Drinking Water
Operator Certification Training

Module 21:
Chemical Addition

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Topical Outline

B. Solving feed rate problems using Davidson pie

IV. Liquid Chemicals

A. Chemicals – Active Strength/Active Ingredient Weight

B. Perform process control calculations including calculating:

1. "Active ingredient" weight
2. Weight of "active chemicals" within a drum
3. Total weight of a gallon of a % solution
4. Drum weight of a % solution
5. Using "active ingredient" weight to convert feed rate of lbs/day to gal/day
6. Theoretical pump output

V. Pump Calibration

A. Steps in Developing a Pump Calibration Curve

B. Calculating # of gallons used in 8 hours from a pump setting

C. Pump Calibration Operator Tips

D. Optional Class Activity: Pump Calibration Workshop

VI. Gas Feeders

A. Direct feed

B. Solution feed

C. Feed rate equation

Unit 4 – Chemical Feed System Schematics

I. Chemical Storage

A. Adequate Supply

B. Storage Areas

II. Dry Chemical Feed Systems

A. Storage Facilities

B. Feed Equipment

C. Accessory Equipment

III. Liquid Chemical Feed Systems

A. Storage Facilities

B. Feed Equipment

C. Accessory Equipment

Appendix

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

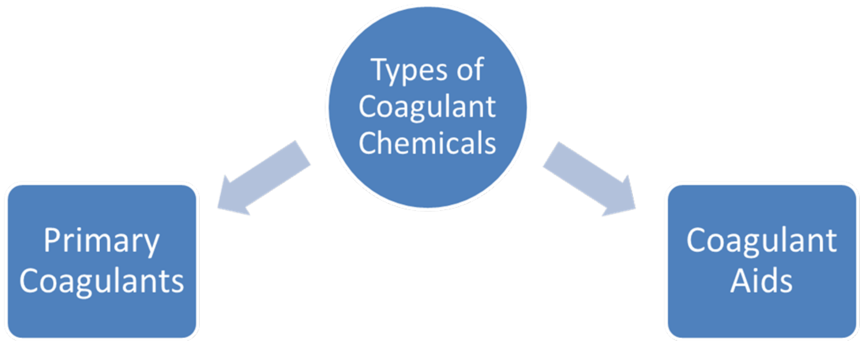
Water Treatment Plants are being designed and operated using chemicals for improving both process performance and finished water quality.

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.



- **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.

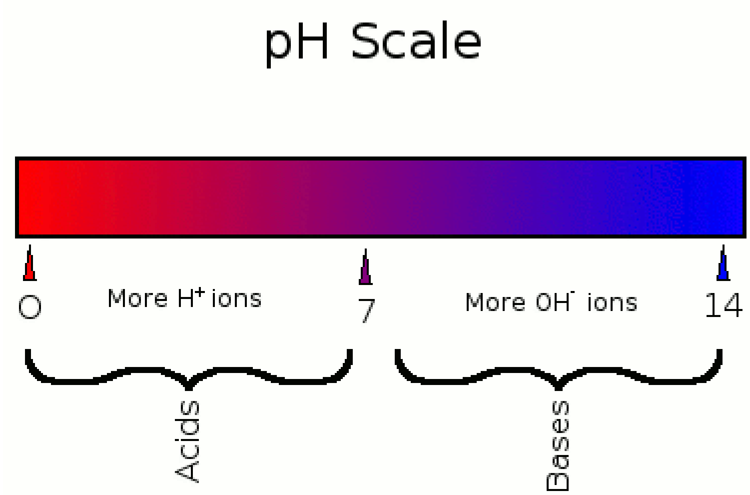
Table 1.1

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.

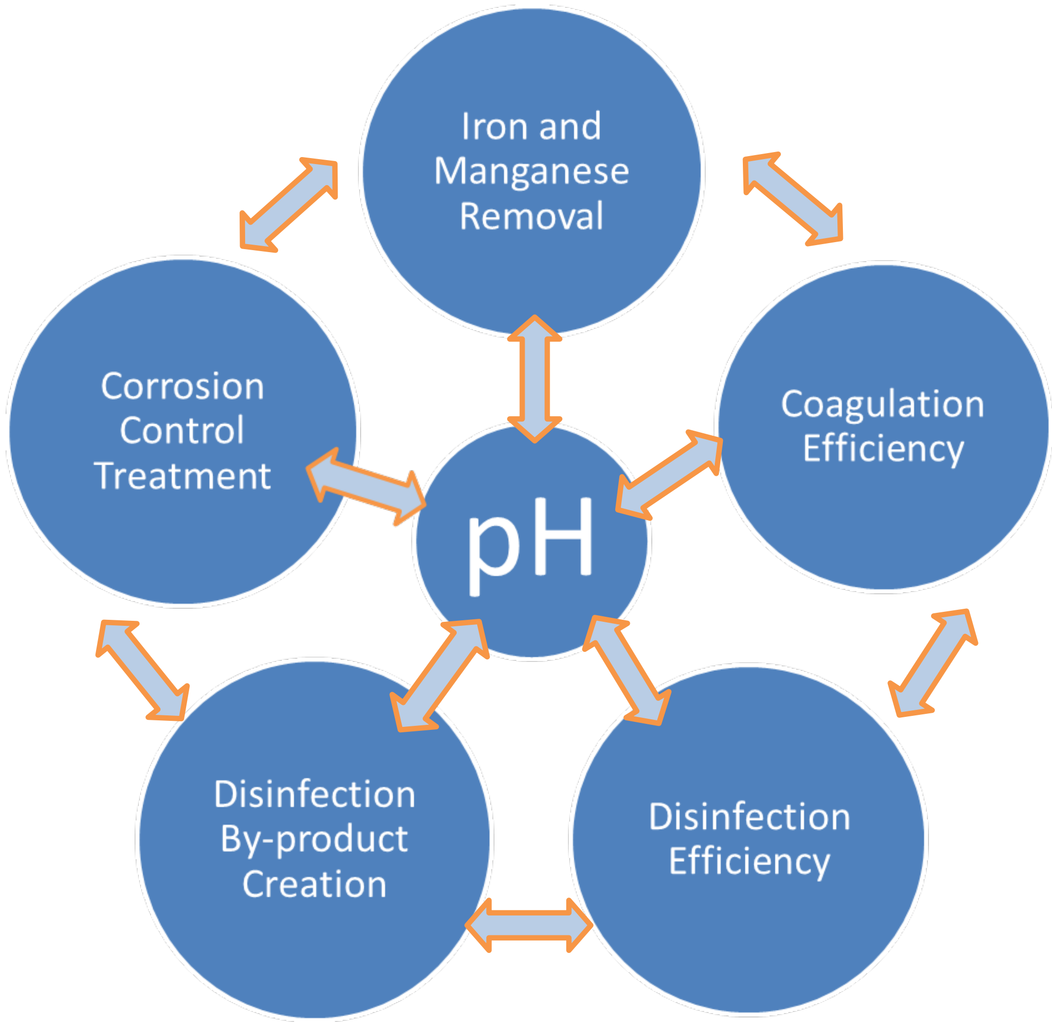
$H^+ > OH^-$ = acidic solution
$H^+ < OH^-$ = basic solution
$H^+ = OH^-$ = neutral solution

- 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.

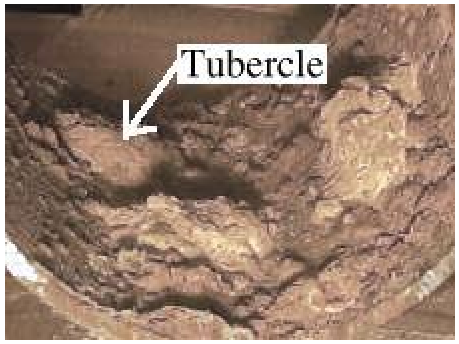
Removal of Trace Elements and Heavy Metals

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.

- NOTE: Fluoridation chemicals are hazardous to handle – be sure to use appropriate personal protective equipment, including a face shield, rubber apron, and rubber gloves.

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

ANSI/NSF 60: Water Treatment Chemicals

NSF led the development of American National Standards for all water treatment chemicals. This standard addresses the health effects implementations of treatment chemicals and related impurities. Chemicals used by a water supplier which come in contact with the water may affect the quality of the water. Water treatment chemicals which are certified for conformance with ANSI/NSF Standard 60 are deemed acceptable to the Department. Plant operators should verify that the chemicals used comply with this standard.

ANSI/NSF 61: Drinking Water System Components-Health Effects

Materials or water treatment equipment used in the construction or modification of a water system, which may affect the quality of the water and which are certified for conformance with ANSI/NSF Standard 61 are deemed acceptable to the Department. Plant operators should verify that any materials and treatment equipment used comply with this standard.

Switching Treatment Chemicals

There are some important things to consider before you decide to change treatment chemicals. The operations permit for the water supply specifies which treatment chemicals you are permitted to use. Work with DEP engineering staff in order to get a permit amendment issued prior to making a chemical switch. Items to consider include:

- Water chemistry
- Existing chemical feed equipment may not be compatible with a new chemical.
- There may be specific safety concerns with the new chemical that did not exist with the original chemical, so additional safety equipment may be needed.
- Simultaneous compliance and unintended consequences from a chemical switch must also be considered.

