FILTER ASSESSMENT MANUAL

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INTRODUCTION

In 1993, a Cryptosporidium outbreak in Milwaukee, WI affected over 400,000 people. The local water plant's filtered water turbidity was high, but actually ***below*** the regulatory limit. As a result of the outbreak, over 4,400 people were hospitalized and 69 people died. The Milwaukee outbreak highlighted the importance of filtration. Filtration serves as the last physical barrier against pathogens in a conventional surface water treatment plant. Filtration is the fundamental system in a water treatment process that removes suspended solids, including microorganisms such as Cryptosporidium oocysts and *Giardia* cysts.

Protozoa such as *Giardia* cysts and Cryptosporidium oocysts have been one of the primary focuses of evolving drinking water regulations. Cryptosporidium, in particular, is resistant to standard disinfection practices such as chlorination. The phrase "shoot a little chlorine to it" simply will not do the trick when it comes to Cryptosporidium. Optimization beyond the current regulatory limit with respect to filtration has been one technique proposed for improving oocyst removal. Various studies have found that providing a consistent filtration process with effluent turbidities below 0.1 NTU is an important step in process optimization. In fact, studies have shown that by decreasing the filtered water from 0.3 NTU to 0.1 NTU, an additional log removal of cysts can be achieved. That means ten times (10x) more cysts can be removed by improving performance by 0.2 NTU! A variety of techniques in filter optimization have been implemented including monitoring with particle counters and dosing with filter aid polymer. Two techniques which take advantage of more traditional filter tests are filter surveillance and filter assessment programs.

HOW TO USE THIS MANUAL

A *filter assessment* is a comprehensive and full-scale filter investigation. A filter assessment may be performed on a filter that has been performing poorly or it may be required under the IESWTR if a filter has a turbidity > 1.0 in two consecutive measurements taken 15 minutes apart at any time in each of 3 consecutive months. Plant operators and consulting engineers can use this manual in order to meet the Department's expectations for assessments that may be required under the IESWTR. A full-scale filter assessment may involve most or all of the test procedures outlined in this manual. In summary, a complete filter assessment is a comprehensive search for anything that is hindering the performance of a non-optimized filter.

A *filter surveillance program* allows the operator to conduct selective tests that provide a periodic check of factors which impact a filter's performance. A recommended maintenance (filter surveillance) schedule is outlined below:

TEST TYPE	TEST FREQUENCY
Filter Rise Rate Test	Check 2-3 filters every 3 months
Backwash Water Turbidity Profile	Check 2-3 filters every 3 months
Bed Expansion Test	Check 2-3 filters every 3 months
Visual Backwash Observation	Observe every backwash
Media Depth & Gravel Mapping	One filter every 6 months
Media Sampling & Testing	One filter per year
Floc Retention Analysis	One filter every 6 months
Filter Excavation Box	Whenever a specific problem needs to be investigated

The tests and procedures listed herein represent only one approach. Each test may be conducted using alternative procedures and equipment. Most of the procedures in this manual are geared towards dual media filters with surface sweeps, but each test can be modified for other kinds of media and other types of backwash systems (i.e., air scour).

It should also be pointed out that very little conclusive information can normally be obtained from a single test or study. Usually, several different filter tests should be performed before any legitimate diagnosis can be issued. In fact, the results of one filter test will usually lead to more tests. For example, if a bed expansion test indicates insufficient bed expansion, then the operator should perform a rise rate test to determine if the backwash rate is appropriate for the particular media being used. Has this led to mud balls, inadequate ripening, lengthened rewash times, etc? More tests will provide the answers.

SAFETY AND SANITATION

Most of the procedures outlined in this manual only describe the actions necessary to perform the tests themselves. There was not a great deal of emphasis placed on safety procedures or proper sanitary practices. This manual assumes that the reader has had adequate training for entering confined spaces (since a filter basin may be considered to be a confined space). The manual also assumes that the reader has a basic understanding of good sanitary practices such as disinfecting new media and disinfecting a filter with HTH after a testing or maintenance has been performed throughout the depth of the filter or the filter bottom (refer to AWWA Standards B100 and C653).

REFERENCES

This document represents a compilation of information from various sources. Many of the testing techniques discussed in this manual have been in use for some time. A complete list of references can be found at the end of this manual.

1. INSTRUMENTATION CHECK & DATA RELIABILITY

PURPOSE:

The first step in evaluating filter performance is to make sure that the turbidity data is accurate. There are basically 2 major sources of unreliable turbidity data, the sample point and the turbidimeters themselves.

PROCEDURE:

1. Check Sample Lines

    a. Make sure that the combined effluent turbidity sample is taken prior to any post-treatment chemicals, especially lime.

    b. Make sure that the on-line turbidimeter sample from each filter is taken prior to the rewash valve.

    c. Make sure that all turbidity sample points are located at the 3 o'clock or 9 o'clock position with respect to the effluent pipe.

    d. If the turbidity sample is pumped, take grab samples prior to the pump to determine if the differential pressure across the sample pump is resulting in air bubbles.

2. Verifying Turbidimeter Accuracy

    a. Calibrate the benchtop turbidimeter prior to performing a filter assessment and then regularly thereafter according to manufacturer's recommendations.

    b. Verify on-line turbidimeters with the calibrated benchtop unit.

    c. If on-line units do not result in comparable readings with the calibrated benchtop unit, then the on-line units should be calibrated with a primary standard.

ISSUES / COMMENTS:

In some cases, an improper sample line or uncalibrated turbidimeter will indicate that the filter(s) are not performing well, even if that is not the case. If the turbidity sample is taken after post-treatment chemicals are added, then those chemicals (such as lime) will scatter light and result in a false turbidity reading. Also, if the turbidity samples are taken from the top of the effluent pipe, air can be introduced into the sample line, also contributing a false turbidity reading. A similar problem can occur if the turbidity samples are pumped prior being analyzed. If the sample is taken from the bottom of the effluent pipe, sediment and rust particles may be introduced, thus increasing the turbidity.

Finally, it is very important that the turbidity sample line be located prior to the filter-to-waste (rewash) valve. If the sample is taken after the rewash valve, then the turbidimeter will not actually "see" any water when the filter is in rewash mode and the registered turbidity will be meaningless. This will lead to an even greater problem if the operator is unaware of the problem and thinks that the registered turbidity is the actual rewash turbidity. (See Figure 13-1 for an illustration).

As stated above, an uncalibrated turbidimeter will provide useless results. In many cases, the turbidimeter will indicate a turbidity that is higher than the actual turbidity. All turbidimeters (benchtop & on-line) must be accurate before starting a filter assessment.

2. GATHERING HISTORICAL FILTER INFORMATION REGARDING PERFORMANCE AND DESIGN

PURPOSE:

The purpose of this exercise is to gather performance and design data on all of the filters. Performance data is important because it will allow the operator to focus on a problem filter. Performance data may also provide some insight as to the potential problem. Design data must be collected prior to the filter assessment as well. Certain design characteristics (such as filter basin size and media type) will be used in subsequent tests and calculations.

PROCEDURE:

A. <u>Performance</u>

1. Determine the 95th percentile for the plant's settled water turbidity and filtered water turbidity for the previous 12 months. Preferably, calculate the 95th percentile for each sedimentation basin and each individual filter.

2. Gather information pertaining to average run time, current backwash procedures, etc. for each filter.

B. <u>Design</u>

1. From construction drawings, determine the size (L x W) of each filter basin and the type of filter bottom that was installed.

2. Determine when the most recent media replacement occurred. Determine the types of media used and the thickness of each layer. From the design specifications, find out what the uniformity coefficient and effective size was supposed to be for each type of media (gravel, sand, coal, etc.).

3. From the construction drawings, determine the dimensions of the backwash troughs as well as the location of the troughs with respect to the top of the media, the gravel layer, and the filter bottom.

ISSUES / COMMENTS:

As stated above, the information gathered relating to performance and design will be needed to perform subsequent tests and calculations. Also, the design data should be verified with field measurements if possible.

Table 2-1. Individual Filter Self Assessment Worksheet

Topic	Description	Information
General Filter Information	Type (mono, dual, mixed)	
	Number of filters	
	Filter control (constant, declining)	
	Surface wash type (rotary, fixed, none)/Air Wash	
	Configuration (rectangular, circular, square)	
	Dimensions (length, width, diameter)	
	Filter-to-waste (capability/specify if used)	
	Surface area per filter (ft^2)	
Hydraulic Loading Conditions	Average operating flow (mgd)	
	Peak instantaneous operating flow (mgd)	
	Average hydraulic surface loading rate (gpm/ft^2)	
	Peak hydraulic surface loading rate (gpm/ft^2)	
Media Design Conditions	Depth, type	
	Media 1 – Sand	
	Media 2 (if applicable) – Anthracite	
	Media 3 (if applicable) – Garnet	
Actual Media Conditions	Depth	
	Media 1 – Sand	
	Media 2 (if applicable) – Anthracite	
	Media 3 (if applicable) – Garnet	
	Presence of mudballs, debris, excess chemical, cracking, worn media	
Support Media/Underdrain Conditions	Is the support media evenly placed (deviation <2 inches) in the filter bed?	
	Evidence of media in the clearwell or plenum	
	Evidence of boils/vortexing during backwash	

Individual Filter Self Assessment Worksheet (continued)

Topic	Description	Information
Backwash Conditions	Backwash initiation (headloss, turbidity/particle counts, time)	
	Sequence (surface wash, air scour, flow ramping, filter-to-waste)	
	Duration (minutes)	
	Introduction of wash water (via pump, head tank, distribution system pressure)	
	Backwash rate (gpm/ft^2)	
	Bed expansion (percent)	
	Coagulant or polymer added to wash water	
	Filter rested prior to return to service	
Other Considerations		

3. GRAVEL MAPPING & MEASURING MEDIA DEPTH

PURPOSE:

The purpose of this particular test is to map the topography of the gravel layer (for filters that use gravel) and determine the actual depth of each media layer. Obviously, if an IMS cap is used, the gravel mapping will not be performed.

PROCEDURE:

1. Sketch a picture of the filter (to scale) and show the location of the backwash troughs. Select and number several representative sample locations on the sketch in a grid pattern. As a general rule of thumb, select *at least* one sample location for every 5 ft^2 of filter area.

2. Close the filter influent valve and allow the filter to drain.

3. Watch for any vortex action as the filter drains.

4. Once all of the water has drained from the filter basin, drop plywood boards (2' x 2') on the top of the media. Then, place a ladder on top of the plywood and enter the filter.

5. Staring at the first sample point numbered on the sketch, use a probe rod to gently penetrate the media until it hits gravel (a probe is typically a 1/4 to ½ inch metal rod about 5 to 6 feet long). Using the probe rod and a ruler, measure the distance from the top of a nearby backwash trough to the top of the gravel layer. If all of the troughs are level and at the same elevation, this will provide a relative depth to the gravel layer.

6. Next, measure the total depth of the sand and anthracite (above the gravel) at that location. This is done by pinching the probe rod where it is flush with the top of the media. Then remove the rod and measure the distance from your finger to the end of the rod.

7. As the measurements are taken, relay the results to a note-taker so that they can be recorded on the sketch. Then use a shovel to dig through the media to find the anthracite/sand interface. Measure the thickness of the anthracite layer and record the measurement.

8. Subtract the anthracite thickness from the total sand/anthracite thickness to determine the thickness of the sand layer at that point.

9. Repeat the process at each designated sample point so that the distance from the trough to the gravel, sand thickness, and anthracite thickness is known for each sample site designated in STEP #1 above. Record all results.

ISSUES / COMMENTS:

Support Media/Underdrains:

Maintaining the integrity of the support gravels and underdrains is extremely important to the performance of a rapid rate granular filter. Disrupted or unevenly placed support media can lead to rapid deterioration of the filtered water quality noticeable by quick turbidity breakthroughs and extremely short filter runs. If the support media is significantly disrupted, the affected area of the filter may act as a short circuit allowing particulates and any microbial pathogens which are present to pass directly through that portion of the filter.

