Analysis

- **Colorimetric Method (SPADNS) can provide satisfactory results, but is subject to many interferences and operator methodology errors**
- **Specific Ion Electrode Method provides more reliable results, but requires greater operator effort**
- **Care and attention to methodology details is essential to achieve satisfactory results**

Laboratory Analysis

Questions?

Water Fluoridation

Health Benefits
Regulatory Perspective
Fluoride Additives
Equipment/Facilities
Laboratory Analysis
Personnel Safety
Operations

Respirators

- **NIOSH approved air purifying respirator with fluoride rated replaceable canisters**

Respirators

- **Correct procurement, training, and maintenance**
  - Ensure mask is correctly sized for the individual and provides the appropriate protection: integral eye protection preferred
  - Verify that canister is particulate and hydrogen fluoride rated
  - Training and practice on correct use
  - Replacement schedule for canister
  - Periodically inspect seals for wear

Dry Additive Safety Equipment

- **Eye protection**

FSA Safety Equipment

- **Heavy apron / coveralls**
- **Long-sleeve gauntlet gloves**
- **Durable rubber boots**

Latex gloves do not provide protection

Turn back the cuff

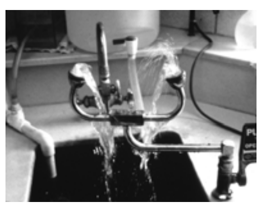
FSA Safety Equipment

- **Full face shield / safety goggles**

FSA Safety Equipment

- **Safety shower / eye wash**

Test regularly!



FSA Safety Equipment

- **Face shield**
- **Safety goggles**
- **Heavy apron**
- **Gloves**
- **Rubber boots**
- **Safety shower**
- **Eye wash**
- **Coveralls**

Fluorosilicic acid

Corrosive acid

Protective gear required

face shield, gloves, apron, boots, and respirator

Water Fluoridation

Health Benefits
Regulatory Perspective
Fluoride Additives
Equipment/Facilities
Laboratory Analysis
Personnel Safety
Operations

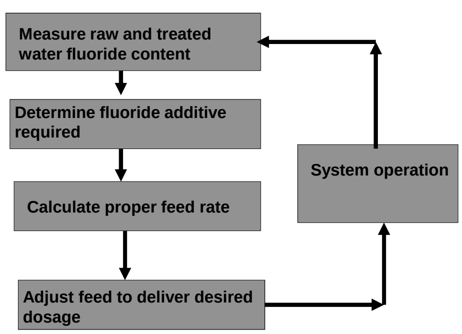
Optimal Fluoride Levels

- Based on maximum daily air temperature (presumed water consumption) from 0.7 to 1.2 mg/L
- Benefits to oral health decline as fluoride levels drops below optimum
- Little incremental benefit gained as fluoride levels increase over optimum
- CDC recommends control range 0.1 mg/L below to 0.5 mg/L above optimum level

Goal Is To Maintain Optimal Level

- For benefits of fluoridation to be realized, fluoride must be maintained at or near optimal level
- Principal reason for low or erratic fluoride levels is poor operation and maintenance

Simplified Process Control Scheme



Process Calculations - Units

- Capacity
  - MGD
  - gpm
  - m³/day
- Fluoride dosage
  - mg/L = ppm
- Fluoride additive feed rate
  - lb/day, lb/hr, mL/min, gpd, gph

Process Calculations

- Desired dosage
  - Amount of fluoride chemical needed to obtain optimal level
- Optimal level
- Natural level

$$\underset{(mg/l)}{\text{Dosage}} = \underset{(mg/l)}{\text{Optimal level}} - \underset{(mg/l)}{\text{Natural level}}$$

Process Calculations

- Chemical purity and available fluoride ion (AFI)

Chemical	Formula	Purity	Available Fluoride Ion (AFI)
Sodium Fluoride	NaF	98%	0.452
Sodium Fluorosilicate	Na_2SiF_6	98.5%	0.607
Fluorosilicic Acid	H_2SiF_6	23%	0.792

Process Calculations

- **Fluoride feed rate**

$$\text{Fluoride feed rate}_{(lb/day)} = \frac{\text{Dosage}_{(mg/l)} \times \text{Capacity}_{(MGD)} \times 8.34}{\text{AFI} \times \text{chemical purity}}$$

Process Calculations

- **Calculated dosage**

$$\text{Fluoride feed rate}_{(lb/day)} = \frac{\text{Dosage}_{(mg/l)} \times \text{Capacity}_{(MGD)} \times 8.34}{\text{AFI} \times \text{chemical purity}}$$

Rearrange to get . . . .

$$\text{Dosage}_{(mg/L)} = \frac{\text{Feed Rate}_{(lbs/day)} \times \text{AFI} \times \text{Chemical Purity}}{\text{Capacity}_{(MGD)} \times 8.34}$$

Process Calculations

- **Quantity to treat 1 MG at 1 mg/L**
  - Sodium fluoride (98%) - 18.8 lbs
  - Sodium fluorosilicate (98%) - 14.0 lbs
  - Fluorosilicic acid (23%) - 45.7 lbs. ~ 4.6 gal

Calculation Problem 1

- **Plant 1 has an average daily flow of 1.4 MGD and the source water has a natural fluoride level of 0.15 mg/L. The optimal level for oral health is 0.9 mg/L. If the FSA has a concentration of 25%, what is the dosage required and how many gallons will be necessary?**

Calculation Problem 1 (step 1)

Average daily flow is 1.4 MGD
Optimal fluoride level is 0.9 mg/l
Natural fluoride level is 0.15 mg/l

Optimal minus natural is the dosage
0.9 – 0.15 = <u>0.75 mg/L</u>

Calculation Problem 1 (step 2)

Average daily flow of 1.4 MGD
Optimal minus natural is
0.9 – 0.15 = 0.75 mg/L

$$\text{Fluoride feed rate}_{(lb/day)} = \frac{\text{Dosage}_{(mg/l)} \times \text{Flow}_{(MGD)} \times 8.34}{\text{AFI} \times \text{chemical purity}}$$

$$44.23\ (lb/day) = \frac{0.75_{(mg/l)} \times 1.4_{(MGD)} \times 8.34}{0.792 \times 0.25}$$

Feed Rate   **AFI**   **Purity**

Calculation Problem 1 (step 3)

Average daily flow of 1.4 MGD
Optimal minus natural is
0.9 – 0.15 = 0.75 mg/L

$$44.23 \text{ (lb/day)} = \frac{0.75 \text{ (mg/l)} \times 1.4 \text{ (MGD)} \times 8.34}{0.792 \times 0.25}$$

44.23 lbs/day divided by 24 hours is 1.8 lbs per hour

FSA at 25 percent purity weighs 10.1 pounds per gallon to give 0.18 pounds per hour

The total feed rate is:

- 4.38 gallons per day (44.23 lbs / 10.1 pounds per gallon)
- 0.183 gallons per hour (4.38 gal per day / 24 hours)
- 692.7 mL per hour (.183 gph X 3780 mL/gal)

Calculation Problem 2 (step 1)

Average daily flow is 5.8 MGD

Optimal fluoride level is 0.8 mg/L

Natural fluoride level is 0.2 mg/L

Optimal minus natural is
0.8 – 0.2 = 0.6 mg/L

Calculation Problem 2 (step 3)

Average daily flow of 5.8 MGD
Optimal minus natural is
0.8 – 0.2 = 0.6 mg/L

$$48.79 \text{ (lb/day)} = \frac{\text{Dosage (mg/l)} \times \text{Flow (MGD)} \times 8.34}{0.607 \times 0.98}$$

The feed rate is 49 pounds per day, or:

- 2.0 lb/hr (48.79 / 24 hours)
- 0.92 kg / hour (2.0 / 2.2 to get Kg)
- 15 mg/ min (0.92 kg/hr X 1000 mg/kg / 60 min/hr)

Calculation Problem 2

- Plant 2 has an average daily flow of 5.8 MGD and the source water has a natural fluoride level of 0.2 mg/L. The optimal level for oral health is 0.8 mg/L. The fluoride product is sodium fluorosilicate with 98% purity. What is the dosage required and how many pounds will be necessary?

Calculation Problem 2 (step 2)

Average daily flow of 5.8 MGD
Optimal minus natural is
0.8 – 0.2 = 0.6 mg/L

$$\text{Fluoride feed rate (lb/day)} = \frac{\text{Dosage (mg/l)} \times \text{Flow (MGD)} \times 8.34}{\text{AFI} \times \text{chemical purity}}$$

$$48.79 \text{ (lb/day)} = \frac{0.6 \text{ (mg/l)} \times 5.8 \text{ (MGD)} \times 8.34}{0.607 \times 0.98}$$

Feed Rate (48.79); AFI (0.607); Purity (0.98)

Calculation Problem 3

- Plant 3 has an average daily flow of 0.45 MGD and the ground water has a natural fluoride level of 0.4 mg/L. The optimal level for oral health is 1.1 mg/L. The fluoride product is sodium fluoride with 96% purity. What is the dosage required and how many pounds will be necessary?

Calculation Problem 3 (step 1)

Average daily flow is 0.45 MGD
Optimal fluoride level is 1.1 mg/L
Natural fluoride level is 0.4 mg/L
Optimal minus natural is
1.1 – 0.4 = 0.7 mg/L

Calculation Problem 3 (step 2)

Average daily flow of 0.45 MGD
Optimal minus natural is
1.1 – 0.4 = 0.7 mg/L

$$\text{Fluoride feed rate}_{(lb/day)} = \frac{\text{Dosage}_{(mg/l)} \times \text{Flow}_{(MGD)} \times 8.34}{\text{AFI} \times \text{chemical purity}}$$

$$6.05\ (lb/day) = \frac{0.7\ (mg/l) \times 0.45\ (MGD) \times 8.34}{0.452 \times 0.96}$$

Feed Rate — AFI — Purity

Calculation Problem 3 (step 3)

Average daily flow of 0.45 MGD
Optimal minus natural is
1.1 – 0.4 = 0.7 mg/L

$$6.05\ (lb/day) = \frac{0.7\ (mg/l) \times 0.45\ (MGD) \times 8.34}{0.452 \times 0.96}$$

The feed rate is 6.05 pounds per day, or:

- 0.252 lb/hr (6.05 / 24 hours)
- 114.3 gram/hr (.0252 lb/hr X 453.6 gram/lb)

Operation

- **Understand how it works**
  - Read the manual
  - Understand the operating cycle
    - When the equipment operates automatically
    - When the equipment shuts down automatically
  - Know what it sounds like

Sampling

- Minimum EPA sampling may only require annual testing
- AWWA and CDC both recommend daily sampling of product water
- Hourly testing of product water is often practiced by larger facilities that are well operated
- Occasional spot-sampling at random locations in the distribution system can identify other problems with system such as storage tanks
- Verify sampling location is representative of flow

Records

- Verify state records and reporting requirements
- Operational records
- Laboratory records
- Maintenance records
- Customer comments

