

# Drinking Water Operator Certification Training



## Module 18: Bag Filtration and Cartridge Filtration

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

The Pennsylvania State Association of Township Supervisors (PSATS)  
Gannett Fleming, Inc.  
Dering Consulting Group  
Penn State Harrisburg Environmental Training Center



### Topical Outline

#### Unit 1: Introduction to Bag Filtration and Cartridge Filtration

- I. Definitions
  - A. Bag Filters
  - B. Cartridge Filters
- II. Applications and Limitations for Use
  - A. Applications
  - B. Limitations

#### Unit 2: System Design and Configuration

- I. Materials and Methods of Construction
  - A. Filters
  - B. Filter Housings
- II. System Components
  - A. Prefilter
  - B. Filter
  - C. Other Components
- III. System Configurations
  - A. Bag Filter Systems
  - B. Cartridge Filter Systems

### Unit 3: Determination of Applicability

- I. Source Water Quality
  - A. Turbidity
  - B. Color/Colloids
  - C. Algae
  - D. *Giardia/Cryptosporidium*
- II. Flow
  - A. Single Train Systems
  - B. Multiple Train Systems
- III. Treatment Goals
  - A. Water Quality
  - B. Costs of Operation
- IV. Site Specific Piloting
  - A. Regulatory Requirements
  - B. Water Quality
- V. Regulatory Approval
  - A. Pilot Protocol
  - B. Seasonal Testing
  - C. *Giardia and Cryptosporidium* Challenge Testing
- VI. Economics
  - A. Capital Expense
  - B. Operational and Maintenance Expense
  - C. Life Cycle Costs
- VII. Advantages/Disadvantages of Bag Filtration and Cartridge Filtration
  - A. Advantages
  - B. Disadvantages

### Unit 4: System Operation and Maintenance

- I. System Startup
  - A. Flow Rate
  - B. Air Bleed
  - C. Filter-to-Waste
  
- II. Filter Performance
  - A. Allowable Flow Rates
  - B. Surface Water Treatment Rule and Performance Standards
  
- III. System Checks
  - A. Daily Checks
  - B. Weekly Checks
  - C. Monthly Checks
  - D. Biannual Checks
  - E. Annual Checks
  
- IV. System Maintenance
  - A. Filter Replacement
  
- V. System Troubleshooting
  - A. High Differential Pressure
  - B. Short Run Times
  - C. Water Quality

### **Unit 5: Record Keeping**

- I. Operational Records
  - A. Analytical Results
  - B. Sampling Records
  - C. Filter Replacement Records
  
- II. Plant Records
  - A. Shop Drawings
  - B. As-Builts
  - C. Plant Flow Schematics
  
- III. Equipment Maintenance Records
  - A. Maintenance Procedures
  - B. Documentation of Maintenance Conducted
  - C. Uses of Maintenance Records

### **APPENDIX**

- I. Definitions
  
- II. Related Information
  
- III. Regional Offices Contact Information

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# Unit 1 - Introduction to Bag Filtration and Cartridge Filtration

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## Learning Objectives

As a result of this unit, the learner will:

- Be introduced to the principal similarities of and differences between bag filters and cartridge filters.
- Be able to identify the two major applications and two major limitations of both bag filtration and cartridge filtration.

Bag filters and cartridge filters are used for a variety of applications, from industrial processes to water treatment and home use. Some common examples are:

- Cartridge filters: filtering water that enters a home or an automobile oil filter
- Bag filters: vacuum cleaner bag

## Bag Filters



**Bag filters** are defined as a fabric filter designed primarily to remove particulate material from fluids. Bag filters are usually non-rigid, disposable, and easily replaceable.

- Bag filters are typically contained in a pressure vessel.
- Bag filters can be used either individually or as an array of bags in the vessel.
- Fluids usually flow from the inside of the bag to the outside.
- The primary application for bag filters in water treatment is to remove *Cryptosporidium* oocysts and/or *Giardia* cysts from source water. Bag filters typically do not remove bacteria, viruses, or fine colloids.



***Giardia* cysts and *Cryptosporidium* oocysts** are protozoan found in water. They can cause diarrhea and other health-related problems if ingested.

- The use of coagulants or a pre-coat with bag filters is not usually recommended since removal of particulate material is based on the absolute pore size of the filter instead of the development of a layer on the surface of the filter to enhance its removal capabilities. Therefore, coagulants or a pre-coat only increase the pressure loss through the filter, necessitating more frequent filter exchanges.



Figure 1.1 Examples of Bag Filters<sup>1</sup>

## Cartridge Filters



**Cartridge filters** are defined as fabric or polymer-based filters designed primarily to remove particulate material from fluids. They are usually rigid or semi-rigid and manufactured by affixing the fabric or polymer to a central core. Cartridge filters are disposable and easily replaceable.

- Cartridge filters are typically housed in a pressure vessel.
- Cartridge filters can be used either individually or as an array of cartridges in a vessel.
- Fluids usually flow from the outside of the filter to the inside.
- The primary application for cartridge filters in water treatment is to remove *Cryptosporidium* oocysts and/or *Giardia* cysts from source water. Cartridge filters typically do not remove bacteria, viruses, or fine colloids.
- The use of coagulants or a pre-coat with a cartridge filter is not usually recommended since removal of particulate material is based on the absolute pore size of the filter instead of the development of a layer on the surface of the filter to enhance its removal capabilities. Therefore, coagulants or a pre-coat only increase the pressure loss through the filter, necessitating more frequent filter exchanges.



Figure 1.2 Examples of Cartridge Filters<sup>2</sup>

### Applications

#### Industrial

Currently, bag filtration and cartridge filtration are more widely used for industrial purposes than in water treatment. Industrial uses include process fluid filtering and solids recovery.

- **Process Fluid Filtering:** Process fluid filtering is the purification of a fluid by the removal of undesirable solid material. Process fluids include fluids used to cool or lubricate equipment. In mechanical equipment, or during the processing of a fluid, particulate material can accumulate. In order to maintain the purity of the fluid, the particles must be removed. The oil filter in your vehicle is a good example of a cartridge filter being used to maintain the quality of a process fluid.
- **Solids Removal/Recovery:** Another industrial application is in solids recovery. Solids recovery is done to either recover desirable solids from a fluid or to “purify” the fluid prior to subsequent treatment, use, or discharge. For instance, some mining operations will use water to convey the minerals being mined from site to site. After the slurry arrives at its desired location, it is filtered to remove the desired product from the carrier water.

#### Water Treatment

There are three general applications for bag filtration or cartridge filtration in a water treatment plant. They are:

1. Filtration of surface water or ground water under the influence of surface water.
2. Prefiltration prior to subsequent treatment.
3. Solids removal.

**Surface Water Treatment Rule (SWTR) Compliance:** Bag filters and cartridge filters may be used to provide filtration of surface water or ground water under the influence of surface water. Given the nature of bag filters and cartridge filters, their application is likely limited to small systems with high quality source water. Bag filters and cartridge filters are used for:

- *Giardia* cyst and *Cryptosporidium* oocyst removal
- Turbidity

**Prefiltration:** Bag filters and cartridge filters can also be used as a prefilter prior to other treatment processes. An example would be membrane filter systems which utilize a bag or cartridge prefilter to protect the membranes from any large debris that may be present in the feed water.

### Limitations

The use of bag filtration or cartridge filtration for water treatment is limited by two major factors.

- Source water quality
- System size

### Source Water Quality

If the source water to be treated has high levels of turbidity, colloids, or algae, it will not be suitable for bag filtration or cartridge filtration. There are no hard and fast rules, but some general guidelines can be proposed.

- **Turbidity:** Less than 1 NTU (Nephelometric Turbidity Units).
- **Fine Colloids:** Even low levels of fine colloids or clays may make the source water unsuitable for bag filtration or cartridge filtration.



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.

- **Algae:** Although different manufacturers may have different algae loading criteria for their filter systems, all systems require source water with low levels of algae.

### System Size

Although bag filter systems and cartridge filter systems are modular and can theoretically accommodate any flow rate by increasing or decreasing the number of filter or filter arrays, economics tend to favor their use in smaller water systems. The following items must be considered when determining if a bag filter system or a cartridge filter system would be feasible.

- **Capital Costs:** Pressure vessel(s), pumps, chemical feed, and analytical equipment.
- **Operation & Maintenance (O&M) Costs:** Filter change-out frequency.
- **Flow Rate:** System sizes in excess of 100,000 gpd may be too large for bag filtration or cartridge filtration systems to be economical.

**Exercise****Unit 1 – Exercise****Multiple Choice – Choose the best answer:**

1. Which statement is true about bag and cartridge filters?
  - a. Bag and cartridge filters tend to be non-rigid.
  - b. Bag and cartridge filters are typically rigid.
  - c. Bag filters tend to be non-rigid, cartridge filters are typically rigid.
  - d. Bag filters tend to be rigid, cartridge filters are typically non-rigid.
  
2. Which type of systems are bag and cartridge filters usually limited to?
  - a. Small sized systems
  - b. Medium sized systems
  - c. Large sized systems
  
3. Which of the following is **not** a water treatment application for bag or cartridge filters?
  - a. For use with coagulants or a pre-coat.
  - b. For use as a prefilter prior to another treatment process.
  - c. To provide filtration of high quality surface water or ground water under the influence of surface water (GUDI) sources.
  