Disruption of the support media is permanent and will only get worse until the filter is rebuilt. Filter support media can become disrupted by various means including sudden violent backwash, excessive backwashing flowrates, or uneven flow distribution during backwash. In many cases, the gravel is disrupted because the operator will begin the backwash at a high rate instead of gradually increasing to the maximum backwash rate. This is an especially crucial step when backwashing a filter that has been drained (has no water in it), such as when performing a filter assessment. When backwashing an empty filter, the initial backwash rate should not exceed 5 gpm/ft^2.

Besides gravel mapping, an inspection of the clearwell (using a diver or a spotlight) may also indicate underdrain/support media problems if the inspection reveals that sand and/or anthracite is in the clearwell. The distance from the fixed reference point (top of troughs) to the support gravels should deviate less than 2 inches if the support media and underdrain are in good condition.

Media Depths:

After determining the actual depth of the sand and anthracite layers, the results should be compared to the original design. Ideally, the actual thickness of the sand and anthracite layers should match that of the original plans and specifications. If the actual depth is less than the design depth, then some media has been lost (probably via backwashing) and it should be replaced. In many cases, media loss can have a detrimental impact on filter performance. In addition, anthracite loss can result in shortened filter runs due to accelerated head loss.

A common rule of thumb used in filter design is to maintain an L/d_e ratio of at least 1000, where L is the media depth and d_e is the effective size of the media. For dual media, the L/d_e ratios for the sand and anthracite are added together. For example, a filter with 6 inches of sand and 12 inches of anthracite has a L/d_e ratio of 653 (335 + 318). The media depth for this example is not sufficient since the L/d_e ratio is less than 1000.

Note: If sand or anthracite is replaced, be sure that it meets the same specifications (effective size, uniformity coefficient) as the existing media. See section #6 for more information on these parameters.

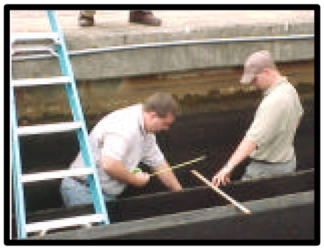


Figure 3-1: Measuring distance from trough to gravel

Figure 3-2: Measuring media depth

EXAMPLE:

<u>The following example was taken from EPA Guidance Document #EPA815-R-99-010.</u>

Operators, while draining a poor performing filter, observed vortexing occurring at the far end of the filter. The operators constructed a support gravel placement grid by probing through the media down to the support gravel every 2 feet throughout the filter using a 6 feet long aluminum rod that had been marked at 1-inch intervals. The operator using the probe measured the depth of probe penetration against the wash water trough. Examination of the grid (shown in Table 3-1) indicated that the support gravels were extremely disrupted at the far end of the filter.

Table 3-1. Example Filter Support Gravel Placement Grid

Depth of Filter Support Gravels (in inches)
Measured from the Wash Water Trough

			Filter Control Panel		
	2 ft	**4 ft**	**6 ft**	**8 ft**	**10 ft**
2 ft	41	40.75	41	41	41
4 ft	40.75	40.5	41	41	40.75
6 ft	41	41.25	40.75	41	41
8 ft	40.75	41	41	40.75	40.75
10 ft	41	41	40.5	40.5	40.75
12 ft	41	**<u>46</u>**	**<u>46.5</u>**	41	41
14 ft	40.75	**<u>46</u>**	**<u>46.25</u>**	39	40.75
16 ft	41	39	38.75	37	40.75
18 ft	40.75	41.25	40.75	41	41

The results of the gravel map can also be graphically represented by drawing a topographic map (by hand or using computer software) showing the peaks and valleys of the filter support gravel. Keep in mind that the numbers which have been recorded represent a distance from a fixed reference point (troughs). To make a true topographic map, you will have to convert the distance from the troughs into a deviation from where the gravel layer should be according to the filter design. For example, if the gravel should be 40 inches from the trough, but it is measured to be 37 inches, then this number indicates a 3 inch peak on the gravel surface.

4. FILTER EXCAVATION BOX

PURPOSE:

Boil checks and gravel mapping may provide the general location of potential problems with a filter bed. Causes may include plugged or broken underdrains. In order to make a final determination of these issues generally requires partial or complete removal of the filter media. This can be a drastic action which requires both the commitment of labor and considerable down time for the filter. The use of a filter excavation box provides a means of verifying the condition of the filter bottom prior to committing to more extensive investigations.

The filter excavation box may also be used to provide a viewing window into the filter media. After the box has been inserted into the media and excavated, the operators can see a cross-section of the media. This allows for inspection of the sand/anthracite interface as well as exposing any intermixing between the media types.

FILTER EXCAVATION BOX:

A filter excavation box consists of a four-sided box made of plexiglass with an open top and an open bottom. The bottom edge should be mitered to aid in penetration of the media. A rope should also be attached to help lower the box into place and remove it. The actual size of the box should be taylored to the filter to be excavated. That is, it should not be so large that it cannot fit between the backwash troughs. In addition, it should be about 3 inches taller than the depth of the sand/anthracite bed.

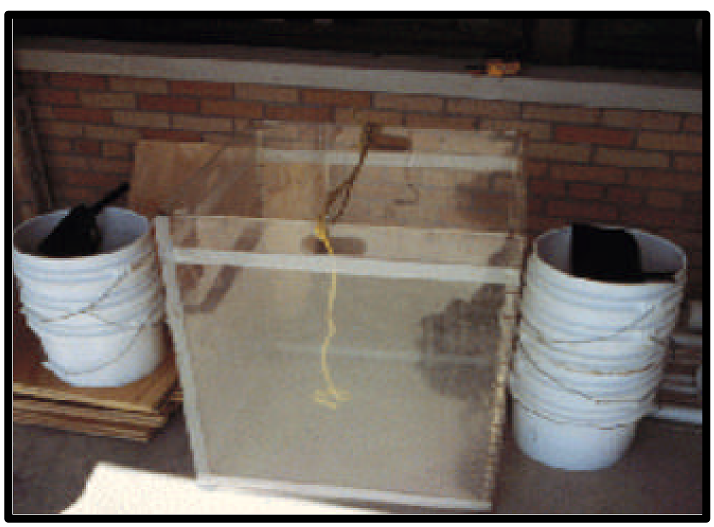


Figure 4-1. Box Used for Excavation

PROCEDURE:

1. Select the point for installation of the box based on the contour map developed during gravel mapping. The box should be positioned over an area where a sharp rise or fall in the media was noted or where boils or vortexing have been observed.

2. Insert the box into the media at the selected location. The box may be installed one of two ways:

   a. <u>Method #1</u> involves backwashing the filter at a very low rate (just enough to fluidize the media). Carefully lower the box into the media at the desired point until the resistance of the gravel stops the box. Slowly lower the backwash rate until the backwash valve is closed. Drain and isolate the filter. This method may be easier, but keep in mind that the media was partially fluidized and may not be segregated.

   b. <u>Method #2</u> involves draining and isolating the filter first. Then lower the box into the filter at the desired location and drive it into the media with a rubber mallet. This method can be more difficult, but the media will not be disturbed.

3. Using a ladder and plywood boards, enter the filter basin and begin excavating all of the sand & anthracite in the box. Be sure to place all of the excavated media on a tarp or in a bucket so that it can be used to fill the box after the excavation. Stop digging when the gravel bed is reached.

4. Take notes on media layering, media mixing, and media segregation.

5. If problems are suspected with the filter bottom, carefully remove the gravel until the filter bottom is exposed.

6. Take notes on the condition of the filter bottom.

7. Begin filling the excavation. Replace the media in the order that it was removed.

8. Remove the box by slowly withdrawing it as media is replaced or by fluidizing the media.

9. Make sure that all equipment has been removed from the filter and backwash the filter prior to placing it on-line. HTH should be added to disinfect the filter.

Figure 4-2. Box Excavation

ISSUES:

If major problems are discovered relating to the filter bottoms, the bottoms should be replaced or repaired as soon as possible. Any problems associated with the support media or the filter bottoms will only get worse with time. Damaged filter bottoms will compromise filtered water quality and the structural integrity of the filter.

5a. VISUAL INSPECTION OF THE MEDIA CONDITION

PURPOSE:

Mudballs in filters form when suspended solids in the water stick to the filter media and grow too large to be removed during the backwash process. As they grow larger and heavier they can sink and become impassable regions within the filter media. These regions result in short circuiting, shorter filter runs, higher effective filtration rates, and turbidity breakthrough. The purpose of this test is to detect the presence of mudballs, mud deposits, or poorly stratified media. The operator should also look for other deficiencies such as severe cracking in the media, separation of the media from the filter wall, and media mounding.

PROCEDURE:

1. Drain and isolate filter.

2. Visually inspect the filter for signs of media mounding, separation of the media from the filter wall, and severe cracking on the surface of the media.

3. Next, enter the filter using a ladder and some plywood boards.

4. Traverse the filter bed using plywood boards to avoid stepping into the media.

5. Select several areas to investigate. Be sure to dig in at least one of the corners and along at least one of the filter walls.

6. By hand, begin digging a hole in the media. Digging by hand allows for creation of a much smaller hole, and requires less time than holes dug with a shovel.

7. To determine if there are mudballs present, gently sift through each handful of media. As media falls through the fingers, mudballs can be identified. Note that a wet clump of media is not necessarily a mudball. A mudball can be a couple of centimeters to several inches in diameter and they usually have a soft, but dense feel (See Figure 5-1).

8. While digging for mudballs, look for a well defined line separating the sand and the anthracite coal. Make a note if the sand and anthracite are not distinctly segregated or if there is no segregation at all. This can especially be a problem in the corners of a filter equipped with surface sweeps.

9. It is a good idea to document all findings with a digital camera.

ISSUES / COMMENTS:

The presence of mudballs in the filter media is an indication of inadequate filter backwashing over time. Once they have formed, mudballs have to be removed manually or by soaking the media with acidified or chlorinated water and then actually raking the media clean if needed (as described on the following page). The backwash procedures will have to be modified to help prevent subsequent mudball formation, usually by increasing the backwash rate to achieve the appropriate bed expansion. (See subsequent tests in this manual).

If media mounding is observed, it may be an indication that there is mud in the media or an irregularity in the support gravel. If a depression is observed, the underdrains may be damaged. If the media is cracking or if it is separated from the filter walls (there may be a crack of up to 3 inches between the wall and the media) it is usually an indication that there is mud in the media along the walls of the filter. This can occur if surface sweeps are used with an insufficient backwash rate and it will create a path for water to flow around the media instead of through the media. Mud in the corners and along the walls will also result in a much smaller effective filtering area, thus having a high-rate effect on the rest of the filter. If any of these conditions occur, the media should be thoroughly cleaned to remove the mud and the backwash procedures should be modified to prevent re-occurence.

Figure 5-1. Two large mudballs removed from a dual media filter.

Figure 5-2. Cracks in the media

Figure 5-3. Mounding in the corners and along the filter wall

5b. PROCEDURES FOR CHEMICALLY CLEANING FILTER MEDIA

PURPOSE:

The purpose of this procedure is to chemically and physically clean a filter bed in order to remove mudballs and mud deposits that have developed over time due to insufficient backwashing. The following method involves cleaning the filter with a chlorine solution.

PROCEDURE:

1. Isolate the filter.

2. Using HTH or a bleach, add enough chlorine to produce a 50 ppm concentration.

   lbs needed = (Length * Width * Depth * 3.785 * 7.48) * (Desired Dosage/454,000)
   Example: Filter is 10 ft X 12 ft X 6 ft, to get 50 ppm:
   (10 * 12 * 6 * 3.785 * 7.48) * (50 / 454,000) = 2.265 lbs Cl_2

3. If necessary, turn on the backwash or surface wash system just enough to mix the solution throughout the filter.

4. Allow the filter to soak in the 50 ppm chlorine solution for at least 12-24 hours.

5. Initiate a full backwash cycle.

6. If mud deposits and/or mudballs are still present, repeat steps 1-4 and use a rake or high pressure nozzle to physically breakup the mud deposits.

