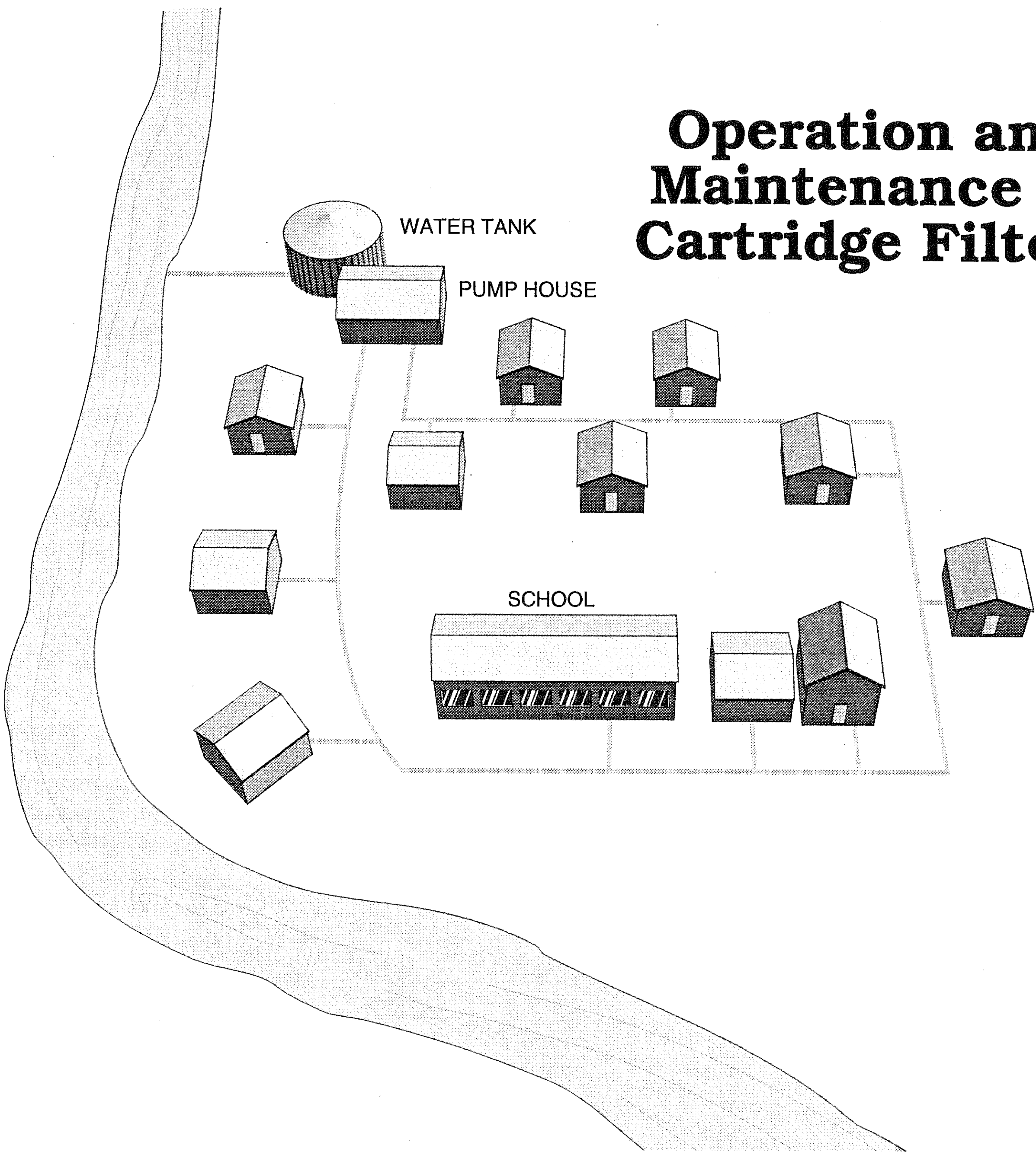
O & M of Small Water Systems

Operation and Maintenance of Cartridge Filters



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O & M of Small Water Systems

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O & M OF CARTRIDGE FILTERS

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- Dosage
- Filtration rates
- Giardia
- Headloss
- Micron
- ntu
- Pathogen
- Pressure drop
- pH
- Residual
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O & M OF CARTRIDGE FILTERS

INTRODUCTION

SWTR

In most instances the **SWTR**[1] requires public water systems using surface water or **GUDISW**[2] to filter the supply. The rule describes performance criteria for four types of common **filtration**[3] systems; conventional, direct, slow sand filters and diatomaceous earth.

Assumption

It is assumed that if these systems are properly designed and effectively operated and used in conjunction with disinfection they can protect the customer against infection from waterborne **pathogens**[4].

Alternative Technology

The typical filtration systems are often too expensive for small systems to construct or operate. One of the ways to reduce the construction and operation cost is to use an alternative filtration technology such as cartridge or bag filters. These systems can be cost effective in systems where the consumption is less then 100,000 gallons per day. In order for a cartridge or bag filter to effectively protect the customer it must meet specific criteria. These criteria are discussed below.

Consensus Protocol

The EPA has produced a document called the "Consensus Protocol." This document was the result of an effort undertaken by a workgroup composed of drinking water agency representatives from seven (7) western states including Alaska. The document describes the methods to be used for evaluation and acceptance of any alternative filtration technologies for small systems. The document gives specific guidelines for cartridge and bag filters.

