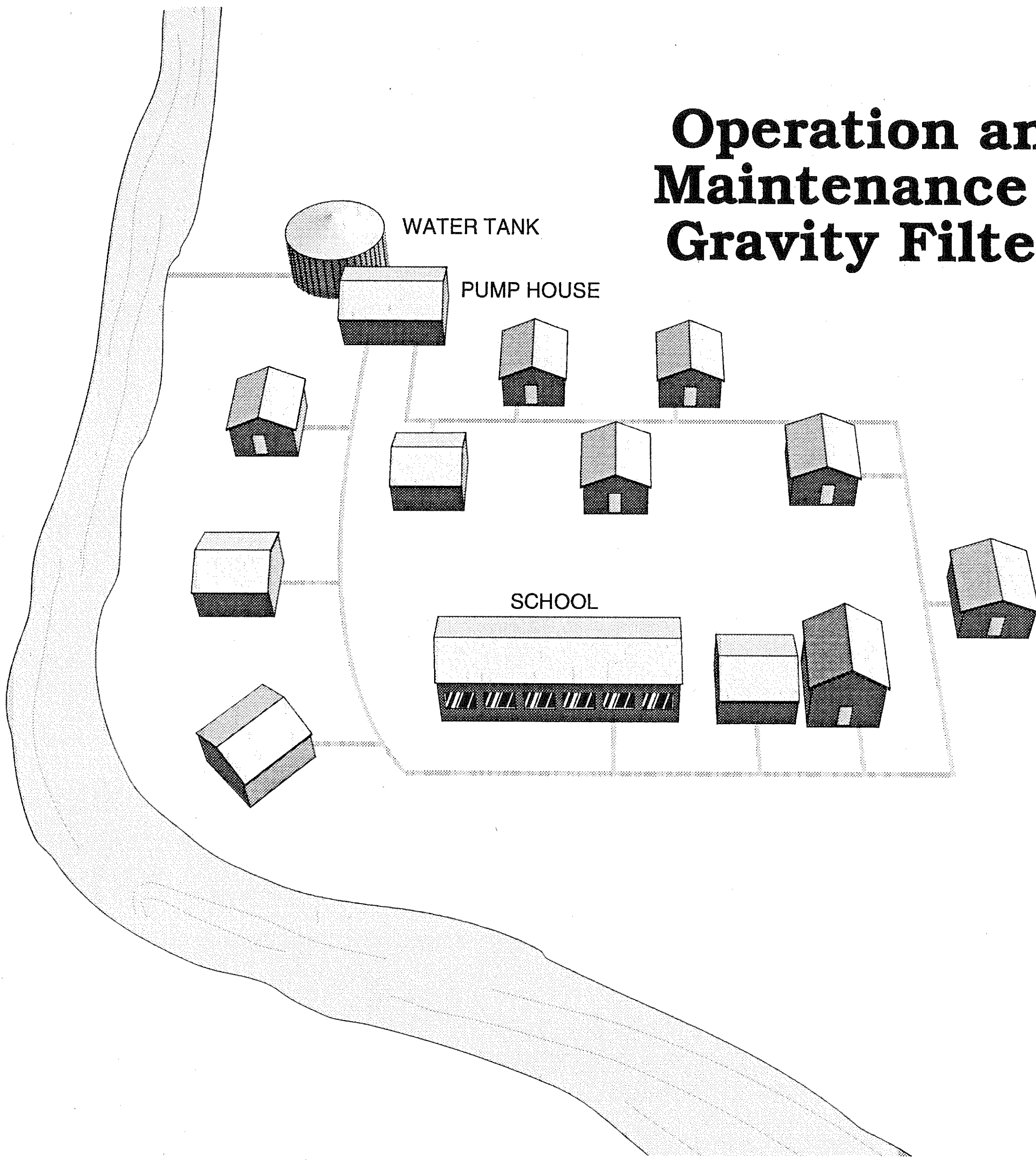
O & M of Small Water Systems



Operation and Maintenance of Gravity Filters

Alaska Department of Environmental Conservation
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O & M of Small Water Systems

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- Backflow
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- Coagulation
- Color
- Demand
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- Direct filtration
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O & M GRAVITY FILTERS

INTRODUCTION

Module Content

In this module on the O & M of gravity treatment plants the focus will be on the theory of coagulation, the physical process found in a small gravity treatment plant. More specifically this module is written around the operation of a package treatment plant.

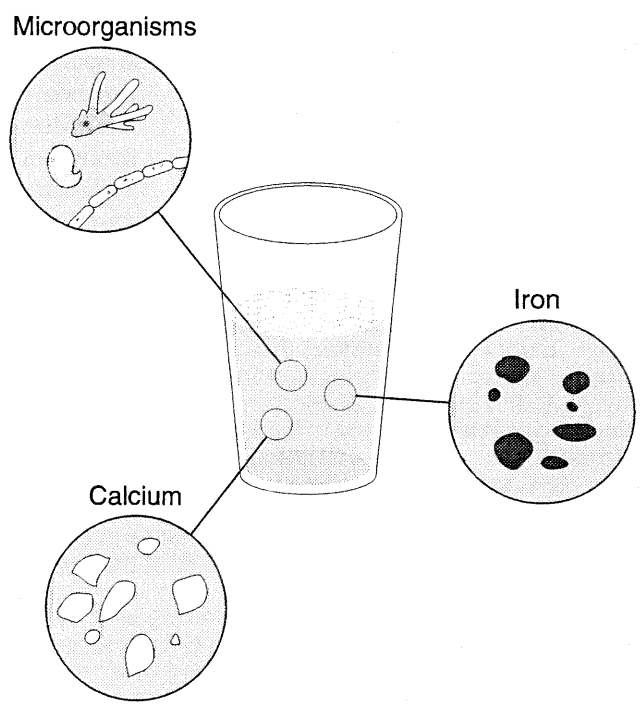
Small System

While most of the concepts and mechanical equipment discussed in this module are used in small and large systems the focus of the module will be on small systems. Primarily those systems with a population of less than 500 and located in Rural Alaska.

REASONS FOR TREATMENT

Introduction

Treatment systems are primarily installed for two general reasons, to protect health and to deal with substances in the water that create nuisances. The type of treatment facility and chemicals used is dependent on the quantity and type of substances found in the water. The procedures discussed here are for turbidity and color removal as well as the reduction and/or removal of viruses and protozoa such as Giardia and Cryptosporidia. The removal or reduction of turbidity and color are considered indirect health related considerations. The removal or inactivation of virus and protozoa are considered health related treatment considerations.



TURBIDITY

Why Remove Turbidity?

One of the primary health related treatments is associated with the removal of **turbidity**[1]. Turbidity itself is not a health hazard but makes the water aesthetically unpleasant. However, it is an indirect health hazard. First of all, drinking water that is high in turbidity causes people to seek other water that may be **palatable**[2] but not **potable**[3] (looks good but not safe to drink). Second, turbidity particles provide a hiding place for **microorganisms**[4] reducing the possibility that they will be killed by a disinfectant such as chlorine. Finally, turbidity increases the amount of chlorine required (**demand**[5]) and reduces the amount of chlorine that is available to kill disease causing (**pathogenic**[6]) microorganisms.

Turbidity Requirements

In order to reduce the health impacts of turbidity performance standards have been established depending on the type of filtration system being used. Generally these standards range from 0.5 ntu to 1.0 ntu.

Turbidity Reduction Goals

Most conventional water treatment plants have the ability to produce water with turbidity below 0.1 ntu. It is commonly considered in the waterworks industry that 0.1 ntu is good water and 0.2 ntu is cause for making corrections to a water treatment plant.

COLOR

Not a Direct Health Hazard

Color[7] like turbidity, is not in itself a health hazard. However, like turbidity, colored water is an **aesthetic**[8] problem causing people to seek unsafe water that has less color and possibly resulting in illness. Because of this secondary effect, a secondary MCL standard of 15 color units has been established for drinking water.

Indirect Health Problems

A secondary health problem has to do with the compounds that makeup color. The compounds that come from decaying vegetation and create color can, when mixed with chlorine, produce chemicals that we call Trihalomethanes (**THM's**[9]). Some of these compounds can contribute to cancer. While the current regula-

1 **Turbidity** - A condition in water caused by the presence of suspended matter, resulting in the scattering and absorption of light rays.
2 **Palatable -** In relation to drinking water, it is that water which does not give off unpleasant taste and odors, is cool in temperature, has low color and low turbidity. Water which is pleasant to drink.
3 **Potable Water -** Water satisfactory, safe, for drinking purposes from the standpoint of its chemical, physical, and biological characteristic
4 **Microorganisms -** Minute organisms, either plant or animal, invisible or barely visible to the naked eye.
5 **Demand** - When related to chlorine, the amount of chlorine utilized by iron, manganese, algae, and microorganisms in a specified period of time.
6 **Pathogenic Organisms -** Bacteria, virus and protozoa which and cause disease.
7 **Color** - Primarily, organic colloidal particles in water.
8 **Aesthetic** - Concerning an appreciation of the beauty. With water it means pleasant in appearance, odor and taste.
9 **THM's -** Trihalomethanes, also referred to as TTHM's or Total Trihalomethanes - (1) Regulations - The sum of the concentrations of bromodichloromethane, dobromochloromethane, trbromomethane, and trichlormethane. (2) Compounds formed when natural organic substances from decaying vegetation and soil (such as humic and fulvic acids) react with chlorine.

tions on THM's do not apply to small systems they could in the future. Nonetheless, if the system has high color in the raw water and uses chlorine as a disinfectant there could be an obvious health concern that would cause the owner to check the finished water for THM's.

WATER TREATMENT GOAL

Basic Goal

The basic goal is to protect pubic health. However, the more acceptable goal is to provide potable and palatable water. That is, water that is safe to drink and is pleasant in appearance, taste and odor.

TURBIDITY AND COLOR REMOVAL PROCESS

Introduction

The control of turbidity, color, microorganisms and to some extent taste and odor is commonly accomplished through some type of **filtration**[10]. The Surface Water Treatment Rule describes five different types of filtration systems, **conventional treatment**[11], **direct filtration**[12], **slow sand filters**[13], **diatomaceous earth filters**[14], and alternate filtration systems such as cartridge filters. The basic system used in this discussion is one of the conventional treatment types called rapid gravity filtration.

Sequence

The conventional treatment plant is composed of four processes;

- **coagulation**[15] a process where chemicals are added to destabilize small particles suspended in the water.
- **flocculation**[16] a slow mixing process where the coagulated particles are formed into feather-like material called **floc**[17].
- sedimentation is a physical process that allows the majority of the floc to settle, removing a large portion of the material in the water.
- filtration, the process of straining the remaining floc from the water.

What is Removed

These processes are used to remove or reduce organic and inorganic material that form turbidity, color and cause odor and taste.

Organic Contaminants

The organic component of this material contributes to color, odor, taste and disease. The organic component includes microorganisms, (viruses, bacteria, protozoa), algae, and organic material from plants and animals.

Inorganic Contaminates

The inorganic portion of this material is the primary contributor to turbidity. The inorganic portion includes silt, sand and inorganic chemical complexes.

The Contribution to Settling

Most organic and inorganic material is suspended in the water and not dissolved and therefore will settle out if given enough time. However, the main materials that contribute to color and turbidity are too small to

[10] **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.

[11] **Conventional Treatment** - A standard treatment process involving, coagulation, flocculation, sedimentation, filtration and disinfection.

[12] **Direct Filtration** - A gravity or pressure filter system involving coagulation, flocculation, filtration and disinfection.

[13] **Slow sand filters** - A filter composed of 24 to 42 inches of filter media, used to remove turbidity from waters with raw water turbidities of less than 10 ntu's. No chemicals are used in slow sand filters. Filtration rates range from 0.016 gpm/ft^2 to 0.16 gpm/ft^2.

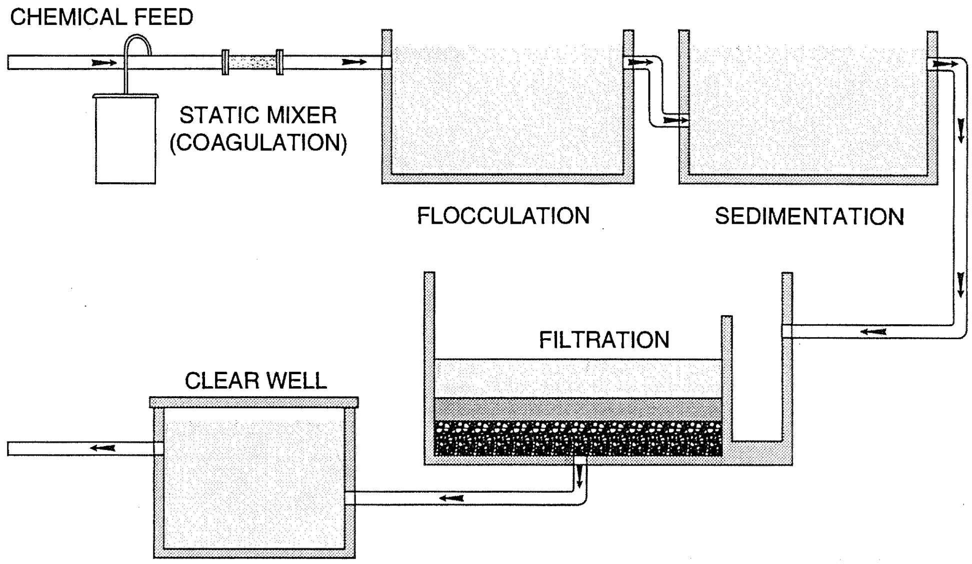
[14] **Diatomaceous Earth Filter** - A pressure filter utilizing a media made from diatoms.

[15] **Coagulation** - In water treatment, the destabilization and initial aggregation of colloidal and finely divided suspended matter by the addition of a floc-forming chemical.

[16] **Flocculation** - The agglomeration of colloidal and finely divided suspended matter after coagulation by gentle stirring by either mechanical or hydraulic means.

[17] **Floc** - Small gelatinous masses formed in a liquid by the reaction of a coagulant added thereto.

settle. The basic problem comes from solids that are less than one micron in size, called **colloidal**[18]. The Greek letter "μ", called "mu" is used to identify a micron. One micron would be written 1μm.



Colloids

For instance, a particle 0.01 mm in diameter will settle 1 foot in 33 minutes but a particle 0.0001 mm in diameter (a colloid) will only settle 1 foot in 230 days. This is hardly a reasonable settling time.

Why Colloids Don't Settle

Colloids do not settle in a reasonable length of time due to electrical charges on their surface. At one micron in size the influence of the surface charges offsets the attraction due to gravity and the particles stay suspended.

Particle Diameter mm	Representative Particle	Time Required to Settle in 1 ft. (0.3 m) Depth
		Settleable
10	Gravel	.03 sec
1	Coarse Sand	3 sec
0.1	Fine Sand	38 sec
0.01	Silt	33 min
		Considered Nonsettleable
0.001	Bacteria	55 hours
0.0001	Color	230 days
0.00001	Collodial Particles	6.3 years
0.000001	Collodial Particles	63 year minimum

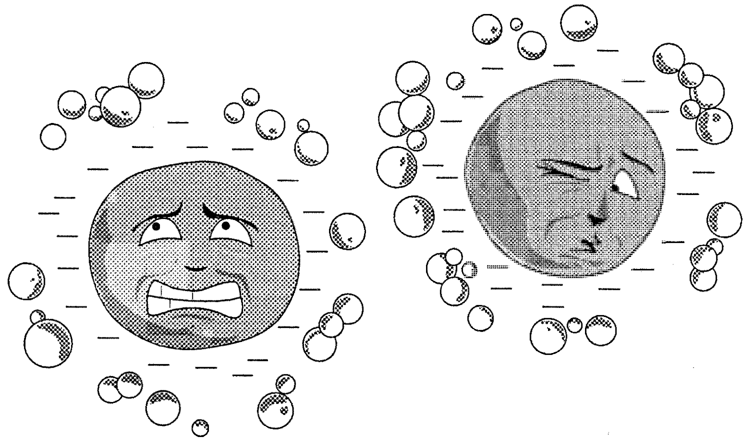
18 **Colloidal** - Any substance in a certain state of fine division in which the particles range in diameter from about 0.2 to 0.005 micron.

Types of Colloidal Material

There are generally two types of colloidal material **hydrophobic**[19] and **hydrophilic**[20].

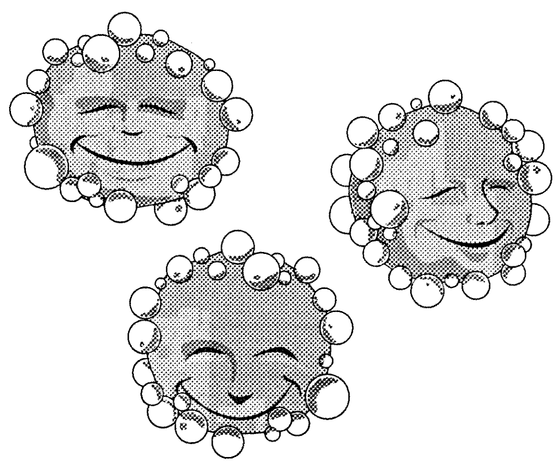
Hydrophobic

Hydrophobic means water fearing. Hydrophobic colloidal material is basically inorganic material that contributes to turbidity. Hydrophobic colloidal material generally carries a negative electrical charge.



Hydrophilic

Hydrophilic means water loving. Hydrophilic colloidal material is basically composed of organic material that is the common source for color. Hydrophilic compounds are surrounded by water molecules and because of their polarization, they tend to make these particles negatively charged.



Opposing Forces

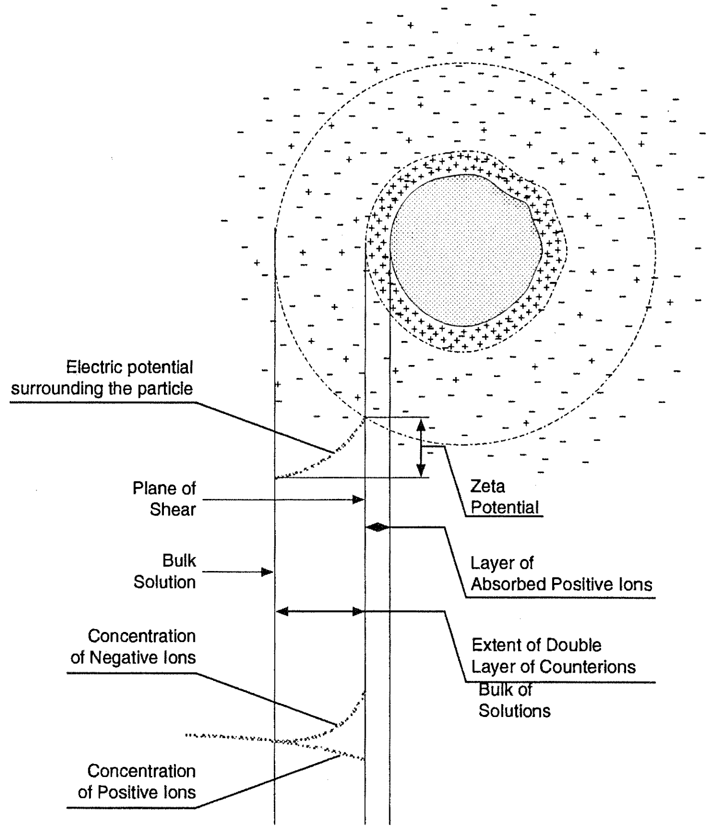
There are two opposing forces that impact the removal of colloidal material. These are stability factors and instability factors. Stability factors are those factors that help to keep colloids suspended, instability factors are those that contribute to the natural removal of colloids.