COMMENTS:

The procedure outlined should provide a thorough cleaning of the filter media. By using a concentrated chlorine solution to clean the media, any bacteriological growth within the filter will also be destroyed. Finally, the procedure outlined above will also clean iron and manganese deposits along the filter walls and within the filter itself.

It is recommended that all filters be chemically cleaned every 6 months in order to further prevent mud deposits, mudball formation, manganese buildup, and bacteriological growth.

6. FILTER MEDIA SAMPLING

PURPOSE:

Filter media begins to change the moment it is placed in a filter. Repeated backwashing tends to grind the edges on the media. Often, the anthracite will wear at a faster rate than the sand. Media wear can have several impacts on the filter. Older, worn media may result in head loss building up more rapidly. Media washout may also increase. Also, as the media wears, the size can change, thus affecting the backwash rate needed for thorough cleaning. Finally, the sand and anthracite may become mixed if they are not properly matched during the design process.

Filter media sampling allows the tester to compare the current condition of the media with the specified or as-built condition of the media. Keep in mind that media sampling can be done in conjunction with other filter surveillance tests in order to save time.

DEFINITIONS:

Effective Size (E.S.): This is the size exceeded by all but the finest 10% of the filter media, also known as the d_{10}. In other words, this is the mesh size that will catch 90% of the media (by weight).

Uniformity Coefficient (U.C.): The ratio of the size exceeded by all but the finest 60% of the filter media to the Effective Size (d_{60}/d_{10}). In other words, it is a measure of media size variability. A U.C. of 1.0 would indicate that all of the media is the exact same size. A U.C. of 1.5 is typical, but a U.C. of less than 1.4 is desired for most new construction.

Specific Gravity (S.G.): The specific gravity compares the density of the media to the density of water. If a media has a specific gravity of 1.0, then it has the same density as water. Typical values for anthracite is 1.3 – 1.7. Sand generally has a specific gravity of 2.5 – 2.7 and garnet has a s.g. of 4.

60% Particle Size: This number will be used later in Test #11. It can be determined by multiplying the U.C. by the E.S.

Coring Device: For this test, a coring device may be a pipe that is 1.5 inches in diameter. One end should be beveled and the other end should be equipped with a removable cap or plug (or the operator can cover it with his hand to create a suction seal).

PROCEDURE:

1. Drain and isolate one of the filters.

2. Plan the sampling points within the filter. Choose at least 3-4 sample points in order to obtain a representative composite sample for the filter.

3. Access the filter bed by placing plywood panels on the bed surface.

4. Go to the first sample point. Remove the plug from the end of the coring device (unless you plan to use your hand as the plug). Place the beveled edges of the coring device into the filter bed. Rotate the coring device as it sinks into the media. STOP when resistance is encountered. When the coring device has reached the gravel it will be apparent by the grinding noise made as the device is rotated.

5. Replace the removable plug from the end of the coring device (or simply place your hand over the end to form a seal).

6. Slowly raise the coring device out of the filter media.

7. Place a long strip of aluminum foil along the top of one of the plywood boards.

8. Gently tap the edge of the coring device so that the contents are slowly emptied across the length of the aluminum foil.

9. Separate the media along the anthracite/sand interface. *See note.

10. Repeat steps 4-9 for each sample location.

11. Label bags for sand and anthracite samples. Collect and mix the anthracite samples and place the composite sample in the appropriately labeled bag. Do the same for the sand.

12. Remove all materials from the test filter.

13. Backwash the filter before placing it on-line. The filter should be disinfected with HTH.

14. Send the sample bags to a lab for sieve analysis. Be sure that the sand and anthracite samples are analyzed for effective size, uniformity coefficient, and specific gravity.

ISSUES / COMMENTS:

After the sand and anthracite composites have been analyzed, the operator or engineer can compare the current condition of the media with the design specifications. Since media selection is often process dependent, the media may have to be replaced if it has worn to the point where it can no longer provide the desired treatment. In most cases, however, the media may not need replacing, but the media sampling results can have other impacts. For example, the size and specific gravity of the filter media affects fluidization and they are critical in determining the appropriate backwash rate (See Test #11). If the backwash rate is too low, then the filter will not be cleaned. If it is too high, the media may be cleaned too much and media loss can occur.

Another issue is the proper matching of the sand and anthracite used in dual media filters. As shown in Test #11, the sand and the anthracite will require a unique backwash rate. Obviously, they will both be exposed to the same backwash rate during a backwash event. Therefore, it is important that the sand and anthracite be matched with respect to backwash rate. This is primarily a design issue, but it is also important when replacing lost media. The operator should also be aware that if the filter is topped off with new media, that can have an effect on the effective size and the uniformity coefficient of the filter as a whole.

A final issue pertaining to media characteristics is the L/d_e ratio. The L/d_e ratio is a common rule of thumb used in filter design, where L is media depth and de is the effective size of the media. For dual media filters, the L/d_e ratio is calculated separately for the sand and the anthracite before being added together. For the total media depth to be adequate (for a given type of media), the total L/d_e ratio for the filter media should be at least 1000.

*Note: For sand and anthracite interface that is not clearly defined, Benzene (CAS#71-43-2) + 1122 Tetrabromoethane (practical grade CAS#79-27-6) can be used to separate the two prior to analysis. The mixture has a density between that of sand and anthracite, so the sand will sink and the anthracite will float.

-Provided by Terry Irvin

7. FLOC RETENTION ANALYSIS

PURPOSE:

Filter media is designed to allow turbidity to penetrate deep into the bed while achieving the desired filtered water quality, although most particles should be removed in the shallow regions. This is mainly due to the porosity of the anthracite layer, which allows particulates to be adsorbed throughout the depth of the anthracite layer. If a filter were to have little or no anthracite, then the majority of the turbidity would accumulate on the sand surface, thus blinding the filter. The tendency to accumulate turbidity only in the upper layer of a dual media filter leads to a phenomenon called filter binding. Filter binding leads to rapid buildup of head loss within the filter, resulting in shorter run times. Floc penetration or retention can be impacted by a variety of factors other than the filter media itself such as the settled water turbidity, the filtration rate, the backwash procedures, and the use of a filter aid polymer.

A floc retention analysis provides a measure of how effectively the filter bed is accumulating particles/turbidity and how effective the filter backwashing system is. This test may be done in conjunction with other tests such as filter media sampling.

PROCEDURE:

1. Drain and isolate the filter to be tested. The filter should be at the end of a complete run and ready to be backwashed.

2. Plan the sampling locations within the filter. At least three sample points should be used. The sample points should not all come from the same area, try to achieve a good composite. At each sample location, 5 separate samples will be taken:

   1 sample @ 0-2 inches below the media surface
   1 sample @ 2-6 inches below the media surface
   1 sample @ 6-12 inches below the media surface
   1 sample @ 12-20 inches below the media surface
   1 sample @ 20-30 inches below the media surface

3. Prepare 5 labeled bags, one for each sample depth.

4. Enter the filter.

5. Remove the removable plug from the end of the coring device, unless you plan on using your hand as the plug (see test #6 for more information on a coring device). Place the beveled end of the coring device into the filter bed. Rotate the coring device as it is pushed downward to the desired depth (the first sample will be from 2 inches down). Use a series of pre-taped marking points on the coring device to identify each stopping point.

6. Once the coring device has reached the desired depth, seal the top of the coring device with a plug or with your hand. Gently rotate the coring device as you extract the sample.

7. Break the seal by removing the plug and empty the contents of the coring device into the appropriate sample bag.

8. Repeat this process for each of the sample depths outlined in step #2.

9. Repeat the entire process for each sample location, thus producing a composite sample bag for each sample depth.

10. At this point, remove all materials from the filter, backwash the filter, and return it to service.

11. Take each sample bag to the laboratory.

12. For the first sample bag (0-2 inches), weigh out approximately 50 grams (which equates to about 50 ml) of media and place the media in a 500 mL flask.

13. Add 100 mL of tap water to the flask, close the top with a stopper, and shake vigorously for 1 minute.

14. After 1 minute of shaking, decant the resulting turbid water into a second 1,000 mL flask.

15. Repeat steps 13 &14 four more times so that there is a total of 500 mL of “decant” water in the second flask.

16. Thoroughly mix the 500 mL of dirty water to re-suspend any settled particles, and perform a turbidity analysis using a benchtop turbidimeter.

17. Multiply the turbidity result from step #16 by 2 in order to calculate the turbidity per 100g of media sample (since only 50g was used). Record the results.

18. Repeat the process for the other sample bags (2-6 inches, 6-12 inches, etc.) and record the results.

19. Repeat Steps 3-18 immediately after the filter has been backwashed.

20. Record the turbidity values as a function of depth for both the before and after backwash samples.

DATA ANALYSIS

The chart below shows the kind of graphic that should be generated from the floc retention test data, as performed for a dirty filter (blue line) and then again following backwash (black line).

