Drinking Water
Operator Certification Training

Module 21:
Chemical Addition

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The Pennsylvania State Association of Township Supervisors (PSATS)
Gannett Fleming, Inc.
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B. Feed Equipment

C. Accessory Equipment

Unit 1 – Chemicals Used in Water Treatment

Learning Objective

- When given a source water problem, participants will be able to identify on the ***Chemical Usage Table*** those chemicals used to address and correct the problem in the treatment of drinking water.

General Overview

Use of chemicals in the treatment of water is not new.

Historically

- Chlorine was reported to have been added to drinking water as early as 1835 to control foul odors in the water.
- Chlorine was proven as an effective disinfectant in the 1890's.
- The Louisville Water Company introduced a new treatment technology combining coagulation with rapid-rate filtration in 1896.
- Chlorination as disinfection was first practiced at a U.S. public water supply in 1908.

Requirements for improved treatment have resulted in greater chemical use during recent years.

Currently

Water Treatment Plants are being designed and operated using chemicals for improving both process performance and finished water quality.

Chemical Uses

The current practice of adding coagulants, pH adjustment chemicals, oxidants, disinfectants, alum, and polymers during the water treatment process results in improved process performance and, ultimately, enhanced finished water quality.

Coagulation

Definition: The clumping together of very fine particles into larger particles (floc) caused by the use of chemicals (coagulant chemicals). The chemicals neutralize the electrical charges of the fine particles and cause destabilization of the particles. This clumping together makes it easier to separate the solids from the water by settling, skimming, draining or filtering.

Types of Coagulant Chemicals

Primary Coagulants

Coagulant Aids

- **Primary Coagulants**: neutralize the electrical charges of particles in the water which causes the particles to clump together. Primary coagulants are always used in the coagulation/flocculation process.

- **Coagulant aids**: add density to slow-settling flocs and add toughness to the flocs so that they will not break up during the mixing and settling process. Coagulant aids are not always required and are generally used to reduce flocculation time.

- Coagulant chemicals are either metallic salts (such as alum or ferric) or polymers. Polymers are man-made organic compounds made up of a long chain of smaller molecules. Polymers can be cationic (positively charged), anionic (negatively charged) or nonionic (neutrally charged).

- Common primary coagulant chemicals and their corresponding pHs are listed in Table 1.1.

    - Aluminum Sulfate (alum) is very widely used.
    - Poly Aluminum Chloride (PAC) has some advantages particularly for coagulation of "difficult" waters.
    - Ferric chloride and sulfate are aggressive, corrosive, acidic liquids; even more so than aluminum salts.

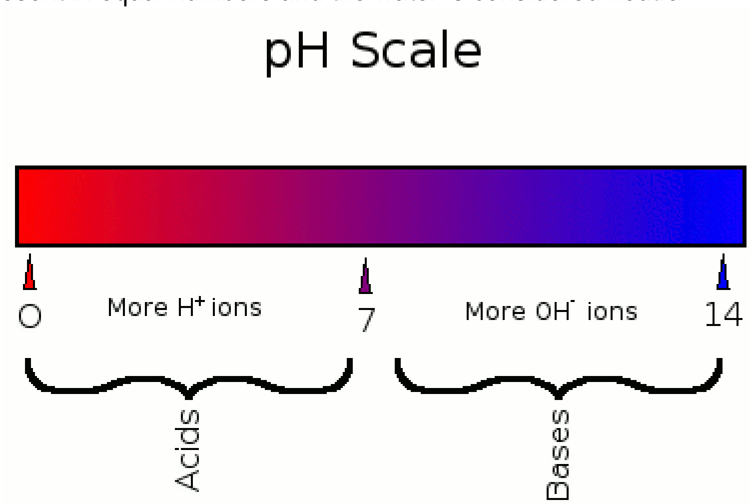
Table 1.1

Common Primary Coagulant Chemicals		
Type	**Chemical**	**pH**
Aluminum Salts	Dry Alum (Aluminum Sulfate)	3.3-3.6
	Liquid Alum (Aluminum Sulfate)	2.1
	Poly Aluminum Chloride	1.8
Iron Salts	Ferric Chloride	less than 2
	Ferric Sulfate	1

pH Adjustment

Definition: pH is an expression of the intensity of the basic or acidic condition of a liquid. Mathematically, pH is the logarithm (base 10) of the reciprocal of the hydrogen ion activity. The pH may range from 0 to 14, where 0 is most acidic, 14 is the most basic, and 7 is neutral. Natural waters usually have a pH between 6.5 and 8.5.

- pH is the measure of the hydrogen ion strength. At equilibrium, the hydroxyl and hydrogen ions are present in equal numbers and the water is considered neutral.



- The balance of the H^+ and OH^- determines the pH of the water. Adding an acid to neutral water increases the number of hydrogen ions, conversely adding a base will increase the number of hydroxyl ions.

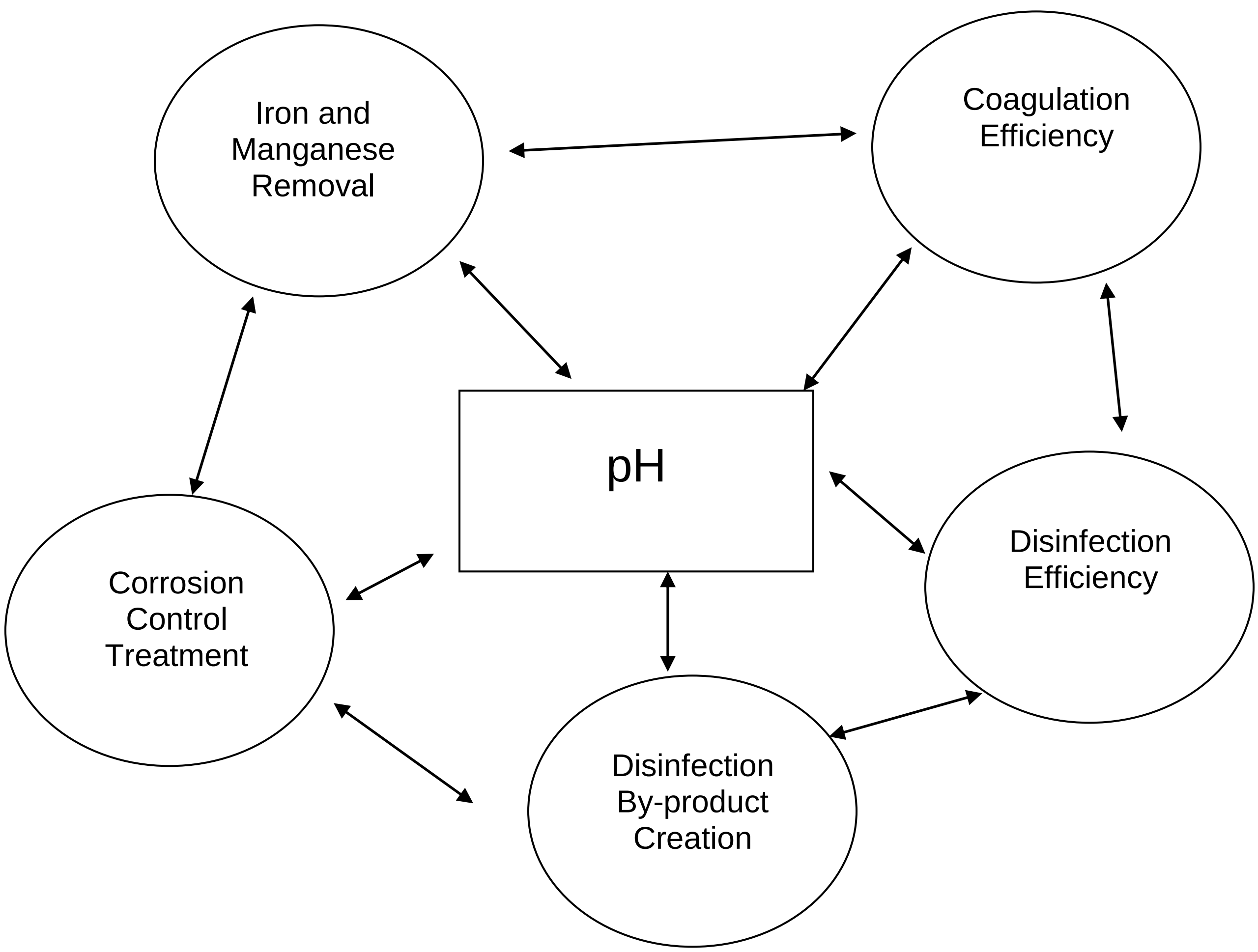
$H^+ > OH^-$ = acidic solution
$H^+ < OH^-$ = basic solution
$H^+ = OH^-$ = neutral solution

- Like the acidic coagulants listed above, other chemicals in water treatment affect pH.

Table 1.2

If you add		The pH will be: raised/lowered
Potassium hydroxide	K**OH**	
Nitric Acid	**H**NO_3	
Calcium Hydroxide Hydrated Lime	Ca(**OH**)$_2$	
Calcium Hydroxide Slaked Lime	Ca(**OH**)$_3$	
Sulfuric Acid	**H**$_2SO_4$	
Sodium Hydroxide AKA: Caustic Soda	Na**OH**	
Soda Ash	Na_2CO_3	
Hydrochloric Acid	**H**Cl	

- pH is the single most important parameter in water treatment. Practically every phase of water treatment is pH dependent. The pH of a water system is usually dynamic and a change in water chemistry will often be reflected by a change in pH.



Alkalinity

Definition: the capacity of a water to neutralize acids. This capacity is caused by the water's content of bicarbonate, carbonate and hydroxide.

- A system's ability to maintain stable water chemistry seems to be influenced by the alkalinity concentration of its water.
- Generally, alkalinity should be 20 mg/L or above to give sufficient buffering (prevent pH from changing). Without sufficient buffering, pH control is very difficult.
- The amount of alkalinity in the source (raw) water is generally not a problem unless the alkalinity is low.
- Alkalinity is needed to provide anions, such as (OH) for forming insoluble compounds to precipitate them out. Alkalinity can be naturally present or may need to be added. However, it is important to note that 1 part alum uses 0.5 parts alkalinity and 1 part ferric chloride will consume 0.92 parts alkalinity for proper coagulation.
- Sodium bicarbonate (Bicarbonate Soda) will make water more alkaline. It can be used when you only want to increase the alkalinity.
- pH adjustment chemicals may also increase alkalinity. Therefore, alkalinity may be increased by the addition of lime, caustic soda or soda ash.

Taste and Odor Control

Taste and odor in drinking water are among the most common and difficult problems that confront waterworks operators. And most customers judge their water quality by taste and odor. Ironically, many harmful contaminants cannot be detected by the taste or odor of the water and many of the tastes and odors that are detected are not harmful. However, the extensive public relations difficulties resulting from taste and odor make it important to treat these problems. Sources of taste and odor problems can be found in ground and surface water.

- Prevention of taste and odor is considered the best way to treat taste and odor.
    - Source water protection is the best way to prevent taste and odor issues.
        - Protect supply from contaminants such as gasoline, industrial solvents, and volatile organics.
    - Many taste and odors come from algae growth.
        - Source water protection can help reduce algae growths from pollution from domestic waste, run-off from fertilizer and animal, domestic and industrial waste.
        - Use copper sulfate in reservoirs to prevent algae growth.
    - Possibly use chlorine shock treatments to avoid algae growth in treatment plant basins.
    - Periodically flush distribution system and ensure adequate chlorine to keep pipes clean and odor free.

- Treatment of taste and odor compounds can be accomplished through the use of various chemicals which are added to remove tastes and odors. There are two general methods for controlling tastes and odors.

    - Removal of the causes of the tastes and odors can be accomplished through:

        - Optimum coagulation/flocculation/sedimentation.

        - Degasification / Aeration are practical solutions for taste and odor when the problem is cause by volatile compounds, such as hydrogen sulfide.

        - Adsorption with activated carbon.

    - In most cases, oxidation is the best way for controlling taste and odor problems. Oxidation/Destruction can be carried out with the following chemicals:
        - Potassium permanganate is a very strong oxidant. A dosage range of 0.1 to 0.5 mg/L can control taste and odor problems.
        - Ozone is effective in oxidizing taste and odor compounds. Ozone changes the characteristics of the taste and odor in addition to reducing the level of the odor producing compounds.
        - Chlorine dioxide, sodium chlorite, chlorine and sodium hypochlorite are also effective methods of taste and odor control.

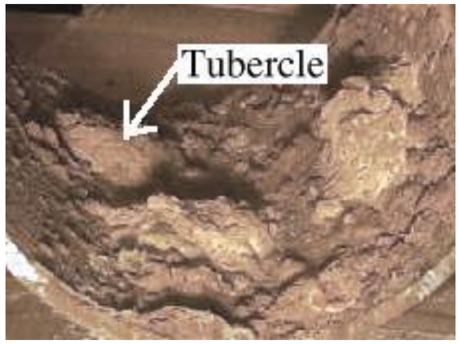
Removal of Trace Elements and Heavy Metals

Water may need softened to remove excess hardness caused by calcium and magnesium. Additionally, iron and manganese are undesirable because they will cause undesirable color in water and stain clothes and plumbing fixtures. There are three processes by which these removals are accomplished.

- Oxidation
- Improved Coagulation/Flocculation/Sedimentation
- Lime Softening

Corrosion Control and Sequestration

Corrosive water is characterized by pH and alkalinity values that are somewhat lower than they should be for the water to be considered “stable”. Corrosive water can cause the materials it comes in contact with to deteriorate and dissolve into the water.



- Chemical Treatment of Corrosive Water
  - Stabilizing the water is often the simplest form of corrosion control.
    - As pH increases, corrosion decreases.
    - As alkalinity increases, corrosion decreases.
      - Add alkalinity in the form of lime, soda ash, or caustic soda to make the water stable or slightly scale-forming.
  - The second type of corrosion control treatment is the use of corrosion inhibitors.
    - Corrosion inhibitors are specially formulated chemicals that:
      - Form thin protective films on pipe walls which can prevent corrosion.
      - Can be used to control scale build up.
    - Types of inhibitors include:
      - Phosphate inhibitors (polyphosphates, Orthophosphates, Ortho/Poly blends)
      - Silicate Inhibitors
- Sequestering
  - Polyphosphates are also sequestering agents:
    - They keep iron, manganese and calcium in solution thereby preventing the formation of precipitates that could deposit scale or cause discoloration.

Fluoridation

- Fluoride compounds are voluntarily added to some drinking water systems in Pennsylvania. Water systems may decide to fluoridate a water supply as a public health measure to reduce the number of dental cavities in children who drink the water. Fluoride is not required by EPA or DEP.

Disinfection

Disinfection kills or inactivates disease-causing organisms in a water supply. Methods of disinfection include chlorination, chloramines, ozone, and chlorine dioxide. There are two kinds of disinfection:

- Primary disinfection achieves the desired level of microorganism kill or inactivation.

- Secondary disinfection maintains a disinfectant residual in the finished water that prevents the regrowth of microorganisms.

Residuals Management

Sludge conditioning prepares sludge for further processing.