One-Hour Reporting Violations or Situations

A public water supplier shall report the circumstances to the Department within an hour of discovery for the following:

- A primary MCL or an MRDL has been exceeded or treatment technique requirement has been violated.
- A sample result that requires check samples to collected.
- Circumstances exist which may adversely affect the **quality** or **quantity** of drinking water.
- Any sample result that is *E. Coli* positive.

Some examples of when one-hour reporting is required:

- *A failure or significant interruption or breakdown in a key water treatment process*
- *A chemical spill*
- *An overfeed of a drinking water treatment chemical that exceeds a maximum use value.*

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 include 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 components of Chemical Handling Equipment.

Safety Data Sheets

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.

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) Figure 2.1

Hydrofluorosilicic Acid

Safety Data Sheet 217

Revision date: 04/30/2015 : Version: 1.0

SECTION 1: Identification of the substance/mixture and of the company/undertaking

1.1. Product identifier

Product form	:	Mixture
Product name	:	Hydrofluorosilicic Acid
Product code	:	HFSA
Formula	:	H_2SiF_6 (aq)
Synonyms	:	HFSA, Fluorosilicic acid

1.2. Relevant identified uses of the substance or mixture and uses advised against

Use of the substance/mixture : Industrial use

1.3. Details of the supplier of the safety data sheet

1.4. Emergency telephone number

Emergency number

SECTION 2: Hazards identification

2.1. Classification of the substance or mixture

GHS-US classification

Acute Tox. 4 (Oral)	H302
Acute Tox. 4 (Inhalation:dust,mist)	H332
Skin Corr. 1A	H314
Eye Dam. 1	H318
Aquatic Acute 3	H402

04/30/2015 EN (English) SDS Ref.: 217 1/12

2.2. Label elements

GHS-US labelling

Hazard pictograms (GHS-US) :

Signal word (GHS-US) : Danger

Hazard statements (GHS-US) : H302 - Harmful if swallowed
H314 - Causes severe skin burns and eye damage
H318 - Causes serious eye damage
H332 - Harmful if inhaled
H402 – Harmful to aquatic life

Precautionary statements (GHS-US) : P260 - Do not breathe fume, mist, vapours, spray
P264 - Wash hands and forearms thoroughly after handling
P270 - Do not eat, drink or smoke when using this product
P271 - Use only outdoors or in a well-ventilated area
P273 – Avoid release to the environment
P280 - Wear eye protection, face protection, protective gloves, protective clothing
P301+P330+P331 - IF SWALLOWED: Rinse mouth. Do NOT induce vomiting
P303+P361+P353 - IF ON SKIN (or hair): Remove/Take off immediately all contaminated clothing. Rinse skin with water/shower
P304+P340 - IF INHALED: Remove person to fresh air and keep comfortable for breathing
P305+P351+P338 - If in eyes: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing
P310 - Immediately call a POISON CENTER or doctor
P312 - Call a POISON CENTER or doctor if you feel unwell
P363 - Wash contaminated clothing before reuse
P405 - Store locked up
P501 - Dispose of contents/container according to local, regional, national, and international regulations

2.3. Other hazards

Hazardous to the aquatic environment

No additional information available

SECTION 3: Composition/information on ingredients

3.1. Substances

Not applicable

3.2. Mixture

Name	Product identifier	%	GHS-US classification
Fluorosilicic acid	(CAS No.) 16961-83-4	24	Acute Tox. 3 (Oral), H301 Acute Tox. 2 (Inhalation:dust,mist), H330 Skin Corr. 1A, H314

Hydrofluorosilicic Acid
Safety Data Sheet 217

			Eye Dam. 1, H318 Aquatic Acute 3, H402
Water	(CAS No.) 7732-18-5	76	Not classified
Fluorides, as F		19	Not classified

SECTION 4: First aid measures

4.1. Description of first aid measures

First-aid measures general : If exposed or concerned: Get medical advice/attention. If you feel unwell, seek medical advice (show the label where possible).

First-aid measures after inhalation : Using proper respiratory protection, immediately move the exposed person to fresh air. Keep at rest and in a position comfortable for breathing. Give oxygen or artificial respiration if necessary. Seek immediate medical advice. Symptoms may be delayed.

First-aid measures after skin contact : Remove/Take off immediately all contaminated clothing. Rinse immediately with plenty of water (for at least 15 minutes). Seek medical attention immediately if exposure is severe. Obtain medical attention if irritation develops or persists. Wash contaminated clothing before reuse.

First-aid measures after eye contact : Immediately rinse with water for a prolonged period (at least 15 minutes) while holding the eyelids wide open. Seek medical attention immediately if exposure is severe. Obtain medical attention if irritation develops or persists.

First-aid measures after ingestion : If swallowed, do not induce vomiting. Seek medical advice immediately and show this container or label.

4.2. Most important symptoms and effects, both acute and delayed

Symptoms/injuries : Corrosive. Causes burns. Harmful if swallowed. Harmful if inhaled.

Symptoms/injuries after inhalation : Causes severe respiratory irritation if inhaled. Symptoms may include: Burning of nose and throat, constriction of airway, difficulty breathing, shortness of breath, bronchial spasms, chest pain, and pink frothy sputum. Contact may cause immediate severe irritation progressing quickly to chemical burns. May cause pulmonary edema. Symptoms may be delayed.

Symptoms/injuries after skin contact : Contact may cause immediate severe irritation progressing quickly to chemical burns.

Symptoms/injuries after eye contact : Contact may cause immediate severe irritation progressing quickly to chemical burns. Can cause blindness.

Symptoms/injuries after ingestion : May cause burns or irritation of the linings of the mouth, throat, and gastrointestinal tract. Swallowing a small quantity of this material will result in serious health hazard.

Chronic symptoms : Repeated or prolonged inhalation may damage lungs. Prolonged and repeated contact will eventually cause permanent tissue damage. Repeated and prolonged exposure to flourine containing compounds may cause flourosis, a condition characterized by changes in bone density and strength, accompanied by stiffness and pain in joints.

4.3. Indication of any immediate medical attention and special treatment needed

No additional information available

Hydrofluorosilicic Acid

Safety Data Sheet 217

SECTION 5: Firefighting measures

5.1. Extinguishing media

Suitable extinguishing media : Use extinguishing media appropriate for surrounding fire.

Unsuitable extinguishing media : Do not get water inside containers. Do not apply water stream directly at source of leak. Do not use a heavy water stream. A direct water stream will cause violent splattering and generation of heat.

5.2. Special hazards arising from the substance or mixture

Fire hazard : Not flammable. Under conditions of fire this material may produce: Silicon oxides. Hydrogen fluoride. Tetrafluorosilane. Decomposes above 108 °C (227 °F)

Explosion hazard : Product is not explosive.

5.3. Advice for firefighters

Firefighting instructions : Keep upwind. Use water spray or fog for cooling exposed containers.

Protection during firefighting : Firefighters must use full bunker gear including NIOSH-approved positive-pressure self-contained breathing apparatus to protect against potential hazardous combustion and decomposition products.

Other information : Do not allow run-off from fire fighting to enter drains or water courses.

SECTION 6: Accidental release measures

6.1. Personal precautions, protective equipment and emergency procedures

6.1.1. For non-emergency personnel

Protective equipment : Use recommended respiratory protection. Wear suitable protective clothing, gloves and eye/face protection.

Emergency procedures : Stop leak if safe to do so. Eliminate ignition sources. Evacuate unnecessary personnel. Ventilate area. Keep upwind.

6.1.2. For emergency responders

Protective equipment : Use recommended respiratory protection. Wear suitable protective clothing, gloves and eye/face protection.

Emergency procedures : Stop leak if safe to do so. Eliminate ignition sources. Evacuate unnecessary personnel. Ventilate area.

6.2. Environmental precautions

If spill could potentially enter any waterway, including intermittent dry creeks, contact the U.S. COAST GUARD NATIONAL RESPONSE CENTER at 800-424-8802. In case of accident or road spill notify CHEMTREC at 800-424-9300. In other countries call CHEMTREC at (International code) +1-703-527-3887.

6.3. Methods and material for containment and cleaning up

For containment : Contain any spills with dikes or inert absorbents to prevent migration and entry into sewers or streams. Do not allow into drains or water courses or dispose of where ground or surface waters may be affected.

Methods for cleaning up : Ventilate area. Small quantities of liquid spill: take up in non-combustible inert absorbent material and shovel into container for disposal. Collect absorbed material and place into a sealed, labelled container to be disposed at an appropriate disposal facility according to current applicable laws and regulations and product characteristics at the time of disposal.

Liquid spill: neutralize with powdered limestone or sodium bicarbonate.

Practice good housekeeping – spillage can be slippery on smooth surface either wet or dry.

6.4. Reference to other sections

No additional information available

SECTION 7: Handling and storage

7.1. Precautions for safe handling

Precautions for safe handling : Avoid all eyes and skin contact and do not breathe vapour and mist. Wear recommended personal protective equipment. Ensure there is adequate ventilation. Keep away from heat and open flame. Employ good maintenance practices to prevent leaks. Use good process control measures to prevent releases.