Stability Factors - Hydrophobic

The stability factors associated with hydrophobic inorganic clay are its electrical charges. Basically hydrophobic particles have a negative charge on the surface of the clay. This attracts a layer of water to the

[19] **Hydrophobic** - Water fearing. In water hydrophobic refers to inorganic colloidal particles that contribute to turbidity.
[20] **Hydrophilic** - Water loving. In water hydrophilic refers to organic colloidal particles that contribute to color.

clay. This layer is called a boundary layer because it moves with the particle. This boundary layer attracts a second layer of water molecules that include various compounds. The overall charge of the particle remains negative. The phenomena is referred to as the electrical double layer. The electrical charge is called the **Zeta potential**[21]. The result is that the particle remains negatively charged. Since like charges repel, these negative charged particles keep one another in motion in the water and thus do not settle.



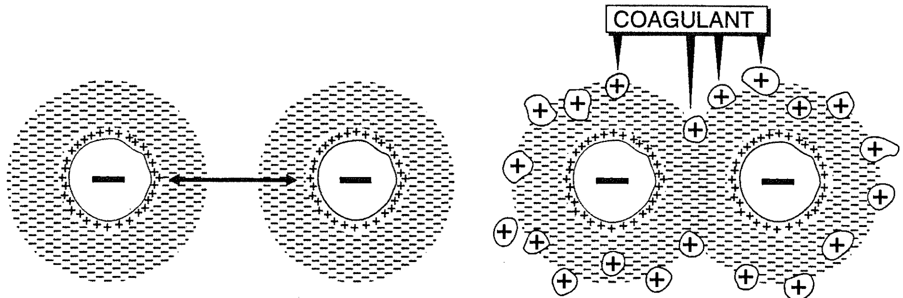
Stability Factors - Hydrophilic

Hydrophilic, color causing, organic particles are kept in solution due the layer of water molecules around them. This prevents the particles from colliding. If they were to collide they might stick together and become large enough to settle. The water layer contains chemicals that are combined with the water molecule. The most important of these chemicals are the carboxyl ion and **Hydroxyl ion**[22] that contribute to **alkalinity**[23]. While the chemical compounds contained in the water may be either negative or positive most are negative. The negative charges, like the ones on the hydrophobic particles along with the layer of water keep the hydrophilic particles from colliding.

21 **Zeta Potential** - A measurement (in millivolts) of the particle charge strength surrounding colloidal solids. The more negative the number, the stronger the particle charge and the repelling force between the particles.

22 **Hydroxyl ion** - The monovalent (OH^-) radical characteristic of hydroxides, and oxygen acids.

23 **Alkalinity** - The buffering capacity of water to retard the change in pH by an acid. Alkalinity is composed of bicarbonates, carbonate and hydroxide.



Instability Factors

There are two instability factors: the **Brownian movement**[24] and the **London-Van der Waals forces**[25]. When particles are very small their collision with a water molecule will impart enough energy to keep the particle in motion. Particles in motion are more likely to collide with one another. If the particles collide the London - Van der Waals Forces will cause them to stick together. If this happens enough times the particles will become large enough and heavy enough to settle.

Natural Waters

Natural waters contain colloids that are neither purely hydrophobic or hydrophilic, but are a heterogeneous; a mixture of hydrophobic and hydrophilic particles. The net result is a fluid containing negatively charged particles and microorganisms which are also negatively charged. These charges allow us to use chemicals to remove the material.

TREATMENT THEORY

Introduction Materials

The general theories concerning coagulation, flocculation, sedimentation and filtration are discussed in the "Introduction to Small Water Systems" training manual. Because the coagulation theory is the most important of these, only it will be reviewed and expanded in this module.

COAGULATION - THEORY

The Chemicals

The process of decreasing the stability of the colloids in water is called coagulation. Coagulation results from adding salts of iron or aluminum or polymers to the water. Common coagulants are:

- **Alum**[26] - Aluminum Sulfate $Al_2(SO_4)_3 \bullet 14H_2O$
- Sodium Aluminate - $NaAlO_2$
- Ferric Sulfate - $Fe_2(SO_4)_3$
- Ferrous Sulfate - $FeSO_4 \bullet 7H_20$
- Ferric Chloride - $FeCl_3$
- **Polymers**[27]

24 **Brownian Movement** - The erratic movement of colloidal particles, due to the collisions of the molecules of water.
25 **London - Van der Waals Forces** - The attractive force existing between colloidal particles that causes colloids that collide to stick together.
26 **Alum** - Trade name for the common coagulant aluminum sulfate, $Al_2(SO_4)_3 \bullet 14H_2O$.
27 **Polymer** - High-molecular-weight synthetic organic compound that forms ions when dissolved in water. Also called polyelectrolytes.

Coagulation

The reaction between one of these chemicals and water is called coagulation. The simplest coagulation process to follow is the reaction between alum and water. When alum is placed in water a chemical reaction occurs that produces:

- a weak acid.
- an insoluble molecule of aluminum hydroxide that is positive charged,
- and consumes 0.5 mg/L of alkalinity for each 1 mg/L of alum that is introduced. (If an iron salt is used, the active compound that is produced is a positive charged ion of ferric hydroxide.) Without alkalinity this reaction could not occur.
- The typical way to indicate this insoluble ion is with the symbol Al^{+++}.
- The reaction will have a tendency to drive the **pH**[28] down.

Alkalinity Reactions

The following are the reactions with various alkalinity producing compounds and how they react with 1 mg/L of alum.

Natural alkalinity	0.5 mg/L
85% Quick **Lime**[29] (CaO)	0.33 mg/L
95% hydrated lime $Ca(OH)_2$	0.39 mg/L
Soda Ash[30], Na_2CO_3	0.54 mg/L

Reaction - Hydrophobic Particles

The positive charged ions (Al^{+++}) reduce the negative charge of the hydrophobic particles by being adsorbed onto the surface of the particle and by being in the vicinity of the negative charged particle. This is referred to as the physical portion of the reaction.

Reaction - Hydrophilic Particles

The positive charged ions (Al^{+++}) combine chemically with the alkalinity that is attached to the water molecules which in turn are attached to the particle. The result is a sticky substance and a reduction in the negative electrical charge.

Combined Reaction

The overall result is the reduction of electrical charges and the formation of a sticky substance. These two destabilizing factors are the major contributions that coagulation makes to the removal of turbidity, color and microorganisms.

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

29 **Lime** - A common term used to describe a caustic powder containing calcium oxide (CaO). The term is used to identify quick lime CaO and hydrated lime $Ca(OH)_2$. Lime is used in water treatment to add alkalinity in the coagulation process, reduce pH and reduce corrosion for corrosive and aggressive waters.

30 **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.

FACTORS THAT INFLUENCE COAGULATION

Overview

There are a number of factors that influence the coagulation process, five of the most important are; pH, the amount of turbidity, the temperature of the water, the amount of alkalinity and the use of polymer. The degree to which these factors influence coagulation is dependent upon the coagulant used. The following discussion is based on the use of alum as the coagulant.

Least Soluble pH

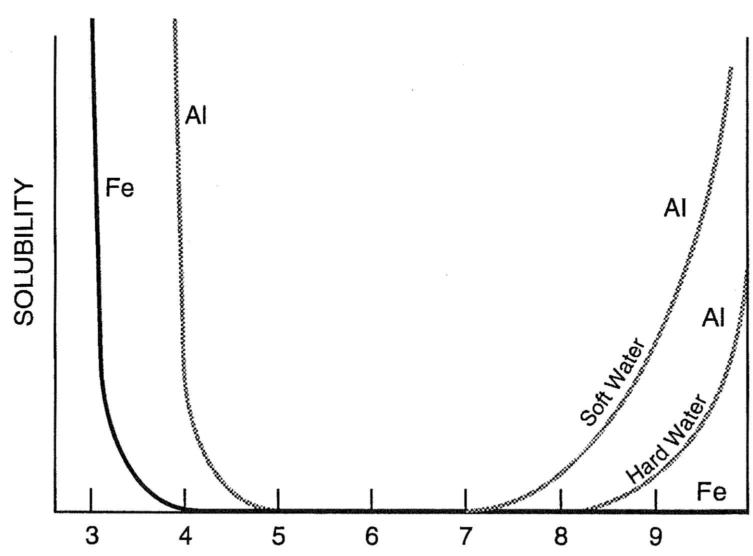
One of the major keys to effective coagulation with alum is to maintain the pH in the range where alum is least soluble. It is not intended or desirable for the alum to be dissolved. Quite the reverse, what is needed is for the alum to be in suspension and be removed in the treatment process so that the amount of Al^{+++} in the finished water is very low. The amount of aluminum in the finished water is called alum carry through.

Desirable pH

When the goal is to reduce turbidity, it is generally agreed that a pH between 6.0 and 7.8 is best. However, the proper pH for any specific water must be determined by testing. When the goal is to reduce color the desirable pH range is between 4 and 6. This low pH will require the addition of soda ash or lime after the color is removed, in order to raise the pH to an acceptable level.

Solubility Curve

The curve below is taken from a series of tests and shows that the solubility of iron and aluminum salts in relationship to pH. The most desirable pH range is the range of least solubility. This will give the lowest aluminum carry through. Notice that the iron curve is flat from pH 4 up past pH 10



Solubility curves for ferric and aluminum hydroxides

Impact of Turbidity

Generally, the greater the turbidity the greater the alum **dosage**[31] required. However, there is commonly a point where an increase in turbidity does not require a corresponding increase in alum. This is because the increased number of particles, increases the collision probability and improve the treatment naturally.

Low water Temperatures

In theory a few degrees drop in water temperature should not affect the amount of coagulant needed. However, in actual practice, as the water temperature drops below 40°F the water becomes very difficult to treat. For most cold water it has been determined that the optimum pH is shifted downward as the water temperature drops.

ALKALINITY

Function

From our discussion above about hydrophilic particles you should remember that the chemical reaction between alum and water is actually between the alum and the alkalinity in the water.

Alkalinity Requirements

Some natural water, especially those in coastal streams of the Pacific Northwest and Southeast Alaska are very low in alkalinity and therefore very difficult to coagulate. When the natural alkalinity is below 80 mg/L the water is said to have a low alkalinity. Such water may require the addition of alkalinity in order for a floc to be formed. The waters in Southeast Alaska will typically have alkalinity much lower that 80 mg/L. The combination of low temperature, low alkalinity and low winter turbidities make these waters very difficult to treat.

Lowering the pH

A secondary problem with low alkalinity waters is the addition of a coagulant such as alum may drive the pH down below the point of least solubility. This is an operational problem in Southeast and Southcentral Alaska where the natural pH is below 7.

Alkalinity Chemicals

The two most common chemicals used to add alkalinity to water are soda ash and hydrated lime. The relationship between these two chemicals and alum is; 1 mg/L of alum will combined with 0.54 mg/L of soda ash or 0.39 mg/L of hydrated lime. What that means is that a dosage of 20 mg/L of alum would combine to form a floc with approximately 11 mg/L of alum or 8 mg/L of lime.

Other Considerations

The raw water conditions, optimum pH for coagulation and other factors must be considered before deciding which chemical is to be fed and at what levels.

[31] **Dosage** - The amount of a chemical applied to the water. Commonly expressed in mg/L.

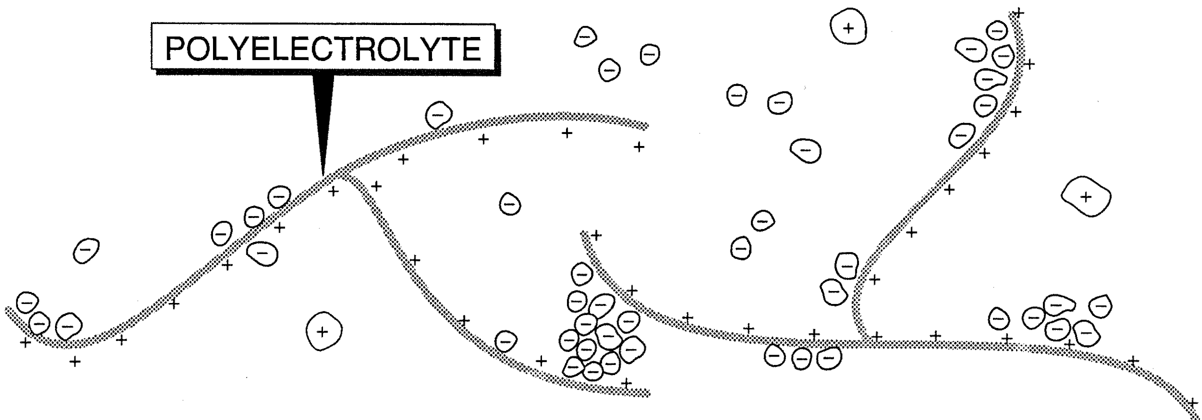
POLYELECTROLYTES

Common

Polyelectrolytes or polymers as they are commonly called can be used as an aid to coagulation. In some waters they have been successfully used as the primary coagulant instead of alum or one of the **iron salts**[33]. The practice of using a polymer as a primary coagulant is not always successful.

What are Polymers

Polymers are long, string-like chain molecules with charges placed along the string. There are three common types of polymers; positive charged polymers called cationic polymers, negative charged polymers called anionic polymers, and polymers with no charge called nonionic polymers. The correct charge is selected depending on the use of the polymer, filter aid, coagulation air or primary coagulant.



Determining Chemical Dosage

In order to determine the correct chemical dosage a device called a jar test is used. The most common of these is composed of six stirrers connected together and six one-liter beakers. A sample of the water along with the coagulation chemicals is poured into the jars. The jars are stirred in an attempt to approximate the flash mix of the plant and then slowly stirred to approximate the flocculation portion of the plant. The proper dosage is determined by observing the best forming floc, the pH and the turbidity of a filtered sample of the water. This procedure is explained in detail in the Process Control Module.

SYSTEM COMPONENTS

Introduction

The following discussion is based on a conventional treatment, gravity filter plant.

Five Systems

The conventional treatment gravity filter process can be divided into five systems:

- The building and chemical storage

[33] **Iron Salts** - Iron based chemical compounds containing trivalent ions of Fe. These salts are used as primary coagulants. Common iron salts including ferric chloride $FeCl_3$, Ferric sulfate $Fe_2(SO_4)_3 \cdot 9H_2O$, and Ferrous sulfate $FeSO_4 \cdot 7H_2O$.

- 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 are found in the text. Process control and trouble shooting are in companion modules. Information on the theory and chemistry of the process is described above and in the "Introduction to Small Water Systems" training manual.

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 chemicals and feed equipment are located inside of the water treatment plant building next to the filters. Regardless of the setting the building should be kept locked and vandal resistant.

CHEMICALS

There are three chemicals commonly used by small gravity filter systems in Alaska, alum, soda ash and various polymers. The alum and polymers are commonly used as primary coagulants. In many facilities additional polymers are used as coagulant aids, flocculant aids and filter aids. Soda ash is used to add alkalinity to the water and to raise the pH. Each of these chemicals requires a unique set of handling procedures. The following is designed to give general guidelines on handling these three chemicals.

ALUM - ALUMINUM SULFATE

Storage

Alum is purchased as a dry crystal and is delivered in 110 pound paper bags. The crystals are 100% aluminum sulfate. The bags should be stored in a clean cool dry place. It is OK to store dry powdered alum in the same room with $KMnO_4$ and soda ash. **Do not** store alum with oxidizers such as chlorine or fluoride.

Properties

Tends to cake under high relative humidity. Acidic, hydroscopic, mildly corrosive if wet.

OSHA Classification

Alum is classified by **OSHA**[34] as a Corrosive. The container should display the dry-corrosive placard.

UN Classification

The UN (United Nations) Classification for alum is 8G226, indicating a mild corrosive material. A table showing the various UN classifications is provided below.

NFPA Ratings

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

- Health Hazard – 1
- Flammability – 0
- Reactivity – 1

DOT Identification

The **DOT**[35] (Federal Department of Transportation) has given alum a placard number of #9078. When determining how to handle a spill of alum the DOT has provided this information in there handbook under reference #31

Common accidents and Recommended First Aid

Common alum accidents and related first aid practices are:

- Contact with eyes - flush for 15 minutes with fresh clean water - Reference DOT 31.
- Contact on skin - wash with soap and water - Reference DOT 31.

Handling Spills

DOT describes the following methods of handling Alum spills.

- Small Dry Spills - With clean shovel place material into clean, dry container, cover and remove from area.
- Small liquid spills - Pick up with dry sand, place in clean dry container and remove from area.
- Large spill - dike liquid, cover dry material with plastic sheet.

Fire Control

The following methods are identified as recommended procedures for dealing with a fire involving alum.

- Dry chemical CO_2, Halon, water spray or standard foam.

Health Hazards

- Irritating to skin and mucous tissues. Can cause serious eye damage.

[34] **OSHA** - Occupational Safety and Health Administration.
[35] **DOT** - Federal Department of Transportation

SODA ASH - SODIUM CARBONATE

Na_2CO_3

Storage

Alum is purchased as a dry powder and is delivered in 80 and 100 pound paper bags. The crystals are 100% Na_2CO_3. The bags should be stored in a clean cool dry place. It is OK to store dry powdered soda ash in the same room with $KMnO_4$ and alum. Soda ash is very stable and is not considered to be either toxic or hazardous. However, the dust can dry the mucus membranes and be an extreme irritation to the eyes.

Properties

Tends to lump and is mildly corrosive if wet. Depending on the amount of water contained in the crystal, the weight of soda ash can vary. However, the most common concentration used in water treatment has a weight of 60 lbs/ft^3.

OSHA Classification

Soda ash is classified by OSHA as a Mild Corrosive. The material is not classified as either hazardous or toxic. The container should display the dry corrosive placard.

UN Classification

The UN (United Nations) Classification for soda ash is 8, indicating a mild corrosive material. A table showing the various UN classifications is provided below.

NFPA Ratings

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

- Health Hazard – 2
- Flammability – 0
- Reactivity – 0

DOT Identification

Because soda ash is neither hazardous or toxic the DOT (Federal Department of Transportation) has not provided a placard number and does not list the material in their emergency response guidebook.