4. Bag and cartridge filters typically remove which of the following? (Choose all that apply)
  - a. Bacteria
  - b. Giardia cysts
  - c. Viruses
  - d. Cryptosporidium oocysts
  - e. Fine colloids
  
5. What are the two main factors that limit the use of bag or cartridge filtration for water treatment (Select two)
  - a. pH
  - b. source water quality
  - c. water temperature
  - d. system size
  - e. chemical pretreatment

## Unit 1 Summary



### Key Points:

- Bag and cartridge filters typically do not remove bacteria, viruses, or fine colloids.
- The primary application of bag and cartridge filters in water treatment is the removal of Cryptosporidium and Giardia.
- Bag and cartridge filters are limited to small systems with high quality source water.
- Chemical pretreatment is not required in bag filtration because the pore size of the filtration devices is small enough for effective particle removal without the need for pre-treatment
- 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.

<sup>1</sup> Courtesy of Strainrite Companies - A Division of Lapoint Industries.

<sup>2</sup> Strainrite Companies.

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# Unit 2 – System Design and Configuration

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## Unit 2 - Learning Objectives

As a result of this unit, the learner will:

- Be able to identify the main components of both bag and cartridge filtration systems.

Many different materials and manufacturing techniques can be used to make bag and cartridge filters and their filter housings. In addition, the orientation of the filter in the housing can also be quite different depending on the manufacturer of the filter. In this section, we will examine the materials and the construction methods used to manufacture bag and cartridge filters and their housings.

### Filters

Each manufacturer has a unique way of designing and constructing their filters. The filters can be different in terms of:

- Length,
- Diameter,
- Construction materials, and
- Manufacturing techniques.

Since this module is an overview, the following discussion of materials and manufacturing techniques will be as generic as possible, applying to most bag or cartridge systems.

**Materials**

Bag filters and cartridge filters can be constructed of various materials. The choice of material depends on the characteristics of the source water to be filtered and the desired quality of the effluent.

Table 2.1 Materials Used in the Construction of Bag and Cartridge Filters

<b>Construction Material</b>	<b>Bag Filter</b>	<b>Cartridge Filter</b>
Cotton	X	X
Nylon	X	X
Polypropylene	X	X
Polyester	X	X
Teflon	X	
Glass	X	X
Saran	X	
Acetate		X
Acrylic		X
Ceramic		X
Metal		X
Polyethylene		X
Rayon		X

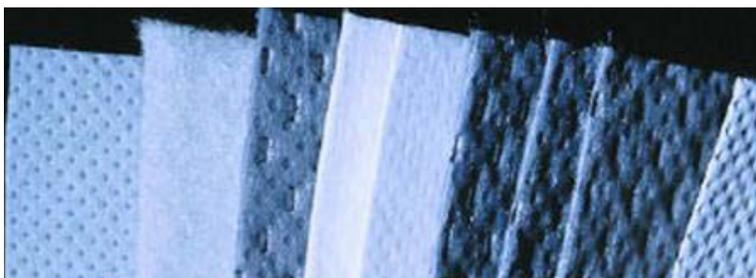


Figure 2.1 Examples of Bag Filter Fabrics<sup>1</sup>

### Manufacturing Techniques

The specific manufacturing techniques for bag and cartridge filters are usually manufacturer specific and in some cases they are proprietary. However, these techniques can be explained in general terms.

The process begins by creating the fabric from which the filter will be made. The fabric can be manufactured as either a sheet or as a “thread.”

- **Bag Filters:** After the fabric sheet is manufactured, it must be formed into a bag. This can be done in a number of ways, but it usually involves sewing the sheet together. During the manufacturing process, a collar is sewn into the top of the bag in order to provide a seal to the filter housing.

One disadvantage to sewing a bag is that it could allow the influent water to “short-circuit” through the sewn seam. In order to avoid this, manufacturer’s use different techniques to form the seam, or some manufacturer’s weld the bag together to avoid creating the sewn seam.

Some bag filters utilize multiple layers of the filter fabric or even layers of different materials. This is done to provide successive layers of filtration with each subsequent layer providing finer and finer filtration. This can extend the time between filter changes by allowing the larger material to be removed prior to clogging the finest filtering layer.

- **Cartridge Filters:** The method used to manufacture a cartridge filter is quite different from the method used to manufacture a bag filter. There are two general styles of cartridge filters:
  - ① **Wound:** Consists of a fabric thread wound around the central core.
  - ② **Pleated:** Has pleats in the fabric. The pleated section of the material is attached to the central core.

The pleated style offers more filtration surface area per cartridge.



Cartridge filters are rated by tensile strength.

The smaller the pore size in a cartridge filter, the higher the inlet pressure requirement.

### Filter Housings

The filter housing of a bag or cartridge filter system serves a number of functions. It:

- Delivers the water to the filter.
- Collects the filtrate.
- Supports or holds the filter in the proper position to prevent “short circuiting” around the filter.
- Maintains the pressure of the filter system.

### Materials and Construction

The filter housings can be constructed of many types of materials but are made primarily of plastic or metal. The housings usually consist of:

- The body of the housing.
- A lid or a cap which can be easily removed to facilitate filter change-out.
- Some type of mechanical seal, usually a rubber O-ring, between the two parts of the housing.

The O-ring is a critical part of the system. It prevents the loss of water pressure by maintaining a seal between the cap and body of the housing and also prevents unfiltered water from by-passing around the filter and into the effluent side of the housing.

Although each filter may be unique, there are some common elements on most bag or cartridge filter housings.

- **Bag Filter Housing:** The major components of the filter housing in a bag filter system include the body of the filter housing and the cap or lid.
  - The lid may contain the inlet port and taps for pressure gauges.
  - There is usually some type of pressure relief valve on either the body or the lid to allow for the housing to be depressurized for filter change-out.
  - The hardware on the body of the housing secures the lid to the top of the housing and with the help of an O-ring provides the necessary seal between them.
  - A support screen or basket provides rigidity to a bag filter. The screen or basket helps the bag maintain its shape when it is placed in the filter housing. This assures that the entire surface of the filter is available for filtration.
  - The body of the housing includes:
    - Outlet port.
    - Taps or ports for pressure gauges.
    - Legs or a stand to support the housing.
    - The necessary hardware to hold the lid or cap.



Figure 2.2 Examples of Bag Filter Housings<sup>2</sup>



Figure 2.3 An Example of the Internal Components of a Bag Filter Housing<sup>3</sup>

- **Cartridge Filter Housing:** There are two basic styles of cartridge filter systems. Smaller systems usually use a single wound cartridge; larger systems usually consist of multiple cartridge filters which can be either pleated or wound. The type of system determines the configuration of the housing.
- Smaller cartridge filter systems such as those used in a home filtering system typically are constructed from some type of plastic or stainless steel.
    - The body of the vessel usually is made of clear plastic (or stainless steel) the top of which is threaded to facilitate its connection to the lid or cap.
    - The bottom of the body sometimes includes a barb or indentation which allows for the proper positioning of the cartridge in the housing.
    - The lid usually has the female thread which accepts the male threads of the body and an O-ring to provide the seal between the two portions of the housing.
    - The lid usually contains the inlet and outlet ports as well as the pressure relief valve used to depressurize the housing for filter change-out.
    - Smaller cartridge filter systems may or may not contain taps or ports for pressure gauges.
  
  - Larger cartridge filter systems can use either pleated or wound filters and usually use multiple filters in a single housing. From the outside, a multiple filter housing looks very much like the housing for a bag filter. Internally however, the housing has specific slots to accept the cartridges themselves. The housing itself consists of:
    - ① The **body**. As with the bag filter housing, the body may include:
      - Outlet ports,
      - Taps or ports for pressure gauges,
      - Legs or a stand to support the housing, and
      - The necessary hardware to hold the lid or cap.
    - ② The **lid or cap**. The lid may contain:
      - An inlet port and
      - Taps or ports for pressure gauges.
  
  - There is usually some type of pressure relief valve on either the body or lid to allow for the housing to be depressurized for filter change-out.
  
  - Cartridge filters are usually rigid. Therefore, they do not require the use of a support screen or basket.

### **Orientation**

The filter housing for a bag filter system is usually vertical. The lid is located on the top of the housing and the bag is placed vertically into the housing.

Most small single cartridge filter systems are vertically mounted. Larger systems are either horizontally or vertically oriented.

Most bag or cartridge filter systems consist of a prefilter, a final filter, and the necessary valves, gauges, meters, chemical feed equipment, and on-line analyzers. Again, since bag and cartridge filter systems are manufacturer specific, these descriptions will be generic in nature—individual systems may differ somewhat from the descriptions offered below.

### Prefilter

In order for a filter to remove parasitic protozoan like *Giardia* and *Cryptosporidium*, the pore size of the filters must be very small. Since there are usually other larger particles in the water being fed to the filter system, removal of these larger particles by the bag filter or cartridge filter would tend to dramatically shorten their useful life.

To alleviate this problem, many manufacturers construct their systems with a prefilter. The prefilter can be either a bag or cartridge filter of somewhat larger pore size than the final filter. The prefilter traps the larger particles and prevents them from being added to the final filter. This increases the amount of water that can be filtered through the final filter.