Hygiene measures : Handle in accordance with good industrial hygiene and safety procedures. Emergency eye wash fountains and safety showers should be available in the immediate vicinity of any potential exposure. Wash contaminated clothing before reuse.

7.2. Conditions for safe storage, including any incompatibilities

Incompatible materials : Reacts with many metals to produce flammable and explosive hydrogen gas.

Prohibitions on mixed storage : Keep away from strong acids and bases, chlorites, organic peroxides, combustible materials, and metals.

Storage area : Store in dry, cool area. Store in a well-ventilated place away from heat and sources of ignition. Large tanks should be bermed and electrically grounded. Keep away from combustible materials. Avoid using glass, metal, or stoneware containers.

7.3. Specific end use(s)

Industrial use.

SECTION 8: Exposure controls/personal protection

8.1. Control parameters

Fluorides		
USA ACGIH	TWA	2.5 mg/ m^3
USA OSHA	TWA	2.5 mg/ m^3
USA NIOSH	TWA	2.5 mg/ m^3

8.2. Exposure controls

Appropriate engineering controls : Ensure adequate ventilation, especially in confined areas.

Hydrofluorosilicic Acid
Safety Data Sheet 217

Personal protective equipment	: Protective goggles. Face shield. Gas mask at concentration in the air > > TLV. Protective clothing.

Hand protection	: Impermeable protective gloves, such as: nitrile, neoprene, or PVC. Wear gauntlet gloves. Check glove manufacturer's permeation / degradation information.
Eye protection	: Chemical safety goggles. Face shield. Do not wear contact lenses.
Skin and body protection	: Wear suitable protective clothing. Chemical resistant suit. Rubber apron, boots.
Respiratory protection	: Use a NIOSH-approved respirator or self-contained breathing apparatus whenever exposure may exceed established Occupational Exposure Limits. Use respirator approved for acid fumes and mist.
Environmental exposure controls	: Emergency eye wash fountains and safety showers should be available in the immediate vicinity of any potential exposure.

SECTION 9: Physical and chemical properties

9.1. Information on basic physical and chemical properties

Physical state	: Liquid
Colour	: Water white to straw yellow.
Odour	: Pungent
Odour threshold	: No data available
pH	: 1.5 - 2
pH solution	: 10 %
Molecular mass	: 144 g/mol (Hydrofluorosilicic acid)
Relative evaporation rate (butylacetate=1)	: No data available
Melting point	: -18 - -20 °C (-1 - -4 °F)
Freezing point	: No data available
Boiling point	: 136 - 163 °C (277 - 326 °F)
Flash point	: No data available
Self ignition temperature	: No data available
Decomposition temperature	: 108 °C (227 °F)
Flammability (solid, gas)	: No data available
Vapour pressure	: 24 mm Hg at 25 °C (77 °F)
Relative vapour density at 20 °C	: No data available
Relative density	: 1.2 at 24 °C (75 °F)
Density	: 10.3 lb/gal
Solubility	: Water: Miscible
Log Pow	: No data available

Log Kow	:	No data available
Viscosity	:	No data available
Explosive properties	:	No data available
Oxidising properties	:	No data available
Explosive limits	:	No data available

9.2. Other information

No additional information available

SECTION 10: Stability and reactivity

10.1. Reactivity

May react violently with water.

10.2. Chemical stability

Stable at standard temperature and pressure.

10.3. Possibility of hazardous reactions

Hazardous polymerization will not occur.

10.4. Conditions to avoid

Temperatures above 108 °C (227 °F).

10.5. Incompatible materials

Keep away from strong acids and bases, chlorites, organic peroxides, combustible materials, and metals. Attacks glass and stoneware.

10.6. Hazardous decomposition products

Thermal decomposition generates : Silicon oxides. Hydrogen fluoride. Tetrafluorosilane.

SECTION 11: Toxicological information

11.1. Information on toxicological effects

Acute toxicity : Harmful if swallowed. Harmful if inhaled.

Fluorosilicic acid (16961-83-4)	
LD50 oral rat	125 mg/kg
LC50 inhalation rat (mg/l)	0.28 mg/l (reported as 1.11 mg/l/1h)

Skin corrosion/irritation	:	Causes severe skin burns and eye damage. pH: 1.5 - 2
Serious eye damage/irritation	:	Causes serious eye damage. pH: 1.5 - 2
Respiratory or skin sensitisation	:	Not classified
Germ cell mutagenicity	:	Not classified
Carcinogenicity	:	Not classified

Fluorosilicic acid (16961-83-4)	
IARC group	3

Reproductive toxicity : Not classified

Hydrofluorosilicic Acid

Safety Data Sheet 217

Specific target organ toxicity (single exposure)	:	Not classified
Specific target organ toxicity (repeated exposure)	:	Not classified
Aspiration hazard	:	Not classified

SECTION 12: Ecological information

12.1. Toxicity

Ecotoxicity	**EPA Ecological Toxicity rating :**	No data available.
	Acute Toxicity to Fish:	No data available.
	Chronic Toxicity to Fish:	No data available.
	Acute Toxicity to Aquatic Invertebrates:	(Frog) Subcutaneous: LD_{LO} = 140 mg/kg.
	Chronic Toxicity to Aquatic Invertebrates:	No data available.
	Acute Toxicity to Aquatic Plants:	No data available.
	Toxicity to Soil Dwelling Organisms:	No data available.
	Toxicity to Terrestrial Plants:	No data available.
Environmental Fate:	**Stability in Water:**	Product is NSF certified to ANSI Standard 60 for the fluoridation of municipal water supplies.
	Stability in Soil:	No data available.
	Transport and Distribution:	No data available.
Toxicity:	No data available	
Degradation Products:	**Biodegradation:**	No data available.
	Photodegradation:	No data available.

SECTION 13: Disposal considerations

13.1. Waste treatment methods

Sewage disposal recommendations	:	This material is hazardous to the aquatic environment. Keep out of sewers and waterways.
Waste disposal recommendations	:	Place in an appropriate containerdispose of contaminated material at a licensed site.
Additional information	:	Dispose of waste material in accordance with all local, regional, national, and international regulations.

SECTION 14: Transport information

In accordance with DOT / TDG / ADR / RID / ADNR / IMDG / ICAO / IATA

14.1. UN number

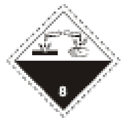
UN-No.(DOT)	:	1778
DOT NA no.		UN1778

14.2. UN proper shipping name

DOT Proper Shipping Name	:	Fluorosilicic acid
Department of Transportation (DOT) Hazard Classes	:	8 - Class 8 - Corrosive material 49 CFR 173.136

Hydrofluorosilicic Acid
Safety Data Sheet 217

Hazard labels (DOT) : 8 - Corrosive substances



Packing group (DOT) : II - Medium Danger

DOT Special Provisions (49 CFR 172.102) : A6 - For combination packagings, if plastic inner packagings are used, they must be packed in tightly closed metal receptacles before packing in outer packagings.
A7 - Steel packagings must be corrosion-resistant or have protection against corrosion.
B2 - MC 300, MC 301, MC 302, MC 303, MC 305, and MC 306 and DOT 406 cargo tanks are not authorized.
B15 - Packagings must be protected with non-metallic linings impervious to the lading or have a suitable corrosion allowance.
IB2 - Authorized IBCs: Metal (31A, 31B and 31N); Rigid plastics (31H1 and 31H2); Composite (31HZ1). Additional Requirement: Only liquids with a vapor pressure less than or equal to 110 kPa at 50 C (1.1 bar at 122 F), or 130 kPa at 55 C (1.3 bar at 131 F) are authorized.
N3 - Glass inner packagings are permitted in combination or composite packagings only if the hazardous material is free from hydrofluoric acid.
N34 - Aluminum construction materials are not authorized for any part of a packaging which is normally in contact with the hazardous material.
T8 - 4 178.274(d)(2) Normal............. Prohibited
TP2 - a. The maximum degree of filling must not exceed the degree of filling determined by the following: (image) Where: tr is the maximum mean bulk temperature during transport, tf is the temperature in degrees celsius of the liquid during filling, and is the mean coefficient of cubical expansion of the liquid between the mean temperature of the liquid during filling (tf) and the maximum mean bulk temperature during transportation (tr) both in degrees celsius. b. For liquids transported under ambient conditions may be calculated using the formula: (image) Where: d15 and d50 are the densities (in units of mass per unit volume) of the liquid at 15 C (59 F) and 50 C (122 F), respectively.
TP12 - This material is considered highly corrosive to steel.

DOT Packaging Exceptions (49 CFR 173.xxx) : None

DOT Packaging Non Bulk (49 CFR 173.xxx) : 202

DOT Packaging Bulk (49 CFR 173.xxx) : 242

14.3. Additional information

Emergency Response Guide (ERG) Number : 154

Other information : No supplementary information available.

Hydrofluorosilicic Acid
Safety Data Sheet 217

Overland transport

No additional information available

Transport by sea

DOT Vessel Stowage Location : A - The material may be stowed "on deck" or "under deck" on a cargo vessel and on a passenger vessel.

