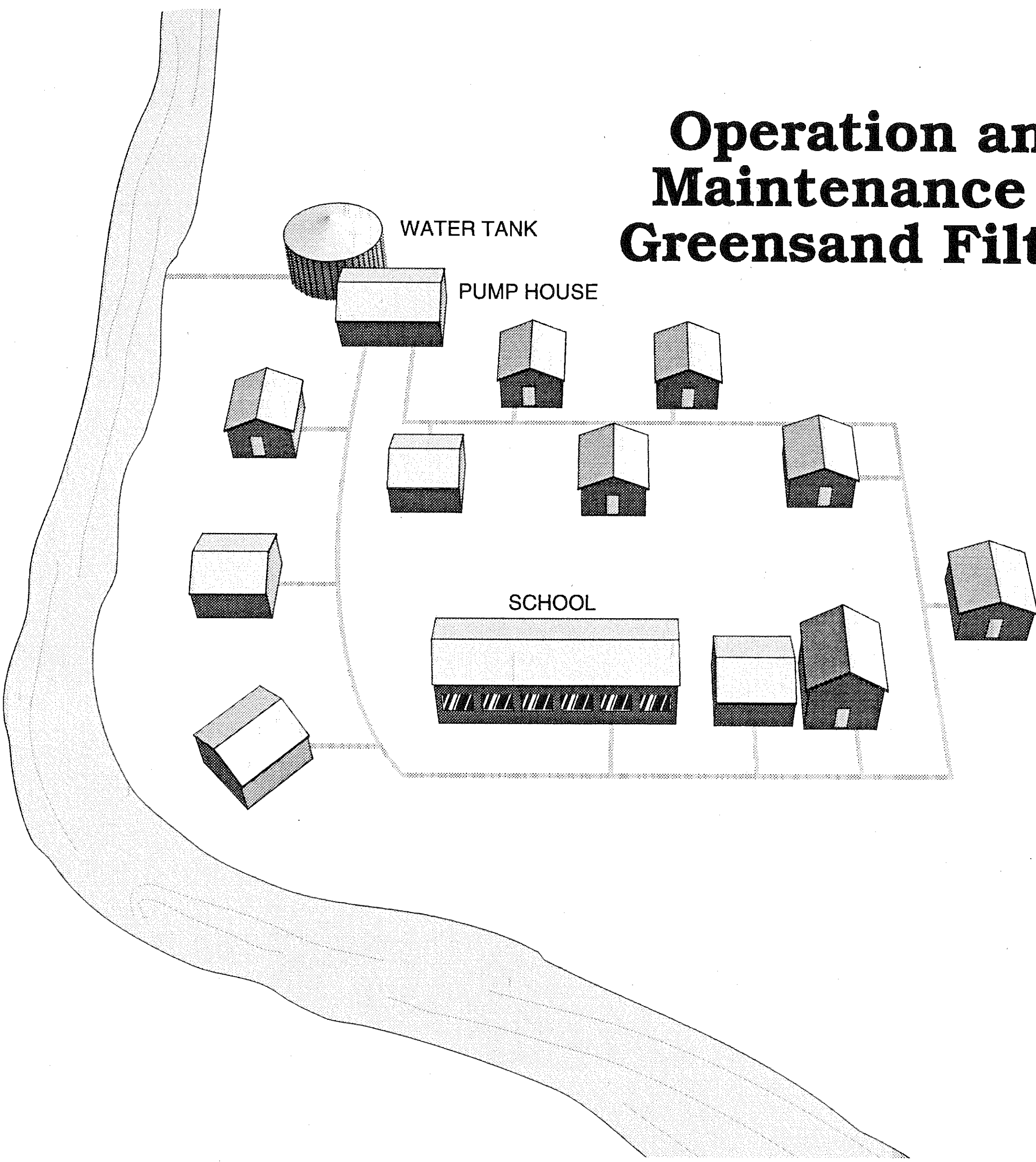
O & M of Small Water Systems

Operation and Maintenance of Greensand Filters



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O & M of Small Water Systems

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- Auxiliary contact
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REDUCTION OF IRON AND MANGANESE

WHAT ARE IRON AND MANGANESE?

Iron

Iron and manganese are natural metals found through out the earth's crust. Iron, chemical symbol Fe (for Ferrum), accounts for 5% of the earth's crust. Iron in a pure form is a silver white metal with an atomic number of 26, an atomic weight of 55.85 and a specific weight of 7.87. Iron easily combines with nonmetals such as sulfur, oxygen and carbon to form ore deposits. It is seldom found in the pure form.

Manganese

Manganese, chemical symbol Mn, is a silver gray metal with a pinkish tinge. It has an atomic number of 25, and an atomic weight of 54.93. In its pure form, it is of very little value. It greatest use is in the production of iron and steel products. Manganese is the 11th most abundant element in the earth's crust and yet represents much less than 1% of the total of the earth's crust. Iron, oxygen, magnesium and silicon make up 93% of the earth's crust.

Forms of Iron and Manganese

At the pH found in natural water, iron and manganese exists in solution in two basic forms.

Iron

The two forms of iron are **ferrous**[1] iron (Fe^{++} - sometimes shown as Fe(II)) and **ferric**[2] iron (Fe^{+++} - sometimes shown as Fe(III)). Ferrous iron is called the reduced state and ferric iron is called the oxidized state. **Ferric** iron is the more stable of the two forms.

Manganese

The two forms of manganese are **manganous**[3] manganese (Mn^{++} - sometimes shown as Mn(II)) and **manganic**[4] manganese (Mn^{++++} - sometimes shown as Mn(IIII)). The manganous state is called the reduced state and the manganic state is called the oxidized state.

Solubility

Ferrous iron and manganous manganese are soluble in water and ferric and manganic are forms that are insoluble in water.

Summary

Symbol	Name	State	Soluble in Water
Fe++	Ferrous	Reduced	Yes
Fe+++	Ferric	Oxidized	No
Mn++	Manganous	Reduced	Yes
Mn++++	Manganic	Oxidized	No

Iron is generally found in the ferrous (colorless and soluble) form in groundwater supplies.

[1] **Ferrous** - A form of iron with a plus two charge Fe^{++}. Commonly referred to as the reduced soluble form of iron.
[2] **Ferric** - A form of iron with a plus three charge, Fe^{+++}. Commonly referred to as the oxidized insoluble form of iron.
[3] **Manganous** - The form of manganese with a plus two charge, Mn^{++}. This form is said to be reduced and is soluble in water.
[4] **Manganic** - The form of manganese with a plus four charge Mn^{++++}. This form is said to be oxidized and is not soluble in water.

WHAT IS THE PROBLEM?

Iron and manganese in their natural forms in the earth's crust are basically in the insoluble ferric and manganic forms. Through a process that will be described later, they are oxidized to a soluble form. This still does not represent a problem until they are once again reduced through the chemical process called oxidation. (Yes, it is confusing that the process of oxidation is chemically reducing a compound. No one said life was fair.) When they are oxidized they;

- Alter the appearance of the water
- Cause deposits and slime buildups in pipe
- Cause stains in laundry and on fixtures
- Cause the water to taste strange, some say metallic

Oxidizing

When water containing excessive quantities of iron or manganese are allow to splash into the sink, sit in a container open to the atmosphere or chlorine is added, the iron and manganese are oxidized (chemically reduced) to their insoluble forms. This causes stains and discoloration of the fixtures and clothing. Iron causes red, rust colored stains and manganese causes black stains.

OTHER PROBLEMS

How Much is Too Much

Iron will cause stains and buildup inside of pipes, reducing their flow capacity anytime the concentration is above 0.3 mg/L. Manganese causes similar problems when the concentration is above 0.05 mg/L. As a result of these problems, a Secondary **SMCL**[5] has been established for each of these contaminants. They are:

Iron (Fe) 0.3 mg/L

Manganese (Mn) 0.05 mg/L

Slimes

One of the problems with the presence of soluble iron and manganese is the increase in the growth of "iron bacteria." Iron bacteria are generally aerobic, filamentous bacteria. They oxidize soluble iron and manganese. The precipitates that they produce accumulate in their sheaths and cell walls. When present in large numbers, they produce slimes and tubercles large enough to; plug well screens, reduce the carrying capacity of pipe lines, they increase chlorine demand, their sloughing can lead to customer complaints of red or black water, they create a color in the water and they can cause metallic taste.

[5] **SMCL** - Secondary Maximum Contaminant Level - The maximum permissible level of a secondary contaminant in water delivered to a user of a public water system. Secondary contaminants are those contaminants that affect the aesthetic quality of the water.

CREATING THE PROBLEM

Natural Occurrence

The presence of iron and/or manganese in groundwater is generally a result from the minerals contained in the rocks that are part of the aquifer. The concentration of iron and manganese in a specific water is dependent upon a number of factors, one of them is the level of iron and/or manganese found in the various rock formations. For instance, iron naturally occurs in the silicate minerals of igneous rocks. Manganese is found in great abundance in metamorphic and sedimentary rocks, with only a small amount in igneous rocks.

Anaerobic Conditions

Under anaerobic conditions that naturally occur in deep aquifers and can occur on the bottom of deep lakes and impoundments, insoluble iron and manganese are reduced and brought into solution. The reduction is thought to be associated with the lowering of the **pH**[6] that commonly is found in anaerobic conditions.

Anaerobic Lake Conditions

When the water in a deep lake or impoundment is allowed to stratify, the bottom layer often becomes devoid of oxygen, giving rise to anaerobic conditions. These conditions allow anaerobic bacteria to produce in numbers significant enough to produce high levels of CO_2 that mixes with the water forming carbonic acid driving down the pH. These conditions speed the process of reducing insoluble iron and manganese to their soluble forms. These conditions are more often found in lakes than in aquifers, because the presence of organic compounds in the lake stimulate the organisms that contribute to these problems.

Maximum Levels

While the conditions described above are very common it is unusual to find natural iron in an aquifer or stratified lake exceeding 10 mg/L or manganese exceeding 2 mg/L. However, College Utilities in Fairbanks has raw water containing 17 mg/L of iron.

[6] **pH** - An expression of the intensity of the basic or acidic strength of a water. Mathematically, pH is the logarithm (base 10) of the reciprocal of the hydrogen ion concentration. pH may range from 0 to 14, where 0 is the most acid, 14 most basic, and 7 neutral. Natural waters usually have a pH between 6.5 and 8.5.

TREATMENT PROCESS & THEORY

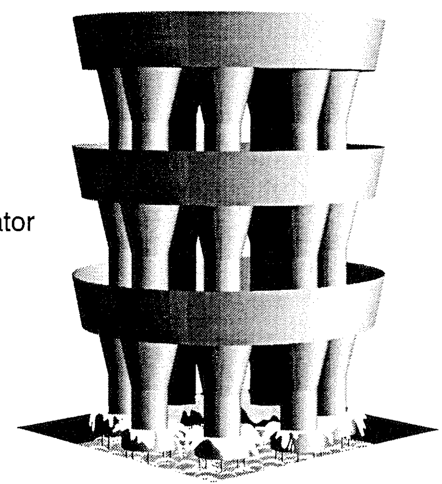
Oxidation

All of the common iron and manganese removal processes utilize the oxidation process. Oxidation changes the dissolved iron and manganese to a fine particulate called a precipitate. This precipitate is removed by **filtration**[7]. The three most common removal techniques vary primarily in the method used to oxidize the contaminants. The three oxidants used are; air, chlorine and **potassium permanganate**[8].

Air Oxidation

Aeration followed by filtration is an effective method of removing inorganic iron. Water with excessive concentrations of iron can be aerated using stack towers or pan aerators. In the process, the iron is oxidized and the precipitate is removed using a conventional sand **filter media**[9]. This is a relatively slow process requiring 15 minutes at a pH of 7.5 to 8.0. For the removal of manganese, the reaction time is nearly the same, but the pH must be raised to above 9.5. If the water contains manganese and no iron, air oxidation is not an effective treatment process.

Cone Aerator



Oxidation with Chlorine

Under certain conditions chlorine can be effectively used to oxidize iron and manganese, forming a precipitate that can be removed using a conventional sand filter. Some of the conditions are:

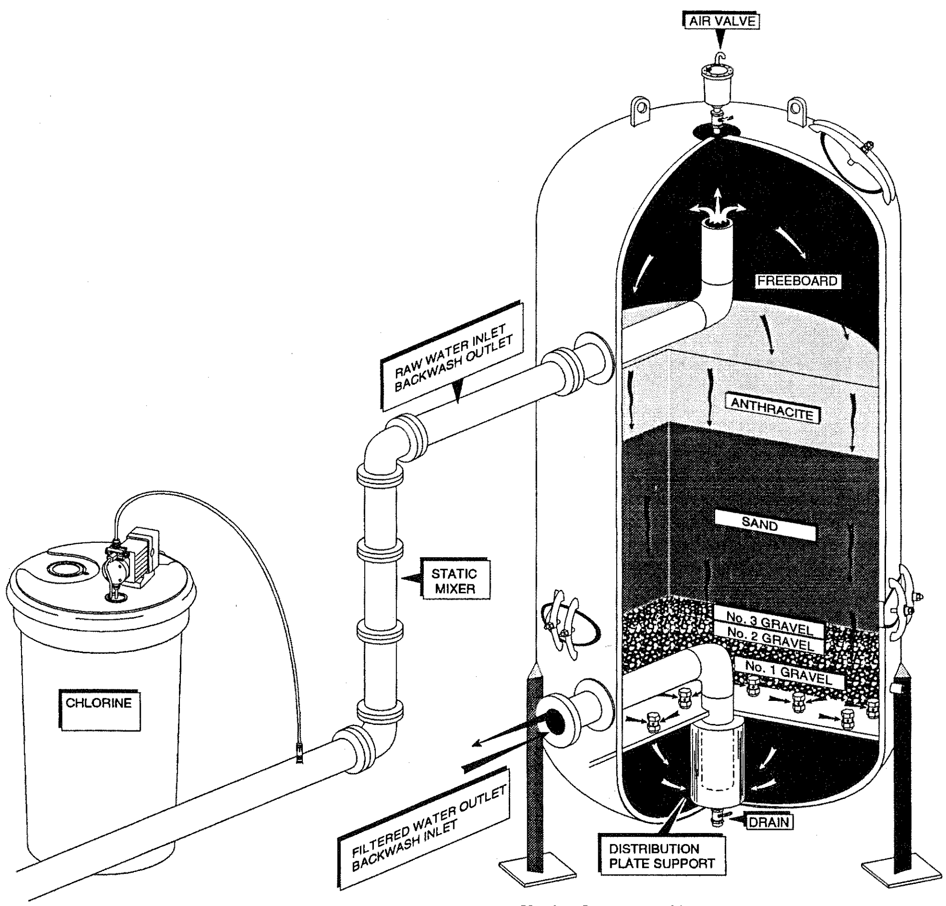
- Oxidation must be accomplished using free chlorine residuals.
- 0.64 mg/L of chlorine will oxidize 1 mg/L of iron if it is in the ferrous bicarbonate form.

[7] **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.

[8] **Potassium permanganate** - Potassium permanganate, $KMnO_4$, is a dry purple crystal and a very reactive oxidizer used to treat water for the removal of iron and manganese as well as oxidizing organic compounds that contribute to color (DOT #1490).

[9] **Filter media** - Specially selected material such as sand, anthracite or greensand used to filter precipitates and other material from water.

- The oxidation of iron with chlorine can be accomplished between pH 4 and 10, however the process works best at pH 7.0.
- The process works best when the manganese level is below 0.2 mg/L.
- 0.77 mg/L of chlorine will oxidize 1 mg/L of manganese when the manganese is in the manganous sulfate form.
- Manganese oxidation can take place between pH 6 and 10. However, it works most rapidly at pH levels above 9.5. At pH 10, the oxidation process is completed in a few minutes. When the pH is lowered to 8 the process takes 2 to 3 hours.
- When using chlorine to remove iron and manganese from waters containing organic **color**[10], there is the high possibility of producing THM's.
- Because this process often requires high chlorine residuals, it is typical to require dechlorination after the oxidation process has been completed.



Tank - Courtesy of BCA Industrial Controls, Ltd.

[10] **Color** - Primarily, organic colloidal particles in water.

POTASSIUM PERMANGANATE - GREENSAND

Most Common in Alaska

The most common method used in Alaska for the reduction of iron and manganese in public water systems is the use of potassium permanganate as an oxidant followed by a **greensand** [11]filter.

Reason for Use

The potassium permanganate greensand process is popular because $KMnO_4$ will rapidly and completely oxidize iron and manganese, forming a precipitate that is easy to remove using greensand or greensand and anthracite coal.

Oxidation Process

When $KMnO_4$ is added to water it disassociates forming various manganese oxides, one of the most important of these oxides is MnO_2, manganese dioxide. If the water contains soluble iron and manganese (Fe^{++}, Mn^{++}) the MnO_2 oxidizes the iron and manganese to their insoluble forms (Fe^{+++}, Mn^{++++}). The precipitates of iron and manganese along with any excess manganese dioxide is fed to a greensand filter.

What is Greensand

Greensand is a natural occurring **zeolite**[12] (natural ion exchange medium). More specifically greensands are naturally occurring silicates of sodium and aluminum, some of which appear green.

Coating the Greensand

While the greensand filters out the precipitates it also acts like a sponge to "take up" the excess manganese dioxide. The excess manganese dioxide attaches to or coats the greensand. This reaction is sometimes shown as $Z\text{-}MnO_2$ (Z is the greensand). Notice that there is no chemical reaction between the greensand and the manganese dioxide. The exact process of attachment is not clearly understood, but makes little difference to the operation of the filter.

Buffering

If more iron or manganese enters the facility than can be oxidized by the $KMnO_4$, the manganese dioxide coated on the greensand is used to oxidize them, forming insoluble precipitates and degenerating the greensand. This process is often called **sorption**[13]. The reverse is also true, if an excess amount of $KMnO_4$ is fed the excess manganese dioxide is attached to the greensand, regenerating the greensand.

Continuous or Batch

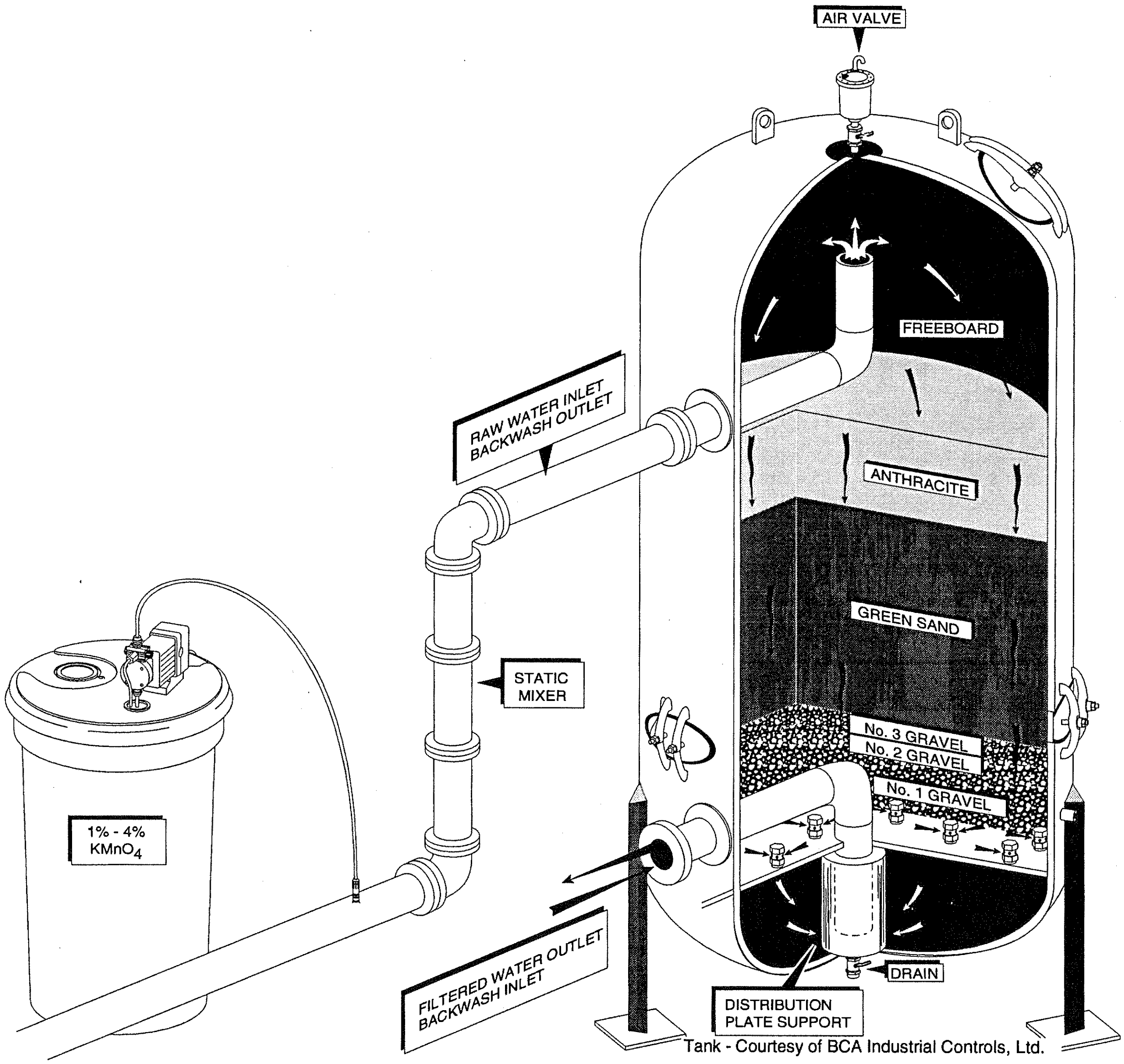
The process described above, where is $KMnO_4$ fed continuously to the raw water and the greensand filter is used as a buffer is called Continuous Regeneration (CR). There is a second process, called Intermittent

[11] **Greensand** - Naturally occurring silicates of sodium and aluminum that respond as a natural ion exchange medium. Commonly used as the primary filter medium in a potassium permanganate, greensand, iron and manganese removal process.

