Drinking Water Operator Certification Training

Module 16:
Diatomaceous Earth Filtration

This course includes content developed by the Pennsylvania Department of Environmental Protection (Pa. DEP) in cooperation with the following contractors, subcontractors, or grantees:

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Topical Outline

Unit 1 – Overview of the Diatomaceous Earth Filtration System

I. Background Information
   A. Introduction
   B. Parameters of Diatomaceous Earth (D.E.) Use
   C. Advantages of the D.E. Filtration System
   D. Disadvantages of the D.E. Filtration System

II. Regulatory Requirements
   A. Applicable Regulations
   B. Disinfection
   C. Monitoring
   D. Combined Filter Effluent Turbidity
   E. Pathogen Removal
   F. Reporting
   G. Other Requirements

Unit 2 – Components of the Diatomaceous Earth Filtration System

I. System Overview
   A. Operation
   B. Components

II. Filter Elements
   A. Function
   B. Types
   C. Design Considerations

III. Filter Septum
   A. Function
   B. Materials
   C. Design Considerations

IV. Filter Vessel
- A. Pressure
- B. Vacuum
- C. Design Considerations

V. Filter Media
- A. Types
- B. Coating
- C. Characteristics

VI. Feeding Equipment
- A. Storage
- B. Conveyance

Unit 3 – Operations and Maintenance of the Diatomaceous Earth Filtration System

I. Precoating
- A. Fill Vessel and Piping with Clean Water
- B. Recirculate
- C. Feed Precoat Slurry
- D. Bridging Process
- E. Coat Thickness
- F. Completed Precoat

II. Body Feeding
- A. Body Feed Concentration Determination
- B. Effect of Flow Rate

III. Spent Cake Removal and Disposal
- A. Cake Removal
- B. Cake Disposal

Unit 1 – Overview of the Diatomaceous Earth Filtration System

Unit 1 - Learning Objectives

As a result of this unit, the learner will:

- Be introduced to the operating concept of Diatomaceous Earth (D.E.) filtration.
- Be able to determine what types of source water can best be treated by D.E. filtration
- Receive information on the common uses of D.E. filtration in the United States.
- Be aware of the treatment effectiveness of D.E. filtration on particles, *Giardia*, and *Cryptosporidium*.

Introduction

Diatomaceous Earth (D.E.) filtration, commonly called precoat filtration, is one of the acceptable filtration techniques for meeting the requirements of Pennsylvania's Surface Water Filtration Rule (SWFR).

Diatomaceous Earth is composed of skeleton of microscopic plants.

Diatomaceous Earth is a good filter media because of its high permeability.

D.E. filtration is a process that removes particles from water by passing water through a layer of finely ground media (the D.E) that is deposited on a fine mesh screen, called a septum.

Headloss is pressure drop. It is the difference between the pressure on the upstream side of the filter and the pressure on the downstream side of the filter.

Operating Concept

- Precoat
  - This is the first stage of operation.
  - A slurry containing the filter media is recirculated around the filter until the media is deposited evenly over the filter septum.
  - When the coat is developed, filtration of the raw water begins and the precoated media strains particles from the water.
- Body Feed
  - To maintain porosity and to lengthen the filtration cycle, additional media is added. This media is known as the body feed.
  - As the body feed and the particles that were removed from the water collect on top of the precoat, headloss through the filter increases.
  - When the headloss reaches a preset point, filtration ceases and the media and entrained particles are removed from the septum for disposal.
  - When the filter is cleaned, the precoat stage begins again.

Parameters of D.E. Use

Turbidity is an indication of the clarity of a fluid. Turbidity measures the scattering of light through the water by materials in suspension or solution. The greater the turbidity, the less clear the water is.

ntu is nephelometric turbidity units. A nephelometer is the instrument used to measure the scattering of light that indicates turbidity measurement in ntu.

Appropriate Source Waters

D.E. filtration is usually limited to treating source waters of good quality in terms of the following parameters: turbidity; particle type; color; and quality variability. Consideration for using D.E. filtration is the effluent quality as well as length of filter run time and septum pore sizes.

- Turbidity
  - DE Filtration is best for treating water with low turbidity.
  - Typical source waters that best for DE filtration have a turbidity of 10 ntu or less, with occasional spikes up to 40 ntu. [1]
- Particle Type
  - Waters with similar turbidity, but different particle types, will not all be equally treatable.
  - Incompressible materials, such as sand and some types of clay, are more favorable to treatment.
  - Smaller particles and colloidal matter are more difficult to remove.
    - Colloids are even more difficult to remove due to the electrical charges on them.
- Color
  - DE Filtration is best for treating water with low color.
  - D.E. filters will not remove dissolved color from water.
  - Color removal may be treated before or after the filters.
- Quality Variability
  - Source water should be of consistent, high quality.
  - Periods of high turbidity, color, or taste and odor may result in unacceptable finished water quality without additional treatment in place to handle these episodes.

Even if you are using low turbidity sources waters there is still the concern the water intake could contain large objects such as fish or other debris. Intake screening devices may be used to prevent or minimize the entry of large objects or fish into the treatment facility.

Pretreatment

Some pretreatment options that may be used in conjunction with D.E. filtration to remove various source water contaminants include:

- Microstraining.
- Oxidation of iron and manganese.
- Taste and odor removal.
- Color removal.
- Softening.

More detail on pretreatment options is available in the Appendix.

Treatment Effectiveness

D.E. filtration can effectively remove particles greater than about 1 μm in diameter, if proper media grades are selected. Two microbiological organisms that are of particular concern in the United States, *Giardia lamblia (Giardia)* and *Cryptosporidium parvum (Cryptosporidium),* can be removed at high levels if the filter is operated properly.

- *Giardia* removal has been measured at 2-log (99%) to 4-log (99.99%) at filtration rates up to 1.5 gpm/ft^2. [2]
- *Cryptosporidium* removal has been measured at greater than 3-log (99.9%) removal at filtration rates up to 2 gpm/ft^2.
- Removal rates for some particles can be increased by coating the filter media with a coagulant or polymer.[3]

Common Uses

- D.E. filtration is commonly used to treat water for swimming pools.
- Industrial applications where particle-free water is required, such as the food and beverage industry, use D.E. filtration.
- There are more than 170 D.E. municipal drinking water installations in the United States. In 2004 there were an estimated seven systems in Pennsylvania using DE filtrations.
- The largest D.E. filtration plant produced 20 million gallons per day (mgd).

Advantages of the D.E. Filtration System

- Few chemicals are used for D.E. filtration; removal is based on physical, not chemical, processes.
- Capital costs may be low due to the small land and building size requirements.
- Waste residuals are easily dewatered, minimizing sludge treatment requirements.
- Residuals may have reuse possibilities, including soil conditioning and land reclamation.[4]
- The media may be reused, with up to 90% recovery of the media.
- Less water is used for cleaning the filters than in granular media filters.[5]
- The water used for cleaning is generally less than 1% of the filtered water flow.
- Particles generally do not break through the filter since they are removed by straining; filtered water quality remains good throughout the filter cycle.

Disadvantages of the D.E. Filtration System

- There is a cost to purchasing and disposing of the filter media.
- D.E. filtration does not adequately remove algae, dissolved color, taste and odor, or disinfection by-product precursors.
- Proper design, construction, and operation are essential to ensure that the filter cake does not fall off or crack during operation; if the cake is damaged, particles that should be removed may escape through the cracks.
- D.E. filtration is effective only for consistently high quality waters with low turbidity.

Applicable Regulations

The removal of *Giardia* and *Cryptosporidium* pathogens is assumed to be adequate as long as certain turbidity requirements are met. Those requirements are listed later in this unit.

Four regulations that set guidelines for filtration of surface water and ground water under the influence of surface water are:

- Pennsylvania's Surface Water Filtration Rule (SWFR) – 1989.
- Pennsylvania's Interim Enhanced Surface Water Treatment Rule (IESWTR) – 2001.
- Federal Long-Term I Enhanced Surface Water Treatment Rule (LT1) – 2002.
- Federal Long-Term II Enhanced Surface Water Treatment Rule (LT2) – not yet promulgated.

Disinfection

As an added protection against pathogens, filtration plants are required to disinfect the water as it leaves the plant.

- The minimum disinfectant residual entering the distribution system is 0.2 mg/L as free chlorine or its equivalent for other disinfectants.
  - The maximum residual chlorine or chloramines measured as chlorine is 4.0 mg/L.
  - The maximum residual chlorine dioxide is 0.8 mg/L.
- The minimum disinfectant residual at any location in the distribution system is 0.02 mg/L as total chlorine, combined chlorine, or chlorine dioxide.
- Disinfection must provide at least 1-log (90%) of *Giardia* inactivation and 3-log (99.9%) of virus inactivation through the plant. The amount of inactivation achieved is dependent upon the disinfectant used, the contact time provided, and the disinfectant residual.

Monitoring

The following items must be monitored:

- Combined filter effluent turbidity must be measured every four hours.
- Disinfectant residual leaving the plant must be measured continuously.
- Disinfectant residual in the distribution system must be measured at a frequency determined by the size of the population served by the system.