Common Accidents and Recommended First Aid

Common soda ash accidents and related first aid practices are:

- Contact with eyes - flush for 15 minutes with fresh clean water - Reference - AWWA Safety Training package .
- Contact with skin - wash with large quantities of water - Reference - AWWA Safety Training package.

Handling Spills

Spills are cleaned-up with a liberal use of water.

Fire Control

Soda ash will not burn or support combustion.

Health Hazards

- Irritation to respiratory tract and mucous membranes and eyes.

POLYMERS

Introduction

There are several hundred polymers available for water treatment. They are shipped as liquids and as powders. They may be fed directly or mixed with water. Each polymer has its own unique properties regarding mixing, aging and feed concentration recommended by the manufacturer.

Handling

To find the proper procedure for handling a specific polymer carefully read the MSDS. If the MSDS is not available contact the supplier before mixing the polymer.

Storage

Dry polymers should be stored in a cool dry location. Liquid polymers should be stored in a location that prevents freezing.

Neat Polymers

A polymer that is not diluted with water is called a "Neat" polymer.

Clean-up of spills

In most cases a polymer spill can be cleaned up with liberal amounts of water. Neat polymers will have a tendency to swell and become slick prior to dilution. Continue to apply water until the material dilutes and is washed away.

Table - UN Classifications

Number	Class Name/Hazard
1	Explosive
2	Gases
3	Flammable liquids
4	Flammable solids, spontaneously combustible material, materials dangerous when wet
5	Oxidizers and organic peroxides
6	Poisonous and etrologic (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

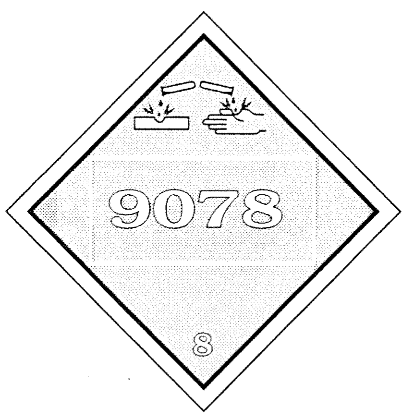
Reactivity (Stability) hazard

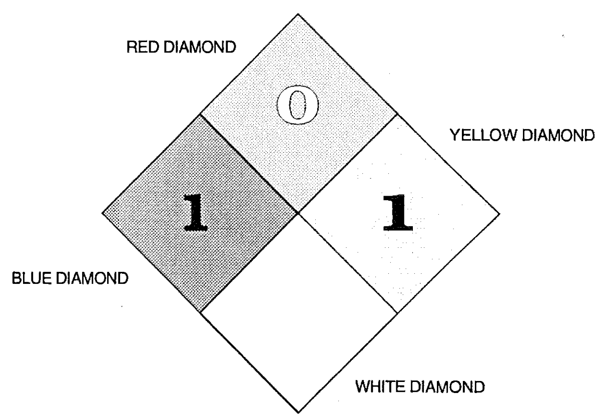
4 Readily detonates or explodes
3 Can detonate or explode but requires strong initiating force or heating under confinement
2 Normally unstable but will not detonate
1 Normally stable. Unstable at high temperature and pressure. Reacts with water
0 Normally stable. Not reactive with water

Special Notice Key

~~W~~ Water reactive
OX Oxidizing agent

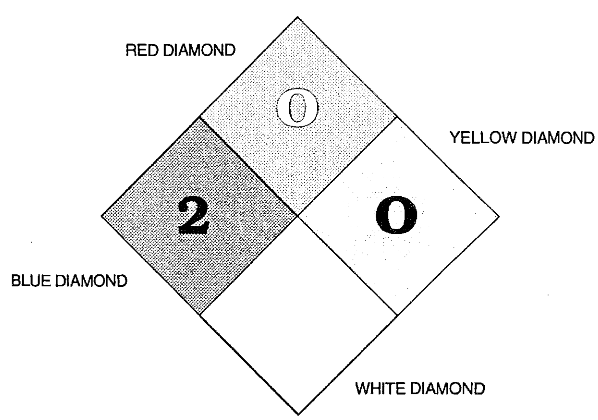
Alum





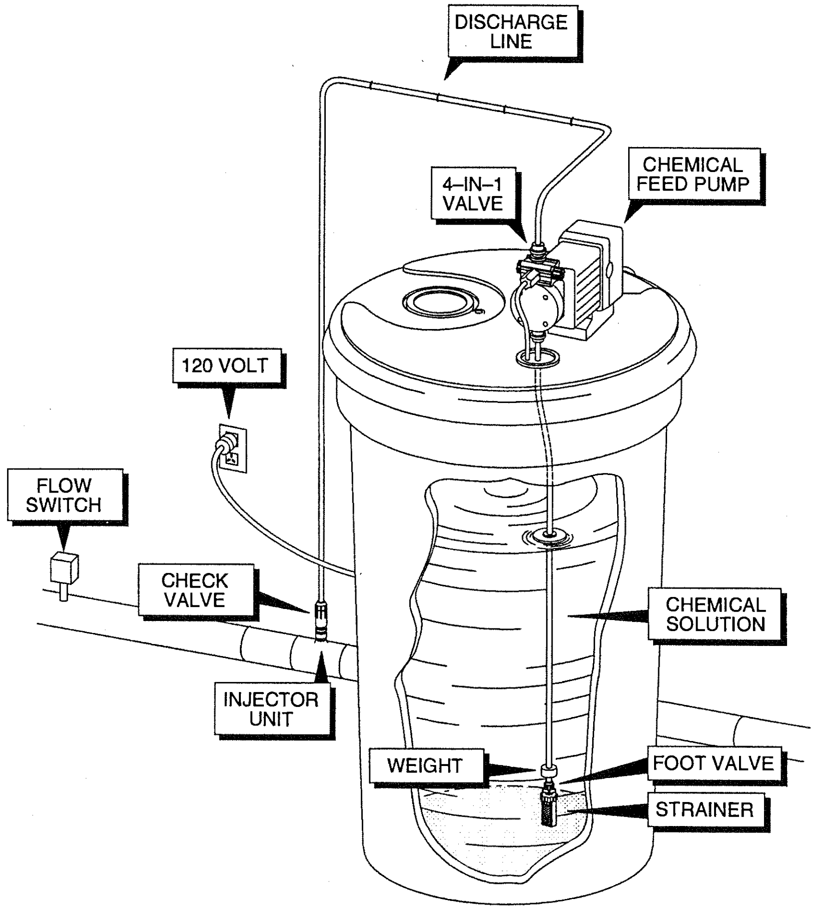
Soda Ash

A DOT placard is not required for Soda Ash



CHEMICAL FEED SYSTEM

There are three common chemicals fed in small gravity filter plants, polymers, alum and soda ash. Polymer feed systems may be dry or liquid feeders. In some small plants soda ash is fed directly into the facility with a dry chemical feeder. This module will provide information on only the more common batch feed system. The most common alum and soda ash chemical feed system is composed of the following components:



Tank

The basic unit of the system is the corrosion resistant mixing tank. The tank may range in size from 50 gallon to 800 gallons. The tank is used to hold dilution of the powdered chemical.

Fill Line

A potable water fill line must be provided in order to mix and dilute the alum or soda ash. This line should be protected from **backflow**[36] by an **atmospheric vacuum breaker**[37]. The hose or line leading into the chlorine 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.

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

[37] **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 and has an approximate one year life span. The life of the piping can be reduced if it is exposed to sunlight.

Pump

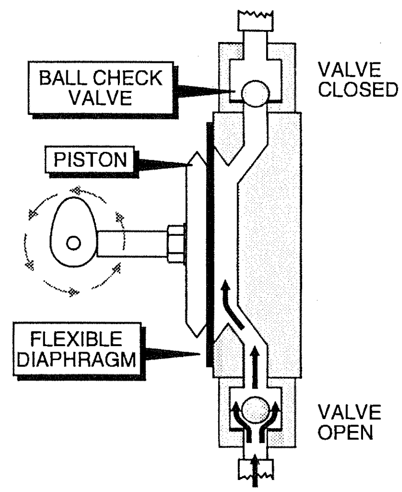
The most common pumps used in Alaska are LMI and W&T diaphragm, positive displacement pumps. This type of pump has a suction and discharge valve, valve seats and may have a spring on one or both of the valves to help them seat properly.

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.

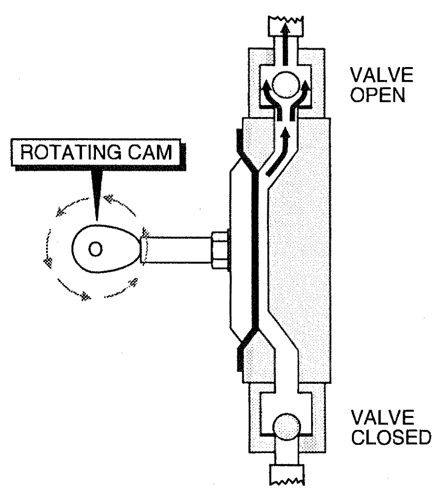
Pump Operation - Suction

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.



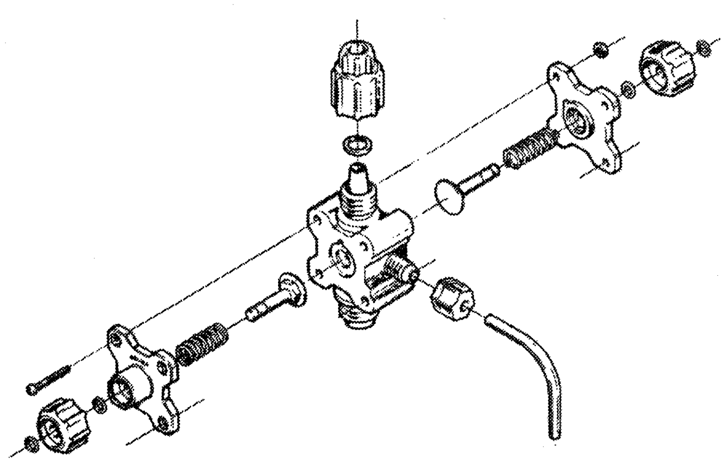
Pump Adjustment

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 damaging the pump.

Anti-Siphon Valve

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 valves prevent 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**[38], 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; helps 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.

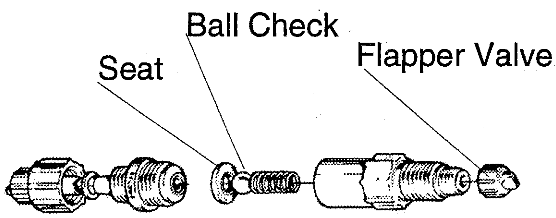


[38] **Diffuser -** A section of pipe or porous plates used to mix a gas or liquid with the flow of water.

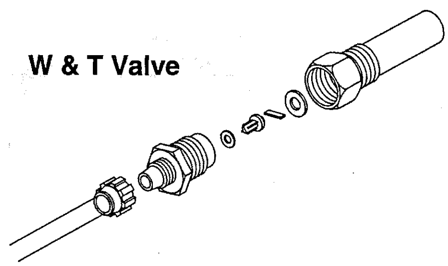
Injection Point

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.

LMI Valve



W & T Valve



Chemical Separation

The sequence that chemicals are added to water can impact the rate of coagulation and floc production. Typically soda ash is added first followed by the alum. The polymer may be added before or after the other chemicals. However, it may respond differently depending upon when it is added. It is not desirable to add chlorine or fluoride prior to coagulation. If potassium permanganate is added for odor control it should be injected into the line at least five (5) minutes before the soda ash alum injection point.

HYDRAULIC SYSTEM

RAW WATER

Pressure Reduction

The raw water usually enters the plant through a basket strainer and one or more pressure reducing valves. The pressure is commonly reduced to below 50 psi.

Flow Meter

In most facilities the water flows from the pressure reducing valve through a flow meter. The signal from the meter is used to pace the chemical feed pumps.

COAGULATION

Static Mixers

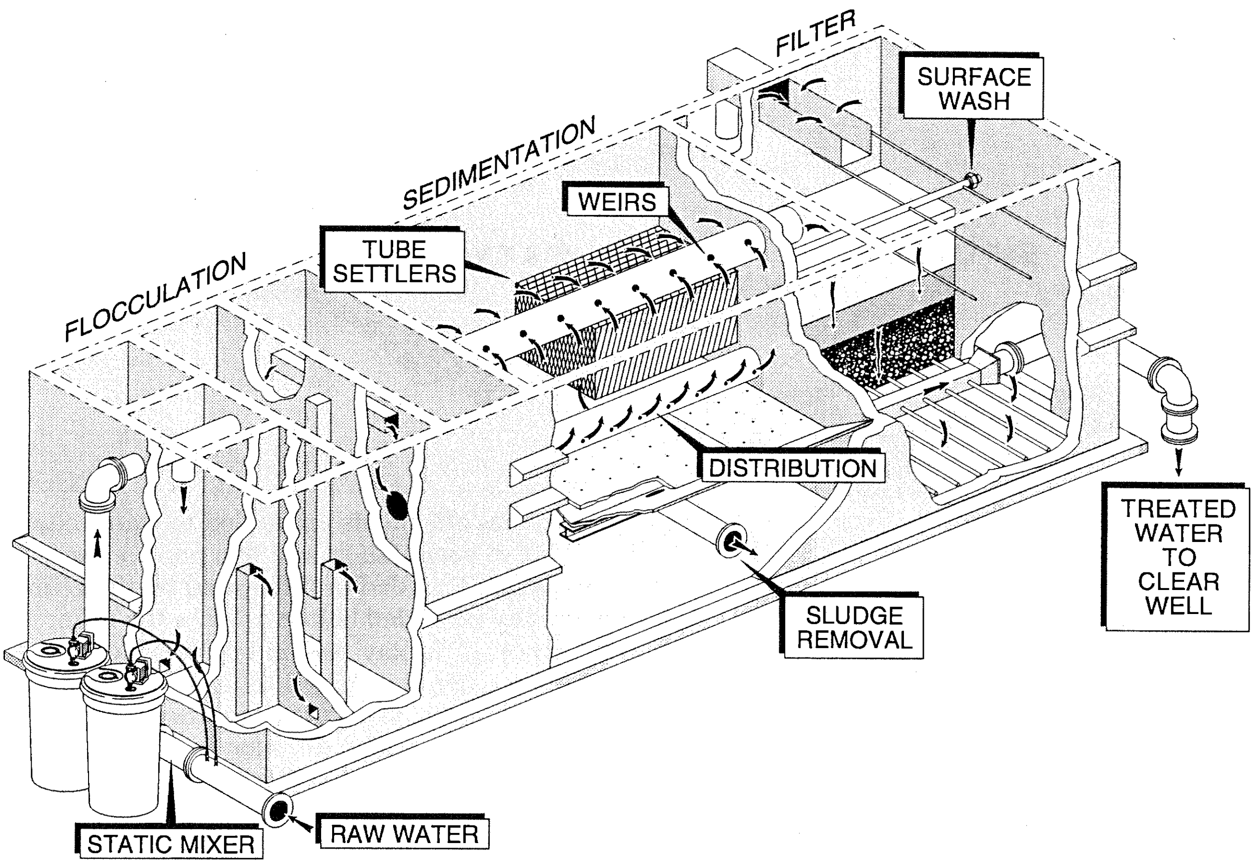
From the flow meter, water usually flows through a chemical injection manifold where the alum, soda ash and polymer are added. The manifold is just before a static mixer. A static mixer is a fixed component device, usually made of twisted pieces of metal that are used to mix the chemicals and allow coagulation to take place. Static mixer **detention times**[39] are between 2 and 15 seconds; the amount of time required for coagulation.

Flow Control

Water commonly flows from the static mixer through some type of flow control valve. This valve is used to

[39] **Detention time** - The theoretical time required to displace the contents of a tank or unit at a give rate of discharge or flow.

regulate the flow into the plant. A discussion of the operation of flow control valves is discussed in the control section of this module.



FLOCCULATION

Process

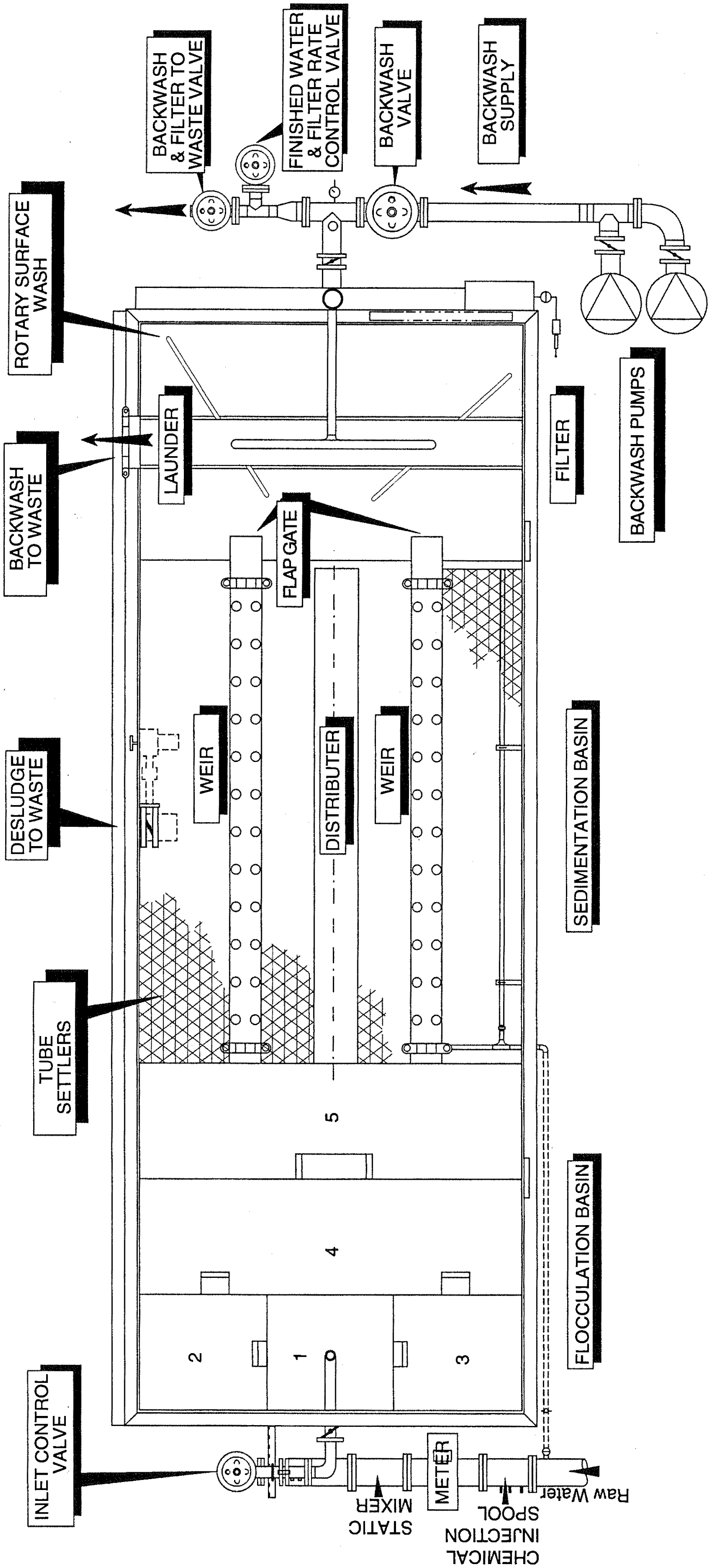
From the control valve, water flows into the flocculation basin. Flocculation is a physical process of slowly mixing the water to enhance the probability of collision between coagulated particles and thus form floc.