Air transport

DOT Quantity Limitations Passenger aircraft/rail (49 CFR 173.27) : 1 L

DOT Quantity Limitations Cargo aircraft only (49 CFR 175.75) : 30 L

IATA ERG Number : 8L

SECTION 15: Regulatory information

15.1. US Federal regulations

Hydrofluorosilicic Acid	
SARA Section 311/312 Hazard Classes	Immediate (acute) health hazard Delayed (chronic) health hazard

Fluorosilicic acid (16961-83-4)
Listed on the United States TSCA (Toxic Substances Control Act) inventory

15.2. US State regulations

The following states have an OSH program approved by OSHA. If you are located in any of these states you may be under state jurisdiction rather than federal jurisdiction and your state may have more stringent requirements than OSHA. You should consult your state regulations to ensure compliance.

Alaska	Indiana	Minnesota	North Carolina	Utah
Arizona	Iowa	Nevada	Oregon	Vermont
California	Kentucky	New Mexico	Puerto Rico	*Virgin Islands
*Connecticut	Maryland	*New Jersey	South Carolina	Virginia
Hawaii	Michigan	*New York	Tennessee	Washington
*Illinois				Wyoming

*The state plans in these states apply only to public sector employers. In these states private sector employers are subject to USOL – OSHA jurisdiction. All other state plans apply to both public and private sector employers.

Fluorosilicic acid (16961-83-4)
U.S. - Massachusetts - Oil & Hazardous Material List - Groundwater Reportable Conc. - Reporting Category 1
U.S. - Massachusetts - Oil & Hazardous Material List - Groundwater Reportable Conc. - Reporting Category 2
U.S. - Massachusetts - Oil & Hazardous Material List - Reportable Quantity
U.S. - Massachusetts - Oil & Hazardous Material List - Soil Reportable Concentration - Reporting Category 1
U.S. - Massachusetts - Oil & Hazardous Material List - Soil Reportable Concentration - Reporting Category 2
U.S. - Massachusetts - Right To Know List
U.S. - New Jersey - Right to Know Hazardous Substance List
U.S. - New Jersey - Special Health Hazards Substances List
U.S. - Texas - Effects Screening Levels - Long Term

04/30/2015 EN (English) SDS Ref.: 217 10/12

U.S. - Texas - Effects Screening Levels - Short Term

15.3. Canadian regulations

Hydrofluorosilicic Acid	
WHMIS Classification	Class D Division 1 Subdivision A - Very toxic material causing immediate and serious toxic effects Class E - Corrosive Material

Fluorosilicic acid (16961-83-4)
Listed on the Canadian DSL (Domestic Sustances List) inventory. Listed on the Canadian Ingredient Disclosure List – Disclosure at 1%.

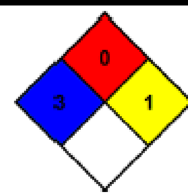
This product has been classified in accordance with the hazard criteria of the Controlled Products Regulations (CPR) and the MSDS contains all of the information required by the CPR.

SECTION 16: Other information

NFPA health hazard : 3 - Short exposure could cause serious temporary or residual injury even though prompt medical attention was given.

NFPA fire hazard : 0 - Materials that will not burn.

NFPA reactivity : 1 - Normally stable, but can become unstable at elevated temperatures and pressures or may react with water with some release of energy, but not violently.



Full text of H-phrases:

Acute Tox. 2 (Inhalation:dust,mist)	Acute toxicity (inhalation:dust,mist) Category 2
Acute Tox. 3 (Oral)	Acute toxicity (oral) Category 3
Acute Tox. 4 (Inhalation:dust,mist)	Acute toxicity (inhalation:dust,mist) Category 4
Acute Tox. 4 (Oral)	Acute toxicity (oral) Category 4
Eye Dam. 1	Serious eye damage/eye irritation Category 1
Skin Corr. 1A	skin corrosion/irritation Category 1A
H301	Toxic if swallowed
H302	Harmful if swallowed
H314	Causes severe skin burns and eye damage
H318	Causes serious eye damage
H330	Fatal if inhaled
H332	Harmful if inhaled

Previous PotashCorp MSDS Number : MSDS 52 – Hydrofluorosilicic Acid

SDS US (GHS HazCom 2012)

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. Nitrile gloves
    c. Face shield
    d. Dust mask
4. What is the specific gravity of fluorosilicic acid? _______
5. 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 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, Protective Equipment, and Protective Chemical Storage.

Components of Chemical Handling Equipment

1. Selection of Equipment

When handling chemicals use equipment listed on the SDS.

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

6. Protective Chemical Storage

- ❑ Avoid storing and handling incompatible chemicals in close proximity to each other. The EPA fact sheet in the Appendix provides practical guidance on the dos and don'ts of chemical storage at a water treatment plant.

Chemical Receiving Safety

When chemicals arrive at the water treatment plant, plant personnel shall follow all SOP's for how to receive the treatment chemical. There are several things to check prior to offloading the chemical so that the wrong or contaminated chemical is not received at the water treatment plant:

- Taking a tanker sample for analysis (color, pH, specific gravity, chemical concentration)
- Verify the supplier's paperwork matches what was ordered
- Checking the driver's credentials,
- Identifying the bulk storage tank capacity
- Wear the proper personal protective equipment before any chemical is transferred

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.

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

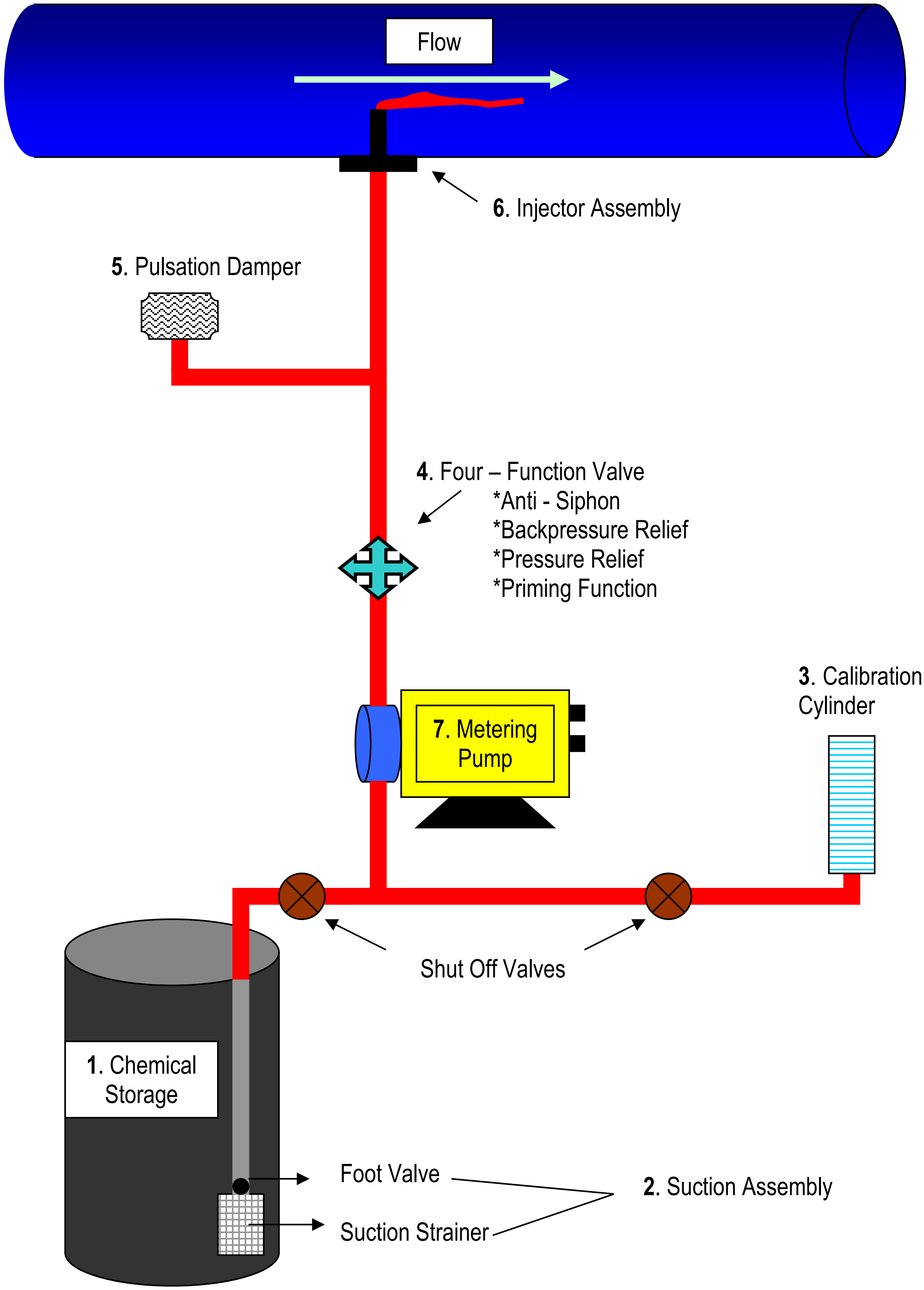


Figure 3.2

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).