Combined Filter Effluent Turbidity

- Turbidity must be less than, or equal to, 1.0 ntu in 95% of the samples taken per month. Slow sand filtration also permits up to 1.0 ntu. Conventional and direct filtration are limited to 0.3 ntu.
- The turbidity must never go above 2.0 ntu.

Pathogen Removal

- 2-log (99%) of *Giardia* and *Cryptosporidium* must be removed by filtration.
- 2-log (99%) of viruses must be removed by filtration.
- Pathogen removal requirements are assumed to be met if turbidity requirements are met.
- Additional removal of *Cryptosporidium* by supplementary treatment may be required through LT2 rules, dependent upon source water *Cryptosporidium* concentrations.

Reporting

- All turbidity and disinfection residual concentrations must be reported monthly.
- Any violation of turbidity or disinfection residual requirements must be reported to PA Department of Environmental Protection (DEP) within one hour of discovery.
    - Disinfection residual at plant effluent is reported if below 0.2 mg/L for more than four hours.
- If an outbreak of any waterborne disease occurs—and could possibly be attributed to the system—it must be reported within one hour of discovery.

Other Requirements

D.E. filtration plants are also required to meet drinking water regulations regarding maximum contaminant levels (MCLs) for numerous organic and inorganic contaminants, lead and copper, disinfection by-products (DBPs), total coliform, and other water quality issues. Guidance documents are available from the PA DEP and the US Environmental Protection Agency (EPA).

Exercise

Unit 1 – Exercise

Part 1: Multiple Choice – Choose the best answer

1. Diatomaceous Earth is a good media filter because of its ____ permeability

   a. very low
   b. low
   c. medium
   d. high

2. D.E. Filtration cam remove Giardia and Cryptosporidium at _______ levels if the filter is operated properly.

   a. very low
   b. low
   c. medium
   d. high

3. Diatomaceous earth is composed of skeletons of microscopic __________

   a. chemicals
   b. plants
   c. sand

4. Intake screening devices can prevent the entry of _________________________.

   a. Crytopsporidium
   b. Giardia
   c. Fish
   d. Color
   e. Disinfection Byproducts

5. In ___________% of the measurement taken, the filtered water turbidity for D.E. filtration must be less than or equal to _______ ntu.

   a. 95%, 0.3 ntu
   b. 95%., 1.0 ntu

Part 2 – Case Study – Group Exercise

Case Study

1. With your small group discuss the following raw water sources and the applicability of D.E. filtration for each. Note which of the listed qualities may present a challenge for each source, and which qualities are ideal for D.E. filtration.

Water A - Ground Water

- Low turbidity (2 to 3 ntu)
- Low particulates
- High hardness
- High iron content
- Low color
- Consistent quality

Water B - Mountain Spring

- Low turbidity (3 to 6 ntu)
- Particles mostly sand-like with some degraded vegetation
- Low color
- Low to medium hardness
- Occasional turbidity spikes up to 30 ntu

Water C - Major River

- Turbidity 5 to 15 ntu
- Particles mixture of sand-like and organic
- Medium to high color
- Occasional high iron and manganese
- Turbidity spikes up to 150 ntu
- Occasional taste and odor problems

Water D - Reservoir

- Turbidity 3 to 10 ntu
- Particles mostly organic
- High algae concentrations in summer
- Occasional taste and odor problems
- Low hardness
- Occasional high color
- Turbidity spikes to 30 ntu

2. Best on presentation of each small group, which source would be the best candidate for D.E. filtration?

Unit 1 Summary

Key Points:

- Diatomaceous Earth is composed of skeleton of microscopic plants.
- Diatomaceous earth (D.E.) filtration is a process that removes particles from water by passing water through a layer of finely ground media (the D.E) that is deposited on a fine mesh screen called a septum.
- Even for low turbidity sources waters there still may be a need to include intake screening devices at the head of the treatment facility to prevent or minimize the entry of large objects such as fish or debris.
- D.E. filtration is a good filter media because of its high permeability.
- D.E. filtration is best for treating water with low turbidity and low color.
- D.E. filtration can remove Giardia and Cryptosporidium at high levels if the filter is operated properly.
- As well as the effluent water quality, other consideration for using D.E. Filtration is length of filter run time and septum pore size.
- D.E. filtration plants are required to meet drinking water regulations regarding turbidity, disinfection residual concentrations, organic contaminants, inorganic contaminants, lead and copper, disinfection byproducts (DBPs), total coliform, and other water quality standards. Contact your local PA-DEP for more information.
- The Interim Surface Water Treatment Rule was enacted to primarily control turbidity.
- The filtrated water turbidity for D.E. filtration must be less than or equal to 1.0 NTU in 95% of the measurements taken. When treating surface water, D.E. filtration must be continuously monitoring to insure the turbidity standard is met.
- 3-log means the removal of 99.9% of a target organism.

[1] American Water Works Association, *AWWA Manual of Water Supply Practices - M30: Precoat Filtration* (Denver, CO: AWWA, 1995).

[2] American Water Works Association, "Granular Bed and Precoat Filtration," *Water Quality & Treatment: A Handbook of Community Water Supplies, 5th ed.* (New York, NY: McGraw Hill, 1999).

[3] American Water Works Association, "Granular Bed and Precoat Filtration."

[4] American Water Works Association, *AWWA Manual of Water Supply Practices-M30: Precoat Filtration.*

[5] American Water Works Association, *AWWA Manual of Water Supply Practices-M30: Precoat Filtration.*

Unit 2 – Components of the Diatomaceous Earth Filtration System

Unit 2 - Learning Objective

As a result of this unit, the learner will:

- Receive detailed information on the components of a D.E. filtration system.

Operation

The operation of a D.E. filter has three stages.

- **Precoat** is the stage when filter media is being applied to the filter.
- **Body Feed** is the stage in which water is being filtered through the filter media that was applied during the precoat stage. Body feed media is added to the influent water so it will maintain the porosity of the filter cake and reduce the rate at which headloss occurs.
- **Cleaning** is the stage during which the media cake and collected particles are removed from the filter septum to prepare it for a new precoat.

Components

- **Media** is a finely ground, non-compressible material that is used to capture particles in the water.
- **Septum** is a screen with small openings that retains the filter media.
- **Element** is the filtering unit, used to support the septum and provide a chamber into which the filtered water drains.
- **Vessel** is the containment unit for the filter elements and the water being filtered.
- **Feed Equipment** is comprised of these components:
  - **Precoat Slurry Tank** is the tank in which the media for precoating is slurried with clean water to prepare for the precoat operating mode.
  - **Precoat Recycle Tank** is often used in large pressuer filters to hold recirculating water during the precoat operating mode.
  - **Body Feed Hopper** has a metering system and is used for dry feeding of the body feed.
  - **Body Feed Tank** is used to feed the body feed in dry form.
  - **Mixers** are used to store the media in slurry form, as it must be kept mixed to prevent settlement that makes it difficult to re-suspend.
- **Pumps** that are resistant to abrasion are used to transfer slurries and to pump raw and filtered water.
- **Eductors** are a transfer system that can be used, instead of pumps, for moving slurries or dry-fed media. Eductors use high velocity water to pull the media into the feed pipe.

Function

- The filter element is the basic filtering component.
- The external structure is designed to support the filter septum, while the internal structure provides for the collection of the filtered water.

Types

- The filter element can take various forms. Most commonly, it is either flat or tubular.
  - Flat elements are known as leaves.
  - A leaf is generally circular or rectangular in shape.

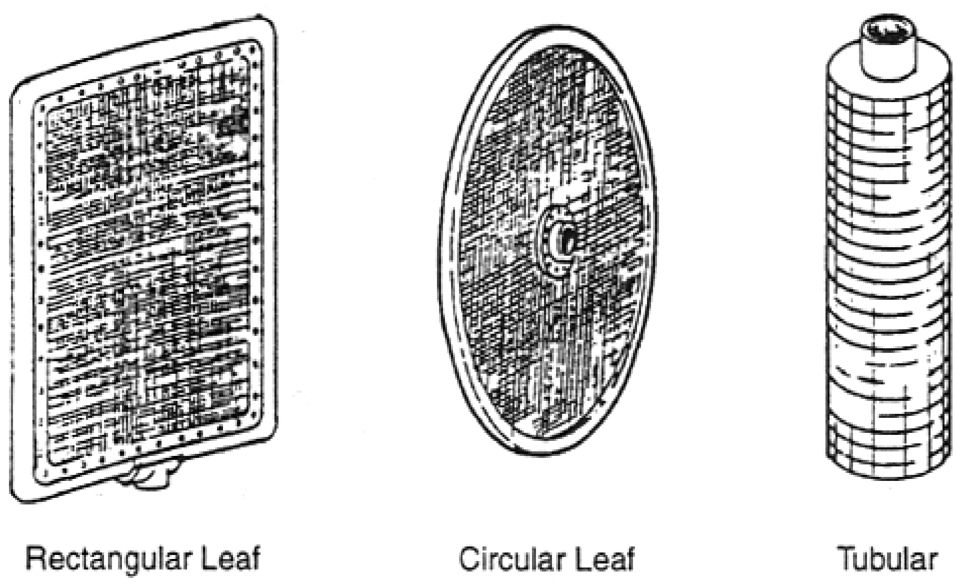

Figure 2.1 Filter Elements[1]

Design Considerations

- The filter element should be designed so that it will evenly distribute the flow through the element with minimal headloss.