[12] **Zeolite** - Natural or man-made minerals that will collect from a solution certain ions (sodium or $KMnO_4$) and either exchange these ions, in the case of water softening, or use the ions to oxidize a substance, in the case of iron or manganese removal.

[13] **Sorption** - The process of taking up and holding a substance by absorption and adsorption.

Regeneration (IR). In this process the greensand is coated with manganese dioxide prior to feeding the raw water. As the raw water is fed to the filter, the manganese dioxide on the greensand oxidizes the iron and manganese and the greensand filters out the precipitate. The IR process is difficult to control and therefore is seldom used in small water systems.



Tank - Courtesy of BCA Industrial Controls, Ltd.

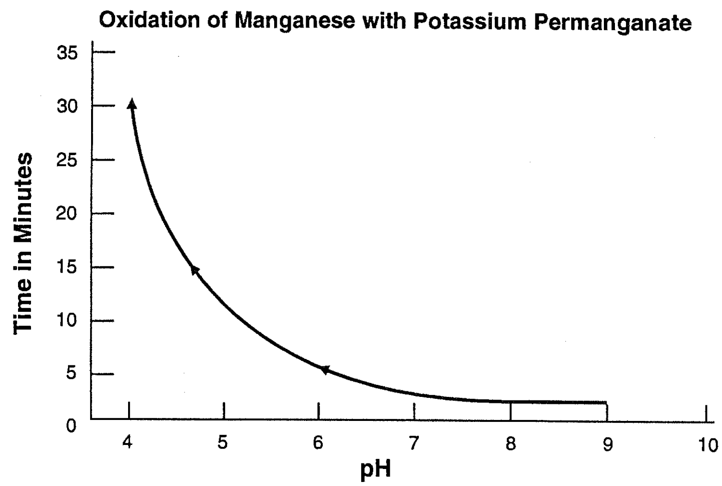
Criteria

The effectiveness of continuous regeneration potassium permanganate greensand process is affected by certain considerations or criteria. Some of the criteria that affect this process are:

Quantity of KMnO4 needed to oxidize 1 mg/L of iron and/or manganese.

mg/L $KMnO_4$	mg/L- Fe	mg/L -Mn
0.94	1	
1.92		1

- It is normally desirable to overfeed $KMnO_4$ by 0.1 mg/L to 0.3 mg/L to be assured that the green-sand remains charged.
- While pH does not impact oxidation of $KMnO_4$ as great as it does chlorine, there is still some impact. In observing the curve below it is apparent that a pH of 7 or above is the most desirable.



- If a polymer is used to enhance filtration, it should be added to the flow stream 1 to 5 minutes after the addition of $KMnO_4$.
- Free chlorine added prior to the $KMnO_4$ has in some instances shown an improvement in removal of iron and manganese. However, if the water contains organic color there is the possibility of producing THM's.

SEQUESTERING AGENTS

What is a Sequestering Agent?

Sequestering agents are chemical compounds that can be used to stabilize metals (iron and manganese) in suspension. Sequestering agents do not oxidize or remove the iron or manganese but chemically keeps them in solution; it maintains the iron and manganese in the soluble state.

Compounds

The compounds used as sequestering agents are called polyphosphates. There are various types of polyphosphates. However, sodium hexametaphosphate is most commonly used because it typically requires the lowest dosage. These chemicals can be fed into the system using either a dry feeder or a standard chemical feed pump.

Low Concentrations

Polyphosphates work best when the manganese concentration is below 0.3 mg/L and the iron is below 0.1 mg/L. They are normally not effective or cost effective when the combined concentration of iron and manganese exceeds 1.0 mg/L.

Dosages

The required dosage ranges between 2 and 5 times the added concentration of iron and manganese. For example, if the iron levels were 0.2 mg/L and the manganese 0.3 mg/L, the dosage would be between 1 and 2.5 mg/L, (2 x 0.5 mg/L = 1 mg/L ;5 x 0.5 = 2.5 mg/L) . The total dosage should remain below 10 mg/L. Above this level of phosphorus added to the water can contribute to significant increases in the growth of slimes and bacteria in the distribution system.

Free Chlorine Needed

Polyphosphates are most effective when a free chlorine residual of 0.25 mg/L is present prior to its addition.

Problems

When the total iron and manganese concentration is less than 1 mg/L, the dispersing properties of polyphosphates are good for about 1 week. After this time iron and manganese will oxidize when exposed to the air and cause typical stain and discoloration problems. Heating the water to near boiling will also cause the polyphosphates to loose their dispersing properties.

Fe & Mn REMOVAL USING THE GREENSAND FILTER SYSTEMS

Overview

The iron and/or manganese removal process using a greensand filter is accomplished by using a standard chemical feed pump system to feed potassium permanganate into the raw water line prior to a pressure filter vessel holding greensand. The $KMnO_4$ oxidizes the iron and/or manganese to form a precipitate on the filter media. Excess $KMnO_4$ is collected on the greensand as a buffer in case there is an under feeding of $KMnO_4$.

Five System

The greensand filter process can be divided into five systems:

- The building and chemical storage
- The chemical feed system
- The hydraulic system
- The electrical system
- The control system

Sequence

The next portion of this module is used to identify the various components of the five systems and follow the hydraulic flow through the system. Details on routine operations and process control are found later in this module. Information on the theory and chemistry of the process is described above.

BUILDING AND CHEMICAL STORAGE

Introduction

Chemical storage includes safety information concerning the chemical storage requirements and concerns and building considerations. Proper methods of handling and mixing chemicals is discussed in the section on normal operations.

Building - Clean and Dry

The interior of the building, in the vicinity of the chemical feed and filter equipment should be kept clean and dry. While dryness is not always possible, cleanliness is necessary in order to provide a safe working environment.

Building - Locked Door

In a small community, the chemical feed is seldom a separate facility. Normally, the potassium permanganate equipment is maintained inside of the water treatment plant next to the filters. Regardless of the setting, the building should be kept locked and vandal resistant.

POTASSIUM PERMANGANATE

Storage

$KMnO_4$ is purchased as a dry crystal and is delivered in 55, 110 and 330 pound drums. The crystals are 100% $KMnO_4$. The drums should be stored in a cool dry place and not with other oxidants such as chlorine or fluoride. It is OK to store $KMnO_4$ in the same room with dry powdered alum and **soda ash**[14].

OSHA Classification

$KMnO_4$ is classified by **OSHA**[15] as an oxidizer and a corrosive. The container should display both the dry corrosive and oxidizer placards.

UN Classification

The UN (United Nations) Classification for potassium permanganate is the number 4; a flammable solid and a spontaneously combustible material that is dangerous when wet. A table showing the various UN classifications is provided below.

NFPA Ratings

The National Fire Protection Association (NFPA) provides the following classifications for potassium permanganate (A table with explanations of the various ratings is provided below).

- Health Hazard – 1
- Flammability – 0
- Reactivity – 0
- Special hazard – OX

DOT Identification

The DOT (Federal Department of Transportation) has given potassium permanganate placard number of #1490. When determining how to handle a spill of potassium permanganate, the DOT has provided this information in their handbook under reference #35

Common accidents and Recommended First Aid

Common potassium permanganate accidents and related first aid practices are:

- Contact with eyes - flush with water for 15 minutes - see doctor
- Contact on skin - flush with water for 15 minutes. Remove contaminated clothing and footwear. Wash clothing and decontaminate footwear before use. Seek medical attention immediately if irritation is severe.
- Inhalation - Get person out of contaminated area to fresh air. If breathing has stopped, resuscitate and administer oxygen if readily available. Seek medical attention immediately.
- Ingestion - Never give anything by mouth to an unconscious or nonbreathing person. If conscious, give large quantities of water. Seek medical attention immediately.

[14] **Soda Ash** - Trade name for Sodium carbonate Na_2CO_3 - a chemical used to add alkalinity to water, adjust pH and/or improve the stability of the water. 1 mg/L of alum will combine with 0.54 mg/L of soda ash.
[15] **OSHA** - Occupational Safety and Health Administration.

Handling Spills

DOT describes the following methods of handling potassium permanganate spills:

- Do not touch spilled material, Keep combustibles (wood, paper, oil, etc.) away from spilled material.
- Small Dry Spills - Use clean shovel to place material into clean, dry container, cover and remove from area.
- Small liquid spills - Take up with sand, earth or other noncombustible absorbent material.
- Large spill - Dike far ahead of liquid spill for later disposal.

Deactivation

Solutions of $KMnO_4$ may be deactivated by mixing with a solution of sodium thiosulfate, a bisulfite or a ferrous salt solution. Mix the formed sludge with sodium carbonate and deposit in an approved landfill.

Fire or Explosion Hazard

Potassium permanganate is a very reactive oxidizer. In handling and storage remember these important points:

- $KMnO_4$ may ignite other combustible materials.
- The reaction of $KMnO_4$ with fuels may be violent.
- Runoff to sewer may create fire or explosion hazard in the sewage collection system.

Fire Control

The following methods are identified as recommended procedures for dealing with a fire involving potassium permanganate

- Small fire - Dry chemical, CO_2, Halon or water spray
- Large fire - Water spray or fog

Health Hazards

- Contact may cause burns to skin and eyes
- Vapors or dust may be irritating.
- Fire may produce irritating or poisonous gases.
- Runoff from fire control or dilution water may cause pollution.

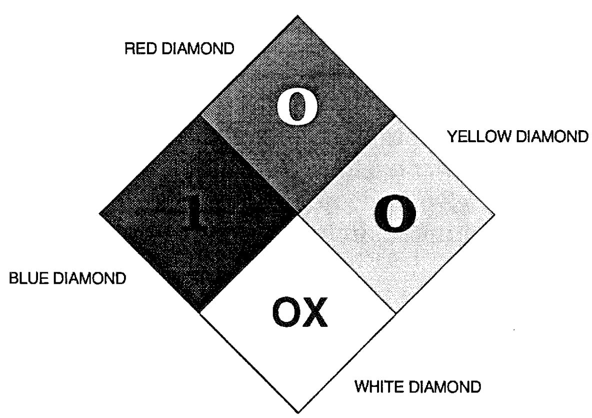


Table - UN Classifications

Number	Class Name/Hazard
1	Explosive
2	Gases
3	Flammable liquids
4	Flammable solids, spontaneously combustible materials, dangerous when wet
5	Oxidizers and organic peroxides
6	Poisonous and etiologic (infectious) material
7	Radioactive materials
8	Corrosives
9	Miscellaneous hazardous materials

NFPA System

Health hazard

4 Can cause death or major injury despite medical treatment
3 Can cause serious injury despite medical treatment
2 Can cause injury. Requires prompt treatment
1 Can cause irritation if not treated
0 No hazard

Flammability hazard

4 Very flammable gases or very volatile flammable liquids
3 Can be ignited at all normal temperatures
2 Ignites if moderately heated
1 Ignites after considerable preheating
0 Will not burn

Reactivity (Stability) hazard

4 Readily detonates or explodes
3 Can detonate or explode but requires strong initiating force or heating under confinement
2 Normally unstable but will not detonate
1 Normally stable. Unstable at high temperature and pressure. Reacts with water
0 Normally stable. Not reactive with water

Special Notice Key

~~W~~ Water reactive
OX Oxidizing agent

CHEMICAL FEED SYSTEM

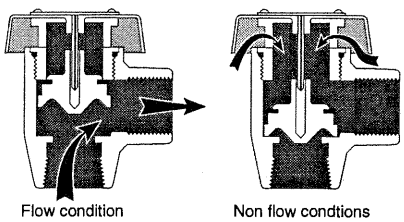
The chemical feed system is composed of the following components:

Tank

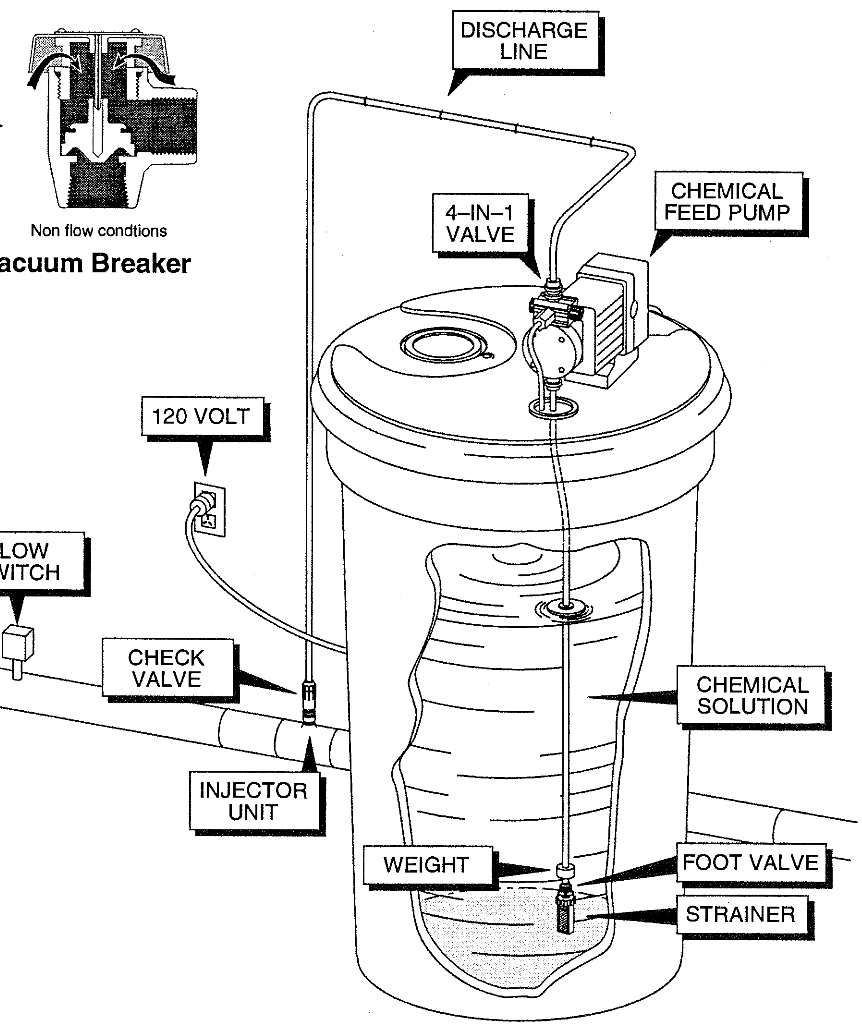
The basic unit of the system is the 25 to 50 gallon corrosion resistant tank. The tank is used to hold a 1% to 4% solution of potassium permanganate.

Fill Line

A **potable water**[16] fill line must be provided in order to mix and dilute the $KMnO_4$. This line should be protected from **backflow**[17] by a **atmospheric vacuum breaker**[18]. The hose or line leading into the tank should stop a distance equal to twice the discharge line diameter or a minimum of one inch above the rim of the dilution tank.



Atmospheric Vacuum Breaker

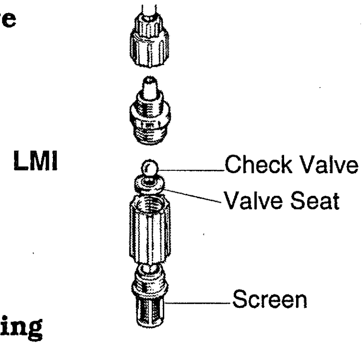


16 **Potable Water** - Water satisfactory, safe for drinking purposes from the standpoint of its chemical, physical, and biological characteristic.

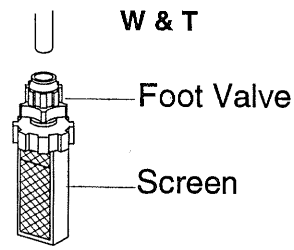
17 **Backflow** - A reverse flow condition, created by a difference in water pressures, which causes nonpotable water to flow into a potable water system.

18 **Atmospheric vacuum breaker** - A mechanical device that prevents backflow due to siphoning action created by a partial vacuum that allows air in to the piping system, breaking the vacuum.

Foot Valve



At the bottom of the pump suction line and 2 to 3 inches from the bottom of the tank is the foot valve and screen. The foot valve reduces the possibility of loss of prime to the feed pump and the screen prevents large debris from entering the pump and damaging the pump diaphragm or valves.



Pump Piping

The piping on the suction and discharge of the pump is commonly polyethylene. This material is flexible but has an approximate one year life span. The life of the piping is reduces if it is exposed to sunlight.

Pump

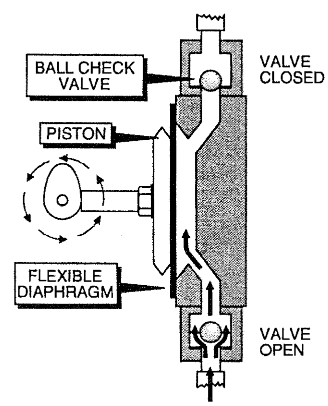
The most common pumps used in Alaska are LMI and W&T diaphragm, positive displacement pumps. This type of pump has a suction and discharge valve, valve seats and may have a spring on one or both of the valves to help them seat properly.

Pump - Diaphragm

The energy input device of the pump is the diaphragm, made of a flexible material and operated by some type of electric or mechanical cam. The diaphragm operates inside of the pump head. The pump head forms a chamber that holds fluid during the pumping cycle.

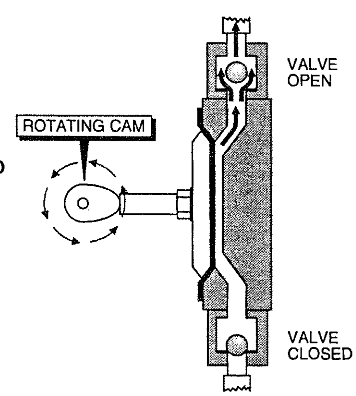
Pump Operation - Suction

The diaphragm pump operates on a two stroke sequence. When the diaphragm is pulled back, a vacuum is developed inside of the pump head. Atmospheric pressure pushes fluid from the tank, through the foot valve, past the suction valve and into the pump head cavity. Discharge backpressure holds the discharge valve closed.



Pump Operation - Discharge

When the cam turns it places pressure on the fluid inside of the pump head. This pressure forces the suction valve closed and the discharge valve open. Fluid is forced out of the pump and the pump is returned to normal operation. The pump cam then turns and starts the suction side of the cycle over again.



Pump Adjustment

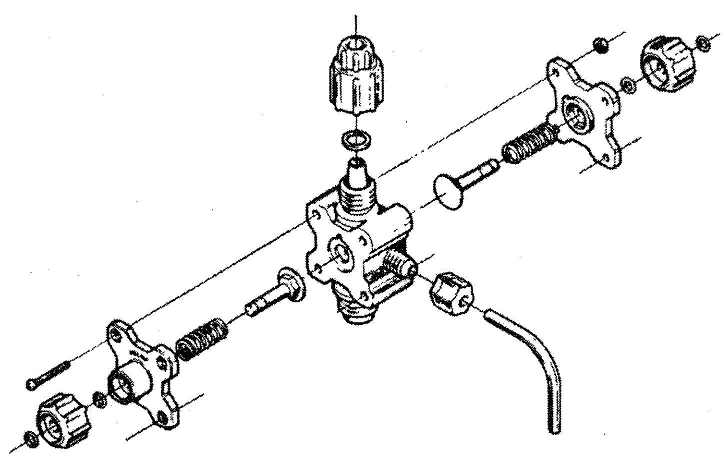
Most of the chemical feed pumps used in Alaska allow two different adjustments of the feed rate. The length of the stroke and the frequency of the stroke can both be adjusted giving a high degree of flexibility. On the LMI feed pumps there is an additional adjustment or safety feature. On these pumps, if the discharge pressure exceeds a set point the pump will fail to pump without damage to the pump.