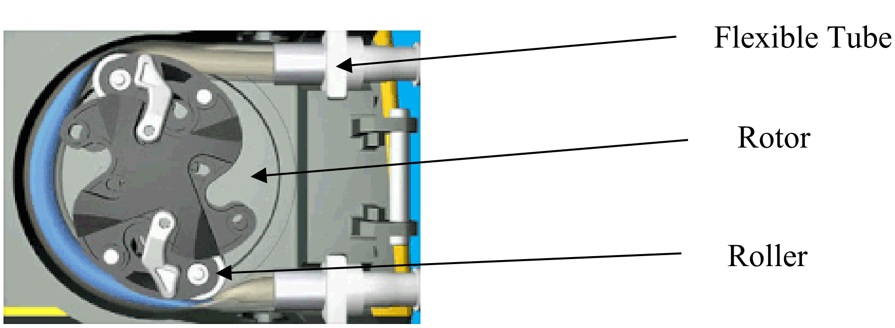
6. **Injector Assembly** - The art of chemical injection is complex.

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

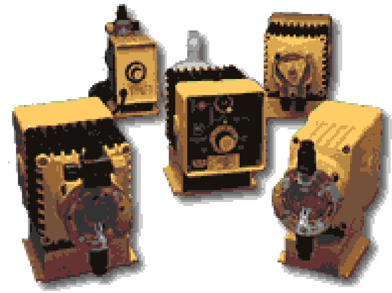
B. Location of the assembly is important for proper mixing. However, it also needs to be placed so it does not become clogged with passing debris that may be in the system.

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. The volume of chemical dispensed is determined by the flexible tubes inner diameter and the speed of the rotor.



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 into the chamber.

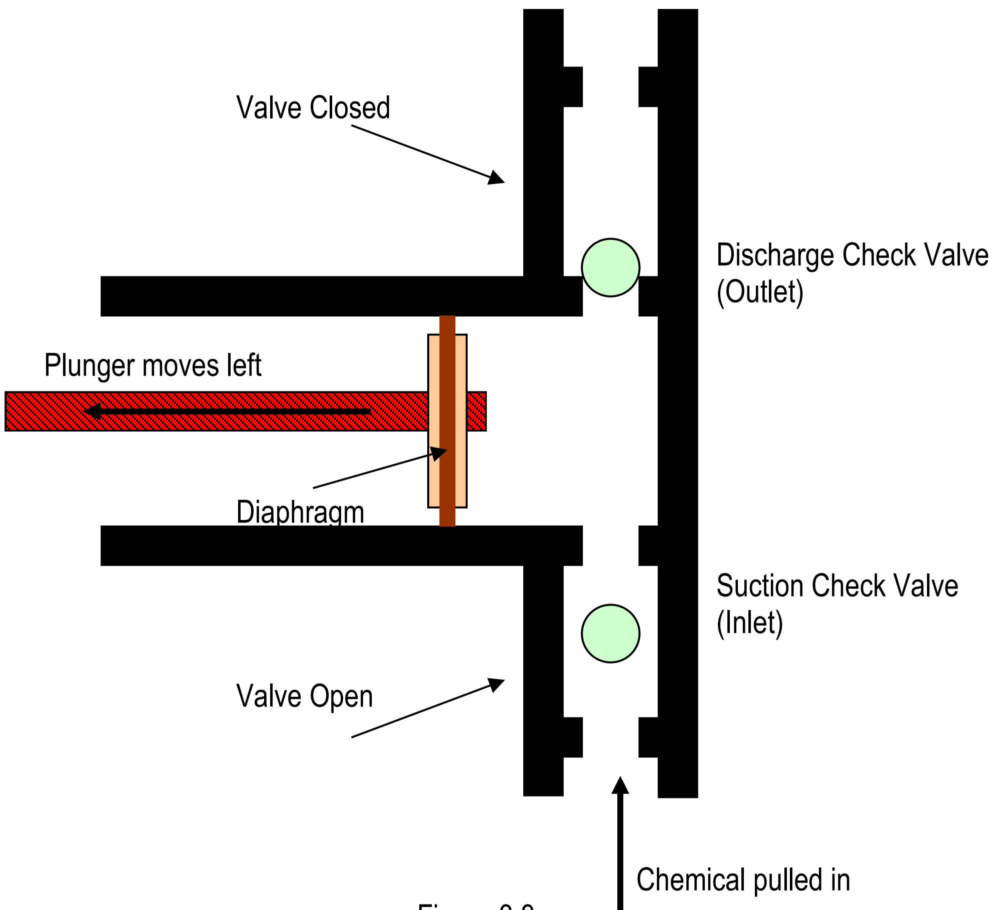


Figure 3.3

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 into the system. The pumping cycle starts over at this point.

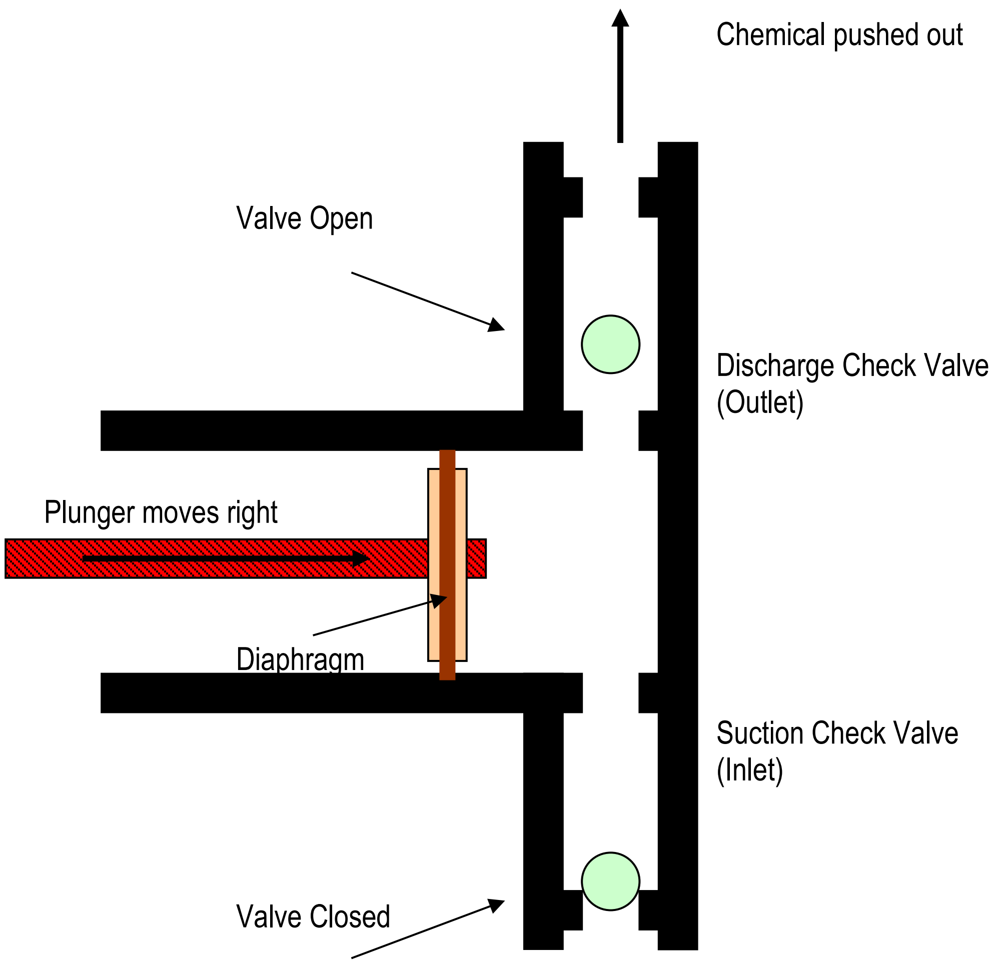


Figure 3.4

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 (typically a rotary type of mechanism using rotating rolls or screws) delivers exactly the same volume of dry chemical to the dissolving tank with each complete revolution. Varying the speed of rotation varies the feed rate.

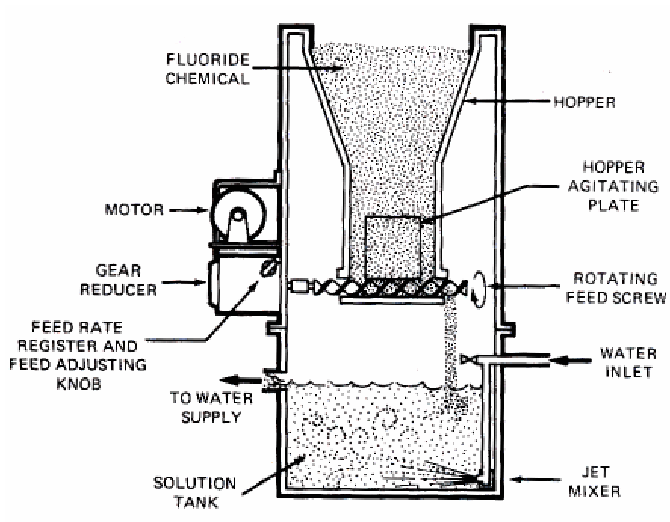


Figure 3.5

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.