Flocculator Devices

There are two types of flocculators used in small plants; mechanical and hydraulic. Mechanical flocculators are commonly made of one or more sets of paddles that slowly stir the water. Hydraulic flocculators are a series of chambers with increasingly larger nozzles placed over the openings that are between the basins. These nozzles serve the same purpose as the paddles. The nozzles are sized so that the amount of energy put into the water, and thus the stirring diminishes as the water moves through the series of basins. In the example shown below the water passes through three nozzles and four basins.

Detention Time

Typical detention time for a flocculation basin is 10 to 60 minutes. Most package treatment plants have flocculator detention times of 10 to 20 minutes.


BACKWASH & FILTER TO WASTE VALVE
FINISHED WATER & FILTER RATE CONTROL VALVE
BACKWASH VALVE
BACKWASH SUPPLY
ROTARY SURFACE WASH
BACKWASH TO WASTE
LAUNDER
FILTER
BACKWASH PUMPS
FLAP GATE
WEIR
DISTRIBUTER
WEIR
DESLUDGE TO WASTE
SEDIMENTATION BASIN
TUBE SETTLERS
5
4
2
1
3
FLOCCULATION BASIN
INLET CONTROL VALVE
STATIC MIXER
METER
CHEMICAL INJECTION SPOOL
Raw Water

Polymers

In the example plant shown, if polymer were added in basins 1, 2, 3 or 4 it would be considered a flocculant aid. If it is added in basin 5 it would be considered a sedimentation or filtration aid.

Floc Formation - Alum

When feeding alum a visible floc should be present by the time the water travels one-half to two-thirds of the length of the basin. Turbidity measurements taken at various points along the basin should show an increase between entry and exit of the basin.

Floc Formation - Polymers

However, if a polymer is used as the primary coagulant then there will seldom be a visible floc. In the case of polymers a turbidity measurement of a sample before and after filtration through a Whatman #1 filter pad should show a significant reduction after filtration.

SEDIMENTATION

Theory of settling

The sedimentation basin is designed to provide a quiescent zone for separation of the floc from the water. With a rectangular basin, the theory of settling says that the flow enters the basin, forms a prism across the end called the inlet zone, the water then moves from the settling zone to the outlet zone. At the outlet zone the water, still in its prism, comes together and exits the basin. (This is theory not actual practice). The floc will settle in the sludge zone. The theory says a particle that falls at a rate great enough to strike the bottom before the water reaches the outlet zone will settle out. In actual practice, one-half of the water leaves the sedimentation basin in one-half of the calculated detention time. Because of this inefficiency actual sedimentation basins use other detention times for design.

Typical Basin

The most common rectangular basin on small plants uses an upflow hydraulic pattern. The water enters the basin, from the flocculator, through a pipe called the distributor, along the bottom of the basin. In our example plant, the distributor is under a perforated plate. Flow from the distributor is directed outward and then upward through the plate.

Upward Flow

As the water moves upward, the floc, being heavier than water, settles toward the bottom. The water is collected in pipes or troughs at the surface called weirs.

Loading

The loading or quantity of water a basin can handle, is dependent on:

- The number of gallons per square foot applied to the basin, called the **surface settling rate**[40]. This rate is calculated in gallons per minute per square foot of the sedimentation basin, (gpm/ft^2). The value can

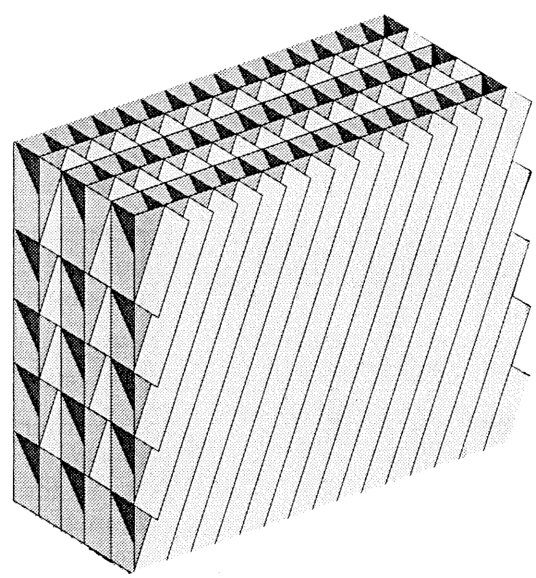
[40] **Surface Settling Rate** - SSR - One of the criteria for the design of settling basins in treatment plants; expressed in gallons per day per square foot of surface area in the settling basin.

be directly related to the settling rate. The lower the surface settling rate (SSR) the smaller or lighter the material that will settle out.

- The rate that water flows over the weirs is called the **weir overflow rate**[41] and calculated in gallons per minute per foot of weir (gpm/ft). The higher the weir overflow rate the poorer the settling characteristics of the sedimentation basin. High weir overflow rates will cause **sludge**[42] from the bottom of the basin to be carried over the weirs and onto the filters. High weir overflow rates indicate high upward velocities in the basin.
- The forward velocity through the basin. This forward velocity is based on the original theory of rectangular basins. Forward velocity is calculated in feet per second (ft/sec). The lower the forward velocity the smaller and lighter the material that will settle out.
- Detention time. This is the theoretical time that the fluid stays in the basin. Detention time is usually calculated in hours, but can be calculated in minutes.

Tube Settlers

To improve the efficiency of the settling basin, reduce detention time and increase surface settling rates **tube settlers**[43] are often placed in sedimentation basins. These devices are a series of tubes placed at 5° to 60° angle. The vertical distance from the top of a partition in the tube to the bottom of the partition is only a matter of a few inches. In order for a particle to be removed from the flow it need only strike the bot-



[41] **Weir overflow rate** - One of the criteria for the design of settling basins in treatment plants; expressed in gallons per day per linear foot of weir in the settling basin.
[42] **Sludge** - Refers to the material removed from water by settling or filtering. The sludge is the portion of the treated water remaining after a fluid has been allowed to settle and the clear water removed.
[43] **Tube Settlers** - A series of plastic tubes about 2 inches square used to improve the efficiency of a sedimentation basin.

tom of the tube. The flow is up through the tube, the material that collects is pulled down through the tube and drops off of the bottom settling in the bottom of the basin.

Sludge Blanket

Another technique that has proven successful with small and large facilities in improving the efficiency of the sedimentation basin is to develop a sludge blanket at the bottom of the basin. The flow of water is up through this blanket. The blanket floc in the blanket helps to "sweep" particles from the water as it passes upward. This process is often referred to as solids contact.

Fluidized Bed

A third method used to improve the efficiency of the sedimentation basin is to place media such as plastic balls or graded granular material in the bottom of the sedimentation basin. Water is passed up through the media which enhances flocculation and improves removal of the floc and other material. The media requires cleaning by **backwashing**[44]. Often the backwash is enhanced with the addition of air into special diffusers placed below the media. This type of sedimentation basin is called a fluidized bed classifier or an adsorption clarifier. The use of air to clean the basin is called an air scour process.

Basin Shapes

Sedimentation basins can be circular or rectangular. In small facilities they are commonly rectangular, upflow devices with tube settlers.

HYDRAULIC CONSIDERATIONS

• Surface settling rates (SSR) for large conventional treatment plants range from 0.25 to 0.38 gpm/ft^2. With tube settlers the SSR ranges from 2 to 3 gpm/ft^2.

• Weir overflow rates for conventional treatment and package plants range from 8 to 15 gpm/ft. This rate is based on using a straight or saw tooth weir.

• Detention time for a conventional sedimentation basin is three to six hours (3 to 6). With a tube settler the detention time is reduced to 30 to 45 minutes.

• Typical theoretical forward velocity for a sedimentation basin is less than 3 ft/sec.

Math Practice

The criteria described above is considered during design, and as such the operator can do little to affect the sedimentation basin characteristics. However, occasional pumping or other conditions change that impact the plant's performance. An operator should be able to perform three classic calculations and then compare the results to the design criteria.

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

Plant Data

A water treatment plant has a sedimentation basin that is 11.25 feet long. 9.4 feet wide and contains 8.8 feet of water. The weirs are made of two 8 inch pipes with 30 equally spaced 1.25 inch holes, 15 on each side. The flow through the plant is 175 gpm.

SSR

The SSR is:

Surface area of basin - 11.25 ft X 9.4 ft = 105.75 ft^2

$$SSR = \frac{175\ gpm}{105.75\ ft^2} = 1.65 \text{ or } 1.7\ gpm/ft^2$$

WOF

The weir overflow rate is:

11.25 ft X 2 = 22.5 ft per weir X 2 = 45 feet of weir

$$WOF = \frac{175\ gpm}{45\ ft} = 3.9\ gpm/ft$$

DT

The detention time in the basin is:

Volume = 11.25 ft X 9.4 ft X 8.8 ft = 930.6 ft^3

930.6 ft^3 X 7.48 gal/ft^3 = 6,961 gal

$$DT = \frac{6{,}961\ gal}{175\ gpm} = 39.7 \text{ or } 40\ min$$

FILTER

Flow

Water flows from the weirs into the filter. In small plants the filter is contained in a concrete, or metal box.

Underdrain

At the bottom of the filter is the underdrain systems. This system is used to collect water from the filter and to distribute backwash water. There are various types of underdrain systems, the most common on package plants is the use of a series of perforated pipes placed laterally to a central header. On larger facilities the underdrain may consist of pre-cast plastic or ceramic tile containing a series of holes, or ceramic balls stacked in a five ball combination, or porous plates. The most common in larger facilities are the pre-cast tile.

Support Gravel

On top of the underdrain system is up to 18 inches of support gravel. This gravel can be up to three (3) inches in diameter. The gravel is graded from largest, next to the underdrain, to smallest next to the **filter media**[45]. The support gravel is used to support the media.

Media

The filter media is made of one or more layers of silica sand, garnet sand and anthracite coal placed in layers to a total depth of 24 to 42 inches. The media commonly ranges in size from 0.25 to 1.2 mm in diameter.

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

Typical media type and sizes are;

- Silica sand - 0.4 to 1 mm
- Garnet sand - 0.2 to 1.4 mm
- Anthracite coal - 0.4 to 1.4 mm

Multi-media

The ideal filter process would be to have the material the escapes the sedimentation basin, start to collect on the top of the media and then slowly work its way down the media like the roots of a tree. Therefore, the most effective filter would be one that is graded with the largest diameter particles on the top and the smallest diameter particles on the bottom. In order to do this the large diameter particles would need to have a specific gravity (weight) less than the small diameter particles. Multi-media filters, those using silica and garnet sand as well as anthracite coal show the best results in approaching this ideal filter.

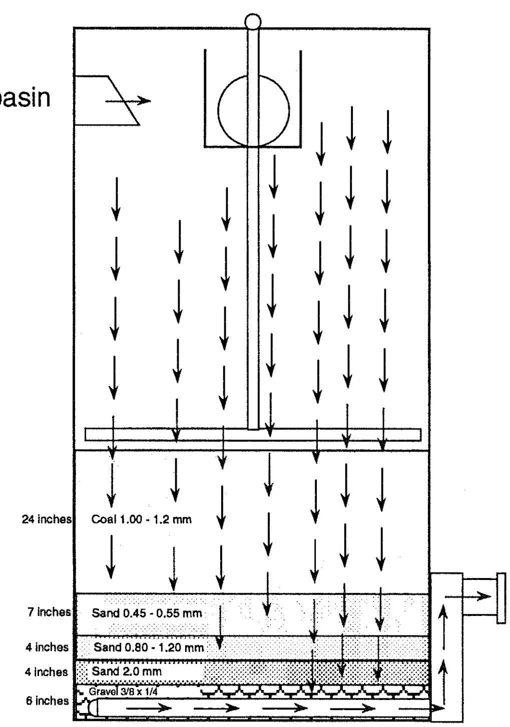
Example

The following is an example of media layers on a two media filter. The size and type of filter media is selected by the engineer and/or manufacturer of the plant to meet a specific water condition.

Filter media

Material	Size	Depth
Coal	1.0 - 1.2 mm	24 inches
Sand	0.45 - 0.55 mm	7 inches
Sand	0.80 - 1.20 mm	4 inches
Sand	2.0 mm	4 inches
Gravel	3/8 x 1/4 inch	6 inches
	Total	45 inches

From sedimentatin basin



Typical Filter Bed

Hydraulic Considerations

Conventional gravity filters are designed to filter water at 2 to 8 gallons per minute per square foot of filter. The most common **filtration rate**[46] is 4 gpm/ft^2.

Math Practice

A filter plant has a gravity filter that is 9.4 ft X 4.7 ft, the flow through the plant is 175 gpm. What is the filtration rate.

Rate = Flow in gpm divided by the area of filter bed

$$\text{Filtration Rate} = \frac{175\,\text{gpm}}{9.4\,\text{ft} \times 4.7\,\text{ft}} = 3.9\,\text{gpm/ft}^2$$

BACKWASH

Pump

Backwash flow and pressure is commonly provided by a pump. The most common pump used in small plants is the end-suction centrifugal.

Flow Control

Flow from the pump is controlled by a rate of flow control valve that typically opens slowly after the pump starts to prevent water hammer and disruption of the filter media.

Surface Wash System

Most modern small and package plants have a surface wash system. The most common systems utilize some type of rotating arm that is operated hydraulically

Flow

In most facilities water is pumped from a clear well or finished water storage reservoir through a control valve. In most facilities water is applied first to the surface wash arms and then to the filter backwash system. The surface wash arms breakup the crust on the surface.

Launders

After the surface wash has been operating for 30 seconds to 1 minute the backwash control valve will open and water will flow up through the filter media and into the **launders**[47]. From the launders the backwash water flows to a sludge lagoon or waste water line.

HYDRAULIC CONSIDERATIONS

Surface Wash Rates

Typical surface wash arms provide a flow of 1 gpm/ft^2 of filter media.

Bed Expansion

The backwash rate needs to be sufficient to provide a fifty percent (50%) hydraulic expansion. This a 20 to 35% physical expansion. A method of determining backwash rates and physical expansion is described in the "Typical Filter Plant Problems" module.

Backwash Rates

The following table was taken from the AWWA Standard on Filtering Material B100-80 and can be used to determine typical backwash rates.

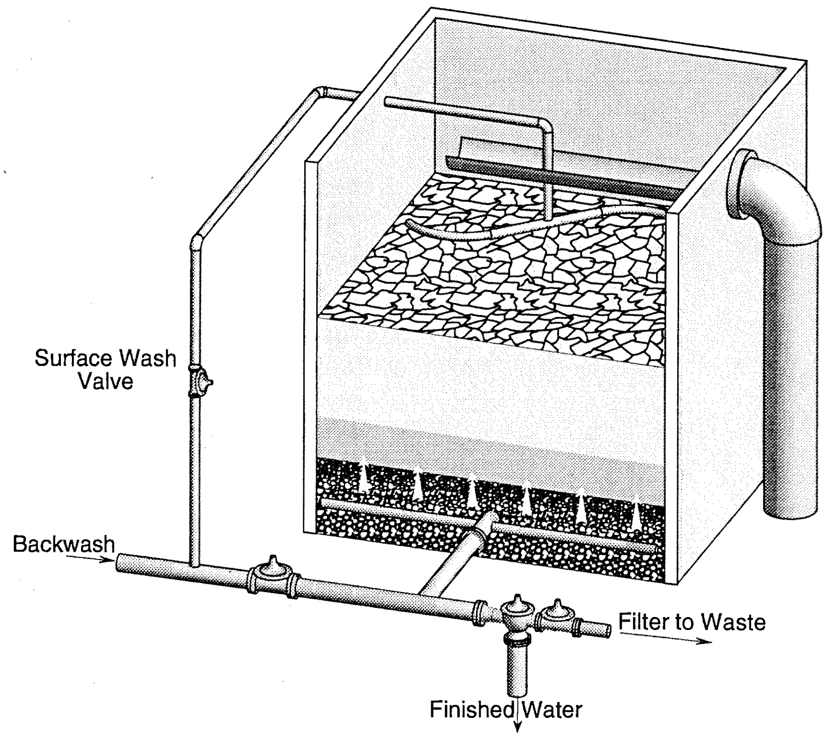
---

[46] **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).
[47] **Launder -** Sedimentation tank effluent troughs.

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

In Alaska, backwash rates range from 15 to 17 gpm/ft^2. The backwash rate is dependent on the water temperature.



Backwash Time

In most small and packaged treatment plants the backwash lasts from six to 15 minutes.

Math Practice

A filter plant has a gravity filter that is 9.4 ft X 4.7 ft, the flow through the plant is 175 gpm. The water temperature is 45 °F. What would be the pumping rate in gpm to provide a backwash rate of 15 gpm/ft^2.

Flow is the backwash rate times the area of the filter.

$15\ gpm/ft^2 \times (9.4\ ft \times 4.7\ ft) = 663\ gpm$

SLUDGE HANDLING

Source

Sludge from the sedimentation basin and from the backwash process commonly flows from the plant into a lagoon or the community sewer system.

Permit Required

If the sludge flows into a lagoon the supernatant may discharge into a receiving stream. When this happens the owner of the system is required to have a NPDES or State discharge permit.

Sludge Disposal

When the lagoon has reached about 1/2 of its solid-holding capacity, the solids are allowed to dry and disposed of in an approved land fill site. This disposal process must be in compliance with the sludge disposal regulations called the 503 regulations. One of the major problems with water treatment plant sludge is it often contain high levels of heavy metals, especially aluminum.

CONTROL SYSTEM

Subsystems

The control system is composed of 5 subsystems;

- Plant rate control system
- Filtration rate control system
- **Headloss**[48] control system
- Backwash control system
- Chemical feed control system

Control System Combinations

The type of control system selected for a plant is based on engineering decisions about what will be most effective. There are several different combinations of plant flow rate and filtration rate systems. Different combinations are selected for constant head influent, pumped influent, variable head influent, automatic or manual backwash and constant or declining filtration rates.

Assumptions

To simply the explanation we have selected a sample plant with the following conditions;

- Constant influent head as a result of a gravity supply.
- Constant head, constant filtration rate.
- Automatic backwash system based on headloss.

While these are our assumptions, some general information on other control systems will be provided where it helps to explain our selected system.

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

RATE OF FLOW CONTROL SYSTEM

Constant Flow

The influent can be variable or constant. With our example plant the rate of flow into the plant is controlled by a wide body globe valve. The flow can be adjusted between 125 and 175 gpm. This adjustment is a manual adjustment and thus provides a constant influent flow. This valve is also used as the on-off control for the plant. A signal from the clear well or storage tank level is used to open and close the valve.