As mentioned, the prefilter has a larger pore size than the final filter and also tends to be significantly less expensive than the final filter. This helps to keep the operational costs of a bag or cartridge filtration system as low as possible. The frequency of prefilter change-out is determined by the quality of the feed water.

It is possible that a bag prefilter could be used on a cartridge filter system or a cartridge prefilter be used on a bag filter system, but typically a bag filter system will use a bag prefilter and a cartridge filter system will use a cartridge prefilter.

### Filter

After the prefiltration step the water will then flow to the final filter, although some filtration systems may utilize multiple filtration steps. The final filter is the filter that is intended to remove the target contaminant. As mentioned, this filter tends to be more expensive due to its smaller pore size and it may undergo more stringent manufacturing procedures to assure its ability to remove the target contaminant.

## Other Components

In order to function properly, a bag or cartridge filtration system will need a variety of components other than the filters and housing.

- **Valves:** As with any water treatment system, numerous valves are required to direct flow in the desired flow path, isolate different sections of the process for maintenance, or to isolate redundant treatment equipment when not needed. In particular, for a bag or cartridge filtration system, valves are required to isolate the pre or final filter housing when filter change-out is conducted.
- **Flow Meters:** Obviously, one of the most important pieces of information in the operation of a water treatment plant is the flow at various locations. Since a bag or cartridge filtration system is relatively simple in terms of equipment and treatment process, a finished water flow meter may be the only meter necessary to control plant processes.
- **Pressure Gauges:** In addition to flow, the pressure at various points of the treatment process is of particular importance to an operator. An item of particular concern is the pressure differential. When the pressure differential exceeds the manufacturer's limit, the effectiveness of the filter may be compromised. An abnormally low pressure differential could indicate a mis-installed filter. The pressure differential across the bag or cartridge filter dictates when filter change-out must be conducted.

The housings for cartridge filters should be equipped with inlet and outlet pressure gauges.



**Pressure Differential:** The difference between the inlet pressure and the outlet pressure of the filter.

The purpose of inlet and outlet pressure gauges on a cartridge filter is to monitor head loss.

- **Chemical Feeders:** A chemical feeder may only be a chlorinator, but there may be a need for raw or finished water chemical addition as well. For instance, caustic soda or soda ash may be needed to raise the pH. A distribution system corrosion inhibitor would also require a feeder.
- **On-line Analytical Equipment:** Although the proper operation of the filters do not require it, the water treatment plant will likely use some type of on-line analytical equipment. Turbidimeters, particle counters, and chlorine analyzers are all likely to be used. Turbidimeters and particle counters in particular may be useful in helping the operator to identify when filters have been installed improperly. They may also help determine when filter change-out is required.

The use of chart recorders at the filters to obtain a continuous record of head loss and flow rate is advantageous because it provides an easily monitored means of determining the best time to change the filter.

Bag and cartridge filtration systems can be configured in many different ways. The configuration selected depends on a number of factors including source water quality and desired production capacity.

### Bag Filter Systems

Bag filter systems can come in a variety of configurations. For each configuration, the PA DEP will require full redundancy of all filter stages.

- **Single Filter Systems:** A single filter system would likely be somewhat rare in a water treatment application. A single filter system would only be applicable for extremely small systems with an extremely high quality source water.
- **Prefilter – Post Filter Systems:** Perhaps the most common configuration of a bag filter system is a prefilter - post filter combination. By using a prefilter to remove the large particles, the loading on the final filter can be dramatically reduced and substantial cost savings can be realized.
- **Multiple Filter Systems:** Intermediate filters are placed between the prefilter and the final filter. Each filtration step would be finer than the previous step.
- **Filter Arrays:** Some bag filter systems utilize more than one bag per filter housing. These are referred to as filter arrays. These filter arrays allow for higher flow rates and longer run times than systems with one bag per housing.



Figure 2.4 An example of a multiple filter system installed at a facility in PA<sup>4</sup>

## Cartridge Filter Systems

Cartridge filter system configurations are similar to the configurations seen in bag filter systems. For each configuration, the PA DEP will require full redundancy of all filter stages.

- **Single Filter Systems:** As in bag filter systems, a single filter system would likely be somewhat rare in a water treatment application. A single filter system would only be applicable for extremely small systems with an extremely high quality source water. Home water filter systems are usually single filter systems.
- **Prefilter - Post Filter Systems:** Like bag filter systems this is one of the more common arrangements in a cartridge filter system. It is configured so that the feed water initially passes through a filter with a relatively large pore size and then is filtered through the finer post or final filter.
- **Multiple Filter Systems:** A multiple filtration system is an extension of the prefilter – post filter configuration described above. Rather than having a prefilter and a post filter, a multiple filtration system would consist of progressively finer filters plumbed in series.
- **Filter Arrays:** Filter arrays are fundamentally the same as the arrays described in bag filter systems. Multiple cartridge filters are grouped together in a single filter housing to provide higher flow rates and longer runtimes between filter change-outs.

**Exercise****Unit 2 – Exercise****Multiple Choice – Choose the best answer:**

1. Which of the following are true statements about cartridge filter? **(Choose all that apply)**
  - a. The larger the pore size in a cartridge filter, the higher the inlet pressure requirements.
  - b. Cartridge filter housings may be made of Teflon.
  - c. Cartridge filters are rated by tensile strength.
  
2. Which of the following statements about pressure gauges are true? **(Choose all that apply)**
  - a. The housings for cartridge filters should be equipped with pressure gauges
  - b. The purpose of inlet and outlet pressure gauges on a cartridge filter is to monitor flow at various locations.
  - c. When the pressure differential exceeds the manufacturer's limit, the effectiveness of the filter may be compromised.
  - d. The pressure differential across the bag or cartridge filter dictates when filter change-out must be conducted.
  
3. Which of the following, when located at the filters, would provide a continuous record of head loss and flow rate as well as an easily monitored means of determining the best time to change the filter?  
**(Choose one)**
  - a. valves
  - b. pressure gauges
  - c. chart recorders

**Matching: Match the letter of the corresponding bag or cartridge filter system component with the number of the correct statement.**

- A. on-line analytical equipment
- B. flow meters
- C. pressure gauges
- D. chemical feeders
- E. prefilter
- F. filter

1. \_\_\_\_\_ Has a smaller pore size and usually removes the target contaminant.
2. \_\_\_\_\_ Examples: Turbidimeters, particle counters, and chlorine analyzers
3. \_\_\_\_\_ Has a larger pore size to remove larger particles
4. \_\_\_\_\_ Measures finished water flow
5. \_\_\_\_\_ Monitors head loss
6. \_\_\_\_\_ Examples: chlorinator, caustic soda, or soda ash feeder

## Unit 2 Summary



### Key Points:

- Cartridge filters are rated by tensile strength.
- The smaller the pore size in a cartridge filter, the higher the inlet pressure requirement.
- Cartridge filter housings are made of plastic or stainless steel.
- The housings for cartridge filters should be equipped with inlet and outlet pressure gauges. The purpose of inlet and outlet pressure gauges on a cartridge filter is to monitor head loss.
- The use of chart recorders at the filters to obtain a continuous record of head loss and flow rate is advantageous because it provides an easily monitored means of determining the best time to change the filter.

<sup>1</sup> Courtesy of Strainrite Companies - A Division of Lapoint Industries.

<sup>2</sup> Strainrite Companies.

<sup>3</sup> Strainrite Companies.

<sup>4</sup> Strainrite Companies.

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# Unit 3 – Determination of Applicability

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## Unit 3 - Learning Objectives

**As a result of this unit, the learner will:**

- Be able to identify the characteristics of source water that can impact the effective operation of either a bag or cartridge filter system.
- Be aware of the reasons why site specific piloting should be considered prior to installing either a bag or cartridge filter system.
- Receive an explanation of the advantages and disadvantages of both bag and cartridge filtration systems.

Ultimately the question of whether a bag or cartridge filter system is suitable to a particular application is determined by the quality of the source water. There are many constituents in the source water that may effect the operation of the filtration system. These are:

- Turbidity
- Color/colloids
- Algae
- *Giardia*
- *Cryptosporidium*

Although each manufacturer's source water quality requirements may be different, some general guidelines for source water quality can be offered.

### Turbidity

Although each filter manufacturer's standards for source water turbidity may be slightly different from one another, all bag and cartridge filter systems require a high quality of source water. Generally, the lower the turbidity of the source water the better the application for bag or cartridge filters. As the source water turbidity increases the amount of water that can be filtered decreases.

Current (as of 2003) Pa. DEP regulations stipulate that cartridge filters should not be used on source waters with a turbidity of 5 NTU or greater without proving their capability during a pilot evaluation. The Interim Surface Water Treatment Rule was enacted to primarily control turbidity.

The DEP regulations do not currently address maximum suitable turbidity for bag filters.

Some surface water sources may have a low average turbidity but get muddy after rainstorms, winter runoff, or other event. In these cases, it would be best to shut off the filter system and allow the source water quality to improve if possible. If this is not possible, the water can still be filtered but the life of the filter itself may be dramatically reduced.