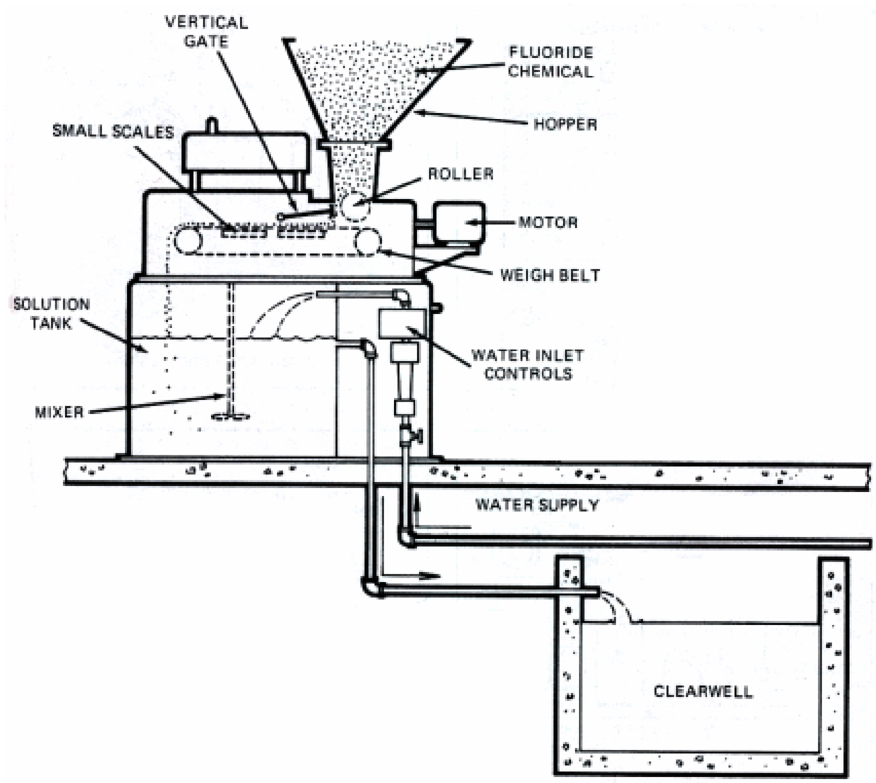


Figure 3.6

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.
- ❑ Turbidimeter – is used to measure turbidity.
- ❑ 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.

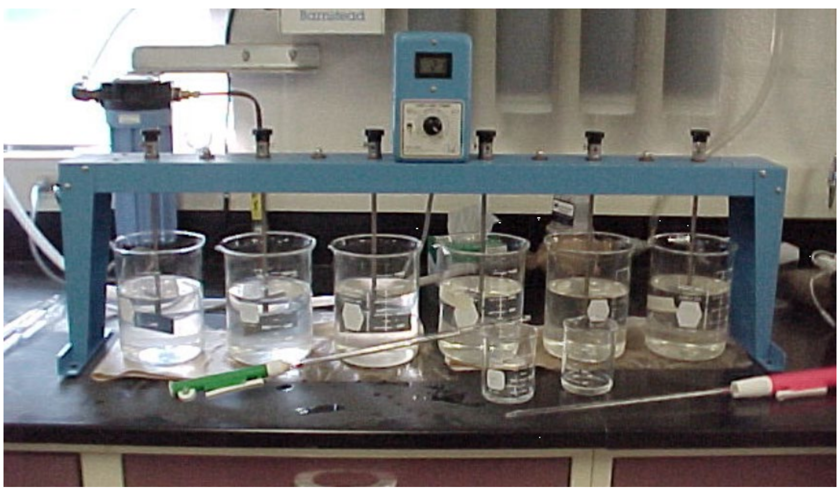


Figure 3.7 Jar Test Stirrer Equipment

- ❑ 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.

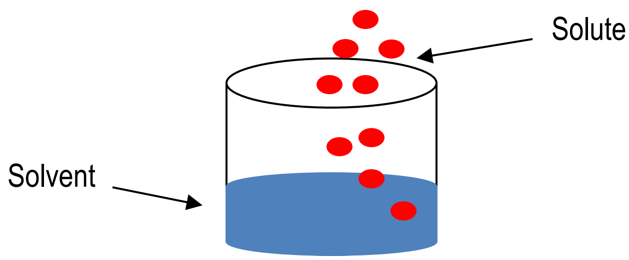
Dry Feeders

"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.

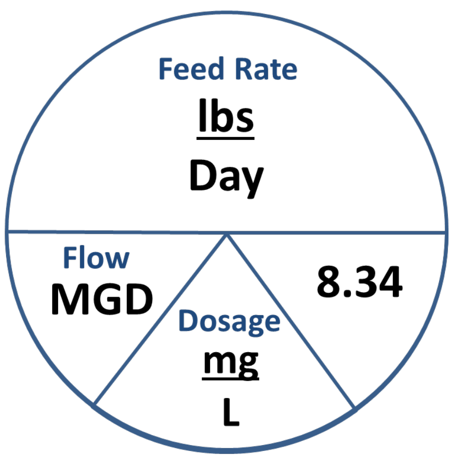
Flow Rate is the amount of water being treated daily at a facility. It is measured and reported in millions of gallons per day (MGD).

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) = Feed Rate (lbs/day) / [Dosage (mg/L) x 8.34]

   $$\text{Flow(MGD)} = \frac{\text{Feed Rate (lbs/day)}}{[\text{Dosage (mg/L)} \times 8.34]}$$

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

   Vertical Format: Dosage (mg/L) = Feed Rate (lbs/day) / [Flow(MGD) x 8.34]

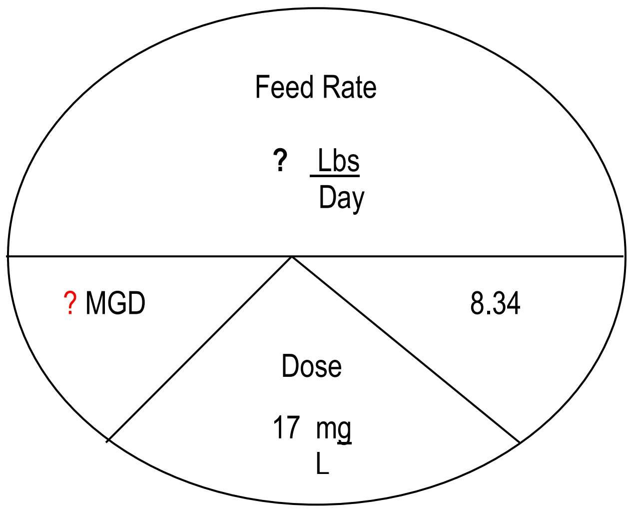
   $$\text{Dosage (mg/L)} = \frac{\text{Feed Rate (lbs/day)}}{[\text{Flow(MGD)} \times 8.34]}$$

☑ 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



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

$$= 0.288 \text{ X } 17 \text{ X } 8.34$$

= ______________ 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:

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

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

$12.76 \frac{\text{pounds}}{\text{gallon}} \times 0.50 =$ 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)

$$? \ \frac{\text{lbs}}{\text{gal}} \text{ of ferric chloride} = 1.38 \times 8.34 \frac{\text{lbs}}{\text{gal}} = \_\_\_\_\_ \frac{\text{lbs}}{\text{gal}}$$

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 SDS 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.

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

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

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

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 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

$$\text{Pump Output} = 24 \frac{\text{gal}}{\text{day}} \text{ X } 0.90 \text{ X } 0.70 = \_\_\_\_\_ \frac{\text{gal}}{\text{day}}$$