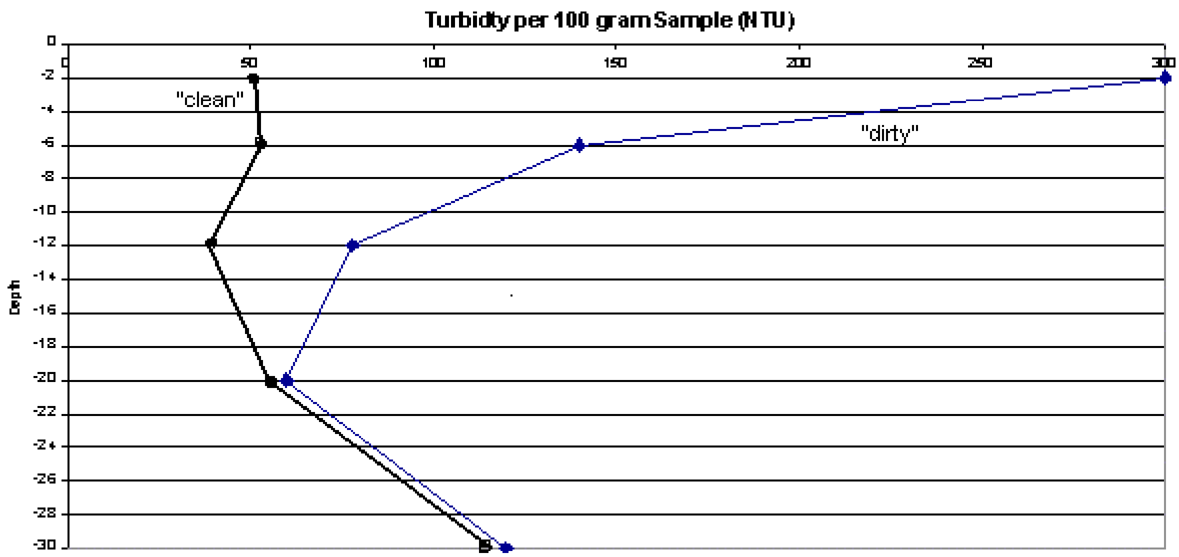


CHART 7-1. SAMPLE FLOC RETENTION ANALYSIS

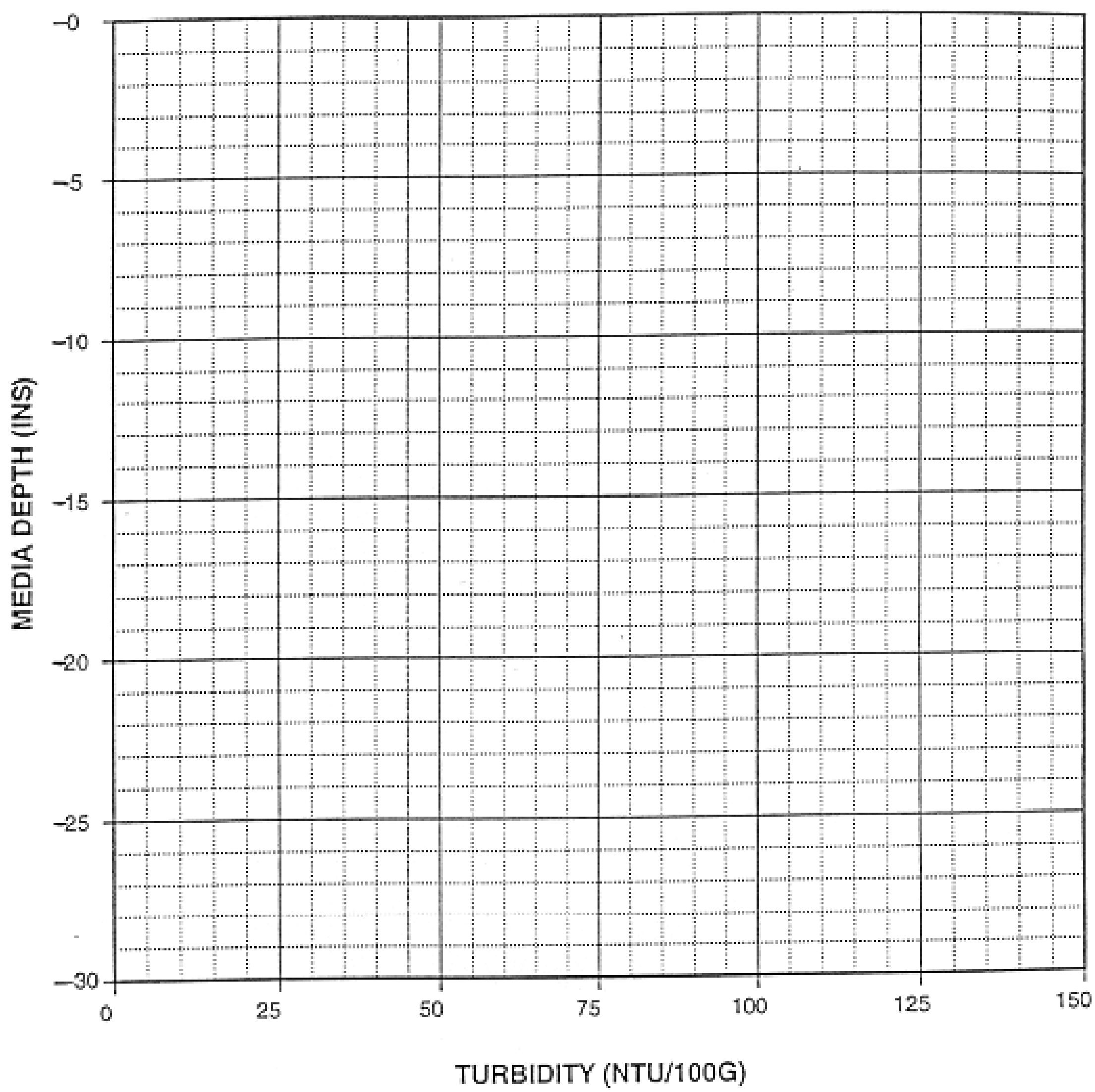
From the example chart above, several determinations can be made. It appears as though most of the particle removal is occurring in the first couple of inches since the 0-2 inch region retained the most turbidity. Even though most of the retained turbidity was in the upper portion of the filter (anthracite layer), that portion of the filter was adequately cleaned after backwashing. You can also see that a fair amount of particles are being removed throughout the sand layer, since it also retained substantial particles/turbidity. However, the sand layer was not well cleaned during the backwash, as indicated in Chart 7-1 above. If these were actual results, the backwash rate would be investigated to make sure that it is sufficient for the type of sand used (See Test #11 for more information regarding appropriate backwash rates).

Ideally, almost all of the particles should be removed throughout the anthracite layer, although some will be removed at the sand/anthracite interface. If the filter is adequately backwashed, all of the filter media should be clean and ripened. It is possible to get a filter too clean. It is also possible for a filter to be dirty following a backwash. Refer to Table 7-1 on the following page to determine if the backwash/rewash resulted in a **clean** *and* **ripened** filter.

Table 7-1. Filter Bed Cleanliness After Backwashing/Rewashing

Floc Retention Test Turbidity (after backwash and rewash)	Bed Cleanliness
10-30 NTU	Very clean, not well ripened
30-60 NTU	Clean and partially ripened
60-120 NTU	Reasonably clean, well ripened
120-300 NTU	Dirty Media, well ripened
300-600 NTU	Dirty Media w/ possible mudballs, well ripened
600-1200 NTU	Very dirty media bed, many mudballs
>1200 NTU	Extremely dirty, chemical cleaning or replacement needed

CHART 7-2



FILTER NO.: ____________

DATE: ____________

TIME: ____________

TESTER: ____________

FLOC RETENTION TEST

WORKSHEET

AWWA ____________ FILTER SURVEILLANCE PROGRAM

8. EVALUATING BACKWASH PROTOCOL

PURPOSE:

Proper filter design alone will not yield good filtered water. Problems with poor performing filters relating to media degradation and disruption of support gravel can often be attributed to inadequate backwashing or excessive backwashing rates. In addition, filtered water quality may suffer due to lengthy run times and poor operation.

Although evaluating backwash protocol may not be an actual filter test, the evaluation of backwash procedures is critical to optimization. Inadequate backwash procedures be detrimental to filtered water quality, even if the filter itself does not have any major problems.

SUMMARY

The first thing that should be included in the backwash procedures is the basis for initiating a backwash. Turbidity or particle count breakthrough should always be one of the primary triggers. The treatment plant should have a filtered water goal, preferably 0.1, but certainly less than the regulatory limit. The operator should always initiate a backwash before particle/turbidity breakthrough occurs, not in response to a breakthrough event. For example, if the effluent turbidity exceeds the plant's stated goal, then a backwash should be initiated regardless of run time or loss of head. However, if the maximum allowable head loss is reached before turbidity breakthrough occurs, then a backwash can also be initiated. Finally, the plant should identify a maximum filter run time after which the filters will be backwashed if no significant turbidity breakthrough or head loss occurs.

In addition to outlining the basis for initiating a backwash, the backwash procedures should provide a step-by-step instruction for how to backwash the filters. The instructions should indicate the backwash sequence including when to use the surface sweep or air scour system and when to turn them off. The operator may need to turn off the surface sweeps during the maximum backwash rate to prevent media loss. The length of backwash, the backwash rate, the length of rewash, should also be included. Various tests in this manual will assist the operators in determining the optimum backwash parameters.

Finally, for plants with filter-to-waste (rewash) capability, the rewash should be of sufficient length to allow the initial turbidity spike to pass. Ideally, rewash should continue until the effluent turbidity is 0.1 NTU or less. If the filter is in good condition and the settled water quality is good, this should occur within 15 minutes.

9. VISUAL BACKWASH OBSERVATION

PURPOSE:

The purpose for visually inspecting the filter backwash is to identify any potential problems that may be exposed during the backwash process. This only applies to filters which have not been disrupted by draining, coring, or any other filter tests. If any potential problems are exposed, followup tests can be conducted which target the suspected problem.

INSTRUCTIONS & COMMENTS:

Initiate a filter backwash. Throughout the backwash cycle, look for the following potential problems:

a. When the backwash cycle begins, does the backwash water come up through the filter media in an uneven and violent manner? If the backwash water is not evenly distributed, filter boils may be observed. Filter boils are usually a sign of problems with the support gravel or the filter bottom/underdrain itself.

b. Where surface sweeps are used, are the nozzles in good condition? Does the arm actually rotate?

c. Is the backwash flow gradually increased to the maximum rate. If the backwash rate is not gradually increased, the surge can disrupt the support media and even blow out the filter bottom.

d. Are there any massive air surges occurring during backwash, especially at the beginning? Some air may become entrained in the media during normal operation and it will be released during backwash. However, excessive air surges will disrupt the support media and can be detrimental to filter performance. This can be caused by air entering the backwash line, especially if the check valve is malfunctioning.

e. Are there any dead zones that do not appear to be cleaned thoroughly? This can indicate many possible problems. The underdrain may be full of media. Another possibility is that there may be impermeable areas of the filter caused by mud deposits or calcification.

f. Are the backwash troughs submerged? Make sure that there is at least a 2 inch freeboard between the water level in the filter and the water level in the trough during backwash. The backwash troughs provide a slow, even way for the backwash water to leave the filter. If the troughs are flooded, all of the water will rush towards the drain at high velocities. The high velocity water can displace the media, resulting in mounding on the drain end of the filter.

g. Is any media being lost over the trough during backwash? Obviously this is undesirable because the filter will no longer be able to perform as it was designed.

h. Does the backwash waste water still look dirty at the end of the backwash cycle?

i. Does the filter media itself look very dirty after the backwash is complete?

<u>Figure 9-1 & 9-2.</u> Filter Boils

COMMENTS:

If any of the above are observed during a backwash, additional tests and studies should be used to find and correct the problem.

10. BED EXPANSION TEST

PURPOSE:

The ability of a filter backwash to remove dirt from the media is dependent on filter bed fluidization. The difference between the depth, or thickness, of the fluidizable media (sand and anthracite) before backwash and the depth of the fluidizable media during backwash is the bed expansion. The purpose of this test is to measure the bed expansion and determine if the expansion is sufficient.

VARIOUS BED EXPANSION TOOLS

There are several ways to construct a bed expansion measuring device. The easiest way is to tie a string to the center of a thin steel plate that is approximately 6-12 inches in diameter (See Figure 10-1). The steel plate is painted with a white reflective paint. A disc attached to the end of a rod will also work. With these plate/disc devices, the disc is lowered into the media prior to backwash to get a baseline distance from a fixed point to the top of the media. During backwash, the disc is lowered again until it disappears into the fluidized anthracite. The distance from the fixed reference point is measured again and the difference is the actual bed expansion.

Another popular device utilizes a pole with several pipes on the end. The pipes are arranged like a set of church organ pipes with each pipe 1 inch longer than the next (Figure 10-2). The unit is lowered onto the top of the media and the pole is then solidly affixed to a rail. During backwash, the expanded media fills the pipes that are in the expanded zone. The height of the tallest pipe that is full of media will be equal to the bed expansion in inches.

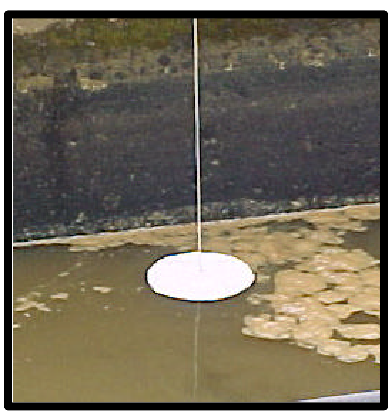


Figure 10-1. String & Plate Device

Figure 10-2. Pipe Organ Device

PROCEDURE:

The procedure outlined in detail below is for the string & plate/disc device as pictured in Figure 10-1.

1. Isolate the filter by closing the influent and effluent valves.

2. Lower the disc into the water until it reaches the top of the filter bed. At that point, make sure that the string is taut and mark the rope at the location corresponding to a fixed reference point (such as the curb top at the filter deck).

3. Remove the disc and measure the string distance from the mark to the disc. This measurement is the distance from the reference point to the top of the media.

4. Begin the backwash sequence.

5. After the backwash has reached its maximum rate, lower the disc into the filter until the black slurry (fluidized media) just begins to flow over the disc. You may have wait until the water begins to clear in order to see the disc.

6. Repeat step #5 a few times to ensure accuracy, marking the rope at the fixed reference point each time the disc disappears (making sure that the rope is taut) .

7. Remove the disc and measure the distance between the new mark to the disc. This is the distance from the reference point to the top of the ***fluidized*** media bed.