Operational Records

- Source/product water fluoride level (daily)
- When and where sampling occurred
- Amount of fluoride additive used (daily)
- Pump or feeder calibration curves and pump or feeder operational settings (quarterly)
- Make-up water for saturators and feeders
- Assay on chemical purity (with each delivery)
- Check with state on other record or documentation requirements

Operational Records

- Reporting of operating results important for public health
- Results are compiled and help public health officials, medical doctors, dentists, and other health care providers make good decisions for communities and patients
- Submit results monthly

Laboratory Records

- Dates, times, technician, location, methodology, etc. for sampling events
- Results of split-sampling with state proficiency laboratory
- Verification of analytical procedure against standards
- Maintenance of laboratory equipment

Maintenance Records

- Dates of maintenance activities
- Documentation when pump hoses or heads are replaced
- Electrical records related to possible fluoride system operation
- Vendor for parts, supplies, and equipment manuals
- Preventative maintenance not repairs:
  - continuous, dependable operation

Suggested Maintenance

- Daily
  - Watch for trouble
    - Inspect system, listen to sounds
    - Look for leaks or differences
  - Liquid systems
    - Check solution levels, check level switch
    - Check hoses for air locks
    - Check pump for prime
    - Refill day tank
  - Dry feeders
    - Check for compaction
    - Refill additive hopper

Suggested Maintenance

- Every 3 months-FSA feed system
  - Check all piping for leaks, and gas venting for integrity
  - Check pipes/hoses for encrustations
  - Inspect tank level measurement (floats, gauges, etc)
  - Calibrate pump delivery rate

Suggested Maintenance

- **Every 3 months-dry feeder**
  - Thoroughly clean, remove cinders/ encrustations
  - Check belts; adjust if necessary
  - Lubricate bearings
  - Calibrate feeder dispensing rate
  - Rotate your additive inventory

Suggested Maintenance

- **Every 3 months-saturator**
  - Thoroughly clean, remove cinders/ encrustations in saturator, pipes and hoses
  - Verify uniform flow through additive bed: no short circuiting or piping
  - Verify water softener in working order
  - Clean water strainer
  - Check all piping for leaks
  - Inspect tank level measurement (floats, gauges, etc)
  - Calibrate pump delivery rate
  - Rotate your additive inventory

Suggested Maintenance

- **Every 6 months**
  - Motor driven pumps
    - Check lubrication, adjustments
  - Foot valves, lines, hoses, injector
    - Check for crystalline deposits
    - Disassemble and clean
  - Vacuum breaker, Anti siphon valve
    - Test operation
    - Disassemble, replace worn parts
  - Saturator
    - Drain, disassemble and clean

Suggested Maintenance

- **Annually**
  - Metering pump
    - Disassemble and replace worn parts
    - Replace hoses, diaphragms, seats, etc
    - Clean valves
      - Foot valve
      - Suction, discharge valves
      - Anti siphon valves; vacuum breaker
      - Injection check valves
  - Dry feeder
    - Check for worn gears, replace worn parts
    - Lubricate, change gear oil

Troubleshooting

- **Change in the equipment**
- **Deviations in sound or smell**
- **Change in amount of chemical fed**
- **Change in fluoride concentration**

Trouble Shooting – continued

- **Pump won't pump**
  - Check hoses & fittings
  - Test check valves, foot valve
  - Check back pressure
  - Verify float/level controller operation
- **Pump won't pump like it used to**
  - Clogged foot valve or strainer
  - Ruptured diaphragm
  - Worn seals
  - Change of pump stroke or speed
  - Pumps or pipes clogged with impurities

Trouble Shooting – continued

- **Softener**
  - Verify water hardness before/after softener
  - Check backwashing/regeneration
- **Excessive output**
  - Siphoning
    - Pumping downhill without an anti-siphon valve
  - Little or no pressure at injection point
  - Change of stroke length or speed

Trouble Shooting – Dry Feeders

- **Feed helix not turning but power ON**
  - Check for obstructions
- **Chemical will not feed**
  - Increase frequency of hopper agitator
  - Check moisture content (fish eyes)
  - Is material bridging or packing in bin
- **Erratic feed**
  - Binding of drive shaft or helix
  - Low speeds

Low Fluoride Readings

- **In a saturator**
  - Inadequate chemical depth
  - Incomplete mixing-verify no short circuiting or piping in bed
  - Inconsistent chemical addition
  - Accumulation of cinders, encrustations
  - Verify no slimes or grease layers in gravel or additive bed
  - Verify softener working properly
  - Test the solution strength to verify that the solution is saturated

High Fluoride Readings

- **Phosphates**
  - When using SPADNS method
  - Verify with ISE meter
- **Sample chlorine residual**
- **Check natural level**
  - Fluctuations due to
    - Run off
    - Low river flows
    - Seasonal variations

Variable Fluoride Readings

- **Check feeder or pump for variable output-recalibrate settings**
- **Air binding in metering pumps**
- **Low chemical levels in saturator or insufficient material in bin hopper**
- **Intermittent operations**
- **Are calculations being conducted correctly? Do they compare to records of actual additive being consumed?**

Variable Fluoride Readings

- **Verify additive purity, water content or silica content**
- **Verify chemical not bridging or packing in bin**
- **Verify additive does not have excessive moisture or fish eyes**
- **Incomplete mixing, verify that mixing tank has adequate volume for hydration / saturation**

Variable Fluoride Readings

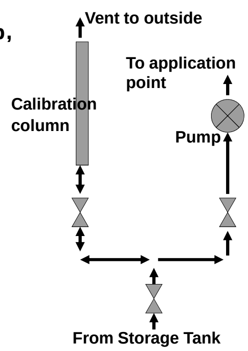
- Is tank experiencing stratification of concentrations? (different batches, complete dissolution, storage tanks?)
- Maintenance can result in unintended changes to controls and wiring
- Are controls and process working as intended?
- Is wiring correct?
- Does solution pump activates with one service pump but not the other?

Low Fluoride Readings

- Interferences with lab tests
- Glassware
  - Poor glassware
  - Improperly cleaned glassware
  - Phosphate detergent used
- Rinse with distilled water
- Sample temperatures
- Improper laboratory methodology
- Instrument errors, damage

Calibration for Pumps

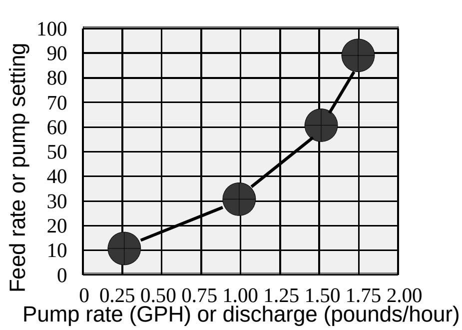
- Close valve to pump, open valve to calibration column and fill
- Close valve from storage tank, open valve to pump
- Measure time to pump measured volume for various pump settings



Calibration for Dry Feeders

- Conduct pan test
  - Fill hopper to normal depth
  - Set machine to low feed rate, allow discharge rate to achieve a stable and consistent rate, then collect discharge over a measured time in first pan
  - Repeat for several higher feed rates collecting discharge over measured time in sequential pans
  - Measure weight of pans with material and subtract pan weight to obtain material feed rate for each discrete machine setting

Calibration Curve



Calibration of Feed Delivery

- Calibration curve must be prepared for each pump or feeder
- Verify curve accuracy monthly, more frequently if additive character changes or maintenance is performed on equipment
- Curve should be based on 4 to 5 settings over the full range
- Always include the date of the calibration test

Overfeed

- CDC provides overfeed recommendations, verify state specific requirements
- Water treatment facilities should have overfeed instructions with operator instruction on procedures

Overfeed

- For overfeeds less than MCL, continue operation while problem is identified
- For overfeeds exceeding MCL
  - Temporarily stop operations while problem is identified
  - Notification of state personnel
  - Flush lines
  - Notify the public

Water Fluoridation Operations

Questions?

Section 6

Emergency Operation Plans

EMERGENCY OPERATIONS PLAN

1

TDEC - Fleming Training Center

PROTECTING THE PUBLIC HEALTH

- Safe and reliable drinking water should be delivered to the public
- Should meet federal and state requirements
- Should be delivered in adequate quantities and at adequate pressures

TDEC - Fleming Training Center 2

EMERGENCY OPERATIONS PLAN

- Also called EOP
- Identifies natural disasters and other emergencies that may strike a water system
- Assists water system in responding to emergencies quickly and effectively

TDEC - Fleming Training Center 3

EMERGENCY OPERATIONS PLAN

- A carefully planned EOP will:
  - Reduce property damage
  - Minimize downtime
  - Prevent illness
  - Save lives
  - Reduce system liability
- Emergency response planning is essential

TDEC - Fleming Training Center 4

EMERGENCY OPERATIONS PLAN

- EOP's include specific responses to:
  - Routine emergencies
  - Natural disasters
  - Accidents
  - Intentional man-made acts
  - Or any other incident that causes casualties, damage or disruption to the water system

TDEC - Fleming Training Center 5

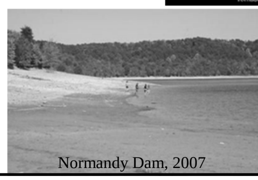
ROUTINE EMERGENCIES

- Line breaks
- Power outage
- Mechanical failure
- Water contamination

TDEC - Fleming Training Center 6

NATURAL DISASTERS

- Tornado
- Flood
- Earthquake
- Ice storm
- Drought


Normandy Dam, 2007

7

ACCIDENTS

- Fire
- Chemical spill
- Explosion

TDEC - Fleming Training Center 8

INTENTIONAL MAN-MADE ACTS

- Vandalism
- Terrorism
- Threats

Training Center 9

VULNERABILITY ASSESSMENT

- For those systems who have done the Vulnerability Assessment (VA), the EOP should include response actions to potential threats and malicious acts identified in your VA

TDEC - Fleming Training Center 10

EMERGENCY OPERATIONS PLAN

- The Tennessee Division of Water Supply defines a document that prepares for an emergency response as an “Emergency Operations Plan”.
- The US EPA refers to this document as an “Emergency Response Plan (ERP)”

TDEC - Fleming Training Center 11

EOP

- State Rules require all community water systems to have an EOP
  - 1200-5-1-.17(7)
  - “… all community water systems shall prepare an emergency operations plan in order to safeguard the water supply and to alert the public of unsafe drinking water in the event of natural or man-made disasters.”