General Criteria

One of the basic criteria set down in the guidance manual is that any alternate technology must be able to meet the turbidity performance criteria for slow sand filters. The basic criteria for slow sand filters is to produce a turbidity of less than 1 **ntu**[5] in 95% of the samples and never exceed a turbidity of 5 ntu's. Also, the alternate technology in conjunction with disinfection must be able to consistently achieve a 99.9 percent (3 log) removal and /or inactivation of

[1] **SWTR** - Surface Water Treatment Rule, a portion of the Safe Drinking Water Act
[2] **GUDISW** - Groundwater Under the Direct Influence of Surface Water - Water under the earth's surface with significant occurrence of insects or other microorganisms or significant and relatively rapid shifts in water characteristics such as turbidity, temperature, conductivity or pH that closely correlate to climatological or surface water conditions.
[3] **Filtration** - The process of passing through a filtering medium (which may consist of granular material such as sand, magnetite, or diatomaceous earth, finely woven cloth, unglazed porcelain, or specially prepared paper) for the removal of suspended colloidal matter.
[4] **Pathogenic Organisms** - Bacteria, virus and protozoa which can cause disease.
[5] **ntu's** - The units of measure of turbidity, Nephelometric Turbidity Units. The measurement as made with a nephelometric turbidimeter.

Giardia[6] and a 99.99 percent (4 log) removal and/or inactivation of **viruses**[7].

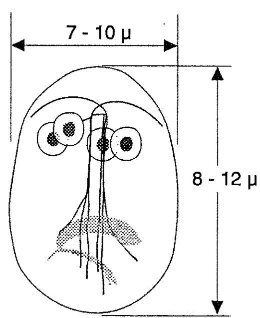
PATHOGENS & CARTRIDGE FILTERS

Source of Giardia

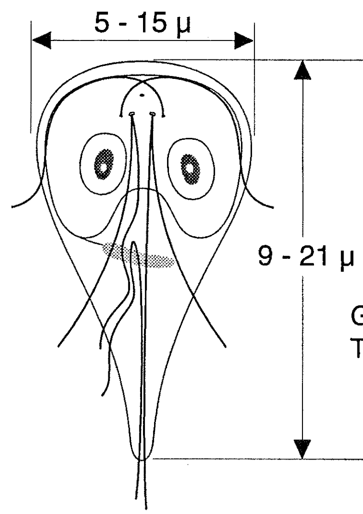
Giardia are pathogenic **protozoa**[8] that normally live in the intestinal track of warm blooded animals. These protozoa enter the water supply from fecal matter deposited directly along side of the water supply. Once outside their host, the Giardia change their form, and develop into a cyst. In this form they are extremely difficult to destroy with chlorine or other forms of disinfection. Once a cyst enters a human the cyst becomes active and begins to multiply infecting the human host.

Giardia Size

Giardia cysts are relatively large, ranging in size from 10 to 15 **microns**[9] in length and 6 to 8 microns in width. Their large size makes it possible to remove them utilizing some forms of filtration.



Giardia lambia
Cyst form



Giardia lambia
Tophoaoite form

National Park Service

In 1990 the National Park Service had 28 surface water systems in the Pacific Northwest that produced between 500 gpd and 60,000 gpd. In 1990, the NPS completed a study of the sources of supply for these systems and tested the ability of cartridge and bag filters to remove Giardia cysts. During the study it was determined that Giardia cysts occurred in 40% of the samples collected and ranged in concentration from 2 cysts per 150 gallons to 6,000 cysts per 95 gallons of water. It should be apparent from this small study that Giardia may be present in any surface water supply and must be addressed.

6 **Giardia** - A pathogenic, flagellated protozoa that forms a cyst and causes the disease Giardiasis in humans.
7 **Viruses** - A submicroscopic organism which passes through filters which will strain out most bacteria and protozoa.
8 **Protozoa** - A small one-celled animal including, but not limited to, amoebae, ciliates, and flagellates.
9 **Micron** - One, one thousandth of a millimeter(1/1000 mm or 0.001mm) or 1/254,000 of an inch.

"Crypto"

The SWTR and the guidance manual do not directly address the protozoa Cryptosporidium. At the time of the development of this training material no studies on the effectiveness of cartridge or bag filters on removal of this protozoa have been completed. The "Crypto", like Giardia, is a large protozoa ranging in size from 4 to 5 microns. The conclusion is that the filters may also be able to remove this protozoa.

About Viruses

At the time that this text was developed no studies had been completed to indicate the effectiveness of cartridge filters in removing viruses. Nearly all of the studies conducted to date utilized filters with a **nominal**[10] micron size of 1 micron or larger. This is much too large to remove viruses.

Disinfection & Virus Inactivation

The SWTR requires that all alternate filtration technology must be combined with appropriate disinfection. On page 4-26 of the Guidance Manual there is the indication that a system which can achieve a 0.5 log inactivation of Giardia cyst using free chlorine will achieve greater than 4-log inactivation of viruses. A total removal or inactivation of 3 logs is required for Giardia. Cartridge filters have proven to provide only a 1.5 to 2 **log removal**[11] of Giardia and are required to provide a **CT**[12] high enough for an additional 1 to 1.5 inactivation of Giardia. Therefore, (based on the indication that 0.5 log inactivation of Giardia provides 4-log removal of viruses) it may be assumed that some inaction of viruses will be accomplished by a cartridge filter system. (However, note the limitations for using cartridge filters described below.)