8. Subtract the measurement taken in step #7 from the measurement taken in step #3. This is the bed expansion in inches.

9. Calculate the bed expansion as a percentage of the total bed depth using the following formula:

   Bed Expansion (%) = [bed expansion (in) / total depth of sand & anthracite (in)] x 100%

10. Complete filter backwash and return filter to service.

A form similar to the table below can be used to document the bed expansion test:
Table 10-1. Bed Expansion Worksheet

Parameter	Result	Units
Filter Number		--
Date of Test		--
Time		--
Tester		--
Depth to Top of Media before Backwash		Inches
Depth to Top of Media during Backwash		Inches
Total Depth of Fluidizable Media (sand & anthracite)		Inches
% Bed Expansion		%
Water Temperature		^{o}C
Backwash Control Valve - % Open		%

COMMENTS / ISSUES:

The American Water Works Association (AWWA) recommends that the filter bed expansion be between 15 and 30% during the maximum backwash rate. According to EPA, optimized bed expansion is 20-25%. If bed expansion is too low, the filter media will not be adequately cleaned. If the bed expansion is too high, the media may be so far apart that there is no scouring action and the media will not be adequately cleaned. Conversely, the media may be cleaned too much, resulting in an unripened filter. In addition, water is wasted and media can be lost if the bed expansion exceeds 30%.

The form above requires that the tester record water temperature. The density of water, and therefore the specific gravity of the media, will change with respect to temperature. This is important because the quantity of backwash water necessary to achieve the same bed expansion will increase with temperature. For example, if a filter is backwashed at 10 ^{o}C water temperature in the winter, the required backwash rate will only be about 75% of the rate needed during the summer when the water is 25 ^{o}C. Therefore, the operators should take temperature into account when selecting backwash rates (this will be discussed further in test #11). For example, the operator may have a summer backwash rate and a winter backwash rate if significant temperature changes are expected.

The bed expansion test can be a useful tool in helping the operator determine the proper backwash rate. Usually, if the bed expansion is insufficient, so is the backwash flowrate. Refer to Test #11 for more information regarding backwash rates.

Note: When calculating the % bed expansion, do not refer to the design depth of the media. It is best to determine what the media depth actually is (see test #3) before calculating the percent expansion. This is important because the filter may have lost several inches of media since the media was installed. Also, if the steel plate method is used, make sure that the steel plate has enough density to sink during backwash.

11. RISE RATE TEST (CONFIRMING BACKWASH RATES)

PURPOSE:

Many operators backwash according to a pre-arranged set of flow rates and corresponding times. Since backwash flow meters are not always accurate it is good practice to determine the "actual" backwash rate, especially if an improper bed expansion is occurring during backwash.

This section will also discuss proper backwash rates for various types of media and at different temperatures.

PROCEDURE:

1. Close filter influent valve.

2. Partially drain the filter, then close the filter effluent valve and the backwash water drain valve.

3. Start backwashing the filter, ramping up from a low backwash rate to the maximum backwash rate.

4. As the water level in the filter rises, use a stopwatch to record how many seconds it takes the water level to rise a certain amount (usually 3 or 6 inches). Then convert this time into minutes. Be sure that the water level is above the backwash troughs during this test so that the volume of the troughs will not lead to erroneous results. <u>Also, perform the test quickly so that the drain valve can be opened in time to prevent flooding the filter basin</u>.

5. Calculate the volume of water that was pumped during the specified time period. The volume can be calculated by multiplying the area of the filter by the vertical displacement of the water surface during the test. For example, consider a 20' x 30' filter. The water level rose 6 inches in 22 seconds. The volume of water pumped during the 22 second time period is as follows:

Volume (gallons) = filter area x vertical distance x 7.48 gal per ft3
Or
Volume = 20' x 30' x .5' x 7.48 = 2,244 gallons

6. Calculate the actual backwash rate in gpm using the volume (from step #5) and the elapsed time (from step #4).

Backwash rate (gpm) = Volume of Water in Gallons / Minutes

7. Calculate the backwash rate in terms of gpm per square foot of filter area using the following formula:

Backwash rate (gpm/ft2) = Backwash Rate in gpm / Filter area in ft2

COMMENTS:

The procedure outlined above can be used to confirm various backwash rates used during a backwash event. If the actual backwash rate does not closely match the flow indicated by the flow meter, the meter must be calibrated. As a general rule of thumb, acceptable backwash rates range from 15 – 23 gpm/ft^2, depending on the type of filter media used and the filter bottom. Refer to Test #6 for a review of media characteristics.

Chart 11-1 is from AWI, a filter optimization company. It provides the appropriate backwash rate for various filter medias at 20 ^oC (68 ^oF). Chart 11-2 provides the appropriate temperature correction factor for temperatures other than 20 ^oC (68 ^oF).

As stated in Test #6, the filter media (sand & anthracite) should be matched if possible so that they both share the same optimum backwash rate. Although this is primarily a design issue, it can come into play when replacing media that has been lost. Ideally, the sand should require a slightly higher backwash rate than the anthracite in order to prevent media mixing and ensure a stratified media bed. For example, a filter has lost 4 inches of anthracite. The plant engineer wants to order some replacement anthracite coal. If the sand has a specific gravity of 2.64 and a D_{60} of 0.7 mm, then the sand will require 45 m/hr (18.4 gpm/ft^2) to become fully fluidized. The anthracite selected should closely match the existing anthracite, while requiring a backwash rate that is slightly lower than that of the sand, say 40 gpm/ft^2.

<u>The main point of a rise rate test is to determine the actual backwash rate and make sure that the backwash rate is appropriate for the media</u>. Contact a filter media expert for more detailed information on media sizing. It should also be pointed out that other design constraints (financial restraints and treatment objectives) may have to be considered.

CHART 11-1

AWI
4450 - 46 Avenue SE
Calgary, AB T2B 3N7
Phone (403) 255-7377 Fax (403) 255-3129

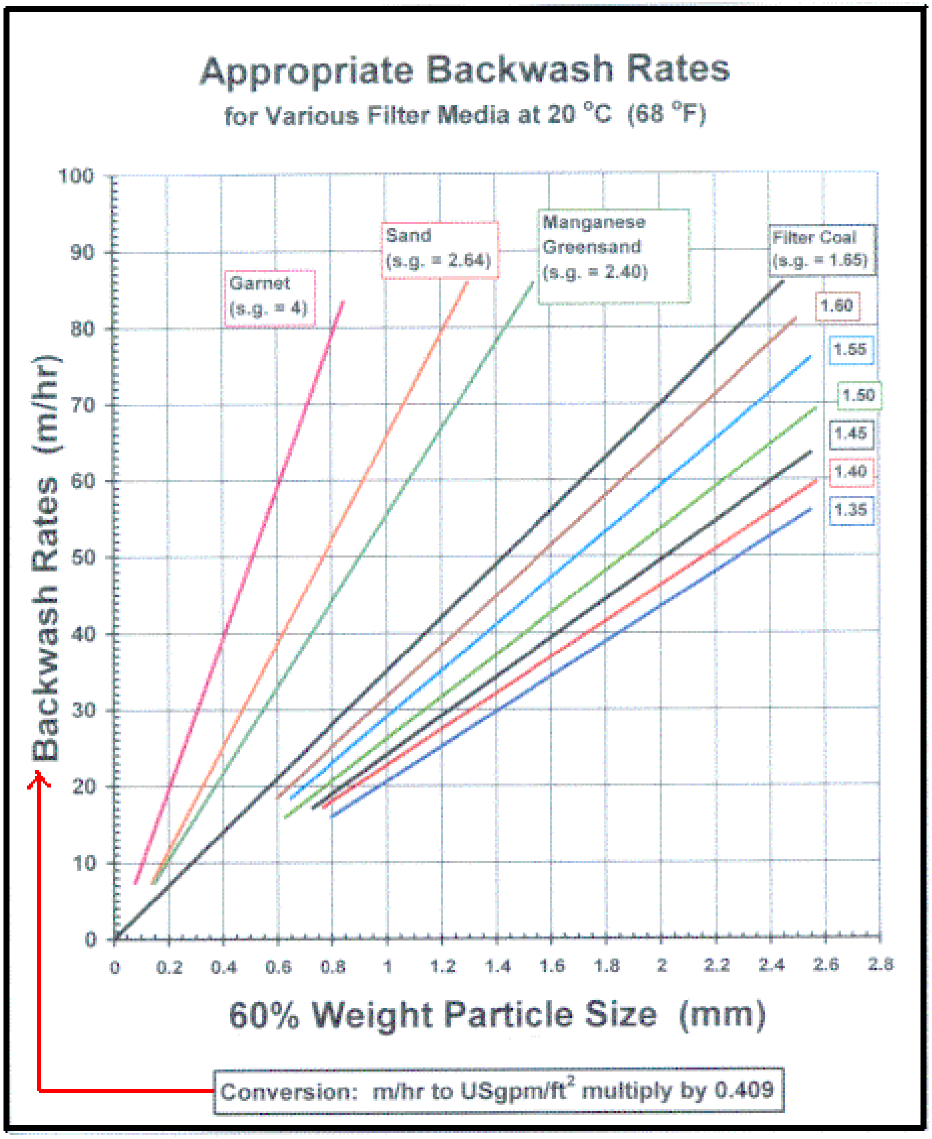
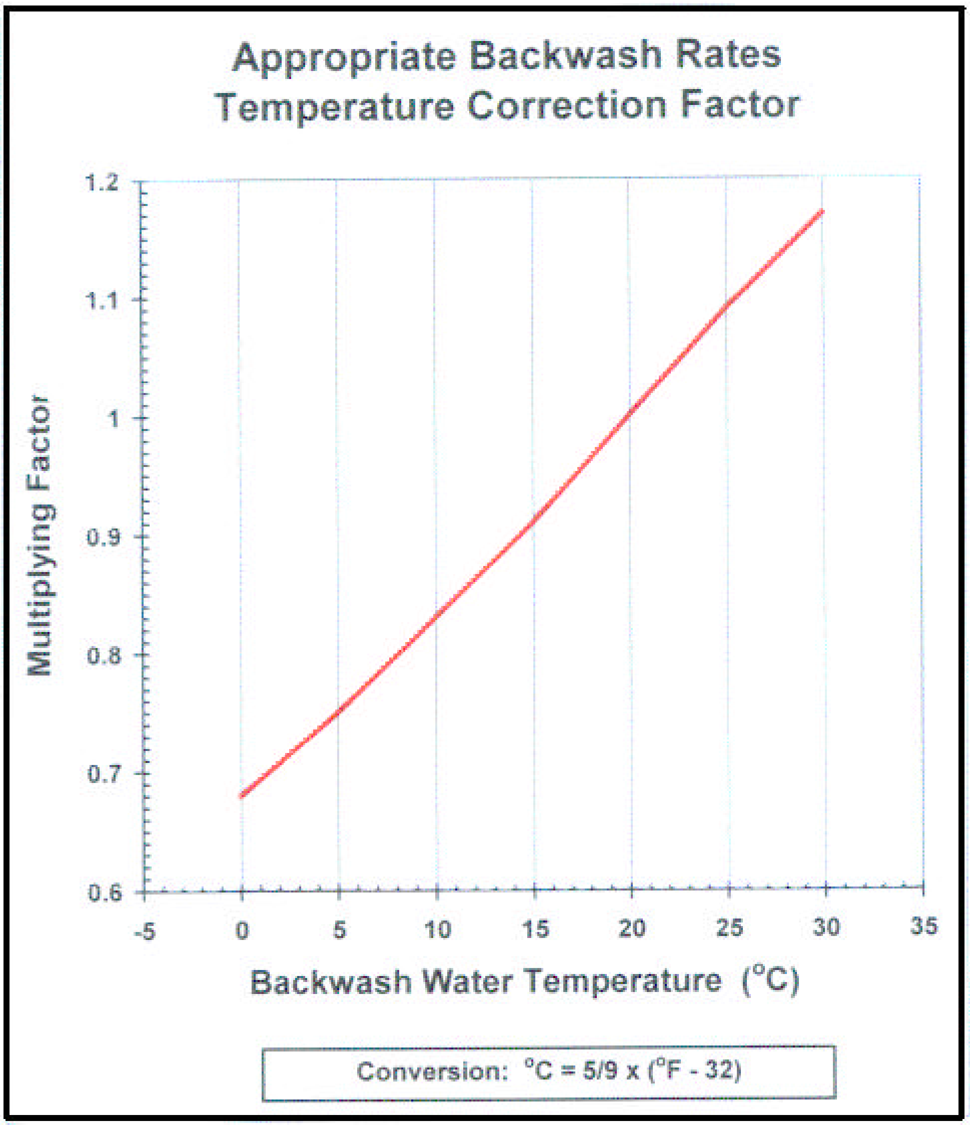


CHART 11-2

AWI
4450 - 46 Avenue SE
Calgary, AB T2B 3N7
Phone (403) 255-7377 Fax (403) 255-3129



12. BACKWASH WATER TURBIDITY PROFILE

PURPOSE:

Extending the filter backwash duration will remove some additional dirt/turbidity from the filter media. However, it is possible to get the media too clean and waste backwash water by backwashing too long. Some portion of turbidity (particles) should be left in the filter to improve removal efficiency when the filter is returned to service. In other words, some dirt/turbidity should remain so that the filter is "ripened" when it is placed online. Although the rewash process (for plants with rewash capability) can help to ripen a filter, the best approach is to optimize the duration of the backwash cycle, which can in turn lead to a shortened rewash cycle. The AWWA recommends that the backwash be terminated when the backwash water from the troughs reaches a level of 10-15 NTU. A backwash water turbidity profile provides an indicator of how effective the backwash duration is.