TDEC - Fleming Training Center 12

HISTORY

- After September 11, 2001 the federal government amended the Safe Drinking Water Act (SDWA) to add regulations on emergency preparedness for utilities, including community water systems

HISTORY CONTINUED

- The BioTerrorism Act of 2002 added amendments to the SDWA that required the revision of water system emergency response plans to incorporate the results of the water system's vulnerability assessment

HISTORY CONTINUED

- The Terrorism Act required that emergency response plans include plans, procedures and the identification of equipment that can be used in the event of a terrorist or other intentional attack on the water system

EOP

- The EOP is a living document and should be reviewed and updated every two years
  - When there is a change to the water system configuration
  - Or when required by state or federal regulations

EOP ELEMENTS

17

EIGHT ELEMENTS OF EOP

- System Specific Information
- Roles and Responsibilities
- Communication Procedures
- Personnel Safety
- Alternate Water Source
- Equipment and Spare Parts
- Property Protection
- Water Sampling & Monitoring

SYSTEM SPECIFIC INFORMATION

19

SYSTEM SPECIFIC INFORMATION

- Water system info
- Maps & critical info
- Water source
- Water treatment process
- Distribution system
- Pumping facilities
- Storage facilities
- SCADA system
- Chemical inventory
- Materials/parts inventory
- Critical customers
- Largest customers
- Security features
- Communication equipment
- Office computer equipment

WATER SYSTEM INFORMATION

- Lists general information about the water system
  - System name & PWSID#
  - Address and directions to plant, office and emergency operations center (EOC)
  - Number of employees and certified distribution operators
  - Utilities used by water plant: electric, phone, gas and cell phone companies
  - Number of connections and population served

MAPS AND CRITICAL INFO

- EOP should reference
  - Location of distribution maps
  - Detailed plan drawings
  - Site plans
  - Valve and hydrant maps/books
  - Process flow diagrams
  - Operations reports
  - Operating manuals
  - Permits
  - Etc.

MAPS AND CRITICAL INFO CONTINUED

- Maps and other critical plans may be kept at a secure location and given out only on a "need-to-know" basis at the discretion of the water system manager
- Maps need to be kept-up to date
- Keep duplicate copies secured off-site

WATER SOURCE

- There are different templates for
  - Surface water
  - Well water
  - Purchased water
  - Spring water

WATER SOURCE CONTINUED

- Give location for intake or master meter
- Intake pipe size
- Raw water pump info
  - Manufacturer, HP, capacity, year installed
- Well depth, diameter, static water levels
- Chemicals added at intake and quantity stored at intake building

TDEC - Fleming Training Center 25

WATER TREATMENT PROCESS

- Dimensions and detention times for
  - Flash mix
  - Flocculation basins
  - Sedimentation basins
  - Filters
- Chemicals added and point of application, especially chlorine and fluoride

TDEC - Fleming Training Center 26

DISTRIBUTION SYSTEM

- Population served
- Number of residential and commercial meters
- Miles of pipe
- Number of booster pumps and backflow preventers
- Peak, average and minimum daily demands

TDEC - Fleming Training Center 27

PUMPING FACILITIES

- Name/location
- Whether it is a building or underground vault
- Elevation
- Capacity
- Suction and discharge pressure

TDEC - Fleming Training Center 28

STORAGE FACILITIES

- Total number of elevated and ground level tanks
- Storage facility name/location
- Description
  - Welded steel, concrete, elevated, etc.
- Overflow or ground level elevation
- Capacity
- Level control
- Access and security

TDEC - Fleming Training Center 29

SCADA SYSTEM

- Manufacturer of SCADA, Computer hardware running SCADA, Network software, Firewall/Security software, Antivirus software
- Outside access to SCADA
  - Phone line, DSL, cable, other, none
- Is system password protected?

TDEC - Fleming Training Center 30

CHEMICAL INVENTORY

- Chemical brand and common name
- What process is it used for?
- Point of use
- Solid, liquid, gas?
- Strength
- Daily consumption
- Suppliers and their contact info

MATERIALS & PARTS INVENTORY

- Description
- Serial # or VIN #
- Quantity
- Location

CRITICAL CUSTOMERS

- Critical customers should be listed and prioritized based on community health issues
  - Hospitals, nursing homes, schools, daycares, etc.
- Name
- Description
- Address
- Phone #
- gal/day needed

LARGEST CUSTOMERS

- List in prioritized order based on critical products or services to the community
- Name
- Description
- Address
- Phone #
- gal/day needed

SECURITY FEATURES

- Location of buildings
- Gates, fences
- Doors/windows
- Locks/card key
- Alarm systems
- Security lighting
- Cameras/monitors

COMMUNICATION EQUIPMENT

- Cell phones
- Pagers
- 2-way radios
- Satellite phones
- Laptops with phone service
- Need description, serial #, quantity and location for all these

OFFICE COMPUTERS & EQUIPMENT

- Name and contact info for internal and outsource IT person
- Office computer hardware
  - Manufacturer
  - Serial #
  - Description/Processor
  - Location

TDEC - Fleming Training Center 37

ROLES & RESPONSIBILITIES

CHAIN OF COMMAND
EMERGENCY RESPONDER COORDINATOR
INCIDENT COMMAND SYSTEM

38

TDEC - Fleming Training Center

CHAIN OF COMMAND

- In an emergency, system personnel should know
  - Where to report
  - Whom to report to
  - What their responsibilities are during the emergency response

TDEC - Fleming Training Center 39

CHAIN OF COMMAND CONTINUED

- Chain of command establishes lines of authority that preserve order and prevent confusion
- Check this document quarterly to confirm accuracy of personnel and phone numbers

TDEC - Fleming Training Center 40

EMERGENCY RESPONSE COORDINATOR

- The first response in any emergency is to notify the lead person
  - This is the person at the top of the chain of command
  - Referred to as the Emergency Response Coordinator (ERC)
- An alternate ERC should be designated in case primary ERC is unavailable

TDEC - Fleming Training Center 41

EMERGENCY RESPONSE COORDINATOR CONTINUED

- The ERC will asses the emergency and initiate the appropriate response actions
- The ERC will manage the entire emergency response unless an Incident Command Structure (ICS) facilitates a transfer of command

TDEC - Fleming Training Center 42

EMERGENCY RESPONSE COORDINATOR
CONTINUED

- Other names given for lead person are
  - Emergency operations coordinator (EOC)
  - Emergency operations leader (EOL)
  - Incident commander (IC)
  - Water utility emergency response manager (WUERM)

TDEC - Fleming Training Center 43

INCIDENT COMMAND SYSTEM

- In a major disaster, emergency or terrorist act, the ERC may need to initiate and/or defer to an Incident Command System (ICS)
- ICS is the model tool for coordinating the response efforts of several agencies as they work an emergency response

TDEC - Fleming Training Center 44

INCIDENT COMMAND SYSTEM CONT

- If another agency takes over command in an ICS situation, the ERC and water system personnel remain in charge of all water system repairs and operations

TDEC - Fleming Training Center 45

COMMUNICATION PROCEDURES

46

TDEC - Fleming Training Center

COMMUNICATION PROCEDURES

- Internal contact list and responsibilities
- External contact list
- Emergency communications plan
- Effective communications
- Personnel safety
- Alternate water source
- Equipment and spare parts
- Property protection
- Water sampling and monitoring

TDEC - Fleming Training Center 47

INTERNAL CONTACTS

- Contact information should be maintained for all people that may need to respond in an emergency
- List should be reviewed quarterly to keep up-to-date
- List should have home and cell number to contact people day or night
- Store back-up file/list at secure off-site location

TDEC - Fleming Training Center 48

EXTERNAL CONTACTS

- Obtain cell phone or 24-hour emergency numbers for all external contacts
- List should be reviewed quarterly to keep up-to-date

TDEC - Fleming Training Center 49

EXTERNAL CONTACTS CONTINUED

- Local police
- Fire and first responders
- Local Government
  - Mayor, Chamber of commerce
- Local media
  - TV, radio, newspaper
- Utilities
  - Electric, natural gas, phone
- Cell phone companies
- Diesel fuel suppliers
- Outside vendors
  - Water plant pipes/parts, chemicals, SCADA
- Contractors
- Pump specialist
- Electricians & Plumbers
- Regulatory agencies
- Critical customers
- Water testing labs

Can you think of other external contacts?

TDEC - Fleming Training Center 50

EXTERNAL CONTACTS CONTINUED

- The TN Department of Homeland Security should be notified of any acts against the water system that may be caused by terrorist
- FBI becomes the lead agency in this case

TDEC - Fleming Training Center 51

EMERGENCY COMMUNICATIONS PLAN

- Communication procedures should be documented
- Alternate communications plans should be included in your EOP in the even that land lines, cell phones or walkie-talkies don't work
- Communicate with cellular companies on the availability of priority channels during an emergency
- Satellite phones should be considered an alternative

TDEC - Fleming Training Center 52

EMERGENCY COMMUNICATIONS PLAN CONTINUED

Emergency Communications Plan

Template A-25 Example

1	Walkie-talkie phones will the be first line of communication in an emergency. If walkie-talkie phones are inoperable, land phones, personal cell phones, and/or 2-way radios should be used to communicate with water system staff and external responders. Office managers will attempt to call phone company/cell phone company to request priority in restoring cell phone signals. (Two trucks and the office currently have three pair of 2-way radios. Two additional pair of 2-way radios are located in the manager's office at the Water System office.) Do not use 2-way radio for communications that should not be released to the public.
2	If phone and radio communication are inoperable, water system personnel should drive to the Emergency Operations Center (EOC) for emergency communication /assignments. Responders should communicate in person by walking or driving until phone service is restored.
3	Contact TEMA immediately for communication /emergency management assistance

TDEC - Fleming Training Center 53

EFFECTIVE COMMUNICATIONS

- Plan how you will communicate with customers and media before emergencies happen
- Designate a media spokesperson
- If 10% of the population speaks Spanish or another language, additional translated versions of public notifications should be made available

TDEC - Fleming Training Center 54

PERSONNEL SAFETY

- The water system should have procedures for securing the safety of utility personnel and the immediate community
- Schedule training sessions on
  - Basic safety procedures
  - Alarm response
  - First aid
  - Personal protection equipment (PPE) usage
  - Evacuation procedures

TDEC - Fleming Training Center 55

ALTERNATE WATER SOURCE

- Identify the sources and procedures for obtaining a short-term and a long-term alternate water supply in the event of an emergency

TDEC - Fleming Training Center 56

PUBLIC NOTICES

- Boil Water Notice
  - No alternate source is required
- Do Not Drink Notice
  - Alternate water source must be provided for drinking and food preparation
- Do Not Use Notice
  - Alternate water source must be provided for drinking, cooking, bathing and even fire fighting (in certain contamination scenarios)

TDEC - Fleming Training Center 57

TANKER TRUCKS

- If tanker trucks are used to transport or store water as an alternate water source, make sure you allow time to disinfect the trucks properly
- See Appendix F for tanker truck disinfection procedures

TDEC - Fleming Training Center 58

EQUIPMENT AND SPARE PARTS

- Identify these that can reduce the impact of an emergency
  - Vehicles
  - Chemicals
  - Tools
  - Spare parts
  - Special equipment
- All heavy equipment, portable generators, spare pumps, etc should be listed here

TDEC - Fleming Training Center 59

EMERGENCY EQUIPMENT

- SCBA
- Toxic gas meters
  - Check and calibrate chlorine alarms and test
- Chlorine repair kits: A, B and/or C kits
  - Plan for chlorine repair parts and supplies
- All PPE for emergency

TDEC - Fleming Training Center 60

PROPERTY PROTECTION

- Establish a procedure for locking down the facility and establishing a secure perimeter to the plant grounds and buildings
- Enter a potential crime scene with caution, if you believe suspects are still present, call 911