Dole Valve

One of other common methods of maintaining a constant flow to the plant is a fixed rate of control valve called a Dole valve. This is a nonadjustable valve. The on-off operation must either be provided manually or by using an air or electric operated butterfly valve in the influent line. This butterfly valve is controlled by a signal from the clear well or storage tank.

RATE OF FILTRATION CONTROL

Two Systems

There are two general filtration rate of control processes; declining rate and constant rate.

Declining Rate

As a filter plugs the natural rate of flow through the filter will decline. This would normally cause the water level above the filter (head) to rise, increasing the flow rate. With declining rate of flow systems the influent must be controlled so that the water level above the top of the filter remains the same, thus giving a declining filtration rate.

CONSTANT RATE - CONSTANT HEAD

General Description

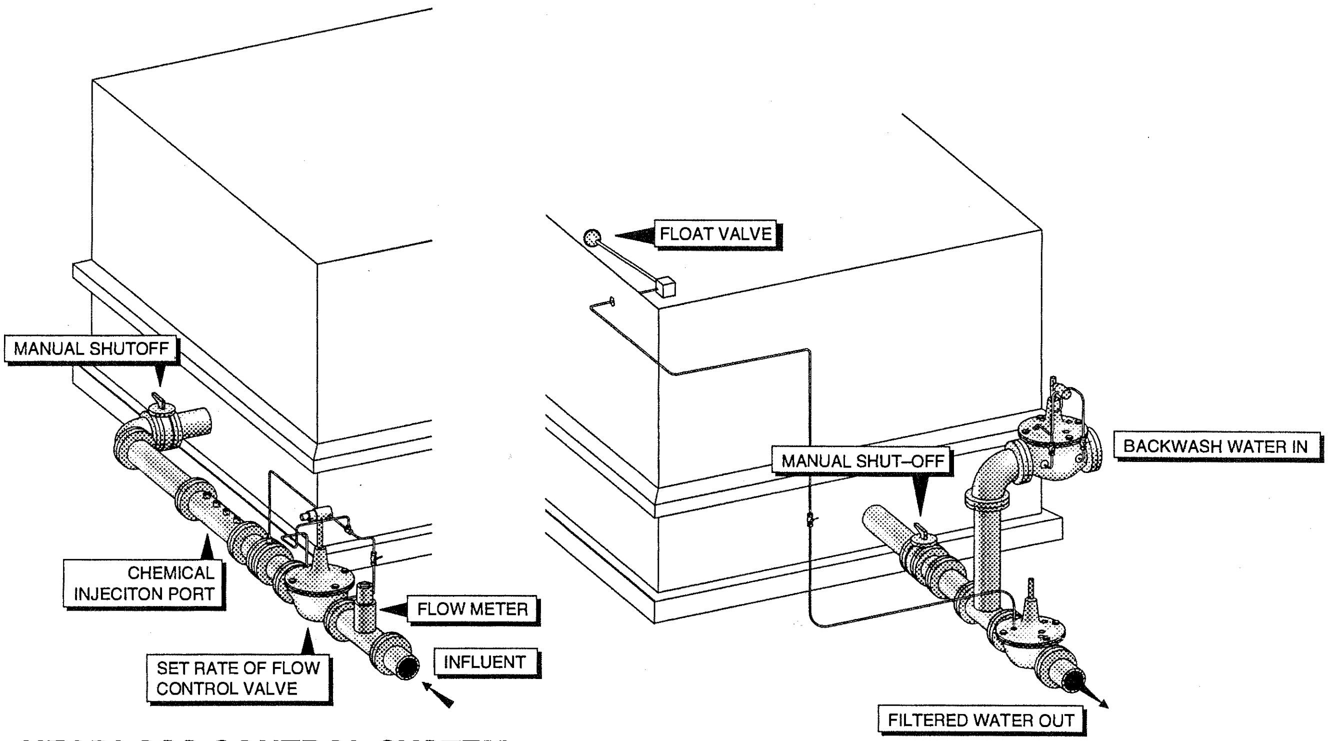
The most common system used in small treatment plants is the constant filtration rate with a constant head over the filter. This system requires an automatic control valve, usually a globe valve, and some type of system for sensing the level of water above the filter like a float. A signal line is connected between the float valve and the discharge control valve

Start of Filter Run

With this system the discharge valve from the filter underdrain system is partially closed at the start of a filter run. As the filter plugs, the level of water above the filter will rise slightly. This rise is sensed by the float and a signal is sent to the control valve causing the control valve to open.

Water Level Variations

Opening the control valve will cause the level of water above the filter to drop back towards normal. If the valve is opened too far the level will fall below normal, a signal will be sent to the control valve to close and the level will rise once again. In a typical small plant the head above the filter is not really constant, but changes 4 to 6 inches. The amount of change is dependent on the accuracy of the control system loop between the float valve and the control valve.



HEADLOSS CONTROL SYSTEM

Normal Operations

As the filter clogs with floc, the headloss across the filter will increase. This is true, even if the filter has a constant head. With a constant head filter the discharge pressure merely drops while the head above the filter remains constant. Thus, there is an increase in headloss.

Breakthrough

One of the keys to proper operation of a filter plant is to backwash the filter before breakthrough occurs. With most small gravity filters this is somewhere between 6 and 8 feet. Breakthrough would force the debris caught on the filter, through the filter and into the **clearwell**[49], contaminating the finished water.

Headloss System

There are several types of headloss indicator systems. Three of the most common are; differential meters, glass tubes and underdrain pressure sensors.

Differential Meters

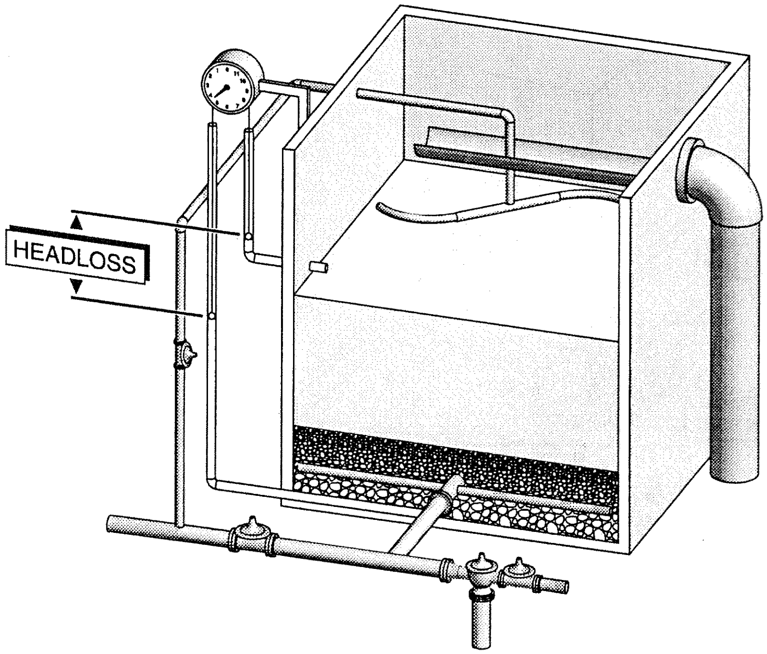
One common system is the differential meter. This meter is connected to the water level above and below the media. The difference in pressure or head in feet can be read directly. A signal from the meter can be sent to the electrical control system and used to either shutdown the plant or start an automatic backwash cycle.

Glass Tubes

One of the simplest systems used in large and small facilities is the duel glass tube system. One glass or clear plastic tube is connected to the underdrain, and a second tube is connected to the water above the fil-

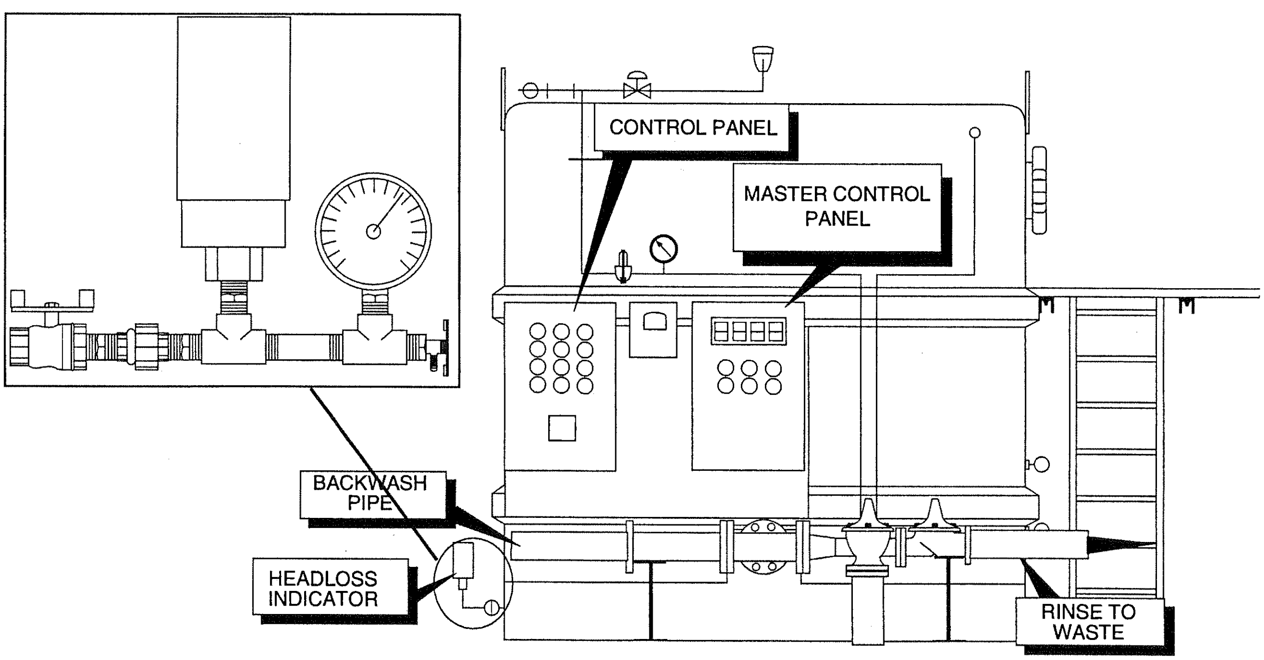
49 **Clearwell** - The tank used to store finished water. The tank is often under or along side of the water treatment plant. This tank typically is used as a chlorine contact chamber.

ter media. The difference in distance between the two water levels is the headloss. This system is normally installed as an operator check device to verify the automatic instrument readings.



Underdrain Pressure

When a filter utilizes a constant head above the filter the underdrain pressure can be used directly as an indicator of headloss. As the filer plugs the pressure would drop. A transducer can be used to sense the pressure and at a predetermined level send a signal to the electrical system to either shutdown the plant or initiate an automatic backwash cycle.



CHEMICAL FEED SYSTEM

CONSTANT RATE PLANTS

General System

The chemical feed system is connected to and controlled by the electrical system. With most small plants the flow rate is either constant or variable. With constant flow rates the chemical feed adjustments need only be based on raw water and finished water quality. Typically, turbidity or color are selected as control parameters. The chemical feed system is then adjusted manually by the operator or electrically by a signal from a turbidimeter or streaming current meter.

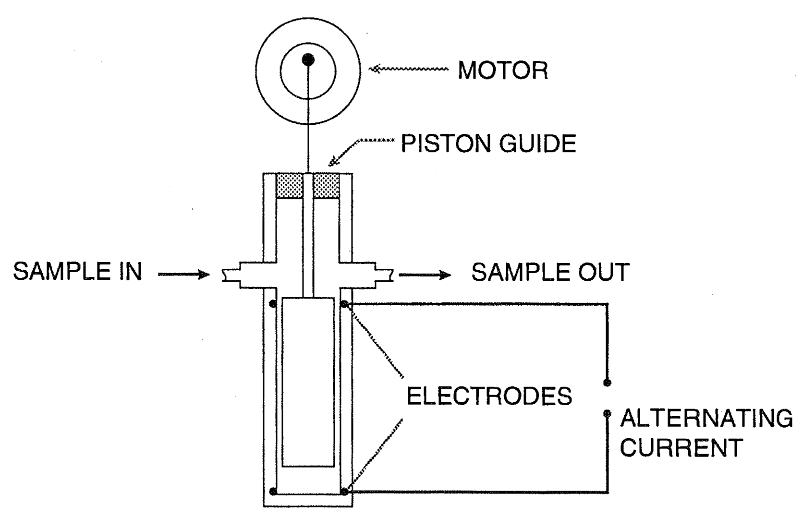
VARIABLE FLOW PLANTS

Turbidimeters

There are several reliable continuous measuring turbidimeters. A standard 4 to 20 ma signal from the turbidimeter can be used to adjust the chemical feed system. With most of the small treatment plants using either a LMI or W & T chemical feed pump, the stroke length of the pump is set manually by the operator and the frequency of the stroke adjusted by the electrical signal. There are systems that measure the raw and finished water turbidities and use the differential to develop a signal that controls chemical feed rates.

Streaming Current Meter

A relatively new instrument that has proven to be very effective in controlling large and small treatment plants is the streaming current meter. This device obtains a sample of the water just after the static mixer. The instrument detects the electrical potential of the water. The addition of alum or other primary coagulants changes this electrical potential. As a result, a specific electric potential can be observed that corresponds to low turbidity water. This value can then be used as a set point and a 4 to 20 ma signal produced around this set point. The signal is then used to control the chemical feed pumps in the same way as a turbidimeter.



ELECTRICAL SYSTEM

Subsystems

The electrical system, like the control system is composed of several subsystems, some of the more common systems are:

- Plant operation system.
- Backwash system.
- Alarm system.

PLANT OPERATIONS

Plant Operations using PLC's

While a water plant is basically a hydraulic device it is most often controlled electrically. The heart of most new water plants is the PLC (programmable logic controller). This device takes the place of most of the contactor relays that have been used in the past. Its primary advantage is the ease with which changes can be made in the control process.

Example Plant

In our example plant, the plant influent valve is controlled electrically by a signal from the clearwell or storage tank. When the level of water in the clearwell drops to a preset point, a float or other electrical device senses the level and sends a signal to the PLC. The PLC in turn, sends a signal to the solenoid on the inlet control valve, opening the valve. Once the clearwell is full the same process is repeated, closing the influent control valve.

BACKWASH SYSTEM

Components

In our example plant, the backwash system is composed of a pump, four electrically operated control valves and the headloss indicator.

General Operation

When the headloss indicator reaches a preset value a signal is sent to the PLC to start the backwash cycle. This sequence, which is described in detail in normal operations, closes the inlet valve, and properly sequences the backwash pump, surface wash valve, backwash flow control valve, finished water valve, sedimentation desludge valve and the filter to waste valve. The process can be fully automatic, returning the plant to normal operations after the backwash cycle is completed.

Time Control

The PLC allows easy control of the sequence and operating time for each function.

ALARM SYSTEM

Flooding

Each plant commonly has several alarm systems built into the electrical control system. One common alarm is the plant flooding alarm. Electrodes are placed above the sedimentation and flocculation basins. When these electrodes are immersed in water, a signal is sent through the PLC to close the influent valve and sends an alarm signal to a control panel light, horn or auto dialer phone system.

High Turbidity

Most newer plants have some type of high turbidity alarm system. The most common system is composed of a turbidimeter that measures finished water turbidity. If the turbidity exceeds some predetermined point, the plant is shutdown and an alarm is sent to a control panel light, horn or auto dialer phone system.

Pump Failure

Many plants have alarms that shutdown the plant and send a visual or audible alarm if the prime is lost or the backwash pump fails, a chemical feed system fails or the finished water pumps fail to operate. Pump failure alarm systems may also be associated with high or low pressures.

START-UP

Assumptions

The following start-up sequence is based on the assumption that the system being used is a package treatment plant as below. The chemical feed is composed of powdered alum and soda ash. Each chemical is mixed in a 100 gallon container. A final assumption is this is a functioning system that has been off line and is being restarted.

Sequence

Starting any package 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 O & M manual should be followed for a specific plant. The following is a suggested generic sequence.

- Mix chemicals according to the procedure below. When handling chemicals use the safety precautions described in the normal operations section.
- Prime the chemical feed pump - see the procedure below.
- Run jar test to determine proper chemical dosages.
- 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 or until the chemical feed is adjusted enough to produce turbidity below 0.5 ntu's.
- Check flow meter, note if the flow rate is normal.
- Check chemical feed during this period.
- Check finished water turbidity.
- Adjust chemical feed - see process control procedure for more details.
- 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. Typical alum dosages range from 5 to 30 mg/L. Soda Ash dosages are typically 1/2 of the alum dosage.
2. Run sufficient jar tests to be assured that the chemical feed settings are reasonable.

3. Determine the concentration of chemical needed or if there is a standard mixture, determine the concentration in the dilution tank.
4. Determine the plant flow rate in gpm.
5. Determine the chemical feed pump pumping rate in mL/min.
6. Determine the pump setting to obtain this feed rate. Set the feed pumps and check their output with a graduated cylinder.
7. Determine how long each tank of solution will last.

Example:

The chemical feed pump used is a LMI B121-91T with a maximum feed rate of 158 mL/min (see the table below). The flow rate through the plant is 175 gpm. The chemical feed tanks are each 100 gallon.

Steps 1 & 2

• A jar test was conducted and it was determined that the alum dosage would need to be 12.5 mg/L. A dosage of 5 mg/L of soda ash in the raw water was needed for coagulation.

Step 3

The maximum amount of alum that can be easily dissolved in water is about 1 pound per gallon. This is a concentration of just under 12%. The standard mixture of soda ash at this plant has been 50 pounds of soda ash in a 100 gallon tank, this is approximately a 6% solution. (Under ideal conditions soda ash can be mixed to a concentration of 49.5%. However, the preferred maximum concentration is 4 to 7%.)

• Determine the exact concentration of the alum solution.

$$\%\ \text{Conc} = \frac{100\ \text{lbs} \times 100}{100\ \text{gal} \times 8.34\ \text{lbs/gal}} = 11.99\,\%\ \text{or}\ 12\%$$

Since 1% is equal to 10,000 mg/L,

11.99% = 119,900 mg/L.

• Determine the exact concentration of the soda ash solution.

$$\%\ \text{Conc} = \frac{50\ \text{lbs} \times 100}{100\ \text{gal} \times 8.34\ \text{lbs/gal}} = 5.99\ \text{or}\ 6\%$$

Since 1% is equal to 10,000 mg/L,

5.99 % = 59,900 mg/L.

Step 4

The plant flow is 175 gpm.