- It is essential to provide enough support to the septum so that it will not flex or become distorted under the filtration pressure.
    - If the septum bends during filtration, it can cause cracks in the media coating and allow unfiltered water to pass through.

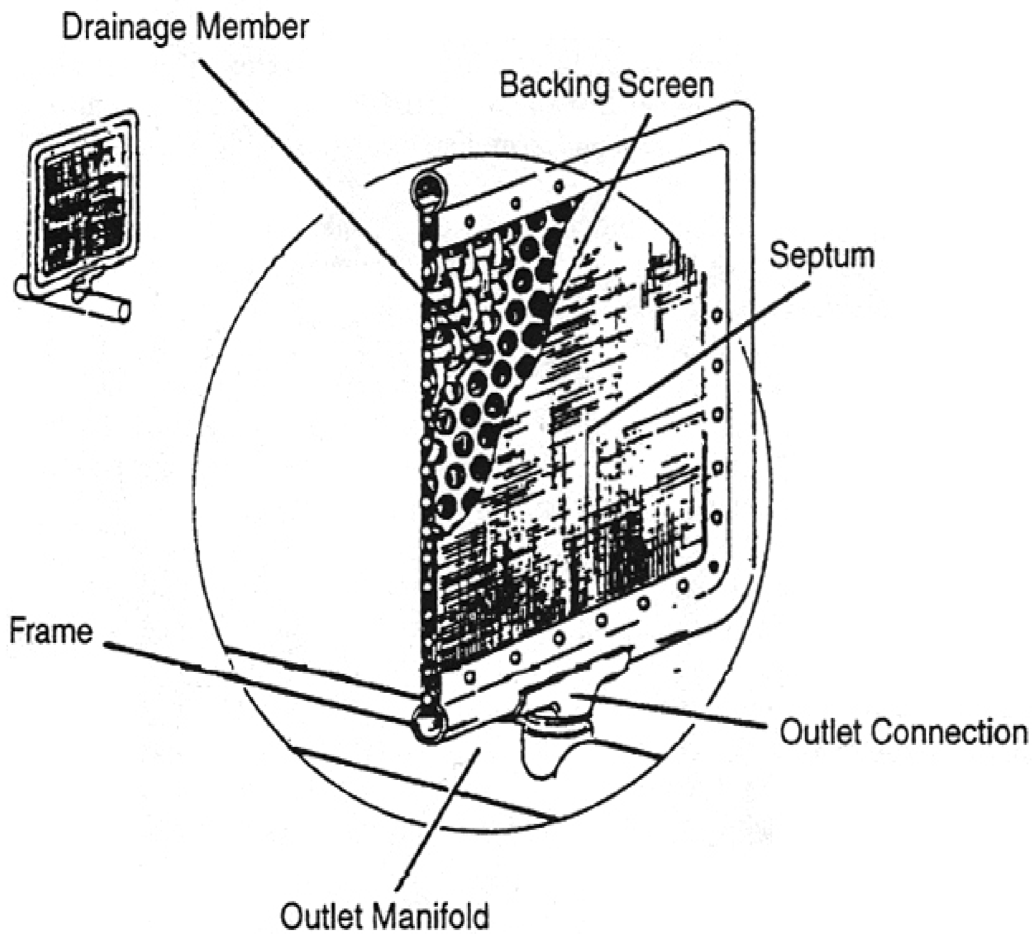

Figure 2.2 Layers of a Typical Leaf Element[2]

In the DE filtration process, the filter media is a pre-coat of diatomaceous earth formed on a filter septum.

Function

- The filter septum is the material upon which the filter media is deposited.
- The septum contains spaces that are small enough to allow the precoat media to form bridges across the spaces. More will be covered on forming bridges in Unit 3.
- It supports the filter cake through the filtration process.

Materials

- The filter septum is the outer layer of the filter element, made of cloth woven with stainless steel wire or plastic monofilaments.
    - The plastic cloth can come as a bag which is placed around the filter element, or it can be caulked to the filter element frame.

Design Considerations

Below are some considerations for selecting septum material.

- Size of the openings should be small enough that the media particles will easily form bridges across them.
- The septum should be non-clogging, allowing the media cake to be removed easily from the septum during cleaning.
    - A septum made of monofilament material with consistent opening sizes will resist clogging better than one made of multifilament materials or one that uses long, twisting pores to retain the filter media.
    - A type of weave known as Multibraid, consisting of woven bundles of wire, is more resistant to clogging than a standard weave design.
    - Wire cloth can also be passed through rollers to flatten round wires at the surface of the weave. This process, known as calendering, helps to minimize clogging.
- The septum material should resist distortion of the openings during use.

Pressure

- A pressure vessel is a cylindrical vessel that completely encloses the filter elements.
- A pump or influent gravity flow produces pressure inside the vessel to force the water through the filter elements.
- It can be oriented horizontally or vertically.

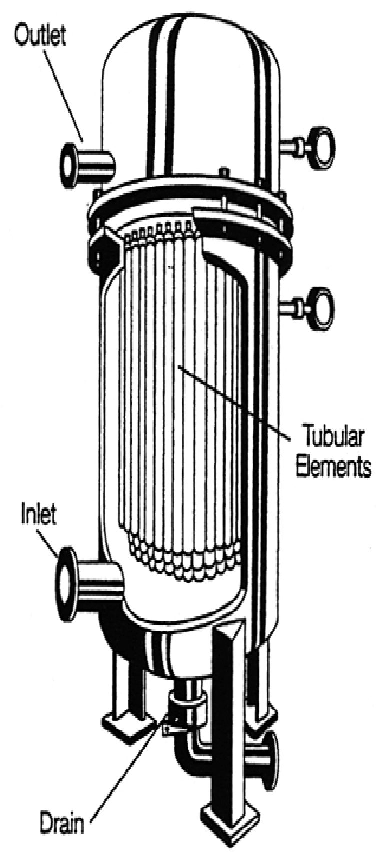

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Figure 2.3 Pressure Filter Vessel[3]

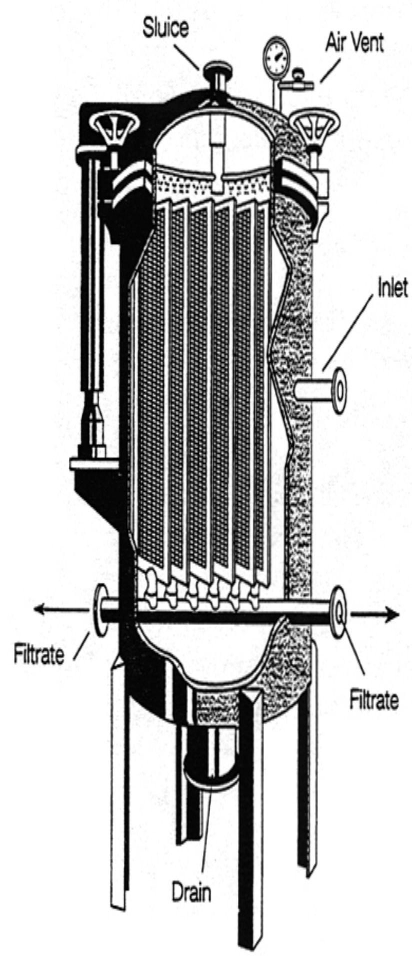

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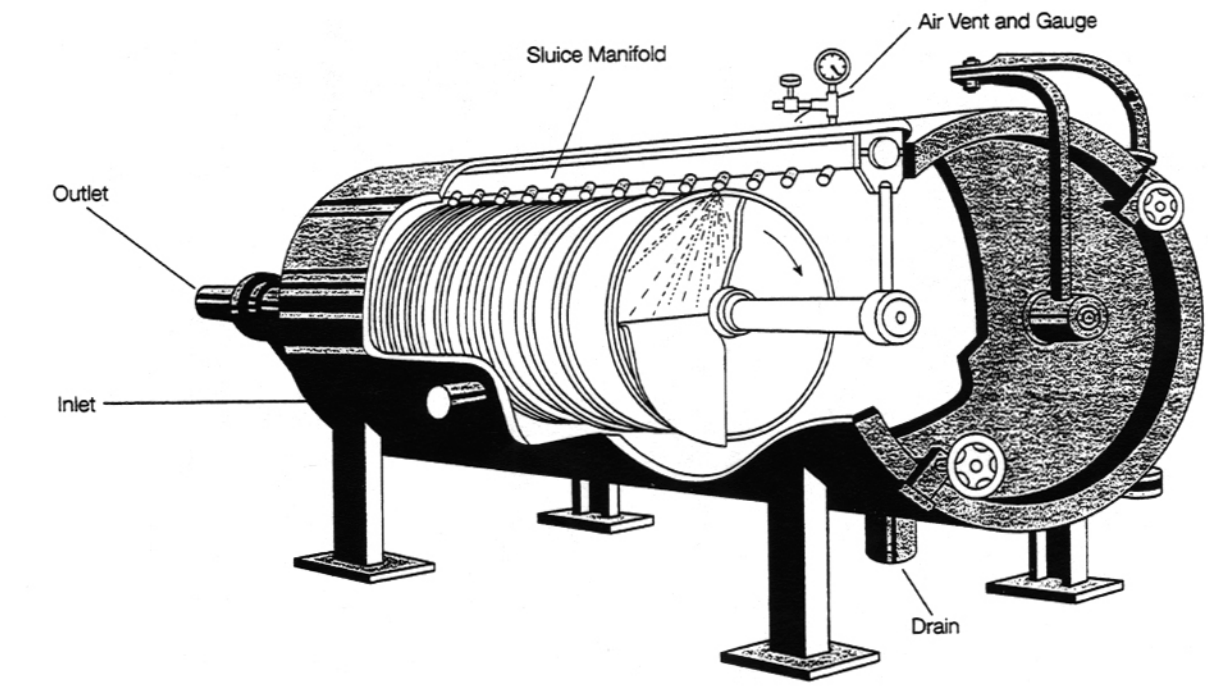
Figure 2.4 Pressure Filter Vessel[4]