- Addition of lime, coagulants or polymers

CHEMICAL USAGE TABLE								
Chemical Name	Chemical Formula	Common Use	Available Forms	Weight lb/ft^3 or lb/gal	Commercial Strength	Best Feeding Form	Active Chemical Strength lb/gal	Batch Strength lb/gal
Activated Carbon	C	Odor Control Organics Removal	Powder	12 lb/ft^3	100	Dry to form slurry (1)	1.0	1.0
Aluminum Sulfate (Alum)	$Al_2(SO_4)_3 \cdot 14\ H_2O$	Coagulation	Lump, Granular, Rice, Ground, Powder	60 – 75 lb/ft^3	98%	Dry to form solution	0.5	0.5
Aluminum Sulfate (Liquid Alum)	$Al_2(SO_4)_3 \cdot X\ H_2O$	Coagulation	Liquid	11.1 lb/gal (SG = 1.33)		Liquid	5.48	Neat
Ammonia	NH_3	Disinfection	Liquefied Gas	40.0 lb/ft^3	100%	Gas	NA	NA
Ammonium Hydroxide	NH_4OH	Disinfection	Liquid			Liquid		Neat
Blended Phosphates	Varies with manufacturer	Corrosion Control	Powder, Liquid	Varies	Varies	Varies	varies	Per Manufacturer
Calcium Hydroxide (Hydrated Lime)	$Ca(OH)_2$	pH Adjustment & Coagulation	Powder	20 – 50 lb/ft^3	82 – 95%	Dry to form slurry	0.93 (10% slurry)	0.93 (10% slurry)
Calcium Oxide (Quick Lime)	CaO	pH Adjustment & Coagulation	Lump, Pebble, Granular, Ground, Pellet	Granules 68 – 80 Powder 32 – 50 lb/ft^3	70 – 96% (below 85% can be poor quality)	¼ - ¾ inch pebble (Slaker) Feed as slurry	1.4 – 3.3 (Slaker) (2.1 avg)	0.93 (10% slurry)
Chlorine Gas	Cl_2	Disinfection, Taste & Odor Control	Liquefied Gas	91.7 lb/ft^3	100	Gas	NA	NA
Ferric Chloride	$FeCl_3$	Coagulation	Liquid	11.2 lb/gal (SG = 1.4)	35 – 45%	Liquid	4.40	Neat
Ferric Sulfate	$Fe_2(SO_4)_3 \cdot X\ H_2O$	Coagulation	Granules	70 72 lb/ft^3	68 – 76%	Dry to form solution	5.5	5.5 lb/gal max

CHEMICAL USAGE TABLE (cont'd.)								
Chemical Name	Chemical Formula	Common Use	Available Forms	Weight lb/cu ft or lb/gal	Commercial Strength	Best Feeding Form	Active Chemical Strength lb/gal	Batch Strength lb/gal
Hydrofluosilicic Acid	H_2SiF_6	Fluoridation	Liquid	10.1 lb/gal (SG = 1.2)	15 – 30 %	Liquid	1.77	Neat
Orthophosphates	Varies with manufacturer	Corrosion Control	Powder, Liquid	Varies	Varies	Varies	varies	Per Manufacturer
Ozone	O_3	Disinfection, Taste & Odor Control	Gas		Generated on Site @ 0.5 – 1.0%	Gas	NA	NA
Poly Aluminum Chloride		Coagulation	Liquid	10.1 lb/gal (SG = 1.2)		Liquid	3.3	Neat
Polymers	Varies with polymer	Coagulation, Sludge Conditioning, Wastewater treatment	Flake, Powder, Liquid, Emulsion	Varies with polymer	Varies with polymer	Varies with polymer & application	Varies with polymer & application	Per Manufacturer
Polyphosphates	Varies with manufacturer	Corrosion Control	Powder, Liquid	Varies	Varies	Varies	varies	Per Manufacturer
Potassium Permanganate	$KMnO_4$	Iron & Manganese Removal, Odor Control	Crystal	86 – 102 lb/ft^3	97%	Dry to form solution	0.5	0.5
Sodium Bicarbonate	$NaHCO_3$	pH Adjustment & Coagulation	Granular, Powder	59 – 62 lb/ft^3	99%	Dry to form solution	0.3	0.3
Sodium Bisulfite	$NaHSO_3$	Dechlorination	Liquid	11.1 lb/gal (SG = 1.33)		Liquid	3.2 – 3.5	Neat
Sodium Carbonate (Soda Ash)	Na_2CO_3	pH Adjustment & Coagulation	Granular, Powder	50 – 70 lb/ft^3	98%	Dry to form solution	0.25	0.25
Sodium Chlorite	$NaClO_2$	Disinfection, Taste & Odor Control	Crystals, Powder, Flakes	65 – 75 lb/ft^3	80%	Dry to form solution	0.12 - 2.0	0.12 – 2.0

CHEMICAL USAGE TABLE (cont'd.)								
Chemical Name	Chemical Formula	Common Use	Available Forms	Weight lb/cu ft or lb/gal	Commercial Strength	Best Feeding Form	Active Chemical Strength lb/gal	Batch Strength lb/gal
Sodium Chlorite	$NaClO_2$	Disinfection, Taste & Odor Control	Solution	10.26 lb/gal (SG = 1.23)	25%	Liquid	2.08	Neat
Sodium Fluoride	NaF	Fluoridation	Granular, Crystals, Powder	65 – 100 lb/ft^3	95 – 98%	Granular to form solution	0.08 – 0.2	0.08 – 0.2
Sodium Hexa-Meta Phosphate	$(NaPO_3)_6$	Corrosion Control	"Glass"	65 – 100 lb/ft^3	67%	Dry to form solution	1.0	1.0
Sodium Hydroxide	NaOH	pH Adjustment & Coagulation	Flake, Lump, Powder	45 – 70 lb/ft^3	99%	Dry to form Solution		
Sodium Hydroxide (Caustic Soda)	NaOH	pH Adjustment & Coagulation	Liquid	12 – 75 lb/gal	12 – 50%	Liquid	6.38 for 50% solution	Neat
Sodium Hypochlorite	NaOCl	Disinfection, Taste & Odor Control	Liquid	10.1 lb/gal	12 – 15 %	Liquid	1.0 – 1.25 as Cl_2	Neat
Sodium Silica fluoride	Na_2SiF_6	Fluoridation	Granular, Powder	60 – 105 lb/ft^3	98.5%	Dry to form solution	0.017	0.017
Sodium Sulfite	Na_2SO_3	Dechlorination	Powder, Crystal	50 – 100 lb/ft^3	93 – 99%	Dry to form solution	0.25 – 0.5	0.25 – 0.5
Sodium Thiosulfate	$Na_2S_2O_3 \cdot 5\,H_2O$	Dechlorination	Crystal, Rice	53 –60 lb/ft^3	98 – 99%	Dry to form solution	0.1	0.1
Sulfur Dioxide	SO_2	Dechlorination	Liquefied Gas	89 lb/ft^3	100	Gas	NA	NA
Sulfuric Acid	H_2SO_4	pH Adjustment	Liquid	14.2 lb/gal (SG = 1.7)		Liquid	11.08	Neat

Exercise

Fill in the blank

1. ________________: The clumping together of very fine particles into larger particles (floc) caused by the use of chemicals. The chemicals destabilize the fine particles.

2. ____________________: Add density to slow settling flocs and toughness to the flocs so that they will not break up during the mixing and settling process.

3. __________: an expression of the intensity of the basic or acidic condition of a liquid.

4. __________________: The capacity of a water to neutralize acids.

5. __________________and __________________ may cause excessive hardness, therefore water may need softened.

6. _____________________ _____________: keep iron, manganese, and calcium in solution thereby preventing the formation of precipitates.

7. _____________ ____________ achieves the desired level of microorganism kill or inactivation.

8. __________________ ______________ maintains a disinfectant residual in the finished water that prevents the regrowth of microorganisms.

9. Complete the following table indicating if the pH will be raised or lowered

If you add:	*The pH will be raised or lowered*
1. NaOH	
2. Aluminum Sulfate	
3. $Ca\ (OH)_2$	
4. Sulfuric Acid	
5. H_2SiF_6	
6. Ferric Chloride	
7. Na_2CO_3	

Use the Chemical Usage Table to complete questions 10 and 11.

10. List the chemicals you might add to control odor. Include the chemical name and best feeding form for each.

11. Name several chemicals which might be added during the coagulation process. Include examples of coagulants and other chemicals that will change the water characteristics to promote coagulation.

- Various chemicals are used in the treatment of water. Chemicals can be a solid, liquid, or gas.
- Coagulation is the clumping together of very fine particles into larger particles (floc) caused by the use of chemicals.
- Chemicals used to increase pH are KOH, $Ca(OH)_2$, $Ca(OH)_3$, NaOH, Na_2CO_3
- Sodium bicarbonate (Bicarbonate Soda) will make water more alkaline. It can be used when you only want to increase the alkalinity.
- pH adjustment chemicals may also increase alkalinity. Therefore, alkalinity may be increased by the addition of lime, caustic soda or soda ash.
- Aluminum salts and ferric salts can have low pH values and will therefore decrease the pH of raw water.
- It is important to know what a chemical does in water treatment so that the incorrect chemical is not used.
- By using the correct amount of chemicals in water treatment operator and public safety is protected while a quality water supply is produced.
- Taste and odor chemicals include potassium permanganate, ozone, chlorine dioxide, sodium chlorite, chlorine and sodium hypochlorite

Unit 2 – Safety and Handling

Learning Objectives

- When given a ***Safety Data Sheet*** and specific chemical names, identify specific information related to chemical characteristics and other information provided.
- List the five components of Chemical Handling Equipment.

Safety Data Sheets (formerly MSDS)

A Safety Data Sheet, or SDS, is available from the chemical manufacturer/supplier for every chemical. For years, these sheets were commonly known as MSDS for Material Safety Data Sheet. However, the Occupational Safety and Health Administration (OSHA) Hazard Communication Standard of 2012 (HazCom 2012) mandates the use of a single format for safety data sheets featuring 16 sections. MSDS sheets can used by manufacturers until June 1, 2015, but many manufacturers are complying before this date.

You should read and understand the SDS for each chemical used in the plant. You should also maintain a personal copy for all hazardous chemicals that are used.

An SDS contains detailed assessments of chemical characteristics, hazards and other information relative to health, safety and the environment. The SDS includes:

- **Section 1, Identification**
- **Section 2, Hazard(s) identification**
- **Section 3, Composition/information on ingredients**
- **Section 4, First-aid measures**
- **Section 5, Fire-fighting measures**
- **Section 6, Accidental release measures**
- **Section 7, Handling and storage**
- **Section 8, Exposure controls/personal protection**
- **Section 9, Physical and chemical properties**
- **Section 10, Stability and reactivity**
- **Section 11, Toxicological information**
- **Section 12, Ecological information**
- **Section 13, Disposal considerations**
- **Section 14, Transport information**
- **Section 15, Regulatory information**
- **Section 16, Other information,** includes the date of preparation or last revision.

Example of an SDS – Fluorosilicic Acid (Fluoride)

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MATERIAL SAFETY DATA SHEET

Fluorosilicic Acid

Section 01 - Chemical And Product And Company Information

Product Identifier ……………………….. Fluorosilicic Acid

Product Use …………………………… Water fluoridation and wood preservation.

Supplier Name…………………………. ClearTech Industries Inc.
2303 Hanselman Avenue
Saskatoon SK S7L 5Z3
Canada

Prepared By……………………………. ClearTech Industries Inc. Technical Department
Phone: (306)664-2522

Preparation Date………………………. February 8, 2011

24-Hour Emergency Phone…………. 306-664-2522

Section 02 - Composition / Information on Ingredients

Hazardous Ingredients………………..	Hydrofluorosilicic acid	23-27%
CAS Number…………………………….	Hydrofluorosilicic acid	16961-83-4
Synonym (s)…………………………….	Fluosilicic acid, hydrofluorosilicic acid, hydrofluosilicic acid, hexafluosilicic acid	

Figure 2.1 Aluminum Sulfate, Liquid – SDS[1]

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Section 03 - Hazard Identification

Inhalation.. Irritating to nose, throat, and respiratory system. May be corrosive to respiratory system with prolonged contact. Symptoms of exposure may include burning sensation, coughing, wheezing, laryngitis, shortness of breath, headache, nausea and vomiting.

Skin Contact / Absorption.............. May cause irritation, redness or swelling with contact.

Eye Contact...................................... Contact may cause severe irritation, watering, redness and swelling.

Ingestion.. May cause nausea, vomiting, abdominal pain and burns if ingested.

Exposure Limits.............................. ACGIH-TLV: 2.5mg/m^3 (as F)
OSHA-PEL: 2.5mg/m^3 (as F)

Section 04 - First Aid Measures

Inhalation.. Remove victim to fresh air. Give artificial respiration only if breathing has stopped. If breathing is difficult, give oxygen. Seek medical attention if difficulties persist.

Skin Contact / Absorption.............. Remove contaminated clothing. Wash affected area with soap and water. Seek medical attention if irritation occurs or persists.

Eye Contact...................................... Flush immediately with water for at least 20 minutes. Forcibly hold eyelids apart to ensure complete irrigation of eye tissue. Seek immediate medical attention

Ingestion.. Do not induce vomiting. Give large amounts of water. Do not give anything by mouth to an unconscious or convulsing person. Seek immediate medical attention.

Additional Information...................Beware of late onset pulmonary edema for up to 48 hours. Treat severe burns as per hydrofluoric acid exposure with a calcium gluconate jelly.

Section 05 - Fire Fighting

Conditions of Flammability............ Non-flammable

Means of Extinction........................ Product does not burn. Where fire is involved, use any fire fighting agent appropriate for surrounding material; use water spray to cool fire-exposed surfaces.

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Flash Point................................. Not applicable

Auto-ignition Temperature............. Not applicable

Upper Flammable Limit .... Not applicable

Lower Flammable Limit.................. Not applicable

Hazardous Combustible Products... Corrosive fumes of hydrogen fluoride and silicon tetrafluoride will occur when decomposition occurs 105°C.

Special Fire Fighting Procedures.... Wear NIOSH-approved self-contained breathing apparatus and protective clothing.

Explosion Hazards........................ Not available

Section 06 - Accidental Release Measures

Leak / Spill....................................... Wear appropriate personal protective equipment. Ventilate area. Stop or reduce leak if safe to do so. Prevent material from entering sewers and surface water. Dike spill area with sand or earth.

Deactivating Materials.................. Small spills can be neutralized with hydrated lime.

Section 07 - Handling and Storage

Handling Procedures...................... Use proper equipment for lifting and transporting all containers. Use sensible industrial hygiene and housekeeping practices. Wash thoroughly after handling. Avoid all situations that could lead to harmful exposure.

Storage Requirements.................... Store in a cool, dry, well-ventilated place. Keep container tightly closed, and away from incompatible materials. Do not store in glass or stoneware. Most metals are incompatible so avoid contact.

Section 08 - Personal Protection and Exposure Controls

Protective Equipment

Eyes.. Chemical goggles, full-face shield, or a full-face respirator is to be worn at all times when product is handled. Contact lenses should not be worn; they may contribute to severe eye injury.

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Respiratory................................ A NIOSH approved cartridge respirator with full-face shield. Chemical cartridge should provide protection against acid fumes (hydrogen fluoride). For concentrations greater than 20ppm, a NIOSH approved self-contained breathing apparatus with full-face shield should be used.

Gloves.. Impervious gloves of chemically resistant material (rubber or neoprene) should be worn at all times. Wash contaminated clothing and dry thoroughly before reuse.

Clothing.. Body suits, aprons, and/or coveralls of chemical resistant material should be worn at all times. Wash contaminated clothing and dry thoroughly before reuse.

Footwear....................................... Impervious boots of chemically resistant material should be worn at all times.

Engineering Controls

Ventilation Requirements.............. Mechanical ventilation (dilution or local exhaust), process or personnel enclosure and control of process conditions should be provided. Supply sufficient replacement air to make up for air removed by exhaust systems.

Other... Emergency shower and eyewash should be in close proximity.

Section 09 - Physical and Chemical Properties

Physical State.................................. Liquid

Odor and Appearance..................... Colourless to pale yellow liquid with a pungent odour

Odor Threshold.............................. Not available

Specific Gravity (Water=1).............. 1.234 at 15.6°C and 24% concentration

Vapor Pressure (mm Hg, 20C)......... 218 at 75°C

Vapor Density (Air=1)..................... Not available

Evaporation Rate............................ Not available

Boiling Point.................................... 105°C

Freeze/Melting Point...................... -15°C

pH.. Approximately 1.0

Water/Oil Distribution Coefficient.... Not available

Bulk Density..................................... 10.29lbs/gal at 25% concentration

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% Volatiles by Volume……….……... Not available

Solubility in Water...…………………... Completely miscible

Molecular Formula.......………….…... H_2SiF_6

Molecular Weight.........………………..... 144.08

Section 10 - Stability and Reactivity

Stability..................……………....…………… Stable under normal conditions.

Incompatibility..........……………...……… Metals, glass, alkali, ceramics, and strong concentrated acids. Strong concentrated acids will cause the liberation of poisonous hydrogen fluoride. Hydrofluorosilicic acid will attack glass and ceramics. Metals will be corroded and liberate hydrogen gas.

Hazardous Products of Decomposition.. Stable at room temperature. Attacks glass and stoneware. Decomposes to form hydrogen fluoride and silicon tetrafluoride when heated. Heat is generated when product is added to water.

Polymerization...........……………….……… Will not occur

Section 11 - Toxicological Information

Irritancy..................………..……………… Product is corrosive.

Sensitization........……........…………..Not available

Chronic/Acute Effects……...……… Liquid or vapours can cause burns which may not be apparant for hours. Prolonged exposure can result in: bone changes; corrosive effect on mucous membranes; ulceration of nose, throat, and bronchial tubes; cough, shock, pulmonary edema, fluorosis, coma, and death.

Synergistic Materials...……....……... Not available

Animal Toxicity Data........…..……….. LD_{50}(oral,guinea pig): 200mg/kg

Carcinogenicity......……......………... IARC: Group 3 carcinogen (listed as ** undefined **).