[10] **Nominal - Nominal Size** - In relationship to cartridge and bag filters this is the manufacturer's rating of the typical size of the smallest particle that can routinely be removed with the filter. The absolute size may be larger or smaller and is commonly derived by testing the filters and determining the percentage of a specific size sphere that can be removed, called the filter efficiency. Also called the filter rating size.

[11] **Log Removal** - A mathematical relationship relating percent inactivation to logarithmic inactivation.

[12] **CT** - The product of "residual disinfectant concentration" (C), in mg/l, determined before or at the first customer, and the corresponding "disinfectant contact time" (T), in minutes.

THE USE OF CARTRIDGE/BAG FILTERS

Criteria

When cartridge and bag filters are used they must be able to meet the following criteria:

- Meet the "Consensus Protocol" selection process,
- Be used in conjunction with an approved form of disinfection,
- Produce a turbidity of less than 1 ntu in 95% of the samples and never produce a turbidity over 5 ntu,
- In conjunction with disinfection provide a 3-log removal and/or inactivation of Giardia and a 4-log removal and/or inactivation of viruses.

Disinfection Criteria

Ultraviolet light is not an acceptable means of disinfection when used with cartridge or bag filters because it has little or no effect on Giardia. Ozone may be used as an alternative, provided chlorine is also used to provide the required residual entering the distribution system.

Chlorine Criteria

When chlorine is used the CT value must be such that a minimum of 0.5 log inactivation of Giardia is achieved.

Limitation

The Consensus Protocol lists the following limitations for using cartridge and bag filters.

- They are mostly suitable on low turbidity waters.
- They can be used only on sources with a low potential for human enteric virus contamination (determined as a result of an on-site review).
- The source must have a turbidity of less than 5 ntu or.
- If the source has a turbidity of greater than 5 ntu, the system must be equipped with continuous turbidity monitoring and a high turbidity bypass or shut down system.
- The system must be equipped with a reliable pretreatment system that reduces the turbidity to less than 5 ntu.

Limitations Identified by NPS

In the study described above, the NPS determined that the six cartridge filters they tested only provided a 20 to 40% reduction in turbidity when the **raw water**[13] turbidity was less than 0.5 ntu. As a result it was assumed that turbidity removal could not be effectively used to determine the effectiveness of the cartridge filter in removal of small particles.

[13] **Raw Water** - Water that has not been treated and is to be used, after treatment, for drinking water.

TYPES AND SELECTION OF CARTRIDGE/BAG FILTERS

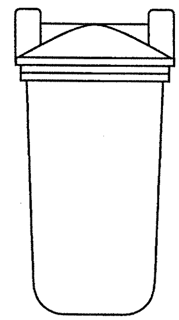
EQUIPMENT

Materials

A bag or cartridge filter is a replaceable, disposable element. Bags are made of various materials, the most common is a polypropylene woven material placed over a wire or plastic frame. The most common cartridges are made from polypropylene, glass fiber, or cellulose material. The fiber is wound into a tube and held together with a resin. One other popular type of cartridge filter is the cleanable ceramic filter.

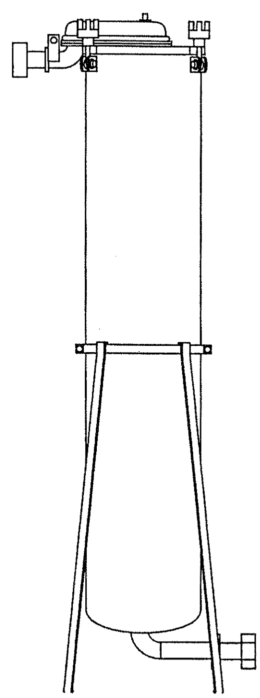
Sizes of Cartridge Filters

Cartridge filters are commonly about 9.75" in length and 2 3/8 inches in diameter. These are referred to as 10 inch filters. Some manufacturers also provide cartridge filters that are 20 and 30 inches in length.



Sizes of Bag Filters

The most common bag filters presently being used are the 3M™ brand filters. These filters are 6.5 inches in diameter and are available in three different lengths; 14 inches, 28 inches and 39 inches. The 28 inch length is the most common and is called a 30 inch filter.



Housings

The small cartridge filters are available with stainless steel or plastic housings. The bag filters are typically installed using stainless steel housings. Housings may hold a single filter or multiple filter elements. With the exception of the bag filters which can hold several filter elements of the same size, the multiple filter elements have not proven to be the most effective in Giardia removal. Several tests that were conducted indicated problems with leakage around the filter element when multiple cartridge housings were used.

OPERATIONAL CONSIDERATIONS

Flow Capabilities

Each manufacturer rates their filter for a set flow and **pressure drop**[14]. Unfortunately there is no set standard for how the flow and pressure drop are to be calculated. Flow rates vary from 1 gpm for the 10 inch ceramic filter and 2 gpm for most other 10 inch filters to 1 gpm per inch for bag filters (30 gpm for a 30 inch bag filter).

Pressure Drop

The manufacturers' literature and the studies performed on various cartridge and bag filters refer to what is commonly called **headloss**[15] on a filter as pressure drop. This is the difference in pressure between the influent and effluent of a filter. This value as provided by the manufacturer is the initial pressure drop when the filter is new.