Some types of turbidity, especially those caused by clays or fine colloidal compounds may not be well removed by bag or cartridge filters. If the filter can not produce water with a turbidity of less than 0.3 NTU in at least 95% of the samples taken on a monthly basis and never exceed 1 NTU, a different filtration system should be considered. For this reason alone, a pilot test of the proposed bag or cartridge filtration system should be conducted to confirm that the system can achieve these turbidity requirements.



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.

## Color/Colloids

There is no hard and fast rule as to the amount of color or colloidal content that a bag or cartridge filter system can handle. The source water's suitability hinges on two items:

- The filtration system's ability to produce an acceptable filtered water quality, and
- The system's ability to produce that quality economically.

Again, there is no substitute for a pilot evaluation of the proposed system to ascertain the system's ability to operate effectively and economically.

## Algae

Algae can be quite troublesome. It can create filtration, taste, and odor problems. Algae is present in nearly all surface waters. Piloting, especially during summer months, can be used to gauge the impact of algae.

## *Giardia/Cryptosporidium*

A bag or cartridge filtration system's primary purpose is to remove *Giardia* and *Cryptosporidium* from source water. Fortunately, a bag filter or cartridge filter will remove most *Giardia* and *Cryptosporidium*.

However, if the source water has extremely high levels of *Giardia* and *Cryptosporidium*, significant numbers of the parasites may remain after filtration. Although this may alarm you, it is important to remember that conventional, direct, and Diatomaceous Earth (DE) filters do not remove 100% of *Giardia* and *Cryptosporidium*. Compliance with the SWTR relies, in part, not in the number of *Giardia* in the filtered water but in the amount removed during treatment. SWTR regulations require a 3-log removal/inactivation of *Giardia* through the treatment process—not on a numerical level of the parasite allowed in the filtered water.



Even 3-log means the removal of 99.9% of a target organism.

The second factor to consider when determining if a bag or cartridge filtration system may be appropriate for a particular application is to look at the required capacity of the system. Allowable flow rates through a bag filter or cartridge filter are manufacturer specific and based on the available surface area of the filter. Surface area of filters vary from manufacturer to manufacturer.

### **Single Train Systems**

PA DEP regulations:

- Limit cartridge filter flow to 1 gpm/sq. ft. of filter area,
- Suggest a limit of 0.5 gpm/sq. ft, and
- Limit overall filter flow through a cartridge filter to 20 gpm unless acceptable performance at higher flow rates has been demonstrated.

There are currently no similar regulatory limitations for bag filtration systems although a pilot evaluation would be required prior to approval by the PA DEP. Some filter manufacturers have demonstrated acceptable filter performance at rates in excess of 100 gpm.

Bear in mind that bag and cartridge filters have a finite capacity to remove particles from the water. The higher the flow rate through the filter, the faster the filter capacity will be exhausted, and the more frequently the filters will need to be changed.

## Multiple Train Systems

In order to accommodate higher flows than can be treated through a single filter, it is possible to operate multiple filter trains in parallel. So if 80 gpm were required and satisfactory treatment is possible through the filter at 20 gpm, four treatment trains could be operated in parallel. Costs for filter housings and monitoring equipment may make this option more expensive than more traditional treatment processes.



Figure 3.1 An Example of a Multiple Train Filter System Installed at Paonia, CO<sup>1</sup>

In order to evaluate whether bag or cartridge filtration would be a viable treatment for a specific source water, objective criteria should be established and evaluated. There are two general areas that these evaluations should examine:

- ❶ Water quality and
- ❷ Cost of operation.

### Water Quality

In order to determine if bag or cartridge filtration is viable for a particular application, the PA DEP performance standards should be used.



The PA DEP requirements are:

- The filter effluent turbidity must be less than 0.3 NTU in at least 95% of the samples analyzed each month.
- The filter effluent turbidity must never exceed 1 NTU.
- The filtration system must provide at least 2-log removal of *Giardia* and *Cryptosporidium* cysts.

The ability of the filtration system to produce a filtrate with an acceptable turbidity can be demonstrated through pilot testing. The systems ability to remove *Giardia* and *Cryptosporidium* cysts can be demonstrated by challenging the system with *Giardia* and *Cryptosporidium* sized microspheres and quantifying the numbers of the microspheres present in the effluent.

### Costs of Operation

A treatment facility must be able to produce an acceptable water supply for its community at a reasonable cost. The costs associated with operating and evaluating a water treatment facility are covered in the Economics section of this Unit.

As mentioned before, bag filters and cartridge filters use the straining mechanism exclusively to accomplish the desired removal of particles. Therefore, there is theoretically no reason to demonstrate a filter's ability to remove *Giardia* and *Cryptosporidium* at every plant location by conducting a pilot evaluation. However, there are several reasons to conduct pilot testing.

- ❶ The first reason is to verify that the filter is capable of producing water that meets regulatory requirements.
- ❷ The second reason is to quantify the systems ability to produce a water quality that will be acceptable to the consumer.
- ❸ The third reason is to aid in the determination of the cost of operation of the proposed system.

### Regulatory Requirements

Site specific pilots are usually required for “innovative” treatment technology or for an unconventional treatment scheme.

Many regulatory agencies have limited experience with bag filtration and cartridge filtration.

To use an “innovative technology,” regulatory agencies may need to be assured through the pilot testing that regulatory requirements can be met after implementation. Check with your PA DEP regional office (listed in the Appendix) on these requirements.

### Water Quality

In addition to meeting the PA DEP requirements for turbidity and *Giardia* removal, a bag or cartridge filtration system should be piloted:

- To ensure that any occasional episodes of taste and odor in the source water are neutralized. This may require the use of powdered activated carbon.
- To ensure that iron or manganese in the source water are adequately removed.

The best way to gain acceptance of an innovative technology is to involve regulators from the very beginning of the project. This will allow all of those involved in the project to become familiar and comfortable with the proposed treatment system.

There are a number of PA DEP requirements regarding the manner in which pilot evaluations are conducted. Some of the PA DEP piloting requirements are discussed below. There may be other requirements that are not included in this discussion.

### Pilot Protocol

The first step in conducting a pilot evaluation is figuring out what to do, when to do it, and how it should be done. All of these items can and should be addressed by the creation of a pilot protocol or an operating protocol. The protocol should discuss:

- The objectives of the test.
- The pilot test conditions and procedures to be used.
- The procedures for any other special tests that need to be conducted.
- The data collection procedures including the parameters to be measured.
- The sampling techniques to be used.
- The methods for handling the data after it is collected.
- The QA/QC procedures to be used.
- The precise location and source water to be tested.
- The date and duration of the test.



After the protocol has been developed it should be submitted to the PA DEP for review and approval. Only after approval is received should testing commence.

## **Seasonal Testing**

Pilot evaluations of surface water sources require three seasons of testing. A season of testing typically consists of 30 days of operation in three different seasons of the year. The purpose is to quantify, as accurately as possible, the impacts of seasonal changes on the quality of the source water.

## ***Giardia* and *Cryptosporidium* Challenge Testing**

The treatment system may be required to demonstrate its ability to remove *Giardia* cysts and *Cryptosporidium* oocysts as part of the pilot evaluation. This demonstration may even be required during each season's testing. Challenge testing consists of introducing *Giardia* cysts and *Cryptosporidium* oocysts or microspheres the same size as *Giardia* cysts and *Cryptosporidium* oocysts into the head of the treatment process and collecting the effluent from the filters. The number of *Giardia* cysts and *Cryptosporidium* oocysts present in the effluent is compared to the number that were introduced to the head of the system and the difference between those two numbers are used to calculate the log removal that the system provided. This testing is critical to create confidence in the regulatory community.

Another measure of a bag or cartridge filter system is the cost to operate. If the system provides superior treatment but is not cost effective it will not be practical to install and operate. Costs for a treatment system can be divided into two categories:

- ❶ Capital
- ❷ Operation and Maintenance (O&M)

The impact of each of these is discussed below.

### **Capital Expense**

Capital expense can be thought of as the “up-front” costs for the system. In other words, how much does the system cost to buy. Many treatment systems can be quite expensive to purchase due to the many components required and the complexity of those components. In a bag or cartridge filter system, the component costs can be quite modest.

Depending on the system, the supplier may need to buy a number of filter housings and piping, meters, valves, and controllers to plumb the system. However, other suppliers may also need to purchase pumps and control equipment if the system can not operate by gravity flow.

With the exception of the filter housing, most of the other required equipment is common to all types of water treatment systems.

Another expense to consider is the cost of installing the new treatment equipment. Bag and cartridge filtration systems again fair well in this area. The plumbing of a filter housing is quite straight forward and can be done relatively inexpensively.

Another significant capital expense is the cost of instrumentation. Turbidimeters, chlorine analyzers, and perhaps other items will be required. Since all systems require instrumentation, bag filters and cartridge filters are again economical.

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## Operational and Maintenance Expense

Operational and Maintenance expenses include:

- **Labor:** With the appropriate on-line instrumentation, the labor expense to operate a bag or cartridge filter system is quite low.
- **Expendables like Replacement Filters:** If a filter must be purchased from a specific manufacturer, a premium might be paid for the replacement filters making a bag or cartridge filter system prohibitively expensive.