TDEC - Fleming Training Center 61

PROPERTY PROTECTION CONTINUED

- The ERC will communicate with local police and emergency response teams to determine if the building should be locked down and site perimeter secured
- Look over the grounds and note any persons or vehicles in the vicinity
- Look, listen and smell for dangerous signs

TDEC - Fleming Training Center 62

PROPERTY PROTECTION CONTINUED

- If you find victims, check out their physical condition, provide comfort and medical attention (if trained)
- Do not clean up, remove items or otherwise disturb the crime scene
- Document any statements/comments made by victims, suspects or witnesses on the scene

TDEC - Fleming Training Center 63

PROPERTY PROTECTION CONTINUED

- After the site is secured and victims are stabilized, begin assessing potential contamination and/or damage to the water system
- Follow the water system's EOP

TDEC - Fleming Training Center 64

WATER SAMPLING & MONITORING

- DWS and approved water lab should be consulted to determine appropriate testing and sampling
- Identify the certified operator or team (and alternates) who is/are responsible for taking samples

TDEC - Fleming Training Center 65

WATER SAMPLING & MONITORING

- Sampling procedures should be outlined for:
  - Decision-making process to determine the tests to run
  - Location and/or source of test kits and/or sample containers
  - When to use preservatives or dechlorinating agents
  - Sample quantity to collect
  - Proper collection procedures

TDEC - Fleming Training Center 66

WATER SAMPLING & MONITORING

- Provide a water sampling plan of your water distribution system
  - Sampling plan is to provide sample protocol and chain of custody
- Laboratory agreements are needed and contacts of outside labs are needed to secure monitoring requirements

TDEC - Fleming Training Center 67

OTHER KEY ELEMENTS TO EMERGENCY PLANNING PROCESS

68

TDEC - Fleming Training Center

WATER CONSERVATION & DROUGHT MANAGEMENT

69

TDEC - Fleming Training Center

DROUGHT MANAGEMENT

- Public water systems and local communities should plan for conditions of low water supply by having an approved drought management plan in place
- *Local Drought Management Planning Guide for Public Water Suppliers*

TDEC - Fleming Training Center 70

DROUGHT MANAGEMENT CONTINUED

- Plan may include, but not limited to the following restrictions
  - Use of water to wash any motor vehicle, motorbike, boat, trailer, or airplane or other vehicle
  - Use of water to wash sidewalks, driveways, decks, home siding, gutters, parking lots or other hard-surface
  - Use of water to irrigate lawns, trees, shrubs, plants and flowers

TDEC - Fleming Training Center 71

DROUGHT MANAGEMENT CONTINUED

- Plan may include, but not limited to the following restrictions (cont.)
  - Use of water to fill indoor or outdoor swimming pools or hot-tubs
  - Use of water in fountain or pond except where necessary to support aquatic life
  - Use of water from a fire hydrant for other than fire fighting purposes

TDEC - Fleming Training Center 72

WATER CONSERVATION

- Voluntary water conservation measures should be emphasized
  - Take short showers
  - Fix leaky faucets and running toilets
  - Don't allow water to run while brushing teeth or shaving
  - Collect rainwater for watering plants, gardens and flowers

WaterSense Meets EPA Criteria

TDEC - Fleming Training Center 73

THREAT EVALUATION

74

TDEC - Fleming Training Center

THREAT EVALUATION

- All threats should be taken seriously
- Threats may be reported or delivered in many different forms
  - Consumer complaint of water taste or odor
  - Witness account of tampering with water tank
  - Phone call from alleged perpetrator
  - Emergency room reporting patients with symptoms after drinking water

TDEC - Fleming Training Center 75

THREAT IDENTIFICATION CHECKLIST

- Should be kept next to every phone at the office and water treatment plant
- If a threat is received, the checklist should be completed
  - See A-32 Threat Identification Checklist

TDEC - Fleming Training Center 76

THREAT IDENTIFICATION CHECKLIST

- If you receive a suspicious letter or package, set it aside and do not open it
- Calmly instruct everyone to leave the room immediately
- Close the door
- Wash your hands with soap and water
- Notify your supervisor and/or call 911 if a suspicious substance is visible

TDEC - Fleming Training Center 77

FOLLOW-UP EOP ACTIVITIES

- EOP approval and review date
  - Keep log on approvals
  - Update every two years
- EOP distribution
  - Keep copies numbered for control purposes
  - Keep log on who has what copy and where
- Training
  - Minimum training once a year

TDEC - Fleming Training Center 78

TRAINING

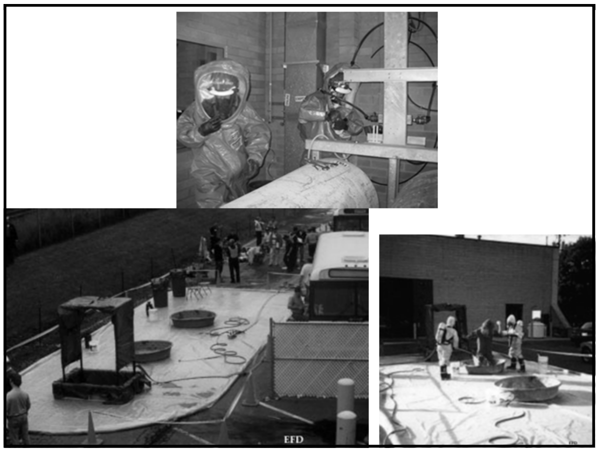
- Orientation or classroom sessions
  - Basic instruction on EOP procedures
- Tabletop workshop
  - Fabricated event with actions/verbal responses and close with evaluation
- Functional exercise
  - Team of simulators develops a realistic major event and staff responds to the event
- Full-scale drills
  - More costly

TDEC - Fleming Training Center 79

TRAINING CONTINUED

- Successful implementation of the EOP plan is going to depend on:
  - Training of employees and contacts
  - Yearly mock trial
  - Rotate personnel on the response teams
  - Annual revisions and updates

TDEC - Fleming Training Center 80



CHLORINE LEAK AT PLANT

- Water plant should have a current evacuation plan for chlorine gas evacuation
- Current plan should evacuate the plant grounds and a minimum ½ mile radius of affected area

TDEC - Fleming Training Center 82

CHLORINE LEAK AT PLANT CONTINUED

1. Chlorine alarms go off and start a response
2. Phone call made of chlorine gas leak in plant
3. Operator makes investigation on site to chlorine room and alarms
4. Leak found and starts response

TDEC - Fleming Training Center 83

CHLORINE LEAK AT PLANT CONTINUED

5. Incident commander notified and incident command started
6. Chlorine alarms acknowledged and evacuation started
7. Chlorine response and repair team activates to contain the leak; locate and isolate chlorine gas leak if possible

TDEC - Fleming Training Center 84

CHLORINE LEAK AT PLANT CONTINUED

8. Water Plant evacuated and secured
9. Staging Area for incident command and safe zone established
10. Notify: 911, Hazmat, Police and Fire Department
11. Coordinate neighborhood evacuated with Police and Fire Department

TDEC - Fleming Training Center 85

CHLORINE LEAK AT PLANT CONTINUED

12. Response Teams are working to isolate the chlorine leak
13. Chlorine repair team finds the leak and repairs the chlorine pressure diaphragm to the chlorine manifold
14. Area is checked for air monitor by gas detector for chlorine gas levels

TDEC - Fleming Training Center 86

CHLORINE LEAK AT PLANT CONTINUED

15. Two hours into the event, the area is secure
    - Incident commander determines that the water plant is safe to return to normal water plant operations
16. Incident command is shut down
17. Normal plant operations and chlorine process are monitored for further compliance
18. Evacuation is canceled

TDEC - Fleming Training Center 87

REFERENCES

- Emergency Operations Planning Guide, TN DWS along with templates can be found at: http://www.state.tn.us/environment/dws/security/svadocuments.shtml

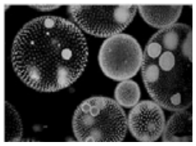
TDEC - Fleming Training Center 88

Section 7

Algae Identification/ Microscopic Examination

Types of Algae
Significance to Water Supplies
Control Measures
Identification with Microscopes

Algae Identification



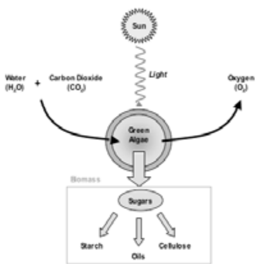
1

Algae

- Algae is a diverse group of organisms that range from single celled forms to giant marine kelps.
- Algae occupy a wide variety of habitats including fresh and salt waters, moist soils, hot springs, snowfields and even deserts.
- Algae use light energy to convert carbon dioxide and water into simple sugars, which they use to grow new cells. This process is called photosynthesis.

2

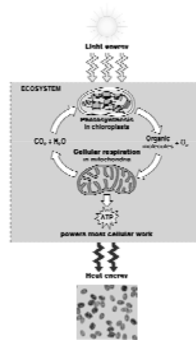
Photosynthesis



- Plants and algae use light energy from the sun, carbon dioxide and water to produce simple sugars.
- Oxygen is released as a byproduct.

3

Cellular Respiration


New cells

- Algae use the sugars they produce as a food source to grow new cells.
- This process is called cellular respiration. It usually occurs at night when solar energy is not available.
- Oxygen is taken in by the algae and sugars are converted into carbon dioxide water and energy.

4

Algae's significance to water supplies

- Tastes and odors are caused by the release of certain compounds by both living algae and decomposing algae.
- A massive bloom of algae can cause rapid and severe oxygen depletion, which can lead to fish kills.
- Some algal species produce toxins, which have caused deaths in cattle, horses, and wildlife. There is some evidence that humans can be affected by the toxins as well.

5

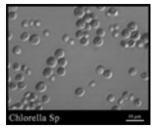
Algae's significance to water supplies

- A variety of algae when abundant in water can rapidly cover the surface of a sand filter. Filter runs are reduced, backwashing must be increased.
- Algae can be an obstruction to water conveyance by plugging screens, and weirs
- Algae can also lead to the formation of disinfection by-products when water containing algae or their metabolites is chlorinated.
- Algae can affect the pH of water in reservoirs. A pH as high as 9.5 during an algal bloom has been observed. The pH can interfere with treatment processes such as coagulation and disinfection.

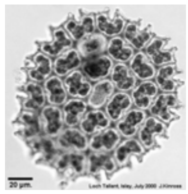
6

Algae morphology

- Algae can be single- celled



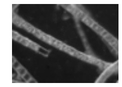
- Algae can be colonial



7

Algae morphology

- Algae can be filamentous



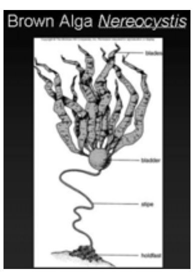
- Algae can be membranous

- Algae can be tubular

8

Algae morphology

- Algae can be complex and multi-cellular



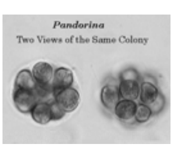
9

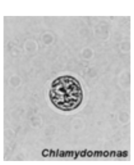
Algal Divisions

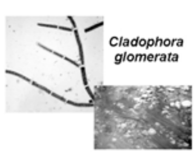
- Chlorophyta- (Green Algae)
- The largest and most diverse group of freshwater algae.
- They can be single celled, filamentous, colonial, membranous or tubular.
- They are common in lakes, ponds, an even in treated water reservoirs.
- They are generally harmless in water supplies.
- Some species can cause taste and odor problems when abundant.
- Filamentous species can form wiry growths and tangled mats.