Pressure Symbols

Symbols used to indicate this pressure differential are; psid for pressure drop or differential and Δp (Δ is the Greek letter delta and is used to indicate change). The rated pressure drop of most of the filter systems is of the filter itself and does not include the housing. Therefore, the actual pressure drop measured under normal operating conditions will be higher than what is printed by the manufacturers.

Cause of Pressure Drop

The pressure drop across a filter is dependent on many factors among them are:

- flow through the filter,
- surface area of the filter,
- thickness of the filter material,
- the size of the fibers used to make the filter,
- the type of filter material, and
- the permeability (directly related to pore size) of the material.

While these factors should be considered and compared when selecting a filter, the two most important factors affecting pressure drop on an existing filter are pore size and flow. As the flow goes up so does the pressure drop. As the pore size, in microns, goes down the pressure drop of the filter goes up.

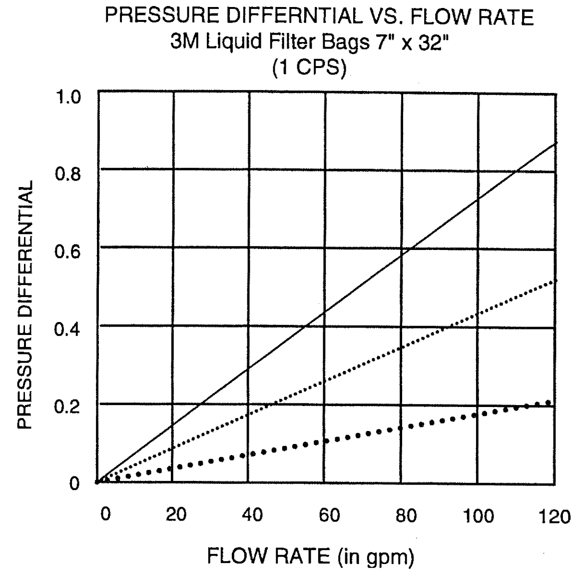
Pressure vs. Flow

As was noted above the pressure drop across a filter and the flow through the filter are directly related to one another. The ceramic filter shows the highest pressure drop with 90 psi at 5 gpm. Most of the other filters, those made from polypropylene, have an initial pressure drop of between 0.15 and 0.6 psi at their

[14] **Pressure Drop** - The difference between the inlet and outlet pressures of a cartridge filter. As provided by the manufacturer of the filter this value does not include the pressure drop across the housing.

[15] **Headloss** - As it applies to a water filter, the difference between the pressure or head on the top of a filter and the pressure or head on the underdrain of the filter.

rated flow. Below are two curves, one is for the ceramic filter and the second is for the 3M™ bag filter. These curves are not intended as a comparison of products but are shared here to show the relationship between pore size, flow and pressure drop.



Water Temperature

One of the problems in comparing the flow rates of one type and brand of filter to another is knowing the temperature of the test water. The colder the water the greater its density and viscosity. Thus, warm waters will filter with a lower headloss at the same flow rates than cold water. Most of the test results observed in the manufacturers' material were at 68°F, much warmer than most water in Alaska.

Removal Efficiency

Filters are rated by micron pore size. However, there is no actual hole or pore through the filter. The water weaves its way through a maze and material is filtered out along the way. The pore size is related to the size of the particles that can be removed by the filter. The manufacturer's rated size is called nominal size. What the filter will actually remove is related to its true size and is dependent on flow rate and differential in pressure. The actual removal of particles through a filter is called its efficiency. The size of material that the filter can remove is called the **absolute size**[16] of the filter.

Comparison of Efficiencies

In the NPS study comparing six filters, efficiency ranged from a low of 58% to a high of 94% for particles ranging in size from less than 10 microns to particles greater than 200 microns. However, in the Giardia size range (10 to 25 microns) the efficiency ranged from 90 to 97%. One of the difficulties in comparing efficiencies is that there is no set of standards on how the efficiency is to be determined. In the NPS study, all of the filters were operated under the same

[16] **Absolute Size** - The absolute size range that a filter can remove with a high (above 90%) efficiency.

flow, pressure, **particle size**[17] and quantity loading conditions. If you are making the selection and wish to compare you should compare, flow rates, pressure drop, and length of operating time at a specific particle size and quantity loading.

Turbidity Considerations

With most filters, turbidity is a good measure of the efficiency of removal. However, cartridge and bag filters selected for small water systems seldom have a pore size of less than one micron. Since colloidal particles that make up turbidity are primarily less than one micron the efficiency of removal of turbidity is not a reliable indicator. Again, in the NPS study efficiency of turbidity removal ranged between 20 and 40% when the raw water was below 0.5 ntu. It is conceivable that this efficiency will improve with waters of higher turbidity. However, higher turbidities will shorten the run time of the filter.

Selection

The selection of a cartridge filter should be based on:

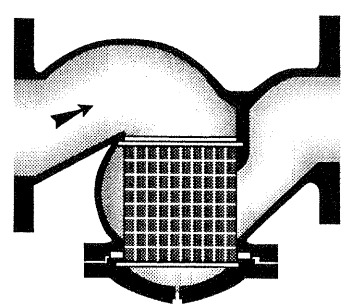
- Desired flow rates.
- Pressure available and pressure drop that can be allowed.
- Efficiency of the filter.
- **Turbidity**[18] of the raw water.