Reproductive Toxicity...….....……... Not available

Teratogenicity..........…....………….. Not available

CLEARTECH

Mutagenicity..........……......………… Not available

Section 12 - Ecological Information

Fish Toxicity..................…………….. Not available

Biodegradability..............………..…..... Not available

Environmental Effects……………….. Not available

Section 13 - Disposal Consideration

Waste Disposal...........…....………….. Dispose in accordance with all federal, provincial, and/or local regulations including the Canadian Environmental Protection Act.

Section 14 - Transportation Information

TDG Classification

Class……………...…………………..…..... 8

Group...............…………….........……... II

PIN Number.................…...…………..... UN 1778

Other……………………………………...... Secure containers (full and/or empty) with suitable hold down devises during shipment.

Section 15 - Regulatory Information

WHMIS Classification.......……………....E, D1

NOTE: THE PRODUCT LISTED ON THIS MSDS HAS BEEN CLASSIFIED IN ACCORDANCE WITH THE HAZARD CRITERIA OF THE CANADIAN CONTROLLED PRODUCTS REGULATIONS. THIS MSDS CONTAINS ALL INFORMATION REQUIRED BY THOSE REGULATIONS.

NSF Certification................................Product is certified under NSF/ANSI Standard 60 for fluoridation at a maximum dosage of 6mg/L.

Section 16 - Other Information

Note: The responsibility to provide a safe workplace remains with the user. The user should consider the health hazards and safety information contained herein as a guide and should take those precautions required in an individual operation to instruct employees and develop work practice procedures for a safe work environment. The information contained herein is, to the best of our knowledge and belief, accurate. However, since the conditions of handling and use are beyond our control, we make no guarantee of results, and assume no liability for damages

Activity – Reading an SDS

Use the SDS on the previous pages to complete the following.

1. True or False – Fluorosilicic acid is an eye and skin irritant, but does not affect the respiratory system.
2. Is fluorosilicic acid flammable Yes/No
3. Protective clothing and equipment to be worn when handling fluorosilicic acid includes which of the following?:
    a. Rubber apron
    b. Rubber gloves
    c. Face shield
    d. Dust mask
5. What is the specific gravity of fluorosilicic acid? _______
6. Which of the following is fluorosilicic acid incompatible with?
    a) Metals
    b) PVC
    c) Glass
    d) Ceramics

The chemicals used at a treatment facility are harmful not only to system employees but also visitors; contractors and anyone else close the facility. The first step in protection is to understand the five components to Chemical Handling Equipment. Next is to develop an Emergency Response Plan.

The components of Chemical Handling Equipment are: Selection of Equipment, Labels and Warning Signs, Breathing Protection, Protective Clothing, and Protective Equipment.

Five Components of Chemical Handling Equipment

1. Selection of Equipment

When handling chemicals use equipment listed on the MSDS.

2. Labels and Warning Signs

Labels

- All containers, whether used to store, dispense, process, or transport chemicals, should bear some form of precautionary labeling.
- The label should identify the chemical and its potential hazards.

Signs

- Warning signs should be used to alert employees to hazardous conditions.
- Three basic sign forms:
  - Warning signs – depict general nature of hazard
  - Regulatory signs – “No Smoking,” “Eye Protection Required,” etc.
  - Pictorial signs for required personal protective equipment

3. Breathing Protection

- Select breathing protection based on exposure.
- Provide adequate protection for the given working condition.
  - Use Mine Safety and Health Administration (MSHA)/ National Institute for Occupational Safety and Health (NIOSH) approved equipment.
- Considerations:
  - Level of airborne contamination.
    - Use appropriate filter for specific contaminant exposure.
  - Type of work activity and exposure.
  - Presence of sufficient oxygen.
    - Self Contained Breathing Apparatus (SCBA) for oxygen deficient atmosphere.
      - Store SCBA equipment upwind from suspect chemicals and in a known location.

4. Protective Clothing

- Select protective clothing based on the chemical to be handled.
- Materials should be compatible with the required protection.
  - Boots, Gloves, Apron
  - Protective chemical safety goggles
  - Face shield

5. Protective Equipment

Emergency	Preventative
Emergency eye wash stations	Dust Collectors
Deluge Showers	Leak monitoring and detection equipment
	Exhaust fans

Emergency Response Planning

An emergency response plan (ERP) must be developed to help a system protect public health, limit damage to the system and the surrounding area, and help a system return to normal as soon as possible. Employees who are prepared know what actions must be taken in the event of an emergency. A good ERP includes:

- Contact information – who do you need to call in the event of an emergency.
    - Internal Organization
    - Outside Contact Information

- Assessment of Available Resources – what equipment do you have on hand that can help during an emergency situation?

- Corrective Actions For Probable Emergency Situations – this would include descriptions of emergency measures to be taken.

The Pennsylvania Department of Environmental Protection has a template you may use to develop an ERP. "Emergency Response Plan Template for Water Suppliers (3800-FM-WSFR0300) - Water suppliers can use this template to address all emergency response plan elements required under Chapter 109.707 including new requirements that became effective May 9, 2009 when the PN revisions were published. This template includes 8 sections. "

Remember, ERP's must:

- Be simple and understandable.

- Be updated annually – this is a living document, people change, numbers change!

- Be placed in secure locations – can it be located when needed?

- Practiced – will it work when put to the test?

Exercise

1. Operators are expected to keep a copy of each ____________ _____________ ____________ with regard to each of the hazardous chemicals used at their treatment facility.

2. List the three basic types of warning signs used and an example of how it will alert employees to hazardous conditions.

Sign	Alert
1.	
2.	
3.	

3. What types of protective clothing may be used with the various chemicals handled? Circle all that apply.

   A. Boots

   B. Gloves

   C. Apron

   D. Goggles

   E. Face Shield

4. List 3 components of a good Emergency Response Plan

   A.

   B.

   C.

- The single most important resource for finding information about a chemical is the Safety Data Sheet (SDS).

- When using chemicals, protections are necessary. These protections include labels, signs, and safe chemical handling equipment. Not all chemicals require the same protections.

- A good Emergency Response Plan contains contact information, an assessment of available resources to be used in the event of an emergency in addition to corrective actions which describe the types of emergency measures to be taken.

[1] ClearTech Chemical Corporation. “Fluorosilicic Acid Safety Data Sheet” www.**cleartech**.ca/**msds**/sillyacid.pdf (08 February 2011)

Unit 3 – Chemical Feed System Components

Learning Objectives

- Review chemical feed system components and the associated purposes.
- Perform detention time calculations.
- Determine the feed rate through jar testing.
- Perform process control calculations including:
    - Adding dry chemicals to produce a % solution for a day tank
    - Solving feed rate equations for dry and liquid feed chemicals
    - Using specific gravity to calculate the weight of a chemical and the weight of the "active ingredients" within a solution.
    - Calculating theoretical pump output
    - Converting a pump output in mL/min to gal/day to develop a pump calibration curve.

Feed Systems

This section discusses chemical feed systems. Chemical feed systems are necessary components of treatment systems. As discussed, there are several chemicals which need fed into treatment systems; some of those chemicals are fed through solution feeders and some are fed through dry feeders.

Feed systems are an important aspect of the treatment process. Feed systems need to deliver chemicals into the treatment system at rates necessary for optimal performance. When designing a chemical feed system consider:

1. Building redundancy into the system so if there is a failure or malfunction in the primary system, a secondary system can be used.
2. Checking the feed pump dosage range. Feed pumps should be sized so that chemical dosages can be changed to meet varying conditions.
3. Evaluating the condition of the chemical feed system regularly. Preventative maintenance is critical for avoiding process upsets due to equipment breakdown.
4. Ensuring a good stock of repair parts for all critical equipment.

The proper knowledge of a chemical feed system is an essential part of controlling treated water chemistry. Since there are various techniques for feeding chemicals, an operator must know the type of chemical being used and the amount to be fed over a certain period of time. An illustration of a properly designed liquid chemical feed system is demonstrated in figure 3.2. Definitions/descriptions of each part follow.

Components of a Liquid Chemical Feed System

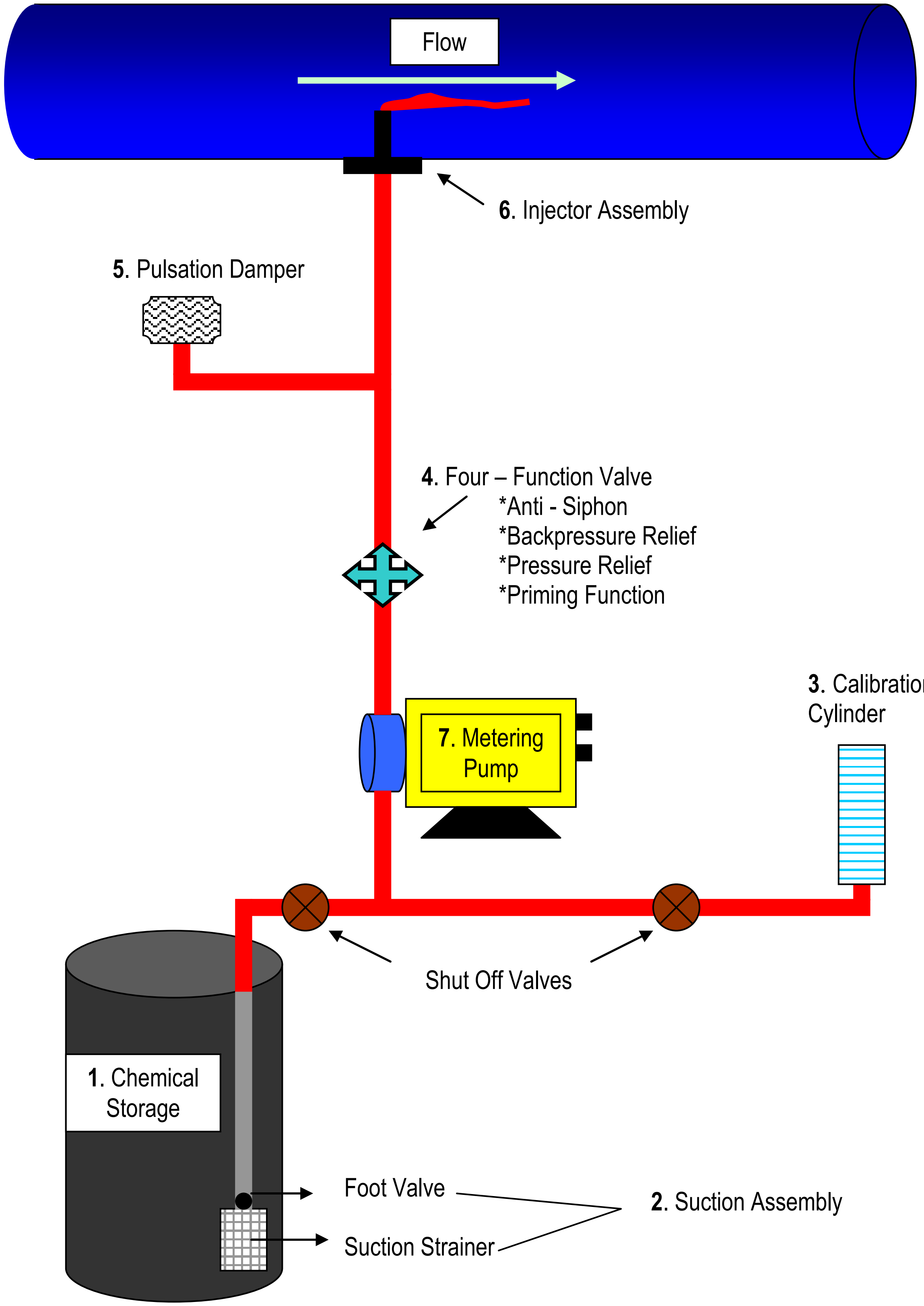


Figure 3.2

Description of Components of a Liquid Chemical Feed System

1. **Chemical Storage Containers** – Chemicals that are shipped from the manufacturer may be stored in containers that have many different shapes and sizes depending on the type and amount of chemical that was shipped. Primarily there are two types of storage containers used; one would be a chemical drum and the other might be a chemical storage tank.

   A. The chemical drum is used primarily when the solution is fed neat (undiluted).

   B. A day tank is used to store, dilute and mix chemicals.

      1. All chemical storage tanks should have some type of measuring device to let the operator know the amount of chemical that is in the storage tank at all times.

      2. Chemical spill containment should be provided to contain accidental spills of chemicals.

2. **Suction Assembly** – Should be suspended just above the bottom of the tank so as not to pull in any solids that might have settled to the bottom of the tank. The suction assembly consist of:

   A. Suction Strainer – A strainer is used to protect the internal components of the pump.

   B. Foot Valve – This is a check valve that is used to prevent the pump from losing prime.

3. **Calibration Cylinder** – A calibration cylinder consists of a graduated cylinder typically located on the suction side of the pump. It is used for accurate determination of the pump's feed rate.

4. **4-Function Valve** - A valve can be used to not only control flow, but the rate, the volume, the pressure or the direction.

   A. **Pressure relief valve** – When line pressure exceeds the set pressure, the diaphragm moves the valve stem off the seat of a pressure relief valve and dissipates the excess pressure.

   B. **Backpressure Valve** – A backpressure valve consists of an adjusting spring loaded diaphragm. It maintains a steady backpressure to ensure accurate delivery. Additionally, a backpressure valve prevents over pumping when little or no backpressure is present.

C. **Anti-Siphon Valve** – Negative pressures can be produced in normally pressurized lines due to power failures, draining of lines, inadvertent valve operation or fouled check valves. The anti-siphon valve prevents siphoning of the chemical storage tank into the distribution system when negative pressure is produced.

D. **Priming Function** – Simple way to prime your pump.

5. **Pulsation Dampener** – This is meant to offset surges created by the pulsating discharge pressure encountered when using either a piston or diaphragm metering pump. This helps a system combat water hammer (clanging of pipes caused by a change in direction of flow when a pump shuts off or a valve is closed).

6. **Injector Assembly** - The art of chemical injection is complex.

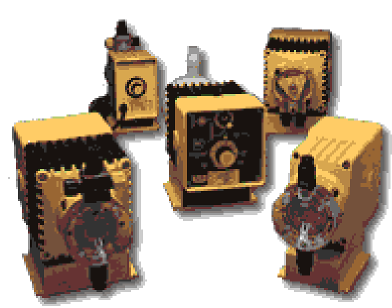
A. Installation is determined by the chemical being fed. And the order of chemical addition is important and should be specific to your system.

B. Location of the assembly is important for proper mixing. However, it also needs to be placed so it does not become clogged with passing debris that may be in the system.

7. **Liquid Chemical Feed Pump** – Pumps are made up of 2 major components; the drive assembly (motor) which provides power for the pumping action and the liquid end which is the area through which the solution is pumped. Positive displacement pumps are used to pump a measured dose of liquid chemical into a treatment system. While there are several types of positive displacement pumps, the most common:

A. Peristaltic Pump – Used for pumping a variety of fluids. The fluid is contained within a flexible tube fitted inside a circular pump casing.

B. Diaphragm Pump – Used to pump a variety of fluids and is more common than a peristaltic pump. Measures a liquid volume ensuring accurate delivery of a chemical solution.



How a Mechanical Diaphragm Metering Pump Works

Mechanical Diaphragm Metering Pump – The diaphragm pump is composed of the following:

- A chamber used to pump the fluid
- A diaphragm
- Two valve assemblies

Figure 3.3 shows the internal components of the pumping chamber when the pump is pulling chemical from the storage container. The plunger moves to the left or inward, the discharge check valve closes, the suction valve opens, and the chemical is pulled in to the chamber.