10

Green Algae







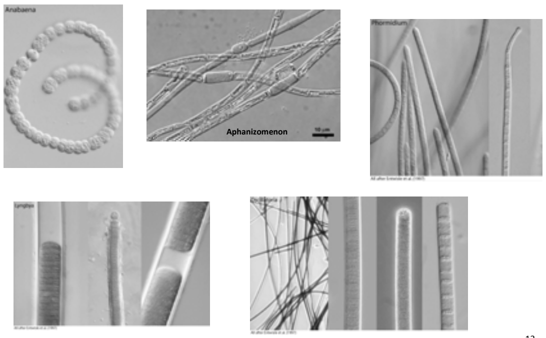
11

Algal Divisions

- Cyanophyta- (blue-green algae)
- Bacteria-like organisms
- Can be single celled, filamentous, or colonial.
- Common is all aquatic environments, soils, and extreme environments.
- Many problems in water supplies are attributed to this group including taste and odors, oxygen depletion, toxins, filter clogging and disinfection byproduct formation.

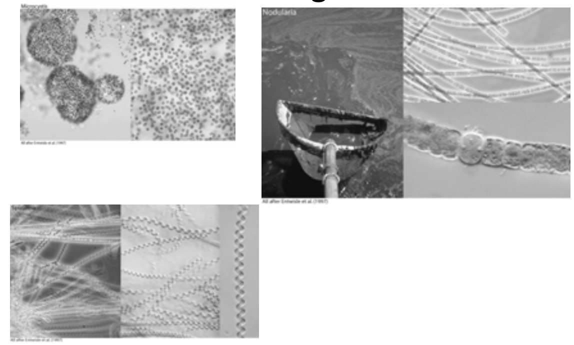
12

Blue-Green Algae- Taste and Odor producers



13

Blue-Green Algae- others



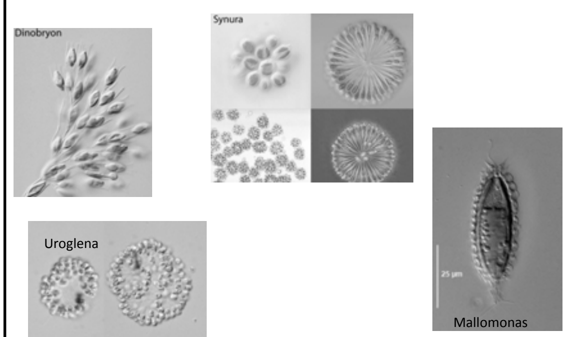
14

Algal divisions

- Chrysophyta-(yellow-green algae)
- Abundant in lakes and reservoirs.
- Includes the diatoms, and dinoflagellates.
- Significant because they are known to cause tastes and odors.
- Fishy and cucumber odors typically
- Some are known filter cloggers.

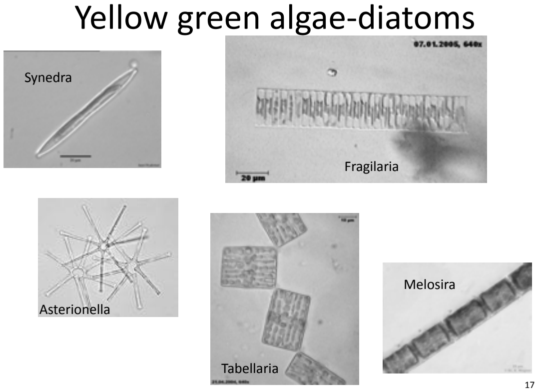
15

Yellow-green algae



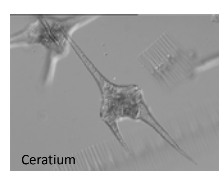
16

Yellow green algae-diatoms

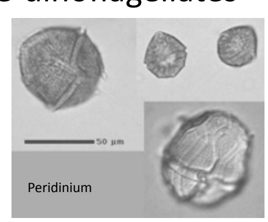


17

Yellow-green algae-dinoflagellates



Ceratium-can produce fishy odors, and septic odors when the organisms die off.



Peridinium can also produce fishy odors.

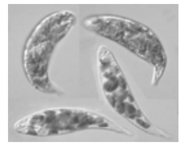
18

Algal Divisions

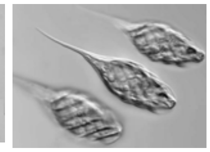
- Euglenophyta- euglenoids
- More animal like type of algae.
- Swim by means of flagella.
- Widely distributed in freshwater.
- Especially in bodies of water high in organic matter, such as ponds accessed by livestock.
- Indicators of water pollution due to sewage effluent.
- One species is known to clog filters

19

Euglenophyta



Euglena viridis



Phacus pyrum

Lepocinclis texta

These three species of euglenoids are particularly important as pollution indicators.

This species is sometimes found to clog filters.

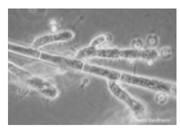
20

Algal Divisions

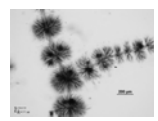
- Rhodophyta-red algae
- Usually found in cold waters, and rapidly flowing streams.
- Minor constituents of drinking water supplies.
- Three species can grow on reservoir walls.
- May lead to disinfection by-products if contacting chlorine compounds

21

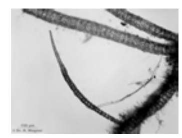
Red algae



Audouinella



Batrachospermum



Compsopogon

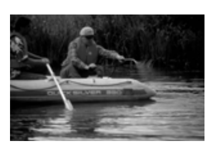
22

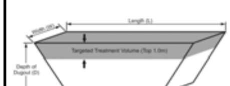
Control Strategies

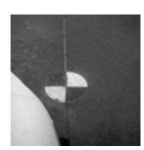
- Copper sulfate has been used for algae control in reservoirs for many years.
- Copper sulfate is usually only applied in shallow areas of reservoirs because it becomes to dilute and less effective in deeper waters.
- When copper sulfate is used it should be accompanied by a monitoring program to determine effectiveness and to minimize chemical usage.
- Excessive amounts of copper can build up in sediments and become toxic to wildlife,beneficial plants and organisms.

23

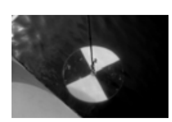
Copper sulfate







Before treatment



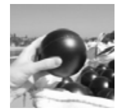
After treatment 24

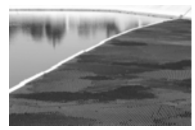
Control strategies

- Another new way to treat algae growth is by restricting light.
- Basins and clarifiers can be enclosed or covered to prevent growth of algae.
- Shade balls are being used in some reservoirs to prevent light penetration, thereby preventing the growth of algae.

25

Shade balls- California Ivanhoe Reservoir





A total of 3 million plastic balls were poured into Ivanhoe Reservoir in Silver Lake, California in 2008.

Each ball cost approximately 34 cents and are expected to last for 5 years.

The reservoir needed to be covered to prevent the formation of disinfection byproducts resulting from algae compounds contacting chlorine.

26

Control strategies

- Other compounds can be fed to kill algae.
- Chlorine- used to be the oxidant of choice, but prechlorination had led to more disinfection byproduct formation.
- Permanganate- both sodium and potassium permanganate are useful in treating algae.
- Hydrogen peroxide- is sometimes used to treat algae in reservoirs

27

Microscopic Examination

- Parts of a microscope
- **Eyepiece Lens:** the lens at the top that you look through. They are usually 10X or 15X power.
- **Arm**: Supports the tube and connects it to the base
- **Base**: The bottom of the microscope, used for support.
- **Always carry the microscope with two hands supporting the arm and the base.**
- **Never hold it by the eyepiece!**

28

Microscopic Examination

- **Light source:** A steady light source (110 volts) .
- **Stage:** The flat platform where you place your slides. Stage clips hold the slides in place. If your microscope has a mechanical stage, you will be able to move the slide around by turning two knobs.
- **Coaxial stage controls** one moves it left and right, the other moves it up and down.
- **Revolving Nosepiece**: This is the part that holds two or more objective lenses and can be rotated to easily change power.

29

Microscopic Examination

- **Objective Lenses**: Usually you will find 3 or 4 objective lenses on a microscope. They almost always consist of 4X, 10X, 40X and 100X powers.
- **Diaphragm or Iris lever:** This diaphragm has different sized holes and is used to vary the intensity and size of the cone of light that is projected upward into the slide.
- **Coarse focus knobs:** The larger of two sets of knobs located on either side of the arm. This adjustment is used to make large adjustments in focusing by moving the lenses up and down. *Never use this adjustment when using the 40X objective.*
- **Fine focus knobs:** The smaller of two sets of knobs located on either side of the arm. This adjustment is used to make small adjustments in focusing. It has a limited amount of movement and is most efficiently used after focusing with the 4X objective and coarse focus.

30

Care and Handling of Microscopes

- A microscope is a **delicate** piece of equipment and should be treated with care.
- Use **two hands** when carrying the microscope. Place one hand around the arm of the microscope and the other under the base for support.
- Carry the microscope **upright** and close to the body.
- Place the microscope **flat on the table**, but not too near the edge where it might be knocked off.
- **DO NOT** slide the microscope back and forth on the lab table.
- If it becomes necessary to clean the lenses on the microscope, ask your instructor for a piece of **lens paper**. Other materials, such as paper towel, can scratch the surface of the lens.

31

Care and Handling of Microscopes

– Throw used slides in the glass disposal container

When storing the microscopes:

-

– **Always rotate the nosepiece so that the LOW POWER objective lens is in line with the eyepiece.**
– Wrap the power cord around the base.
– Place the dust cover on top of the microscope.
– Return the microscope to storage.

32

Viewing Specimens

- Collect a sample (10-50 ml) of raw water or water from areas where you suspect algae might be a problem.
- Prepare a wet mount slide and attempt to identify organisms.
- **Standard Methods for the Examination of Water and Wastewater** contains color plates illustrating several species of problem algae.

33

Making a wet-mount slide

– Place a clean slide on the lab table. **Handle slides at the ends**, not the center, to avoid getting fingerprints in the viewing area of the slide.

– Add specimen to the slide.
  - For liquid samples, place one small drop in the center of the slide.
  - For solid samples, place the sample in the center of the slide and add one drop of **water or stain**.

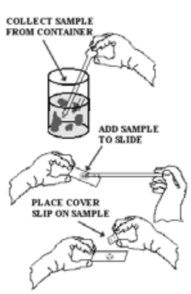
–

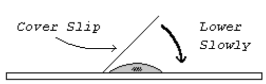
– Hold the coverslip by the edges to avoid fingerprints. Set one edge against the slide and lower it until it contacts the liquid. The liquid should spread across the whole area of the coverslip.