Above all else the filter housing and filter element must be **NSF**[19] approved.

TYPICAL INSTALLATIONS

Number of filters

There is no set standard cartridge/bag filter design. Typical, installations include a Giardia filter preceded by 1 or more pre-filters and/or basket strainers. The pre-filters extend the life of the Giardia filter by removing excessive debris and they are less expensive to replace than a Giardia filter.



Giardia Filter

A Giardia filter may be either a 1, 2.5 or 5 micron filter. The 5 micron filter is the most common used as a Giardia filter. Since Giardia range in size from 8 to 14

[17] **Particle size** - A term used to describe the size, in microns, of the material that can be removed using a cartridge or bag filter.
[18] **Turbidity** - A condition in water caused by the presence of suspended matter, resulting in the scattering and absorption of light rays.
[19] **NSF** - National Sanitation Foundation

microns in length and 7 to 10 microns in width a 5 micron filter with an efficiency in the high ninety percent range should be adequate. Many of the tests conducted on Giardia filters were done using either 2.5 micron or 5 micron filters.

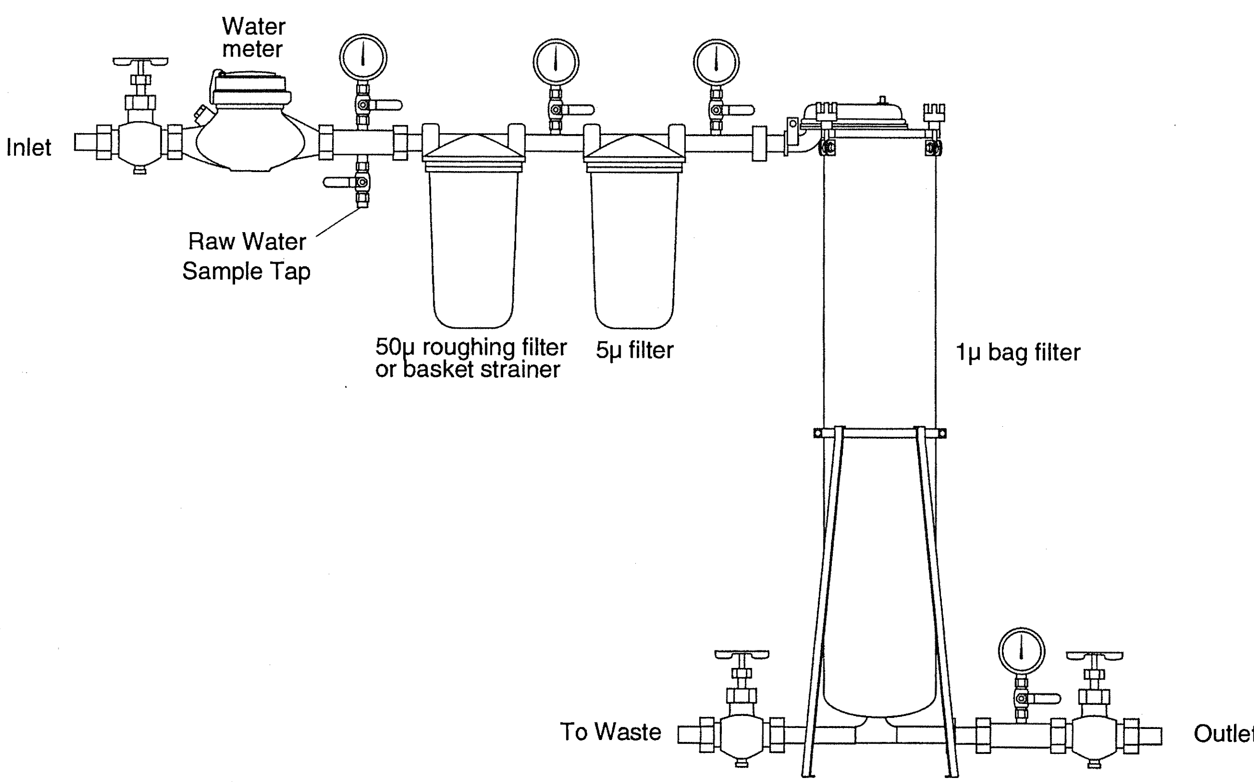
Pre-Filters

Typical micron ratings for pre-filters are 50, 25 and 5 microns. Backwashable basket strainers of 25 or 50 micron pore size are also commonly used. A third type of pre-filter is a small backwashable mixed media filter produced by Culligan with an effective pore size of 10 microns.

Typical Combinations

Typical combinations of filter and pre-filters are:

- 50 and 25 micron pre-filters followed by a 5 micron Giardia filter,
- 50 and 5 micron pre-filters followed by a 2.5 or 1 micron Giardia filter,
- 25 and 5 micron pre-filters followed by a 2.5 or 1 micron Giardia filter,
- Backwashable basket strainers or mixed media filters with 50, 25 or 10 micron effective size and a 95% removal efficiency, followed by a 5, 1.5 or 1 micron Giardia filter.



Flow Demands

In many instances it is desirable to place filters in parallel banks to meet flow demands. This will allow one bank of filters to be shut down for cleaning and not stop flow to the system. In this instance the flow to the other filters may need to be restricted in order prevent excessive pressure drop across the remaining filters.