Step 5

Determine the chemical feed pump feed rate in mL/min.

$$\text{Alum feed rate} = \frac{0.378 \times 12.5\ \text{mg/L} \times 175\ \text{gpm}}{12\%} = 68.9\ \text{or}\ 69\ \text{mL/min}$$

$$\text{Soda Ash} = \frac{0.378 \text{ X } 5 \text{ mg/L X } 175 \text{ gpm}}{6\%} = 55 \text{ mL/min}$$

Step 6

• There are two choices of how to determine the pump setting. 1) use the PHS chart provided at the end of this module or 2) assume some stroke setting and calculate the frequency.

From the chart for alum - stoke 50% and frequency between 80 and 90%.

From the chart for soda ash - stroke 50% and frequency 70%.

From the calculation for alum. The pump has a maximum feed rate of 158 mL/min. If the stroke is set at 50% the feed would be: 158 X 0.5 = 79 mL/min. What should the frequency setting be to obtain 69 mL/min?

$$\text{Frequency} = \frac{69 \text{ mL/min}}{79 \text{ mL/min}} \text{X } 100 = 87\%$$

By using the calculation process, determine the soda ash pump feed setting. Assume that the stroke is to be set at 50% or 79 mL/min.

$$\text{Frequency} = \frac{55 \text{ mL/min}}{79 \text{ mL/min}} \text{X } 100 = 69.6\%$$

Step 7

Determine the number of days that the tanks will last if the flow is 175 gpm for 14 hours a day.

• Total time 14 hrs X 60 min/ hr = 840 min.

• 1 gallon = 3785 mL.

For Alum:

• Alum - 840 min/day X 69 mL/min = 57,960 mL/day

$$\text{Gallons/day} = \frac{57{,}960 \text{ mL/day}}{3{,}785 \text{ mL/gal}} = 15.3 \text{ gal/day}$$

$$\text{Days} = \frac{100 \text{ gal}}{15.3 \text{ gal/day}} = 6.5 \text{ days}$$

For Soda Ash:

• Soda ash, 840 min/day X 55 mL/min = 46,200 mL/day.

$$\text{Gal/day} = \frac{46{,}200 \text{ mL/day}}{3{,}785 \text{ mL/gal}} = 12.2 \text{ gal/day}$$

$$\text{Days} = \frac{100 \text{ gal}}{12.2 \text{ gal/day}} = 8.2 \text{ days}$$

Pumping capacities of various chemical feed pumps

	Model	Capacity gph	Capacity mL/min	Max psi
LMI Pumps				
	A141-150S	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				
	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 new, 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 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 CT value.

Priming W & T 45

If the pump is new, use clear water for the prime. If this is 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 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 OPERATIONS

General Description

The normal operation of a water filtration plant involves; data collection, observations, mixing chemicals, adjusting process control, cleaning, testing and performing routine preventive maintenance activities. The following are general guidelines involving these activities with each of the typical process units found in a small or package water treatment plant.

Raw Water

The raw water system may contain such equipment as pumps, basket strainers and control valves. The pumps will require observation for leakage, vibration and noise. Suction and discharge pressure as well and amperage and voltage readings should be gathered on a regular basis and the pump analyzed for proper performance.

Basket Strainers

If the raw water system contains a basket strainer or other similar device, the differential pressure should be monitored daily and the device backwashed or cleaned when the differential pressure exceeds the manufacturer's recommendation.

Control Valves

The inlet and outlet pressures on control valves should be monitored daily. The valve should receive annual maintenance consisting of disassembly, cleaning and replacement of gaskets, and worn parts.

Flow Measurement

In order for a water treatment plant to operate properly and in order to properly perform process control the plant must have a flow meter. This meter must be read each day. If the meter is used to pace chemical feed equipment, it must be calibrated at least once each year.

Coagulation

The chemical feed rate should be observed and tested on at least a monthly basis. The feed rate in mL/min and the dosage in mg/L should be calibrated each month.

Flocculation

If the flocculator is a mechanical device the rotation frequency, and thus the energy should be adjusted for the best floc formation. To determine floc formation, a sample of water should be collected from the influent and effluent of the basin and observed. The effluent sample should be compared with jar test results.

Sludge in the Flocculator

Valves at the bottom of the floc basin should be opened and the accumulation of sludge observed at least once a week. The preference is there be little or no sludge accumulation. The basins should be drained and cleaned every three to six months. The walls of the basin, above and at water level should be hosed down and scrubbed with a deck brush at least once a week.

Observation of Flocculation

With mechanical or hydraulic flocculators the flow should be observed for excessive turbulence. Turbulence is an indication of short circuiting or excessive flow.

Sedimentation

The key to determining proper sedimentation basin operation is observations. There should be little or no floc entering the weirs and flowing to the filters. A sample of the water entering the filters should be compared with a settled sample of the water entering the basin. They should be very similar in appearance and a turbidity of the supernatant of the settled sample should be nearly the same as the water entering the filter basin.

Tube Settlers

Water flows up through the tube settlers carrying floc to the top. There is a natural tendency for the floc to seal over some of the tubes. As tubes become sealed over, the upward velocity through the remaining tubes is increased, increasing the amount of floc carry over. When one fourth (1/4) of the tubes are sealed it is time to clean the tube settlers. This can be done with a hose and brush. Gentle action is required in order to prevent damage to the tubes.

Sludge Blanket

If the sedimentation basin is the solids contact type, a sludge blanket of approximately 1/3 of the depth should be maintained. This blanket depth can be tested using test ports on the side of the basin or with a sludge judge (a simple clear plastic core sampler). During backwash the desludge valve is operated for a predefined time period. The level of the blanket is maintained by adjusting the length of time the desludge valve is open.

Septic Sludge

Once a week a sample of the sludge should be collected and placed in a 1000 mL or 500 mL beaker. The sludge will go septic, forming gases that will cause the blanket to rise. The rise time should be recorded and observed. A reduction in rise time indicates a need to increase the length of time the desludge valve is open during each cycle.

FILTRATION PROCESS

Normal Process

As has been mentioned before, as the filtration process proceeds through its cycle the floc penetrates the filter bed. The key to proper operation is to backwash the filter bed before this breakthrough occurs.

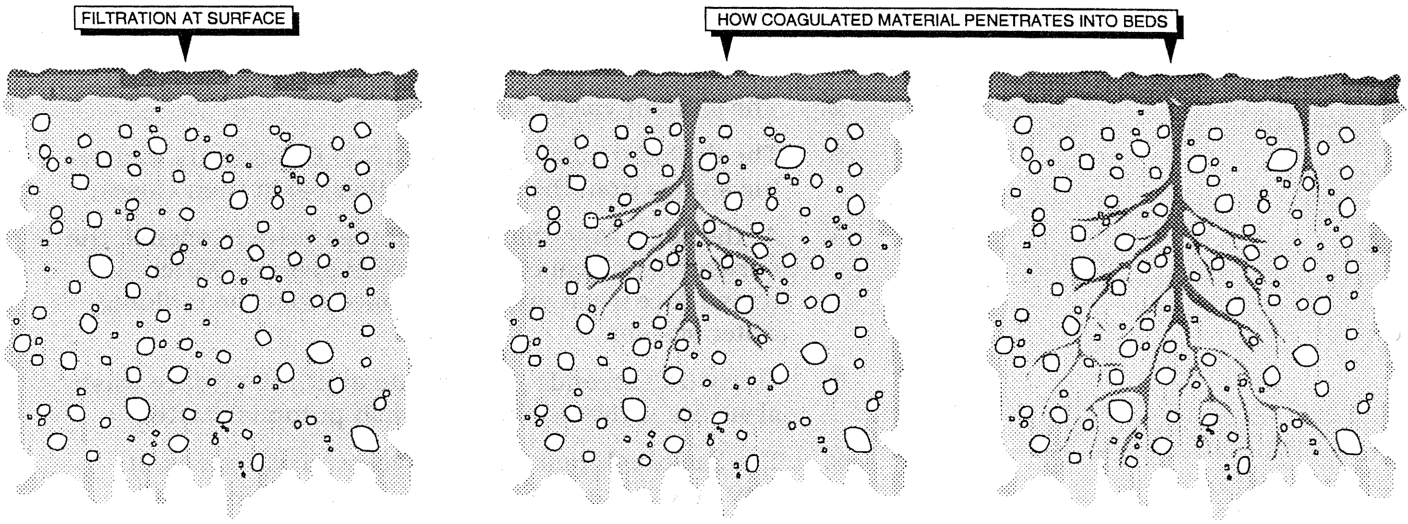
Filtration Rate

The filtration rate should be checked at least twice a year and maintained within the design limitations. Commonly this is between 2 and 8 gpm/ft^2.

Filter Run

At the start of a typical filter run the headloss of the clean filter should be approximately 1 foot. When the headloss reaches 6 to 8 feet, or the finished water turbidity begins to climb, it is time to backwash the filter.

A typical filter run should last from 12 to 72 hours. Filters should not be operated longer than 72 hours without backwashing, regardless of finished water turbidity. The bed can become contaminated with biological growth after this length of time.

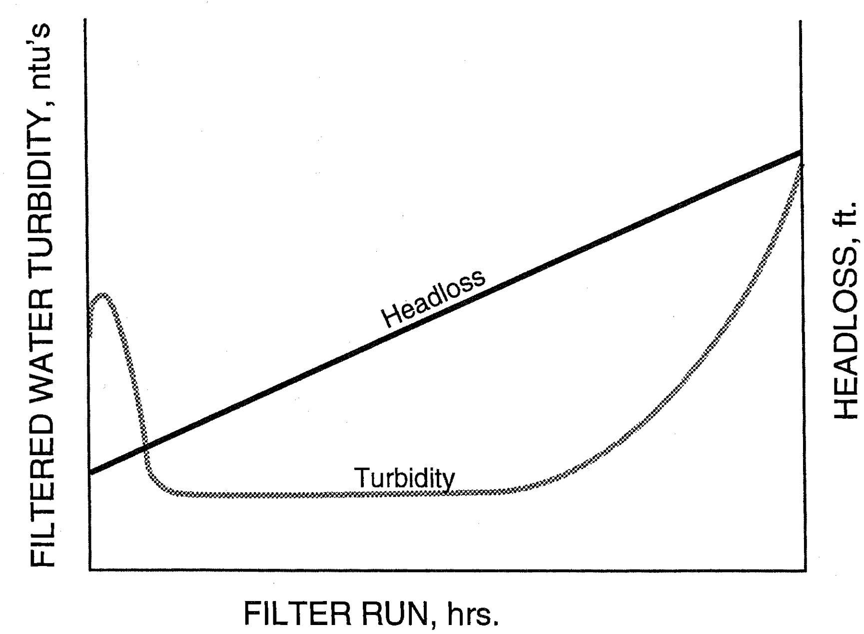


Turbidity

When a filter is backwashed and placed into service, the finished water turbidity will rise sharply and then drop off. This rise and drop should only take a few minutes. During this period the filter is compacting and said to be aging. This process should only take a few minutes. After compaction the filter effluent should remain below 0.1 ntu during most of the filter run. When the turbidity rises to 0.2 ntu a backwash cycle should be considered.

Graph of Turbidity & Headloss

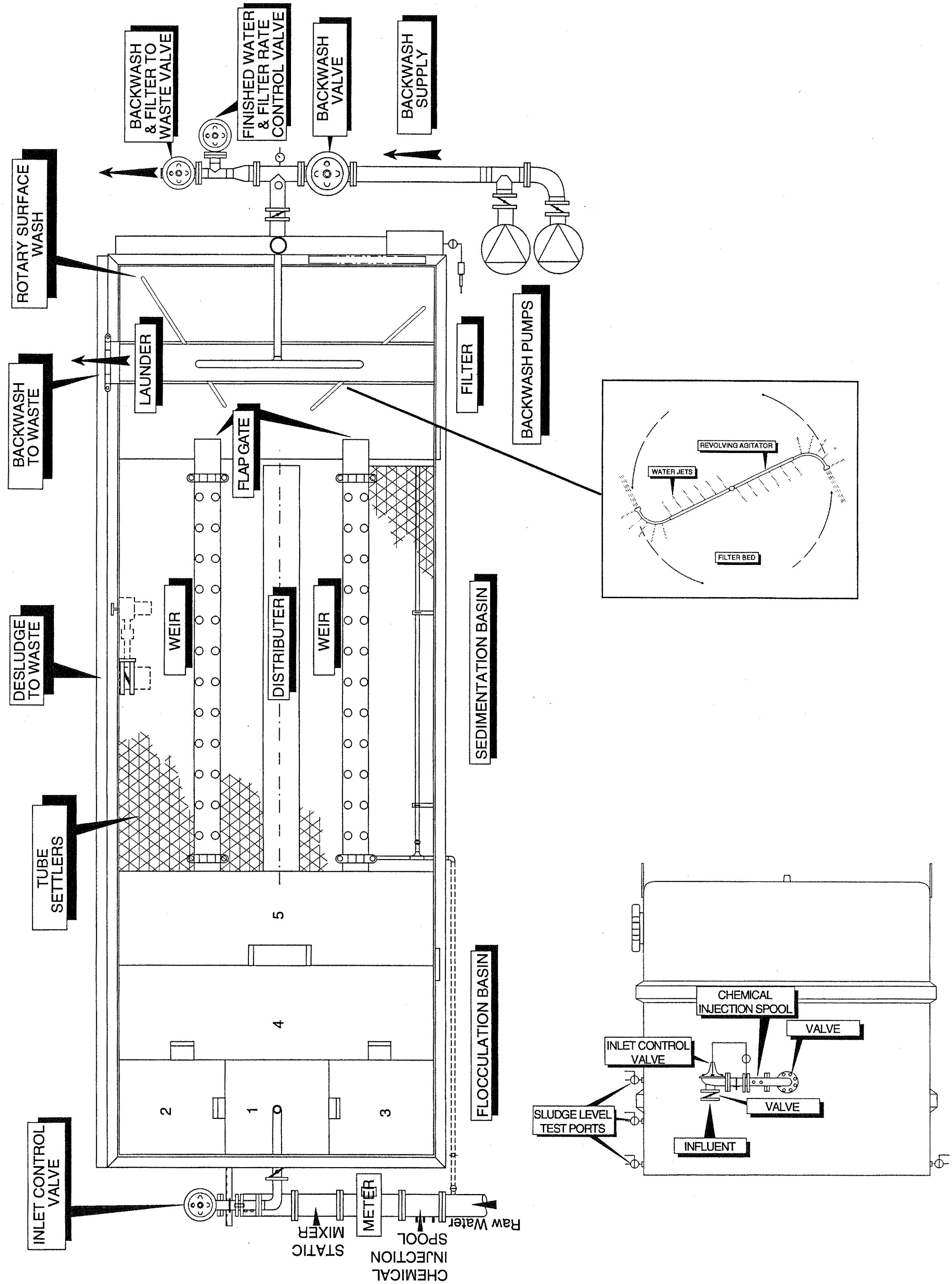
The graph below shows what happens to turbidity and headloss during a typical filter run.



Backwash Process

The backwash process can be manual or automatic. Regardless, the process commonly follows a standard cycle sequence. The plant in the drawing below is used to explain the sequence of events in a standard backwash cycle. A standard cycle follows this sequence:

1. The influent valve is closed.
2. The effluent valve is closed.
3. The desludge valve opens for 10 to 60 seconds, removing sludge from the sedimentation basin then closes.
4. At the same time that the desludge valve is opened the surface wash arm control valve is opened. Water for the surface wash arms is supplied from the building water system.
5. Thirty (30) seconds to 1 minute after the surface wash arms are activated the backwash pump is started.
6. The backwash pump control valve slowly opens. It may take as long as 1 minute for the valve to open.
7. Backwash water is pumped from the clearwell up through the filter and into the launder. From the launder water flows to the waste lagoon.
   - A typical backwash will last from 8 to 15 minutes. Samples collected from the launder each minute and compared, plus a physical observation of the filter bed will determine the length of time backwash is necessary. There should be significant difference in the samples, and they should be relatively clear before backwash is stopped. When backwash is completed the operator should be able to identify the surface wash arms when looking down into the filter bed. A flash light may be necessary.
   - Commonly after 5 to 7 minutes the backwash arms are stopped.
   - During backwash it is necessary to obtain a 50% hydraulic expansion of the bed. This provides the most efficient scouring. A 50% hydraulic expansion is a 20 to 35% physical expansion.
   - The rate of backwash is governed by the temperature of the water. The colder the temperature the lower the backwash rate necessary to provide a 50% expansion. The following table was taken from the AWWA Standard on Filtering Material B100-80, and can be used to estimate backwash rates.



ROTARY SURFACE WASH
BACKWASH & FILTER TO WASTE VALVE
FINISHED WATER & FILTER RATE CONTROL VALVE
BACKWASH VALVE
BACKWASH SUPPLY
BACKWASH TO WASTE
LAUNDER
FILTER
BACKWASH PUMPS
FLAP GATE
REVOLVING AGITATOR
WATER JETS
FILTER BED
DESLUDGE TO WASTE
WEIR
DISTRIBUTER
WEIR
SEDIMENTATION BASIN
TUBE SETTLERS
5
4
2
1
3
FLOCCULATION BASIN
INLET CONTROL VALVE
STATIC MIXER
METER
CHEMICAL INJECTION SPOOL
Raw Water
CHEMICAL INJECTION SPOOL
VALVE
INLET CONTROL VALVE
SLUDGE LEVEL TEST PORTS
VALVE
INFLUENT

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

8. At the conclusion of the backwash cycle the backwash control valve is closed. This commonly takes about 1 minute. When the valve is completely closed the backwash pump is shut-off.

9. A rest of 20 to 30 seconds is then observed, allowing the filter media to compact and stabilize.

10. The influent valve is then opened and at the same time the filter to waste valve is opened.

11. The filter to waste process allows the filter to operate at near normal rate, compacting the filter and wasting any debris that was jarred loose during the backwash but not removed. The filter to waste water is piped to the waste lagoon.

• If the design allows it, samples of this water should be observed each minute to determine that the turbidity has dropped to acceptable levels.

• A normal filter to waste cycle is 4 to 6 minutes.

12. After the filter to waste process is completed. The filter to waste valve is closed, and at the same time the effluent valve is opened. The filter is now back in its normal operation cycle.

ROUTINE INSPECTION

What to Observe?

A filter plant should be visited once each day of operation. During the visit the equipment and water should be observed and tested to assure proper operations. More specifically the following should be checked:

- Level of chemicals in each 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, headloss, floc appearance, tube settlers for plugging, floc carry over onto the filter, raw and finished water turbidity.
- During the visit collect the data described below.

DATA COLLECTION

Raw water

Test and record daily.

- pH.
- Alkalinity.
- Temperature.
- Pressure.
- 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 alum, soda ash and polymer tanks.
- Calculate quantity of each chemical used.
- Calculate dosage of each chemical.

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

Flocculation

- Alkalinity.
- pH.
- Turbidity of a sample that has settled for 1 hour. Compare the results with a sample from the end of the sedimentation basin. They should be the same.
- Observe for turbulence and sludge build-up in the bottom of the basin.

Sedimentation Basin

- pH - Daily.
- Alkalinity - Weekly.
- Turbidity of water as it flows into filter.
- Clarity of water - should be no visible floc carry over.
- Sludge blanket level.
- Time for sludge to rise.