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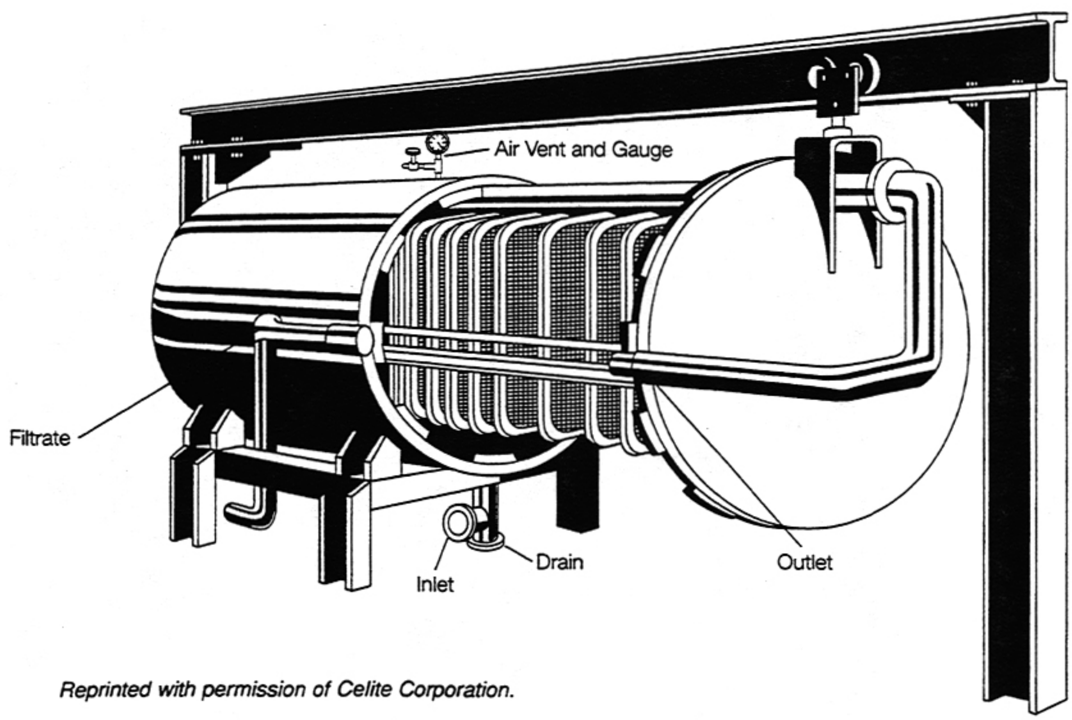

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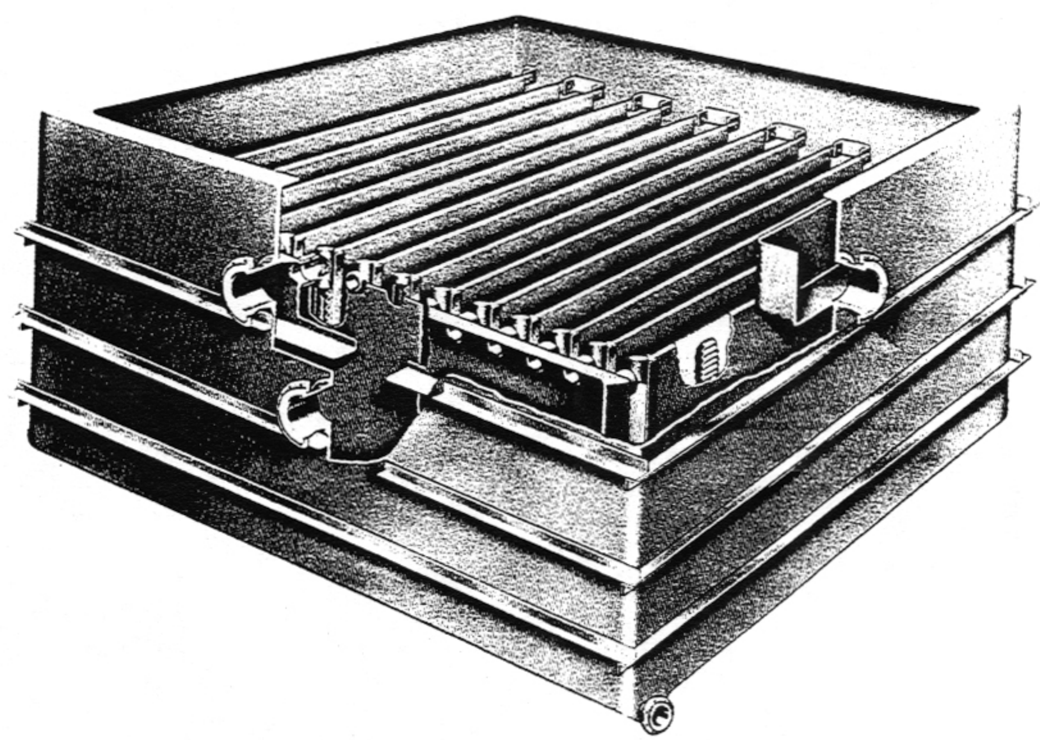
Figure 2.5 Pressure Filter Vessels[5]

Vacuum

- A vacuum filter vessel is usually rectangular and open to the atmosphere, with water drawn through the filter element by a pump downstream of the filter.
- Elements are almost always oriented vertically for municipal water treatment.



Courtesy of Westfall Manufacturing Company.

Figure 2.6 Vacuum Filter Vessel[5]

Design Considerations

A filter vessel, regardless of type:

- Should provide easy access for maintenance.
- Allow the ability to observe the filter while in operation.
- Offer complete drainage.
- Contain baffling to prevent short-circuiting through the filter or scouring of the media cake.
- Needs adequate space between the filter elements; minimum of one inch between elements is required in Pennsylvania.

Types

- The two types of filter media come in multiple grades.
    - The finer grades remove smaller particles more easily.
    - However, the use of smaller grades will result in a higher pressure drop across the filter.

- The specific gravity of wet D.E. is about 2.3; perlite is 32% to 70% less dense.
    - The lower density of perlite lessens the chance that it will migrate to the bottom of the septum during filtration.

Diatomaceous Earth

- D.E., also called diatomite, is the fossilized remains of microscopic water organisms called diatoms.

- D.E. is almost pure silica.

Perlite

- Perlite is derived from glassy volcanic rock.

Coating

- D.E. and perlite are available in a form that is coated with a chemical coagulant or polymer.

- Media can be conditioned by coating with aluminum or iron coagulants or cationic polymers.

- Studies have found that coating can improve the removal of small particles, turbidity, bacteria, and viruses.

Pilot or full-scale studies should be used to determine the media grade and appropriate type for a particular water source.

Characteristics

Diatomite grades commonly used for potable water treatment have a mean diameter ranging from 23 to 36 micrometers. The range and distribution of sizes is different for each grade. Tables 2.1 and 2.2, below, show the average particle size and pore size of some common media grades, as well as their effect on flow rate, water clarity, and particle removal.

Precoat Media Grades	Average Particle Size,* μm	Median Pore Size,* μm	Flow Rate	Clarity
Fine	15	3.5	Lowest	Highest
↑	16	5.0	↑	↑
	22	7.0		
	24	10.0		
↓	34	13.0	↓	↓
Coarse	36	17.0	Highest	Lowest

Source: Stearns and Wheler and *Ray W. McIndoe.*
NOTE: Grades most commonly used for water filtration produce precoat cakes with pore sizes ranging from 5.0 to 17.0 μm.
*Typical sizes may vary slightly from one manufacturer to another.

Table 2.1 Characteristics[7]

Median Diatomite Size, μm	Median Diatomite Pore Size, μm	Particle Size, μm	Removal Rates, %
14	2.5	1	99.9
16.4	5	1	85
24	9	3	99.9
36	17	8	99.9

Source: C.M. Spencer, Wright-Pierce Engineers.