Flow Meter

A flow meter must be installed either upstream or down stream of the filters. Observing and recording the flow through the filters is a key operational tool.

Flow Control

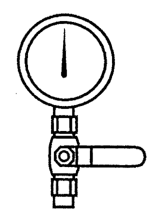
In many instances flow control will be desired. In these cases either a flow restrictor or a manually controlled globe valve is placed in the influent line.

Pressure Control

It is not desirable to have the inlet pressure to most cartridge/bag filters exceed 100 psi. This may require a pressure regulator on the raw water. The minimum pressure desirable at the tap is 20 psi. With a 35 psi pressure drop across the filter a minimum pressure of 55 psi will be needed on the raw water side of the filter.

Pressure Gauges

Pressure gauges must be installed on the raw water and after each filter housing or differential pressure gauges placed across each filter housing. The differential pressure is the key to knowing when to change the filter elements.



Isolation valves

In order to repair and maintain the filters, isolation valves must be placed on each side of the filter bank. Rising stem gate valves or ball valves are very effective in these positions. They allow the operator to easily determine if the valve is open or closed.

Sampling Taps

Sampling taps for raw and **finished water**[20] should be installed in the filter system. These will allow the operator to easily sample turbidity, **pH**[21] and temperature.

Filter to Waste

Because most of the filter media manufacturers recommend that the filter media be rinsed before use, a filter to waste valve is extremely helpful. This valve can be opened for a few minutes after the installation of a new filter and thus allow fine material caught in the filter media during manufacturing to be washed from the filter.

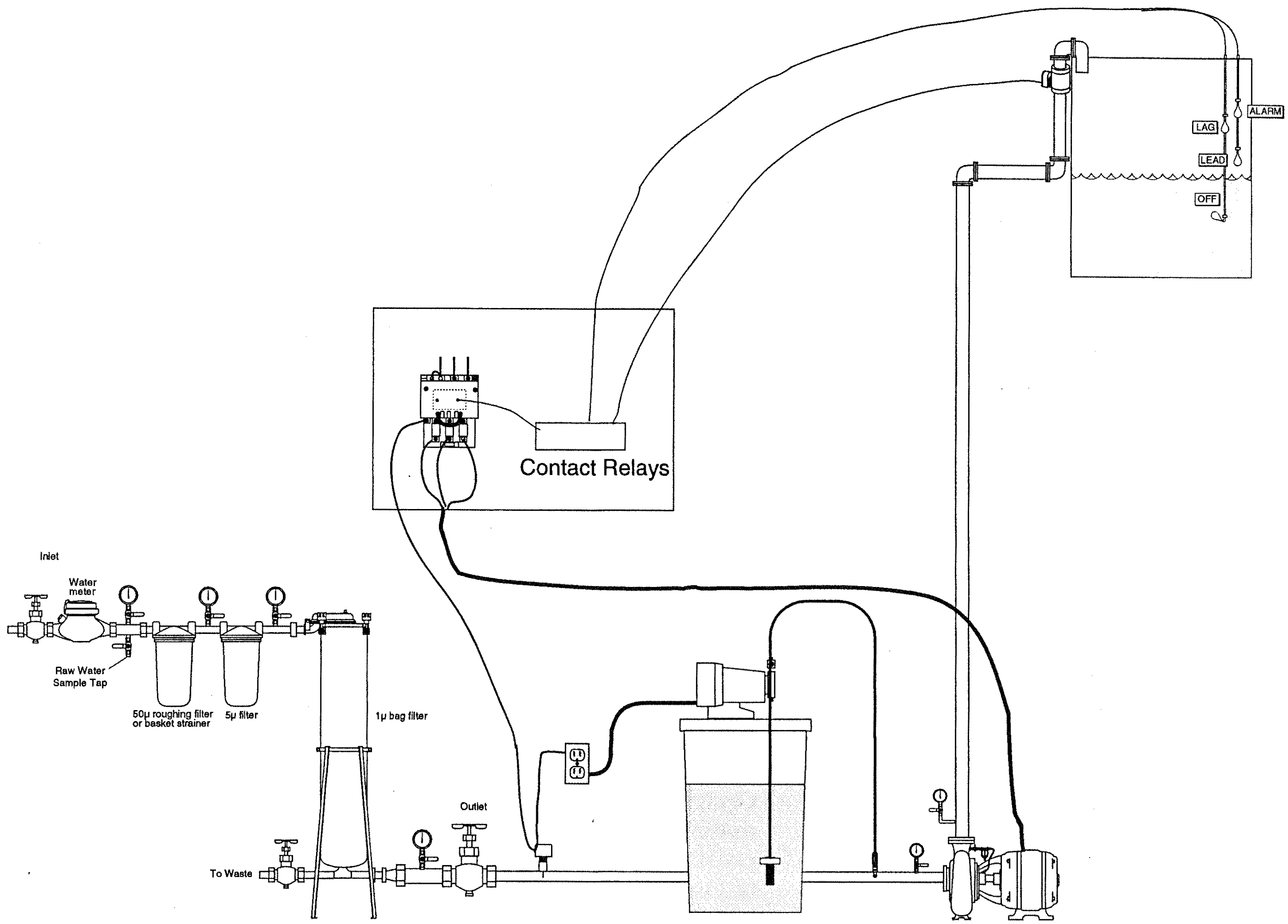
Electrical Control System Gravity

There is no standard electrical control system that has been adapted to cartridge filter systems. The following are examples of two systems that are presently in use. The gravity system shown feeds into the reservoir. A solenoid operated control valve, on the reservoir inlet line, and the chlorine feed pump are controlled by the

[20] **Finished Water** - The water after treatment. The term is applied to the water after all treatment has been completed and the water after a stage of treatment.