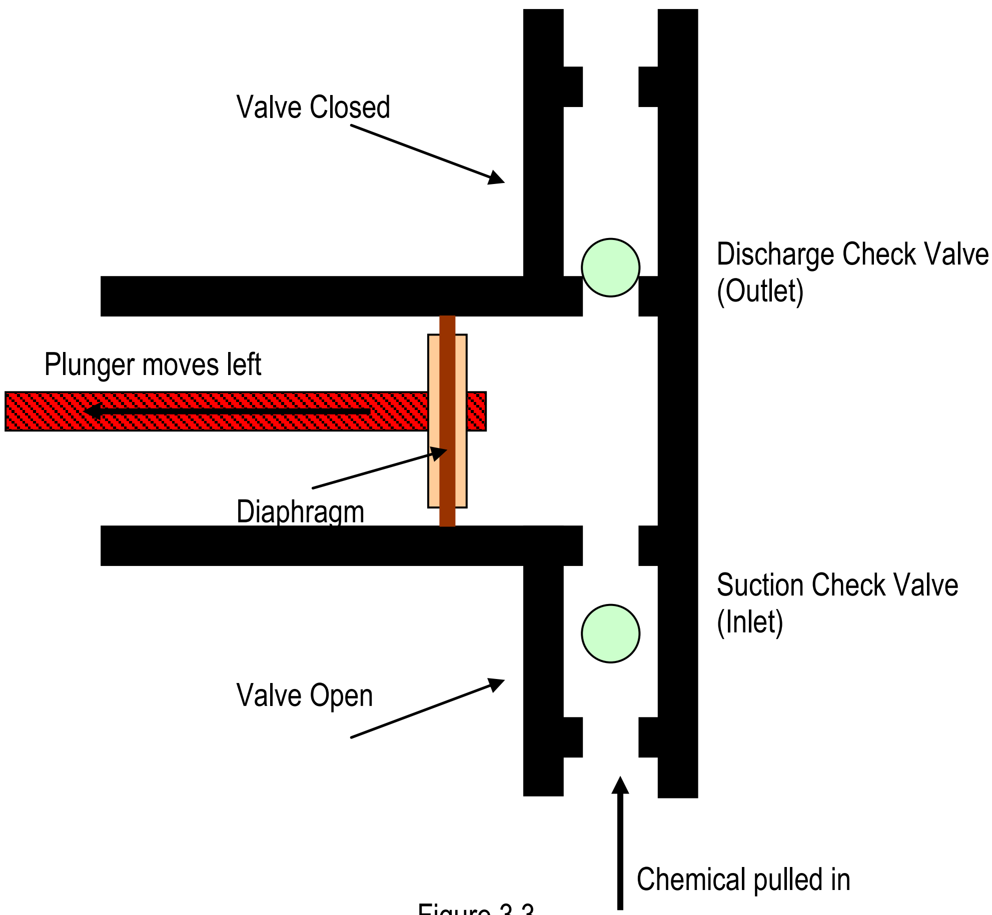


Figure 3.3

Figure 3.4 shows the internal components of the pumping chamber when the pump is pushing chemical into the system. The plunger moves to the right or outward, the suction check valve closes, the discharge check valve opens, and the chemical is pushed in to the system. The pumping cycle starts over at this point.

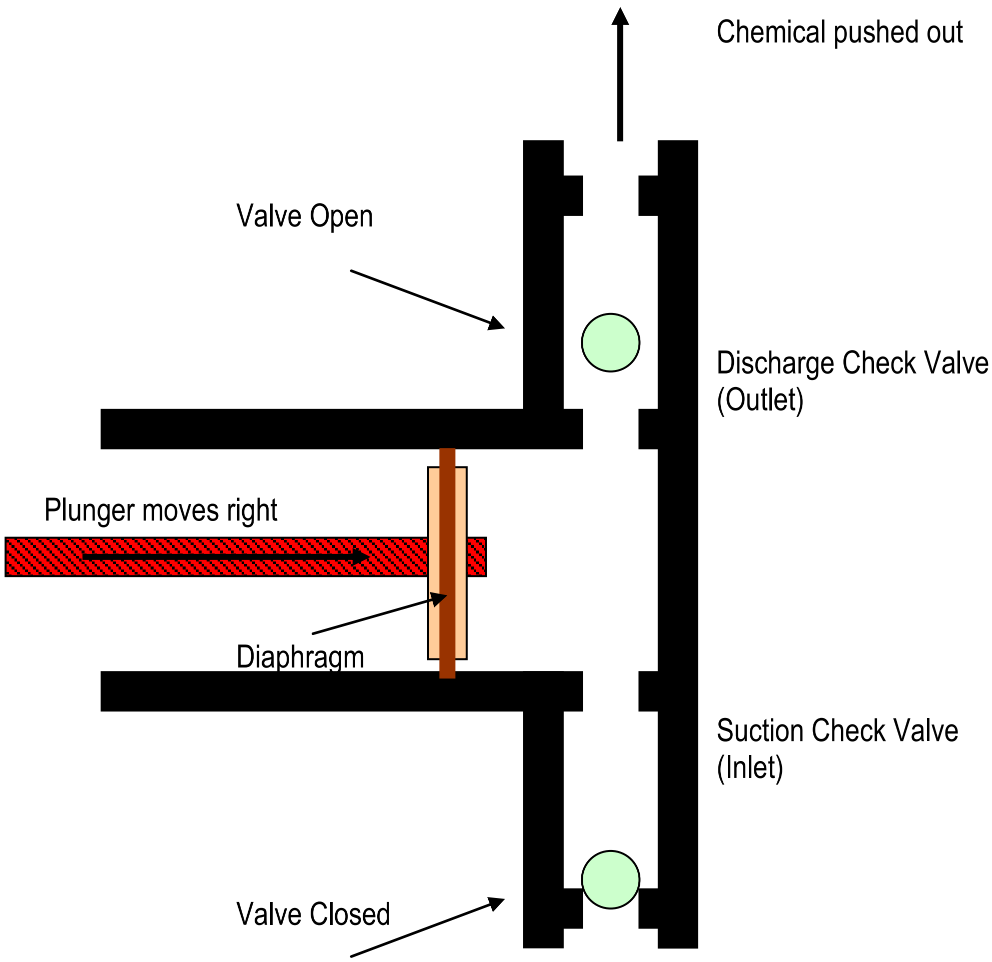


Figure 3.4

Adjusting Chemical Feed Pump Dosage – The output of the pump is controlled by the length of the plunger stroke and the number of repetitions of the stroke (the stroke and the speed).

- Changing the stroke is the way to make a major adjustment to a chemical feed system.
- Flow pacing may be used to control a metering pump. The main flow (usually of water) is monitored by the flow meter which in turn controls a metering pump. In this way, a chemical can be injected at a rate which matches the flow, for uniform concentration (the chemical feed rate is proportional to the water flow). For example, a chemical feed pump will decrease proportionally as plant flow decreases or vice versa.

Liquid Chemical Feed System Operation and Maintenance:

Proper design is important for a successful feed system but there is something that is even more critical: operation and maintenance of feed systems. Chemical feed systems will give years of trouble free operation if the following factors are considered:

1. Observe all operating components daily.

2. Maintain a regular schedule of maintenance on all equipment as per the manufacturer's recommendations.

3. Chemical metering pumps should be calibrated on a regular basis or when the operator suspects a problem with the pump (pump calibration demonstration to follow).

4. Any leak throughout the system will cause a reduction in the amount of chemical solution pumped. All leaks must be repaired as soon as they are discovered.
   - If the pump appears to be operating, but the chemical feed is less than expected, suspect a ruptured diaphragm.

5. The suction assembly on a chemical metering pump should be inspected and cleaned on a regular basis as per the manufacturer's recommendations.

6. All components that contact the chemical solution that is pumped should be disassembled, cleaned and inspected as per the manufacturer's recommendations.

Dry Chemical Feed Systems

Dry feeders are used for many purposes in a treatment facility. They can be used to feed lime, fluoride, carbon, and potassium permanganate. A dry feeder measures dry chemical and mixes it with water in a solution tank. The resulting solution is either pumped into the main water flow of the system or fed in using an ejector. An ejector system uses the Venturi effect to create a vacuum and moves the solution into the main water flow. The two basic types of dry feeders are volumetric and gravimetric feeders.

1. **Volumetric Dry Feeders** – Volumetric Dry Chemical Feeders are usually simpler to use, less expensive to operate, less accurate dry feeders and feed a smaller amount of chemical. The operation of this type of system is fairly simple. The chemical is usually stored in a silo above the unit and each time the system needs to make a new batch of solution a feed mechanism (rolls or screws) deliver exactly the same volume of dry chemical to the dissolving tank with each complete revolution. Varying the speed of rotation varies the feed rate.

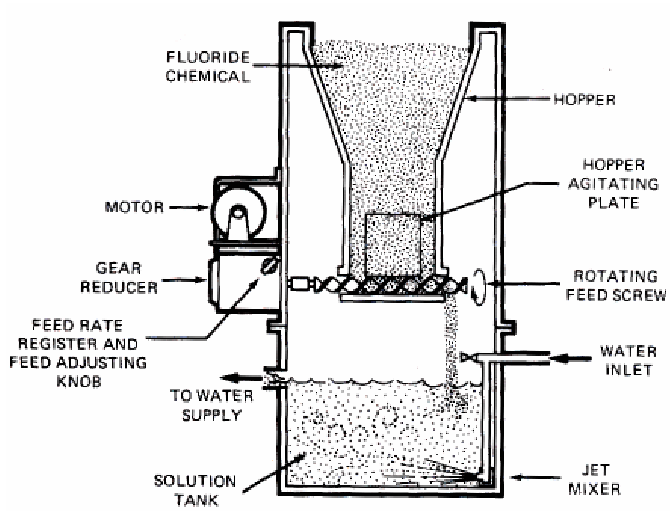


Figure 3.5

2. **Gravimetric Dry Feeders** – Gravimetric Dry Chemical Feeders are extremely accurate and can be adapted to automatic controls and recording. However, they are more expensive than Volumetric Dry Feeders. This is a belt-type feeder that delivers a certain weight of material with each revolution of the conveyor belt. Because gravimetric feeders control the weight of material, not the volume, variations in density have no effect on feed rate. This accounts for the extreme accuracy of this type of feeder.

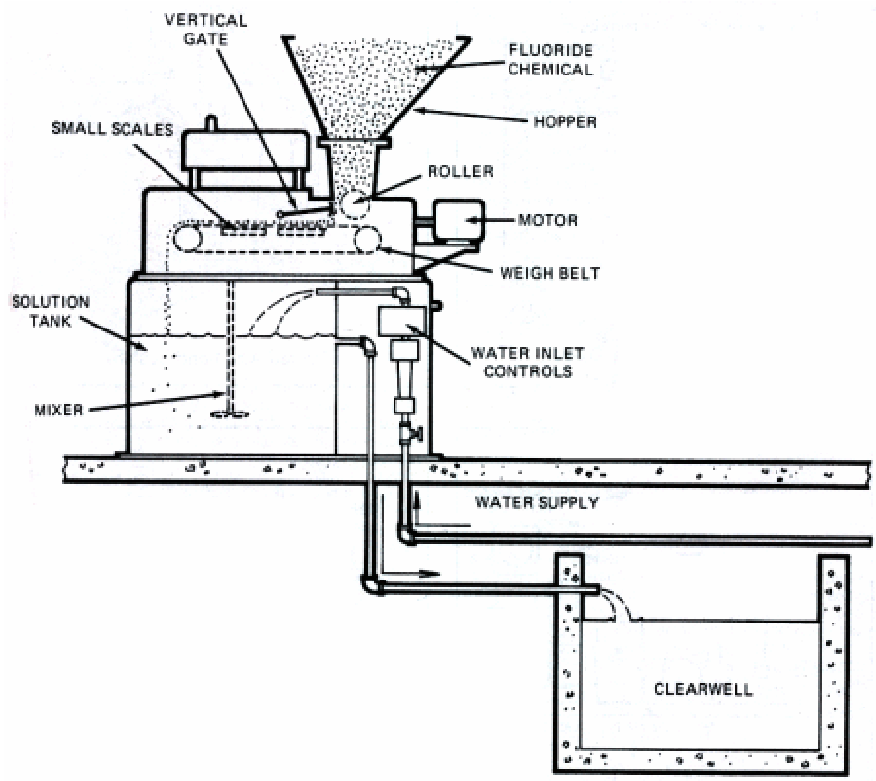


Figure 3.6

Dry Chemical Feed System Operation and Maintenance

1. Observe operating components daily.
2. Follow manufacturer's recommendations when performing maintenance.
3. These units are feeding fine powdery chemicals therefore cleaning and inspection of all moving parts should be conducted routinely.
4. After all preventative maintenance has been completed, proper calibration should be completed.

Detention Time

A properly designed chemical feed system is used to feed various chemicals. However, it is important that the optimum (best minimum) chemical dosage for the water you are treating is determined. Some chemical dosages are easier to determine than others. Jar testing is required to help determine some chemical dosages. However, design drawings may first be needed to help calculate expected detention times throughout the system. Detention time data can then be used during jar testing.

Detention time indicates the amount of time a given flow of water is retained by a unit process. Detention time can be calculated in any unit of time (i.e., seconds, minutes, hrs, days). It is calculated as the tank volume divided by the flow rate:

Detention Time Equation

$$\text{Theoretical Detention Time (minutes)} = \frac{\text{Volume of Tank (gallons)}}{\text{Influent Flow (gpm)}}$$

Volume units match = gallons

Time units match = minutes

There are two basic ways to consider detention time:

1. Detention time is the length of time required for a given flow rate to pass through a tank.

2. Detention time may also be considered as the length of time required to fill a tank at a given flow rate.

In order to calculate the detention times of tanks, basins, or clarifiers, we must know the volume of the container.

1. To calculate the volume of a rectangular tank or basin in cubic feet:
   a. Volume, cu-ft = Length, ft x Width, ft x Depth, ft

2. To calculate the volume of a circular tank or clarifier in cubic feet:
   a. Volume, cu-ft =0.785 x D^2 x H (or depth of water) or 3.14 x r^2 x H (or depth of water)

3. Frequently, we need the volume in gallons, rather than cubic feet:
   a. Volume, gallons = Volume, cu-ft x 7.48gal/ft^3

4. **The time units (second, minutes, hours, days) in the influent flow must match the desired detention time units.**

Example 3.1 – Detention Time Calculation

A sedimentation tank holds 50,000 gallons and the flow into the plant is 500 gpm. What is the detention time in minutes?

$$\text{Detention Time (time)} = \frac{\text{Volume}}{\text{Flow}} =$$

Example 3.2 – Detention Time Calculation

A tank is 20 feet by 35 feet by 10 feet. It receives a flow of 650 gpm. What is the detention time in minutes?

1. First must find volume (in gallons) then plug into Detention Time formula.
   Volume, cu-ft = Length, ft x Width, ft x Depth, ft

2. Convert to gallons from ft^3

   Volume, gallons = Volume, cu-ft x 7.48 gal/ft3

3. Plug into: $\text{Detention Time (time)} = \frac{\text{Volume}}{\text{Flow}} =$

Example 3.3 – Detention Time Calculation

A flash mix chamber has a volume of 450 gallons. The plant flow is set at 5 MGD. What is the detention time of the flash chamber in seconds? (Assume the flow is steady and continuous).

1. First, it is best to convert the flow rate from MGD to gps.

   a. Convert MGD to GPD 5 MGD = _________________GPD

   b. Convert GPD to GPS $\frac{5{,}000{,}000}{1440 \text{ X } 60}$ _________________GPS

2. Plug into: $\text{Detention Time (time)} = \frac{\text{Volume}}{\text{Flow}} = \frac{450 \text{ gal}}{58 \text{ gps}}$ ______ seconds

☑ **Example 3.4 – Detention Time Calculation**

A water treatment plant treats a flow of 1.5 MGD. It has 2 sedimentation basins, each 20 feet wide by 60 feet long, with an effective water depth of 12 feet. Calculate the Theoretical Sedimentation Detention Time with both basins in service (in hours).

1. Step 1, find the volume of the two tanks. Note: to use the formula you have to have the volume in gallons. So, what is the volume of the tanks in gallons?

   Volume of something rectangular: L x W x D

   You have two tanks to take into account

   You have to convert to gallons

2. Step 2, the flow cannot be in million gallons. Keep the *DAY* units. Convert from MGD to gpd to find our detention time in days. How do we do that? So, MGD to GPD – multiply by 1,000,000.

3. Step 3, plug our volume and our flow into the detention time formula.

   $$D.T = \frac{\text{Volume of Tank}}{\text{Flow}} =$$

4. Last step, convert to hours.

   Hours =

So, the theoretical detention time of the sedimentation tanks at a plant flow of 1.5 MGD is ___________

Jar Testing Overview

Precipitation is the chemical conversion of soluble substances (including metals) into insoluble particles.

- Coagulation and flocculation cause a chemical reaction that promotes the formation and agglomeration, or clumping of these particles to facilitate settling.
- The amount or dosage of a precipitant, coagulant, or flocculant needed to precipitate and remove substances in water solutions is dependent on many factors. These include:
  - Concentration of substance in solution
  - Solution pH
  - Chemical used to adjust the pH
  - Different types (and concentrations) of substances present
  - Amount and types of complexing agents present
  - Amount of residual oxidizers present
  - Coagulants and flocculants used
  - Sequence in which chemicals are added

- Untreated waters may contain ingredients other than dissolved metals that will affect the treatment technology.

Jar Testing is a laboratory procedure that simulates coagulation, flocculation, and precipitation results with differing chemical dosages.