Table 2.2 Characteristics[8]

Storage

Media stored in slurry form will settle quickly if not kept agitated. If it settles, it is difficult to re-suspend, so it should be continuously mixed. Mixers should rotate 40 – 60 rpm to keep the slurry mixed without using excessive agitation that can break down the media.

Media is stored in dry and slurry form. Storage equipment includes hoppers, precoat and body feed tanks, and precoat recycle tanks.

Hopper

- Dry media is stored in a hopper.
  - From the hopper, the media can be fed directly into the influent water with a metering system.
  - Media can also be fed into a small slurrying device and then transported into the water.
  - A vibrator should be included to help move the media down the hopper as it is used.

Precoat and Body Feed Tanks

- If media is fed in slurry form, the media is stored in tanks at a concentration of 12% or less.
  - Media should be continuously mixed.
  - Separate tanks are used for precoat and body feed slurries.
  - Precoat is usually fed as a slurry, while body feed is either dry or slurry fed.

Precoat Recycle Tank

- Precoat recycle tank serves two functions.
  - It can be used to store clean water for filling the filter vessel and piping prior to precoat recycling.
  - It can be used to collect and store the water being recycled through the filter.
- With the use of backflow prevention devices to prevent possible contamination of the filtered water, the filter and piping can be filled directly from the plant service water system. This has greatly reduced the size of the required tank.
- A precoat recycle tank is used in pressure filters; it is unnecessary in vacuum filters because the recycle can be pumped directly into the filter influent line.
- In some plants, the precoat feed tank also functions as the precoat recycle tank.
  - In larger plants, the precoat feed tank often contains enough slurry for more than one precoat, so it cannot be used to store recycle flow.

Conveyance

Transporting the media requires certain considerations.

Pumps

- Media slurry is abrasive, so pump materials should be made of abrasion-resistant materials.
- Use peristaltic or rubber-lined pumps for slurries that contain greater than 4% solids.
- Use case-hardened centrifugal pumps or abrasion-resistant chemical feed metering for slurries that contain less than 4% solids.
- Rotation speeds greater than 1750 rpm can damage filter media.

Piping

- Velocity should be no greater than 8ft/s to minimize damage to the filter media, but no less than 3 ft/s to prevent settling and clogging the pipelines.
- Avoid sharp bends in the piping.
- Use Ts instead of bends to provide cleaning access, if necessary.
- Use butterfly, diaphragm, or plug valves with high slurry concentrations.
- Feed slurry as close as possible to the filter inlet.
- Flush piping after the slurry transfer cycle is complete; this prevents clogging.

Exercise

Unit 2 – Exercise

Match the D.E. filtration component terms with their definitions.

_____ 1. A finely ground, non-compressible material that is used to capture particles in the water.	A. Vessel
_____ 2. A screen with small openings that retains the filter media.	B. Element
_____ 3. The filtering unit, used to support the septum and provide a chamber into which the filtered water drains.	C. Pumps
_____ 4. The containment unit for the filter elements and the water being filtered.	D. Precoat Recycle Tank
_____ 5. A tank in which the media for precoating is slurried with clean water to prepare for the precoat operating mode.	E. Media
_____ 6. A tank that is often used in large pressure filters; it is used to hold recirculating water during the precoat operating mode.	F. Mixers
_____ 7. Used for feeding the Body Feed, either in slurry form or dry form.	G. Precoat Slurry Tank
_____ 8. A device that keeps slurry from settling.	H. Septum
_____ 9. Used to transfer slurries.	I. Body Feed Hopper or Tank

Multiple Choice - Choose the best answer for each question.

10. The diatomaceous earth filter media is deposited on the filter __________.

    a. eductor
    b. septum
    c. hopper
    d. gauge

11. The filter elements are usually arranged in the _______________ direction in municipal water treatment plants.

    a. horizontal
    b. vertical
    c. diagonal

12. Two types of filter media commonly used in D.E. filtration are ______________ and __________. (Choose all that apply)

    a. Perlite
    b. Sand
    c. Gravel
    d. Diatomaceous Earth

Unit 2 Summary

Key Points:

- The operation of a D.E. filter has three stages: precoat, body feed, and cleaning.

- The general components of a D.E. filter are: the media used, the septum screen, the element (used for filter and support), the containment vessel, the feed equipment, the pumps, and the eductors.

[1] American Water Works Association and American Society of Civil Engineers, “Slow Sand and Diatomaceous Earth Filtration, *Water Treatment Plant Design, 3rd ed.*, (New York, NY: McGraw Hill, 1998), p. 211.

[2] *Water Treatment Plant Design,* p. 213

[3] American Water Works Association, "Granular Bed and Precoat Filtration," *Water Quality & Treatment: A Handbook of Community Water Supplies, 5th ed.* (New York, NY: McGraw Hill, 1999), pp. 16-19.

[4] *Water Quality & Treatment,* pp. 16-19.

[5] *Water Quality & Treatment,* pp. 16-19.

[6] *Water Quality & Treatment,* pp. 16-19.

[7] *Water Quality & Treatment*, p. 8.

[8] American Water Works Association, p. 9.

Unit 3 – Operations and Maintenance of the Diatomaceous Earth Filtration System

Unit 3 - Learning Objectives

As a result of this unit, the learner will:

- Review the steps in the precoating process.
- Be aware of process parameters that should be monitored routinely.
- Receive information on safety considerations.
- Review spent media disposal options.
- Discuss the safety gear required for handling media of the D.E. filtration system.

The stages of precoating operation are discussed in the following section.

Fill Vessel and Piping with Clean Water

- Fill the empty vessel and any associated piping with clean water.
- All air in a pressure vessel should be vented to ensure that the vessel is filled with water and that filter elements are completely submerged.
- Prepare slurry if it is not already prepared.
  - Start mixing clean water in the precoat tank, then add the filter media.

Recirculate

- When slurry is prepared, if there is a separate precoat recycle tank, begin recirculation.

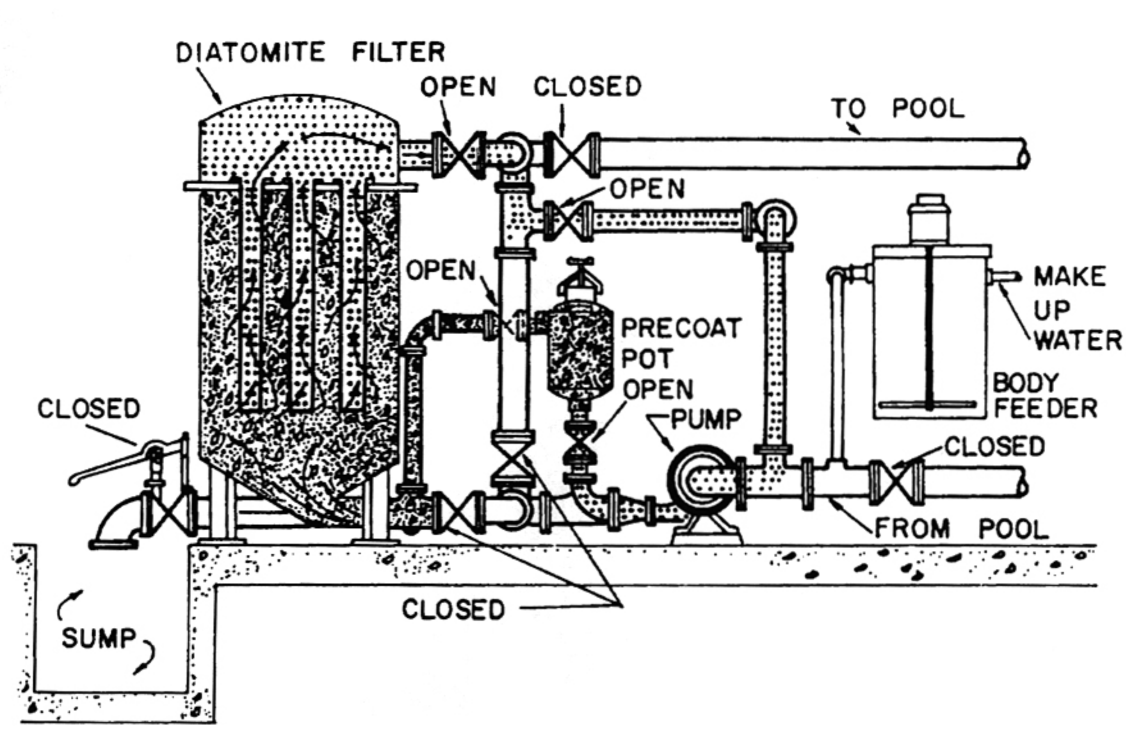


Figure 3.1 Precoat Flow[1]

Feed Precoat Slurry

- Begin pumping the slurry.

Note that the precoat is first mixed with filtered water.

- The precoat slurry tank should be emptied as quickly as is practical.
    - In a vacuum filter system, the slurry usually goes directly into the filter influent piping, or dry media is placed directly into the filter vessel.
    - In pressure filtration, if there is a separate precoat recycle tank, the slurry is pumped or educted into the recycle tank. Otherwise, it is sent directly to the filter influent.
- Continue recycling the slurry and clean water mixture.
- The raw water pump or filtrate pump is generally also used as the recirculation pump.