[21] **pH** - An expression of the intensity of the alkaline or acidic strength of a water. Mathematically, pH is the logarithm (base 10) of the reciprocal of the hydrogen ion concentration.

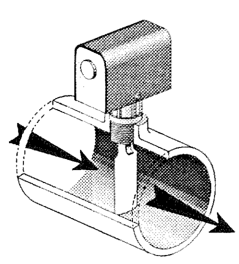
float switch in the reservoir. When the reservoir is full the contacts in the float switch open and the solenoid valve and chlorine feed pump are shut off. When the reservoir falls and the contacts in the float switch close the solenoid valve is opened and the chlorine feed pump turned on.



Electrical Control Pumping

The same electrical control system described above can be used on a pumping system. The only changes are the addition of a signal from the float switch to the motor starter on the raw water pump and the removal of the solenoid valve.

Fail Safe



In either the gravity or pumping system described above the reservoir level could drop causing a demand for water. The signal to open the solenoid valve or start the raw water pump would also start the chlorine feed pump. However, if no water were flowing in the line, due to a loss of raw water or failure of the raw water pump, there would be an overfeed of chlorine. To prevent this from occurring, a flow switch is placed in the main flow line. Without a flow through the line the flow switch will fail to close and the chlorine feed pump will be prevented from starting.

Increasing Chlorine Residual

As the filter media plugs the flow rate through the filters will drop. When a fixed rate chlorine feed pump system is used this process will increase the chlorine **dosage**[22] and thus the **residual**[23]. There are two methods of preventing the residual from fluctuating; one is to keep close watch on chlorine residual and decrease the dosage rate as the residual climbs, the second is to use a flow meter with a 4 to 20 milliamp signal that can be used to pace the chlorine feed pump. While this may sound complicated for a small system, it is a very simple system available from all of the major meter manufacturers. The LMI and W & T chemical feed pumps can be purchased with the ability to handle a 4 to 20 ma signal for regulating the stroke frequency and thus the feed rate.

TYPICAL OPERATION

Filtration Rates

It is important that the manufacturers' flow rates not be exceeded. If these rates are exceeded the efficiency of the filter may be reduced allowing pathogens to enter the water system.

Inlet Pressure

The manufacturer of each cartridge/bag filter provides strict data on maximum pressure ratings of filters. These ratings should not be exceeded. In exceeding the pressure ratings there is the possibility of pushing pathogens through the media and into the finished water. In most cases the maximum pressure should not exceed 100 psi.

When to Replace Filters

Cartridge and bag filters manufactured from textile material should be replaced any time the differential pressure reaches 35 psi. When the pressure differential is at 5 psi, one half of the filter life has been used. It is important to note the volume of water that has been filtered since changing the filter and the turbidity of the raw water. This will allow the operator to estimate when the filter will need to be changed.

Ceramic Filters

Ceramic filters have a much lower permeability than the textile filter elements. The initial headloss across these filters can be as high as 18 psi at 1 gpm on a 10 inch filter when the water temperature is 68°F. One manufacturer recommends cleaning these filters when the pressure differential reaches 90 psi. Cleaning is accomplished with a cloth or stiff nylon brush. The outside layer containing the build up of material is brushed away. The filter can be cleaned several times until the outside diameter reaches 1.75 inches at the

[22] **Dosage** - The amount of a chemical applied to the water. Commonly expressed in mg/L.
[23] **Residual** - What is remaining in the water after a set period of time.

smallest point (5.5 inches in circumference).

Filter Replacement Sequence

The following sequence can be used as a guide for changing the media in a cartridge or bag filter.

1. Shut off the inlet and outlet isolation valves.
2. Drain the pressure from the system. This can be easily accomplished by opening the filter to waste valve.
3. Remove the housing cover.
4. Remove the filter element. Place the filter element in sealed bag for disposal. Use gloves.
5. Using a chlorine solution of 1 to 5 percent (household bleach is approximately 5% chlorine) disinfect the interior of the housing.
6. Install the filter element.
7. Inspect the seal on the housing. If damaged replace.
8. Install the housing.
9. Torque the housing or housing bolts to the correct amount. It may be possible to under and over tighten the housing. Leakage past the housing was one of the major causes of failure during one of the studies of various filters.
10. If not already open - open the filter to waste valve.
11. Slowly return flow to 1/2 of normal.
12. After 5 to 10 min. close the filter to waste valve and open the inlet valve.
13. Record initial headloss across each stage and flow through the filters.

Seasonal Operation

At the conclusion of the season, remove the filter elements and dispose of them in a safe manner. Disinfect the housing or replace it. At the start of the season, disinfect the housing, replace the housing gasket and install a new filter element.