- The single most valuable tool in operating and controlling a chemical treatment process is the variable speed, multiple station Jar Test Apparatus.
  - Various chemicals and/or dosages can be tested simultaneously and the results compared side-by-side.
  - Tests are good indications of dosage and concentrations of treatment chemicals required, but should be followed by full-scale laboratory testing.

Tests will only have meaning if the tested water exactly resembles the flow stream that will ultimately be treated. A single batch of grab sample tests will rarely provide reliable information.

Preparation

In preparation for conducting Jar Tests, equipment, chemicals and procedures must be in place.

Recommended Equipment

- pH Meter – is used to identify the intensity of the basic or acidic strength of a solution. It is measured on a scale of 0 to 14. The values 0 to 7 are in the acidic range, 7 to 14 are basic, and 7 is absolute neutrality. The pH meter measures the value.

- ORP Meter – is a piece of laboratory equipment used to measure the Oxidation-Reduction Potential of a solution. ORP is a measure of the electrical potential required to transfer electrons from one compound (the oxidant) to another compound (the reductant).

- Multi-station Jar Test Stirrer with containers or six 300 – 400 ml Beakers, clear plastic or glass.

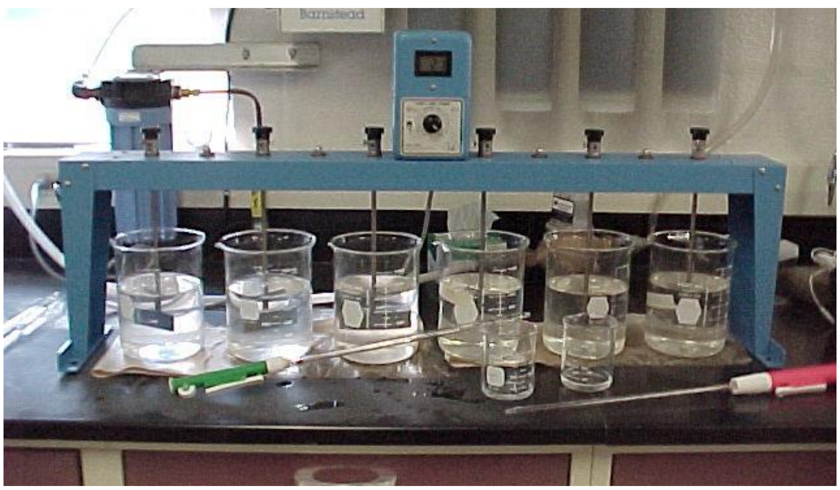


Figure 3.7 Jar Test Stirrer Equipment

- Magnetic stirrer – is a stirring device used to mix chemicals and other solutions.

- Pipets, burettes, or eyedroppers for adding chemical reagents.

- Laboratory Type Filter.

- Metals Test Kit or a Spectrophotometer – equipment used to measure metal ion concentrations in solution. The spectrophotometer measures light absorbance/transmittance of a sample.

Chemical Reagents

- ❑ Sodium Hydroxide (Caustic Soda) solution – Basic solution used to raise pH. Actual testing should be performed using the same chemical as will be used in the actual treatment process.
- ❑ Sulfuric Acid Solution – Acidic solution used to lower pH.
- ❑ Coagulants – Chemicals which neutralize the electrical charges of the small particles and which are used to promote coagulation.
- ❑ Flocculants – Chemicals which add density and toughness to the floc. Often referred to as "Coagulant Aids."
- ❑ Polymers – Long molecular chain chemicals used with other coagulants to aid in formation of strong floc.

Establish Test Procedures

- ❑ Prepare for test.
  - Prepare fresh chemicals.
  - Use test data sheets.
- ❑ Establish test sequence.
  - Determine testing required—what combinations of chemicals will be tested.
- ❑ Establish dosage range.
  - Compare raw water quality with past records and experience.
  - Bracket expected "best" dosage (i.e. – if 15 mg/l of alum is expected to be best, test 5, 10, 15, 20, and 25mg/l).
  - Maintain one container during each run as a Control (no chemicals added).
  - Change only one variable (i.e. pH adjustment chemical dosage) during each test run.
    - Any noted changes in test results are then due to the change in that single variable.
    - Perform multiple runs if multiple variable changes are necessary.

Conducting the Test

General Guidance for Conducting Jar Testing

- ❑ Fill the Jar Testing Apparatus containers with sample water.
- ❑ Add test coagulant chemical to each container at selected dosages.
- ❑ Stir at high speed for 30 seconds to distribute chemical.
- ❑ Reduce stirring speed and continue mixing for 15 to 20 minutes.
- ❑ Turn off mixers and allow containers to settle for 30 to 45 minutes.
- ❑ Evaluate test results in each container—visual evaluation or measure turbidity with turbidimeter.
    - ◊ **Rate of floc formation**.
        - √ Floc formation should begin shortly after high speed mixing.
        - √ Floc should gradually clump together during slow mixing period.
    - ◊ **Type of floc**.
        - √ Discrete, dense floc particles settle better than light, fluffy floc and are less subject to shearing (breaking up of the floc).
        - √ It is desirable to have smaller amounts of sludge to reduce sludge handling and disposal requirements.
    - ◊ **Floc settling rate**, the rate that floc settles after mixer is stopped, is important.
        - √ Floc should start to settle as soon as mixing stops.
        - √ Settling should be 80 to 90 percent complete in 15 minutes.
        - √ Floc remaining suspended longer than 15 minutes is not likely to settle in the plant.
    - ◊ **Clarity of settled water**—quality of floc is not as critical as quality or clarity of settled water.
        - √ Hazy water indicates poor coagulation.
        - √ Properly coagulated water contains well formed floc particles with clear water between the floc.
- ❑ Repeat test as necessary to “fine tune” required chemical dosage.
- ❑ Use test results to compute chemical feeder settings.

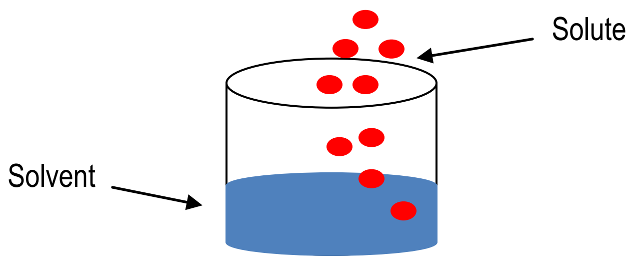
Dry Feeders

"Dry Chemical Solution Day Tanks"

A day tank is used to store a limited supply of diluted chemical solution to be fed into the treatment system. The solution in a day tank can be diluted to a specific concentration (strength). The solution consists of two parts: the solute and the solvent.

1. Solute: The dry product that you are adding or the amount of dry product in a concentrated solution.

2. Solvent: The liquid which is dissolving the solute.



Example Dry Feed Solution Tank Mixing

How many pounds of dry chemical must be added to a 50 gallons day tank to produce a 0.5% solution?
Hint: Every gallon of water weighs 8.34 pounds.

? lbs = Weight of water X Tank volume (gals) X % Solution (as a decimal)

Example Dry Feed Solution Tank Mixing

How many pounds of dry chemical must be added to a 35 gallon tank to produce a 2% solution?

? lbs = Weight of water X Tank volume (gals) X % Solution (as a decimal)

Jar testing is used to determine a chemical dosage. Once the chemical dosage has been determined, the feed rate can be calculated.

Feed Rate is the quantity or weight of chemical delivered from a feeder over a given period of time. A feed rate can have different units of expression, such as lb/day, lb/hr, lb/min, lb/sec, mg/L. Often, determining a feed rate involves time and weight conversions.

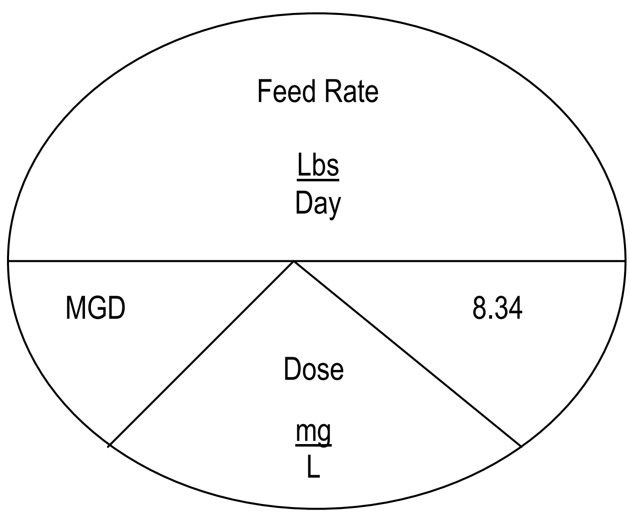
Flow Rate is the amount of water being treated daily at a facility. It is measured and reported in millions of gallons per day (MGD).

Chemical feed rate calculations involve four primary considerations: **chemical product strength, product feed rate, plant flow and dosage** (determined by jar testing). The feed rate can be calculated using a common formula:

"The Pounds Formula"

$$\text{Chemical Feed Rate in } \frac{\text{Pounds}}{\text{Day}} = \text{Plant Flow in MGD} \times \text{Dosage } \frac{\text{mg}}{\text{L}} \times 8.34$$

"Davidson Pie Chart"



To Use the Davidson Pie Chart:

1. To find the quantity above the horizontal line, multiply the three numbers below the horizontal line.
2. To solve for one of the wedges on the bottom, simply cover that pie wedge (either Flow or Dose), multiply the remaining 2 bottom wedges, then divide the feed rate by the product of the denominator (bottom) multiplication.
3. You can only do this if the given units match the units in the pie chart. If they do not, conversions are necessary before you can use the pie chart.
4. Using this chart alone is only applicable to 100% strength chemical products.

Davidson Pie Diagram Interpretation and Formulas

This diagram can be used to solve for 3 different results: dosage, feed rate, and flow (or volume).

As long as you have 2 of those 3 variables, you can solve for the missing variable.

Davidson Pie Interpretation
Middle line = divided by (÷)
Bottom diagonal lines = multiply by (x)

In other words, here are the 3 equations that can be used with these variables:

1. **Feed Rate, lbs/day = Flow (MGD) or Volume (MG) x Dosage (mg/L) x 8.34** (which is the density of water)

2. Flow (MGD) = lbs/day ÷ (Dosage, mg/L x 8.34)

   Vertical Format: Flow(MGD) = $\dfrac{\textbf{Feed Rate (lbs/day)}}{\textbf{[Dosage (mg/L) x 8.34]}}$

3. Dosage (mg/L) = lbs/day ÷ (Flow, MGD x 8.34)

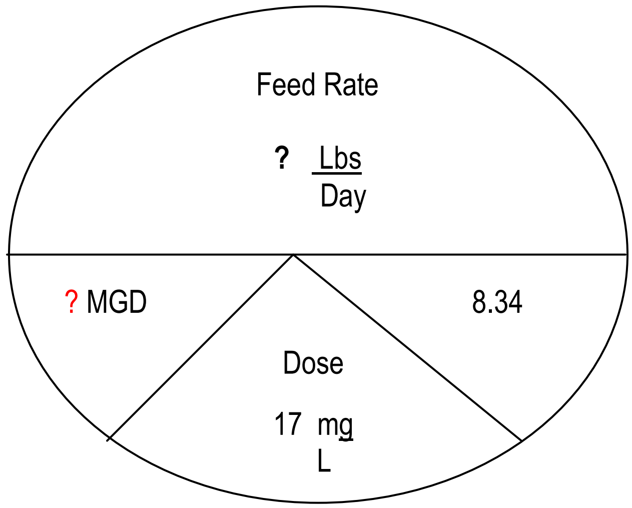
   Vertical Format: Dosage (mg/L) = $\dfrac{\textbf{Feed Rate (lbs/day)}}{\textbf{[Flow(MGD) x 8.34]}}$

Example Dry Feed Rate Calculation

How many pounds of lime are needed for a desired dosage of 17 mg/L when the average daily plant flow is 200 GPM?

200 GPM – must convert to MGD

$\frac{200 \times 1440}{1,000,000}$ = _____MGD



Chemical Feed Rate in $\frac{\text{Pounds}}{\text{Day}}$ = Plant Flow in MGD x Dosage $\frac{\text{mg}}{\text{L}}$ x 8.34

= 0.288 X 17 X 8.34

= _____________ lbs/day

What would the feeder output be in lb/hour?

lbs/hr = lbs/day ÷ 24 = _____________ lbs/hr

This is 100% strength dry chemical, what if we are using a liquid chemical?

Chemicals – Active Strength

Active Strength is the percentage of a chemical or substance in a mixture that can be used in a chemical reaction.

- Active strength of liquid chemicals must be known.
  - Different strength chemicals can be purchased.
    - Caustic Soda commercially available at 25 to 50% NaOH
    - Calcium Hypochlorite is commercially available at 65 to 70% chlorine

In addition to knowing that solutions are not 100% pure (i.e., 100% active), we also need to determine the **weight** of the "active ingredients" within that solution.

Active ingredient weight is the number of pounds of "active ingredient" per gallon of a % solution that cause a chemical reaction. It is calculated using the specific gravity of the chemical and the % solution.

- Active ingredient weight differs with different chemicals.
  - 25% Sodium Hydroxide @ 2.66 lb active/gallon
  - 50% Sodium Hydroxide @ 6.38 lb active/gallon
  - Aluminum Sulfate (Liquid Alum) @ 5.48 lb active/gallon

Calculating the Active Ingredient Weight of a % Solution Chemical

EXAMPLE: How many pounds of caustic soda are there in a gallon of caustic soda that is 50% pure that has a specific gravity of 1.53?

Step 1: Solve weight equation (lbs/gal) for 1 gallon of chemical

Weight, lbs/gal = (Specific gravity of substance) x (weight of a gallon of water)

$$1.53 \times 8.34 \frac{\text{pounds}}{\text{gallon}} = 12.76 \frac{\text{pounds}}{\text{gallon}}$$

Step 2: Determine the "active ingredient" weight of the caustic soda based on the % purity of solution

a) Convert % purity of solution into a decimal:

$$\frac{50\%}{100\%} = 0.50$$

b) Multiply the weight of a gallon by the % purity of the product (as a decimal).

$$12.76 \frac{\text{pounds}}{\text{gallon}} \times 0.50 = \underline{6.38}$$ pounds of caustic soda in a gallon of 50% caustic soda solution

This "active ingredient" weight provides the pounds of active strength ingredients that are found in each gallon of 50% caustic soda solution. Within the 12.76 pounds of 50% caustic solution, there are **6.38 pounds of active ingredients.**

- The active ingredient weight of same chemical may differ with different shipments.
  - The active ingredient weight should be tested periodically.
    - Measure specific gravity and compare with known values.
    - Specific gravity is the weight of a particle, substance, or chemical solution in relation to the weight of an equal volume of water (the weight of water is 8.34 pounds/gallon).

Calculating the Weight of the "Active ingredient" of a % Solution Chemical

Practice Problem: How many pounds of caustic soda are there in a gallon of caustic soda that is 25% pure that has a specific gravity of 1.28?

Step 1: Solve weight equation (lbs/gal) for 1 gallon of chemical

Weight, lbs/gal = (Specific gravity of substance) x (weight of a gallon of water)

$$1.28 \times 8.34 \frac{\text{pounds}}{\text{gallon}} = \_\_\_\_\_\_\_ \frac{\text{pounds}}{\text{gallon}}$$

Step 2: Determine the "active ingredient" weight of the caustic soda based on the % purity of solution

a) Convert % purity of solution into a decimal:

$$\frac{25\%}{100\%} = \_\_\_\_\_\_\_$$

b) Multiply the weight of a gallon by the % purity of the product (as a decimal).

$10.67 \frac{\text{pounds}}{\text{gallon}} \times 0.25 = \_\_\_\_\_\_\_$ pounds of caustic soda in a gallon of 25% caustic soda solution

This "active ingredient" weight provides the pounds of available caustic soda that is found in each gallon of 25% caustic soda solution. Within the 10.67 pounds of 25% caustic solution, there are 2.66 pounds of active ingredients.

We can use this same approach to calculate how many pounds of "active chemicals" there are in a drum.

☑ **Weight Calculation of "Active Chemicals" within % Solution in a Drum**

Example Problem: How many pounds of chemical are there in a 55 gallon drum of liquid alum if the product is 48½ percent pure with a specific gravity of 1.33?

? lbs of active ingredient within drum = Tank or Drum Volume X SG X 8.34 X % solution as a decimal.

? lbs of active ingredient within drum = 55 gal X 1.33 X 8.34 X 0.485 = 295.8 lbs of active ingredient (alum) within the 48.5% solution

Practice Problem: How many pounds of chemical are there in a 55 gallon drum of sodium hypochlorite that is 12½ percent pure with a specific gravity of 1.15?