Anti-Siphon Valve

LMI Pump Face

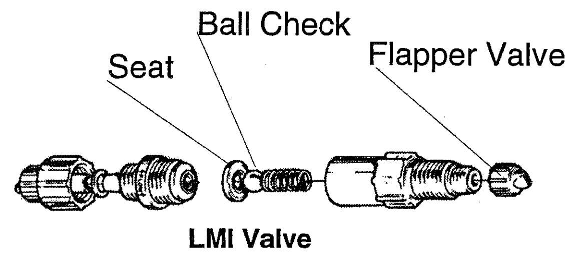
The LMI pumps can be installed with a special valve on the discharge line called a 4 in 1 valve. This valve serves four functions.

- Anti-siphon - the valve prevents the fluid from being siphoned from the tank should there be a below atmospheric pressure drop in the system pressure. This could happen if the system were set up to pump from a well and the foot valve on top of the submersible turbine failed. After pump shutdown, water would fall down the riser pipe and cause a reversal in flow in the discharge pipe of sufficient velocity to cause a venturi action at the **diffuser**[19], siphoning fluid from the tank.
- Back pressure control. The valve maintains a positive discharge pressure of at least 25 psi on the discharge of the pump. This constant pressure exists even if the line pressure should drop to zero; helping to maintain the accuracy of the pump.
- Pressure relief - Should, for some reason, a valve on the discharge line be closed or the line pressure exceed the safety rating of the pump, the 4 in 1 valve will open and discharge the fluid back to the tank. This prevents damage to the pump diaphragm and head.
- Line depressurization - To prevent fluid from spraying onto the operator when starting to repair the pump, the 4 in 1 valve allows the discharge pressure to be relieved.

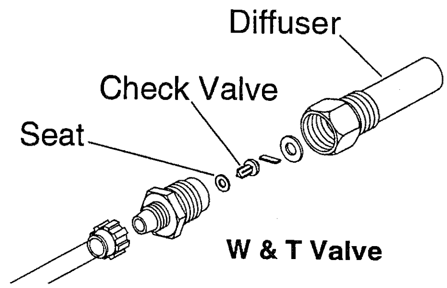


[19] **Diffuser -** A section of pipe or porous plates used to mix a gas or liquid with the flow of water.

Injection Point



At the point where the solution is injected into the system, there is a one way valve that reduces the possibility of backflow from the system into the solution tank. Just past the one-way valve and inserted into the main line is a diffuser. This is a PVC or silver tube extending one third the diameter into the line. The diffuser is inserted into the line a distance that allows for maximum mixing of the solution with the flow of the plant.

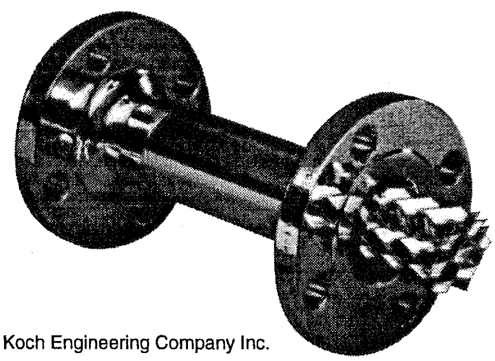


HYDRAULIC SYSTEM

The largest portion of the greensand filter process is the hydraulic system. While this system may be linked electrically to the raw water pump or well pump, the pumping portion of the system will not be discussed in this module.

Static Mixer

Just after the chemical injection point, the raw water line usually contains a static mixer. This is a device placed in the line containing metal ribbons that cause the $KMnO_4$ to be efficiently mixed with the raw water. Most of the oxidation of manganese or iron happens at this point.



Courtesy of Koch Engineering Company Inc.

Vessel

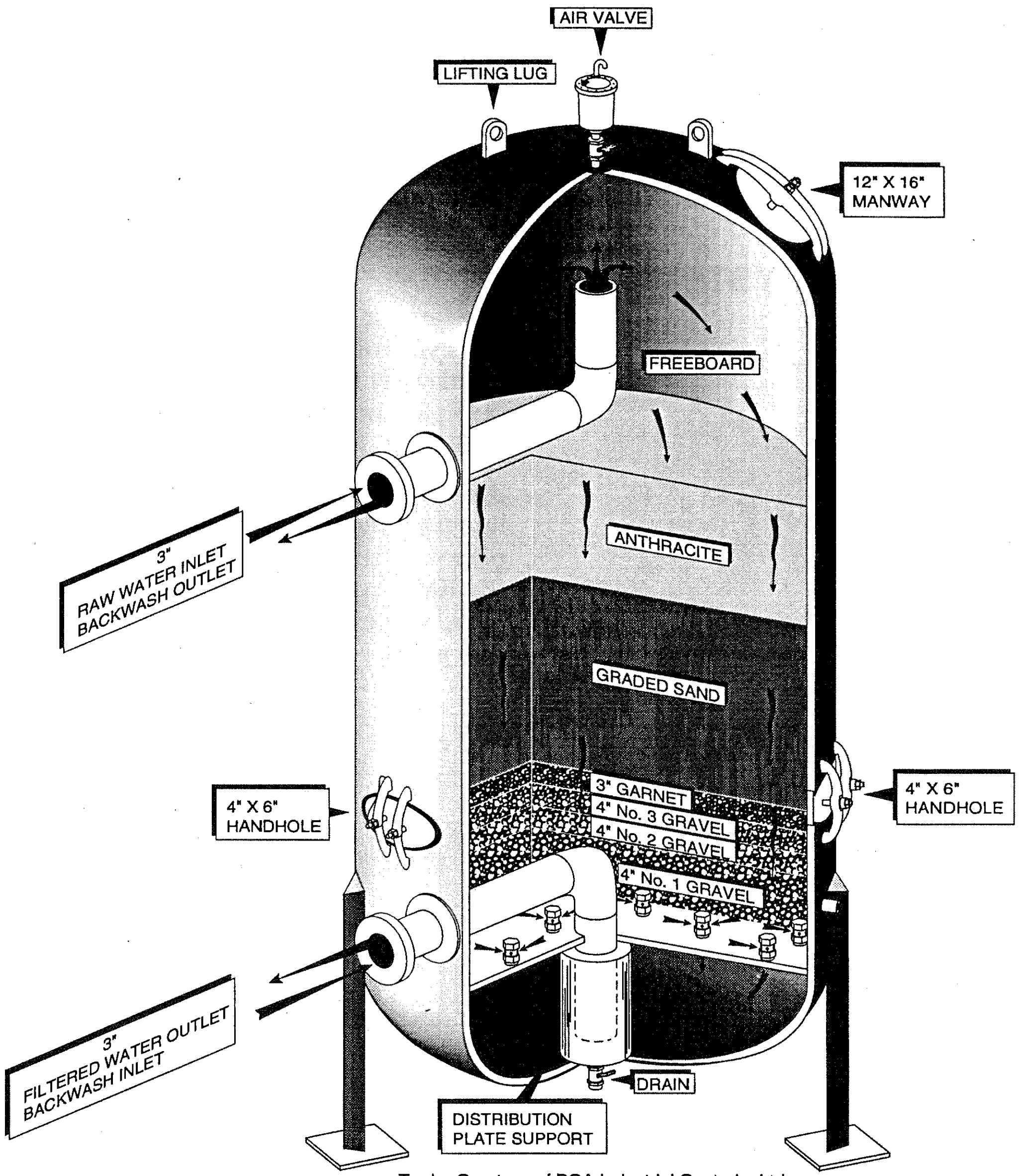
Depending upon the type of system, water flows from the raw water supply, flocculation basin or sedimentation to the pressure filter. Pressure filters are housed in a vertical or horizontal steel vessel. Entrance hatches allow access to the vessel and are used to inspect the media and make repairs. A filter vessel is a confined space. Entrance requires following the OSHA and Alaska Department of Labor requirements for confined space entry.

Inspection Port

One of the new renditions available from some pressure filter manufacturers is a glass viewing port and interior light in the filter. These allow the operator to view the filter media during normal operation and **backwash**[20].

Underdrain

At the bottom of the vessel is the collection piping called the **underdrain**[21] system. This may be lateral pipes with slots or nozzles. In the small systems in Alaska lateral pipes with slots are the most common.



Tank - Courtesy of BCA Industrial Controls, Ltd.

Support Gravel

Placed over the nozzles or laterals are six to eighteen (6 to 18) inches of support gravel. This gravel may be up to three (3) inches in diameter and will be graded from large to small in the direction of the top of the filter. The support gravel supports the filter media.

[20] **Backwash** - The reversal of flow through a filter in order to clean the filter by removal of material trapped by the media in the filter.

[21] **Underdrain** - As it pertains to a filter - A system of nozzles, plates or perforated pipe placed under the filter media, used to collect water that passes through the filter and the backwash water.

Media

Depending upon design the filter media will range from one to two (1 to 2) inches of silica sand, with twelve to forty (12 to 40) inches of greensand topped off with six to twelve (6 to 12) inches of anthracite.

Greensand Description

Greensand is a mined material composed of silicates of sodium and aluminum. Greensand has a lower specific gravity than silica sand and has the unique property of becoming coated with manganese dioxide when treated with potassium permanganate.

Function of Anthracite

Not all greensand filters have a layer of anthracite. Anthracite is used to improve filtration capabilities when the concentrations of iron or manganese are high. Greensand has a small effective size and thus forms very small openings that become easily clogged with the precipitates of oxidized iron and manganese. The addition of anthracite on top of the greensand provides additional filtration capacity that is not as easily clogged as the greensand. This provides longer more efficient filter runs.

Piping

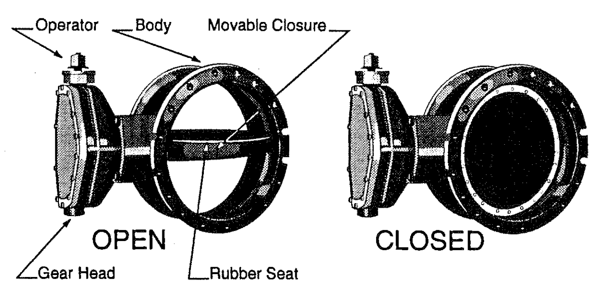
Common piping on a pressure filter include:
- Inlet piping
- Outlet piping, connected to the underdrain
- Backwash piping
- Filter to waste piping

Cross-Connection

It is important that the backwash filter to waste lines be separated from the waste line by an appropriate air gap. If the air gap is not at least twice the diameter of the discharge pipe there is a potential cross connection between the filtered water and the wastewater system.

Control Valves & Piping

The flow of water through the filter is controlled by various isolation and control valves. Most plants have isolation valves (gate or butterfly) on the raw water inlet, filtered water, filter to waste and backwash.



Filter to Waste

After a filter has been backwashed, it is desirable to waste the first water that is filtered. This is because the first water normally contains high **turbidity**[22] caused by the iron and manganese precipitates that were not removed from the filter. As the filter bed compresses the quality of the finished water will improve.

22 **Turbidity** - A condition in water caused by the presence of suspended matter, resulting in the scattering and absorption of light rays.

The compression (aging) of the filter can take from 5 to 15 minutes.

Air Relief

It is normal for a pressure filter to accumulate air in the vessel. Therefore, an air release valve is installed on top of the vessel. The most common valve is the combination valve that allows air out of the filter and air in under the rare conditions, where a vacuum could develop in the filter vessel.

HYDRAULIC CONSIDERATIONS

Normal Flow

Water enters at the top of the filter. Most filters direct the water toward the top of the vessel dissipating the influent energy against the vessel. Water then flows down through the media and out through the underdrain into the clear well, the distribution system or storage tank.

Filtration Rates

Pressure filters are commonly designed to filter water at 3 to 5 gpm/ft^2. Village Safe Water uses 2 to 5 gpm/ft^2 as their design criteria. The **filtration rate**[23] should be checked at least once a year. This is accomplished by dividing the flow rate in gpm by the surface area of the filters.

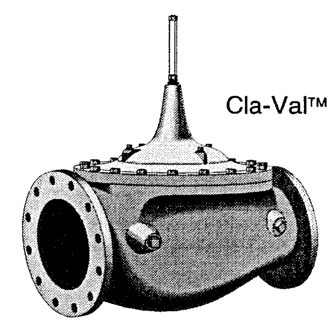
BACKWASH SYSTEM

Pump

With small water systems, the most common backwash pump is a close coupled end-suction centrifugal. The backwash pump is used to pump finished water back through the filter, in order to remove debris collected during filtration.

Control Valves

When the backwash pump is started, the head on the pump is usually low, allowing a high flow. This high flow can damage the filter media, support gravel and underdrain system. For this reason, flow control valves are often placed on the discharge of the pump. There are two types; one restricts flow to a pre-set gpm, the second is a wide body globe valve that slowly opens after the pump starts.



Wide body globe valve

No Control Valve

With a large number of pressure filter systems the control valve system can be eliminated. The backwash cycle sequence is designed to maintain pressure on the filter and thus reduces the normal short burst of high flow that is associated with starting the backwash pump.

[23] **Filtration rate** - The rate that water is allowed to pass through the filter media. Expressed in gallons per minute per square foot of filter media (gpm/ft^2).

Surface Wash

Surface wash systems are installed on pressure filters to break up the accumulation of precipitate on the filter surface. The most common surface wash system utilizes a rotating arm with nozzles. The system is operated hydraulically. Because surface wash systems require additional control valves and piping, they are often not installed in very small systems. When the filter lacks a surface wash system, the media should be inspected at least once a quarter. Accumulations of mud and debris should be removed with a small flat shovel. Failure to remove this debris could cause mud balls to form which can eventually work down into the media and plug the support gravel.

Flow Sequence

The normal backwash sequence with a surface wash is:

- Surface wash comes on for 2 to 5 minutes
- Backwash pump comes on
- Surface wash continues to run until 3 to 5 minutes before the backwash pump shuts down.
- Backwash water flows up through the filter and out the same pipe that was used as an inlet. The valving is used to direct the backwash water to the sewage system or some other disposal site.

Hydraulic Considerations

Backwash rates are based on water temperature. The lower the water temperature, the denser the water and thus lower the backwash rates are needed in order to effectively clean the filter. Details on backwash rates are provided in the section on Normal Operations. Typical backwash rates for small systems in Alaska are between 10 and 12 gpm/ft^2. The backwash rate should be checked at least once a year. For an example of how to check the backwash rate see the section on Normal Operations.

SLUDGE HANDLING

The material backwashed from the filter must be disposed of. The two most common disposal methods are to the sanitary sewer or to a lagoon. With a separate lagoon, a **NPDES** or state wastewater discharge permit for the effluent may be required. When utilizing the lagoon system, the normal process is to have two lagoons. When enough sludge has accumulated in the bottom, it is allowed to dry and be removed for disposal as landfill. One of the problems with water treatment plant sludges is that they may contain heavy metals. As such, the water purveyor is responsible for any short or long term damage caused by the disposal of this sludge.

ELECTRICAL SYSTEM

Introduction

The electrical system is composed of two sub-systems, the chemical feed system and the pumping system.

Breaker

The electrical system starts at the **circuit breaker**[24]. The circuit breaker is designed to prevent a fire should there be a short in the wiring or the electric motor. Power separates below the circuit breaker and goes to the two subsystems.

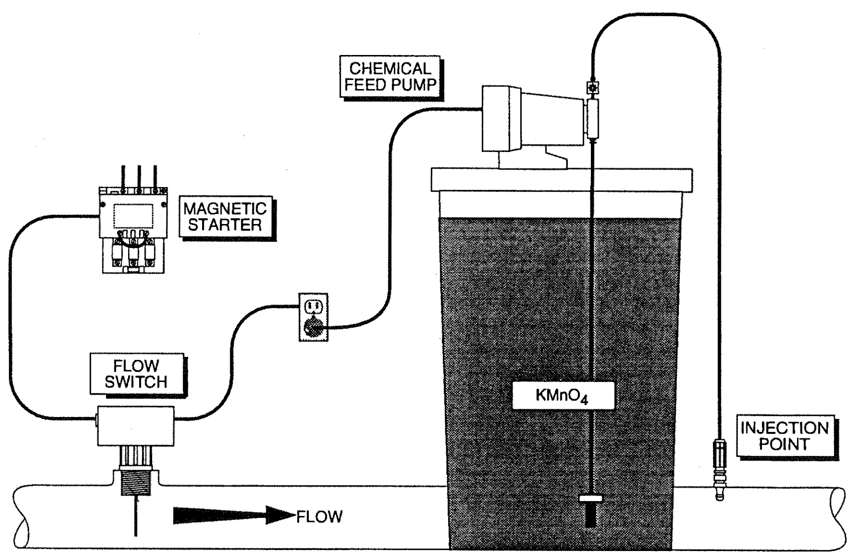
PUMPING SYSTEM

There are two pumps involved in most greensand filter systems, the raw water pump and the backwash pump. The raw water pump is commonly a submersible turbine pump in a well. The backwash pump is typically a end-suction centrifugal pump. The starters for each pump are commonly wired so neither the backwash pumps or the raw water pumps can run while the other pump is operating. On larger systems, with multiple filters, a single filter can be isolated for backwash without shutting down the raw water system.

CHEMICAL FEED

Duplex Plug

The chemical feed pump motor is connected to the electric system via a standard electrical cord and a duplex plug.



System Type

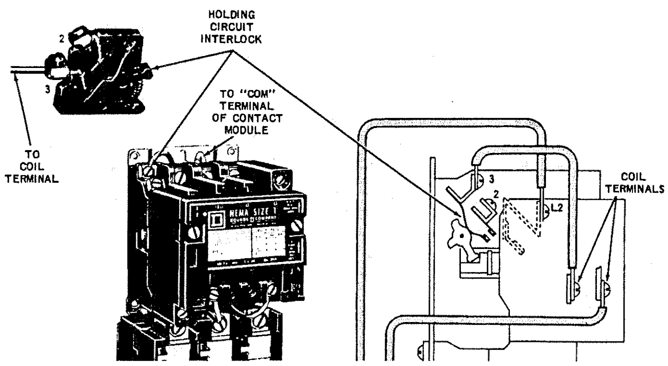
The type of chemical feed systems used with greensand filter systems varies widely with system design. However, the two most common systems are those associated with a constant delivery pump such as a well system and those that adjust the feed rate based on system flow. The system that automatically adjusts to system flow is normally associated with a gravity

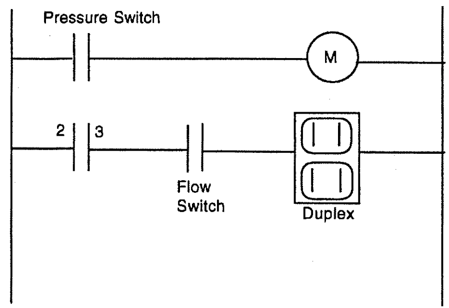
24 **Circuit Breaker** -An electrically operated mechanical device used for over current protection.

feed system. Because iron and manganese are primarily associated with groundwater systems, the gravity flow system is extremely rare.

Constant Flow

When the water that is to be treated flows at a constant rate, as with a well, the potassium permanganate feed pump is commonly connected electrically to the well pump control system. When there is a demand for the well pump to come on, power would be applied to the duplex plug that provides power to the potassium permanganate feed pump. The electrical connection is either through a **contact relay**[25] or the **auxiliary contacts**[26] on the well pump motor starter.



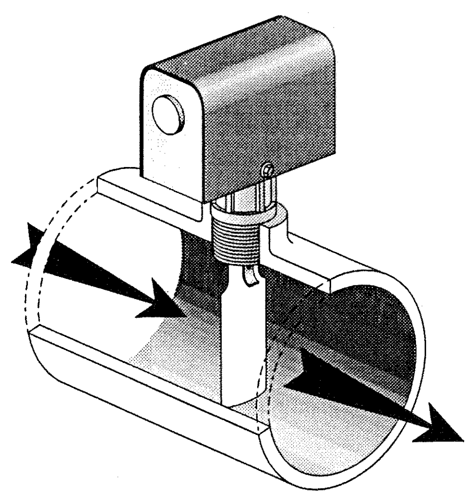


Variable Flow

When the system flow varies over time, as with a gravity flow system, the chemical feed pump must automatically adjust the feed rate in proportion to the changes in the system flow. This type of system utilizes a feed pump with the pumping stroke frequency controlled by a 4 - 20 ma signal. The signal is obtained from a flow meter. Fine adjustment of the $KMnO_4$ dosage can be obtained by manually varying the pump stroke length.

Fail Safe

In order to prevent the feed pump from accidentally running when there is no flow of water in the system, a flow switch is commonly inserted in the flow line. The feed pump electrical control is wired into the control circuit so that the lack of flow will prevent the pump from being energized.