Switching to a different filter supplier would most likely require that the pilot evaluation be repeated with the new filters. The inability to “shop around” for replacement filters may force the operator to pay a premium for the replacement filters.

- **Disposal of the Waste Created by the System:** Although this is not usually a problem, if the material removed from the water is considered hazardous, disposal costs can be significant.
- **System Maintenance:** Bag and cartridge systems are quite simple so system maintenance costs tend to be low.
- **Instrumentation Maintenance:** Instrumentation maintenance costs on a bag or cartridge system are quite modest.

## Life Cycle Costs

A life cycle cost calculation takes into account the value of the equipment over the projected life of the equipment and the value of the money used to initially purchase the equipment spread over the same time frame. Things like monetary interest rates are also taken into account. These figures are manipulated to calculate the cost of the purchased equipment over the life of the equipment. To that result, an estimate of annual O&M costs are added. The result of this calculation is the life cycle cost of the equipment and the operation cost of the system.

This calculation is valuable in comparing competing treatment options. For instance, once all costs are included, a unit that is inexpensive to purchase may cost more over its useful life than a system that is more expensive to purchase.

# **ADVANTAGES/DISADVANTAGES OF BAG FILTRATION AND CARTRIDGE FILTRATION**

Here is a summary of the principal advantages and disadvantages of bag and cartridge filtration systems.

## **Advantages**

The principle advantages of bag and cartridge filtration systems are:

1. Low capital costs
2. Ease of operation
3. Little operator involvement

## **Disadvantages**

There are three principal disadvantages to the use of bag or cartridge filters.

1. The first disadvantage is that the costs of purchasing and the labor expense of replacing filters can become significant if the change-out frequency is high. One of the primary goals of the piloting process should be to estimate the required change-out frequency. If the change-out frequency is too high, operational costs may be too high to allow for the use of bag or cartridge filtration.
2. The second disadvantage is that bag and cartridge filters can only be used on very high quality waters. Most surface water supplies are not suitable for bag or cartridge filters due to high turbidity, high algae content, and/or high content of colloidal materials.
3. The third disadvantage is that, at the present time, bag or cartridge filter operation is suitable only for relatively small flow systems. Higher flow rates tend to push the economic evaluation towards more traditional treatment techniques.

**Exercise****UNIT 3 EXERCISE****Multiple Choice – Choose the best answer:**

1. Which of the following source water qualities will not affect the operation of a bag or cartridge filter:
  - a. turbidity
  - b. color
  - c. colloids
  - d. algae
  - e. Giardia
  - f. pH
  
2. Select the items that are true for bag and cartridge filters:
  - a. low “up front” cost
  - b. ease of operation
  - c. suitable mainly for high flow systems
  - g. little operator involvement
  - h. suitable for waters with high algae content
  
3. Choose the statements that are true about why site-specific piloting should be considered prior to installing a bag or cartridge filter system.
  - a. To verify that the filter is capable of producing water that meets regulatory requirements.
  - b. To quantify the system’s ability to produce a water quality that will be acceptable to the consumer.
  - c. The confidence in bag and cartridge filtration is much higher than in the conventional treatment process.
  - d. To aid in the determination of the cost of operation of the proposed system.
  
4. Is this statement True or False?

The purpose of intake screening devices on the front end of a treatment plant is to allow of large objects to pass through into the treatment plant.

  - a. True
  - b. False
  
5. The Interim Surface Water Treatment Rule was enacted to primarily control?
  - a. chlorine residual
  - b. turbidity
  - c. lead and copper

6. 3-log means the removal of \_\_\_\_\_% removal of a target organism.
- a. 90
  - b. 75 (three quarters of 100%)
  - c. 99.9
  - d. 33.3 (1/3 of 100%)

## Unit 3 Summary



### Key Points:

- Turbidity, color, colloids, algae, Giardia, and Cryptosporidium are all source water qualities that can effect the operation of a bag or cartridge filter system.
- The purpose of intake screening devices on the front end of a treatment plant is to prevent or minimize the entry of large objects or fish.
- Bag or cartridge filters should be pilot tested at the plant location.
- Bag and cartridge filters have the advantage of low “up front” cost, ease of operation, and little operator involvement.
- The Interim Surface Water Treatment Rule was enacted to primarily control turbidity.
- Use the \*current PA DEP performance standards to determine if bag or cartridge filtration is viable for a particular application:
  - a. Filter effluent turbidity less than 0.3 NTU in at least 95% of the samples analyzed each month.
  - b. Filter effluent turbidity never exceeds 1 NTU.
  - c. Filtration system provides at least 2-log removal of *Giardia* and *Cryptosporidium* cysts.
- 3-log means the removal of 99.9% of a target organisms.

\*PA DEP standards as of 2004

<sup>1</sup> Courtesy of Strainrite Companies - A Division of Lapoint Industries

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# Unit 4 – System Operation and Maintenance

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## Unit 4 - Learning Objectives

**As a result of this unit, the learner will:**

- Be able to identify the factors that determine when a filter should be removed and/or replaced.
- Be aware of the four water quality parameters that should be examined to verify the proper operation of a bag or cartridge filter.
- Review the three steps that must be completed in order to start a bag or cartridge filtration system.

Startup of a bag or cartridge filtration system is fairly straight forward. It involves:

- Loading the filter housing.
- Establishing the desired flow rate.
- Bleeding air from the system.
- Operating in filter-to-waste mode for a period of time after startup.

### **Flow Rate**

The first order of business in starting up a bag or cartridge filter system is to determine the flow rate at which to run the unit. There are a number of factors that must be considered when making this determination.

- First, the manufacturer specified maximum flow rate of the filter can not be exceeded.
- Second, it is likely that the PA DEP will have established a maximum allowable flow rate for the system based on the results of the pilot evaluation. This flow rate can not be exceeded. In fact, the PA DEP may require that a flow restrictor be placed in the effluent plumbing to assure that the maximum approved flow rate can not be exceeded.
- Third, bag and cartridge filtration systems are intended to be used primarily by small systems that have varied but low system demands. There would likely be frequent instances when system demand was in excess of the maximum permitted filter flow rate. A finished water holding tank can be used to minimize the problem with fluctuating system demand. The holding tank would likely be required by PA DEP to satisfy post filtration disinfection requirements anyway. So unless system demands vary greatly, and if sufficient finished water storage capacity is provided, the operator will be able to select a flow rate that allows for efficient system operation.

## **Air Bleed**

One important aspect of operation of a bag or cartridge filter system is the requirement to bleed out any air trapped in the system. Usually air will be introduced during filter change-out, but it may enter the system when the filter is off-line to undergo maintenance as well.

Regardless, the first order of business is to remove this air from the filter housings. In order to do this, the feed pump or valve (in a gravity system) is started or opened and water delivered to the first housing, usually the prefilter. Most filter housings have air bleed valves located on the lid. This valve should be opened to allow the air to escape the housing. After all of the air has been removed from the first filter housing, the process is repeated for the next housing. This process is then repeated in series from the first to the last filter until all of the air has been removed from the filter housings.

It is important to remove the air from the housings in order to assure that air is not trapped on the surface of the filter. Air trapped on the surface of the filter would occupy some of the available filtration area. This would cause the flow rate across the remaining filter area to be higher than permitted and could negatively impact filter performance.

## **Filter-To-Waste**

Some recently permitted bag filtration systems have been required to conduct a filter-to-waste after filter change-out.

The filter-to-waste cycle is not required to allow for the filter to mature as is the case with rapid or slow sand filtration. However, some particles that were removed by the previous filter may be inadvertently knocked off the filter during change-out and left behind in the filter housing. These particles could then theoretically pass into the effluent of the housing. For this reason, it may be prudent to conduct a short filter-to-waste after filter change-out.

Objective measures for filter performance can be divided into two main areas:

- ❶ Flow rate and
- ❷ Water quality.

### **Allowable Flow Rates**

Flow rates were discussed in the previous section. The operator's responsibility is to assure that the filter is operating within the allowable range of operation. As mentioned, some systems may be fitted with a flow restrictor to limit its flow to the maximum permitted flow.

On a system without a flow restrictor, the operator may be tempted to allow the filter to operate at a rate higher than approved. This should be avoided because it might compromise the filter's ability to remove *Giardia* and *Cryptosporidium*. By using a higher than approved flow rate, the force applied to the bag or cartridge may be sufficient to deform the fabric of the filter itself. Deforming the fabric could change the pore size of the filter and allow *Giardia* and *Cryptosporidium* to pass through the filter.

### **Surface Water Treatment Rule and Performance Standards**

Compliance with the SWTR relies on adhering to certain removal and monitoring requirements. The goal is to maximize the removal/inactivation of *Giardia* and *Cryptosporidium* from the source water. In order to verify this removal, certain performance levels are required.

- **Turbidity:** Test methods for the identification and enumeration of *Giardia* and *Cryptosporidium* are quite laborious and usually recover only 20% to 30% of the organisms in the sample. It is impracticable for an operator or lab analyst to analyze samples for *Giardia* and *Cryptosporidium* on a routine basis. For this reason, a surrogate test was developed to ensure that acceptable removals are being achieved on a consistent basis. This surrogate method should be automated or simple to do and the results should correlate well with *Giardia* and *Cryptosporidium* removal.