ROUTINE OPERATION

Readings and Testing

Daily perform the following observations and tests and record the results:

- Turbidity of raw and finished water
- pH of raw water
- Temperature of raw water
- Pressure upstream and downstream of each filter unit
- Flow rate
- Chlorine residual
- Perform chlorine dosage and CT calculations

Observations

The following observations are considered part of routine operations of cartridge/bag filter systems;

- Date that new filter elements were installed,
- Appearance of filter media (only possible when the housing is made of clear plastic),
- Differential in pressure across the pre-filters, basket strainers and Giardia filters.

Data Form

The data form on the next page can be used to collect typical data needed for operating a cartgridige filter system. Besides the data shown the common data for chlorine and fluoride should also be collected. For chlorine this data would include:

- Chlorine tank level - inches
- Chlorine used - gallons
- Dosage - mg/L
- Residual - mg/L
- CT

Size of Form

This form has been reduced to 85% of its origional size in order to fit it into the allowable space. The form can be adjusted to a usable size by placing it on a photo copier and enlarging to 115%.

City of ____________________ Month of ____________________

1. Date	2. Time	3. Gauge 1 - psi	4. Gauge 2 psi	5. ΔP - Pre-filter #1	6. Gauge 3 - psi	7. ΔP - Pre-filter #2	8. Gauge 4 psi	9. ΔP - Giardia filter	10. Turbidity Raw Water ntu	11. Turbidity Finished Water ntu	12. Meter reading gallons	13. Gallons Filtered	14. Flow rate - gpm	15. pH	16. Chlorine Residual mg/L
31															
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Common Cartridge Filter Problems and Solutions

Problem	Solution
High headloss across filters	• Replace filter element. Check headloss without element in filter.
High Chlorine Residual	• Check flow rate and dosage. Plugging filters may have reduced flow enough to increase dosage. Reduce dosage by changing feed rate at chlorine feed pump. • Change chlorine system to proportional feed.
Premature high headloss on Giardia filter	• Check seals on top and bottom of cartridges in pre-filters. Leakage could cause excessive debris on the filter. • Check raw water turbidity. Turbidity over 5 ntu will cause plugging of pre-filters and Giardia filter. • Check flow - higher than normal flows will provide higher than normal headloss.

O & M OF CARTRIDGE/BAG FILTERS WORKSHEET

1. A cartridge filter system is classed as:

   _______ a. Conventional treatment

   _______ b. Direct filtration

   _______ c. Slow filtration

   _______ d. Complete filtration

   _______ e. Alternate technology

2. What is the size range for Giardia cysts?

   _______ a. 7 to 10 microns in width

   _______ b. 1 to 5 microns in width

   _______ c. 05 to 2.5 microns in width

   _______ d. 9 to 20 microns in width

   _______ e. .025 to 0.5 microns in width

3. From the filter sizes below select the one that could be used as a Giardia filter.

   _______ a. 0.25 microns

   _______ b. 25 microns

   _______ c. 5 micron

   _______ d. 50 microns

   _______ e. 10 microns

4. In order for a cartridge or bag filter to meet the Consensus Protocol it must be able to produce a turbidity of less than ____ in 95% of the samples.

   _______ a. 5 ntu

   _______ b. 1 ntu

   _______ c. 0.1 ntu

   _______ d. 15 ntu

   _______ e. 3 ntu

5. Cartridge filters are not effective in removing ___________.

_______ a. Giardia

_______ b. Viruses

_______ c. Material larger than 50 microns

_______ d. Algae

_______ e. Microorganisms larger than 20 microns

6. In most tests, cartridge and bag filters have been shown to provide a ______ log removal of Giardia.

_______ a. 3

_______ b. 4

_______ c. 1

_______ d. 2

_______ e. 0.5

7. In order to use a cartridge or bag filter to remove Giardia, what other treatment process is required?

_______ a. Sedimentation

_______ b. Coagulation

_______ c. Disinfection

_______ d. Flocculation

_______ e. Filtration

8. The two common cartridge filter lengths are:

_______ a. 5 inch

_______ b. 28 inch

_______ c. 10 inch

_______ d. 30 inch

_______ e. 40 inch

9. The nominal size of a cartridge filter is...

_______ a. The size of particle that it will remove

_______ b. The size rating of the filter

_______ c. The length of the filter

_______ d. The actual size of the pores through the filter media

_______ e. The pressure rating of the filter

10. The efficiency of a cartridge filter is...

_______ a. The headloss divided by the flow rate

_______ b. The flow rate divided by the headloss

_______ c. The percent of the nominal size particles removed

_______ d. The percentage of the actual size particles removed

_______ e. The relationship between the actual size and the nominal size

11. Typical polypropylene cartridge filters should be changed when the differential pressure reaches __________ .

_______ a. 10 psi

_______ b. 45 psi

_______ c. 5 psi

_______ d. 20 psi

_______ e. 35 psi

12. A polypropylene cartridge filter has reached one half of its life when the differential pressure is at _________.

_______ a. 10 psi

_______ b. 45 psi

_______ c. 5 psi

_______ d. 20 psi

_______ e. 35 psi

13. A common size of a pre-filter in a cartridge filter string would be...

_______ a. 100 microns

_______ b. 2.5 microns

_______ c. 5 microns

_______ d. 50 microns

_______ e. 200 microns

14. In a seasonal operation the cartridge filter housing should be disinfected ....

_______ a. At the end of the season

_______ b. Each month during the off season

_______ c. Each month during operation

_______ d. Need not be disinfected at all since it is a NSF product

_______ e. At the start of the season