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

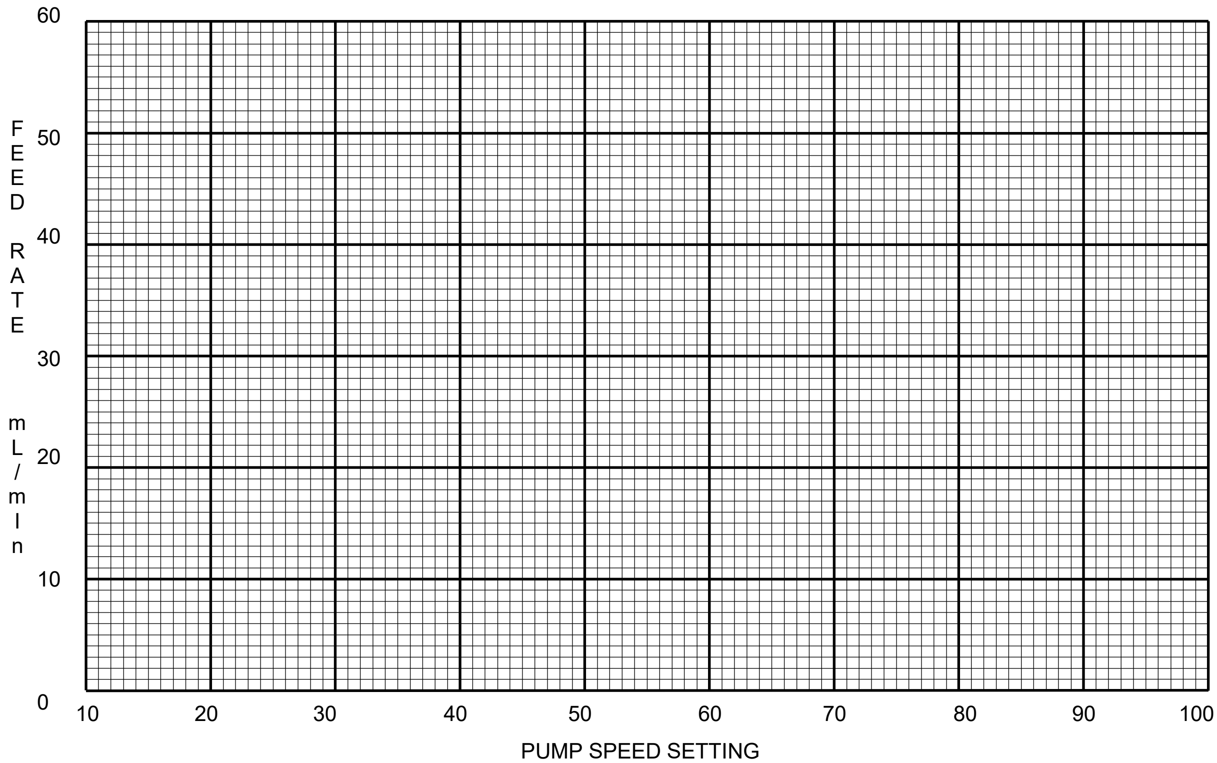
For Pump setting 100= 0.38 X 485.4 = 174.2 gal/day

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.

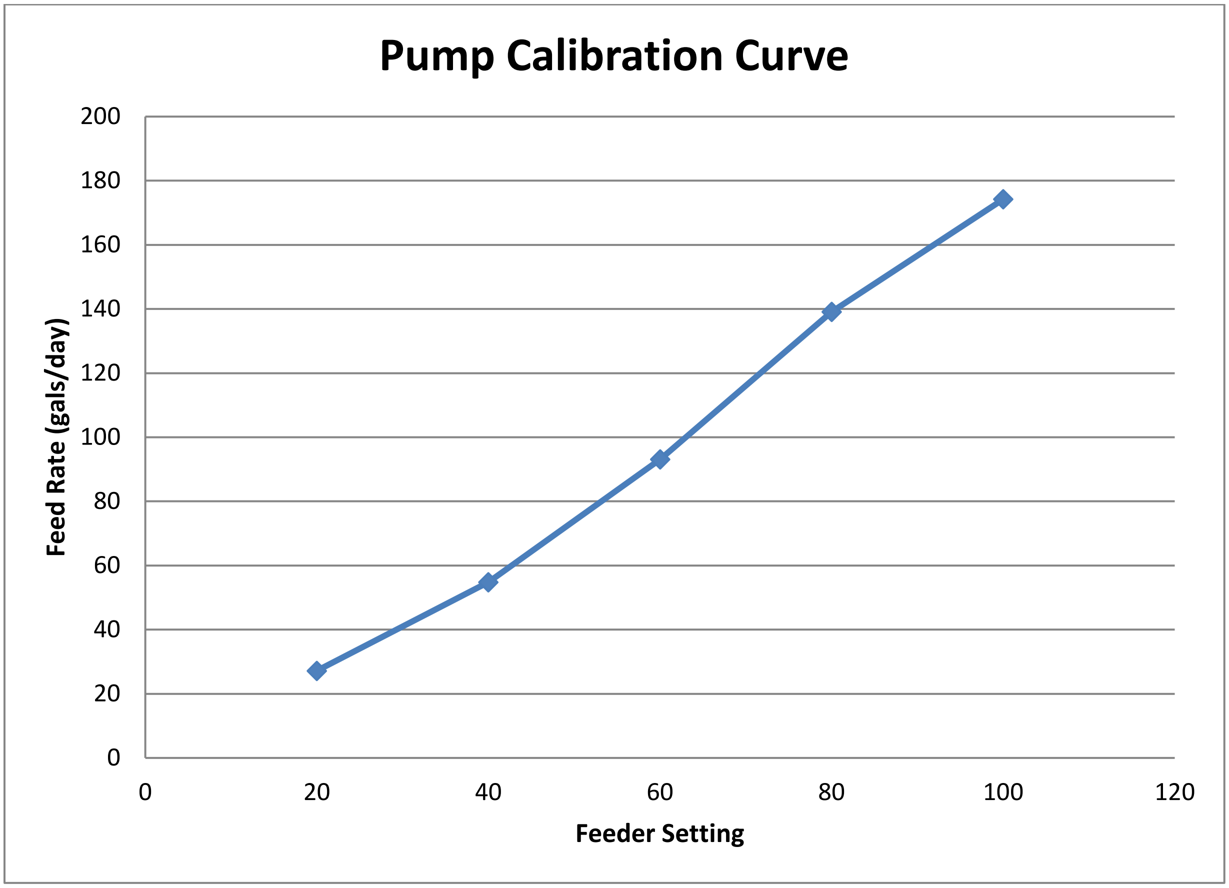


Figure 3.10 – Feeder Calibration Curve for 60% Stroke

Step 3: Select the pump speed 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 because changes to settings will provide a more predictable change in feed rate (dosage).
- For the chemical you are feeding, consider if a higher pump speed will deliver the chemical more consistently into the water stream and promote better chemical mixing.

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

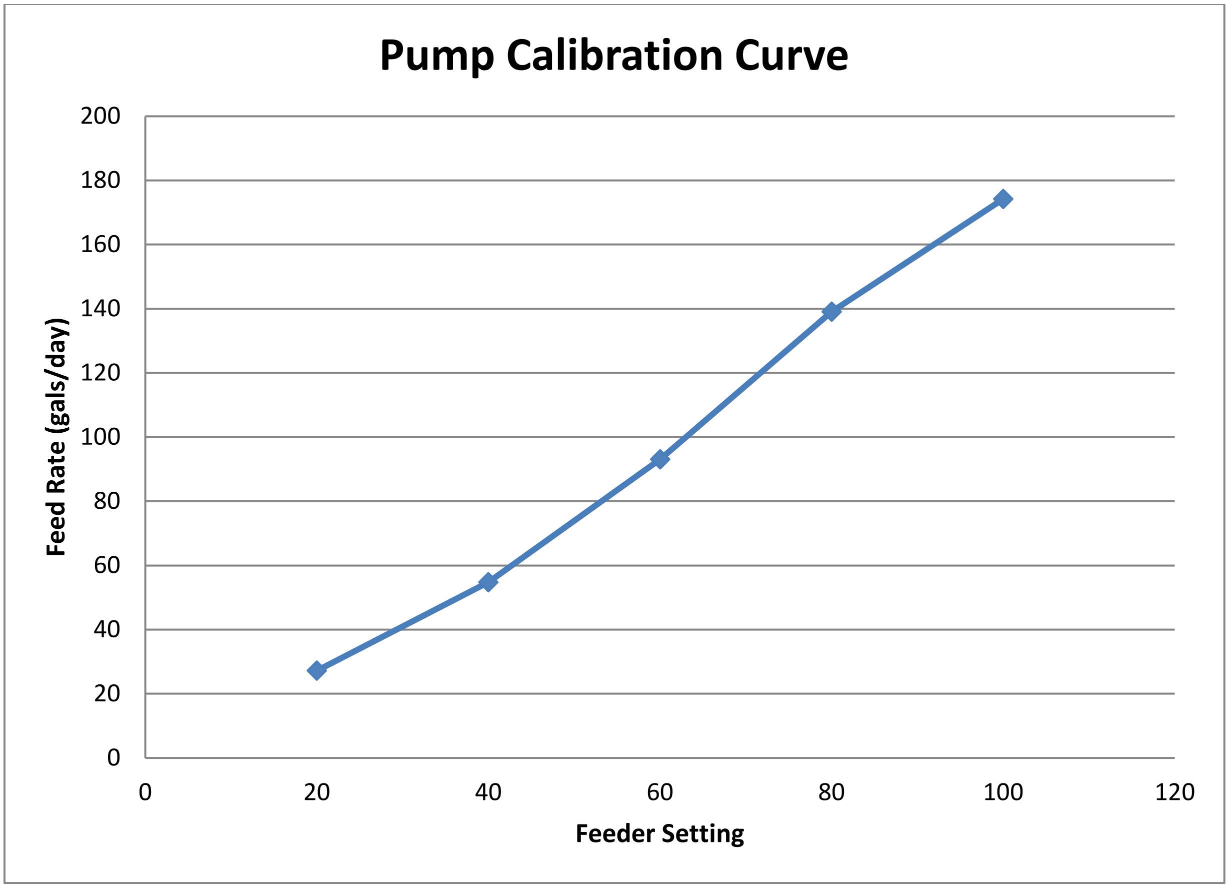


Figure 3.11 – Feeder Calibration Curve for 60% Stroke

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

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:

