Wastewater Treatment Plant Operator Certification Training

Module 7: Basics of Chemical Feed Systems

This course includes content developed by the Pennsylvania Department of Environmental Protection (Pa. DEP) in cooperation with the following contractors, subcontractors, or grantees:

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Unit 1 – Chemical Usage in Wastewater Treatment

Learning Objectives

- Describe the historical use of chemicals in wastewater treatment.
- List six uses of chemicals in wastewater treatment.

Historical Use of Chemicals in Wastewater Treatment

- In 1934, 34 U.S. wastewater plants were using chemical precipitation.
- Chemical use declined during World War II and for some time thereafter for the three primary reasons listed below.
  - The cost of chemicals.
  - Limited availability of chemicals.
  - Greater reliance on biological treatment.
- During recent years, chemical use has increased due to requirements for nutrient removal.
- Currently, wastewater plants are being designed and operated using chemicals for the following purposes.
  - Coagulation, Flocculation and Stabilization
  - Sludge conditioning
  - Disinfection
  - Nutrient removal
  - Alkalinity supplementation
  - Odor control

Coagulation and Flocculation

- Chemicals such as coagulants and flocculants are used to enhance coagulation and flocculation, which improves the operation of the sedimentation and flotation processes.

Coagulation is the addition of chemicals that promote the aggregation of smaller, non-settleable particles and colloidal particles into larger, more settleable or floatable particles.

- As a result of the common electrical charges on the surface of the small particles, the particles tend to repel each other. This is similar to magnets when similar poles are placed near each other. The repelling prevents the particles from clumping together, thereby enabling them to remain in suspension.
- The coagulant chemical neutralizes the electrical charge on the surface of the small particles, resulting in the destabilization of the suspension.
- Typical chemicals used in the coagulation process include hydroxides, such as lime (calcium hydroxide) and aluminum or magnesium hydroxide.

Flocculation is the process of forming larger particles from coagulated matter. It is typically accomplished by gentle mixing to promote additional inter-particle contact of the destabilized particles.

- Typical chemicals used in the flocculation processes include synthetic organic polymers.

Sludge Conditioning and Stabilization

Sludge Conditioning

- By adding coagulants or flocculants, sludge is "conditioned" for further processing such as dewatering.

- During conditioning, individual sludge particles are joined together by the electrostatic charges provided by the coagulant or flocculant chemical. As a result, the "free water" contained in the sludge is released from the sludge particles and can be removed from the sludge, leaving a more concentrated sludge mass.

- Proper chemical conditioning is particularly important for successful sludge dewatering. This kind of bonding is not a chemical reaction, and the electrostatic bonds holding the sludge particles together are relatively weak and easily broken.

Sludge Stabilization

Stabilization is a process that is used to reduce the potential for the sludge to undergo further biological decomposition which can lead to offensive odor generation.

- Sludge stabilization can be achieved by the addition of chemicals that inhibit further biological activity.

- Lime stabilization involves the addition of sufficient amounts of lime to increase the pH of the sludge to 12.0 for 2 hours, and to maintain the pH at 11.5 or greater for the remaining 22 hours during a 24 hour period. The high pH inhibits further biological activity and therefore renders the sludge "stabilized." However, if the pH is allowed to decrease to below 9.0, biological activity could resume and create the potential for offensive odors.

Disinfection

- During disinfection, chemical compounds are added to the treated wastewater prior to discharge to the receiving stream, thereby inactivating pathogens.

- The following are typical chemicals for disinfection.
  - Chlorine Gas
  - Sodium Hypochlorite
  - Ozone
  - Bromine

Nutrient Removal

Chemicals are added for the removal of the nutrients in the wastewater prior to discharge to the receiving stream.

- Phosphorus is a common nutrient removed from the wastewater using chemical addition. Chemicals such as aluminum or iron salts chemically react with the phosphorus in the wastewater to form a new compound that will settle out in the final settling tanks and be removed with the waste sludge.

- The following are typical chemicals used for nutrient removal.
  - Aluminum Sulfate
  - Ferric Chloride
  - Ferric Sulfate
  - Ferrous Sulfate

Alkalinity Supplementation

Alkalinity buffers the wastewater against changes in pH that could disrupt the wastewater treatment process. It is usually expressed as mg/L as calcium carbonate.

- Certain treatment processes will consume alkalinity.
  - Nitrification, the treatment process that converts ammonia to nitrate, consumes alkalinity.
  - Aluminum and iron added for phosphorus nutrient removal reacts with bicarbonate alkalinity in the wastewater to form aluminum and iron hydroxide.