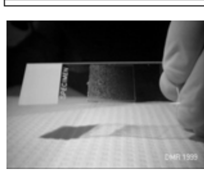
– **Never view a slide without a coverslip.** The coverslip protects the objective lens from the liquid on the slide.

34

Making a Wet-Mount Slide







35

Viewing Specimens

- Because the microscope uses lenses and mirrors, the image you see through most light microscopes will be **upside down** and **backward**.
- In most instances, light must pass through any object to be viewed with a light microscope. For this reason, the object must be **fairly thin**. Thick objects must be sliced into thin sections for viewing.

On the stage

Through the lens

36

Viewing Specimens

- Plug in the microscope and turn the power on.
- Place the slide on the stage so that the area of the slide containing the specimen is over the opening.
- Always start with the low power lens (4X).
- Look through the eyepiece, use the course adjustment knob to focus on the object.
- Use coaxial stage controls to view all areas of the slide for organisms.
- Next change the objective to medium power (10X). The object will almost be in focus.
- Use the coarse adjustment knob slowly to focus.

37

Viewing specimens

- To see more details of the organisms on the slide you can change to objective to high power (40X).
- You should only have to use the fine focus in this objective.
- Do not use the coarse adjustment or you could crack the lens.

38

Worksheet for Microscopic Examination

Algae Identification

Date:____________

Sample Location:____________________________

Temperature:________

Algae Group	Slide 1	Slide 2	Total
Chlorophyta-green algae			
Cyanobacteria- blue-green algae			
Chrysophyta			
Chrysophyta-diatoms			
Chrysophyta-dinoflagellates			
Rhodophyta			
Euglena			

Species Identified	Significance to drinking water

Section 8

Safety

General Safety
Personal Protective Equipment
Chlorine Safety

- An accident is caused by either an unsafe act or an unsafe environment.

TDEC - Fleming Training Center 2

General Duty Clause

- FEDERAL - 29 CFR 1903.1
- 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.

3 TDEC - Fleming Training Center

OSHA

- Occupational
- Safety
- Health
- Administration

4 TDEC - Fleming Training Center

General Safety Procedures

- Preliminary checks
  - ✓ Unsafe circumstances or unusual conditions
  - ✓ Equipment check
  - ✓ Unusual noise in machinery
  - ✓ Fumes or odd odors

5 TDEC - Fleming Training Center

General Safety Procedures

- Unsafe circumstances or unusual conditions
- 29 CFR 1910.23(c)(1)

Every open-sided floor or platform 4 feet or more above adjacent floor or ground level shall be guarded by standard railing on all sides except where there is entrance to a ramp, stairway, or fixed ladder.

6 TDEC - Fleming Training Center

General Safety Procedures

- Unsafe circumstances or unusual conditions

7

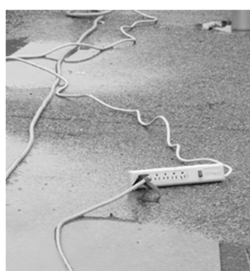
General Safety Procedures

- Unsafe circumstances or unusual conditions

8 TDEC - Fleming Training Center

General Safety Procedures

- Unsafe circumstances or unusual conditions
  - Environment
  - Weather



9 TDEC - Fleming Training Center

General Safety Procedures

- Unsafe circumstances or unusual conditions
  - Unusual noise in machinery
  - Fumes or odd odors

10 TDEC - Fleming Training Center

General Safety Procedures

- Equipment check
  - Right equipment
  - Training
  - Safe load limits
  - Condition

11 TDEC - Fleming Training Center

Slip, Trip and Fall Prevention

12

Leading Cause of Industry Accidents

- For the past three years, slips, trips, and falls have been responsible for the majority of reportable accidents in the workplace.
- Approximately three workers are fatally injured every work day in the U.S.
- Over 300,000 fall injuries reported annually

13 TDEC - Fleming Training Center

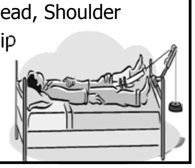
Slip, Trip and Fall Incidents

- 15 percent of all accidental deaths (≈12,000/year), second leading cause behind motor vehicles
- One of the most frequent types of reported injuries
  - about 25% of reported claims per fiscal year
- Over 17% of all disabling work injuries are the result of falls

14 TDEC - Fleming Training Center

Injuries from Slips, Trips, and Falls

- Common types of injuries:
  - Sprains, strains
  - Bruises, contusions
  - Fractures
  - Abrasions, lacerations
- Commonly affected body parts:
  - Knee, Ankle, Foot
  - Wrist, Elbow
  - Back
  - Head, Shoulder
  - Hip



15 TDEC - Fleming Training Center

Slips, Trips, and Falls Are Costly

- To Worker:
  - Pain
  - Lost wages
  - Temporary or permanent disability
  - Reduced quality of life
  - Depression
- To Employer:
  - Loss in productivity and business
  - Increased industrial insurance premiums
  - Costs associated with training replacement worker

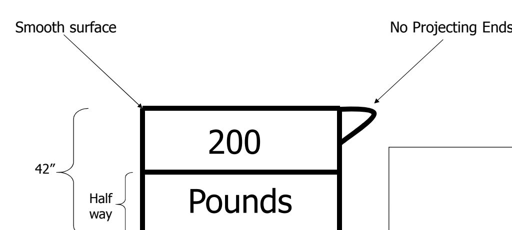
16 TDEC - Fleming Training Center

Leading Cause of Industry Accidents

- Slip, trip, and fall hazards are some of the easiest and most cost efficient risks to manage
- They are the easiest to overlook

17 TDEC - Fleming Training Center

Standard Railing



18 TDEC - Fleming Training Center

Causes of Slips, Trips, and Falls

- Poor housekeeping (water, oil, trash)
- Openings in travel ways
- Improper guardrails and handrails
- Failure to use or improper use of PPE
- Wet and slippery surfaces
- Failure to use fall protection

19 TDEC - Fleming Training Center

Causes of Slips, Trips, and Falls

- COMMON SENSE!!!

20 TDEC - Fleming Training Center

Causes of Slips, Trips, and Falls

- Bucket man & Idiot boy

21 TDEC - Fleming Training Center

Slips

- Occur when there is little or not enough friction or traction between footwear and walking/working surfaces
- According to OSHA, coefficient of friction shall be more than 0.5
  - Coefficient of friction is a measure of slip resistance

22 TDEC - Fleming Training Center

Causes of Slips

- Some common causes of slips include the following:
  - "wet" contamination/spills on smooth floors or surfaces: water, fluids, mud, grease, oil, food, etc.
  - "dry" contamination making surfaces slippery: dusts, powders, granules, wood, lint, plastic wrapping, etc.

Water on floor of PVC pipe manufacturing plant

23 TDEC - Fleming Training Center

Slips – Common Causes

- Loose or unanchored carpet
- Unattached rugs, mats or carpets

24 TDEC - Fleming Training Center

Causes of Slips

- Sloped walking surfaces
- Loose floorboards or tiles that can shift
- Shoes with wet, muddy, greasy, or oily soles

Sloping driveway into the lower level of a garage, which had no safe designated pedestrian walkways

25 TDEC - Fleming Training C

Slips – Common Causes

- Flooring that does not have the same degree of traction in all areas

26 TDEC - Fleming Training Center

Causes of Slips

Transitioning from one type of flooring to another with less traction may cause a slip if one does not adjust for the change.

- Highly polished floors, such as marble, terrazzo, or ceramic tile (can be extremely slippery even when dry)
- Freshly waxed surfaces
- Transitioning from one floor type to another (e.g., carpeted to vinyl/ smooth surface flooring)

27 TDEC - Fleming Training Center

Causes of Slips

- Mounting and dismounting trucks, tractors, heavy equipment, machinery, etc.; getting on and off trailers, truck beds
- Climbing up and down ladders

- Metal rungs, steps, footholds, treads, etc. on equipment and ladders become even slicker when worn smooth and contaminated with water, mud, oil, grease, dirt, and debris.

28 TDEC - Fleming Training Center

Causes of Slips

- Weather hazards
  - Ice or snow
  - Strong wind
  - Rain

29 TDEC - Fleming Training Center

Causes of Slips

- Wearing improper footwear not suitable for the environment
- PPE

30 TDEC - Fleming Training Center

Trips

- Loss of balance that occurs when the leading foot strikes an object (as low as 3/8 of an inch or less) and the upper body is thrown forward.

31 TDEC - Fleming Training Center

Trips – Common Causes

- Poor housekeeping
  - Materials in walking/working areas
  - Trash
  - Oil, water

32 TDEC - Fleming Training Center

Trips – Common Causes

- Behaviours – actions you choose and control (e.g., working safely) – can contribute to a slip, trip, and fall injury if you set yourself up for one.
- Carrying or moving cumbersome objects, or too many objects, that
  - Obstruct your view
  - Impair your balance
  - Prevent you from holding onto handrails

33 TDEC - Fleming Training Center

Trips – Common Causes

- Individual behavior

34 TDEC - Fleming Training Center

Trips – Common Causes

- Obstructed view or obstacle on walkways

35 TDEC - Fleming Training Center

Trips – Common Causes

- Poor lighting, illumination

36 TDEC - Fleming Training Center

Falls

- Falls are usually in conjunction with a slip or trip
- One quarter of all disabling injuries are a result of falling
  - Eight percent are falls from the same level
  - Seventeen percent are falls from the next level

37 TDEC - Fleming Training Center

Two Types of Falls

- Falls from the same level
  - Can exert forces of over 1000 pounds to the body
  - Most frequent type of fall
  - Low severity rate of injury
  - Generally a result of slipping, tripping or improper footwear

38 TDEC - Fleming Training Center

Slips – Common Causes

39 TDEC - Fleming Training Center

Two Types of Falls

- Fall from an elevated level
  - Falls from platforms, docks, ladders, steps or stairs
  - Lower frequency of occurrence
  - High severity rate of injury

40 TDEC - Fleming Training Center

Mine Fatality

On October 12, 2005, a 36-year old bagger, was fatally injured at an industrial sand operation. The victim was shoveling sand from the bulk bag warehouse roof and fell approximately 17½ feet to a concrete loading dock.

41 TDEC - Fle

Two Types of Falls

- Elevated level
- Steps

42 TDEC - Flemin

Slip, Trip, and Fall Hazards

Prevention Safety Methods

43

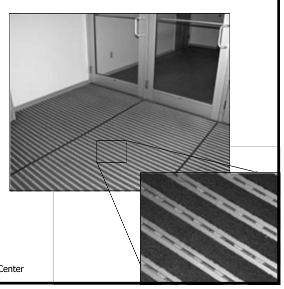
Slips, Trips, and Falls Are Preventable!

- Design the workplace and work processes to prevent potential exposures to slip and trip hazards.
- Maintain clear, tidy work areas free of clutter; follow good housekeeping procedures.
- Follow safe PPE practices.

44 TDEC - Fleming Training Center

Workplace/Work Process Design

- Provide effective drainage, false floors, or platforms.
- Install slip-resistant floors in high risk areas (e.g. entrances, kitchens, etc.).



45 TDEC - Fleming Training Center

Workplace/Work Process Design

- Apply slip-resistant coating, treatment, strips, etc.