PROCEDURE:

1. Begin filter backwash according to standard operating procedures.
2. Construct a sampling device by tying a rope around a bucket handle or fasten a beaker to the end of a rod.
3. Lower the sampling device into the backwash water trough and extract the first sample when the backwash water begins to spill over into the trough (time = 0).
4. Fill the first sample bottle and label it with the sample time (in minutes), the backwash rate used at that time, and the status of the surface wash (on or off).
5. Empty the remaining water from the sampling device and prepare to take the next sample.
6. Additional samples should be taken every minute during the backwash.
7. After the backwash is complete, take all of the sample bottles to the lab for analysis.
8. Thoroughly shake each sample bottle to re-suspend any deposition and analyze for turbidity using a benchtop turbidimeter.
9. Graph the results using the attached form (Chart 12-1). Refer to Chart 12-2 for an example.

CHART 12-1.

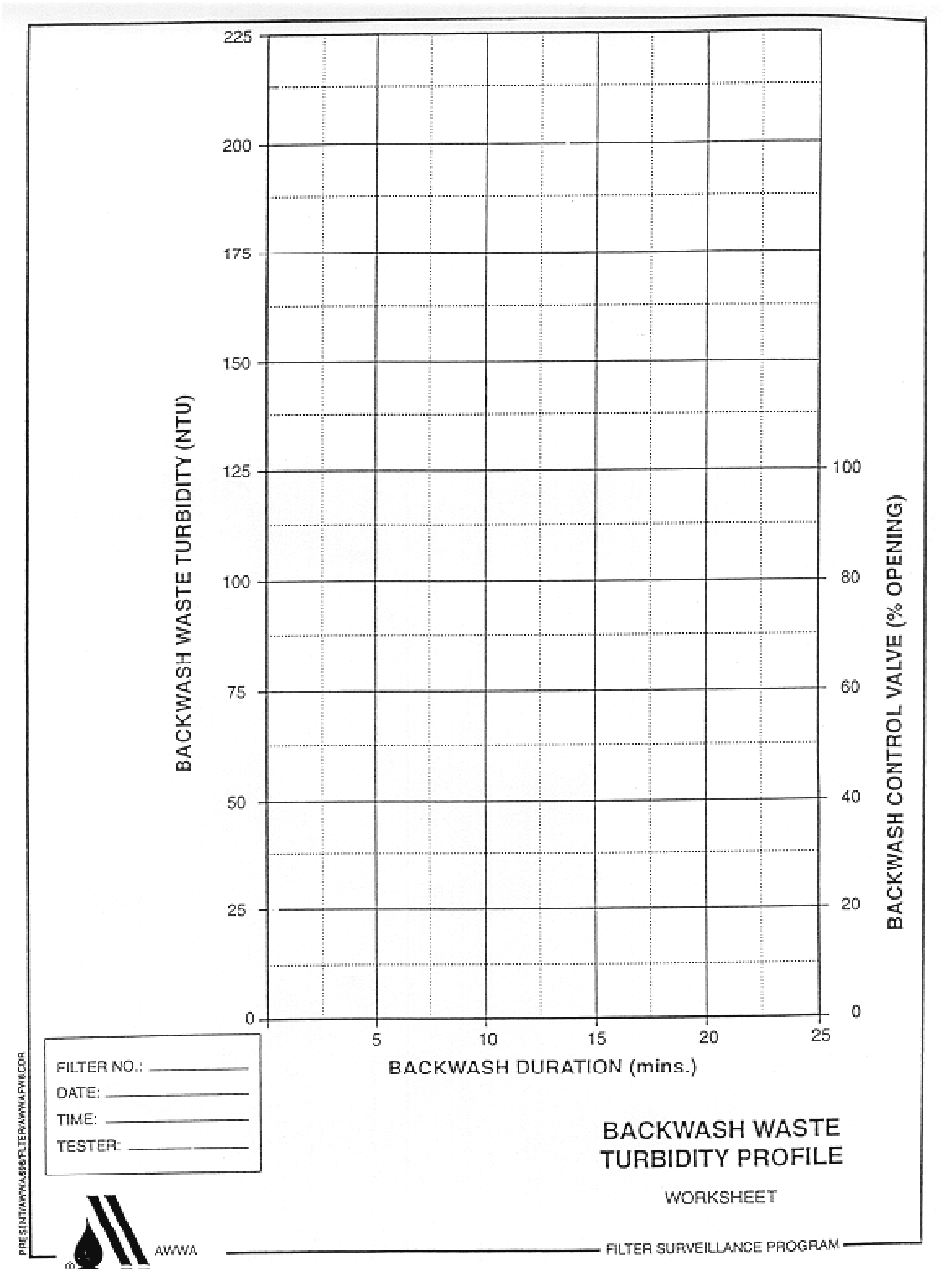
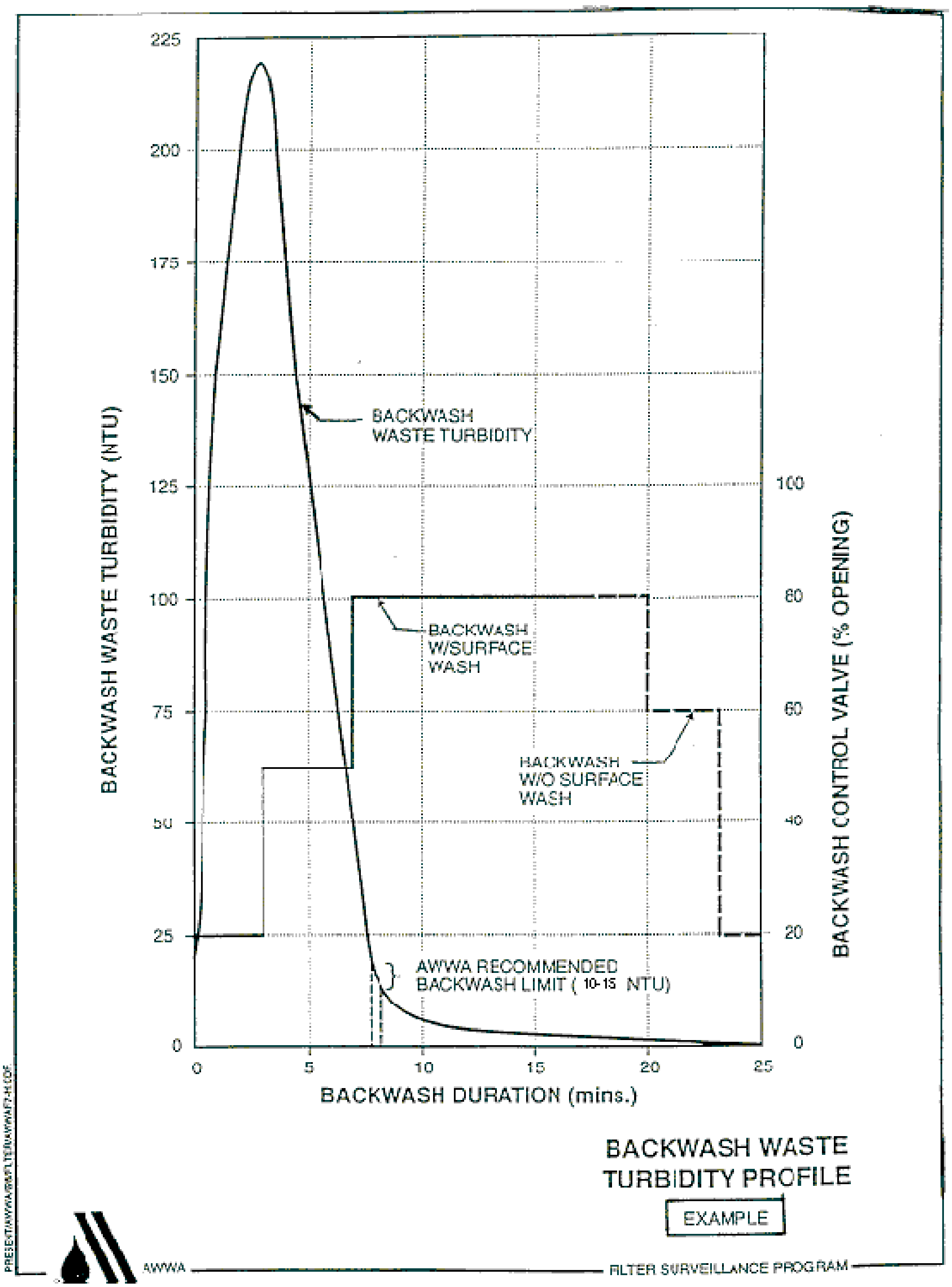

BACKWASH WASTE TURBIDITY (NTU)
225
200
175
150
125
100
75
50
25
0
BACKWASH CONTROL VALVE (% OPENING)
100
80
60
40
20
0
5
10
15
20
25
BACKWASH DURATION (mins.)
FILTER NO.:
DATE:
TIME:
TESTER:
BACKWASH WASTE TURBIDITY PROFILE
WORKSHEET
AWWA
FILTER SURVEILLANCE PROGRAM

CHART 12-2.


BACKWASH WASTE TURBIDITY (NTU)
BACKWASH CONTROL VALVE (% OPENING)
BACKWASH WASTE TURBIDITY
BACKWASH W/SURFACE WASH
BACKWASH W/O SURFACE WASH
AWWA RECOMMENDED BACKWASH LIMIT (10-15 NTU)
BACKWASH DURATION (mins.)
BACKWASH WASTE TURBIDITY PROFILE
EXAMPLE
AWWA
FILTER SURVEILLANCE PROGRAM

COMMENTS:

After plotting the data using Chart 12-1, the adequacy of the backwash duration can be evaluated. Is the filter duration to short, too long, or is the backwash terminated when the backwash water turbidity reaches 10-15 NTU as recommended? As stated earlier, if the duration is too long, then water will be wasted, and the filter will not be ripened when it is returned to service. This can be especially true if the plant does not have filter-to-waste (rewash) capability. On the other hand, if the duration is too short the filter will not be adequately cleaned.