- To prevent alkalinity from being reduced so low that the pH changes, chemicals that add alkalinity must be added to the treatment process.

- Supplemental alkalinity might also need to be added to an anaerobic digester to maintain performance.

- Typical chemicals used to supplement alkalinity are listed below.
  - Lime
  - Sodium Bicarbonate (Baking soda)
  - Sodium Carbonate (Soda ash)
  - Sodium Hydroxide (Caustic soda)
  - Magnesium Hydroxide

Odor Control

Odor masking agents and odor treatment are two methods of odor control.

- Odor masking agents cover offensive odors with a more pleasant smell.

- Odor treatment is accomplished through either neutralization or through adsorption.
  - Neutralizers chemically react with odor causing compounds to change them and neutralize the odor. Common examples are chlorine, hydrogen peroxide and ozone.
  - Adsorption uses activated carbon adsorption units to treat odors. In the adsorption process, matter adheres to the surface of the adsorbent. Activated carbon has an extremely large surface area due to the many pores within the individual carbon particles. In fact, 1 pound of activated carbon has a surface area of 60 to 150 acres. Odor causing compounds are attracted to the activated carbon which acts like a sponge to adsorb these compounds.

Chemical Usage Table

The following table lists some of the more common chemicals found at a wastewater treatment plant, the typical uses of these chemicals and some general information about each chemical.

Chemical Usage Table

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
Potassium Permanganate	$KMnO_4$	Odor Control	Crystal	86 - 102	97%	Dry to form solution	0.5	0.5
Hydrogen Peroxide	H_2O_2	Odor Control	Liquid			Liquid		Neat
Aluminum Sulfate (Alum)	$Al_2(SO_4)_3 \cdot 14\ H_2O$	Phosphorus Removal	Lump, Granular, Rice, Ground, Powder	60 - 75	98%	Dry to form solution	0.5	0.5
Aluminum Sulfate (Liquid Alum)	$Al_2(SO_4)_3 \cdot X\ H_2O$	Phosphorus Removal	Liquid	11.1 (SG = 1.33)	36º Be	Liquid	5.48	Neat
Ferric Chloride	$FeCl_3$	Phosphorus Removal	Liquid	11.2 (SG = 1.4)	35 – 45%	Liquid	4.40	Neat
Ferric Sulfate	$Fe_2(SO_4)_3 \cdot X\ H_2O$	Phosphorus Removal	Granules	70 72	68 – 76%	Dry to form solution	5.5	5.5 lb/gal max
Calcium Oxide (Quick Lime)	CaO	ph Adjustment & Sludge Stabilization	Lump, Pebble, Granular, Ground, Pellet	***Granules*** 68 – 80 ***Powder*** 32 - 50	70 – 96% (below 85% can be poor quality)	¼ - ¾ inch pebble according to Slaker. Feed as slurry	1.4 – 3.3 according to Slaker (2.1 ave)	0.93 (10% slurry)
Calcium Hydroxide (Hydrated Lime)	$Ca(OH)_2$	ph Adjustment & Sludge Stabilization	Powder	20 – 50	82 – 95%	Dry to form slurry	0.93 (10% slurry)	0.93 (10% slurry)
Sodium Hydroxide (Caustic Soda)	NaOH	Alkalinity Supplementation/ ph Adjustment	Flake, Lump, Powder, Liquid	***Dry*** 45 – 70 ***Liquid*** varies	***Dry*** 99% ***Liquid*** 12 – 50%	Liquid	6.38 for 50% solution	Neat
Magnesium Hydroxide	$Mg(OH)_2$	Alkalinity Supplementation/ ph Adjustment & Settling Agent	Powder	15 - 45	NA	Dry to form slurry	0.44 – 0.93 (5 – 10% slurry)	0.44 – 0.93 (5 – 10% slurry)