[25] **Contact relay** - An electrically operated mechanical device used to open and close a circuit.
[26] **Auxiliary contact -** Contacts built into a mechanical starter and manually opened and closed by the magnetic starter.

CONTROL SYSTEM

Components

The control system is composed of the rate of flow controls, control piping and valves, **headloss**[27] indicators and the electrical system described above.

Rate of Flow Control

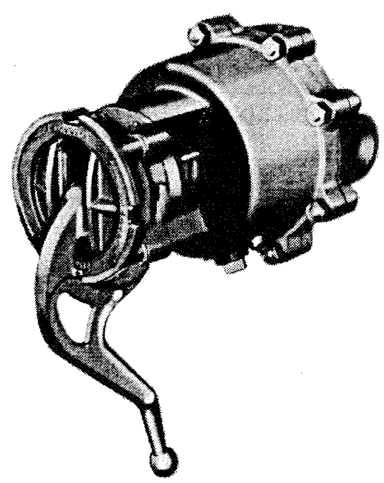
The most common flow rate control used with small pressure greensand filter systems is the one described above in the section on raw water. The flow control is based on pumping rate and a flow restriction valve. Unlike the gravity pressure filter systems where more than one system is used, the pressure filter systems primarily use a modified declining rate process. With this process the maximum flow is restricted by an influent valve, as the filter plugs the differential in head will increase, decreasing the flow rates. If the raw water pump is selected properly, with a flat curve, the flow rate will change only slightly.

Filter Control

Most pressure filters used in Alaska use a multi-port valve that reduces the number of actions that the operator must perform in order to switch the plant from normal flow to backwash. The most common of these valves is the Solo™.

Solo™ Valve

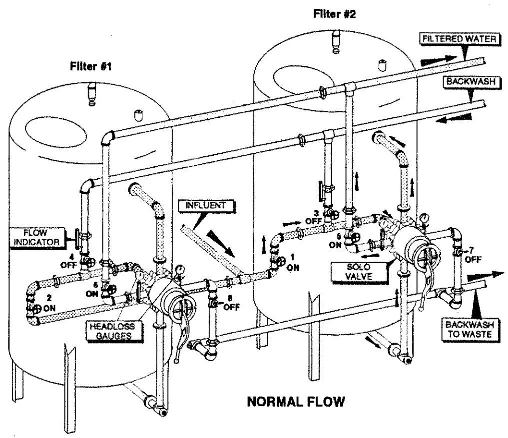
The Solo™ valve manufactured by Aqua Matic Inc. is a multi-port, single lever, manually-operated control valve. Flow is directed through the valve by rotating a multi-port plate in the center of the valve. The rotation of this plate directs the flow of water through the valve and to different portions of the filter system. The valve used with potassium greensand filters typically can be placed in three positions.



Normal Position

In the normal position, water is directed from the raw water supply to the top of the filter and from the bottom of the filter to the storage tank or distribution system.

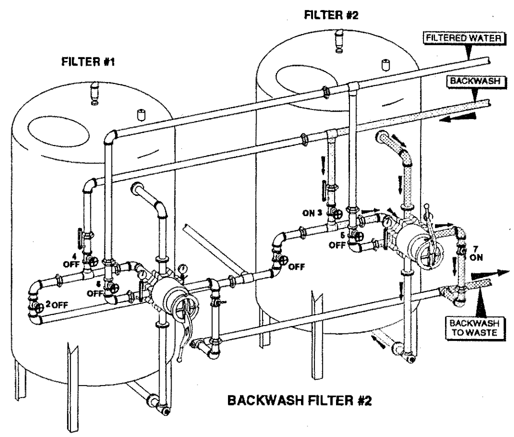
[27] **Head loss -** As it applies to a water filter, the difference between the pressure or head on the top of a filter and the pressure or head on the underdrain of the filter.



NORMAL FLOW

Backwash Position

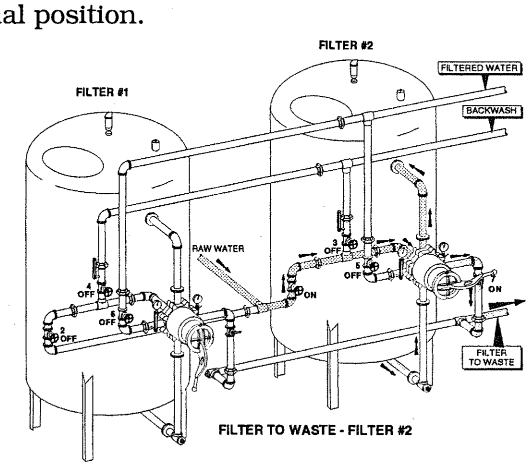
In the backwash position, finished water is pumped in through the raw water inlet and down to the bottom of the filter. Water containing the precipitate caught in the filter is carried up through the filter media, through the valve and out through the backwash line.



BACKWASH FILTER #2

Filter to Waste

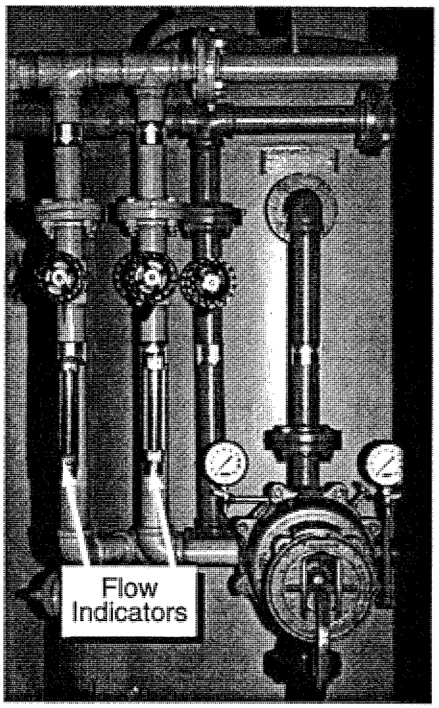
In the regeneration-rinse position, raw water is allowed into the valve and through the filter in the normal manner. The effluent from the filter is routed through the valve and out into the waste line. Once the filter has been compacted, the valve is returned to the normal position.

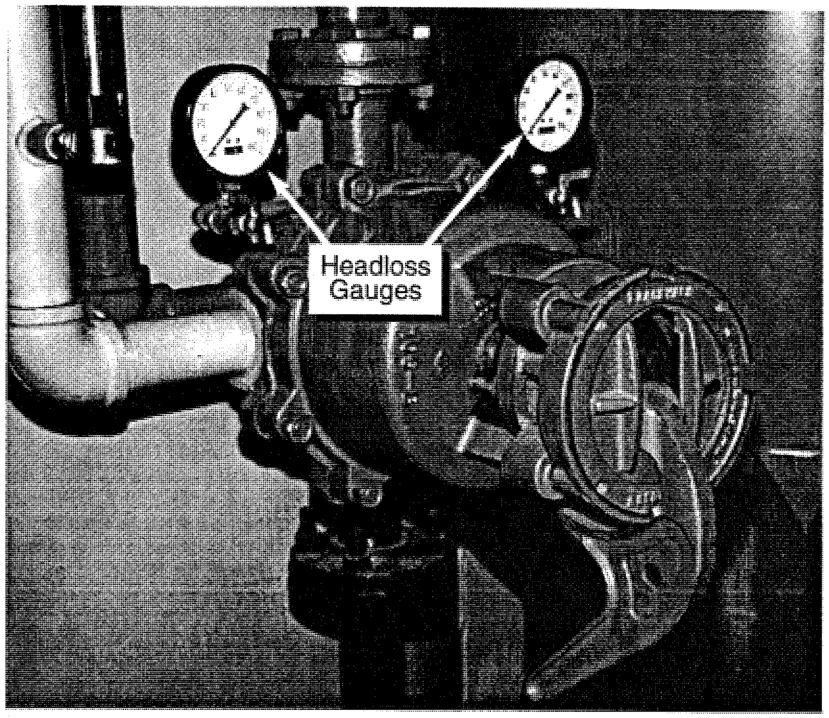


FILTER TO WASTE - FILTER #2

Headloss Control

One of the methods of determining when the greensand filter should be backwashed is headloss. Typically a headloss of 8 - 10 psi indicates a requirement for backwash. The most common headloss control system in Alaska villages is visual observation by the operator of the difference between the pressure gauges on the raw and finished waters. A differential pressure gauge connected between these points is employed in more complicated systems.





Electronic Headloss Control

A recent innovation into the headloss control system is the utilization of pressure transducers. A transducer can be placed in the raw and finished water lines. The difference in pressure can be used to develop an electrical control signal. This signal can then be used to electronically shutdown the influent and start a backwash cycle when a predetermined headloss is reached.

Volume Control

In several instances, operators have determined that backwash is best based on the volume of water treated rather than headloss. A special meter that can be set to automatically start the backwash cycle after a predetermined quantity of water has been treated is required. College Utilities in Fairbanks, Alaska uses such a system. The set point for backwash is determined by experimentation. There is no "rule of thumb" that has been developed to allow the operator to identify a target value.

START-UP

Assumptions

The following start-up sequence is based on the assumption that the system being used is composed of pressure filters with greensand media, uses a continuous feed $KMnO_4$ system, and uses Solo™ control valves. A second assumption, this is an operating system that has been off-line and is being restarted.

Sequence

Starting a $KMnO_4$ plant requires starting the chemical feed system, the pumping system and the filter hydraulics system. There are many correct sequences that can be used to bring the plant on-line. The following is one suggested sequence.

- Mix chemicals according the procedure below. When handling the chemicals, use the safety precautions described in the normal operations section.
- Prime the chemical feed pump - see the procedure below.
- Make preliminary chemical feed pump settings.
- Check the raw water pumps and backwash pumps for proper operations. If the system is so designed, pump each pump to waste to assure that proper flow and pressure is possible.
- Backwash the filter.
- Start the raw water pump and filter to waste for 10 to 15 minutes.
- Check flow meter, note if the flow rate is normal.
- Check chemical feed during this period.
- Check finished water, there should be no pink color.
- Adjust chemical feed - see process control procedure below.
- If all systems are in working order, change control valve to normal operating position.
- Record the steps and their results.

Chemical Concentration

If the required concentration of chemicals for the tank are not known or provided, then use the procedure described below.

1. Estimate desired dosage. To determine the approximate feed rate, multiply the iron in the raw water by 0.94 and the manganese by 1.92, then add these two values together.
2. Estimate the chemical feed pump pumping rate in mL/min, when the settings are 50/50. The feed pump rate can be estimated by either developing a calibration curve as described in the Normal Operations section or selecting from the pump list provided below.

3. Determine the plant flow rate in gpm
4. Determine the concentration needed in the tank. This should only range between 0.5% and 4%.
5. Determine the amount of chemical needed in the tank.
6. Determine how long a tank of solution will last.

Example:

The chemical feed pump used is a LMI A151-91T with a maximum feed rate of 63 mL/m (see the table below). The flow rate through the plant is 50 gpm. The iron is 2.0 mg/L and the manganese is 0.8 mg/L. The system uses a 30 gallon tank. It is desirable to produce only 25 gallons of solution at a time.

- Determine the chemical feed pump rate when the stroke and speed are both at 50%.- 63 mL/min x 0.5 x 0.5 = 15.75 mL/min (step 2)
- Determine the concentration in the tank? (step 4)

$$\% = \frac{0.378 \text{ X } \_\_\_\_ \text{ dosage, mg/L X } \_\_\_\_ \text{ flow, gpm}}{\_\_\_\_\_ \text{ feed rate, mL/min}}$$

$$\% = \frac{0.378 \text{ X } 3.5 \text{ mg/L X } 50 \text{ gpm}}{15.75 \text{ mL/min}} = 4.2\%$$

- Since all of the available tables give quantities needed for whole percentages, it is best to mix a 4% solution and make the final adjustment with the chemical feed pump.
- Determine the quantity of chemical needed. This can be done mathematically or from the table provided in the Normal Operations section of this module. From the table, the requirements are 2 pounds of chemical for each 1% needed to make a 25 gallons solution. 2 lbs x 4% = 8 pounds required. or

$$\text{lbs} = \frac{25 \text{ gal X } 8.34 \text{ lbs/gal X } 4\%}{100\%} = 8.34 \text{ lbs}$$

Again, it may be much easier to place 8 pounds of $KMnO_4$ into the tank and make final adjustments with the chemical feed pump, than to attempt to measure out exactly 8.34 pounds.

- If we assume that 25 gallons of 4% solution will be made, then it is desirable to determine the approximate chemical feed pump setting to obtain the proper dosage. We determined above that the dosage needed is approximately 3.5 mg/L. What is the desired feed rate and pump setting.

$$\text{mL/min} = \frac{0.378 \text{ X } \_\_\_\_ \text{ dosge, mg/L X } \_\_\_\_ \text{ flow, gpm}}{\_\_\_\_ \text{ \% in tank}}$$

$$mL/min = \frac{0.378 \text{ X } 3.5 \text{ mg/L X } 50 \text{ gpm}}{4\%} = 16.5 \text{ mL/min}$$

The feed pump setting can be determined from the chart at the end of this module or mathematically. From the chart we find that the setting is between 50/50 and 50/55. If we set the stroke at 50% we can easily calculate the setting for the frequency.

$$\text{Frequency} = \frac{16.5 \text{ mL/min}}{31.5 \text{ mL/min}} \text{ X } 100 = 52\%$$

- Find how many days the tank will last if the total daily flow is 28,000 gallons. (step 6) Remember the pumping rate is 50 gpm, if the pump were running all day, 1440 min, the total pumped would be 72,000 gallons. Since only 28,000 were pumped, the pump did not run 24 hours. Then how many hours did it run?

$$\text{Min of pumping time/day} = \frac{28{,}000 \text{ gal/day}}{50 \text{ gpm}} = 560 \text{ min/day}$$

560 min/day x 16.5 mL/min = 9,240 mL/day of solution needs to be pumped. The next step is to determine how many gallons will be pumped each day. Since there are 3780 mL per gallon.

$$\text{gal/day} = \frac{9{,}240 \text{ mL/day}}{3780 \text{ mL/gal}} = 2.4 \text{ gal/day}$$

$$\text{Days} = \frac{25 \text{ gallons}}{2.4 \text{ gal/day}} = 10.4 \text{ days}$$

Pumping capacities of various chemical feed pumps

LMI Pumps

Model	Capacity gph	Capacity mL/min	Max psi
A141-150T	0.2 gph	13 mL/min	150 psi
A171-151T	0.4 gph	26 mL/min	140 psi
A151-91T	1 gph	63 mL/min	110 psi
B121-91T	2.5 gph	158 mL/min	100 psi
D121-71T	4 gph	253 mL/min	100 psi

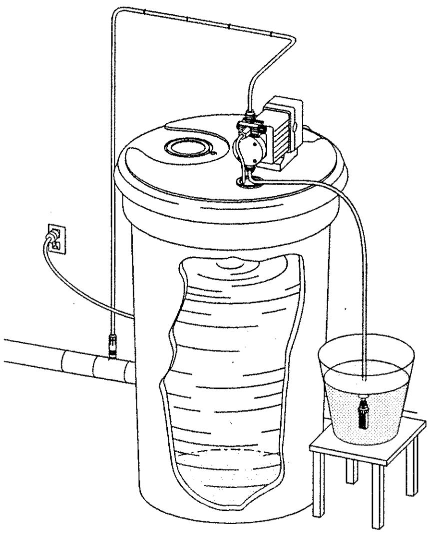
W & T Pumps

Model	Capacity gph	Capacity mL/min	Max psi
45-010	1 gph	63 mL/min	150 psi
45-050	5 gph	315 mL/min	100 psi
45-100	10 gph	630 mL/min	50 psi

PRIMING THE PUMP

Priming LMI

If the pump is a new pump, use clear water for the prime. If this is an existing pumping situation and you are just re-priming the pump, then use the chlorine solution.



Equipment

- Clean water - at least 2 gallons
- Bucket - 2 to 3 gallon size

1. Remove the suction line from the tank and from the pump.
2. Place the suction line into the bucket.
3. Fill suction line with clear water.
4. Disconnect discharge line and add a section of pipe that allows you to discharge the pump into a bucket.
5. Start the pump.
6. Adjust feed to 80% speed and 100% stroke.
7. With the 4 in 1 valve - turn yellow and black knobs 1/4 turn or pull and hold.
8. Once a small amount of fluid starts out of the bypass line the pump is primed.
9. Release or turn the 4 in 1 valve to normal - the pump should pump into the bucket.
10. Shut off pump and reconnect the discharge piping and place the suction line into the tank.
11. Restart the pump.
12. Adjust speed and stroke.
13. Wait appropriate time.
14. Check residual.
15. Adjust feed rate to obtain proper residual for desired treatment.

Priming W & T 45

If the pump is a new pump, use clear water for the prime. If this is an existing pumping situation and you are just re-priming the pump, then use the chlorine solution.

Equipment

- Clean water - at least 2 gallons
- Bucket - 2 to 3 gallon size

1. Remove the suction line from the tank and from the pump.
2. Place the suction line into the bucket.
3. Fill suction line with clear water.

4. Disconnect discharge line and add a section of pipe that allows you to discharge the pump into a bucket.
5. Start the pump.
6. Adjust feed to 80% speed and 100% stroke.
7. Once liquid starts to flow from the discharge piping the pump is primed.
8. Shut off pump, reconnect the discharge piping and place the suction piping back into the tank.
9. Restart the pump.
10. Adjust speed and stroke.
11. Wait appropriate time.
12. Check residual.
13. Adjust feed rate to obtain proper residual.

NORMAL OPERATIONS

ROUTINE OPERATION

Process

Water enters the plant as raw water. Potassium permanganate is added to the flow just before the filter unit. A static mixer is included in some plants in order to improve the mixing efficiency of the potassium permanganate with the water. The addition of the $KMnO_4$ starts the oxidation process and creates a small precipitate of iron and/or manganese. The treated water enters the top of the filter vessel and travels down through the media much like the roots of a tree. To improve the efficiency of the filtration process, anthracite coal is often added to the top of the greensand media. Because there are no coagulants added to the water, the filter must remove the precipitate by a simple straining process.

Filtration Rates

The filtration rate should remain within the design parameters. Typically the filtration rates will range from 3 to 4 gpm/ft^2. Once the filtration rate has been determined the influent flow meter should be monitored for changes in flow rates. Any significant change, especially upward, would require recalculating the filtration rate. If for some reason the design filtration rate is exceeded, the plant should be shutdown and the problem resolved.

Normal Filter Run - Headloss

Under normal conditions, after backwash, a pressure filter should have headloss of between 1 and 2 psi. As the filter run continues, the headloss will rise. Backwash is usually started when the headloss is between 8 and 10 psi.

Backwash on Gallons Used

Many operators have determined that the best control is to backwash on the basis of the number of gallons of water treated rather than on the headloss. As a result some systems are designed with meters that can be set to a specific volume. When that volume has been treated, the plant either shuts down or starts an automatic backwash cycle.

Filtration Rate Control

As was described above, the normal process for filter flow control is the utilization of a flow restrictor valve on the inlet and in some cases also on the outlet. In a few instances, flow control is accomplished in a more traditional manner, using a flow control valve on the outlet. With this process, the inlet valve is set at the maximum filtration rate. An effluent valve is controlled by headloss. The valve starts at a partially closed position. As the filter plugs, the increased pressure above the media is transmitted to the effluent valve which opens maintaining a constant flow through the filter. Should the effluent valve fail, the influent control valve will prevent damage to the filter.

BACKWASH PROCESS

Control Valves

While backwash control can be accomplished manually and with various brands and styles of butterfly and wide body globe, automatic control valves, the most common pressure filters in Alaska use the single valve process. The most common single control valve is the Solo™. The following discussion will be based on the Solo™ control valve. However, the sequence would be the same with any combination of manual and/or automatic control valves.

Sequence

When it is time to backwash the filter, the following sequence is typically followed: (In this sequence it is assumed that only one filter, filter #2, is to be backwashed.)

- Shut off the raw water pump.
- Close the inlet supply valves. #1 & #2
- Pressure differential across the filter should slowly become zero.
- Close the finished water valve, #3.
- Move the Solo™ valve to the backwash position.
- If a manual system, open the backwash valve #5 one quarter open. - If an automatic system go to the next step.
- Turn on the backwash pump. *There may be a automatic control valve in the backwash system that slowly opens, preventing a surge on the filter media. If this is so, this valve will open slowly, usually at least 1 minute.*
- If there is no automatic valve, slowly open the backwash valves, #5 & #7
- If there is surface wash, the valve will open and the surface wash will run for 30 seconds to 1 minute before the backwash valve opens. With the surface wash running the backwash valve will open.
- Backwash for 6 to 15 minutes or until the backwash water comes clear. Taking grab samples during the backwash is the best method of determining the clarity of the backwash water. When observing the sample, look for media, if media is present then the backwash rate is too high.