Filter

Observe daily and record headloss.

If a manual system, at the start of each filter run record the initial headloss.

- Turbidity from the filter should be monitored continuously.
- Alkalinity - daily.
- pH daily.

Every three months.

- Check filtration rates.
- Check backwash rates.

Once each year, inspect the filter media for mud balls and general conditions.

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

Finished Water

Remember this is the water leaving the clearwell or storage tank and not the water leaving the filter.

- Turbidity - daily.
- Alkalinity - daily.
- Temperature - daily.
- pH daily.
- Aluminum - weekly. This is assuming that alum is being used as the primary coagulant.

CALCULATIONS

Calculation Needed

As a result of the daily visit to a filtration plant, dosage should be calculated for each chemical added to the water. While a low turbidity 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 titled "Calculations needed for Alum and Soda Ash."

Example Check list from an automated package plant

Daily Check List -

- ❑ 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 rest room thermostat setting ______ ° F.
- ❑ Check office and lab thermostat setting ______ °F.

- ❑ Alum - power light on ________.
- ❑ Alum % feed on panel _______ %.
- ❑ Alum dilution water rotometer setting _______.
- ❑ Alum feed pump, stroke on pump ______ % and frequency _______%.
- ❑ Alum alarms _________.

- ❑ Soda ash - power light on ______.
- ❑ Soda ash feed rate _____ %.
- ❑ Soda ash feed pump, stroke on pump _______% and frequency ________%.
- ❑ Soda ash mixer motor temperature _______.
- ❑ Soda ash alarms _________.

- ❑ Chlorine pump stroke setting _______ %.
- ❑ Chlorine pump frequency light flashing _______ strokes/min.

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

- ❑ Poly feed pump stroke _____ % and frequency ______ %.

- ❑ Flow rate to number of plants operating _____ gpm.

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

MIXING & FEEDING CHEMICALS

ALUMINUM SULFATE - $Al_2(SO_4)_3$

Properties

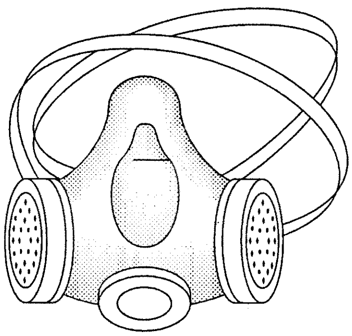
Tends to cake under high relative humidity. Acidic, hydroscopic, mildly corrosive if wet.

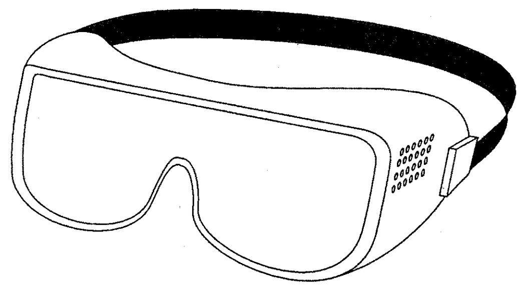
Storage Requirements

Clean, dry area.

Safety equipment required when handling as a powder

- Cartridge dust mask.
- Splash proof chemical safety goggles.





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

Mixing Concerns

- Maximum concentration. Under normal conditions it is difficult to maintain an alum solution of greater than 1 pound of alum per gallon of water, approximately a 12% solution. In order to develop a solution using dry alum an electric mixer is required.

SODA ASH - SODIUM CARBONATE Na_2CO_3

Properties

- Tends to lump and is mildly corrosive if wet. Soda ash is neither a toxic or hazardous material.

Safety equipment required when handling as a powder

- Cartridge dust mask.
- Splash proof chemical safety goggles.
- Loose, denim-quality, dust-proof, long-sleeved cloths with bandanna and cap. Trousers and sleeves tied at ankles and wrist.
- Rubber gloves.
- Cover exposed skin with cream or petroleum jelly.

Mixing Concerns

Under ideal conditions soda ash can be mixed to a concentration of 49.5%. However, the preferred maximum concentration is 4 to 7%. Soda ash is difficult to maintain in a solution without an electric mixer.

MIXING PROCESS

Normal Conditions

It is typical to make an alum solution of 1 to 12% and a 4 to 7% soda ash solution. In some facilities the soda ash is fed directly into the water as a dry powder. While this process is efficient it usually does not provide the process control necessary for a well run filter plant. Both alum and soda ash are considered to be 100% concentrated when in a powered or crystal form. In this form, two pounds (2) of powder are required for each 25 gallons of water for each 1% concentration that is required.

Volume	lbs for each 1% of solution
25 gallons	2 lbs
30 gallons	2.5 lbs
50 gallons	4 lbs
100 gallons	8 lbs
150 gallons	12 lbs
200 gallons	16 lbs

Conversions

1 lb = 16 oz = 454 grams

Assumptions

The following procedure is provided with the assumption that alum and/or soda ash are 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 water.
- Start mixer.
- Dump dry chemical in container.
- Fill with water - continue to mix.

Soda Ash

With soda ash the mixer should run continuously.

Polymers

Some polymers require aging before they can be used. Check with the manufacturer to determine if aging is necessary.

CHEMICAL FEEDING PROCESS

Control of Feed Rates

It is important for proper plant operation to match the chemical feed rate with the plant performance. This is accomplished by relating the turbidity or color levels, temperature, pH 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.

Calibration

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

Using Polymers

If a polymer is being used, the following guidelines can be used in jar tests to determine the most effective feed rate;

Use	**Typical Dosage range**
Primary Coagulant	1 - 5 mg/L
Coagulant aid	0.1 - 1 mg/L
Floc aid	0.1 - 1 mg/L
Sedimentation aid	0.1 - 1 mg/L
Filtration Aid	0.01 - 0.1 mg/L

Colored water - Primary coagulant. The PHS has shown considerable success in the reduction of color in the cold, turbidity-free, low alkalinity waters of Southeast Alaska with dosages of less than 1 mg/L.

ADDING CHEMICALS

Typical Problem

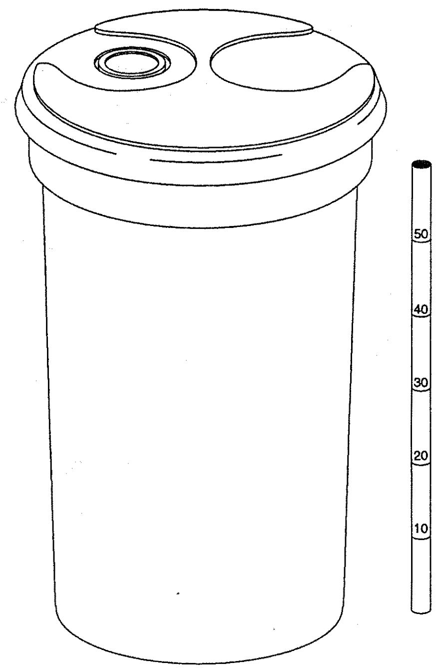
During the visit to the treatment plant it is often necessary to replenish the alum or soda ash in the feed solution tank. If the tank is empty, determining how much chemical to place in the tank is very simple. However, one of the common problems facing operators of these systems is how to determine 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 ten (10) gallons of water.
- Empty the tank.
- Place ten 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 10 gallon mark that you can fill to without overfilling the tank.

- Place the chemical in the tank.
- Fill the tank to the mark with clean 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 months supply plus shipping time. A typical procedure would be:

- Determine the amount of alum and/or soda ash 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 chemical supply is at the six months point, order the amount necessary for the next six months, plus shipping time plus one week lead time.

Example:

The City of Waterhome uses an average of 15 pounds of alum 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 chlorine needed in the order would be 15 lbs/day X 250 days = 3,750 pounds. A standard container of alum is the 100 pound bag. The City of Waterhome order should be for 38 bags.

CALCULATIONS USED WITH ALUM AND SODA ASH

Introduction

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

MAKING SOLUTIONS

Pounds for Set Concentration

It is assumed that dry alum and soda ash are a 100% concentrated product. Therefore, the following formula can be used to find the number of pounds of chemical needed to make a set 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 alum needed to make 50 gallons of a 6% solution.

lbs = 0.06 X 50 gallons X 8.34 lbs/gal = 25 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, therefore 2 cups = 1 pound

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

Finding Concentration

The formula for finding the concentration of alum or soda ash 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 soda ash is placed in a 50 gallon barrel that is filled with water.

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

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.

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

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 in 3 mg/L.

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

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.

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

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.

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

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.

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

Example

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

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

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 and 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

ROUTINE MAINTENANCE

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

PUMPS

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

CONTROL VALVE - GLOBE

Cla-Val

If wide body glove valves such as Cla-Val™ 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.

Cla-Val - Stem Rise

To determine the maximum stem rise on a Cla valve multiply 0.28 X valve size. For instance a six inch valve 0.28 X 6" = 1.68 inches.

Cla-Val - Cavitation

Most wide body globe valves will cavitate in the lower 15% of their stroke. The style of Cla valves used at Craig has a history of seldom experiencing cavitation even in the lower 15% of the stroke. However during the annual inspection the downstream area of the valve should be inspected for cavitation.

Cla-Val- PM

Replace PRV pilot valve diaphragms and disks annually.

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

Wye Strainers on Cla-Val

There are various Cla valve piping and pilot combinations. The two piping set-ups below are the most common. These procedures can be used to properly remove and clean the wye strainer, without changing the downstream pressure.

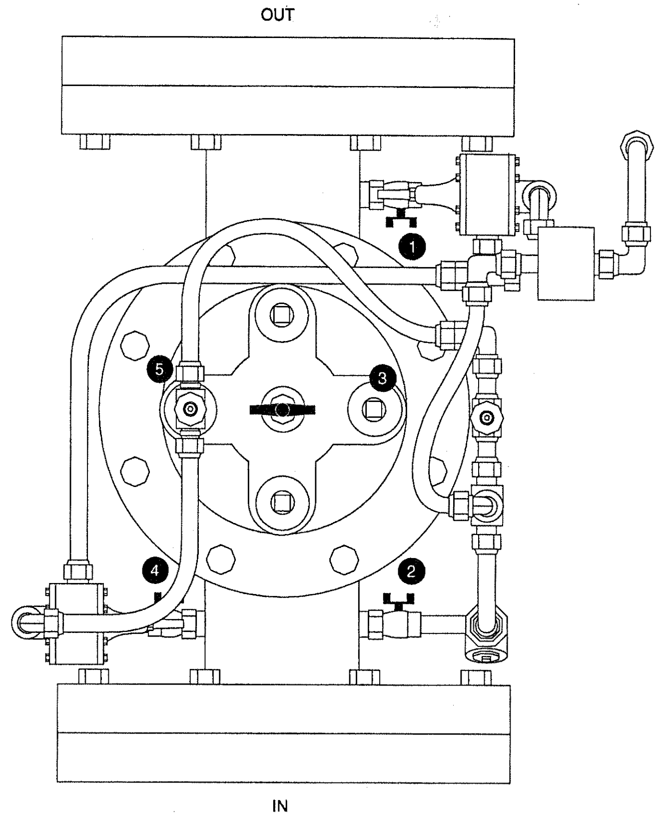
Frequency

The Wye strainers on each of the PRV's should be cleaned weekly. Should the Wye strainers become clogged the PRV's will have a tendency to modulate.

Valve Sequence

The wye strainers can be cleaned without shutting down the plant flow if you follow the valve closing sequence described below. This sequence will lock the valve diaphragm in position. Cleaning should be done promptly and the valves returned to normal operation as quickly as possible.

Solenoid Operated, Dual Pilot



Shut off Sequence

Shut off the valves in the following order as shown on the drawing above.

- Close valve 1 slowly
- Close valve 2
- Close valve 4
- Close valve 5

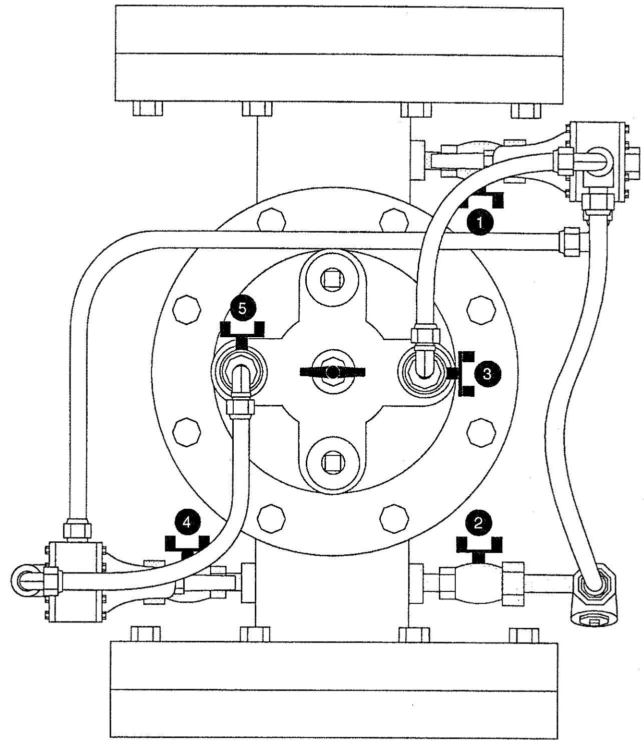
Open Sequence

Open the valves using the following sequence as shown on the drawing above.

- Open valve 2
- Bleed air from cover
- Open 1 slowly
- Open valve 5
- Open valve 4

Hydraulic Operated, Dual Pilot

OUT



IN

Shut off Sequence

Shut off the valves in the following order as shown on the drawing above.

- Close valve 1 slowly
- Close valve 3
- Close valve 2
- Close valve 4
- Close valve 5

Open Sequence

Open the valves using the following sequence as shown on the drawing above.

- Open valve 2
- Open valve 3
- Bleed air from cover
- Open 1 slowly
- Open valve 5
- Open valve 4

FILTER

Routine Procedures

The filtration and backwash rates should be checked every three months. The media rise should be checked at least twice a year. 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.

Confined Space

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

Testing Procedures

Procedures for determining filter media rise, mud ball testing and backwash pump flow rate testing can be found in the module on "Typical Filter Plant Problems."

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

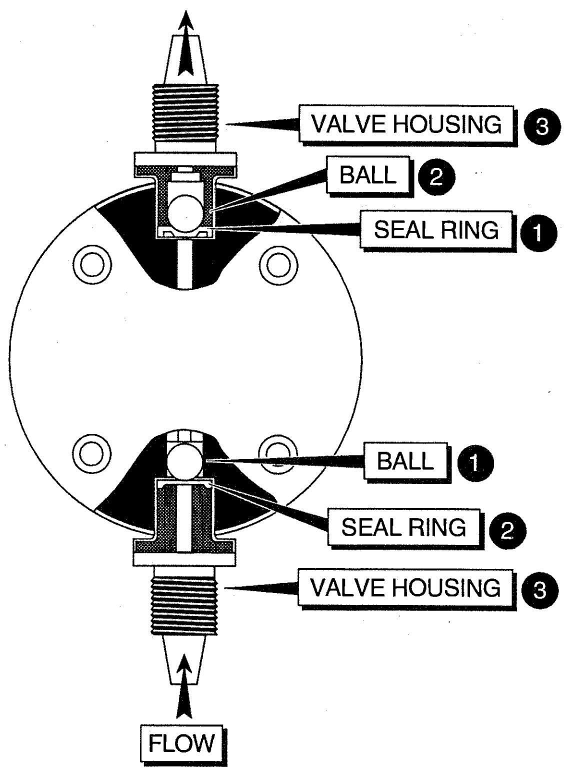
The repair kit required for a LMI pumping alum or soda ash is SP-U3.

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 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.



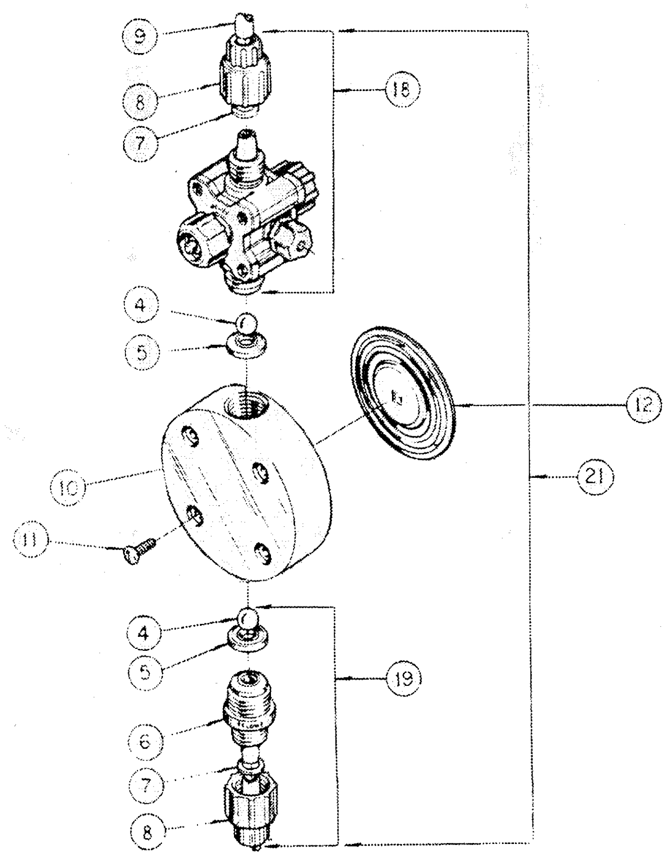
5. Clean and replace injection fitting. No Teflon tape should be used on the fitting or threads. Instead use silicon lube on threads (Dow 33 Moleycoat). Tighten the fitting by hand. If a wrench must be used do not tighten more than 1/8 turn.
6. Replace discharge piping.

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 and depressurize 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.

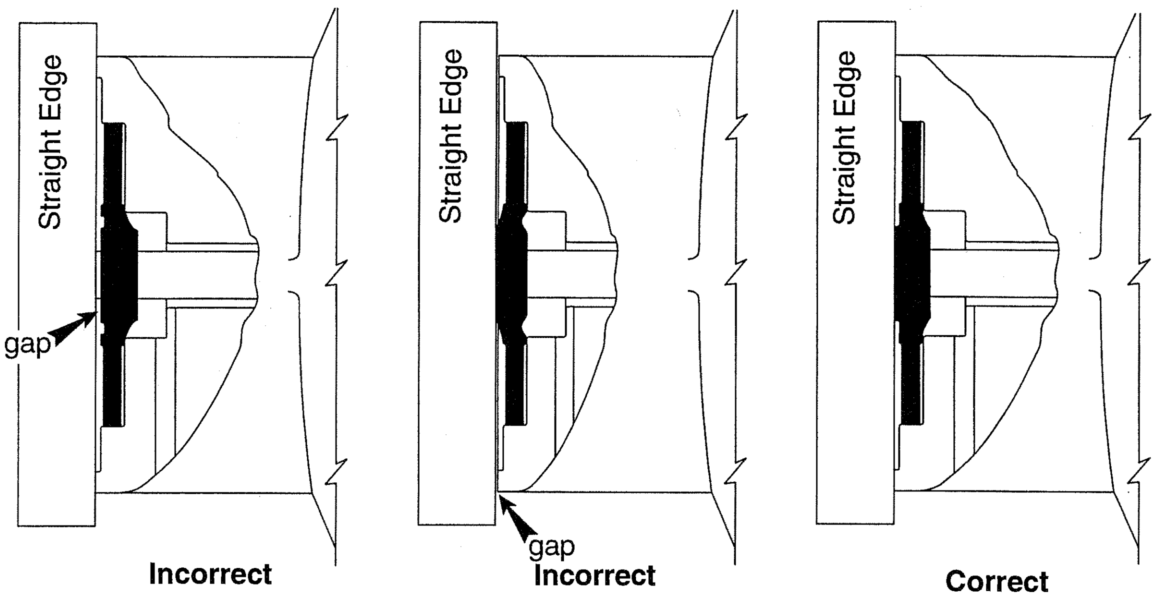


Replace Diaphragm - LMI

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

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 counterclockwise.