Bridging Process

- Continue recycling the slurry and clean water through the system.
- As it is recirculated, the filter media will begin bridging across the openings in the septum.
- When bridging begins, other media is caught behind the bridged particles and the precoat begins to form.

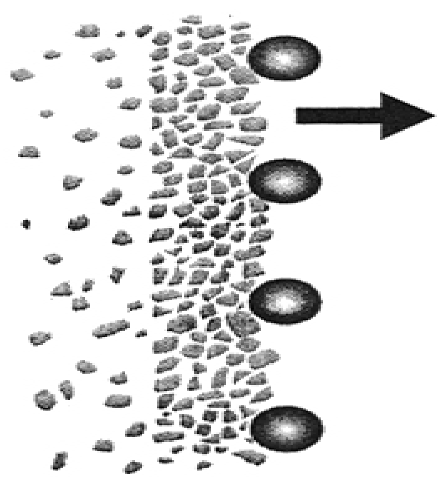


Figure 3.2 Precoat Bridging[2]

Coat Thickness

- The precoat feed amount should be 0.2 lbs/ft^2 of filter area, or enough to form a precoat 1/8 to 1/5 inch thick when complete.

Completed Precoat

- When the recycle water meets the finished water goals, the precoat stage is complete.
- Filtration of raw water can begin.

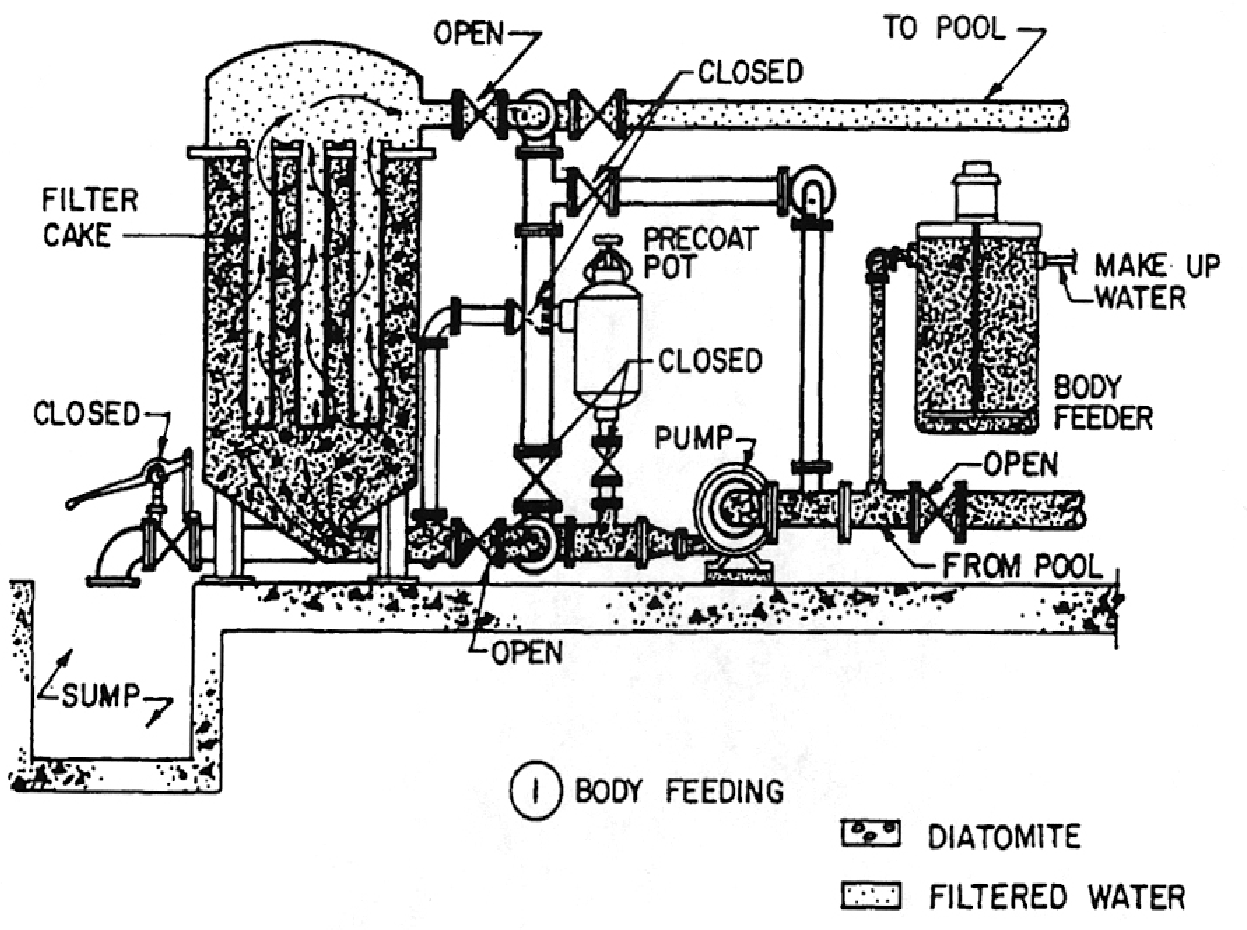


Figure 3.3 Water Flow During Body Feed[3]

The body feed is continuously added to the raw water feed to prevent clogging the filter media.

Body Feed Concentration Determination

Pilot tests should be used to determine what feed concentrations are effective for treating a particular source water.

- The concentration of body feed media to be added to the raw water can range from 1 to 10 mg/L of media per 1 mg/L of suspended solids in the water.
- Pilot tests should be used to determine what feed concentrations are effective for treating a particular source water.
- Generally, as the concentration of the body feed media increases, the amount of filtrate produced before terminal headloss is reached will increase.

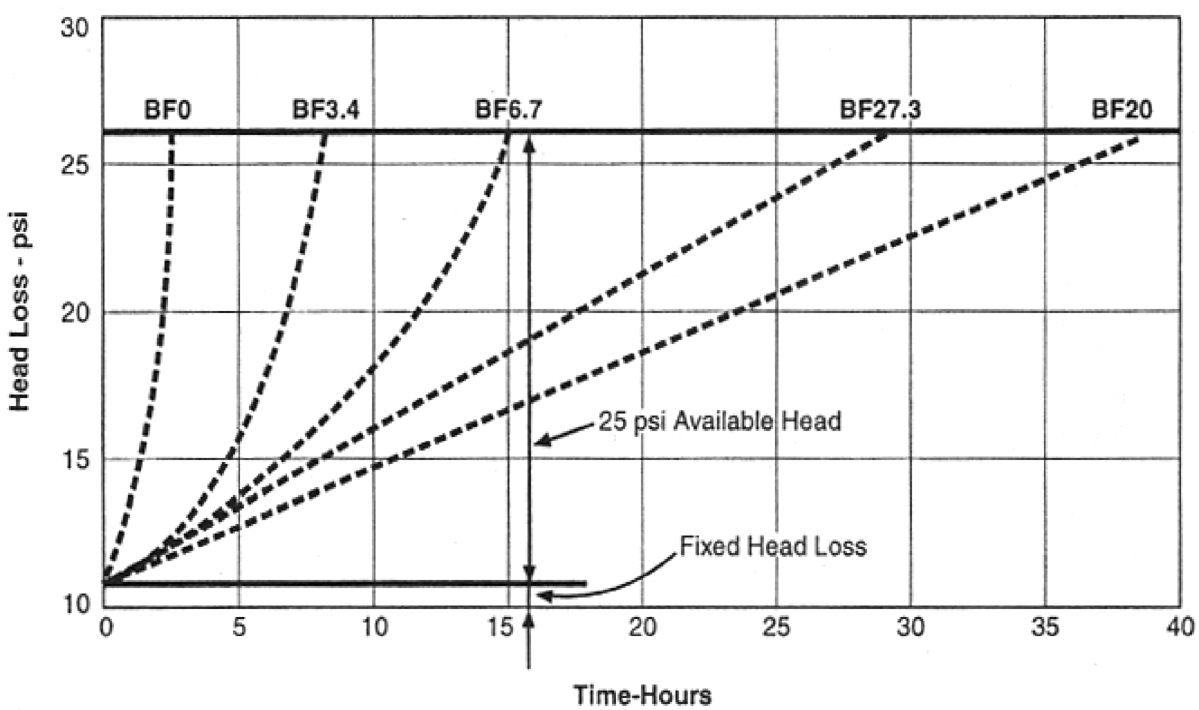


Figure 3.4 Body Feed Concentration and Headloss[4]

Figure 3.4 illustrates the general relationship between body feed concentration and headloss through the filter.

- The cost of the body feed media should be balanced against the cost of precoat media and increased filter cleaning.