Process

During the backwash, the media in the bed will expand 50% hydraulically (the distance between any two particles is one-half the average diameter of the particles), this represents a 20 to 35% physical expansion. Unfortunately, in most pressure filter systems the operator is not able to observe the expansion.

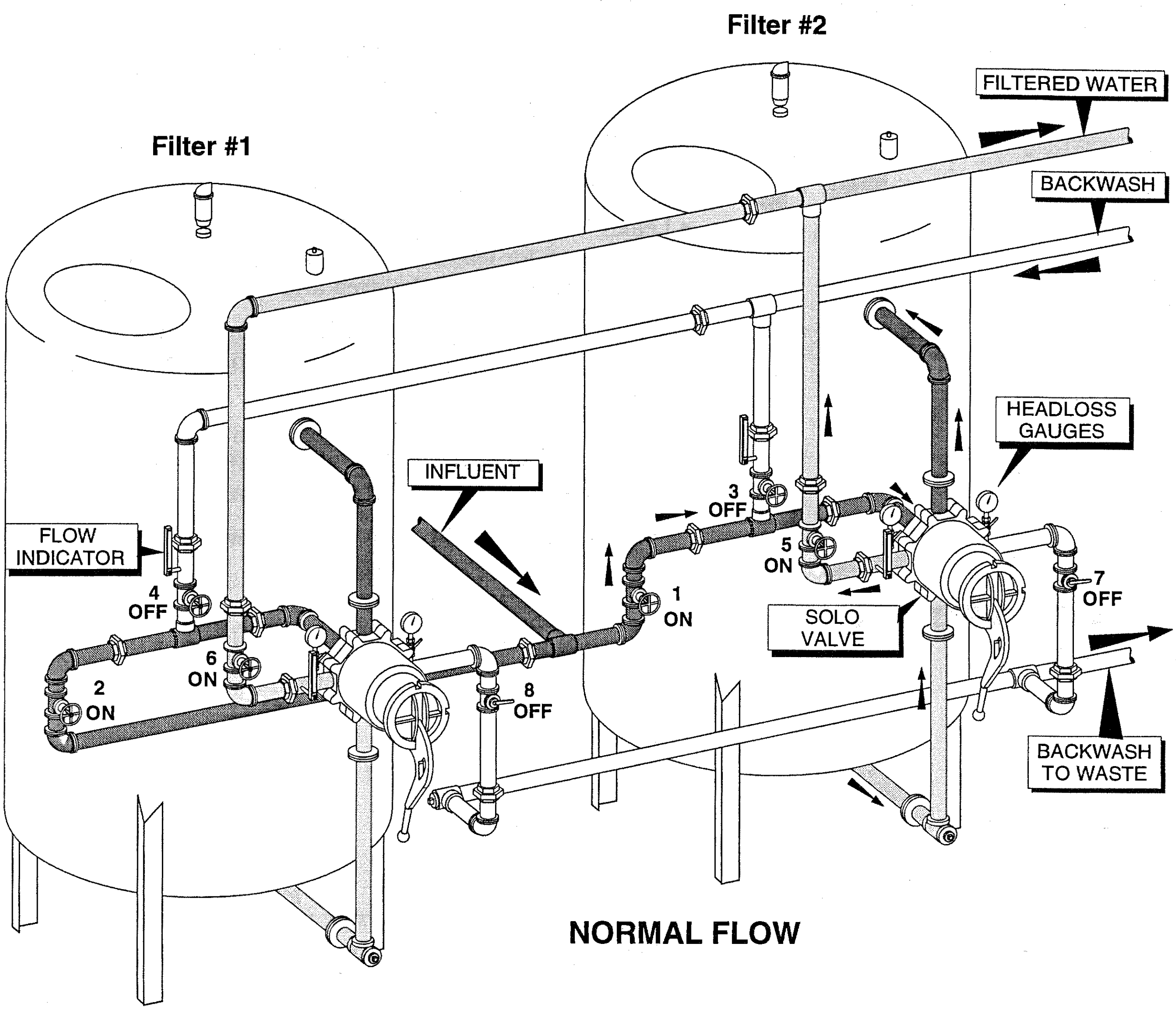
Rate

The backwash rate is dependent on the temperature of the water. The warmer the water, the greater the backwash rate needs to be. This is because the warmer the water the lower the water density. The following backwash rate table was taken from the AWWA Standard on Filtering Material B100-80 and can be used to determine proper backwash rates.

Maximum Backwash Rates

Water Temperature, ° F	Maximum Backwash RATE, gpm/ sq ft
50 or less	15
51-55	16
56-60	17
61-65	18.5
66 - 70	20
71-75	21
Above 75	22.5

- At the conclusion of the backwash cycle, the surface wash system should shutdown 2 to 3 minutes before the backwash pump shuts off.
- Shut off the backwash pump.
- Close backwash line control valves, #5 & #7.
- Wait 20 to 30 seconds for the filter to become stable.
- Rotate the Solo™ valve to "Filter to Waste" position. *On some valves this position is called Regeneration.*
- Turn on the raw water pump.
- Open valves #2 & #4 on filter #1 to 1/2 of normal open position. This prevents excessive high filtration rates on filter #1.
- Slowly open the influent valve (valve #1). The pressure on the inlet gauge should rise to just above normal.
- When the pressure is at the normal rate slowly open the waste valve, valve #7.
- The first water though the filter will be exited to waste. During this period the filter is compressing (aging) and becoming more efficient. If you were able to observe the effluent turbidity, you would see a spike at the start of this process and then the turbidity should fall quickly down to normal.
- Run the filter to waste for 4 to 6 minutes.
- Close the waste valve, valve #7.
- Open the effluent valve, valve #3.
- Rotate the Solo™ valve to Normal. Water should now be routed to the clear well or storage tank.
- Return the valves for filter #1 to normal position.


Filter #2
Filter #1
FILTERED WATER
BACKWASH
HEADLOSS GAUGES
INFLUENT
FLOW INDICATOR
3 OFF
5 ON
4 OFF
1 ON
SOLO VALVE
7 OFF
6 ON
2 ON
8 OFF
BACKWASH TO WASTE

NORMAL FLOW

ROUTINE INSPECTION

What to observe?

A potassium greensand installation should be visited each day of operation. When visiting the installation, look generally for proper operation. More specifically observe the following:

- Level of chemical in the tank.
- Leaks - observe all piping, the tank and chemical feed pump for leaks. If there is a leak, shutdown the system, wash down the area and fix the leak.
- Observe pump - Observe the operation of the chemical feed pump to be sure that solution is being pumped.
- Filter system - Observe the operation of the filter by checking flow rate, pressure differentials and color of the water before and after filtration.
- During the visit collect the data described below.

DATA COLLECTION

Raw water

Test or and record daily:

- pH
- Temperature
- Pressure
- Iron and/or Manganese
- Flow

If fluoride is being fed, test raw water fluoride level monthly.

Chemicals and chemical feed

Observe and/or calculate daily:

- Level of liquid in $KMnO_4$ tank
- Calculate quantity of $KMnO_4$ used
- Calculate dosage of $KMnO_4$

Once a month inventory the quantity of chemicals on hand. There should be a six month supply at all times.

Filter

Observe daily and record differential in filtration pressures.

At the start of each filter run, record the initial headloss. If there is no headloss gauge, then record the raw and finished water pressures.

Every three months:

- Check filtration rates

• Check backwash rates

Once each year, remove the inspection cover and inspect the filter media for mud balls and general conditions. If there is no surface wash, then this inspection should be made once a quarter.

Once each year remove the top 1 inch of the filter media and replace with new media

Finished water

Once each day test, observe and record the following:

• Iron and/or manganese concentration

• Check water color to determine if proper dosage has been maintained. There should be no pink color in the finished water

• pH

• Water temperature

• Chlorine residual

• Fluoride residual

DATA COLLECTION FORM

A typical small potassium greensand filter plant daily data form should have the following columns.

Date

Raw water meter reading

Water treated

Raw Water

Temperature

pH

Iron & Manganese

Chemicals

Tank level in inches

Inches used

Gallons used

Dosage in mg/L

Filter

Time and date filter run started

Initial headloss

Present headloss

Date and time backwashed

Finished Water

Iron & manganese

Water color

Temperature

pH

Chlorine residual

Fluoride residual

CALCULATIONS

Calculation Needed

As a result of the daily visit to the iron and manganese removal plant, the $KMn0_4$ dosage should be calculated. While the lack of color in the finished water is a key to determining proper dosage, the dosage calculation is important to understanding what is happening with the plant and the raw water quality. A change in dosage can give information on why there is a change in finished water quality. The formula for calculating dosage is given below under the topic title of Calculations for Potassium Permanganate.

Daily Check List - Example

❑ Collect data as per data collection form.
❑ Has there been a use of chemicals in the last 24 hours? This can be determined by comparing your level readings with the previous readings.
❑ If you enter the data into the computer, compare dosage and use to history.

❑ Check all plant thermostat settings _____ ° F
❑ Check restroom thermostat setting ______ ° F
❑ Check office and lab thermostat setting ______ °F

❑ $KMnO_4$ liquid level _____ inches.
❑ $KMnO_4$ pump stroke setting ____ %
❑ $KMnO_4$ pump frequency _______ strokes/min.
❑ Flow rate ________ gpm
❑ Flow meter totalizer reading ______________ gallons
❑ Raw water pH _______
❑ Raw water Temperature _______°F
❑ Inlet pressure to filter ______ psi
❑ Outlet pressure from filter _______ psi

❑ Chlorine liquid level _____ inches
❑ Chlorine pump stroke setting ____ %
❑ Chlorine pump frequency light flashing _______ storks/min.
❑ Chlorine residual _____ mg/L

❑ Fluoride pump stroke setting ____ %
❑ Fluoride crystal level _____ inches
❑ Fluoride pump frequency light flashing ________ strokes/min.
❑ Fluoride residual _____ mg/L

❑ Poly liquid level _____ inches
❑ Poly pump stroke setting ____ %
❑ Poly feed pump stroke _____ % and frequency ______ %

❑ Finished water pH _______
❑ Finished water temperature ________°F
❑ Is there a pink color in the finished water? ______

❑ Temp. of high service pumps _______
❑ Compare switch settings with notes on tags
❑ Check for leaks

MIXING & FEEDING CHEMICALS

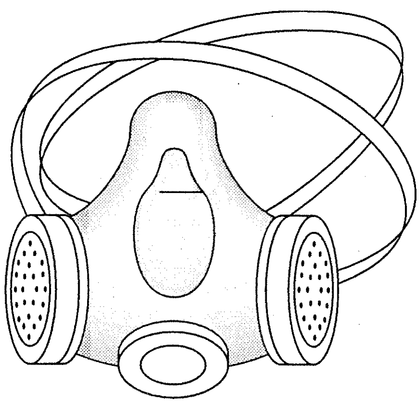
POTASSIUM PERMANGANATE

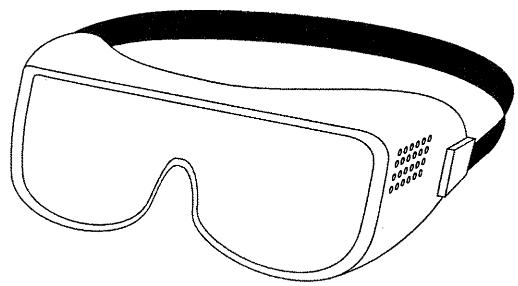
Properties

- $KMnO_4$ forms a purple solution with water. Tends to cake, and lump.
- $KMnO_4$ is an oxidant that reacts with acids and combustibles, therefore should not be handled by any equipment that has been used or exposed to acids and combustibles.
- This chemical is considered a fire hazard and is dangerous.

Safety equipment required when handling as a powder

- Cartridge dust mask.
- Chemical safety glasses.
- Rubberized gloves.





- Loose, denim-quality, dust-proof, long-sleeved clothes with bandanna and cap. Trousers and sleeves tied at ankles and wrist.

Mixing Concerns

- Maximum concentration 4%.

MIXING PROCESS

Normal Condition

It is normal to make a chemical solution of 1% to 4% concentration. In making a $KMnO_4$ solution, consider the powder to be 100% active ingredient. Using this assumptions the following guidelines can be used to determine the amount of chemical needed.

Volume	lbs for each 1% of solution
25 gallons	2 lbs
30 gallons	2.5 lbs
50 gallons	4 lbs

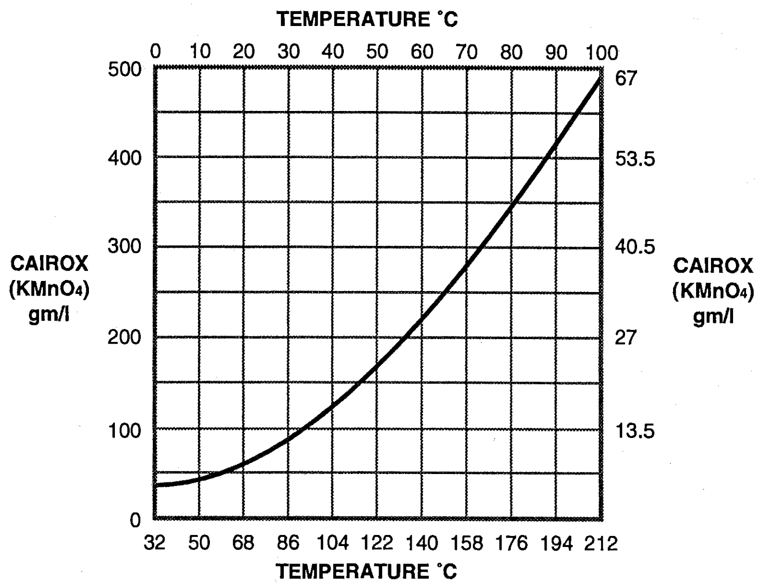
Conversions

1 lb = 16 oz = 454 grams

Solubility

The solubility of $KMnO_4$ improves with increase in water temperature. The following table can be used to determine the maximum amount of potassium permanganate that can be dissolved into solution in three different size tanks.

Temperature		Tank Size		
°F	°C	25 gal	30 gal	50 gal
		Pounds $KMnO_4$		
32	0	5.8	6.9	11.5
50	10	9.0	10.8	18.0
68	20	13.5	16.2	27.0
86	30	18.8	22.5	37.5
104	40	26.0	31.2	52.0
122	50	38.0	45.6	76.0
140	60	48.0	57.6	96.0



Assumptions

The following procedure is provided with the assumption that $KMnO_4$ is being mixed in a batch solution and a dry feeder is not being used.

Procedure

When making up a new solution batch, the following procedure can be adapted to local conditions.

- Put on personal protective equipment
- Fill container 1/2 full of hot water
- Start mixer
- Dump dry chemical in container
- Fill with water - continue to mix

CHEMICAL FEEDING PROCESS

Control of Feed Rates

For proper plant operation match the chemical feed rate with the plant performance. This is accomplished by relating raw water iron and manganese concentrations and flow to the chemical feed rate.

Automatic Feed Rate Control

Some water treatment plant chemical feed systems are controlled by a signal from the raw water flow meter. This system provides one of the most precise methods of changing feed rates to match flow rates. Unfortunately, most pressure filter systems for small communities use a chemical feed system that is a fixed flow rate. This is based on the assumption that the flow through the filter remains constant throughout the filter run. With pressure filters, as the filter clogs the head above the filter increases, increasing total dynamic head on the raw water pump and thus reducing the flow rate. As a result, chemicals are overfed and the most desirable dosage is not achieved.

Calibration

Calibration of chemical feeder and calculations for determining chemical concentrations are to be found in the **process control** module.

Using Polymers

If a **polymer**[28] is added prior to the filter, it should be 1 to 5 minutes after the $KMnO_4$ injection point.

ADDING CHEMICALS

Typical Problem

During the visit to the treatment plant, it is often necessary to replenish the $KMnO_4$ in the feed tank. If the tank is empty then determining how much chemical should be placed in the tank is very simple. However, one of the common problems facing operators of these systems is how to determine the amount of chemical that needs to be placed in the tank, when the tank is not completely empty.

Solution

The simplest way to resolve this problem is with a job-aid. A job aid is developed using this procedure:

- Cut a piece of 3/4 or 1 inch PVC pipe the height of the tank depth.
- Determine how much chemical will be required for five (5) gallons of water.
- Empty the tank.
- Place five gallons of water in the tank and, using a water resistant felt tip marker, place a mark on the piece of PVC.
- Continue this process until the tank is full.
- Make a note on the side of the piece of PVC, how many pounds, gallons, cups, etc. of chemical is needed for each five gallons of water.
- When performing the routine inspection, hold the bottom of the piece of PVC even with the level of solution in the tank. Place a pencil mark on the tank at the nearest 5 gallon mark that you can fill to with out overfilling the tank.

28 **Polymer** - High molecular weight synthetic organic compound that forms ions when dissolved in water. Also called polyelectrolyte

- Place the chemical in the tank.
- Fill the tank to the mark with clean hot water.

ORDERING CHEMICALS

Six Months Supply

In rural Alaska it is best to keep at least a six month supply of chemicals on hand. This means that each order must be for a six month supply plus shipping time. A typical procedure would be:

- Determine the amount of $KMnO_4$ used per month
- Multiply times six.
- This is the amount that needs to be on the shelf when you order.
- Set up a procedure to inventory the chemicals each month.
- When the supply is at six months, order the amount necessary for six months, plus shipping time plus one week lead time.

Example:

The city of Waterhome uses an average of 0.75 pounds of $KMn0_4$ per day. Shipping time is 60 days. Therefore the total amount needed would be for 183 days (six months) + 60 days + 7 day = 250 days. The amount of $KMn0_4$ needed in the order would be 0.75 lbs/day x 250 days = 188 pounds. A standard container of $KMn0_4$ is 55, 110 and 330 pounds. The City of Waterhome uses 55 pound containers, therefore the order should be for 4 containers.

CALIBRATION OF FEED PUMPS

When to Calibrate

Chemical feed pumps should be calibrated at start-up and then quarterly.

Why Calibrate

The calibration of the chemical feed pump is the only reliable method of determining the actual feed rate of the pump. It is from this data that we are most able to properly set the pump. The second reason for calibrating the pump is to obtain data that allows us to develop a calibration curve. It is from the calibration curve that we can determine the proper setting to obtain the desired dosage.

Equipment

The following equipment is necessary in order to complete the calibration.

1. Five gallon bucket
2. 1000 mL graduated cylinder
3. Stop watch
4. Writing pad

5. Pen or pencil

6. Latex gloves

7. Safety goggles

Considerations

When calibrating an auto paced feed pump, shut off the auto pacing. That is change the local/remote switch to local.

With pumps that have both speed and stroke length settings, a series of calibrations will need to be made for each major stroke length setting, i.e. 20%, 40%, 60%, 80% and 100%.

Assumption

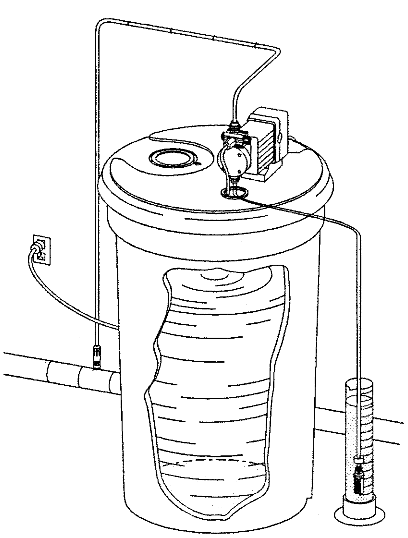
In proceeding with the calibration process described below, it is assumed that feed pumps with stroke length and stroke frequency are being calibrated.

General Procedure

The calibration of a chemical feed pump is accomplished in four general steps.

1. Calibrate the pump by observing amount pumped from suction side of the pump. Calibrating from the suction side is much more accurate that calibrating from the discharge side of the pump. The discharge rate will vary with, and increase in, discharge pressure. Therefore, the amount that is measured during calibration may be much like what is actually pumped when the pump is pumping against a high head.
2. The greatest accuracy is obtained by manually setting the stroke length and making a series of readings at various stroke frequencies.
3. The data is recorded in a table.
4. The data from the table is then transferred to a graph.

PROCEDURE - SPECIFIC



1. Adjust the speed to 10 percent and the stroke length to 20%.
2. Shut off the pump.
3. Fill the graduated cylinder to 800 mL with solution from the tank.
4. Set the cylinder on the floor beside the tank.
5. Remove the suction line from the tank and place it in the cylinder.
6. Fill the cylinder to 1000 mL.
7. Start the pump.
8. After running 1 min, observe level in cylinder and start the stop watch.
9. Run the pump for at least 1 min - 3 minutes is better.
10. At end of time, observe reading.