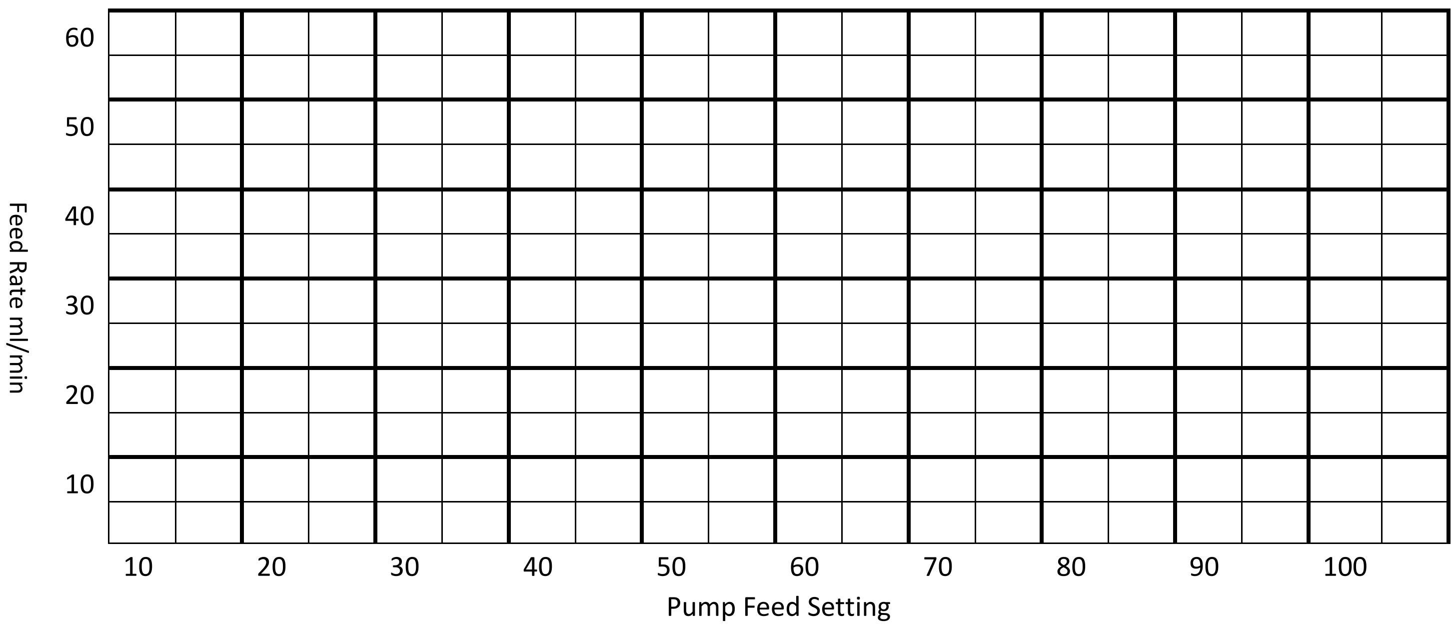
$$\text{Feed Rate (ml/min)} = \frac{80\text{ ml}}{2\text{ min}} = 40\text{ ml}$$

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?

Key points for Unit 3 Chemical Feed Components and Pump Calibration

- 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.
- Setting the proper feed pump setting to deliver the selected dosage involves:
    - **Step 1: Determining actual feed pump output for each stroke and speed setting.**
    - **Step 2 – Developing a feed pump calibration curve for each stroke setting.**
    - **Step 3 – Selecting the pump setting from all the % stroke calibration tables (and plotted calibration curves) that provides the calculated feed rate.**
        - The optimal pump setting would consider:
            - The dosage required.
            - The manufacturer's recommendations for minimum and maximum settings.
            - The linearity of the "curves". A more linear (straight) curve is better.

- **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 ensure 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 housekeeping 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 ensure 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

EPA Incompatible Chemical Storage

Practice Math Problems

Homework

United States Environmental Protection Agency

Incompatible Chemicals Storage

A sanitary survey quick reference guide for determining how to properly store chemicals at a water treatment plant

Dos and Don'ts

Do not store liquid chemicals and dry chemicals together regardless of which compatibility group they fall into.

Do not store chemicals from different **compatibility groups** together. Water treatment chemicals are divided into six incompatible groups: Acids, Bases, Salts & Polymers, Adsorption Powders, Oxidizing Powders, and Compressed Gasses. **To ensure the safety of system personnel and the system itself, store each of these groups of incompatible chemicals separately (compatibility groups listed on reverse side).**

Do not store products such as paint, antifreeze, detergent, oil, grease, fuel, solvent, and beverages in the same area as water treatment chemicals.

DO store all chemicals in secure, well-ventilated areas that are free of moisture (especially dry chemicals), excessive heat, ignition sources and flammable/ combustible materials.

DO see your Material Safety Data Sheet (MSDS) if you encounter a chemical that is not listed on one of the following tables (MSDS required by OSHA Regulation 29.CFR.1910.1200 for all organizations/water systems that handle hazardous chemicals).

Warning

Storing incompatible chemicals together could create a hazardous reaction such as the production of toxic gas, accelerated corrosion, or an exothermic reaction (a chemical reaction that releases heat), which could result in an explosion and/or fire. This reaction could be catastrophic, resulting in loss of life and rendering the water plant inoperable.

Examples:

Examples of Incompatible Chemicals	Hazardous Reactions
Powdered Activated Carbon (PAC), an adsorption powder, should not be mixed with Potassium Permanganate, an oxidizing powder	Excessive heat generation, with the possibility of explosion and fire. Note: PAC alone is extremely combustible.
Calcium Hypochlorite, a combination base/oxidizer should not be exposed to moisture or mixed with viscous fluid such as oil.	Excessive heat, fire or explosion possible. Can provide an ignition source for combustible materials.
Concentrated Sulfuric Acid, a strong acid, should not be mixed with Concentrated Sodium Hydroxide, a strong base.	Excessive heat and liquid explosion. Note: Highly concentrated acids and bases when mixed together will have a much more hazardous reaction than weak acids and bases.
Calcium Oxide, a strong base available only as a powder, should not be exposed to moisture	Excessive heat, fire. Can provide an ignition source for combustible materials.

Compatibility Groups: Common Water Treatment Chemicals

Group I: Acids

Name	Common Name	Available Forms
Acetic Acid	Ethanoic Acid	Liquid
Hydrofluosilicic Acid	Fluosilic Acid	Liquid
Hydrogen Fluoride Acid	Hydrofluoric Acid	Liquid
Hydrochloric Acid	Muriatic Acid	Liquid
Nitric Acid	Sulfuric Acid	Liquid

Group II: Bases

Name	Common Name	Available Forms[1]
Calcium Hydroxide	Hydrated Lime	Dry
Calcium Oxide	Quicklime	Dry
Calcium Hypochlorite	HTH	Dry
Sodium Bicarbonate	Sodium Bicarbonate	Dry
Sodium Carbonate	Soda Ash	Dry
Sodium Hydroxide	Caustic Soda, Lye	Liquid, Dry
Sodium Hypochlorite	Bleach	Liquid
Sodium Silicate	Water Glass	Liquid

[1] Certain concentrated dry chemicals, like calcium hypochlorite and calcium oxide (quicklime) will produce an exothermic reaction when exposed to liquid or even small amounts of moisture.

Group III: Salts & Polymers

Name	Common Name	Available Forms
Aluminum Sulfate	Alum	Liquid, Dry
Copper Sulfate	Blue Stone	Liquid, Dry
Ferric Chloride	Ferrichlor	Liquid, Dry
Ferric Sulfate	Ferri-Floc	Dry
Ferrous Sulfate	Copperas	Liquid Dry
Polyaluminum Chloride	PACL	Liquid
Polyelectrolytes (Cationic, Anionic, Non-ionic)	Polymer	Liquid, Dry
Sodium Aluminate	Soda Alum	Liquid, Dry
Sodium Fluoride	Sodium Fluoride	Liquid, Dry
Sodium Hexametaphosphate	Glassy Phosphate	Dry
Sodium Phosphate	Sodium Phosphate	Liquid, Dry
Zinc Orthophosphate	Zinc Ortho	Liquid

Group IV: Adsorption Powders

Name	Common Name	Available Forms
Powdered Activated Carbon	PAC	Dry
Granular Activated Carbon	GAC	Dry

Group V: Oxidizing Powders

Name	Common Name	Available Forms
Potassium Permanganate	Permanganate	Dry

Group VI: Compressed Gases[2]

Name	Common Name	Available Forms	Incompatible Chemicals Within This Category[3]
Ammonia	Ammonia	Liquid, Gas	Chlorine
Chlorine	Gas Chlorine	Liquid, Gas	Ammonia
Carbon Dioxide	Dry Ice	Liquid, Gas	-
Sulfur Dioxide	SO_2	Liquid, Gas	-

[2]Each compressed gas should have its own separate storage/feed area.

[3] Chlorine and ammonia should be stored separately from each other, as well as from all other chemical groups.

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 55 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 theoretically feeding?
    d. Measure how many gallons you actually fed in 24 hours.
        i. Determine if pump is feeding within the expected range:
        ii. $\pm$ 10% is within expected range.
            1. $\frac{(\text{Theoretical} - \text{Actual})}{\text{Theoretical}} \times 100 =$ __________%

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.