In addition to determining the proper backwash duration, the resulting chart will allow the operator to see what is happening as each phase of the backwash is performed (turning on backwash at low rate, increasing the backwash rate, turning on the surface sweeps, turning off the surface sweeps, and ending the backwash without the sweeps on, etc.).

Remember that the two biggest things that affect the efficiency of a backwash are intensity and duration. Make sure that the proper backwash rate(s) for the media has been selected first by performing Tests #7, 10, & 11. Once the proper backwash rate has been selected, THEN perform a backwash water turbidity profile to determine the proper duration.

13. REWASH WATER TURBIDITY PROFILE

PURPOSE:

Filter-to-waste, or rewash, usually has a duration of 15-30 minutes. This allows the initial particle/turbidity spike to be wasted before placing the filter online. For a well-conditioned filter, the initial turbidity spike should pass within the first 15 minutes. Ideally, the filter should not be placed online until the rewash turbidity is at or below 0.1 NTU. This test will determine if the rewash duration is adequate.

This test only applies to plants with filter-to-waste capability.

PROCEDURE:

1. Take the filter out of service and then backwash it.

2. After the backwash is complete, open the rewash valve and begin filtering to the waste basin.

3. Record the turbidity every minute during the rewash.

4. After the rewash ends and the filter is placed online, chart the results on the attached graph (Chart 13-1) or create a similar graph by using a computer.

COMMENTS:

Before conducting this test, make sure that the turbidimeters are accurate. Also, make sure that the turbidity sample line for the filter is BEFORE the rewash valve. Otherwise, the turbidimeter will not be receiving any water and the results will be erroneous.(Refer Figure 13-1 below).

After the test has concluded and the results have been graphed, determine if the initial spike has passed. Also, did the rewash last long enough for the turbidity to fall below 0.1 NTU before the filter was placed back online? If not, the rewash duration may need to be extended. If the turbidity is not acceptable after rewashing for 30 minutes, then the filter may have other deficiencies (the filter was not cleaned good enough, the filter was cleaned too much, there is short circuiting within the media, etc.). It should be noted that some SWTP's have found that required filter ripening time may be shortened if the backwash flow is gradually reduced rather than abruptly stopped.

It should be pointed out that several design constraints may limit the effectiveness the rewash cycle. For example, if the rewash line is improperly sized, then it cannot handle the same flow as the filter. Therefore, even if the turbidity is below 0.1 NTU after rewash, the filter may see an increase in flow when placed online, and therefore a potential increase in particles/turbidity. The size of the plant's waste handling capabilities must also be considered. For example, the optimum rewash time may be 30 minutes, but the decant basin may only be large enough to handle 20 minutes of rewash.

Note: For plants not equipped with filter-to-waste capability, filter ripening can be enhanced by allowing the filter to "sit" after backwashing. Dosing alum or a filter aid polymer directly on top of the filter while it is filling (after a backwash) can also be effective.

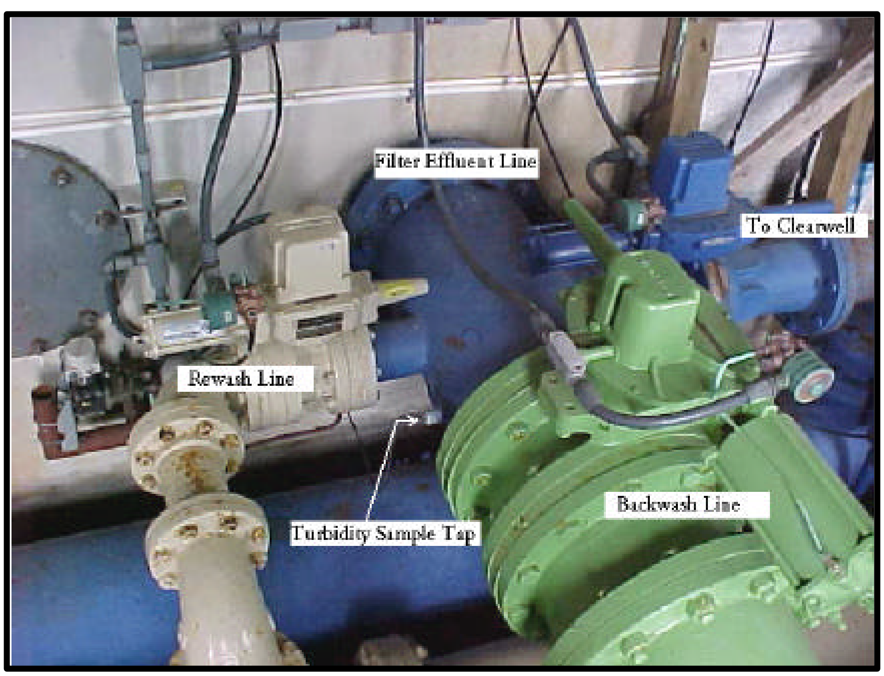
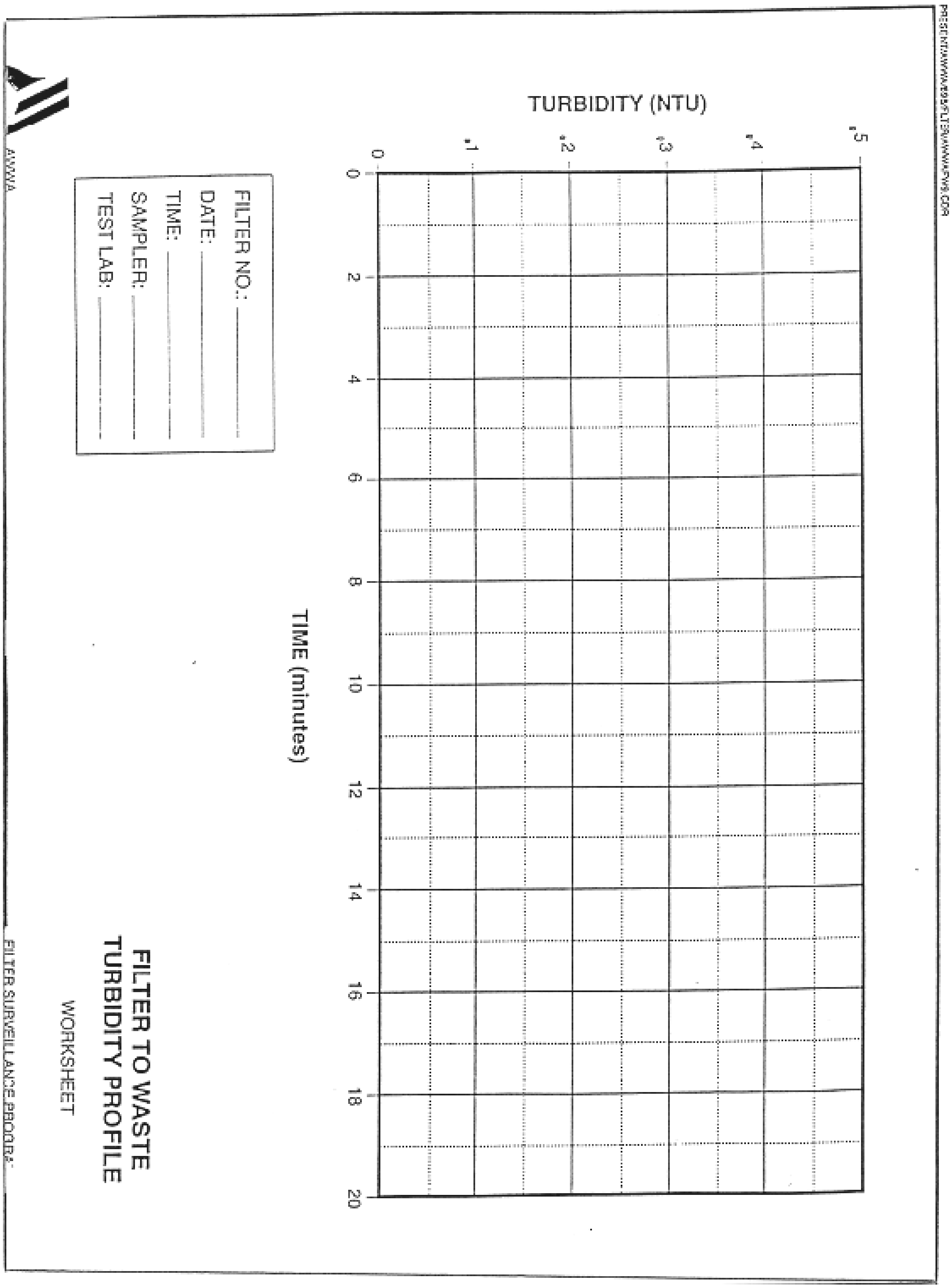


Figure 13-1. Improper turbidity sample location (sample point is located *after* the rewash valve)

CHART 13-1


TURBIDITY (NTU)
0
.1
.2
.3
.4
.5
TIME (minutes)
0
2
4
6
8
10
12
14
16
18
20
FILTER NO.:
DATE:
TIME:
SAMPLER:
TEST LAB:
FILTER TO WASTE
TURBIDITY PROFILE
WORKSHEET
AWWA

14. ASSESSING RATE-OF-FLOW CONTROLLERS & FILTER VALVE INFRASTRUCTURE

PURPOSE:

There are four major types of flow controllers that affect the filtration process. There are filter effluent control valves, total plant flow controlling valves, backwash valves, and rewash valves (for plants with filter-to-waste capability). Because these devices can potentially affect water quality, they should be evaluated as part of any filter assessment.

1. Filter Effluent Control Valves

The practice of instantaneously changing the filtration rate as opposed to gradually adjusting the filtration rate is referred to as filter bumping. Hydraulic changes, such as those caused by filter bumping, can cause filters to shed particles. Filters become increasingly sensitive to hydraulic changes as filter run time increases. Filter effluent control valves that are in need of maintenance have the potential to cause filter bumping.

In most water plants, the filter effluent valves change position in order to maintain the desired flowrate. However, if there are problems with the filter effluent control valves, they will constantly open and close while seeking the correct position (similar to a bad thermostat). This will lead to constant filter bumping.

As an example, Figure 14-1 shows online turbidity measurements for two filters in a treatment plant. Each of the two filters had problems with the filter effluent control valves, which became more evident as headloss built up in the filters. This phenomenon is especially evident in filter #4. As run time and headloss increases, the filtered water turbidity increases and becomes increasingly variable.