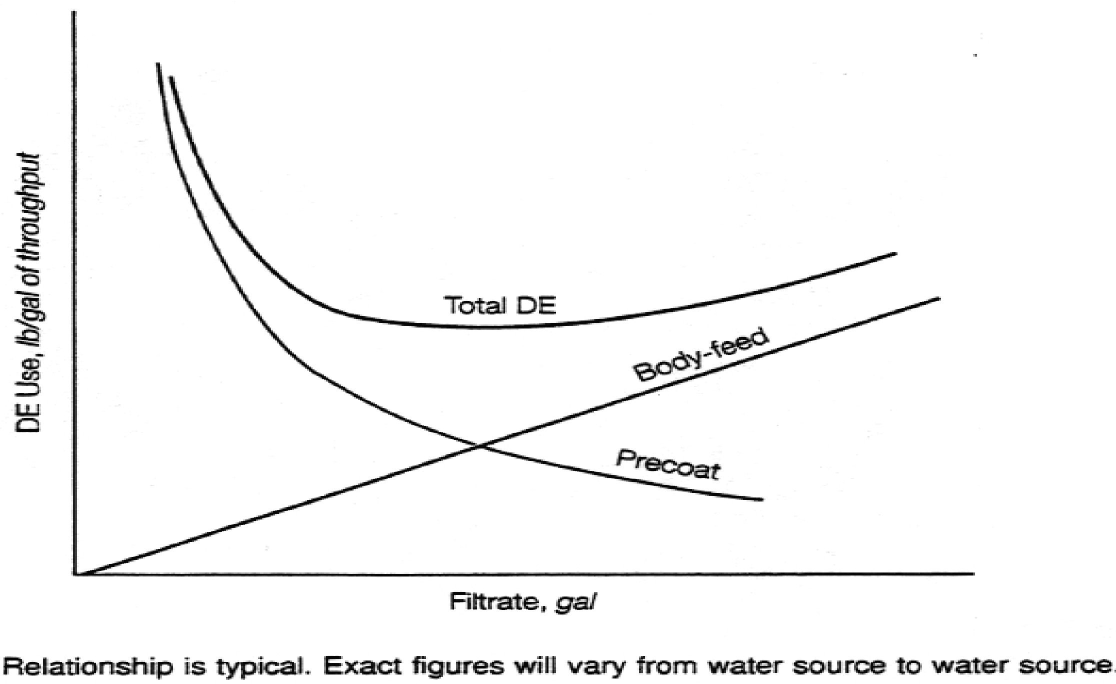


Figure 3.5 Typical Precoat Use Rates[5]

Effect of Flow Rate

- The filtration rate will also affect the rate of headloss buildup.
- Typical filtration rates range from 0.5 to 3 gallons per minute, per square foot of filter area (gpm/sf).
- A filter rate of 1.0 gpm/sf is most common and is recommended in the PA DEP Water Supply Manual.

Cake Removal

When the pressure drop in the filter reaches the terminal headloss, the media cake must be removed from the septa and rinsed out of the filter vessel.

Sluicing

- Cake is removed from the filter elements with high-pressure water sprayed onto the septum.
  - To ensure good cleaning, the entire surface area of the septum should be covered by sprays from stationary or moving nozzles.
  - The nozzle should be designed to prevent clogging during filter operation.
  - To ensure good cleaning, the water pressure minimum should be 60 psig.
  - For those filters that have the ability to rotate the filter elements under the spray, there should be enough space under the elements to clear the media collecting at the bottom of the filter vessel.

Flow Reversal

- Clean water is pumped backwards through the filter element at high enough velocity and volume to push the cake off the septum.
- In some cases, the filter vessel is filled with high pressure air, and then a valve is opened to suddenly release the pressure.
  - This rapid drop in pressure causes a high velocity reverse flow through the filter elements.
  - The burst can cause media to bridge between septa, so enough water flow should be available to remove these bridges.

Draining, Drying, and Vibrating

- The tank is drained under differential air pressure, the cake is dried, and then the filter elements are vibrated to remove the cake.
- The drying technique is most commonly used in industries where the liquid being filtered is valuable, or where disposing of the dry media is more economical than disposing of slurry.

Problems with Cake Removal

- If the media is not completely removed from the septa, the headloss through the filter after precoating may be unusually high.
  - Lumps or bare spots in the precoat may form, which result in poor filter performance.
- If the draining is not adequate, some media will remain in the vessel after cleaning. Then, during the following precoating mode, it can become re-suspended and will be reapplied to the septum.
  - This results in unusually high initial headloss, and can cause fouling of the septum that will become noticeable over multiple cycles.

Cake Disposal

Dewatering can be accomplished in sedimentation basins or through mechanical means, such as vacuum filters or belt filter presses. This is easily accomplished due to the nature of the media.

Disposal

Depending upon the treatment site's permit, water from the dewatered media can be recycled or discharged to a natural body of water, or to the sanitary sewer. The media cake can be disposed of in a landfill or put towards beneficial use.

Beneficial uses include:

- Soil conditioner.
- Mixture with sand for golf course sand traps.
- Mixture with sand used for coating roads in winter conditions.

If the water has been treated by oxidation or precipitation of a hazardous contaminant, care should be exercised in disposing of the media.

Reuse

Media can be recovered for reuse, especially in treatment plants filtering at least 10 mgd.

- Media is separated from the water and the particles that were captured during filtration by passing through a series of hydrocyclones.
    - Some research indicates that up to 90% of the media can be recovered through this process.
- Because pathogens may not be removed entirely from the media, recovered media should not be used for precoat formation.
- Disinfect the recovered media before reusing it for body feed.

Headloss

- Terminal headloss will affect the media usage rates and electrical costs.
- It may require adjustment for seasonal water quality to maintain economic operation of the filter.
- The maximum allowable headloss in Pennsylvania is 30 psi for a pressure filter, or 15 inches of mercury for a vacuum filter.

Filtration Rate

- Filtration rates usually are between 0.5 and 1.0 gpm/sf for vacuum filters; and filtration rates are up to 3 gpm/sf for pressure filters.
- PA DEP recommends 1.0 gpm/sf as a nominal filtration rate, with a recommended maximum rate of 1.5 gpm/sf.
- If the filtration rate is adjusted during the filtration cycle, the adjustment must be made slowly and smoothly; any sudden changes may disrupt the media cake and allow pathogens through the filter.
- Typically, flow rate is controlled with a control valve on the effluent side of the filter or with a variable frequency drive (VFD).
    - A VFD can reduce energy costs during low flow periods by reducing the motor speed.
- If flow through the filter is greatly reduced, the cake can fall off the septum.
    - To prevent the cake from falling, the minimum flow rate should be 0.1 gpm/sf.
    - If demand is less than needed to maintain the minimum flow rate, filtered water can be recycled through the filter to maintain enough flow.

Body Feed Concentration

- Body feed concentration can be adjusted to maintain reasonable filter run times as the source water properties change, or can be kept constant, allowing the filter run times to fluctuate.
- The flow of the body feed is adjusted as the plant flow rate changes in order to maintain the desired concentration of body feed.
- The ideal body feed concentration will change with the raw water turbidity and particle nature, the plant flow rate, and the desired filter run time before terminal headloss is reached.

Automation

Some examples of controls that can be automated are included on the list below.

- Flow control valves can be automated to minimize pressure pulses and surges that accompany the opening and closing of valves.
- Body feed can be automatically adjusted based on influent flow, source water turbidity or metal content, or other water quality issues.
- Flow rates can be adjusted based on water levels in finished water storage vessels.

Cleaning and precoat cycles should not be completely automated because visual inspection of the filter by the operator is important to ensure that these stages are being performed correctly.

Turbidity

Influent Turbidity

- As the turbidity of the water changes, adjustments can be made to the precoat amount or body feed concentration.

- Influent turbidity can be compared to the effluent turbidity and operating data to discover how the source water quality affects the performance of the filter.

Effluent Turbidity

- Effluent turbidity must be monitored and recorded to meet drinking water regulations; it is an indicator of how well the filter is performing.

- When treating surface water, D.E. filter must be continuously monitored to see that the turbidity standard is met.

- The use of chart recorder at the filters to obtain a continuous record of head loss and flow rate is advantages because it provides an easily monitor means of determining the best time to backwash a filter.

- If the septum bends or breaks, the element frame develops a leak, or the integrity of the system is breached, a jump in the effluent turbidity will alert the operator to the problem.

- To prevent water of inferior quality from entering the clearwell, the filter-to-waste process should be performed.

Flow

Influent Flow

- Influent flow is monitored to adjust the body feed rate to maintain the desired concentration and to adjust the feed rates of other chemicals that may be used for pretreatment or disinfection.
- It is also monitored to ensure that the system demands can be met.

Effluent Flow

- The flow going to the distribution system needs to be monitored so that system demands are known.
    - The flow is compared to the sum of the customer uses to determine the amount of water that is unaccounted.

Wash Water Flow

- The amount of water used to wash the filters should be known, as this water will have to be recycled or disposed.
    - It should be monitored to ensure that adequate flow is being used to thoroughly clean the filter elements.

Plant Service Flow

- Plant service water is the water used at the plant. Keep track of the amount of filtered water that is used, and for what purpose it was used.

Pressure

- Tracking how the filter pressure changes with flow rate, source water quality, and any chemical concentration changes can help identify what parameters are negatively impacting the filter run.
- Tracking how the filter pressure changes over the length of the filter run can help identify problems.
- Monitoring pressure ensures that the terminal pressure is not exceeded.

Precoat

- If any bare spots, lumps, or uneven coating are seen, these can indicate a problem with incomplete cleaning or draining, clogging of the septum or sluicing nozzles, or uneven flow distribution in the vessel.