The surrogate is filter effluent turbidity. Filter effluent turbidity has been shown to be a reliable predictor of water quality in terms of *Giardia* and *Cryptosporidium* content.

- The PA DEP performance standards for combined filter effluent turbidity are that the filter effluent turbidity must be less than or equal to 0.3 NTU in 95% of the samples taken each month and never exceed 1 NTU. Samples of the combined filter effluent must be analyzed at least every four hours. In addition, the regulations require that individual filter effluents (or the filter effluent from individual filter trains in the case of bag or cartridge filters that use a series of filters in the train) be monitored on a continuous basis.
- Exceeding 1.0 NTU in an individual filter train effluent in consecutive samples taken 15 minutes apart at any time in three consecutive months requires the system to perform a filter self-assessment.
- Exceeding 2.0 NTU in an individual filter train effluent in consecutive samples taken 15 minutes apart at any time in two consecutive months requires the system to arrange for PA DEP to conduct a comprehensive performance evaluation no later than 30 days following the exceedence.

The PA DEP reserves the right to impose alternate compliance criteria on systems employing innovative treatment techniques like bag or cartridge filtration. These alternate compliance criteria can be no less stringent than the levels discussed above.

- ***Giardia* and *Cryptosporidium* Removal Requirements:** The operation of the filtration system will be evaluated from time to time by the PA DEP. During the evaluation, samples of raw and filter effluent water will be collected and analyzed for presence of *Giardia* and *Cryptosporidium*. If *Giardia* or *Cryptosporidium* is present in the raw water, the filter effluent must be evaluated to demonstrate that the filter is achieving a 2-log removal.
- **Virus Removal Requirements:** Viruses are extremely small organisms. Only membrane processes with extremely small pore sizes are capable of physically removing viruses from source water. Fortunately, viruses are susceptible to most disinfection techniques. In order to comply with SWTR requirements, the treatment system must demonstrate a 2-log inactivation of viruses. This is usually easily accomplished by satisfying post filtration CT requirements. CT concepts and calculations are presented in the Disinfection Module.
- **Chlorine Residual:** All treatment plants treating surface water or ground water under the direct influence of surface water are required to maintain at least a 0.2 mg/l chlorine residual at the plant tap at all times. In order to comply with this requirement, the system must continuously monitor the chlorine residual of the plant tap water.



For surface water systems, a residual disinfectant concentration may not be less than of 0.2 mg/L for more than four hours before the first customer.

- **Monitoring Requirements:** A bag or cartridge filtration system is required to continuously monitor individual filter effluent turbidity and plant tap chlorine residuals. The plant must also monitor and record the combined effluent turbidity at least every four hours.

As with any type of treatment process, certain operations must be monitored on a regular basis. The frequency of this monitoring is determined to a certain extent by the importance of the process. These checks can be classified as:

- Daily
- Weekly
- Monthly
- Annual

### Daily Checks

There are specific items that should be checked on a daily basis.

- **System Controls:** All control panels and equipment should be inspected to verify that they are functioning properly.
- **Pumps, Motors, and Valves:** These pieces should be visually checked for unusual conditions that may impact their ability to function properly.
- **Chemical Feed Equipment:** Daily checks should be conducted on the chemical feed equipment to verify its proper operation. The operator should note the amount of chemical used on a daily basis. Significant changes in the amount of chemical used from day to day could indicate a problem in the chemical feed system.



Cartridge filter vessel drains should be flushed daily.

On a daily basis the operator must check and verify that the flow, differential pressure, raw turbidity, filtered turbidity, and chlorine residual are within established acceptable ranges. The importance of each of these measurements is discussed below.

- **Flow:** As mentioned, each filter manufacturer has established a maximum flow rate for their filters. Even if the filter is operating within the prescribed range it is important to keep track of differences in instantaneous flow results since they can indicate changes in raw water quality, filter condition, or distribution system conditions.

Daily totalized flows should also be read and recorded to keep track of estimated remaining filter life or to indicate changes in system demand. Sudden changes in system demand may indicate a main line distribution system leak.

- **Feed Pressure and Differential Pressure:** The feed water pressure and differential pressure across each filter in each filter train must be read and recorded on at least a daily basis. Exceeding the manufacturer's recommended maximum feed pressure could compromise the integrity of the filter and/or the filter housing.  
  
By reading and recording the differential pressure on a daily basis the operator can predict when the next filter change-out will be due. Also, rapid changes in differential pressure can indicate significant changes in feed water quality that may require investigation.
- **Turbidity:** The importance of monitoring turbidity on a continuous basis has been previously discussed at length. It is important for an operator to become familiar with what the "normal" filter effluent turbidity is. Sudden changes in filter effluent turbidity may indicate a change in feed water quality or a problem with the installation of the filter or the filter itself.
- **Chlorine:** Finished water chlorine is a part of the process that assures the operator that the water he is producing is safe to drink. Also, sudden changes in finished water chlorine residual can indicate a change in the feed water quality or a problem in the filtration system.

### Weekly Checks

There are certain maintenance activities that should be looked at on a weekly basis (at a minimum):

- **Clean Equipment:** While it is not necessary to get the scrub brush out and scrub down all of the operating equipment every week, it is important to check the equipment once a week to make sure it is in a presentable condition. Remember, a water plant produces a product for human consumption. In addition, by keeping equipment clean, it may be easier to spot changes in the condition of the equipment. For instance, a gearbox leaking grease may not be noticed if you didn't wipe off the housing after the last time you greased it.
- **Chemical Inventory:** Running out of a critical treatment chemical is inexcusable. For this reason, a weekly chemical inventory check should be done. The weekly check can also reveal changes in chemical demand that may not be apparent on a day to day basis. Chemical feed pumps tend to loose capacity gradually, so succeeding days' usages may be just slightly less than the previous day and not readily noticeable. However, after a week, a pump's loss of capacity will become apparent.
- **Lubricate Equipment:** Rotating equipment like pumps undergo a significant amount of stress even under normal operating conditions. In order to minimize the effects of this stress, it is important to provide all of the mechanical equipment with the necessary lubrication. Follow manufacturer's recommendations and maintain a regular lubrication schedule.

- **Operate Valves, Other Mechanicals, and Standby Equipment:** Many valves and other mechanical equipment do not operate on a regular basis. For instance, the suction and discharge valves on a high service pump may always be in the open position. These valves are provided primarily as a way to isolate the pump for maintenance. If the valves are not exercised on a regular basis they may seize in place and be inoperable when they are needed. For this reason, it is important to operate all of the mechanical equipment on a regular basis to ensure that it will function when needed.  
  
A similar situation may occur with emergency standby equipment such as a diesel generator or pump. If these pieces of equipment are not regularly used, they may not work properly when needed.
- **Change Charts/Verify Archive:** Most water facilities have a method to record certain types of operating data. It may be a circular or strip chart recording the filter effluent turbidity, or it could be tank elevation data being saved by a Supervisory Control and Data Acquisition (SCADA) system. Regardless of how the data is collected and stored, the operator should verify that it is being saved on a weekly basis. This may consist of saving files in the PC or querying the SCADA system to verify that the data exists. Or it may involve changing the weekly circular chart and putting last week's on the stack with the others.
- **On-line Analytical Equipment:** The proper operation of the on-line analytical equipment should be verified on at least a weekly basis. Verifying that there are proper flow rates and accurate equipment readings is critically important to the operation of a water treatment facility. Recommended flow rates will be listed in the O&M manuals provided with the equipment. Accuracy of the readings can be determined by comparing the on-line analyzers readings to the results obtained from a calibrated bench top instrument.

## Monthly Checks

After completing daily and weekly checks the operator can have confidence that the day to day operations of the plant will be relatively trouble free. However, there are activities that can be conducted less frequently to assure long term reliable plant operation. Some of these activities are described below.

- **Inspect Pumps and Chemical Feed Equipment:** Although this equipment is checked on a daily basis, more intensive monthly inspections may reveal significant problems that are not obvious to a cursory visual inspection. More intensive inspection activities may include verifying that pump flow and discharge pressures are within original specifications and verifying that the bearing or pump motor temperatures are not exceeding manufacturer's recommendations.
- **Verify Proper Functioning of Safety Equipment:** Safety equipment is not useful if it malfunctions at the time it is needed. A good monthly inspection of safety equipment will ensure that the equipment will function properly when needed. Items to check include fire extinguishers and self-contained breathing apparatus.

- **Calibrate On-line Analytical Equipment:** On-line analytical equipment can be a valuable tool to an operator. An operator's duties do not permit time to continually analyze raw and tap water samples. That is one of the greatest benefits of on-line analytical equipment. It watches the water quality for the operator.

If this equipment is not reading accurately, it is at best useless and at worst misleading. In order to have complete confidence in the on-line analytical equipment, it should be calibrated at least monthly. If the operator is confident in the accuracy of the on-line analyzers, he can react quickly to changes in raw or finished water quality.

### Biannual Checks

While it is important to keep an eye on all the components of a plant, inspection of some items can be less frequent. Biannual (twice per year) inspection is suggested for the following items.