Slip-resistant strips on steps

46 TDEC - Fleming Training Center

Housekeeping

- Keep walkways, aisles, and stairs clear of materials, equipment, and other hazards.
- Cover or secure cables, cords, wires, and hoses away from walkways and other paths of travel.

47 TDEC - Fleming Training Center

Housekeeping

- Clean spills immediately.
  - Mop or sweep up any debris
- Keep floors clean and free of water, mud, grease, debris, etc.

48 TDEC - Fleming Training Center

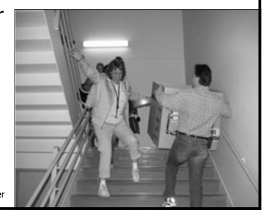
Proper PPE

- Proper PPE can help prevent or reduce the risk of a slip, trip, and fall incident.
- Right PPE for the right job
- Wear slip-resistant shoes/boots with good tread.
- Inspect regularly for any damage

49 TDEC - Fleming Training Center

Safe Walking Practices

- Pay attention to your surroundings.
- Walk, don't run or rush.
- Give yourself enough time.
- Do not engage in activities that distract your attention. Do not read, write, or work while you are walking.
- Use the handrails when climbing or descending the stairs. Do not rush and skip steps.



50 TDEC - Fleming Training Center

Safe Walking Practices

- Walk carefully and slowly when you transition from one type of walking surface to another.
  - Adjust your walking (pace, stride).
- Take extra care when you come indoors with wet shoes or boots.
- Slow down and take small careful steps if the surface is uneven, cluttered, slippery or at an angle.
- Wear stable shoes with non-slip soles.

51 TDEC - Fleming Training Center

Personal Protective Equipment

Protecting Employees from Workplace Hazards

- Employers must protect employees from hazards such as falling objects, harmful substances, and noise exposures that can cause injury
- Employers must:
  - Use all feasible engineering and work practice controls to eliminate and reduce hazards
  - Use personal protective equipment (PPE) if the controls don't eliminate the hazards.
- PPE is the last level of control!

Engineering Controls

If . . .

The work environment can be physically changed to prevent employee exposure to the potential hazard,

Then . . .

The hazard can be eliminated with an engineering control

Engineering Controls

Examples . . .

- Initial design specifications
- Substitute less harmful material
- Change process
- Enclose process
- Isolate process

Work Practice Controls

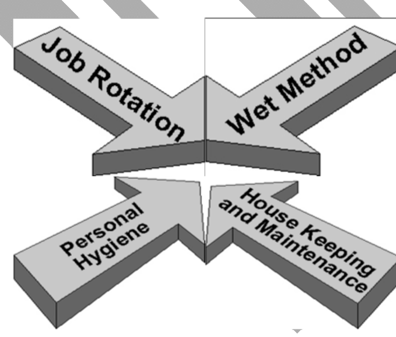
If . . .

Employees can change the way they do their jobs and the exposure to the potential hazard is removed,

Then . . .

The hazard can be eliminated with a work practice control

Work Practice Controls -- Examples



Responsibilities

- Employer
  - Assess workplace for hazards
  - Provide PPE
  - Determine when to use
  - Provide PPE training for employees and instruction in proper use
- **Employee**
  - **Use PPE in accordance with training received and other instructions**
  - **Inspect daily and maintain in a clean and reliable condition**

OSHA Office of Training and Education 7

Examples of PPE

Body Part	Protection
Eye	safety glasses, goggles
Face	face shields
Head	hard hats
Feet	safety shoes
Hands and arms	gloves
Bodies	vests
Hearing	earplugs, earmuffs

OSHA Office of Training and Education 8

Hazardous Material Information System

- A – Safety glasses
- B – Safety glasses, gloves
- C – Safety glasses, gloves, apron
- D – Face shield, gloves, apron
- A - K

OSHA Office of Training and Education 9

PPE Program

- Includes procedures for selecting, providing and using PPE
- First -- assess the workplace to determine if hazards are present, or are likely to be present, which necessitate the use of PPE
- After selecting PPE, provide training to employees who are required to use it

OSHA Office of Training and Education 10

Training

If employees are required to use PPE, train them:

- Why it is necessary
- How it will protect them
- What are its limitations
- When and how to wear
- How to identify signs of wear
- How to clean and disinfect
- What is its useful life & how is it disposed

OSHA Office of Training and Education 11

Head Protection

OSHA Office of Training and Education 12

Causes of Head Injuries

- Falling objects such as tools
- Bumping head against objects, such as pipes or beams
- Contact with exposed electrical wiring or components

OSHA Office of Training and Education 13

Selecting the Right Hard Hat

Class A

- General service (building construction, shipbuilding, lumbering)
- Good impact protection but limited voltage protection

Class B

- Electrical / Utility work
- Protects against falling objects and high-voltage shock and burns

Class C

- Designed for comfort, offers limited protection
- Protects against bumps from fixed objects, but does not protect against falling objects or electrical shock

OSHA Office of Training and Education 14

Eye Protection

OSHA Office of Training and Education 15

When must Eye Protection be Provided?

When any of these hazards are present:

- Dust and other flying particles, such as metal shavings or sawdust
- Corrosive gases, vapors, and liquids
- Molten metal that may splash
- Potentially infectious materials such as blood or hazardous liquid chemicals that may splash
- Intense light from welding and lasers

OSHA Office of Training and Education 16

Eye Protection
Criteria for Selection

- Protects against specific hazard(s)
- Comfortable to wear
- Does not restrict vision or movement
- Durable and easy to clean and disinfect
- Does not interfere with the function of other required PPE

OSHA Office of Training and Education 17

Eye Protection for Employees Who Wear Eyeglasses

Ordinary glasses do *not* provide the required protection

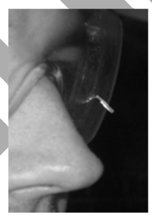
Proper choices include:

- Prescription glasses with side shields and protective lenses
- Goggles that fit comfortably over corrective glasses without disturbing the glasses
- Goggles that incorporate corrective lenses mounted behind protective lenses

OSHA Office of Training and Education 18

Safety Glasses

- Made with metal/plastic safety frames
- Most operations require side shields
- Used for moderate impact from particles produced by jobs such as carpentry, woodworking, grinding, and scaling



OSHA Office of Training and Education 19

Goggles

- Protects eyes and area around the eyes from impact, dust, and splashes
- Some goggles fit over corrective lenses

OSHA Office of Training and Education 20

Laser (Welding) Safety Goggles

Protects eyes from intense concentrations of light produced by lasers

OSHA Office of Training and Education 21

Face Shields

- Full face protection
- Protects face from dusts and splashes or sprays of hazardous liquids
- Does <u>not</u> protect from impact hazards
- Wear safety glasses or goggles underneath

OSHA Office of Training and Education 22

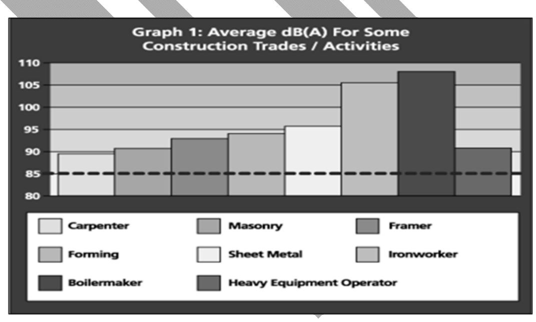
Welding Shields

Protects eyes against burns from radiant light

Protects face and eyes from flying sparks, metal spatter, & slag chips produced during welding, brazing, soldering, and cutting

OSHA Office of Training and Education 23

Hearing Protection

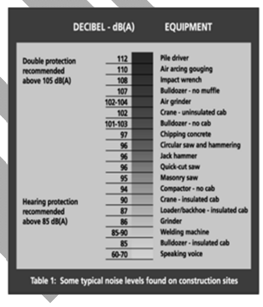


OSHA Office of Training and Education 24

Hearing Protection

When it's not feasible to reduce the noise or its duration – use ear protective devices

Ear protective devices must be fitted



	DECIBEL - dB(A)	EQUIPMENT
Double protection recommended above 105 dB(A)	112	Pile driver
	110	Air arcing gouging
	108	Impact wrench
	107	Bulldozer - no muffle
	102-104	Air grinder
	102	Crane - uninsulated cab
	101-103	Bulldozer - no cab
	97	Chipping concrete
	96	Circular saw and hammering
	96	Jack hammer
	96	Quick-cut saw
	95	Masonry saw
	94	Compactor - no cab
Hearing protection recommended above 85 dB(A)	90	Crane - insulated cab
	87	Loader/backhoe - insulated cab
	86	Grinder
	85-90	Welding machine
	85	Bulldozer - insulated cab
	60-70	Speaking voice

Table 1: Some typical noise levels found on construction sites

OSHA Office of Training and Education 25

When Must Hearing Protection be Provided?

After implementing engineering and work practice controls

When an employee's noise exposure exceeds an 8-hour time-weighted average (TWA) sound level of 90 dBA

OSHA Office of Training and Education 26

Examples of Hearing Protectors

Earmuffs

Earplugs

Canal Caps

OSHA Office of Training and Education 27

Foot Protection

OSHA Office of Training and Education 28

When Must Foot Protection be Provided?

When any of these are present:

- Heavy objects such as barrels or tools that might roll onto or fall on employees' feet
- Sharp objects such as nails or spikes that might pierce ordinary shoes
- Molten metal that might splash on feet
- Hot or wet surfaces
- Slippery surfaces

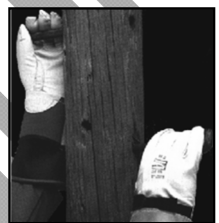
OSHA Office of Training and Education 29

Safety Shoes

- Impact-resistant toes and heat-resistant soles protect against hot surfaces common in roofing and paving
- Some have metal insoles to protect against puncture wounds
- May be electrically conductive for use in explosive atmospheres, or nonconductive to protect from workplace electrical hazards

OSHA Office of Training and Education 30

Hand Protection



OSHA Office of Training and Education 31

When Must Hand Protection be Provided?

When any of these are present:

- Burns
- Bruises
- Abrasions
- Cuts
- Punctures
- Fractures
- Amputations
- Chemical Exposures

OSHA Office of Training and Education 32

What Kinds of Protective Gloves are Available?

- Durable gloves made of metal mesh, leather, or canvas
  - Protects from cuts, burns, heat
- Fabric and coated fabric gloves
  - Protects from dirt and abrasion
- Chemical and liquid resistant gloves
  - Protects from burns, irritation, and dermatitis
- Rubber gloves
  - Protects from cuts, lacerations, and abrasions

OSHA Office of Training and Education 33

Types of Rubber Gloves

***Nitrile* protects against solvents, harsh chemicals, fats and petroleum products and also provides excellent resistance to cuts and abrasions.**

***Butyl* provides the highest permeation resistance to gas or water vapors**

OSHA Office of Training and Education 34

Other Types of Gloves

***Kevlar* protects against cuts, slashes, and abrasion**

***Stainless steel mesh* protects against cuts and lacerations**

OSHA Office of Training and Education 35

Fall Protection Options

Personal Fall Arrest System (PFAS)

OSHA Office of Training and Education 36

Fall Protection Planning

Fall protection systems and work practices must be in place before you start work.