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
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
Polymers	Varies with polymer	Sludge Conditioning for Dewatering & Improved Settling	Flake, Powder, Liquid, Emulsion	Varies with polymer	Varies with polymer	Varies with polymer & application	Varies with polymer & application	Per manufacturer
Sodium Thiosulfate	$Na_2S_2O_3 \cdot 5H_2O$	Dechlorination	Crystal, Rice	53 –60	98 – 99%	Dry to form solution	0.1	0.1
Sulfur Dioxide	SO_2	Dechlorination	Liquefied Gas	89	100	Gas	NA	NA
Sodium Bisulfite	$NaHSO_3$	Dechlorination	Liquid	11.1 (SG = 1.33)	36º Be	Liquid	3.2 – 3.5	Neat
Sodium Sulfite	Na_2SO_3	Dechlorination	Powder, Crystal	50 - 100	93 – 99%	Dry to form solution	0.25 – 0.5	0.25 – 0.5
Chlorine Gas	Cl_2	Disinfection	Liquefied Gas	91.7	100	Gas	NA	NA
Sodium Hypochlorite	NaOCl	Disinfection	Liquid	10.1	12 – 15 %	Liquid	1.0 – 1.25 as Cl_2	Neat
Ferrous Sulfate (Odophos)	$FeSO_4 \cdot 7H_2O$	Odor Control & Phosphorus Removal	Granular, Crystal, Powder, Lump	63 – 66	55%	Dry granular to form solution	0.5	0.5

Key Points for Unit 1 – Chemical Usage in Wastewater Treatment

- Chemicals have been used for many decades to enhance or make possible many processes in wastewater plants.

- Important uses of chemicals in wastewater plants include:
  - Coagulation, flocculation and stabilization
  - Sludge conditioning
  - Disinfection
  - Nutrient removal
  - Alkalinity supplementation
  - Odor control

- Chemicals used in the coagulation process will neutralize the electric charge on small suspended particles and allow them to clump together.

- Typical disinfectant chemicals include:
  - Chlorine gas
  - Sodium hypochlorite
  - Ozone
  - Bromine

- Activated carbon is one method of controlling odors by adsorbing the chemicals that cause odors.

Exercise for Unit 1 – Chemical Usage in Wastewater Treatment

1. List the chemicals you might add to wastewater to control odor.

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2. List several chemicals that might be added to wastewater to promote nutrient removal.

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3. Synthetic organic polymers can be used to enhance the flocculation process in wastewater treatment plants.

   a. ____ True b. ____ False

4. In a lime stabilization process, if the pH is allowed to fall below 9.0, __________________ activity could resume and create the potential for offensive odors.

5. Which of the following chemicals are commonly used to supplement alkalinity in wastewater treatment processes? (Check all that apply.)

   a. ____ Lime

   b. ____ Sodium Hydroxide

   c. ____ Sulphuric Acid

   d. ____ Magnesium Hydroxide

   e. ____ None of the above.

Unit 2 – Safety and Handling

Learning Objectives

- Explain the purpose of the Material Safety Data Sheet (MSDS) and describe the typical information found on an MSDS.
- Explain the role of labels and warning signs and list three basic forms.
- Explain the purpose of breathing protection when handling chemicals and explain how to select appropriate protection.
- List common types of protective clothing used when handling chemicals and explain how proper protective clothing is selected.
- List five common types of protective equipment.

Material Safety Data Sheet (MSDS)

An MSDS is available from the chemical manufacturer for every chemical. You should read and understand the MSDS for each chemical used in the plant and maintain a personal copy for all hazardous chemicals used. The MSDS contains a detailed assessment of chemical characteristics, hazards and other information relative to health, safety and the environment.

Typical information present in an MSDS includes:

- Product name and synonyms.
- CAS number.
- Address and telephone number of manufacturer.
- Components and contaminants.
- Physical data.
- Fire and explosion hazard data.
- Toxicity data.
- Health hazard data such as exposure limits, effects of exposure and emergency and first aid procedures.
- Reactivity data such as storage and disposal recommendations and conditions to avoid.
- Spill or leak procedures.
- Protective equipment.
- First aid procedures.

When handling chemicals, a Treatment Plant Operator should ensure he uses the equipment listed on the MSDS.

Sample MSDS

The following MSDS is from Delta Chemical Corporation for Liquid Aluminum Sulfate.[1]

Delta Chemical Corporation

Aluminum Sulfate, Liquid — **MSDS No. 011**

Date of Preparation: 3/15/02 — Revision: 2.0

Material Safety Data Sheet

Section 1 - Chemical Product and Company Identification

Product/Chemical Name: Aluminum Sulfate, Liquid
Chemical Formula: $Al_2(SO_4)_3 \bullet 14(H_2O)$
CAS Number: 10043-01-3
General Use: Water Treatment Chemical
Emergency Contact: **800-424-9300**
Chemtrec

Manufacturer:
Delta Chemical Corporation,
2601 Cannery Avenue,
Baltimore, MD 21226-1595,
Phone 410-354-0100, (7:00am 5:00pm)
FAX 410-354-1021

HMIS	
H	1
F	0
R	0
PPE†	

†Sec. 8

Section 2 - Composition / Information on Ingredients

Ingredient Name	CAS Number	% wt
Aluminum Sulfate	10043-01-3	27.8
Water	7732-18-5	72.2

	OSHA PEL		ACGIH TLV		NIOSH REL		NIOSH
Ingredient	**TWA**	**STEL**	**TWA**	**STEL**	**TWA**	**STEL**	**IDLH**
Aluminum Sulfate	2 mg/m^3 *as aluminum*	none estab.	none estab.	none estab.	none estab.	none estab.	none estab.