? lbs of active ingredient within drum = Tank or Drum Volume X SG X 8.34 X % solution as a decimal.

? lbs of active ingredient within drum = 55 gal X 1.15 X 8.34 X 0.125 = _______ lbs of active ingredient (chlorine) within the 12.5% solution

☑ **Total Weight Calculation of a single gallon of a % Solution**

The measured specific gravity of the 11% strength Ferric Chloride delivered to your plant is 1.38. Find how much each gallon weighs.

Weight, lbs/gal = (Specific gravity of substance) x 8.34 (weight of water)

? $\frac{\text{lbs}}{\text{gal}}$ of ferric chloride = 1.38 x 8.34 $\frac{\text{lbs}}{\text{gal}}$ = _____ $\frac{\text{lbs}}{\text{gal}}$

We can also use the same approach to calculate the total weight of a drum or tank.

☑ **Drum Weight Calculation of a % Solution**

How much does a 55 gallon drum of zinc orthophosphate weigh if the MSDS says the specific gravity of zinc orthophosphate is 1.46.

Drum Weight, lbs = (gallons of drum or tank) x (SG) x (8.34 lbs/gal)

? Drum weight, lbs = 55 x 1.46 x 8.34 = 671 lbs

Specific gravity is used in two ways:

- To calculate the **total weight** of a % solution (either as a single gallon or a drum volume).

  Total Weight = Drum Vol X SG X 8.34

- To calculate the **"active ingredient" weight** of a single gallon or a drum.

  Active Ingredient Weight within Drum = Drum Volume X SG X 8.34 X % solution as a decimal.
  (i.e., Total Weight X % solution as a decimal)

  NOTE: Both ways start with solving for the total weight (Drum Vol X SG X 8.34). When solving for "active ingredient" weight, you have to then multiply by % solution as a decimal.

Now let's show you how to use this "active ingredient" weight to convert a liquid feed rate calculation from "lbs/day" to "gal/day.

Using "Active Ingredient" Weight to Convert Feed Rate from lbs/day to gal/day

Example: A water plant uses sodium hypochlorite (12%) to disinfect the water which provides 1.2 lbs/gal of available chlorine ("active ingredient" weight). The required dosage is 2.5 mg/L. They treat 118,000 gallons per day. How many gallons of sodium hypochlorite will need to be fed?

Step 1: Convert flow in gallons (per day) into MGD so that the feed rate (lbs/day) formula can be used.

$$? \text{ MGD} = \frac{1 \text{ MG}}{1{,}000{,}000 \cancel{\text{gal}}} \times \frac{118{,}000 \ (\cancel{\text{gal}})}{1 \ \text{day}} = 0.118 \text{ MGD}$$

Step 2: Solve for pounds per day (feed rate) for 100% pure chemical (no impurities).

? pounds per day = flow x dose x 8.34 = (0.118)(2.5)(8.34) = 2.46 pounds of chlorine is required.

Step 3: Use "active ingredient" weight with unit cancellation steps to convert lbs/day to **gals/day**

Active Ingredient Weight of 12% hypo solution

Feed Rate of 100% pure chlorine

NOTE: Inverted weight so that gallon unit was in numerator to position the numerator

$$? \frac{\text{gal}}{\text{day}} = \frac{1 \text{ gallon}}{1.2 \text{ lbs}} \times \frac{2.46 \text{ lbs}}{\text{day}} = 2.05 \frac{\text{gal}}{\text{day}}$$

NOTE: When you are given the "active ingredient" weight of a solution to solve a feed rate problem, you do not need to use the % purity factor because it was used in the weight calculation.

Practice Problem: A water treatment plant uses liquid alum for coagulation. At a plant flow rate of 2.0 MGD, an alum dosage of 12.5 mg/l is required. The alum has an "active ingredient" weight of 5.48 lb/gallon. Compute the required alum feed rate in **gallons/day.**

Step 1: Solve for pounds per day (feed rate) for 100% pure chemical (no impurities).

Using the formula pounds per day = flow x dose x 8.34 = (2)(12.5)(8.34) = ______ pounds of liquid alum.

Step 2: Use "active ingredient" weight with unit cancellation steps to convert lbs/day to **gal/day**

Active Ingredient Weight of liquid alum

Step 1 Feed Rate of 100% pure alum

$$? \frac{gal}{day} = \frac{1\ gallon}{5.48\ lbs} \times \frac{\_\_\_\ lbs}{day} = \_\_\_\_\ \frac{gal}{day}$$

NOTE: When you are given the "active ingredient" weight of a solution to solve a feed rate problem, you do not need to use the % purity factor because it was used to derive the "active ingredient" weight.

Theoretical Pump Output

Using the maximum pump output from the dataplate of a pump, you can determine the theoretical pump output.

Pump Output = Maximum Pump Output x % Speed x % Stroke

For example, if a 24 GPD pump is set at 80% stroke length and 100% speed, the theoretical pump output would be:

$$\text{Pump output} = \frac{24.0 \text{ gal}}{\text{day}} \times 1.0 \times 0.80 = \frac{19.2 \text{ gal}}{\text{day}}$$

When choosing a pump for a facility, you want a pump that can maintain a stroke between 20% and 80% and keep the speed setting high.

Practice – Theoretical Pump Output

An operator wants to estimate the approximate speed and stroke settings on a diaphragm pump that is rated to deliver a maximum pump output of 24 gallons per day. The system needs to deliver approximately 15 gallons per day of sodium hypochlorite. Where would the speed and stroke need to be set?

This is a guessing game of sorts; however, go again with the concept of a higher speed setting and a stroke setting between 20% and 80%.

Pump Output = Maximum Pump Output x % Speed x % Stroke

$$\text{Pump Output} = 24 \frac{\text{gal}}{\text{day}} \times 0.90 \times 0.70 = \underline{\quad\quad} \frac{\text{gal}}{\text{day}}$$

This formula should only be used as an estimate. The values are accurate only when the pump is brand new and under ideal conditions.

Because the output will change with wear and tear on the pump, pump calibration is still the most accurate tool used to determine the pump's output.

Chemical Feed Pump Settings

Feed Rate is the quantity or **weight** of chemical delivered from a feeder over a given period of time. The chemical feed pump must be calibrated to **deliver the selected dosage**. A feed rate can have different units of expression, such as lb/hr, lbs/day, mg/L, mL/min, or gal/day. Often, determining a feed rate involves weight and time conversions.

Pump calibration is the process of measuring and recording the output at each dial setting. Once the data is recorded, it offers a quick reference for adjusting the feed rate in response to varying water quality or chemical demand.

- Feed pumps are calibrated with the use of a pump calibration curve.
- A new pump calibration curve should be constructed:
    - At least once per year.
    - If troubleshooting points to the need for a new pump calibration.
    - If any maintenance is performed on the pump.

For start-up, an operator would construct a calibration curve for the **full range of percent stroke settings** (20-100%) to determine the optimal pump setting.

Steps in Developing a Pump Calibration Curve

Step 1: Determine actual feed pump output.

- Operate feed pump over full operating range
- Determine actual pump output

Pump Setting (% Full Speed)	Alum Pumped (mL)	Time (sec)
0	0	30
20	65.6	55
40	141.9	59
60	249.1	61
80	195.2	32
100	267.4	35

Figure 3.8 Liquid Feeder Operation Test Results – Alum Feed Pump Output

Here's an example of the type of data you would collect for each stroke setting (20 – 100%)

LIQUID FEED PUMP CALIBRATION TABLE

% Stroke: __________

PUMP SPEED SETTING	VOLUME (mL)	TIME (min)	FEED RATE (mL/min)
20			
40			
60			
80			
100			

To convert each pump speed setting into mL/min, use this equation:

$$? \frac{mL}{min} = \frac{65.6\ mL}{55\ sec} \times \frac{60\ sec}{1\ min} = 71.56\ \frac{mL}{min}$$

$$? \frac{mL}{min} = \frac{141.9\ mL}{59\ sec} \times \frac{60\ sec}{1\ min} = 144.31\ \frac{mL}{min}$$

$$? \frac{mL}{min} = \frac{249.1\ mL}{61\ sec} \times \frac{60\ sec}{1\ min} = 245.02\ \frac{mL}{min}$$

$$? \frac{mL}{min} = \frac{195.2\ mL}{32\ sec} \times \frac{60\ sec}{1\ min} = 366\ \frac{mL}{min}$$

$$? \frac{mL}{min} = \frac{267.4\ mL}{35\ sec} \times \frac{60\ sec}{1\ min} = 458.40\ \frac{mL}{min}$$

Here's an example of a completed liquid alum feed pump calibration table for 60% Stroke.

60% Stroke Pump Calibration Table				
Pump Speed Setting	Alum Pumped (mL)	Time (sec)	Feed Rate (mL/min)	Feed Rate (gal/day)
0	0.0	30	0.00	0.000
20	65.6	55	71.56	27.2
40	141.9	59	144.31	54.8
60	249.1	61	245.02	93.1
80	195.2	32	366.00	139.1
100	267.4	35	458.40	174.2

Figure 3.9 Liquid Feeder Pump Calibration Table

Converting mL/min into gal/day:

For Pump Setting 20: $? \frac{gal}{day} = \frac{1\ gal}{3785\ \cancel{mL}} \times \frac{71.56\ \cancel{mL}}{\cancel{min}} \times \frac{1440\ \cancel{mins}}{day} = 27.22\ \frac{gal}{day}$ **Note:** $\mathbf{\frac{1440}{3785} = 0.38}$

For Pump setting 40= 0.38 X 144.31 = 54.83 gal/day

For Pump setting 60= 0.38 X 245.02 = 93.1 gal/day

For Pump setting 80= 0.38 X 366 = 139.1 gal/day

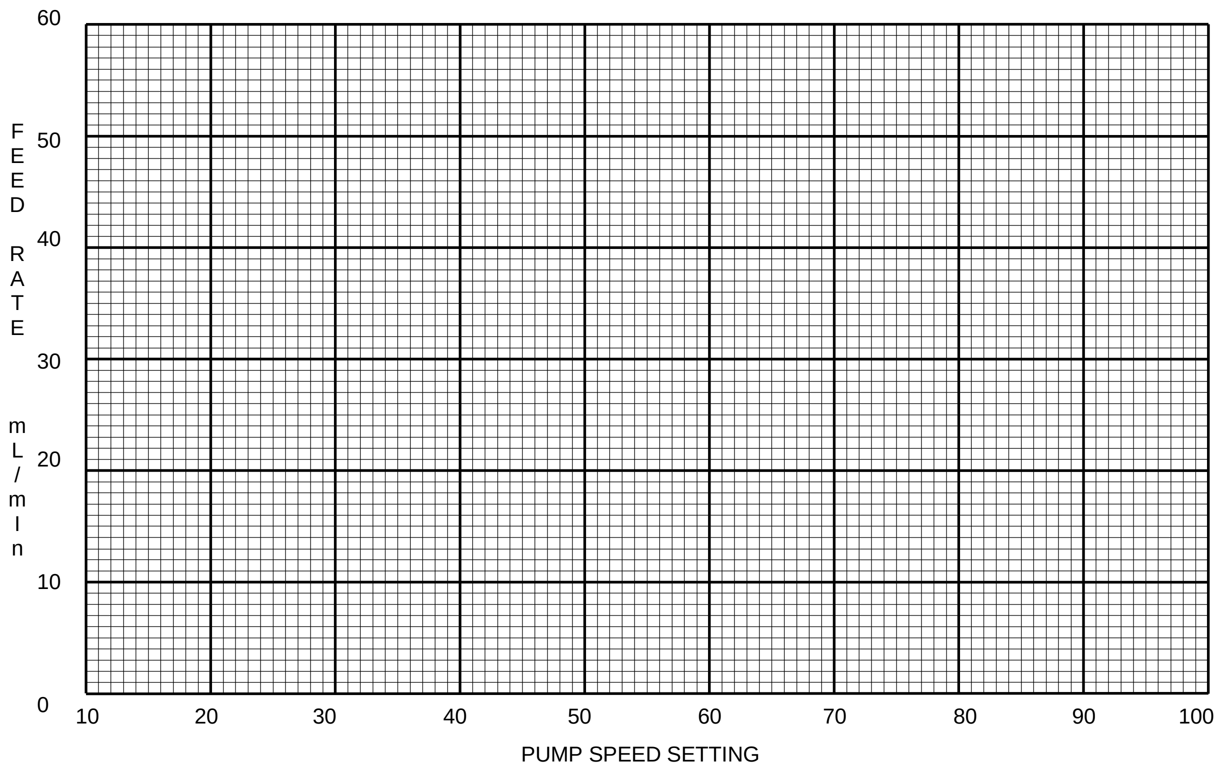
For Pump setting 100= 0.38 X 485.4 = 174.2 gal/day

Step 2: Develop feed pump calibration curve.

- Plot each **Feed Rate (mL/min or gal/day)** vs. **Pump Speed setting** on the graph.
- Connect each of the points together with a straight line.

PUMP: ______________________________ PUMP CALIBRATION CURVE DATE: ____________________

% Stroke: ____________________________



Here's the pump calibration curve for the data from Figure 3.9.