OSHA Office of Training and Education 37

Personal Fall Arrest Systems

- **You must be trained how to properly use PFAS.**
- **PFAS = anchorage, lifeline and body harness.**

OSHA Office of Training and Education 38

Safety Line Anchorages

- **Must be independent of any platform anchorage and capable of supporting at least 5,000 lbs. per worker**

OSHA Office of Training and Education 39

Safety Line Anchorages

OSHA Office of Training and Education 40

Body Protection

OSHA Office of Training and Education 41

Major Causes of Body Injuries

- Intense heat
- Splashes of hot metals and other hot liquids
- Impacts from tools, machinery, and materials
- Cuts
- Hazardous chemicals
- Radiation

OSHA Office of Training and Education 42

Body Protection
Criteria for Selection

- Provide protective clothing for parts of the body exposed to possible injury
- Types of body protection:
  - Vests
  - Aprons
  - Jackets
  - Coveralls
  - Full body suits

Coveralls

OSHA Office of Training and Education 43

Body Protection

Cooling Vest

Full Body Suit

Sleeves and Apron

OSHA Office of Training and Education 44

Summary

Employers must implement a PPE program where they:

- Assess the workplace for hazards
- Use engineering and work practice controls to eliminate or reduce hazards before using PPE
- Select appropriate PPE to protect employees from hazards that cannot be eliminated
- Inform employees why the PPE is necessary, how and when it must be worn
- Train employees how to use and care for their PPE, including how to recognize deterioration and failure
- Require employees to wear selected PPE

OSHA Office of Training and Education 45

Chlorine Safety

TDEC - Fleming Training Center 1

Elemental Chlorine (Cl_2): Chemistry

Chlorine + Water ⇨ Hypochlorous Acid + Hydrochloric Acid

$Cl_2 + H_2O \Rightarrow HOCl + H^+ Cl^-$

TDEC - Fleming Training Center 2

Physical and Chemical Properties of Chlorine Gas

- Under normal atmospheric pressure at room temperature, Chlorine is a yellow-green gas
- 2.5 times heavier than air
- Chlorine gas becomes a liquid at - 30° F

TDEC - Fleming Training Center 3

Physical and Chemical Properties of Chlorine Gas

- Chlorine Gas is highly Corrosive
- Eyes, nose, throat, mucous membranes
- Pungent, noxious order
- By-products
  - Phosgene
  - Sulfuryl Chloride

TDEC - Fleming Training Center 4

Calcium Hypochlorite: Chemistry

Calcium Hypochlorite + Water ⇨ Calcium Hydroxide + Hypochlorous Acid

$Ca(OCl)_2 + 2H_2O \Rightarrow Ca(OH)_2 + 2HOCl$

TDEC - Fleming Training Center 5

Physical and Chemical Properties of Calcium Hypochlorite

- Dry, white or yellow granular material
- Strong Oxidizer
- Dangerous fire hazard in the presences organic material.

TDEC - Fleming Training Center 6

Sodium Hypochlorite: Chemistry

Sodium Hypochlorite + Water ⟶ Hypochlorous acid + Sodium Hydroxide

$NaOCL + H_2O \longrightarrow HOCL + NaOH$

TDEC - Fleming Training Center 7

Physical and Chemical Properties of Sodium Hypochlorite

- *Clear greenish-yellow liquid*
- *Strong Oxidizer*
- *Corrosive*
- *15-5% chlorine*

TDEC - Fleming Training Center 8

Chlorine Dioxide (ClO_2): Chemistry

Sodium Chlorite + Chlorine ⇨ Sodium Chloride + Chlorine Dioxide

$2NaClO_2 + Cl_2 \Rightarrow 2NaCl + 2ClO_2$

Chlorine dioxide + Water ⇨ Chlorate Ion + Chlorite Ion + Hydrogen Ion

$2ClO_2 + H_2O \Rightarrow ClO_3^- + ClO_2^- + 2H^+$

9

TDEC - Fleming Training Center

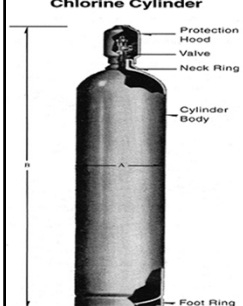
Physical and Chemical Properties of Chlorine Dioxide

- *Red and yellow gas*
- *Strong Oxidizer*
- *Generated onsite*

TDEC - Fleming Training Center 10

Chlorine Cylinder (100 or 150 lb.)

Chlorine Cylinder



Net Cylinder Contents	Approx. Tare, Lbs.*	Dimensions, Inches	
		A	B
100 Lbs.	73	8¼	54½
150 Lbs.	92	10¼	54½

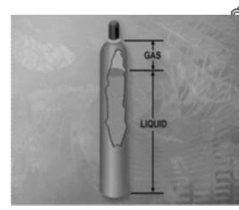
* Stamped tare weight on cylinder shoulder does not include valve protection hood.

11

TDEC - Fleming Training Center

Chlorine Cylinder (100 or 150 lb.)

- Always keep away from heat
- Always replace the cap(hood) when transporting
- Always store in upright position



TDEC - Fleming Training Center 12

Safety tips for 100-150 pound cylinders and one-ton containers

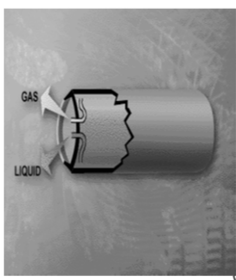
- *Never lift a cylinder by its hood*
- *Always keep the hood in place, except when the cylinder is being used.*
- *Never expose cylinder to heat or direct sunlight*
- *Never drop or knock a cylinder over*

Safety tips for 100-150 pound cylinders and one-ton containers

- *Always secure empty and full cylinders with a cable or chain*
- *Do not connect liquid valves of two or more containers to a common manifold*
- *Never store combustible or flammable materials near chlorine containers.*

1 – Ton chlorine Container

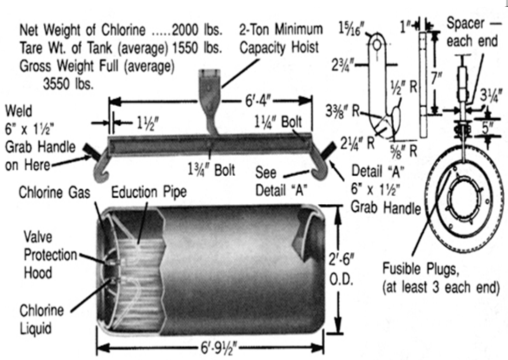
- Ton tanks should be stored and used on their sides



Hoisting a 1- Ton Container

- Two ton capacity
- Protective hood in place during handling

Ton Container



Protective Equipment

- *Compressed air*
  - *30 minute capacity*
- *Annually inspected*
- *Trained/fit tested*
- *Rubber gloves*
- *Apron*

Protective Equipment

- *Goggles*
- *Eye-wash station*
- *Deluge shower*
- *Water-holding tank*

TDEC - Fleming Training Center 19

Rules and Regulations

- *From Community Public Water Systems Design Criteria Division of Water Supply Tennessee Department of Environment and Conservation, 2008*

TDEC - Fleming Training Center 20

Separate Chlorine Room

5.3.4 Chlorine gas feed and storage shall be:

a. enclosed and separated from other operating areas in order to prevent injury to personnel and damage to equipment.

b. provided with an inspection window to permit viewing of the interior of the room and the equipment.

c. Provided with doors opening outward with a crash bar, assuring ready means of exit.

TDEC - Fleming Training Center 21

Separate Chlorine Room

5.3.5 Where Chlorine gas is used, ventilation for each room shall be provided for one complete air change per minute; and

a. The air outlet from the room shall be near the floor and the point of discharge shall be so located as not to contaminate air inlets to any rooms or structures, or adversely affect the surrounding environment.

b. Air inlets shall be through louvers near the ceiling, and temperature controlled to prevent adverse affect on chlorinator.

TDEC - Fleming Training Center 22

Separate Chlorine Room

5.3.5 (cont.)

c. Switches for fans and lights shall be outside of the room, at the entrance.

d. Vents from feeders and storage shall discharge t the outside atmosphere, above grade.

5.3.6 Chlorinator rooms should be heated to 60° F, but should be protected from excess heat; cylinders and gas lines should be protected from temperatures above that of the feed equipment.

TDEC - Fleming Training Center 23

Separate Chlorine Room

5.3.7 gaseous feed chlorine installations shall be equipped with a gas detection device connected to an audible alarm to prevent undetected, potentially dangerous leakage of chlorine gas.

TDEC - Fleming Training Center 24

Operator Safety

5.4 Operator Safety

e. All gaseous feed chlorine installations shall be equipped with appropriate leak repair kits.

25

TDEC - Fleming Training Center

Chlorine First Aid

- *Inhalation*
  - *Remove victim from contaminated area*
  - *Keep victim in a reclining position with head and shoulders elevated*
  - *Administer oxygen as soon as possible*
- *Skin Contact*
  - *Shower victim, removing all contaminated clothing.*
  - *Wash affected area with soap and water*

TDEC - Fleming Training Center 26

Chlorine First Aid

- *Eye Contact*
  - *Irrigate eyes with water for 15 minutes*
  - *Irrigate a second 15- minute period if a physician is not immediately available*
- *Health Effects*
  - *Low concentrations: Burning eyes, nose, and throat; coughing, redness in the face*
  - *High concentrations: Tightness in the throat and difficulty breathing*

TDEC - Fleming Training Center 27

Chlorine First Aid

- *Health Effects*
  - *1,000 parts per million (ppm) is fatal after a few breaths.*
  - *Even an hour later, 35-51 ppm can be fatal.*

TDEC - Fleming Training Center 28

Emergency Numbers

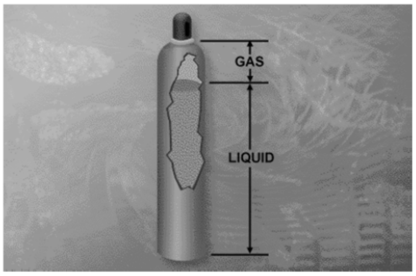
- *Make a list of relevant contact numbers:*
  - *Fire Department*
  - *Police Department*
  - *County Emergency Management Office*
  - *Department of Health Office*

TDEC - Fleming Training Center 29

A look at Chlorine Equipment

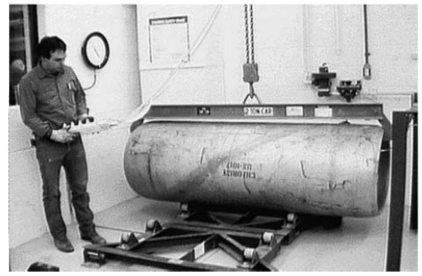
TDEC - Fleming Training Center 30

150 lb Chlorine Container



TDEC - Fleming Training Center 31

Handling a 1- Ton Container



TDEC - Fleming Training Center 32