Toxicity Data:

Section 3 - Physical and Chemical Properties

Physical State: liquid
Appearance and Odor: colorless, clear amber or light green
Odor Threshold: negligible odor
Vapor Pressure: NA
Vapor Density (Air=1): NA
Density:
Specific Gravity (H_2O=1, at 4 °C): 1.32
pH: 2.1 ± 0.5

Water Solubility: Complete
Other Solubilities:
Boiling Point: 109° C/228° F
Freezing/Melting Point: -13° C/9° F
Viscosity:
Surface Tension:
% Volatile: NA

Section 4 - Fire-Fighting Measures

Flash Point: NA
Burning Rate: NA
Autoignition Temperature: NA
LEL: NA
UEL: NA

NFPA

Flammability Classification:
Extinguishing Media: NA
Unusual Fire or Explosion Hazards: If evaporated to dryness and exposed to temperatures greater than 1400°F aluminum sulfate will decompose generating toxic and corrosive gas.
Hazardous Combustion Products: See Section V
Fire-Fighting Instructions: Do not release runoff from fire control methods to sewers or waterways.

Revision: 2.0	Aluminum Sulfate, Liquid	MSDS No. 011

Section 5 - Stability and Reactivity

Stability:	Aluminum Sulfate, Liquid is stable at room temperature in closed containers under normal storage and handling conditions.
Polymerization:	Hazardous polymerization cannot occur.
Chemical Incompatibilities:	Alkalies and water-reactive materials.
Conditions to Avoid:	N/A
Hazardous Decomposition Products:	Thermal oxidative decomposition of Aluminum Sulfate occurs at temperatures greater than 1400°F and can produce sulfur oxides.

Section 6 - Health Hazard Information

Potential Health Effects

Primary Entry Routes:	Ingestion
Target Organs:	N/A
Acute Effects	No unusual
Eye:	May cause a burning feeling.
Skin:	May cause a skin rash or burning feeling.
Ingestion:	
Carcinogenicity:	IARC, NTP, and OSHA do not list Aluminum Sulfate, Liquid as a carcinogen.
Medical Conditions Aggravated by Long-Term Exposure:	None reported.
Chronic Effects:	There is no evidence that aluminum sulfate causes cancer or affects reproduction.

Emergency and First Aid Procedures

Inhalation:	(mist or spray) Remove from exposure, seek medical treatment if any symptoms occur.
Eye Contact:	Immediately flush with large amounts of water for at least 15 minutes, occasionally lifting upper and lower lids. Seek medical attention.
Skin Contact:	Remove contaminated clothing and wash contaminated skin with water.
Ingestion:	Do not induce vomiting, drink milk or water and immediately seek medical attention.

After first aid, get appropriate in-plant, paramedic, or community medical support.

Section 7 - Spill, Leak, and Disposal Procedures

Spill /Leak Procedures:	Spill procedures are dictated by site wastewater flow controls and will vary from site to site. General procedures are provided in this document, but authorization for any wastewater discharge must be obtained prior to the discharge.
Small Spills:	If directed to an industrial sewer, wash down with large volumes of water. Spills can be neutralized and absorbed with soda ash or lime, but neutralization will release carbon dioxide, which can generate a breathing hazard.
Large Spills	For large spills, dike far ahead of liquid spill for later disposal. Do not release into sewers or waterways. Pump residue into storage containers or neutralize with lime or soda ash. Neutralization will release carbon dioxide, which can generate a breathing hazard.
Containment:	
Cleanup:	Wash or neutralize impacted areas after liquid removal to remove residues.
Regulatory Requirements:	Follow applicable OSHA regulations (29 CFR 1910.120).
Disposal:	Contact your supplier or a licensed contractor for detailed recommendations. Follow applicable Federal, state, and local regulations.
Container Cleaning and Disposal:	