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.

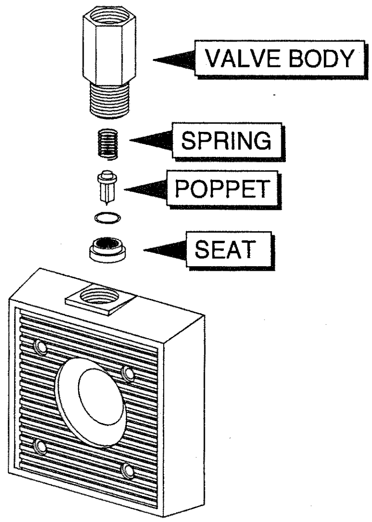


W & T PUMPS

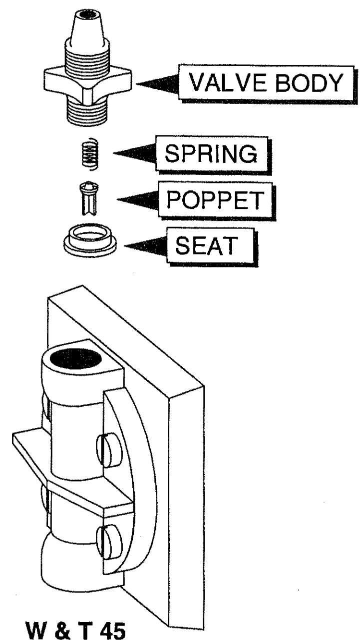
Discharge & Suction Valves

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

1. Shut off pump and depressurize.
2. Remove Union nut.
3. Remove half union.
4. Remove and replace spring, poppet, gasket and 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 and lock-out or unplug.
4. Remove screws (34) from pump head (33).
5. Lift diaphragm by edge, turn counterclockwise.
6. Hold hub (26) and remove nut (13) and lock washer (14) and diaphragm.
7. Remove two screws (35).
8. Hold washer with pliers and turn diaphragm counter-clockwise.
9. Replace diaphragm, lock washer and nut.
10. Tighten nut 30 inch pounds for1 gph and 100 inch pounds for 5 and 10 gph.
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.

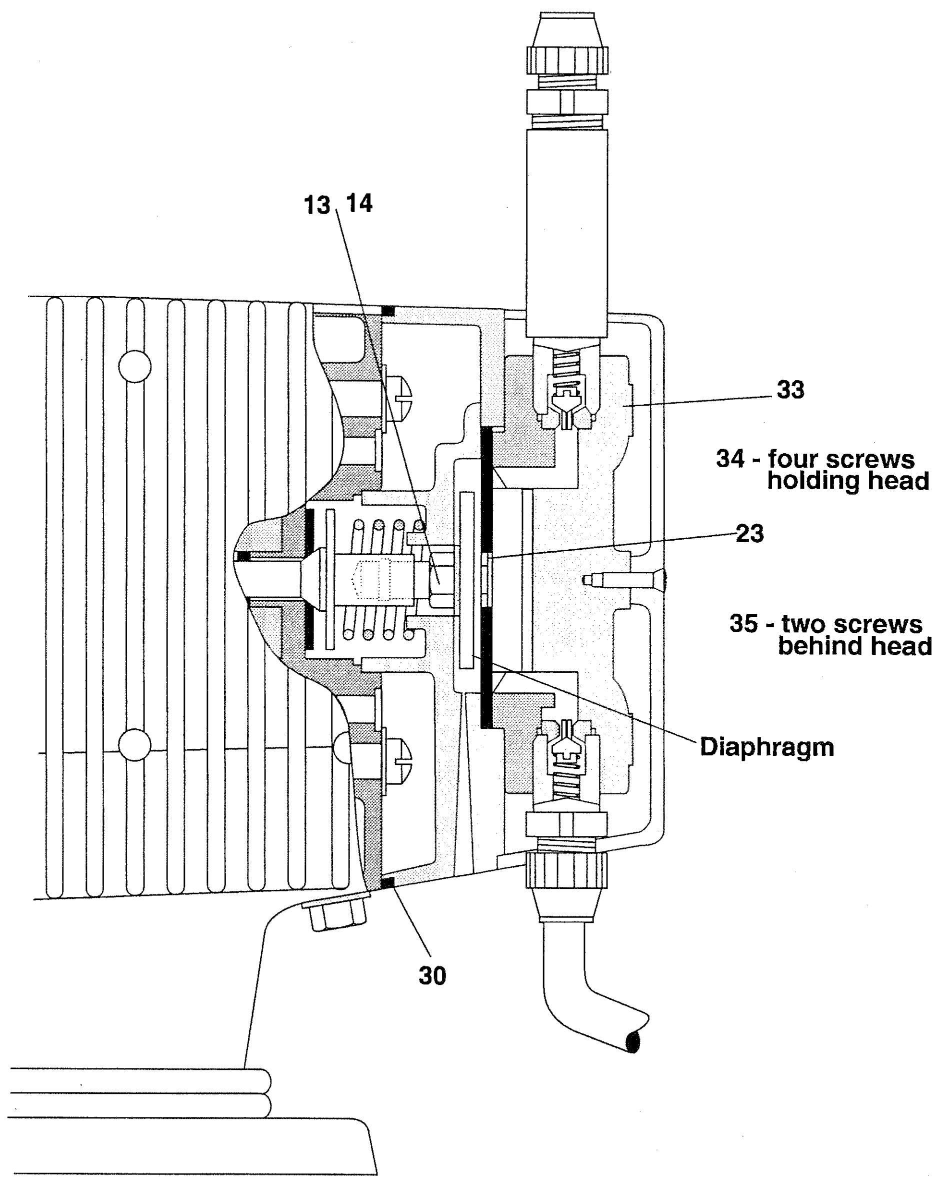
15. Replace screws (35).

16. Stretch O-ring (31) 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 lightly 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.)

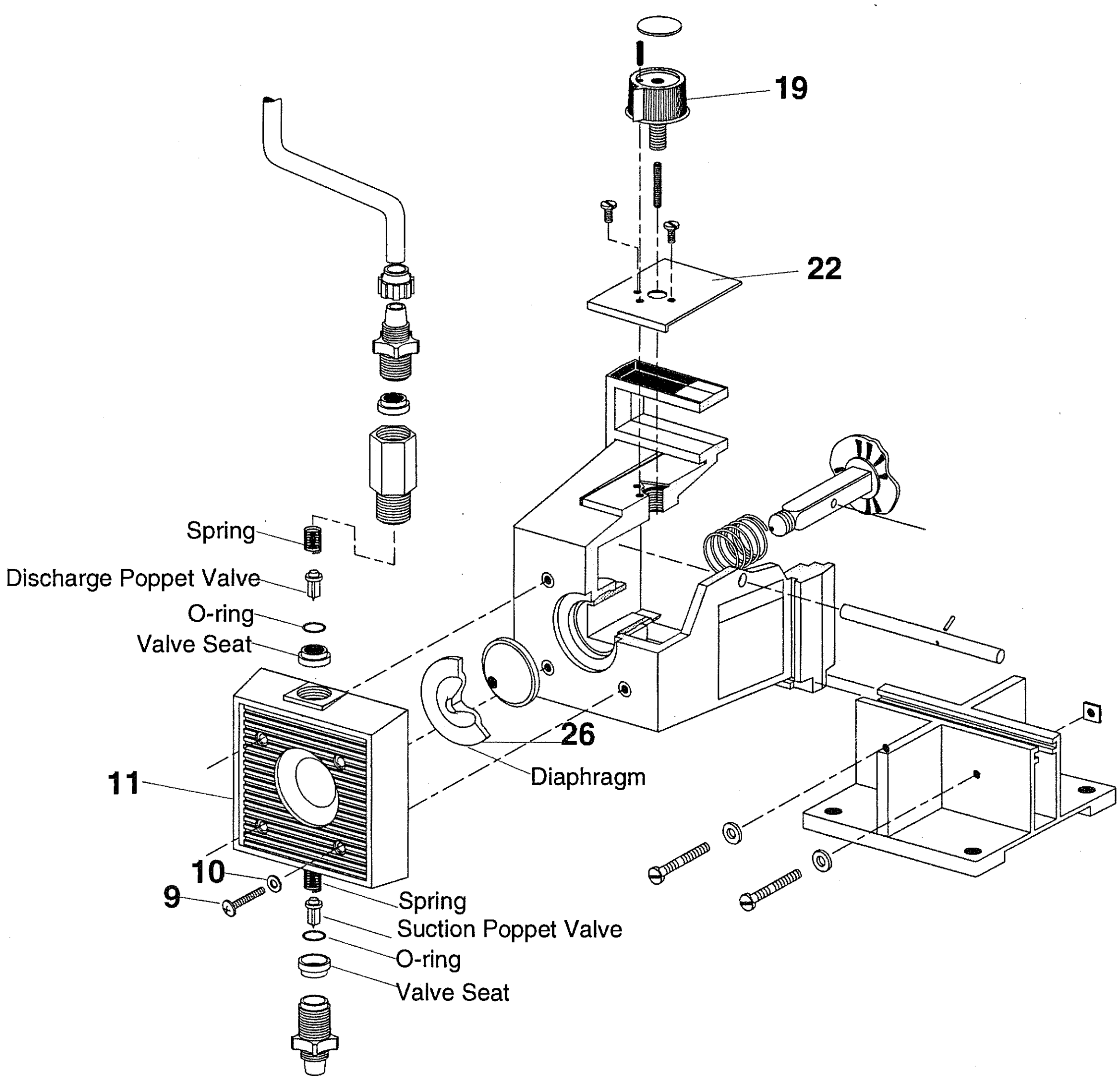
19. Install head & screws. Tighten screws to 28 inch pounds.



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 counterclockwise.
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 the diaphragm.
8. Install pump head (11) with four screws (9) and washers (10).
9. Tighten screws to 14 in-lbs.



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.

Polymer

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 and 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.

Soda Ash

Because soda ash will take on water and become hard, chemical should not be left in the hopper if the unit is to be off line for more than 24 hours.

PROBLEMS - SEE THE MODULE ON "TYPICAL PLANT PROBLEMS."

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% F=30%	S=50% F=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 GRAVITY FILTERS

WORKSHEET

1. The difference between conventional filtration and direct filtration is a direct filtration system does not have a __________.

   ______ a. Flocculation chamber

   ______ b. Chemical feed system

   ______ c. Sedimentation chamber

   ______ d. Surface wash system

   ______ e. Influent control valve

2. One method that has been successful in the removal of color in cold waters is to add a special coagulant called a ___________.

   ______ a. Iron salt

   ______ b. Lime

   ______ c. Soda Ash

   ______ d. Nonionic sulfur

   ______ e. Polymer

3. When turbidity shows up in the finished water prior to the end of the filter run the most probable cause is......

   ______ a. Breakthrough

   ______ b. Underfeeding alum

   ______ c. Excessive mud balls in filter media

   ______ d. The lack of proper coagulation

   ______ e. Low water temperatures

4. Alum is another name for .....

   ______ a. Ferric Sulfate

   ______ b. Alkalinity

   ______ c. Soda Ash

   ______ d. Aluminum Sulfate

   ______ e. Sodium Aluminate

5. A gravity filter should be backwashed when the headloss is between ____ and ____ feet.

_______ a. 6 and 8

_______ b. 1 and 5

_______ c. 8 and 10

_______ d. 6 and 12

_______ e. 10 and 15

6. A multi-media filter contains which three medias?

_______ a. Silica sand

_______ b. Coal

_______ c. Fine gravel

_______ d. Garnet sand

_______ e. Anthracite coal

7. A typical gravity filter has a media bed that is _____ to ____ inches deep.

_______ a. 12 to 24 inches

_______ b. 48 to 54 inches

_______ c. 36 to 60 inches

_______ d. 24 to 60 inches

_______ e. 24 to 42 inches

8. Typical filtration rates for gravity filters are between _____ and _____ gpm/ft^2.

_______ a. 1 to 5

_______ b. 2 to 4

_______ c. 3 to 6

_______ d. 1.5 to 4

_______ e. 4 to 8

9. Typical backwash rates for gravity filters should be between _____ and ______ gpm/ft^2.

_______ a. 15 to 17

_______ b. 2 to 4

_______ c. 10 to 20

_______ d. 6 to 15

_______ e. 9 to 12

10. Identify the valves and piping on the package filter plant below by matching the numbers with the list provided.

_______ a. Influent

_______ b. Finished water VALVE

_______ c. Filter to waste valve

_______ d. Static mixer

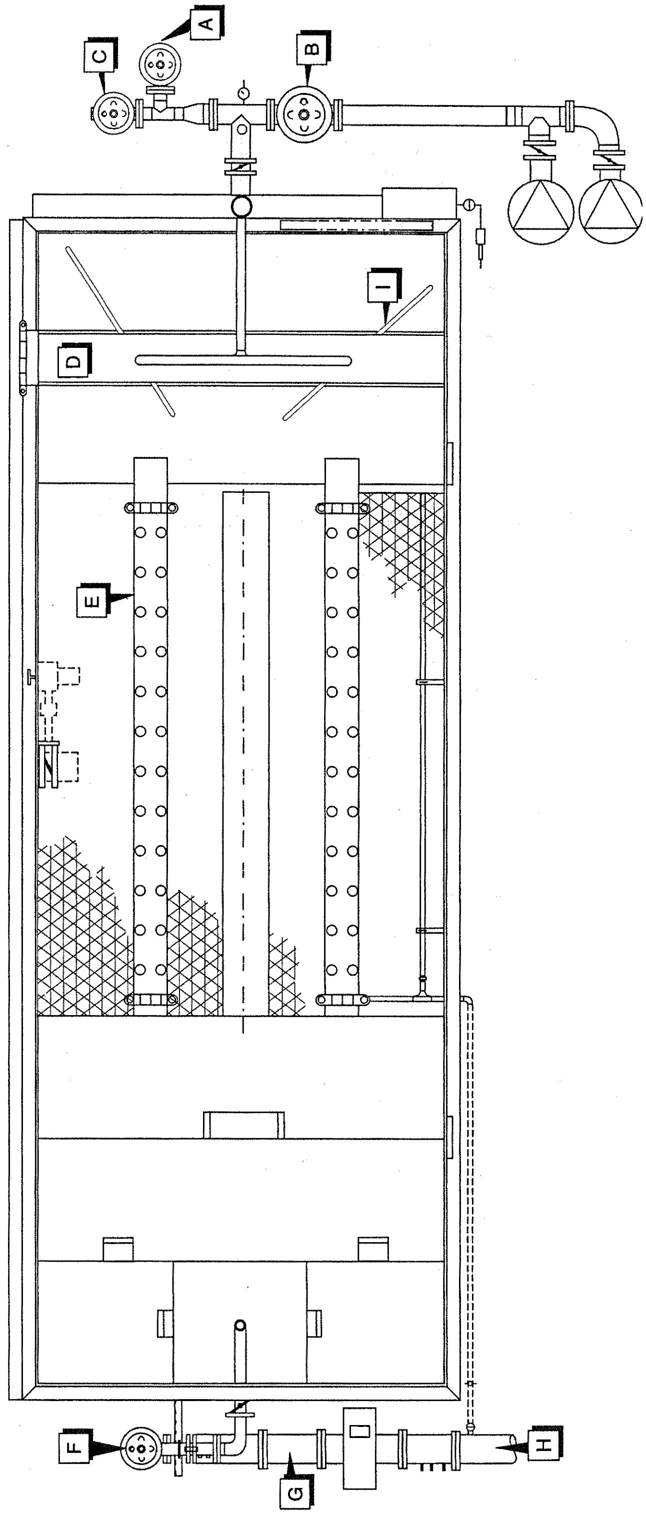
_______ e. Inlet control valve

_______ f. Surface wash arms

_______ g. Launder

_______ h. Weirs

_______ i. Filtration rate control valve



11. A package plant has a filter that is 5 ft by 10 ft. The flow rate is 120 gpm. What is the filtration rate?

_______ a. 2.4

_______ b. 6.8

_______ c. 1.5

_______ d. 3.8

_______ e. 4.8

12. A package plant has a filter that is 5 ft by 10 ft. What would the backwash pumping rate be if it were necessary to backwash the filter at 17 gpm/ft^2?

_______ a. 55

_______ b. 107

_______ c. 214

_______ d. 321

_______ e. 850

13. What type of breathing protection is required when handling alum?

_______ a. Dust mask

_______ b. Full face cartridge respirator

_______ c. SCBA

_______ d. None

_______ e. Cartridge dust mask

14. The two most common chemicals used in small water treatment plants are alum and soda ash. Both are a powder. Which is the most hazardous to handle?

_______ a. Alum

_______ b. Soda Ash

15. Which is the recommend material for handling a fire associated with alum?(Mark the most correct answer (s))

_______ a. Dry chemical

_______ b. CO_2

_______ c. Halon

_______ d. Water

_______ e. All of the above

16. When using a polymer as a primary coagulant in cold water to remove color, the most common dosage range is between _____ and ______mg/L.

    ______ a. 4 and 10

    ______ b. 17 and 24

    ______ c. 0.1 and 0.4

    ______ d. 1 and 4

    ______ e. 12 and 20

17. 50 pounds of alum was placed into a 50 gallon container to make 45 gallons of solution. Find the concentration of the solution in percent.

    ______ a. 6%

    ______ b. 13%

    ______ c. 25%

    ______ d. 95%

    ______ e. 54 %

18. 12 gallons of an 8% solution was pumped into a flow of 34,000 gallons. What is the dosage in mg/L?

    ______ a. 13 mg/L

    ______ b. 17 mg/L

    ______ c. 21 mg/L

    ______ d. 3 mg/L

    ______ e. 28 mg/L

19. A typical backwash should take approximately ________ min.

    ______ a. 5 min

    ______ b. 30 min

    ______ c. 15 min

    ______ d. 45 min

    ______ e. 4 min

20. 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	________