11. Record the data.

12. Adjust the stroke frequency to the next step (commonly this is either 10 or 20 percent increments).

13. Refill the cylinder to 1000 mL.

14. Repeat steps 9 through 13 for each setting.

15. Adjust the stroke length to the next increment (10 or 20 % increments) and repeat steps 9 through 14.

16. Upon completion - return the suction line to the tank, clean the cylinder.

17. Transfer the data to a graph.

Example

The following data was collected during a calibration of a chlorine feed pump.

Frequency/Stroke

Under normal operations, the frequency setting of the pump is controlled by a signal from the plant flow meter. In our example there were four pumps that supplied water to the plant. With one pump running the signal from the meter would set the feed pump at 20%; with two pumps running, the signal would be set at 40% and so on. Therefore, the decision was made to calibrate the pumps at these various frequency settings. This will allow the operator to make chemical feed adjustments by changing only the stroke length.

20% Frequency - based on 1 minute samples

Stroke	Start level	Stop level	mL	mL/min
20%	1000	993	16	16
40%	985	947	38	38
60%	920	860	60	60
80%	800	724	76	76

40% Frequency - based on 1 minute samples

Stroke	Start level	Stop level	mL	mL/min
20%	1000	978	22	22
40%	950	885	65	65
60%	850	742	108	108
80%	700	555	145	145.8

60% Frequency - based on 2 minute samples

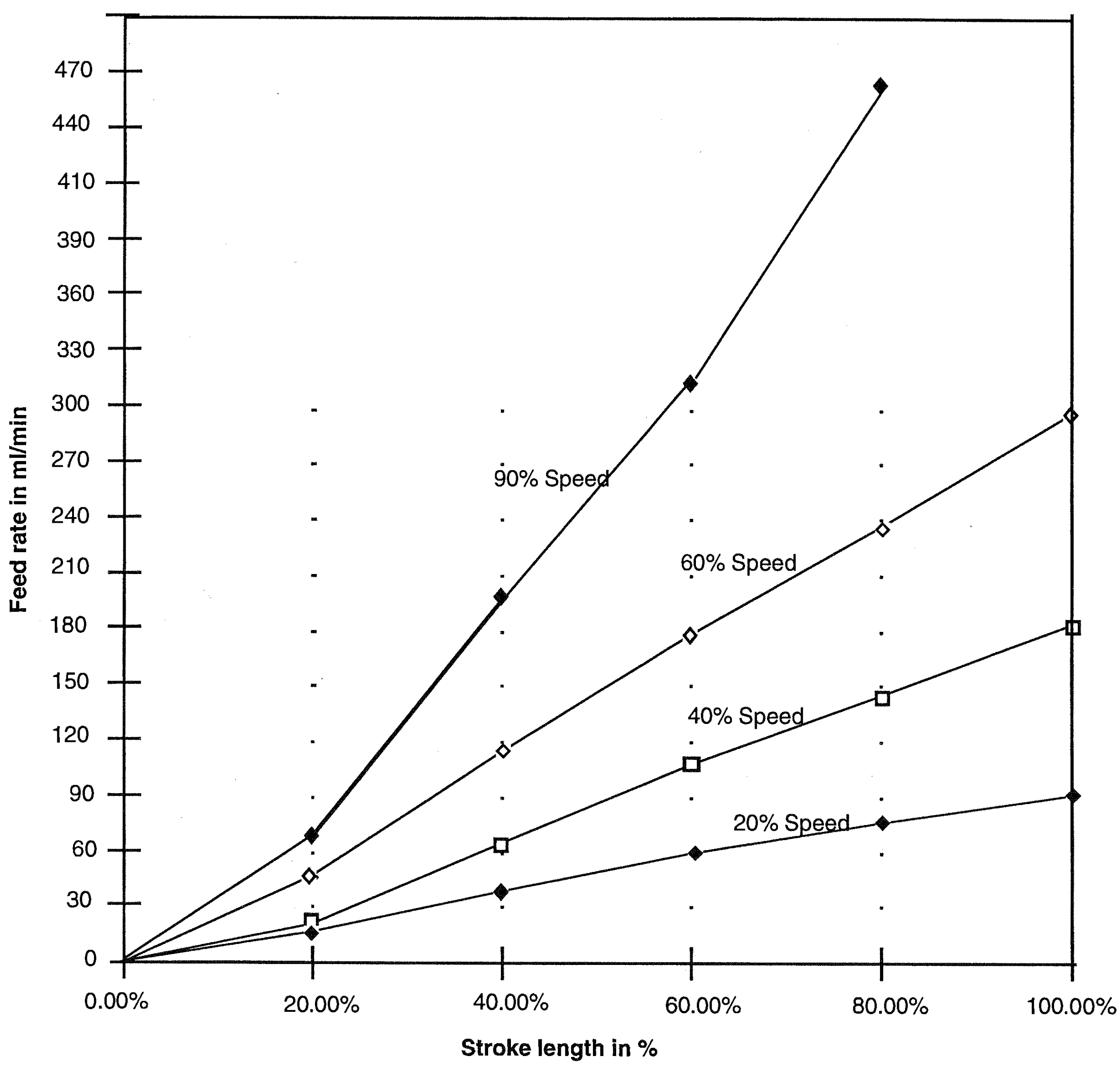
Stroke	Start level	Stop level	mL	mL/min
20%	1000	905	95	47.5
40%	875	645	230	115
60%	600	244	356	178
80%	1000	525	475	237.5

90% Frequency - based on 1/2 minute sample

Stroke	Start level	Stop level	mL	mL/min
20%	1000	967	33	66
40%	900	803	97	194
60%	775	617	158	316
80%	600	442	232	464

Curve

The following family of curves were plotted from the data in the 20%, 40% and 60% frequency settings above. The three curves correspond to the 20%, 40% and 60% frequency readings. The stroke length was plotted along the bottom and the milliliters per minute plotted along the side. To use the curve, determine the frequency and stroke settings. Select the proper curve to correspond with frequency. Find the stroke setting along the bottom. Follow this reading up until you reach the proper frequency curve. Now extend a line to the left and read the flow in mL/min.



CHECKING FILTRATION AND BACKWASH RATES

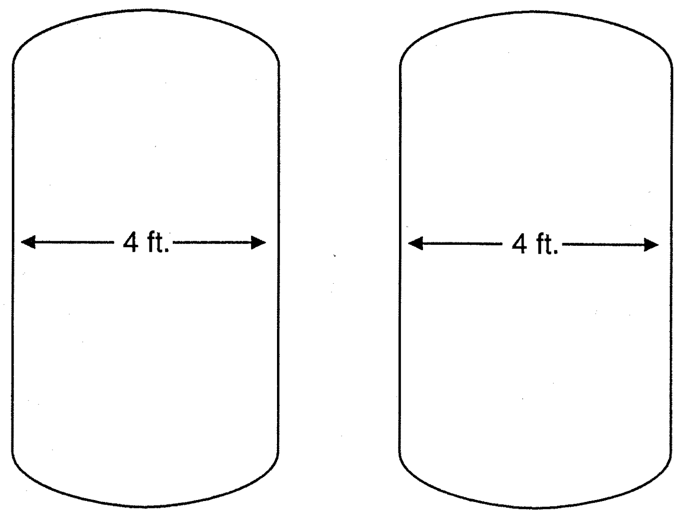
Frequency

It is desirable to check filtration and backwash rates every three months. These simple tests will give you valuable information on the performance of the plant and the backwash pump.

FILTRATION RATE

Example

The City of Noorvik uses two greensand filters, each is four feet in diameter. The raw water pump produces a flow of 110 gpm. What is the filtration rate in gpm/ft^2?



Find the surface area of the filters

$$A = \pi r^2 = \pi(2ft)^2 = \pi \times 4 ft^2 = 12.6 ft^2$$

This is the surface area of one filter. To obtain the total surface area this value must be multiplied by 2.

$12.6\ ft^2$ x 2 filters = $25.2\ ft^2$

Find the filtration rate.

$$\frac{110\ gpm}{25.2\ ft^2} = 4.4\ gpm/ft^2$$

Conclusion

Filtration rates should be between 3 and 4 gallons per minute per square foot of filter media. This plant is operating above the recommended flow rate. The flow should be throttled back to below 100 gpm.

BACKWASH RATE

Example

The City of Waterhome uses two pressure greensand filters, each is four feet in diameter. The backwash pump pumps water into a tank. The tank is 46" x 46". It took 3 minutes to fill 27 inches of the tank. What is the backwash rate in gpm/ft^2?

Convert inches to feet

46"/12" per foot = 3.8'

27"/12" per foot = 2.25 ft

Find volume in cubic feet

3.8' X 3.8' x 2.25' = 32.49 ft^3

Find volume in gallons

32.49 ft^3 x 7.48 gal/ft^3 = 243 gal

Find flow rate in gpm

243 gal/3 min = 81 gpm

Find filtration rate

$$\frac{81 \text{ gpm}}{12.6 \text{ ft}^2} = 6.4 \text{ gpm/ft}^2$$

Conclusion

The normal backwash rate should be between 12 and 15 gpm/ft^2. At the time that this test was performed the filter was inspected and approximately one half to three eighths of an inch of mud was found on the filter. The mud accumulation was the result of low backwash rates. The conclusion was to replace the backwash pump with one that would produce at least 215 gpm.

CALCULATIONS USED IN IRON AND MANGANESE REMOVAL

Introduction

Depending on the situation, an operator may need one or more of the following formulas.

Pounds for Set Concentration

It is assumed that potassium permanganate is a 100% concentrated product. Therefore, the following formula can be used to find the number of pounds of chemical needed to make a specific concentration.

Start by converting the percent desired to a decimal (2% = 0.02, 4% = 0.04, etc.)

____ lbs = ___ % solution needed x___ gal in tank x 8.34 lbs/gal

Example

Determine the number of pounds of $KMnO_4$ needed to make 25 gallons of a 1% solution.

lbs = 0.01 x 25 gallons x 8.34 lbs/gal = 2 pounds

No Scales

In many locations there are no scales to measure out the amount of chemical needed. In these locations a standard household cup is often used. The following conversions can be used in order to determine the correct chemical concentration.

1 cup = 8 oz

16 oz = 1 pound

To convert the number of cups to pounds, divide the weight.

Finding Concentration

The formula for finding the concentration of $KMnO_4$ in a tank when the number of pounds of material added is known is:

$$\_\_\_ \text{ \% in tank} = \frac{\_\_\_ \text{ lbs of powder X 100}}{\_\_\_ \text{ gal of tank X 8.34 lbs/gal}}$$

Example

Find the concentration when 16 lbs of $KMnO_4$ placed in a 50 gallon barrel that is filled with water.

$$\% = \frac{16\,\text{lbs} \times 100}{50\,\text{gal} \times 8.34\,\text{lbs/gal}} = 3.8\%$$

PUMPS & DOSAGE

Feed Rate

The following formula can be used to find the chemical pump feed rate when the system flow and the tank concentration are known.

$$\text{mL/min} = \frac{0.378 \times \_\_\_\ \text{mg/L (dosage)}\ \_\_\_\_\ \text{gpm (flow rate)}}{\_\_\_\ \%\ \text{in tank}}$$

Example

Find the feed rate in milliliters per minute for a feed pump that must pump a 2% solution into a 2 inch line that flows at 50 gpm. The desired dosage is 3 mg/L.

$$\text{mL/min} = \frac{0.378 \times 3\ \text{mg/L} \times 50\ \text{gpm}}{2\%} = 28\ \text{mL/min}$$

Concentration @ Set Dosage

The following formula can be used to find the concentration needed to provide a set dosage at a specific chemical feed pump pumping rate.

$$\_\_\_\ \%\ \text{concentration} = \frac{0.378 \times \_\_\_\ \text{mg/L (dosage)} \times \_\_\_\ \text{gpm (flow rate)}}{\_\_\_\ \text{mL/min (feed pump rate)}}$$

Example

Find the concentration needed to supply a dosage of 4 mg/L to a flow of 60 gpm when the chemical feed pump is producing 30 mL/min.

$$\% = \frac{0.378 \times 4\ \text{mg/L} \times 60\ \text{gpm}}{30\ \text{mL/min}} = 3\%$$

Determining Dosage

The following formula can be used to find the dosage in mg/L, when the flow rate and the concentration of the solution are known.

$$\_\_\_\ \text{mg/L} = \frac{\_\_\_\_\_\ \text{gal of solution used} \times \_\_\_\_\ \%\ \text{of solution} \times 10{,}000}{\_\_\_\_\ \text{gal, flow for the day}}$$

Example

Find the dosage in mg/L when 10 gallons is used from a 50 gallon tank in a flow of 60,000 gallons. The concentration in the tank is 2%.

$$\_\_\_\ \text{mg/L} = \frac{10\ \text{gal} \times 2\% \times 10{,}000}{60{,}000\ \text{gal}} = 3.3\ \text{mg/L}$$

Feed Rate for Dual Control Pumps

When a pump has both speed and stroke adjustments, the feed rate can be estimated if the maximum feed rate is known. The maximum feed rate is often either given by the pump manufacturer or is part of the model number. When this information is known, the feed rate can be estimated by doing the following:

Feed rate = Max pump output X% speed X% stroke

Example

Find the feed rate of a pump with a maximum feed rate of 158 mL/min, the speed set at 65% and the stroke at 55%.

Feed mL/min =

158 mL/min x 0.65 x 0.55 = 56.5 mL/min

PROCESS CONTROL

Process Control Tools

The key to proper operation of a potassium permanganate greensand filter is process control. The major process control tools for an operator are a pH meter and a sensitive eye. The sensitivity of the eye can be augmented with a jar test kit, white porcelain pan or white Styrofoam coffee cup.

Dosage Requirements

The standard dosage rates for oxidation of iron and manganese using potassium permanganate are 1 mg/L $KMnO_4$ for each 1.06 mg/L Fe or 0.52 mg/L Mn. This can also be written as 1 mg/L of iron will require 0.94 mg/L of $KMnO_4$, and 1 mg/L of Mn will require 1.92 mg/L of $KMnO_4$.

Example:

A water has a manganese level of 0.8 mg/L and a iron level of 1.2 mg/L. What is the recommended $KMnO_4$ dosage rate?

0.8 mg/L of Mn x 1.92 = 1.5 mg/L

1.2 mg/L of Fe x 0.94 = 1.1 mg/L

The total dosage would be 2.6 mg/L

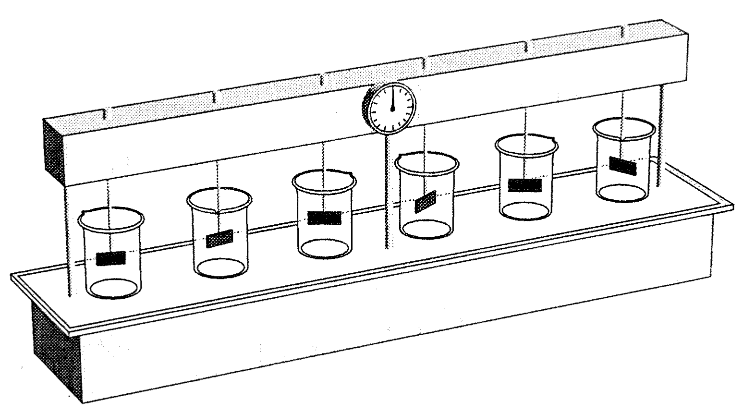
Visual Observation

When no equipment is available to determine the dosage required, or you wish to check the existing dosage, follow this simple procedure:

- Adjust dosage so that a pink color persists just before filter. Use a white pan or white coffee cup to collect the sample. The pink color should persist for 1 to 2 minutes. At this level you are overfeeding $KMnO_4$.
- Cut back until you see no pink color in the finished water, but there is a slight pink color in the water just above the filter. This slight pink color should only persist for 1 to 2 minutes.

JAR TEST

The proper dosage can be closely estimated using a standard jar test gang stirrer.



Stock Solution - 5 grams

Start by making a standard stock solution. A standard solution can be made by weighing and mixing 5 grams of $KMnO_4$ in 500 mL of water. This will give a 1% solution (10,000 mg/L).

Transfer 1 mL

Using a pipet transfer 1 mL of this stock solution to a 100 mL volumetric flask and dilute with distilled water.

1mL in 1000 mL = 0.1 mg/L

Placing 1 mL of this final solution in a 1000 mL sample will give a dosage of 0.1 mg/L of $KMnO_4$.

High Iron or Manganese

If the concentration of iron is greater than 5 mg/L or Mn is above 2.5 mg/L, make a stronger solution. Transfer 10 mL of stock solution to the 100 mL volumetric flask and dilute with distilled water. 1 mL of this solution in 1000 mL is equivalent to a dosage of 1.0 mg/L.

Procedure

- Set up 6, 1000 mL jars with samples of the raw water.
- Dose each jar with progressively greater amounts of the dosage solution.
- Rapidly mix the samples for a length of time equivalent to the rapid mix in the plant.
- Allow the samples to stand a length of time that is equivalent to the travel time between the chemical injection and the top of the filter media.
- Decant the solution from the jars and filter using a Millipore filter (220mμ).
- Test the filtrate for residual iron and manganese should be below 0.05 mg/L for best results.

pH considerations

As pH increases, the oxidation rate increases and thus the amount of time required to oxidize the iron and manganese. If the oxidation rate is too slow, the best performance is typically obtained when the pH is above 7.7. For example, in one test, 5 minutes was required for the reaction to come to completion when the pH was 6. Raising the pH to 7.5 reduced the reaction time to 1 min.

If the pH is low, it may be best to add soda ash prior to the addition of $KMnO_4$. This can be determined by experimentation or by using the jar test.

Visual considerations

Collect and observe two samples. One from the influent to the filter and one from the effluent of the filter. The best results are found when:

1. The influent sample has a pink color that lasts for 1 to 2 minutes and,
2. There is no pink color in the effluent sample.

Polymer addition

The addition of filter aid polymers may increase removal rates of iron and manganese precipitate by improving the efficiency of the filtration process. If polymers are added, it is best if they are added after the $KMnO_4$ has had time to react. This could be 1 to 5 minutes depending on water temperature and pH.

Residuals

The feed rate, and pH adjustments should be made so that at no time is the total residual of Fe and Mn above 0.02 mg/L.

Addition of Chlorine

Several operators have found that the addition of chlorine prior to $KMnO_4$ may improve oxidation rates and thus iron and manganese removal. However, potassium permanganate residuals will interfere with chlorine residuals. DPD reacts with potassium to give a color that is exactly like the color developed with chlorine. Therefore, subtract the potassium permanganate residuals from chlorine residuals to obtain true chlorine residuals. (The potassium permanganate residual is obtained from performing a manganese test on the effluent of the filter.)

Coffee Cup Test

One of the simplest, but most effective, process control tools for checking dosage rates is the coffee cup test. This test requires a stock solution of $KMnO_4$ and a white Styrofoam coffee cup.

To make the stock solution, add one eye dropper full of the mixed $KMnO_4$ (the mixture in the feed tank) to a standard eye dropper bottle.

Fill the eye dropper nearly full with distilled water and mix. (Leave enough head space to mix the solution.)

Obtain a sample of finished water in a white Styrofoam coffee cup.

Add 5 drops of the stock solution into the coffee cup.

If a pink color persists for 2 to 5 minutes, the dosage is OK. If pink color does not develop or disappears quickly, increase the feed rate.

If a pink color appears after the first 1 or 2 drops and does not fade, reduce the dosage rate.

OPTIMIZATION OF IRON AND MANGANESE REMOVAL

The following procedure was condensed from an article in the March 1993 Saskatchewan Operators Clearwater Reporter. The article was written by John Magyar. The data used to produce the article was taken from the Kelliher water treatment plant.

Plant Data

The plant was originally designed and constructed in 1963. The plant consists of two 4.5 ft diameter manganese greensand filters. Iron and manganese are oxidized using $KMnO_4$. The media is greensand with an anthracite cap. The raw water iron concentration is

1.8 mg/L and manganese is 0.5 mg/L. The manufacturer estimated the removal rate for the filters to be between 500 and 700 grains/ft^2 .

Optimization Parameters

The following procedures can be used to optimize:

- $KMnO_4$ demand
- Filter run length
- Filtration rates
- Backwash rates
- Length of backwash
- Filter headloss

Equipment Needed

Millipore or equivalent filters of 0.45μm size

A method of measuring iron and manganese; in this study a HACH DR2000 was used.

Several white (at least 12) Styrofoam cups.

$KMnO_4$ DEMAND CURVE

To develop a $KMnO_4$ demand curve follow these steps:

- Calculate the estimated demand.

  (In this study, the theoretical dosage of 1 mg/L $KMnO_4$ for each 1 mg/L of Iron and 2 mg/L of $KMnO_4$ for each 1 mg/L of manganese was used.)