Revision: 2.0	Aluminum Sulfate, Liquid	MSDS No. 011

Ecological Information:

EPA Regulations:

RCRA Hazardous Waste Number:	Not listed (40 CFR 261.33)
RCRA Hazardous Waste Classification	(40 CFR 261.??): Not classified
CERCLA Hazardous Substance (40 CFR 302.4)	listed CWA, Sec. 311 (b)(4)
CERCLA Reportable Quantity (RQ)	5,000 lbs (2,270 kg) as $Al_2(SO_4)_3$ 17,900 lbs (8,120 kg) as a 27.8% solution
SARA 311/312 Codes:	immediate (acute) health hazard
SARA Toxic Chemical (40 CFR 372.65):	Not listed
SARA EHS (Extremely Hazardous Substance) (40 CFR 355):	Not listed

OSHA Regulations:

Air Contaminant (29 CFR 1910.1000, Table Z-1, Z-1-A):	Not listed
OSHA Specifically Regulated Substance (29CFR 1910.????)	Not listed

State Regulations:

Section 8 - Exposure Controls / Personal Protection

Engineering Controls:

Ventilation: Under normal conditions, liquid alum will not generate mists or vapors. No special ventilation is recommended.

Administrative Controls:

Respiratory Protection: Seek professional advice prior to respirator selection and use. Follow OSHA respirator regulations (29 CFR 1910.134) and, if necessary, wear a MSHA/NIOSH-approved respirator. Select respirator based on its suitability to provide adequate worker protection for given working conditions, level of airborne contamination, and presence of sufficient oxygen. For emergency or non-routine operations (cleaning spills, reactor vessels, or storage tanks), wear an SCBA. *Warning! Air-purifying respirators do not protect workers in oxygen-deficient atmospheres.* If respirators are used, OSHA requires a written respiratory protection program that includes at least: medical certification, training, fit-testing, periodic environmental monitoring, maintenance, inspection, cleaning, and convenient, sanitary storage areas.

Protective Clothing/Equipment: Wear chemically protective gloves, boots, aprons, and gauntlets to prevent prolonged or repeated skin contact. Wear protective chemical safety goggles, per OSHA eye- and face-protection regulations (29 CFR 1910.133). Contact lenses are not eye protective devices. Appropriate eye protection must be worn instead of, or in conjunction with contact lenses.

Safety Stations: Make emergency eyewash stations, safety/quick-drench showers, and washing facilities available in work area.

Contaminated Equipment: Separate contaminated work clothes from street clothes. Launder before reuse. Remove this material from your shoes and clean personal protective equipment.

Comments: Never eat, drink, or smoke in work areas. Practice good personal hygiene after using this material, especially before eating, drinking, smoking, using the toilet, or applying cosmetics.

Section 9 - Special Precautions and Comments

Handling Precautions:

Storage Requirements:

Revision: 2.0 **Aluminum Sulfate, Liquid** **MSDS No. 011**

DOT Transportation Data (49 CFR 172.101):

Shipping Name:	Aluminum Sulfate	**Packaging Authorizations**	
Shipping Symbols:	G	**a) Exceptions:**	173.155
Hazard Class:	9	**b) Non-bulk Packaging:**	173.203
DOT No.:	UN3082	**c) Bulk Packaging:**	173.241
Packing Group:	III	**Quantity Limitations**	
Label:	Class 9	**a) Passenger, Aircraft, or Railcar:**	no limit
Special Provisions (172.102):	8, T1	**b) Cargo Aircraft Only:**	no limit
		Vessel Stowage Requirements	
		a) Vessel Stowage:	A
		b) Other:	

Prepared By:
Revision Notes:

Disclaimer: The information presented herein is believed to be accurate and reliable, but is given without guaranty or warranty, expressed or implied. The user should not assume that all safety measures are indicated so that other measures may not be required. The user is responsible for assuring that the product and equipment are used in a safe manner that complies with all appropriate legal standards and regulations.

Labels and Warning Signs

- 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.
- Warning signs should be used to alert employees to hazardous conditions.
- There are three basic sign forms:
  - Warning signs, which depict the general nature of the hazard.
  - Regulatory signs such as "No Smoking" or "Eye Protection Required".
  - Pictorial signs for required personal protective equipment.

Breathing Protection

Breathing protection should be selected based on exposure.

- It should provide adequate protection for the given working conditions.
- Use MSHA/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. Use self-contained breathing apparatus (SCBA) for an oxygen deficient atmosphere.