Body Feed Rate

- The body feed rate is monitored so it can be adjusted as needed.
- Monitoring can track the effects of the body feed concentration under various circumstances.

Filter Run Time

- Tracking filter run times under various circumstances will help to optimize the plant operations.
    - Filter run times are directly related to the cost per volume of water produced.

Operations

- Pressure filters can be operated at higher headloss, and higher flows, than vacuum filters.
  - Fewer filters or filter elements are required to produce the same amount of filtrate.
- Pressure filters generally use a precoat recycle tank, which is not necessary for vacuum filtration
- systems.
- Pressure filter vessels are more expensive than filter vessels.
- Vacuum filters have lower power costs.
- Vacuum filter operation is simpler than pressure filters.
- The vacuum applied to vacuum filters may cause air to come out of solution, especially in cold weather.
  - The air bubbles can disturb the cake and release particles entrained on the media, thus producing turbidity.
  - This phenomenon is not observed in all cold weather operations.

Maintenance

- Enclosed pressure filters are neater installations with easy housekeeping.
- Vacuum filters are open; maintenance is easier.
- Vacuum filters need to be protected from the weather.
  - Wind, rain, or ice can disturb the filter cake.
  - Sunlight will promote algae growth.

Monitoring

- It is easier to observe the various cycles in a vacuum filter.
  - Operators can manually control the cycles.
  - Operators can become more familiar with the filtration mechanisms.
  - Operating problems may be detected easily and quickly by viewing the operations.

Microstraining

- Prestraining the water can improve filter run times, especially in water high in algae concentrations.
- The microstrainer will remove planktonic organisms and amorphous matter.

Disinfection

- Disinfection adequate to provide 1-log *Giardia* and 3-log (99.9%) virus removal is required.
- A chlorine, chloramine, or chlorine dioxide residual is required in the distribution system.

Metal Removal

- High concentrations of dissolved iron and manganese are commonly found in ground water.
- Metals can be oxidized to form a precipitate that can be removed in a D.E. filter.
- Some detention time before filtration is needed in order to give the metals time to oxidize.
- The filter-to-waste process helps dilute iron in the discharge.

Softening

- To remove hardness from water, soften with lime and soda ash upstream of the D.E. filter.
- The filter can remove residual precipitates from the water.

Taste and Odor Treatment

- To remove taste and odor, follow D.E. filtration with granular activated carbon columns.
- It may be possible to incorporate powdered activated carbon with the precoat and body feed media to remove taste and odor in the filter.

Color Removal

- D.E. filtration can remove 80% or more of particulate color.
- Treatment upstream with a strong oxidant, such as ozone, can increase color removal.
- Coagulation is the most effective method of removal for dissolved color.
- Oxidation, softening, or ion exchange can be used to remove dissolved color.

Media Handling

- Wherever dry media is manually loaded into hoppers or tanks, dust collectors should be installed to minimize dust.
- When creating slurry, the dry media should be added to moving water to minimize dust.
- The media is very abrasive and can cause irritation or injury.
- Crystalline silica, present in diatomaceous earth and in lesser amounts in perlite, is a probable carcinogen when inhaled.
- Personnel should wear protective clothing, such as goggles, gloves, and a respirator, when handing the media.
- An eyewash should be available nearby.

Pressure Tanks

- Pressure tanks must be equipped with a pressure relief device.
- Rupture disks should be fitted with drain piping that can handle the impact of a shattered disk and the initial pressure surge.
- Pressure relief valves can be used.
- Drain piping for pressure relief devices should carry the flow safely away from personnel, electrical equipment, and media storage.
- Before a pressure tank is opened, verify that the tank is depressurized.
    - Some tanks have safety features to prevent the access door from opening unless the tank is depressurized and drained.

Automatic Shutdown

- The filtering system should be shut down in case of a power outage or a pressure tank rupture disk failure.
- When the problem has been corrected, the plant should be brought back online manually.

Exercise

Unit 3 – Exercise

Put the following tasks in the order in which they occur during the precoating process.

_____ Feed Precoat Slurry

_____ Completed Precoat

_____ Fill Vessel and Piping with Clean Water

_____ Bridging Process

_____ Begin Recirculation

Multiple Choice: Select the best answer

1. The D.E. precoat is first mixed with ________ water.
    a. raw
    b. filtered
    c. waste

2. Effluent _____________ must be monitored and recorded to meet drinking water regulations and is an indicator of how well the filter is performing.
    a. color
    b. softening
    c. turbidity

3. The body feed is continuously added to the filter media to prevent __________________ of the filter media.
    a. Clogging
    b. Contamination
    c. Collection
    d. Drying

4. It is advantageous to obtain a continuous record of head loss and flow rate during D.E. filtration to determine when it is best to backwash the filter; a good instrument to use for this purpose is a __________ _____________.

    a. filter element
    b. body feeder
    c. chart recorder
    d. pressure gauge

5. D.E. Filtration is best for treating source waters with _______ turbidity and ___ color.

    a. high turbidity and low color
    b. low turbidity and high color
    c. low turbidity and low color
    d. high turbidity and high color

True or False: Select the best answer

6. Cleaning and precoat cycles should not be completely automated.

    a. True
    b. False

7. One concern about reducing the flow through the filter is that the media cake can fall off.

    a. True
    b. False

8. The maximum recommended filtration rate is 2.5 gpm/sf.

    a. True
    b. False

9. Personnel should wear protective clothing, such as goggles, gloves, and a respirator, when handling the diatomaceous earth media.

    a. True
    b. False

Unit 3 Summary

Key Points:

- The precoat is first mixed with filtered water.
- The body feed is continuously added to the raw water feed to prevent clogging the filter media.
- When treating surface water, D.E. filter must be continuously monitored to see that the turbidity standard is met.
- The use of chart recorder at the filters to obtain a continuous record of head loss and flow rate is advantages because it provides an easily monitor means of determining the best time to backwash a filter.
- Turbidity, flows, pressure, body feed rate, and filter run time are five D.E. process parameters that should be monitored routinely.
- Filter-to-waste prevents inferior quality water from entering the clearwell as well as helps dilute iron in the discharge.

[1] United States Army, *Army Technical Manual TM5-662*, p. 13-2.

[2] American Water Works Association and American Society of Civil Engineers, "Slow Sand and Diatomaceous Earth Filtration, *Water Treatment Plant Design, 3rd ed.,* (New York, NY: McGraw-Hill, 1998), p. 208.

[3] United States Army, p. 13-4.

[4] *Water Treatment Plant Design*, p. 209.

[5] American Water Works Association, "Granular Bed and Precoat Filtration," *Water Quality & Treatment: A Handbook of Community Water Supplies, 5th ed.* (New York, NY: McGraw Hill, 1999), p. 12.

Definitions:

Body feed is the continuous addition of diatomaceous earth during the filtering cycle to provide a fresh filtering surface as the suspended material clogs the precoat**.**

Colloidal matter is the finely solids that will not settle but may be removed by coagulation or membrane filtration.

Diatomaceous Earth is composed of skeleton of microscopic plants.

D.E. filtration is a process that removes particles from water by passing water through a layer of finely ground media (the D.E) that is deposited on a fine mesh screen, called a septum.

Headloss is pressure drop. It is the difference between the pressure on the upstream side of the filter and the pressure on the downstream side of the filter.

ntu is nephelometric turbidity units. A nephelometer is the instrument used to measure the scattering of light that indicates turbidity measurement in ntu.

Perlite is derived from glassy volcanic rock.

Precoat is a very fine granular media, such as diatomaceous earth, applied to a retaining membrane or fabric surface prior to a service run.

Turbidity is an indication of the clarity of a fluid. Turbidity measures the scattering of light through the water by materials in suspension or solution. The greater the turbidity, the less clear the water is.

DEPARTMENT OF ENVIRONMENTAL PROTECTION FIELD OPERATIONS REGIONAL OFFICES:

REGION	ADDRESS
SOUTHEAST	PA DEP - SOUTHEAST FIELD OPERATIONS 2 EAST MAIN STREET NORRISTOWN, PA 19401 Phone: 484-250-5900
NORTHEAST	PA DEP - NORTHEAST FIELD OPERATIONS 2 PUBLIC SQUARE WILKES-BARRE, PA 18711-0790 Phone: 570-826-2511
SOUTHCENTRAL	PA DEP - SOUTHCENTRAL FIELD OPERATIONS 909 ELMERTON AVENUE HARRISBURG, PA 17110 Phone: 717-705-4704
NORTHCENTRAL	PA DEP - NORTHCENTRAL FIELD OPERATIONS SUITE 101 208 WEST THIRD STREET WILLIAMSPORT, PA 17701 Phone: 570-327-3675
SOUTHWEST	PA DEP - SOUTHWEST FIELD OPERATIONS 400 WATERFRONT DRIVE PITTSBURGH, PA 15222-4745 Phone: 412-442-4217
NORTHWEST	PA DEP - NORTHWEST FIELD OPERATIONS 230 CHESTNUT STREET MEADVILLE, PA 16335-3481 Phone: 814-332-6899