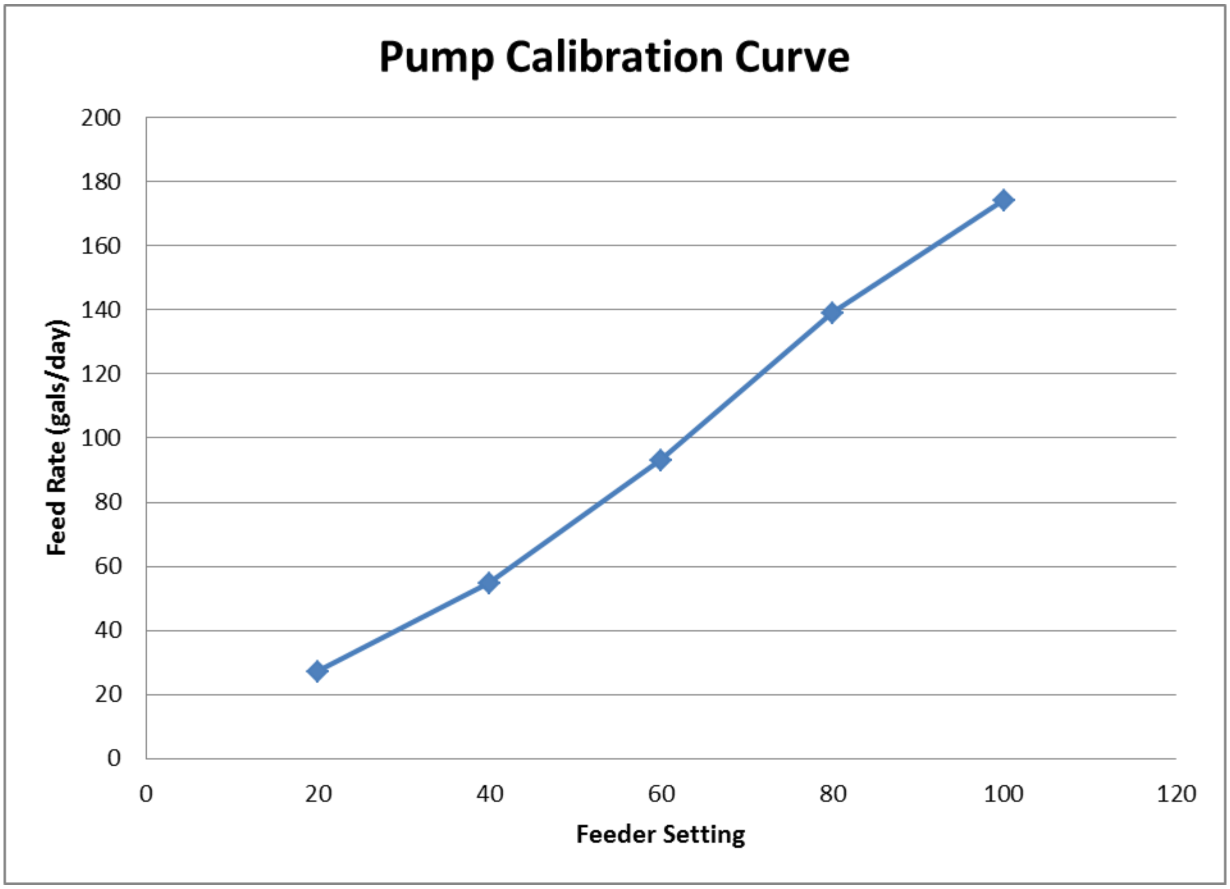


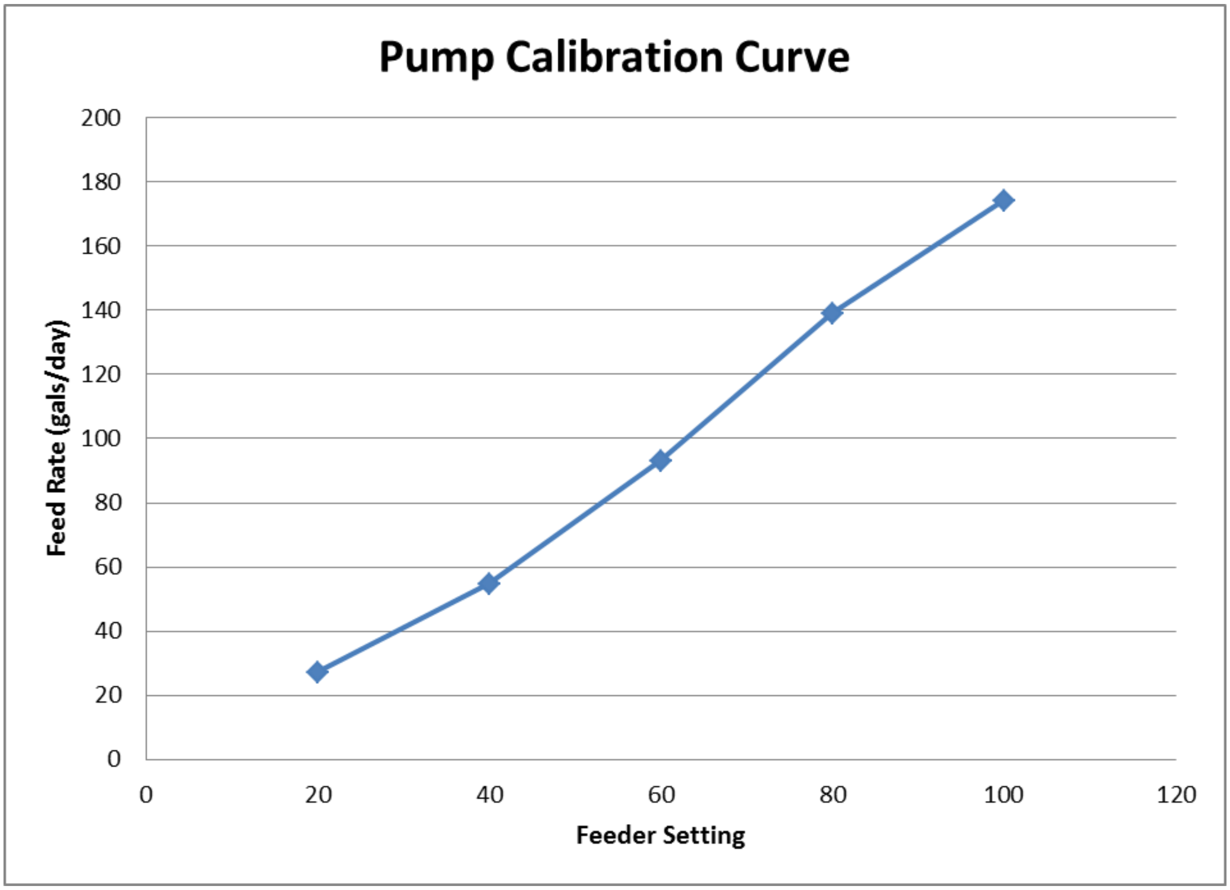
Figure 3.10 – Feeder Calibration Curve for 60% Stroke

Step 3: Select the pump setting from all the % stroke calibration tables that provides the calculated feed rate.

The optimal pump setting would take into account:

- The dosage required.
- The manufacturer's recommendations for minimum and maximum settings.
- The linearity of the "curves". A more linear (straight) curve is better.

Once the appropriate percent stroke setting has been determined, future calibration would only involve the speed range (20-100) at that percent stroke.



Question: Using this pump calibration curve, approximately what pump setting is required for a plant that has a liquid feed rate of 40 gal/day? ________

☑ **Example – Liquid Feed Calculations**

Using Figure 3.9, if the plant ran for 8 hours, determine how many mL the pump would deliver at a pump setting of 20%. How many gallons would you expect to use?

60% Stroke Pump Calibration Table				
Pump Speed Setting	Alum Pumped (mL)	Time (sec)	Feed Rate (mL/min)	Feed Rate (gal/day)
0	0.0	30	0.00	0.000
20	65.6	55	71.56	27.2
40	141.9	59	144.31	54.8
60	249.1	61	245.02	93.1
80	195.2	32	366.00	139.1
100	267.4	35	458.40	174.2

Figure 3.9 Liquid Feeder Pump Calibration Table

Pump Setting 20: Total Volume (mL) = $\frac{71.56 \text{ mL}}{\text{min}} \times \frac{60 \text{ mins}}{1 \text{ hour}} \times 8 \text{ hrs} =$ __________mL

?Total Volume (gal) = $\frac{1 \text{ gal}}{3785 \text{ mL}} \times 34{,}348.8 \text{ mL} =$ ______ gallons

Operator Tips: Pump Calibration

- Pump calibration is conducted to determine the pump's feed rate.
- A pump calibration curve is constructed to serve as a quick reference should the pump setting need to be adjusted in response to varying water quality or chemical demand.
- The pump speed setting equals the number of strokes per minute. A pump calibration should run for at least 50 strokes at each setting.
- If a calibration curve is constructed in ascending (increasing) order and a decrease in pump output is required, the pump control dial(s) should be turned down below the desired setting and then slowly increased to the appropriate setting. Q: Why? (Pump output is different going up the scale than it is going down the scale. Output from 30 - 40 is different than 40 - 30.)

☑ **Optional Class Activity**

Required Equipment for a Pump Calibration Using Calibration Column:

Ruler or straight edge
LMI chemical feed pump
Calibration column with adapter fittings
Discharge tubing
Calculator
Adjustable 8” wrench
400 ml beaker
Stop watch
Paper Towels
Safety glasses
Rubber Gloves
Bucket to collect discharge

Pump Calibration

A chemical feed pump must be adjusted to deliver a systems selected dosage (feed rate). The feed rate determines how the chemical will be added to the water and could be expressed in terms of mL/min, gal/day, or lbs/day. As discussed, feed pumps are adjusted with the use of a pump calibration curve.

The key to chemical feed is knowing where to set the dials on a mechanical diaphragm metering pump. The dials are:

1. Length of the stroke – considered the major/best adjustment. This controls the displacement of a fixed volume of chemical per stroke.
    a. Dial setting from 0-100 percent.
2. Speed – controls the number of strokes per minute.
    a. Dial setting from 0-100 percent.

During a pump calibration, each setting is measured and recorded. Once the data is recorded, it offers a quick reference for adjusting the feed rate in response to varying water quality or chemical demand changes.

Chemical feed pumps should be calibrated during start-up to determine the optimal pumping range. A new pump calibration curve should be constructed:

- At least once per year
- If trouble shooting points to a need for a new pump calibration.
- If any maintenance is performed on the pump.

Procedure

1. Prime the pump.
   A. Fill the calibration chamber with water.
   B. Turn on the pump. Set the "Percent of Full Stroke" to 80% and the speed to 100%. (For many pumps, the dial settings can only be adjusted while the pump is on. Do not adjust the stroke length when the pump is not running. This can damage the mechanical components of the stroke length.)
   C. Allow the pump to run until water is pumped through the discharge tubing. Then, turn the pump off. The pump is now primed.
2. Refill the chamber with water to the 0-0 (ml/min) level on the calibration column.
3. Re-check that the "Percent Stroke Length" setting is at **80%**.
4. Record the starting volume of water in the calibration chamber.
5. Set the speed control to **20%**.
6. Turn the pump on and allow the pump to run for **three (3) minutes**. Then turn the pump off.
7. Read the ending volume of the time the pump was allowed to run in the *Liquid Feed Pump Calibration Table*.
8. Repeat steps 2-7 at speed settings of 40%, 60%, 80%, and 100%. Record the results on the Liquid Feed Pump Calibration Table. Note: allow the pump to run for **(2) minutes** at the speed of **40%**. For all others (**60%, 80%, and 100%)**, allow the pump to run for one **(1) minute**.
9. When all of the results have been recorded on the table, perform the following calculation to determine the feed rate in ml/min:
   A. Calculate the feed rate (ml/min) by dividing the volume pumped by the elapsed time. For example, if 80ml's were pumped in two (20) minutes, the feed rate would be:

$$\text{Feed Rate (ml/min)} = \frac{80\text{ ml}}{2\text{ min}} = 40\text{ ml}$$

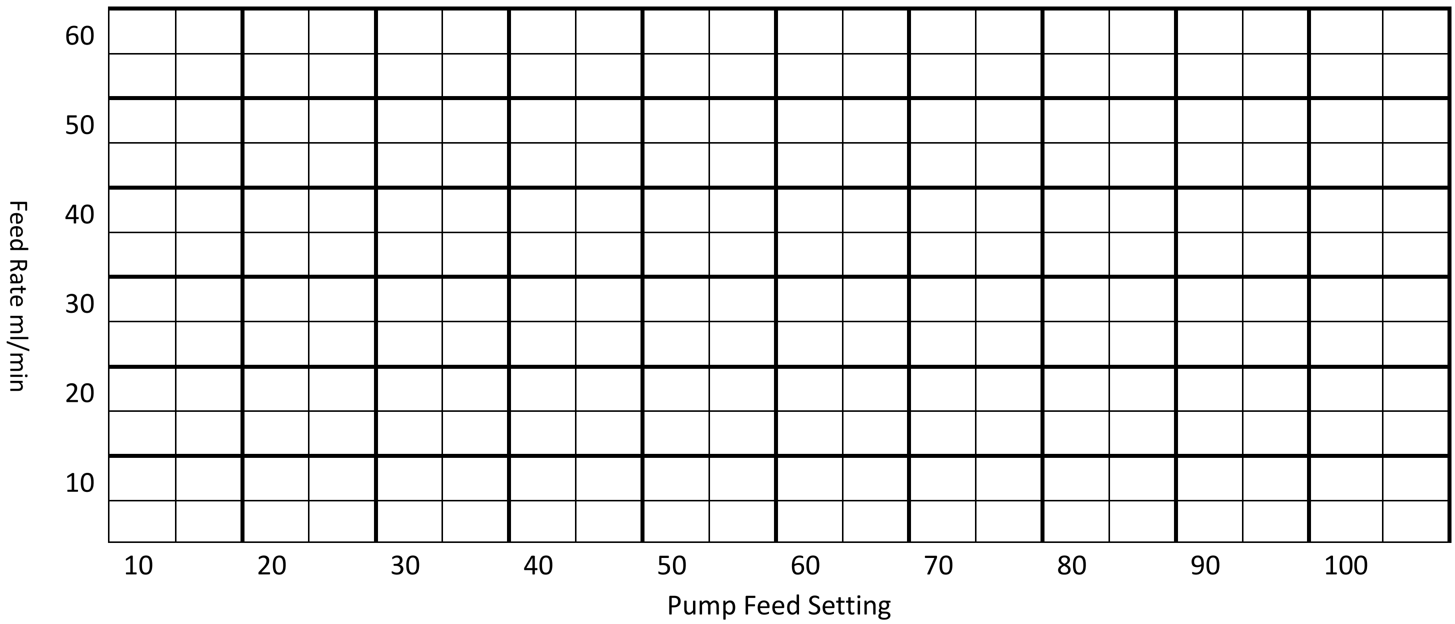
Liquid Feed Pump Calibration Table			
% Stroke: 80%			
Pump Speed Setting	Volume (ml)	Time (min)	Feed Rate (ml/min)
20%			
40%			
60%			
80%			
100%			

10. Construct a calibration curve.
    a. Plot each Feed Rate (ml/min) Vs Pump Setting on the graph.
    b. Connect each of the points together with a straight line.

Construction of a Calibration Curve

Pump:______________ Date:________________

%Stroke:___80%______



Gas Feeders

Types of Gas Feeders

- Direct feed
  - Gas is fed directly under pressure to flow stream to be treated
  - Limited application
    - Gas is distributed under pressure
      - Leaks in piping result in gas escape
    - Limited feeder capacity

- Solution feed (commonly referred to as vacuum-type feeders)
  - Gas is drawn by vacuum through piping system
    - Safer than direct feed—piping leak results in loss of vacuum and shut down of gas supply
  - Greater available capacity than direct feed systems
  - Requires use of ejector to create necessary vacuum for operation

Feed Rate Equation

Tip Box

Feed rate calculation for gas is the same as for other chemicals.

Feed Rate (lb/day) = Flow Rate (MGD) x Chemical Dosage (mg/L) x 8.34 lb/gal

- Chemical dosage is dependent on the desired purpose. For example, Chlorine addition serves many purposes in water treatment as illustrated below.

Purpose for chlorination	Dosage Range (mg/l)
Algae Control	1.0 – 10.0
Ammonia (NH_3-N) Removal	10 x NH_3-N content
Color Removal	1.0 – 10.0
Disinfection:	
With Combined Residual	1.0 – 5.0
With Free Residual	1.0 – 10.0
Hydrogen Sulfide (H_2S) Removal	2.22 x S content to free sulfur 8.9 x S content to sulfate
Iron (Fe) Removal	0.64 x Fe content
Manganese (Mn) Removal	1.3 x Mn content
Slime Control	1.0 – 10.0
Taste & Odor Control	1.5 – 15.0

- Gas withdrawal from cylinders is limited and temperature dependent.
  - 100 or 150 pound cylinders – 1 pound/day/°F
  - Ton Cylinders – 8 pounds/day/°F
- If withdrawal exceeds these limits, evaporators are required.
  - Liquid is withdrawn for cylinder and converted to gas by the evaporator.

Exercise

1. The suction assembly consist of:
   A. ___________________ – Used to protect the internal components of a pump.
   B. ___________________ – Used to prevent the pump from losing prime.

2. A __________________ is used for accurate determination of a pump's feed rate. This is typically located on the suction side of a pump.

3. Adjusting chemical feed pump dosage is controlled by:
   A.
   B.

4. A ______________________ has chemical stored in a silo above the unit and each time the system needs to make a new batch of solution, a feed mechanism delivers exactly the same volume of dry chemical to the dissolving tank.

5. A _________________ is a belt type feeder that delivers a certain weight of material with each revolution of the conveyor belt.

6. _____________________ is a laboratory procedure that simulates coagulation, flocculation, and precipitation results with differing chemical dosages.

7. _________________ is a percentage of a chemical or substance in a mixture that can be used in a chemical reaction.

8. A pump calibration curve shows:
   A. ____________________
   B. ____________________

9. List three purposes of chlorine addition:
   A. ______________________
   B. ______________________
   C. ______________________

10. A tank is 25 feet long, 15 feet wide and has 10 feet of water in it. Two wells pump into the tank; the first well pumps at a rate of 150 gpm and the second well pumps at a rate of 75 gpm. What is the detention time of the tank in hours?

11. A system is using "Aqua Mag" (specific gravity 1.34) to sequester iron and manganese in addition to corrosion control. What is the weight of 30 gallons of "Aqua Mag"?

12. A treatment plant is feeding 25% caustic soda that has a specific gravity of 1.28. How many pounds of "active ingredient" are there in the 55 gallon drum?

13. If a 24 gallon per day pump is set at 60% speed and 80% stroke, how many gallons per day should the plant expect to feed?

- Once it is determined what chemical is needed for treatment, it must be determined how much chemical must be applied.

- A calibration cylinder is used to determine a pump's feed rate.

- The amount of chemical applied to a treatment system over a given period of time is called the feed rate.

- The most common types of positive displacement pumps are peristaltic and diaphragm.

- In order to calculate feed rate, unit conversions may be necessary. Unit conversion is the process of standardizing values in a calculation.

- The output of a chemical feed pump is controlled by the length of the plunger stroke and the number of repetitions of the stroke (stroke and speed).

- An ejector system uses the Venturi effect to create a vacuum and move solution into the main water flow.

- A volumetric dry feeder uses a rotating feed screw to deliver a consistent volume of dry chemical into a dissolving tank; varying the speed of the rotating feed screw changes the feed rate.

- A gravimetric dry feeder uses a belt to deliver a certain weight of material with each revolution of a conveyor belt.

- A pump calibration curve graph shows chemical Feed Rates Vs Pump Settings.

- **Active Strength** is the percentage of a chemical or substance in a mixture that can be used in a chemical reaction. (i.e., 25%, 48.5%, 50%)

- **Active ingredient weight** is the **number of pounds** of "active ingredient" per gallon of a % solution that cause a chemical reaction. It is calculated using the specific gravity of the chemical and the % solution.