Fe = 1.8 mg/L

Mn = 0.5 mg/L

Demand = (1 x Fe mg/L) + (2 x Mn mg/L)

Demand = (1 x 1.8 mg/L) + (2 x 0.5 mg/L)

Demand = 1.8 mg/L + 1.0 mg/L = 2.8 mg/L

- Determine the chemical feed metering pump setting required for the following dosages:

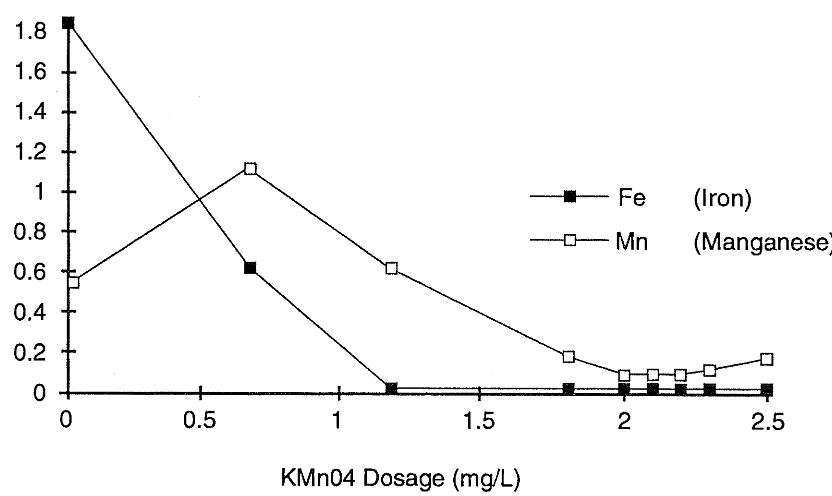
0.65 mg/L
1.15 mg/L
1.8 mg/L
2.0 mg/L
2.1 mg/L
2.2 mg/L
2.3 mg/L
2.5 mg/L

- Adjust the chemical feed pump to a dosage of 0.5 mg/L. Wait an appropriate length of time and collect a sample just before the flow enters the filter. (An appropriate length of time is the time required for the chemical feed pump to balance its discharge and for the flow to travel from the injection point to the filter. This should normally not take more than 5 minutes.)

- Filter the sample through the Millipore device. This is an attempt to simulate the filtration capabilities of the greensand filter and to remove the precipitated material.
- Split the sample, test one portion for residual iron and manganese Observe the color in the remaining portion of the sample by pouring the sample into a white Styrofoam cup.
- Record the results
- Repeat this procedure for each of the other dosages.

$KMnO_4$ Dosage mg/L	**Total Fe mg/L**	**Total Mn mg/L**	**Color of Filtrate**
0.00	1.8	0.500	Slightly yellow
0.65	0.59	1.080	Slightly yellow
1.15	0.02	0.598	Clear
1.8	0.02	0.159	Clear
2.0	0.03	0.069	Clear
2.1	0.02	0.059	Clear
2.2	0.02	0.072	Slightly yellow
2.3	0.02	0.089	Slightly pink
2.5	0.01	0.145	Pink

- Plot the data as shown below in the example.



- Note that the most ideal dosage is 2.1 mg/L. This is below the estimated dosage. It is desirable to feed 0.1 to 0.3 mg/L above what is needed to oxidize the iron and manganese, thus assuring constant regeneration of the filter media. Therefore, a dosage between 2.2 and 2.4 mg/L is considered to be best. Notice that as the dosage approaches 2.5 mg/L the residual manganese begins to increase.

FILTRATION RUN LENGTH

The length of the filter run should be based on the manufacturers data. The data provided to Kelliher by the manufacture indicated a removal of 500 to 700 grains/ft^2 for this filter. (A grain is a unit of weight per gallons of water and is equivalent to 17.12 grains per US gallon.) The following calculation were used to determine the maximum filtration run time.

• Filters were 4.5 ft in diameter. Surface area is therefore, $A = \pi r^2$. The radius is 4.5 ft/2 = 2.25 ft

$A = \pi\ (2.25\ ft)^2 = 15.9\ ft^2$

• Since there are two filters - 15.9 ft^2 x 2 = 31.8 ft^2

• Based on the removal rates provided by the manufacturer the removal range would be:

31.8 ft^2 x 500 grains/ft^2 = 15,900 grains

31.8 ft^2 x 700 grains/ft^2 = 22,260 grains

• Based on the theoretical dosage required of 2.8 mg/L and 1 grain/gal = 17.2 mg/L the removal would be;

2.8/17.2 = 0.16 grains per gallon

• Based on these parameters the theoretical number of gallons that can be treated are;

$$\frac{15{,}900\ \text{grains}}{0.16\ \text{grains/gal}} = 99{,}375\ \text{gal}$$

$$\frac{22{,}260\ \text{grains}}{0.16\ \text{grains/gal}} = 139{,}125\ \text{gal}$$

This indicates that the filters theoretically can filter between 99,375 gallons and 139,125 gallons. As the production reaches the 99,000 gallon mark, the filter effluent should be checked several times per day and tested for residual manganese at least twice per day. This data will help determine a more precise filter run.

FILTRATION RATES

Standard filtration rates of 3 to 4 gpm are typical for this type of plant. Based on the filter area, the flow rate through the plant should remain between 95 and 127 gpm.

3 gpm/ft^2 x 31.8 ft^2 = 95 gpm

4 gpm/ft^2 x 31.8 ft^2 = 127 gpm

BACKWASH RATES

Standard backwash rates for greensand filters range between 12 and 15 gallons per minute based on water temperature. At low water temperature the backwash rate can be reduced. The key to proper backwash rates is proper hydraulic expansion of the filter beds. A 40% expansion of a greensand bed is considered ideal.

Only one filter is backwashed at a time. Therefore, the backwash flow rate need only be calculated for one filter bed. Each filter bed has a surface area of 15.9 ft^2. The backwash rates for this plant should range between:

$12\ gpm/ft^2 \times 15.9\ ft^2 = 191\ gpm$

$15\ gpm/ft^2 \times 15.9\ ft^2 = 239\ gpm$

A key test to backwash rates is to collect samples of the backwash water and observe for the presence of filter media. Anything other than a few grains of filter media is considered too high of backwash.

LENGTH OF BACKWASH

A typical backwash cycle lasts from 10 to 15 minutes. The filter should be backwashed until the effluent appears clear in a white Styrofoam cup. Samples should be collected at 1 to 2 minute intervals during backwash and each sample compared with the previous one. When the water appears clean, stop the backwash and record the time needed.

FILTER HEADLOSS

Excessive pressure across the filter can cause filter breakthrough in the same manner as with a standard sand filter used to remove turbidity and color. With pressure filters this differential in pressure should not exceed 10 psi. It is recommended that gauges be tested or replaced once a year to assure that this pressure is not exceeded.

ROUTINE MAINTENANCE

There are four major components of a potassium greensand filter plant that require scheduled, routine maintenance; the pumps, control valve(s), filter media and chemical feed pumps

Pumps

Once a year efficiency test should be run on the raw water and backwash pumps. Once every three months the amperage, voltage and flow should be tested and recorded.

If the pumps use packing in the stuffing box, it should be replaced once each year.

Control Valves - Solo™

Once each year the Solo™ control valve should be disassembled, cleaned and new gaskets installed. Inspect the backwash nozzle. If there is observable wear then replace the nozzle.

Control Valve - Globe

If wide body globe valves such as Clay™ valves are used for control valves, they should be disassembled once each year. The valve seat, movable closure and diaphragm should be inspected, if damaged or worn they should be replaced.

If a pilot valve is used with the globe valves, the pilot valve seat, spring and diaphragm should be replaced once each year.

Filter

The filtration and backwash rates should be checked every three months. Filter media should be inspected once each year. In most cases, the top one inch of media should be removed and replaced each year. When the media is backwashed, the media particles rub against one another and some particles are worn down to a very small size. These small particles accumulate on the top of the media and reduce the effectiveness of the filter media.

Entry into a pressure filter vessel is entry into a confined space. Every effort should be made to perform this task without actual entry into the vessel.

CHEMICAL FEED PUMPS

The chemical feed pumps should be calibrated once each year. The process of calibration is described above in the section on normal operation.

Annual Procedures

On all pumps once each year replace:

- All suction and discharge lines
- Foot valve and screen
- Injection valve
- Pump suction and discharge valves, seats and springs

- Pump diaphragm
- 4 in 1 valve

About LMI Pump

The LMI pumps are composed of two units, the electrical unit and the pumping unit (also called the liquid end). The model number includes indicators for both ends. For instance with the model A101-91FS, the A101 is the electrical end and the 91FS is the liquid end. The electrical end may be used to pump all chemicals, however, the wet end must be selected for the proper chemical. There are three common wet ends used in small communities in Alaska; they are:

Model	Chemical it is designed for
91S	Chlorine
91T	Alum, $KMnO_4$, Soda Ash, etc.
91FS	Fluoride

Repair Kits

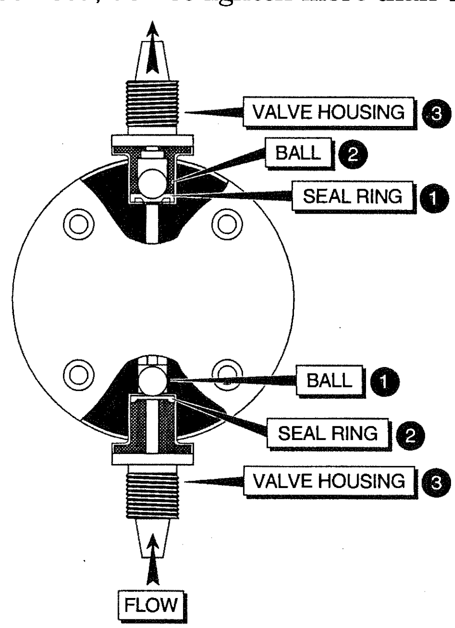
The repair kit required for a LMI pumping potassium permanganate is SP-U3.

LMI PUMPS

LMI Discharge Valves

The following procedures can be used to make the annual replacement of the discharge valves on an LMI feed pump.

1. Shut off and depressurize the pump.
2. Loosen hose fitting & remove hose.
3. Remove - Injection fitting.
4. Remove and replace, ball, spring seat and seal ring. No Teflon tape should be used on the fitting or threads. Instead use silicon lube on threads (Dow 33 Moleycoat). Tighten the fitting by hand. If a wrench must be used, do not tighten more than 1/8 turn.



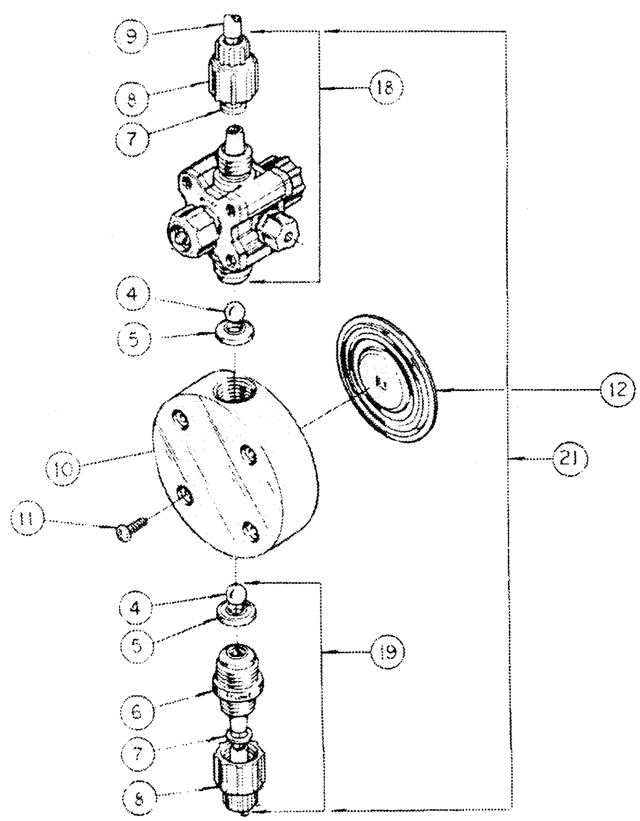
5. Clean and replace injection fitting. No Teflon tape should be used on the fitting or threads. Instead use silicon lube on threads (Dow 33 Moleycoat). Tighten the fitting by hand. If a wrench must be used do not tighten more than 1/8 turn.
6. Replace discharge piping.

LMI Suction Valve

The following procedure can be used for the annual replacement of the suction valve on a LMI chemical feed pump.

1. Shut off an depressurize the pump.
2. Loosen hose fitting & remove hose.
3. Remove - Coupling nut.
4. Remove suction valve seat.
5. Remove and replace ball, seat and seal ring. No Teflon tape should be used on the fitting or threads. Instead use silicon lube on threads (Dow 33 Moleycoat). Tighten the fitting by hand. If a wrench must be used do not tighten more than 1/8 turn.
6. Clean and replace coupling nut. No Teflon tape should be used on the fitting or threads. Instead use silicon lube on threads (Dow 33 Moleycoat). Tighten the fitting by hand. If a wrench must be used do not tighten more than 1/8 turn.
7. Replace discharge piping.

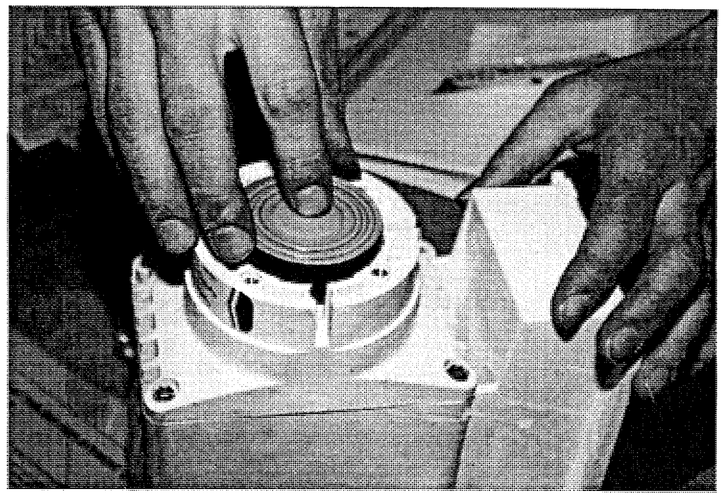
Key	Description
4	Check ball
5	Check seat
10	Pump head
12	Diaphragm
18	4 in 1 valve



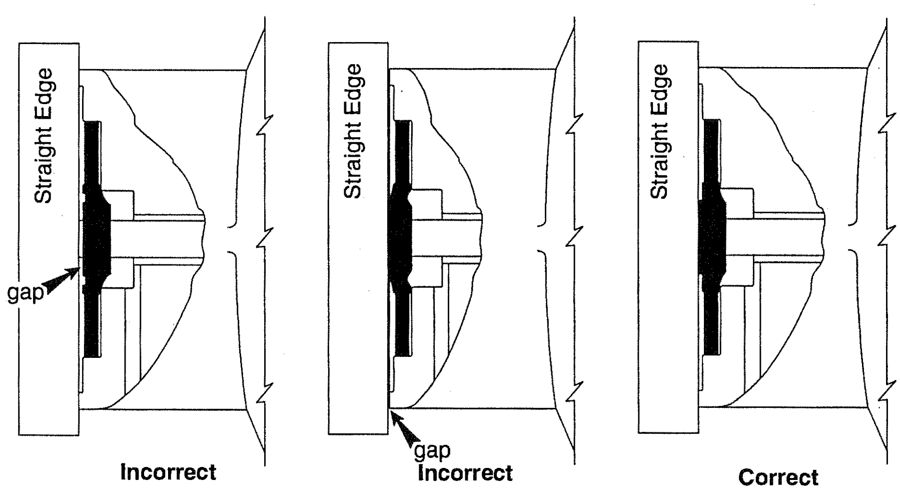
Replace Diaphragm - LMI

The following procedure can be used for the annual replacement of the diaphragm on LMI feed pump.

1. Flush pump by pumping clean water 10 min with stroke & frequency at 100%.
2. Turn settings to zero.
3. Shut off pump.
4. Remove pump head.
5. Remove diaphragm. Grasp other edge and rotate counter clockwise.
6. Restart pump.
7. Adjust stroke to 90%.
8. Screw on diaphragm until center begins to buckle.



9. Stop pump.
10. Check position with straight edge. Adjust as necessary.



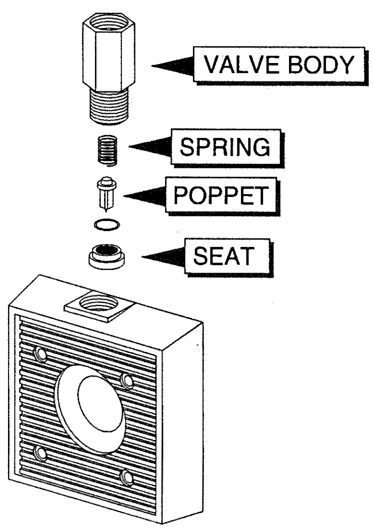
11. Replace head. Tighten the head bolts using a criss-cross pattern.

W & T PUMPS

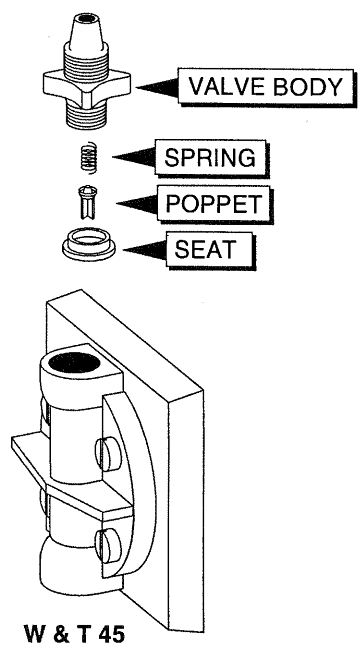
Discharge & Suction Valves

The following procedure can be used for the annual replacement of discharge & suction valves on a W & T chemical feed pump.

1. Shut off pump & depressurize.
2. Remove Union nut.
3. Remove half union.
4. Remove and replace spring, poppet, gasket & valve seat. There may or may not be a spring on the suction side.
5. Replace half union. Use Teflon tape on the threads.
6. Replace union nut. No Teflon tape should be used on the fitting or threads. Instead use silicon lube on threads (Dow 33 Moleycoat). Tighten the fitting by hand. If a wrench must be used do not tighten more than 1/8 turn.



W & T 94



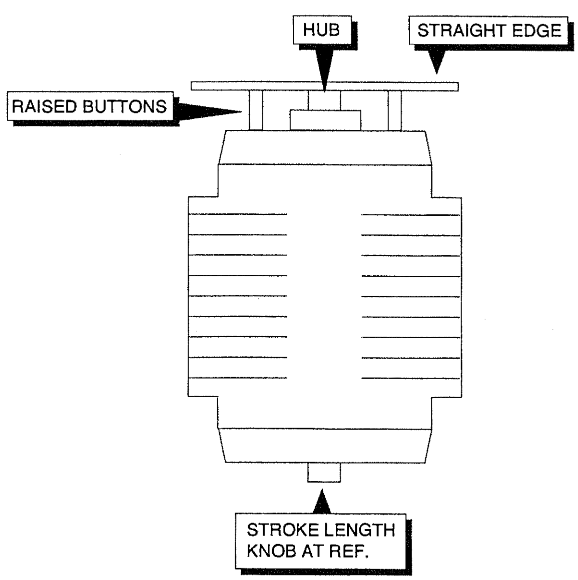
W & T 45

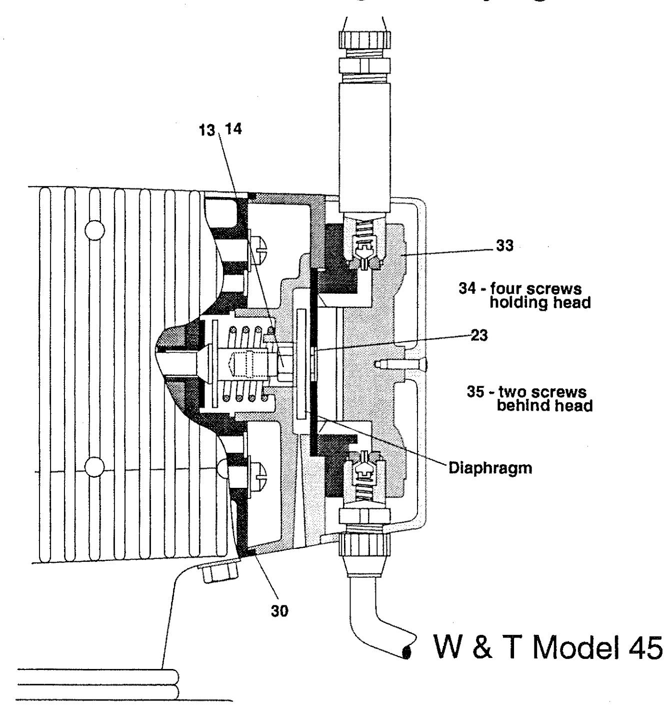
Replace Diaphragm on W & T 45

The following procedure can be used for the annual replacement of the diaphragm on a W & T model 45.