- **Piping:** Although the vast majority of piping in a water system is buried and can not be regularly inspected, there are usually a number of pipe segments in the plant that can be visually inspected. Things such as leaking joints or misalignment can be observed during inspections and repairs made prior to a catastrophic leak.
- **Other Equipment and Facilities:** A water treatment plant consists of the treatment equipment and the buildings that house it. Most of the treatment equipment is inspected at least on a monthly basis. The buildings and other facilities should be inspected regularly to verify that they are still in serviceable condition. For instance, building walls should not show signs of cracking and the perimeter fence should be intact.

### Annual Checks

There are some preventative maintenance activities which can be conducted even less frequently than those described above. Annual checks should be conducted on the following items.

- **Internal Pump Inspection:** Although an operator should visually check pumps daily, some problems may not be apparent unless the pump is disassembled and inspected. Follow manufacturer's recommendations for pump inspection and maintenance.
- **Calibrate Flow Meters:** Nearly all of an operator's treatment activities are based on flow through the plant. Chemical dosages, production figures and other items rely on accurate flow readings. For this reason the plant's influent and effluent meters should be calibrated at least annually.

Maintenance requirements for a bag or cartridge filter system are very minor. Some of these activities for the mechanical equipment were discussed in the previous section. The activities required to maintain the filtration system itself will be discussed in this section.

### Filter Replacement

The only significant maintenance activity for a bag or cartridge filter system is the replacement of the filter itself. Two areas that will be discussed are the:

- ❶ Criteria used to determine when filter replacement is necessary, and the
- ❷ Procedure used to change the filter.

#### Criteria

There are three main criteria that may be used to determine when filter replacement is necessary. They are filter pressure differential, filtered water quality, and flow rate.

- **Pressure Differential:** This is the most important and widely used criterion to determine when filter replacement is necessary. Because a deformed filter may not operate properly, if the filter becomes deformed because of a pressure differential, it must be replaced.



Cartridge filters should be changed when the pressure drop reaches 15 psi.

- **Filtered Water Quality:** Filter replacement may be required if the filtered water quality is unsatisfactory. Even if the filter has not reached its maximum pressure differential, if the filtered water quality is unsatisfactory, filter replacement may be required.

Specifically, the filter effluent turbidity may be higher than allowed. If that's the case, filter replacement may correct the problem. If it does not, changes in feed water quality may be responsible for the change.

- **Flow Rate:** It is possible (though not very likely) that as the filter ages the flow rate through the filter will decrease to the point that the minimum desired flow can not be maintained even though the pressure differential is acceptable. In this case, it may be possible to increase the flow rate by replacing the filter.

## Procedure

The procedure used to replace a bag or cartridge filter is specific to each manufacturer's filter. There are however a number of steps common to all bag and cartridge filters and those will be discussed in general terms. These steps are:

1. Depressurization
2. Filter removal
3. Filter replacement
4. Re-pressurization/air bleed
5. Filter-to-waste cycle

- **Depressurization:** The first step in the filter replacement procedure is to shut off the filter and depressurize the system. The procedure used to shut off the filter will be site-specific and dependent on the way the system was constructed and plumbed, but it most likely involves closing the feed valve (or shutting off the feed pump or both) to the filter train or housing. (Note: depending on the way the system is plumbed and the hydraulic characteristics of the system, it may be necessary to close the effluent valve of the filter train as well.)

After the valve has been closed, the filter housing will still be under pressure. It must be bled before it can safely be opened. Most filter housings will include small taps and valves somewhere on the filter housing. In order to depressurize the system, one of these valves should be opened slowly and the pressurized water allowed to drain from the housing.

- **Filter Removal:** Depending on the type of filter and the manufacturer's housing design, the procedure to remove the filter may be somewhat different from the method described herein. Removal consists of loosening and removing the lid or cap of the filter housing to access the filter itself. A bag filter system usually includes some type of wire basket or mesh in which the filter is placed. During replacement, the filter and basket are removed from the housing. A cartridge filter typically does not include a basket and the removal consists of merely removing the filter from the housing. Some bag or cartridge filters may have clips, retaining rings, or glands that will need to be removed in order to remove the filter from the housing.



The vast majority of bag and cartridge filters are not reusable. Do not attempt to clean and reuse your spent filter unless the manufacturer allows for filter cleaning and the cleaning and rinsing procedure is followed to the letter.



A bag or cartridge filter approved for Giardia removal should be replaced if it becomes clogged.

- **Filter Replacement:** After removal of the spent filter, a new one should be placed in the basket (if bag filters are used) and then placed into the housing. The proper placement of the filter is critically important so that no unfiltered water can bypass the filter. If the filter assembly consists of

clips, rings, or glands, they must be used to secure the new filter. There can not be any “spare” parts left over after the replacement is complete.



When performing a routine inspection or maintenance on a bag or cartridge filter approved for Giardia removal, divert the flow through a back up filter unit.

- **Re-pressurization/Air Bleed:** After the filter has been replaced, the system will need to be placed back into service. The first step to accomplish this is to re-pressurize the system. This basically means sealing up the filter housing and opening the influent (and perhaps effluent valve). There will be a significant amount of air in the housing at this point.

In order to allow the filter to function properly, this air will need to be removed from the system. This can be accomplished by opening the valve that was used to depressurize the system and allowing the air to escape through it. (If there is more than one valve on the filter housing, it could be used to bleed the air from the system. Choose the one closest to the top of the housing.) After all of the air has been removed from the housing, the valve can be shut.

- **Filter-To-Waste:** After the filter has been replaced and the system re-pressurized, the system should be run in filter-to-waste mode for a period of time. This can be accomplished by manipulating valves on the effluent side of the filter train and directing the filter effluent away from the clearwell and into a waste handling or discharge system.

The need to conduct filter-to-waste on a mechanical filter system has been debated in the past. However, to safeguard the quality of the effluent, a short filter-to-waste cycle is a prudent safety measure.

The length of time required to operate the filter in filter-to-waste mode is open to question. Some plants filter-to-waste until the effluent turbidity is less than regulatory regulations, 0.3 NTU in this case. Some plants operate until the effluent turbidity is equal to or less than the combined effluent turbidity of the other filter trains. Still others pick a certain amount of time, usually about 15 minutes to operate in filter-to-waste and then return the filter train to service. The decision on how long to filter-to-waste or what quality to accept should be made by the operator in consultation with the PA DEP.

There are a number of unusual conditions that an operator may observe during the operation of a bag or cartridge filter. These conditions can indicate specific problems with the feed water quality or in the system itself. Since all of the bag or cartridge filter systems are manufacturer specific, the troubleshooting tips presented are general in nature.

## High Differential Pressure

High differential pressure can be classified in two ways:

- ❶ A rapid climb in differential pressure or
- ❷ An abnormally high initial differential pressure.

A rapid climb in differential pressure during the filter run is most likely caused by a deterioration in feed water quality. If feed water turbidity has not changed significantly, the problem may well be caused by an increase in the algae content or other constituent in the feed water. Consistent monitoring of feed water quality will help the operator in identifying what characteristics of the feed water have changed.

The only way to fix a problem with the feed water quality is to treat it prior to entering the filtration system. For instance, if the system used a raw water reservoir as a source of supply and algae was causing the increase in the pressure differential, treatment of the reservoir with an algaecide may help to alleviate the problem.

If the pressure differential is abnormally high at the beginning of the filter run, suspect that the filter may have been mis-installed. To verify this, check the installation and if necessary remove and reinstall the filter. If necessary, the filter showing the high initial differential can be replaced with another filter. If the problem persists, suspect a change in feed water quality.

## Short Run Times



**Run Time:** the length of time a filter can produce filtrate before being clogged.

If the run times of the filter are shorter than previously experienced, the problem could be related to feed water quality or filter installation. Again, there is no substitute for water quality records. Examine these records and compare them to current water quality. If the water quality appears to be satisfactory, suspect a problem with the installation or operation of the filter train. For instance, if the final filter is experiencing extremely short run times and the prefilter has not shown any head loss for the last two weeks, suspect that the prefilter has failed and is not doing its job.

## Water Quality

There are a number of finished water quality parameters that should be monitored

- Turbidity
- Particle counts
- *Giardia* and *Cryptosporidium* levels

If the operator notices an increase in turbidity or particle counts immediately after a filter change out, a mis-installation of the filter should be suspected. If the turbidity or particle counts increase to abnormal levels later in the filter run, the operator should suspect a change in feed water quality or a filter failure.

A failure of a filter would likely be extremely rare and would most likely be accompanied by other changes in the operational characteristics of the system. For instance, if the filter has failed, a change in water quality would probably be accompanied by an increase in flow or a decrease in pressure differential or both.

Troubleshooting is a talent that must be learned. The more experience an operator has with a treatment system, the more adept he will become at identifying and correcting operational abnormalities.