Suction assembly consists of a suction strainer (used to protect the internal parts of a pump) and a foot valve (used to prevent the pump from losing prime).

Here are equations that operators need to use:

Detention time:

Rectangular Volume, cu-ft = Length, ft x Width, ft x Depth, ft

Circular Volume, cu-ft =0.785 x D^2 x H (or depth of water)

Volume, gallons = Volume, cu-ft x 7.48gal/ft^3

$$\text{Detention Time} = \frac{\text{Volume}}{\text{Flow}}$$

NOTE: The time units (second, minutes, hours, days) in the influent flow must match the desired detention time units. Both volume and flow must be in the same units. (typically gals)

Adding dry chemicals to create a % solution:

? lbs = Weight of water X Tank volume (gals) X % Solution (as a decimal)

Calculating Weight in lbs:

Calculating total weight of a single gallon of a solution, (lbs) = SG of substance X 8.34
Total Drum Weight, lbs = (gallons of drum or tank) X SG X 8.34

Calculating "Active Ingredient" Weight in lbs:

Single gallon = SG X 8.34 X % solution (as a decimal)
Drum = Drum Vol X SG X 8.34 X % solution (as a decimal)

Feed Rate:

Dry Feed Rate, lbs/day = Flow (MGD) x Dosage (mg/L) x 8.34 (100% strength chemicals)

$$\text{Using “active ingredient” weight to convert lbs/day into gal/day} = \frac{\text{100\% Feed Rate}}{\text{Active Ingredient weight}}$$

Theoretical Pump Output = Maximum Pump Output x % Speed x % Stroke

Unit 4 – Chemical Feed System Schematics

Learning Objectives

- Identify storage considerations for dry, liquid, and gaseous chemicals.

Operators should maintain the proper tools and an inventory of spare parts necessary to repair chemical feed equipment in the event of a malfunction. Typically, the required tools and spare parts are recommended by the equipment manufacturer.

Adequate Supply

- ❑ Provide sufficient chemicals in storage to insure an adequate supply at all times.
- ❑ General Guideline – Provide a minimum chemical storage of the larger of:
  - 30 day’s supply at average usage, or
  - 10 day’s supply at maximum usage

Storage Areas

Chemical storage is located in the vicinity of feeders to avoid unnecessary handling and house keeping problems. Depending on the chemical, storage will usually be in the same room as the feed equipment. However, for gaseous chemicals (i.e. chlorine and ammonia) storage will usually be in an adjacent room or outside the building at a location close to the feed room.

All liquid chemicals should be stored in spill containment areas. These are areas designed to retain the contents of the largest storage tank should that tank burst and release the contents into the room. Typically, 10% additional capacity is provided for a total containment of 110% such that the containment area maintains a freeboard of unfilled space. Spill containment areas have special coatings which are not affected by the stored chemical so that in the event of a major spill, all of the chemical is retained within the designated area.

Dry chemicals should be kept dry either by storage in a silo (for bulk chemical storage) or on wooden shipping pallets.

Dry Chemical Storage Facilities

The type of storage facility for dry chemicals is dependent upon the quantity of dry chemical to be stored.

- Bulk silo storage for large amounts:
  - Minimum 110% of maximum delivery quantity
- Bag Storage:
  - Dry area on shipping pallets

Feed Equipment

- Feeder Hopper – stores daily chemical required for delivery by feeder. Used for chemical usage monitoring and inventory control purposes.
- Volumetric Feeder – feeds chemical at set controlled rate.
- Dissolving Tank – provides contact of water and dry chemical with sufficient mixing and detention to form feed solution.
- Dry Batch System Solution Tank – tank in which operator manually mixes daily chemical solution from dry chemicals and water.

Accessory Equipment

- Dust Collector – eliminates air borne dust from feed area. Helps to provide clean, healthy, safe work area.
- Dissolving Tank Float Valve – maintains a constant water level in the dissolver tank.
- Mixer – aids dissolving of the chemical in the dissolver tank. Helps to maintain slurries in suspension.
- Eductor – jet pump which draws chemical solution from dissolving tank and mixes it with drive water for transmission to the chemical feed point.

Liquid Chemical Storage Facilities

- Dependent on quantity of chemical to be stored.
  - Bulk storage tanks for large amounts:
    - Minimum 110% of maximum delivery quantity
  - Drum Storage for smaller amounts.
- All liquid storage and feed equipment should be stored in chemically resistant containment areas.
  - Areas should be large enough to contain a spill of 110% of the largest single container.
  - Containment areas should contain leak detection equipment to provide an alarm in the event of a chemical spill.

Feed Equipment

- Transfer Pump – transfers chemical from bulk storage tanks to day tanks.
- Day Tank – stores daily chemical required for delivery by feeders. Used for chemical usage monitoring and inventory control purposes.
- Chemical Feed Pump – accurately feeds a specific volume of chemical at selected rate.

Accessory Equipment

- Calibration Chamber – used to measure actual feed pump output.
- Pressure Relief Valve – limits discharge pressure of feed pump; protects feed piping.
- Backpressure Valve – maintains a constant backpressure on feed pump discharge.
- Anti-siphon Valve – prevents back siphonage of process water into chemical feed system.

Polymer Storage Facilities

Polymer is shipped either dry (bags) or liquid (drums), Therefore storage facilities need to be the same as other chemicals of similar type.

Feed Equipment

- Polymer must be activated prior to feeding to obtain expected results.
  - Requires addition of water, proper mixing, and aging prior to usage.
  - Improper mixing and activation results in formation of globs or clumps of inactivated polymer, commonly known as “Fish-Eyes.”
- Specialized feed equipment available for activating and feeding both dry and liquid polymers.
  - Includes mixing, activation and aging components, as well as liquid feed pumps.

Gaseous Chemical Storage Facilities

- Separate storage and feed rooms.
- Size dependent on quantity of chemical to be stored.
- Storage of ton cylinders requires additional accessory equipment.
  - 2 Ton capacity monorail for moving ton cylinders.
  - Roller trunions for orienting cylinders.
    - Cylinders have 2 valves—valves must be oriented vertically.
      - Top for gas
      - Bottom for liquid
    - Both gas and liquid can be drawn from cylinder depending on which valve is used.

Feed Equipment

- Vacuum Regulator – controls vacuum operated systems.
- Automatic Switchover System – provides for continuous gas supply. Automatically switches to a standby container in the event the active container becomes empty.
- Gas Feeder – controls gas feed rate.
- Ejector – produces the vacuum under which vacuum type systems operate.

Accessory Equipment

Not all of the accessory equipment listed here may be required for all systems.

- ❑ Evaporator – used at large installations to convert gas from liquid phase to gaseous phase, permitting higher withdrawal rate from the ton container.
- ❑ Gas Solution Distributors – provides method where a single properly sized ejector can be used to split gas solution to several different feed points.
- ❑ Container Scales – used to measure the quantity of gas remaining in the containers.
- ❑ Gas Detectors – used to actuate an alarm if unacceptable levels of the gas are sensed in the ambient air of storage and feed rooms.
- ❑ Self Contained Breathing Equipment – used to protect operation personnel in case of gas leaks or during emergency access to areas with gas leaks.
- ❑ Feed Water Booster Pump – raises pressure of ejector water supply for proper operation of ejector.
- ❑ Emergency Repair Kits – used to stop leaks in gas containers (2 sizes available – ton container and cylinder).

☑ **Exercise**

1. A general guideline to insure an adequate supply of chemicals at all times is to provide a minimum chemical storage the larger of either:

   A. ______________________________

   B. ______________________________

2. Spill containment areas should be designed to provide how much total containment?

   A. 80%
   B. 90%
   C. 100%
   D. 110%

3. Polymer requires addition of water, proper mixing, and aging prior to usage.
   A. True
   B. False

4. A self-contained breathing apparatus should be stored in the chlorine storage room.
   A. True
   B. False

5. Name the piece of equipment that provides the vacuum in a gas chemical feed system.
   A. Evaporator
   B. Emergency repair kit
   C. Self-contained breathing apparatus
   D. Ejector

- It is important to have an understanding of the types of equipment and equipment interconnections for feeding water treatment chemicals.
- Chemicals are fed differently depending upon the amount of chemical required, type of chemical, and form of chemical (gas, liquid, or solid).
- All liquid storage and feed equipment should be stored in chemically resistant containment areas. Areas should be large enough to contain a spill of 110% of the largest single container.

Appendix

Practice Math Problems

Homework

Extra Practice Math Problems

1. A sedimentation tank holds 60,000 gallons and the flow into the plant is 600 gpm. What is the detention time in minutes?
2. A tank is 20 feet by 35 feet by 10 feet. It receives a flow of 650 gpm. What is the detention time in minutes?
3. Two wells flow into a 30,000 gallon tank. Well 1 flows at a rate of 475 gpm. Well 2 flows at a rate of 175 gpm. What is the detention time of the tank (in minutes)?
4. A tank is 30 feet high, with a 53 foot diameter. It receives a flow of 900 gpm. What is the detention time in hours?
5. How many pounds of dry chemical must be added to a 80 gallon tank to produce a 10% solution?
6. How many pounds of dry chemical must be added to a 100 gallon tank to produce a 2% solution?
7. How many pounds of dry chemical must be added to a 35 gallon tank to produce a 3% solution?
8. How many pounds of dry chemical must be added to a 50 gallon tank to produce a 5% solution?
9. Determine the weight of a 55 gallon drum of zinc orthophosphate (specific gravity 1.46).
10. The clearwell at a system is 25 feet long, 35 feet wide and contains 15 feet of water. It is to be disinfected at a dosage of 25 mg/l. How many pounds of 12.5% sodium hypochlorite do you need?
11. How many pounds of dry chemical must be added to a 30 gallon tank to produce a 3% solution?
12. You receive a shipment of ferric chloride. They tell you it has a specific gravity of 1.39. How much does each gallon weigh (lbs)?
13. A tank receives a flow of 350 gpm. The tank has a diameter of 30 feet and has 25 feet of water in it. What is the detention time (in minutes) in the tank?

14. The flow to a clarifier is 2,400,000 gpd. If the lime dose required is determined to be 11.9 mg/L, how many lbs/day of lime will be required?
15. How much does a 30 gallon drum of 60% fluorosilic acid weigh (lbs) if it has a specific gravity of 1.46?
16. A plant is set at a flow of 3 MGD. The sedimentation tank is 30 feet long, 20 feet wide and has a water depth of 15 feet. What is the detention time (in minutes)?
17. What is the volume (ft^3) of a tank that has a diameter of 48" and has 6 ft of water in it?
18. What would the volume (gallons) of a tank be if the tank had a diameter of 30 feet and was 30 feet high?
19. DelPac has a specific gravity of 1.29. How much would you expect a 30 gallon drum to weight (in pounds)?
20. An operator wants to estimate the approximate speed and stroke settings on a diaphragm pump that is rated to deliver a maximum output of 30 gallons per day. The system needs to deliver approximately 19 gallons per day of 50% caustic soda. Where would the speed and stroke need to be set?
21. An operator wants to estimate the approximate speed and stroke settings on a diaphragm pump that is rated to deliver a maximum output of 24 gallons per day. The system needs to deliver approximately 10 gallons per day of 12.5% sodium hypochlorite. Where would the speed and stroke need to be set?
22. A treatment plant uses liquid alum for coagulation. The plant is treating 875 gpm and an alum dosage of 10.5 mg/l is required. The alum has an "active ingredient" weight of 5.48 lb/gallon. Compute the required alum feed rate in gallons/day.

Homework

1. ___________ The clumping together of very fine particles into larger particles (floc) caused by the use of chemicals (coagulant chemicals). The chemicals neutralize the electrical charges of the fine particles and cause destabilization of the particles. This clumping together makes it easier to separate the solids from the water by settling, skimming, draining or filtering.
2. Name three types of primary coagulants:
   a.
   b.
   c.
3. Name three chemicals which will raise pH and three chemicals which will lower pH:
   a. Raise

   b. Lower

4. _____________________________: the capacity of a water to neutralize acids. This capacity is caused by the water's content of bicarbonate, carbonate and hydroxide.
5. ______________________and ____________________may be increased by the addition of lime, caustic soda or soda ash. ____________________ will only make water more alkaline.
6. Name the two general methods for controlling tastes and odors.
   a.
   b.

7. Water may need softened to remove excess hardness caused by ______________________________.
8. What factors should be considered when selecting a fluoridation chemical:
    a.
    b.
    c.
9. Chlorine can be added to the water in the form of:
    a.
    b.
    c.
10. _________________________ contain detailed assessment of chemical characteristics, hazards, and other information relative to health, safety, and the environment.
11. The SDS for Aluminum Sulfate states the:
    a. Specific gravity =
    b. pH =
12. An ________________________ must be developed to help a system protect public health, limit damage to the system and the surrounding area, and help a system return to normal as soon as possible.
13. ___________________ – Should be suspended just above the bottom of the tank so as not to pull in any solids that might have settled to the bottom of the tank.
14. A _________________ consists of a graduated cylinder typically located on the suction side of the pump. It is used for accurate determination of the pump's feed rate.
15. The output of the pump is controlled by the length of the plunger and the number of repetitions. This is the:
    a.
    b.
16. What chemicals can be fed using a dry feeder?
    a.
    b.

c.

17. Name the two types of dry feeders:

    a.

    b.

18. __________________ is a laboratory procedure that simulates coagulation, flocculation, and precipitation results with differing chemical dosages.

19. After a jar test, evaluate jar test results for:

    a.

    b.

    c.

    d.

20. ____________: The dry product that you are adding or the amount of dry product in a concentrated solution.

21. _______________is the quantity or weight of chemical delivered from a feeder over a given period of time.

22. A tank holds 75,000 gallons. A pump is flowing at 75 gpm. What is the detention time in hours?

23. A flocculation basin is 7 ft deep, 15 ft wide, and 30 ft long. If the flow through the basin is 1.35 MGD, what is the detention time in minutes?

24. A basin, 4 ft by 5 ft, is to be filled to the 2.5 feet level. If the flow to the tank is 5 gpm, how long (in hours) will it take to fill the tank?

25. A tank has a diameter of 60 feet with an overflow depth at 44 feet. The current water level is 16 feet. Water is flowing into the tank at a rate of 250 gallons per minute. At this rate, how many days will it take to fill the tank to the overflow?

26. How many pounds of dry chemical must be added to a 50 gallon tank to produce a 2% solution?

27. How many pounds of dry chemical must be added to a 100 gallon tank to produce a 5% solution?

28. How many pounds of dry chemical must be added to a 75 gallon tank to produce a 8% solution?

29. How much does each gallon of zinc orthophosphate weigh (pounds) if it has a specific gravity of 1.46?

30. How much does a 55 gallon drum of 25% caustic soda weigh (pounds) if the specific gravity is 1.28?

31. 60% hydrofluosilicic acid has a specific gravity of 1.46. How much (in pounds) does a 30 gallon drum weigh?

32. An operator wants to estimate the approximate speed and stroke settings on a diaphragm pump that is rated to deliver a maximum output of 24 gallons per day. The system needs to deliver approximately 10 gallons per day of sodium hypochlorite. Where would the speed and stroke need to be set?

33. An operator wants to estimate the approximate speed and stroke settings on a diaphragm pump that is rated to deliver a maximum output of 30 gallons per day. The system needs to deliver approximately 19 gallons per day of 50% caustic soda. Where would the speed and stroke need to be set?

Classroom/System Connection

Components of your liquid chemical feed system

1. What type of chemical addition tank/vessel do you have?
    a. Day Tank?
    b. Chemical Drum?
    c. Bulk tank?
2. What type of measuring device do you have?
    a. Scale?
    b. Sight glass?
    c. Yardstick
    d. Increments marked on day tank?
    e. Electronic level indicator?
3. Describe one of your chemical feed pumps.
    a. How many gpd can you feed?
    b. What is the speed and/or stroke of your pump currently set at?
    c. Using the max gpd, your current speed and stroke, how many gpd are you <u>theoretically</u> feeding?
    d. Measure how many gallons you <u>actually</u> fed in 24 hours.
        i. Determine if pump is feeding within the expected range:
        ii. $\pm$ 10% is within expected range.
            1. $\frac{\text{(Theoretical – Actual)}}{\text{Theoretical}} \times 100 =$ ________%
4. Do you have a calibration column?
5. Valve location.
    a. Where is your pressure relief valve?
    b. Where is the backpressure/anti-siphon valve?
6. Do you have a pressure gauge on your feed system? What does the pressure read?
7. Describe location of injection assembly.