1. Flush pump by pumping clear water at maximum stroke
2. Adjust stroke length to REF.
3. Turn pump off & lock-out or unplug.
4. Remove screws (34) from pump head (33).
5. Lift diaphragm by edge, turn counter clockwise.
6. Hold hub (23), remove nut (13), lock washer (14) and diaphragm.

7. Remove two screws (35).
8. Hold washer with pliers & turn diaphragm counter-clockwise.
9. Replace diaphragm, lock washer and nut.
10. Tighten nut 30 inch pounds for 1gph & 100 inch pounds for 5 & 10gph.
11. Replace return spring into counter bore on inside of head adapter.
12. Clean internal threads of extension shaft.
13. Place extension shaft on top of spring - cone end out.
14. Place assembly on pump housing. Engage the cone with the recess on the solenoid shaft. A thin rod inserted through the head side of the adapter plate into the female thread of the extension shaft will help hold the parts together while assembling.
15. Replace screws (35).
16. Stretch O-ring (30) around the gap between head adapter and pump housing. Loosen the two screws (35) enough to allow the O-ring to tuck into the groove. Tighten screws to snug assembly together.





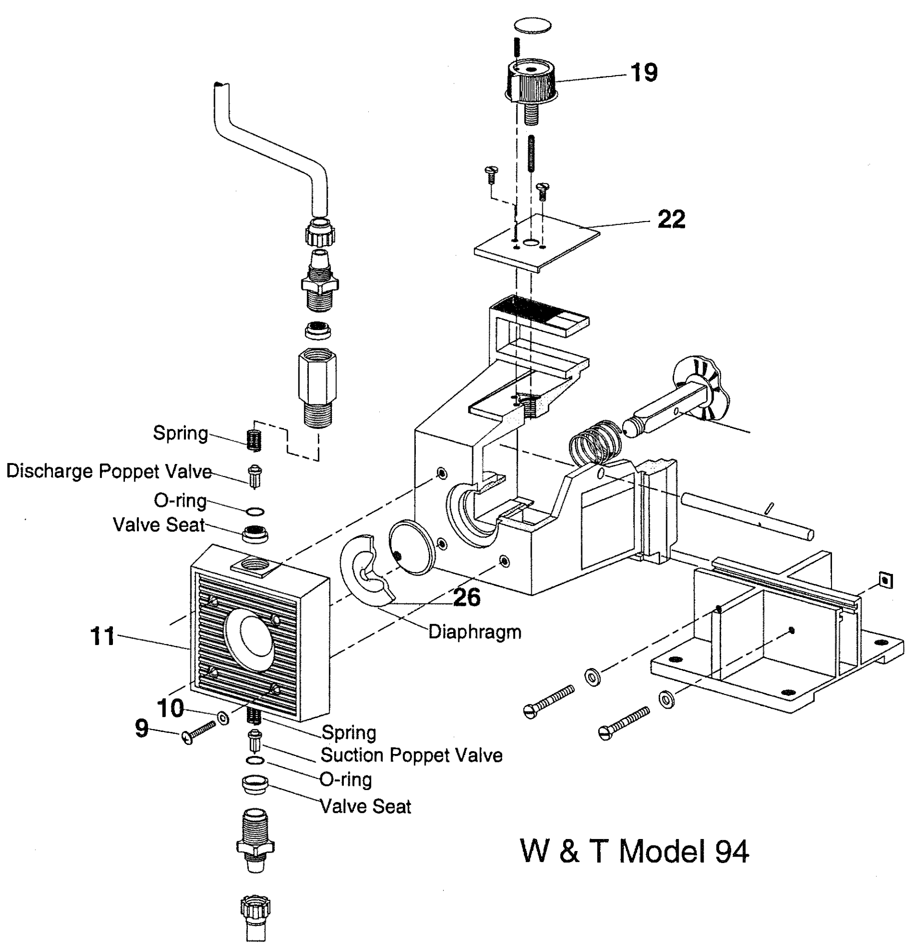
17. Place a drop of loctite on the thread of the diaphragm.
18. Screw on the new diaphragm. Correct position is when a straight edge laid across center of diaphragm hub just touches the top of the two studs. (For 1 gpm tighten until there is 0.020 inch gap between diaphragm and straight edge.)

19. Install head & screws. Tighten screws to 28 inch pounds.

Replace Diaphragm on W & T 94

The following procedure can be used for the annual replacement of the diaphragm on a W & T model 94.

1. Flush pump by pumping clear water at maximum stroke
2. Turn pump off & lock-out or unplug
3. Remove four screws (9) from pump head (11)
4. Turn knob (19) to zero with dial (22) in order to advance the diaphragm (26).
5. Lift diaphragm by edge, turn counter clockwise
6. Replace diaphragm (26) onto cam unit.
7. Turn knob (19) to 10 on dial (22) this will position the pump mechanism to fully retract diaphragm.
8. Install pump head (11) with four screws (9) and washers (10).
9. Tighten screws to 14 in-lbs



W & T Model 94

SHUTDOWN

Introduction

Shutting this plant down is a relatively simple process. Just shut the equipment off in the following order.

Main Plant Control

Turn the plant selector control knobs to off.

Automatic Valves

Observe the plant influent and effluent valves to see that they close.

Raw water

Shutdown raw water valve

Chemicals

Turn the power selector switches on the alum and soda ash feed systems to off.

$KMnO_4$

Unplug the feed pumps and the make-up pump.

Chlorine

Unplug the power cord to the chlorine pump.

Fluoride

Shut off the inlet water supply, unplug the chemical feed pump and the inlet solenoid valve power supply.

Backwash Pump

Turn the power selector to off.

High Service pumps

Turn the power selector to off.

EXTENDED OUT OF SERVICE NOTES

Plants

If you intend for any one plant to be off line for more than 24 hours, the floc basins and sedimentation basins should be drained. This will keep the sludge from going septic.

Chemicals

If you intend for the chemicals to be off line several days, you should drain and clean the tanks and flush the feed pumps with clean water.

TYPICAL PROBLEMS

Trouble	Cause	Solution
1. Manganese higher than raw water effluent clear -iron low	Manganese being leached from greensand	Increase $KMnO_4$ feed
2. Effluent turbid and yellow Iron and manganese high	pH too high prior to filter	Adjust pH to 7.7
	Channeling through filters	Backwash and repair filter
	Organic material bound to iron	Feed coagulant prior to filter
3. Excessive headloss just after backwashing	Greensand fines on top of filter	Remove top 1 inch of media
	Backwash rate too low	Should be 10 - 12 gpm/ft^2
	Filter bed cemented	Physical breakup the bed may need replaced
	Fines being pumped from well	Inspect raw water - may need sand separator
4. Iron breakthrough before backwash headloss below 10 psi	Fine iron precipitate passing through filter	Backwash based on total gallons not headloss
5. Pink color in finished water	$KMnO_4$ feed rate to high	Shut off feed for 1 to 2 hours then reduce

CHEMICAL FEED PUMP PROBLEMS

Low $KMnO_4$ Reading

Causes	Check and/or Solution
Pump air bound	Check electrical make-up solenoid valve for blockage, may require upstream strainer.
Pump setting too low	Check slotted strainer assembly for blockage
	Adjust pump feed rate

High $KMnO_4$ reading

$KMnO_4$ not dissolving	Use hot water or a mechanical mixer
Pump setting too high	Adjust feed pump
Decreased pump rate through plant	Adjust feed pump

Will not prime

Not plugged in	Plug in
Not turned on	Turn on
Speed and stroke not set properly	80% speed 100% stroke
Suction lift too high	Maximum of 5 feet
Suction line out of solution	Check solution level
Fittings over tightened	Can cause seals to distort and not seal
Air trapped in suction valve and tubing	Suction line not vertical
Discharge pressure too high	Check pressure
Suction screen plugged	Replace

Lost Prime

Solution tank dry	Refill
Foot valve not in vertical position	Adjust
Suction lift too great	Maximum 5 feet
Fittings over tightened	Can cause seals to distort and not seal
Air trapped in suction valve and tubing	Suction line not vertical
Air leak in suction fittings	Check for cracked fitting

Motor will not run

Power off	Check outlet
EPU failure on LMI pumps	See manufacturers info
Pulser failure	See manufacturers info

Excessive output

Siphoning	Replace anti-siphon valve
Loss of discharge pressure	Needs to be at least 25 psi
Excessive stroke frequency	Replace pulser

Pump Setting Table

This table is applicable for any solution and any concentration. The table is used to determine the frequency and stroke settings on a LMI chemical feed pump, once the feed rate in mL/min is known. **F = Frequency, S = Stroke**

Pump Rate mL/min	LMI/Z141 -152S	LMI* A101-91FS	LMI/A171 -150FS	W & T 94-100	LMI** A151-91FS	LMI B121-91FS	LMI D1221-71FS
2	S=50% F=30%						
4	S=50% F=60%						
6	S=65% F=70%	S=50% S=30%	S=50% S=45%				
8	S=80% F=90%	S=50% F=40%	S=50% F=60%				
10	S=85% F=90%	S=50% F=55%	S=50% F=75%				
12		S=50% F=65%	S=70% F=65%		S=50% F=40%		
14		S=50% F=75%	S=70% F=75%		S=50% F=45%		
16		S=50% F=85%	S=70% F=90%	S=3.0	S=50% F=50%		
18		S=70% F=50%	S=80% F=85%	S=3.5	S=50% F=55%		
20		S=70% F=75%	S=90% F=85%	S=4.0	S=50% F=65%		
25		S=80% F=80%		S=5.0	S=50% F=80%		
30		S=90% F=90%		S=6.0	S=70% F=70%	S=50% F=40%	
35				S=6.5	S=70% F=80%	S=50% F=45%	
40				S=7.5	S=90% F=90%	S=50% F=50%	
50						S=50% F=65%	S=50% F=40%
60						S=50% F=75%	S=50% F=45%
70						S=50% F=90%	S=50% F=55%
80						S=70% F=70%	S=50% F=65%
90						S=70% F=80%	S=50% F=70%
100						S=70% F=90%	S=50% F=80%
120							S=70% F=70%
130							S=70% F=75%
140							S=70% F=80%
150							S=70% F=85%

* A101-91FS has been replace by A171-150FS

** A151-91FS replaces A122-91FS

Table originally produced by USPHS - Alaska

O & M OF GREENSAND FILTERS

WORKSHEET

1. The symbol for iron is _________.

    _______ a. Pb

    _______ b. I

    _______ c. Fe

    _______ d. Mn

    _______ e. Ca

2. The symbol for manganese is__________.

    _______ a. Mn

    _______ b. Fe

    _______ c. Mg

    _______ d. Ca

    _______ e. M

3. Are iron and manganese considered to be

    _______ a. Primary contaminants

    _______ b. Secondary contaminants

4. The MCL for iron is____________.

    _______ a. 100 mg/L

    _______ b. 0.05 mg/L

    _______ c. 2.5 mg/L

    _______ d. 1.5 mg/L

    _______ e. 0.3 mg/L

5. The MCL for manganese is___________.

    _______ a. 100 mg/L

    _______ b. 0.05 mg/L

    _______ c. 2.5 mg/L

    _______ d. 1.5 mg/L

    _______ e. 0.3 mg/L

6. Which of the compounds listed below are said to be soluble in water?

_______ a. Ferrous iron

_______ b. Ferric iron

_______ c. Manganous manganese

_______ d. Manganic manganese

7. Bacteria that reduce iron and manganese and produce slimes in the inside of pipes are called what type of bacteria?

_______ a. Anaerobic

_______ b. Flagellate

_______ c. Iron

_______ d. Aerobic

_______ e. Facultative

8. Iron and manganese is said to be oxidized and brought into solution when the pH is..

_______ a. Low

_______ b. High

9. Conditions that contribute to iron and manganese being brought into solution are those where the dissolved oxygen is..

_______ a. Low

_______ b. High

10. When using chlorine as an oxidant for the removal of manganese it is best if the pH is ..

_______ a. Below 4

_______ b. Between 5 - 7

_______ c. Above 6

_______ d. Between 6 & 8

_______ e. Above 9.5

11. Which compound is commonly used to oxidize iron and manganese other than potassium permanganate and chlorine?

_______ a. Nitrogen

_______ b. Fluoride

_______ c. Air

_______ d. Hot water

_______ e. Soda ash

12. A natural occurring zeolite used in the removal of iron and manganese is called..

_______ a. Polyphosphate

_______ b. Greensand

_______ c. Anthracite coal

_______ d. Silica sand

_______ e. Garnet sand

13. A ____________________ is a common name for chemicals that are used as sequestering agents.

_______ a. Polyphosphates

_______ b. Zeolites

_______ c. Greensand

_______ d. Sorption chemicals

_______ e. Oxidation

14. When using potassium permanganate for the removal of iron and manganese, _____ of potassium permanganate will oxidize 1 mg/L of iron.

_______ a. 1

_______ b. 0.6

_______ c. 0.94

_______ d. 2

_______ e. 2.5

15. When using potassium permanganate for the removal of iron and manganese, ______ of potassium permanganate will oxidize 1 mg/L of manganese.

_______ a. 1

_______ b. 0.6

_______ c. 0.94

_______ d. 1.92

_______ e. 2.5

16. Potassium permanganate becomes _________ soluble in warm water.

______ a. more

_______ b. less

17. Potassium is classified by OSHA as an________________ & ____________.

_______ a. Poison

_______ b. Compressed gas

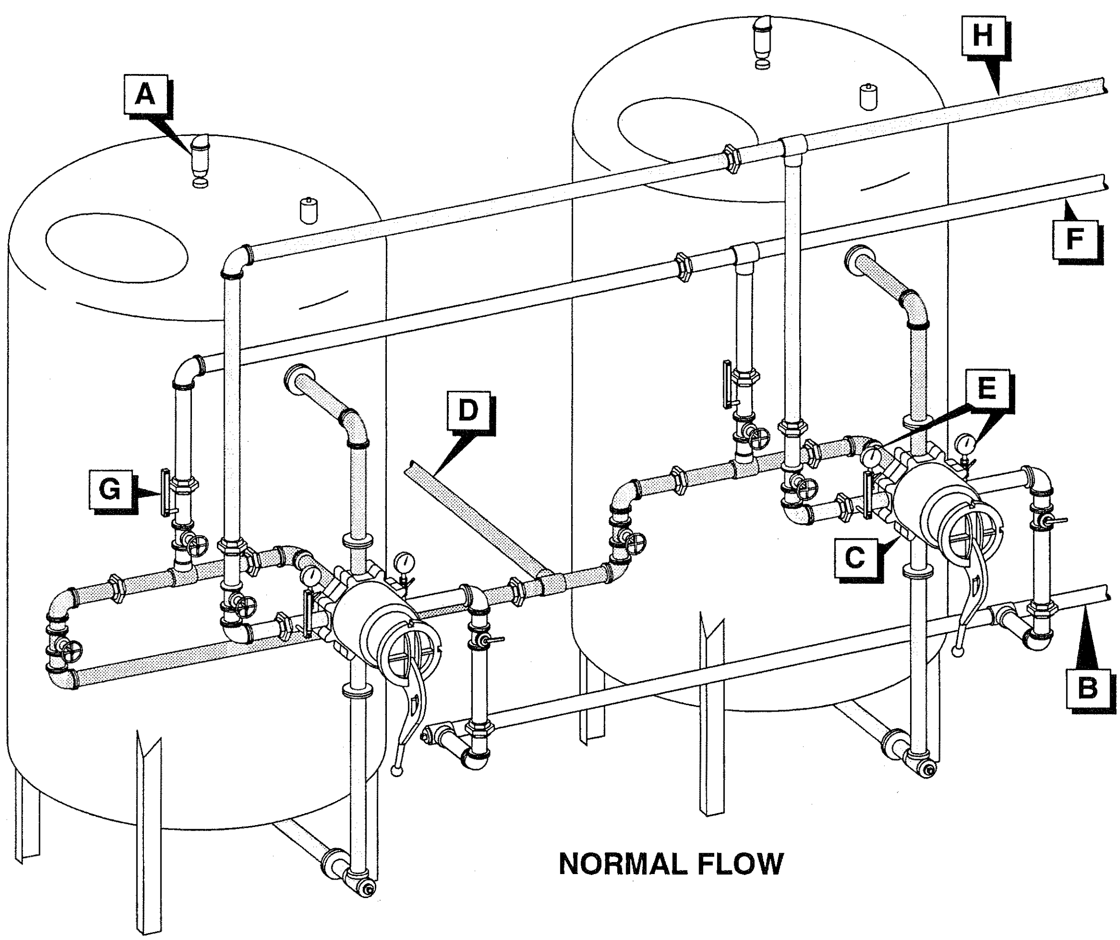
_______ c. Dry crystal

_______ d. Oxidizer

_______ e. Corrosive

18. Identify the components identified below

_______ Influent	_______ Vent
_______ Finished water	_______ Headloss gauges
_______ Waste line	_______ Flow inicator
_______ Backwash supply	_______ Control valve



19. Typical filtration rates for a potassium permanganate greensand iron removal plant would range between ____ and ____ gpm/ft^2.

_______ a. 2 - 4

_______ b. 4 - 8

_______ c. 3 - 9

_______ d. 3 - 5

_______ e. 3 - 7

20. A typical backwash of a greensand filter should last __________ minutes.

_______ a. 30

_______ b. 20

_______ c. 15

_______ d. 10

_______ e. 5

21. The headloss in a pressure greensand filter should not exceed ________

_______ a. 5 psi

_______ b. 20 feet

_______ c. 10 feet

_______ d. 10 psi

_______ e. 8 feet

22. Find the dosage in mg/L when 5 gallons of 2% $KMnO_4$ solution was used from a 50 gallon tank to treat a flow of 80,000 gallons.

_______ a. 1.7 mg/L

_______ b. 1.1 mg/L

_______ c. 1.4 mg/L

_______ d. 0.9 mg/L

_______ e. 1.3 mg/L

23. What is the required feed rate for a $KMnO_4$ pump when the system flow is 55 gpm, the desired dosage is 1.4 mg/L and the feed solution is 3%?

_______ a. 23 mL/min

_______ b. 8 mL/min

_______ c. 63 mL/min

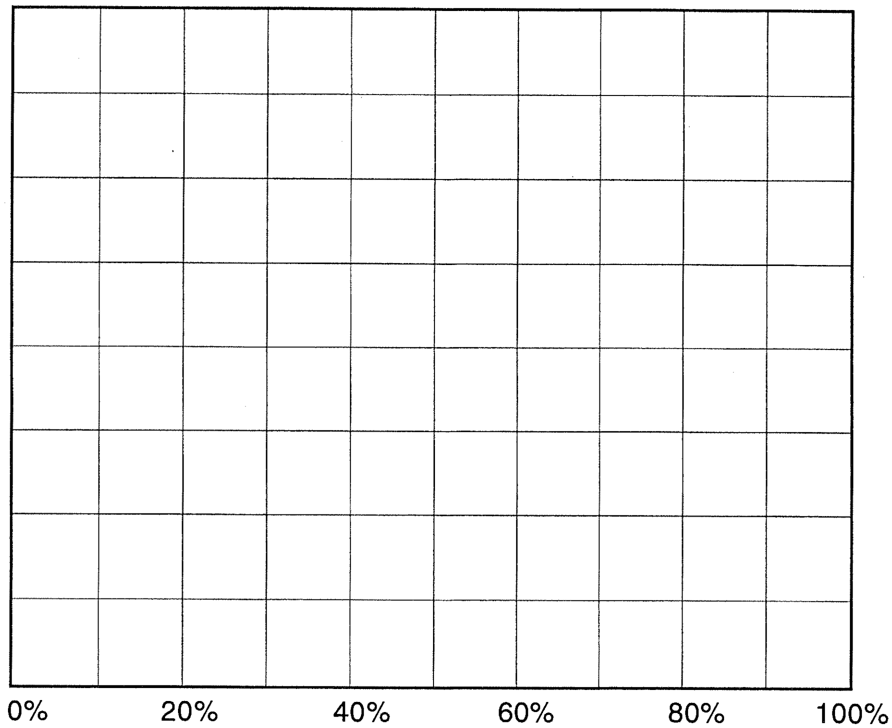
_______ d. 17.75 mL/min

_______ e. 15.5 mL/min

24. Complete the last column and develop a curve for the following chemical feed pump calibration data.

20% Frequency - based on 2 minute samples

Stroke	Start level	Stop level	mL	mL/min
20%	1000	993	32	______
40%	985	947	76	______
60%	920	860	120	______
80%	800	724	152	______



25. The iron level in a water supply is 1.8 mg/L and the manganese is 0.5 mg/L. What is the estimated $KMnO_4$ dosage in mg/L?

______ a. 2.7 mg/L

______ b. 2.3 mg/L

______ c. 3.8 mg/L

______ d. 1.3 mg/L

______ e. 4.1 mg/L