## Exercise

## Unit 4 Exercise

## Multiple Choice – Choose the best answer:

1. Cartridge filters should be changed when the pressure reaches \_\_\_\_\_ psi.
  - a. 5 psi
  - b. 10 psi
  - c. 15 psi
  - d. 20 psi
2. Cartridge filters drains should be flushed \_\_\_\_\_ .
  - a. daily
  - b. bi-weekly
  - c. weekly
  - d. monthly
3. Which one of the following statements is true? **(Choose all that are correct)**
  - a. A bag or cartridge filter approved for Giardia removal should always be repaired if it becomes clogged.
  - b. A bag or cartridge filter approved for Giardia removal should always be removed and replaced with a new filter if it becomes clogged.
  - c. When doing a routine inspection or performing maintenance on a bag or cartridge filter approved for Giardia removal, divert the flow through a backup filter unit.
  - d. When doing a routine inspection or performing maintenance on a bag or cartridge filter approved for Giardia removal, divert the flow through a chlorinator or UV light.

## Fill in the blank:

4. Four water quality parameters that should be examined to verify the proper operation of a bag or cartridge filter are: filtrate turbidity, Giardia and Cryptosporidium removal, \_\_\_\_\_, \_\_\_\_\_, and chlorine residual.
5. The three steps that must be completed to start a bag or cartridge filter system are: establish/verify the proper flow rate, then bleed any air from the system, and finally operate in \_\_\_\_\_ mode.
6. The use of \_\_\_\_\_ at the filters to obtain a continuous record of head loss and flow rate is advantageous because it provides an easily monitored means for determining the best time to change the filter.
7. For a surface water system, the required residual disinfectant concentration may not be less than \_\_\_\_\_ mg/L for more the \_\_\_\_\_ hours before the first customer.

### Unit 4 Summary



#### Key Points:

- Cartridge filters should be changed when the pressure drop reaches 15 psi.
- Cartridge filter vessel drains should be flushed daily.
- A bag or cartridge filter approved for Giardia removal should always be removed and replaced with a new filter if it becomes clogged.
- When doing a routine inspection or performing maintenance on a bag or cartridge filter approved for Giardia removal, divert the flow through a backup filter unit.
- The use of chart recorders at the filters to obtain a continuous record of head loss and flow rate is advantageous because it provides an easily monitored means for determining the best time to change the filter.

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# Unit 5 – Record Keeping

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## Learning Objectives

**As a result of this unit, the learner will:**

- Review the three types of operation records that should be maintained for bag and cartridge filtration systems.
- Receive a description of the three types of plant records that should be maintained.
- Be aware of reasons to maintain good maintenance records.

### **Analytical Records**

Records of raw and finished water quality can be a very useful reference for an operator experiencing treatment difficulties. Referring to past treatment practices may reveal the solution to a current treatment problem. State regulations require that some records be maintained at the treatment plant. At a minimum, the operator will want to save the results of raw and finished turbidity and finished chlorine. Raw water pH levels may also be of particular interest, especially if raw water algae levels become problematic.

### **Sampling Records**

A log of date, time, and location of samples taken for SDWA compliance should be maintained. This can be a useful guide for a new employee who may not know what the sampling requirements are. It can also serve as verification that the samples were collected and submitted. In addition, a record of samples taken to maintain operational control can be useful.

### **Filter Replacement Records**

At times questions arise as to when an activity was last conducted. For instance, filter replacement will most likely be a fairly regular activity. By consulting operational records, the operator can predict when the next filter replacement will be required. Likewise, if the operator suspects that the filter replacement frequency is increasing, a quick check of the records can verify it.

After filter replacement, a record of initial pressure differential across the filter can be helpful in verifying proper filter installation or problems in the filter train.

Any mechanical system will require periodic maintenance and repair. The procedures used to take the equipment off-line and conduct the maintenance or repair activities are facility and equipment specific. For this reason, it is imperative that the facility maintain records of:

- The equipment installed at the plant (shop drawings),
- The configuration of the equipment as installed (as-builts), and
- The flow path of the water as it travels through the facility (plant flow schematics).

### **Shop Drawings**

Shop drawings are the manufacturer supplied information about the equipment installed at the plant. The shop drawings should include the specific make and model of the equipment, any major component parts, and suggested spare parts list. The shop drawings should also include suggested maintenance activities and frequencies. Shop drawings are critically important for any water treatment facility. Care should be taken to maintain these records in an organized fashion. It may be advisable to make photocopies of the shop drawings for each piece of equipment. The photocopy can be used while conducting maintenance while the original is safe and undamaged in the plant files.

### **As-Builts**

Plant as-builts are drawings of how the equipment at the plant was assembled and its position in the facility. Usually a plant is designed by an engineering firm and blue prints showing the layout of plant equipment and facilities are created. At times, the contractor constructing the facility happens upon conditions in the field which would make it difficult or impossible to construct a portion of the facility as designed. In those cases, field changes to the design may be required. As-built drawings reflect these changes and depict the actual conditions. For this reason, plant as-built drawings are an indispensable part of the plant records.

### **Plant Flow Schematics**

Although a bag or cartridge filtration facility is relatively simple and offers a very simple flow path, it is important to have a schematic diagram of the flow path through the plant. At times, piping and valves can form a “spaghetti” of lines at the plant. Plant flow schematics are a good way to identify the major lines at the plant without digging out the as-built drawings. Plant flow schematics are also a good way to introduce new employees to the treatment process.

Plant equipment maintenance records should include a list and description of the procedures that need to be conducted and a record of the procedures that were conducted. Well kept maintenance records can be a valuable tool for the operator.

### Maintenance Procedures

As mentioned previously, plant shop drawings should contain the manufacturer specified maintenance procedures and frequencies. The operator may find it helpful to create a file that contains a list of maintenance procedures and techniques for each piece of equipment at the facility. This will aid in conducting the maintenance procedures on the proper schedule and will help in using the proper procedures when conducting the maintenance.

### Documentation of Maintenance Conducted

Maintenance records should include, at a minimum:

- Date the maintenance was conducted.
- Who conducted the procedure.
- Comments on the condition of the equipment before or after the maintenance.

### Uses of Maintenance Records

One use of maintenance records has already been described. The records can also be used to determine when the next scheduled maintenance will be due and assist the operator in planning his activities for the next week or month.

Maintenance records can also be used in budgeting. By examining the scheduled maintenance for next year, the operator can estimate what the cost of replacement parts or contractor conducted maintenance will be. This can be useful when computing the plant's operating budget for the following year.

**Exercise****Unit 5 Exercise****Fill in the blank.**

1. A log of date, time, and \_\_\_\_\_ of samples taken for SDWA compliance should be maintained (check with your local PA DEP office in the Appendix for sample record keeping requirements).
2. Filter replacement records may assist the operator in determining if \_\_\_\_\_ replacement frequency is increasing.
3. Good maintenance records can aid in conducting maintenance procedures on the proper schedule and will help in using the proper \_\_\_\_\_ when conducting maintenance.
4. At a minimum, \_\_\_\_\_ and \_\_\_\_\_ water turbidity and finished chlorine records should be kept. (Check with your local PA DEP office in the Appendix for analytical record keeping requirements).
5. It is recommended the following three plant records be maintained: shop drawings, as-built and \_\_\_\_\_ schematics.

### Unit 5 Summary



#### Key Point:

- Maintain the analytical records for raw and finished water turbidity and finished chlorine.
- It is a good idea to kept good maintenance records
- It is a recommend that shop drawings, as-built drawings, and plant flow schematics be retained.

***Definitions:***

**Bag filters** are defined as a fabric filter designed primarily to remove particulate material from fluids. Bag filters are usually non-rigid, disposable, and easily replaceable.

**Cartridge filters** are defined as fabric or polymer-based filters designed primarily to remove particulate material from fluids. They are usually rigid or semi-rigid and manufactured by affixing the fabric or polymer to a central core. Cartridge filters are disposable and easily replaceable.

**Colloid** is a small solid particle in suspension that will not settle by gravity.

**Giardia cysts and Cryptosporidium oocysts** are protozoan found in water. They can cause diarrhea and other health-related problems if ingested.

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

**Pressure Differential** is the difference between the inlet pressure and the outlet pressure of the filter.

**Run Time** is the length of time a filter can produce filtrate before being clogged.

**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.

### ***Related information***

**Solids Removal:** In some instances, bag filtration or cartridge filtration is used to remove solids from a waste stream. For instance, many water treatment plants discharge their waste water to a receiving stream or sanitary sewer system.

- National Pollution Discharge Elimination System (NPDES) Discharge: Nearly all NPDES Permits contain a limitation on the amount of total suspended solids limits that can be discharged. A bag filter or cartridge filter can be used to remove suspended solids from the plant's wastewater effluent.
  
- Sanitary Sewer Discharge
  - Solids accumulation in collection system: Some sewer systems may have inadequate velocities in sections of their collection systems due to low flows or an oversized sewer main. If this is the case, these sections of the system can accumulate solids. For this reason, some sewer authorities will require water plant wastewater to be filtered prior to discharge to the collection system. The filter removes the solids so that they cannot accumulate in the collection system. Bag filters or cartridge filters can be used for this application.
  
  - Interference with treatment process: Sewer plants are designed to treat human or perhaps industrial wastes. Solid inert material contained in the wastewater from a water treatment plant can inhibit the effectiveness of the sewer plant's treatment process. By filtering the water plant's wastewater, the solids can be removed before they can have a negative impact on the sewer plant's processes.

**DEPARTMENT OF ENVIRONMENTAL PROTECTION FIELD OPERATIONS  
REGIONAL OFFICES:**

<u>REGION</u>	<u>ADDRESS</u>
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