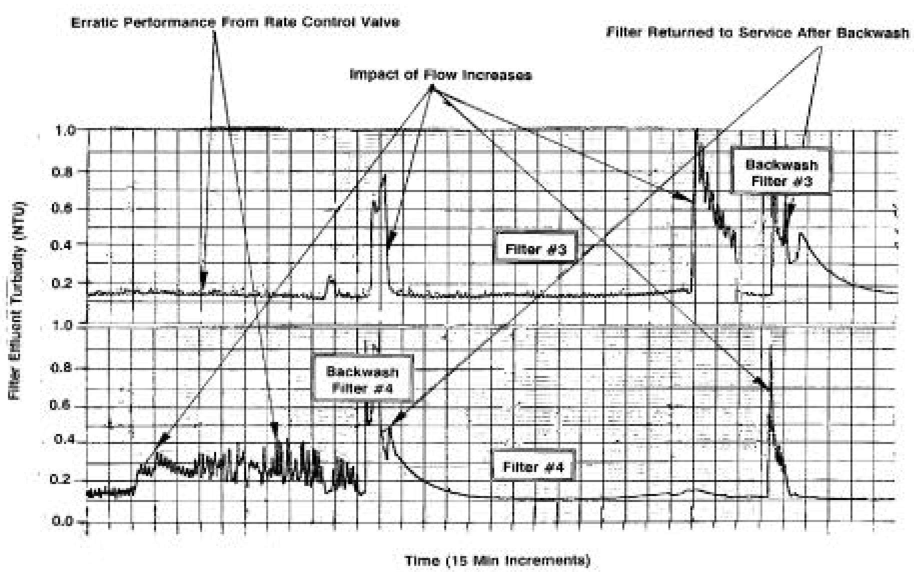


Figure 14-1. Problems due to Faulty Filter effluent Control Valves

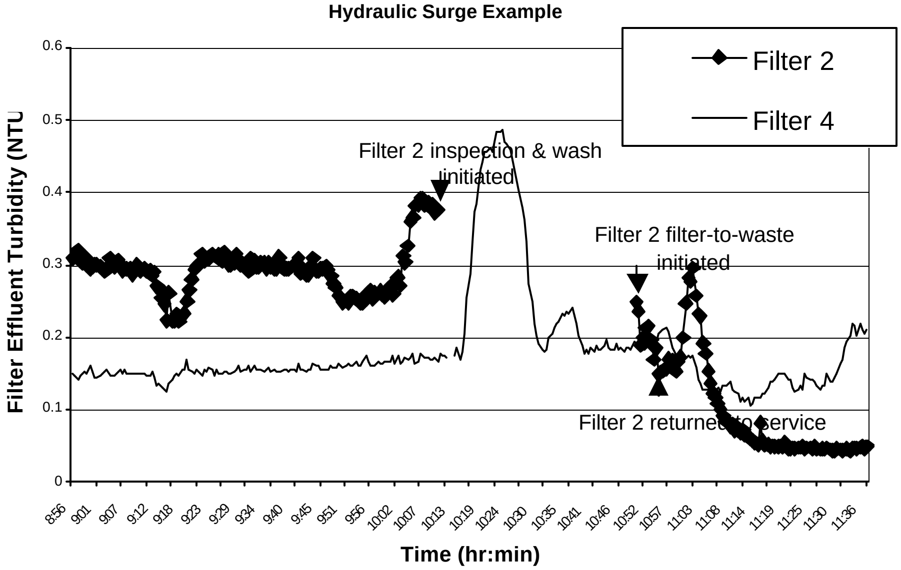
2. Total Plant Flow Rate Controllers

Some treatment plants are designed to treat water at varying flowrates by using a throttling valve between the raw water intake and the rapid mix or by using variable speed drives. Other plants can vary their flowrate by manipulating the number of raw water pumps being used. There are also some treatment plants with no control over the plant flow rate. For these plants, there is flow or there is no flow. This topic is important to filtration because of the hydraulic surge that can result from a filter being removed from service (for backwashing, maintenance, investigation, etc). As stated earlier, filters are sensitive to instantaneous increases in flow, especially as run time and headloss increase. As an example, consider a 10 MGD plant with 4 filters. If one of the filters is taken offline without reducing the plant flowrate, the remaining three filters could instantly see up to 33% more water. This hydraulic surge will cause turbidity/particle breakthrough.

For plants equipped with some sort of raw water throttling valve or variable speed drives, the best practice is to decrease the total plant flow to the proper rate when one of the filters is taken offline. By doing this, the other filters will not see an appreciable change in flow. Depending on the size and number of raw water pumps, other plants can obtain similar results by adjusting the raw water pumping configuration. Of course, there are some treatment plants that are either operating at the design flow or the plant is shut down. For this kind of plant, the raw water pumps can be turned off while one or all of the filters are backwashed. This may not always be practical, especially in drought scenarios or during peak demand, but the operator should at least be aware that substantial turbidity and particle breakthrough can occur when the filters receive a hydraulic surge.

To illustrate the potential effects of a hydraulic surge, consider the following example. Figure 15-1 shows two filters that share the same sedimentation basin. In this example, filter #4 recieves the additional flow and encounters a hydraulic surge when filter #2 is taken offline for backwashing. A substantial number of particles, including pathogens, can pass through the filter during such an event.

Figure 14-2
Hydraulic Surge Example



3. Backwash Valves

Improperly seated valves can have negative impacts on filter performance. If backwash valves are improperly seated, washwater can be introduced as the filter is producing water. This is especially a problem when the primary source of backwash water is water from the distribution system or water from an on-site elevated tank dedicated to backwash.

For plants that pump backwash water from a clearwell or wet well, the check valve and/or air release valve can malfunction, thus introducing air into the backwash water line. This can disrupt the support media in a filter during backwash..

4. Rewash Valves

Malfunctioning rewash valves can negatively affect filter performance immediately following the backwash/rewash cycle. If the rewash valve does not open 100%, then the rewash flow rate will be reduced even if the actual rewash line itself is properly sized. Even if the turbidity falls below 0.1 NTU at the end of the rewash, a spike may occur after the filter is placed online because of an instantaneous increase in flowrate.

15. EVALUATING FILTER RUN PROFILES

PURPOSE:

The purpose is to produce filter run profiles that provide a visual representation of filter performance with respect to time. The filter run profile can then be used as a tool to explain the cause of performance spikes and poor performance in general.

COMMENTS:

The profile for the filter being evaluated should include a graphical summary of filter performance for an entire filter run from backwash-to-startup-to-backwash. Performance is typically represented by turbidity although particle counts may be used in addition to, or in lieu of, turbidity.

When evaluating a filter run profile, the operator should identify all turbidity spikes as well as sustained turbidity excursions. For each one, the operator should ask the question, "WHY?" This exercise will not only account for past turbidity excursions, but it will also allow the operator to see what happens to filter performance when certain process changes occur.

Common causes for turbidity spikes can include hydraulic surges associated with pump changes, an increase in plant flow due to backwash water recycle, and backwashing an adjacent filter. An example taken from EPA document **815-R-99-010** is provided on the following page.

Example

A utility has plotted total turbidity data versus time for a filter that cannot meet requirements for individual filters. The filter run is typically 24 to 28 hours with a resting period after backwash that varies from 8 to 10 hours. The generated filter profile is shown below in Figure 15-1. The review of turbidity data showed an inordinate number of spikes occurring during the filter run. This data corroborated with turbidity data that triggered the filter assessment. These spikes corresponded to changes in hydraulic loading rates made by the staff and may be indicative of greater problems within the filter itself. The significant increases in turbidity passing the filters occurred when the plant staff initiated recycle of treated backwash water to the head of the plant and when plant loading rates were modified during the evening to take advantage of off-peak electrical costs (represented by item B&D). Table 15-1 provides explanations for turbidity spikes.

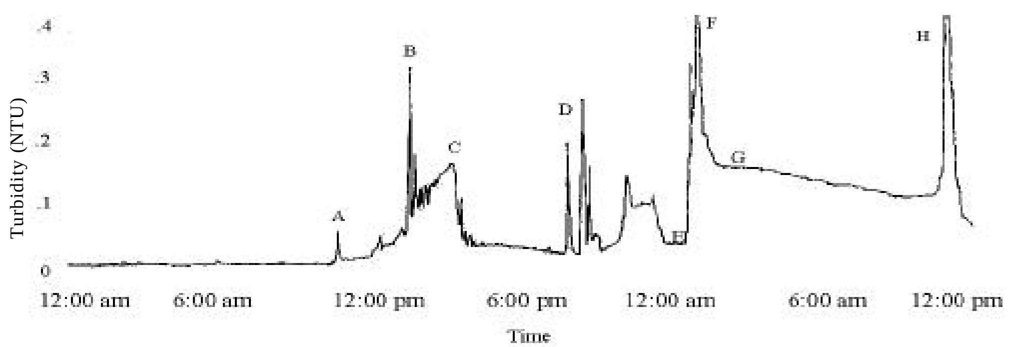


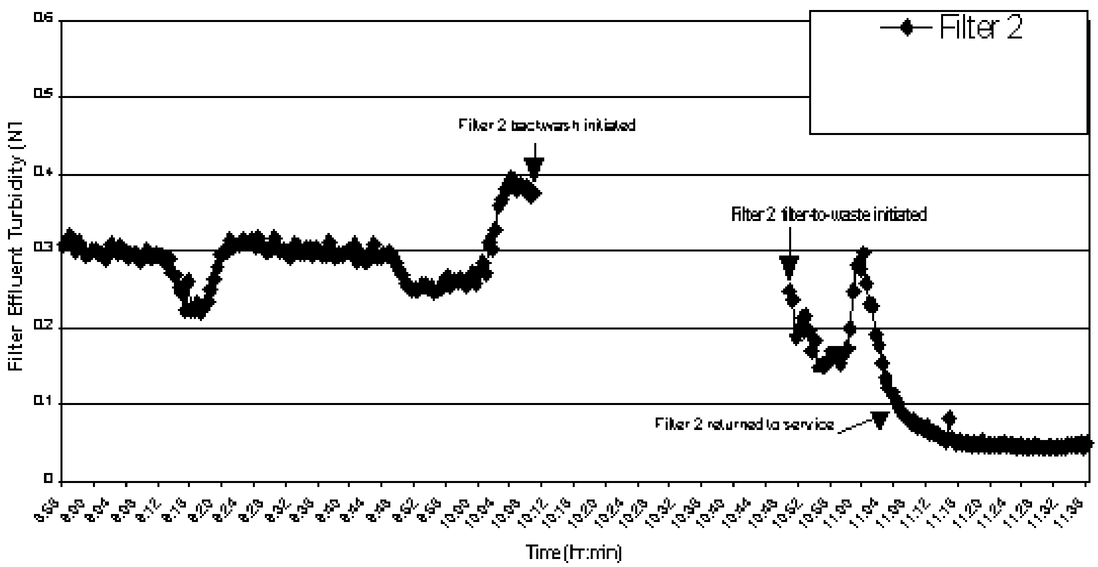
Figure 15-1. Filter Run Profile – Turbidity (NTU) vs. Time

Table 15-1. WTP Performance Deviation Trigger Events

Event	Performance Deviation Trigger Explanation
A	Pump change
B	Backwash water decant recycle to head of plant initiated
C	Backwash water decant recycle completed
D	Pumping rate increased to take advantage of off-peak electrical costs
E	Immediately following backwash of adjoining filter
F	Filter backwash
G	Filter taken out of service
H	Filter placed back in service

Poor filter performance may also be the result of prolonged filter runs. From the example in Figure 15-2 below, one can see that filter #2 is capable of producing a high quality effluent after being backwashed. However, the turbidity had climbed to 0.4 just prior to backwash. This may be the result of an extended filter run. For optimization, a backwash should be initiated when the turbidity exceeds 0.1 NTU. At a minimum, in order to ensure compliance with the IESWTR turbidity provisions, a backwash should be initiated when the effluent turbidity reaches 0.3 NTU. If this practice results in extraordinarily short filter runs, then there may be other problems with the filter. The filters may be too dirty, there may be mudballs, the filter bottoms may be damaged, the backwash may be inadequate, or the settled water coagulation may be poor. The tests outlined in this manual should help identify such problems.

Figure 15-2. Turbidity Breakthrough Resulting From an Extended Filter Run



16. FOLLOW-UP ACTIONS

PURPOSE:

To make physical and/or operational changes to a filter based on the results of a filter assessment or a filter surveillance program.

DOCUMENTATION OF RESULTS:

If a treatment plant performs a complete filter assessment, the findings should always be compiled in the form of a report. If the filter assessment is required as the result of a DHEC enforcement action or an IESWTR turbidity excursion, then a complete and detailed report will be required. However, a report should also be prepared if a utility performs a voluntary filter assessment. A well written report can be a powerful and persuasive tool when justifying capital expenditure relating to filter maintenance.

Although a formal report may not be necessary, proper documentation is also an important part of a filter surveillance program. By documenting the results, the operator will be able to identify trending relating to filter condition and performance.

TAKING ACTION:

If a thorough filter assessment is completed for a poorly performing filter, the assessment will likely lead to a diagnosis of the filter's deficiencies. However, the filter assessment is an exercise in futility unless the results are documented and then **applied** in a way that improves the filter performance. If a filter is found to have 6 inches of anthracite loss, more media should be added. If the backwash rate is determined to be too low or too high, then it should be optimized. If mud and mudballs are found within the filter, the media should be cleaned or replaced and the backwash procedures should be modified to prevent re-occurrence, etc.

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