Protective Clothing

Protective clothing is selected on the basis of the chemical to be handled.

- Materials should be compatible with the required protection:
  - Boots, glove, apron
  - Protective chemical safety goggles
  - Face shield

Protective Equipment

Common types of protective equipment include:

- Emergency eye wash stations.
- Deluge showers.
- Dust collectors.
- Leak monitoring and detection equipment.
- Exhaust fans.

Key Points for Unit 2 – Safety and Handling

- A Material Safety Data Sheet (MSDS) is available from the chemical manufacturer for every chemical.
- The MSDS will tell you what appropriate protective equipment should be used when working with this chemical
- Appropriate labels and warning signs should be used with all chemical containers.
- Protective breathing equipment should be MSHA / NIOSH approved.
- The proper protective clothing will vary depending on the nature of the chemical to be handled. Consult the MSDS for the chemical in question.
- Become familiar with all MSDS information for chemicals in your work area.

☑ Exercise for UNIT 2 – SAFETY AND HANDLING

Use the MSDS on pages 2-3 through 2-6 to complete the following.

1. MSDS stands for ____

2. This MSDS is for what chemical? ____________________________________

3. What protective clothing precautions should you take when working with this chemical?

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4. List the five components of chemical handling equipment.

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5. Who is responsible for providing the MSDS for a manufactured chemical?
   - a. ____ the user
   - b. ____ the manufacturer
   - c. ____ your end customers
   - d. ____ Pa. DEP

6. Emergency eye wash stations and deluge showers are common types of protective equipment?

   a. ____ True   b. ____ False

Unit 3 – Chemical Dosage Calculations

Learning Objectives

- Explain what jar testing is and why it is important.
- List the equipment and chemical reagents used for the jar testing procedure.
- Explain the jar testing procedure, including the following:
  - Preparing for the test.
  - Establishing the test sequence.
  - Performing the actual test.
- Correctly perform calculations for dry, liquid, and gas chemicals.
- Define active strength and explain its importance.

Overview

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

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.

- 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.[2]
  - Tests are good indications of dosage and concentrations of treatment chemicals required, but should be followed by full-scale laboratory testing.

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

Preparation

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

Recommended Equipment

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

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

- ❑ Multi-station Jar Test Stirrer with four to six containers at least the size of 300 – 400 ml Beakers, clear plastic or glass.

Figure 3.1 Jar Test Stirrer Equipment

- ❑ Magnetic stirrer or paddle stirrers are devices 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). The exact method of bracketing will depend on how many beakers can be used in your test equipment.
  - 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

Test Procedure for Coagulation/Flocculation

- ❑ Fill the Jar Testing Apparatus containers with sample water.
- ❑ Add test coagulant chemicals simultaneously 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

Once the chemical dosage has been determined the feed rate can be calculated.

Feed Rate – is used to define two different parameters:

1. The quantity of a chemical required to effect change in water. This is referred to as Feed Rate in pounds per day (#/day). This can be used to calculate the amount of chemical needed for a day tank or an even larger batch.
2. The quantity of chemical delivered from a feeder. This is referred to as Feed Rate in pounds per hour (#/hr). This type of information can be used in setting up an online process.

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).

Feed Rate Equation

❑ Feed Rate (#/day) = Flow Rate (MGD) x Chemical Dosage (mg/l) x 8.34 #/gal

(Note: mg/L is the same as 1 ppm, thus mg/L = ppm = 1 / 1,000,000.)

Determine Chemical Feeder Setting

❑ To determine actual output of the feeder:

- Operate the feeder at a full operating range of settings. This range is determined by the manufacturer.
- Collect a sample of the chemical over a timed period for each setting and record findings on a chart like Table 3.1.
- Weigh each sample.

Setting	Sample Weight (lb)	Time (min)	Feed Rate (lb/hr)
0	0	0	0
100	0.1	1.9	3.15
200	0.1	1.0	6.0
300	0.2	1.25	9.6
400	0.2	0.9	13.3
500	0.2	0.75	16.0

Figure 3.2 - Feeder Operation Test Results

Once the data is collected:

❑ Determine actual feeder output at each setting using the data collected.

- Feed Rate (#/hr) = (weight of sample (#) ÷ time period (min)) x 60 min/hr

  Example:

  = (0.1# ÷1.9 min) X (60 min/hr)

  = (0.0526 #/min) X (60 min/hr)

  = 3.15 #/hr

- ❑ Develop feeder calibration curve.
  - o Plot each chemical feed rate against the feeder setting.

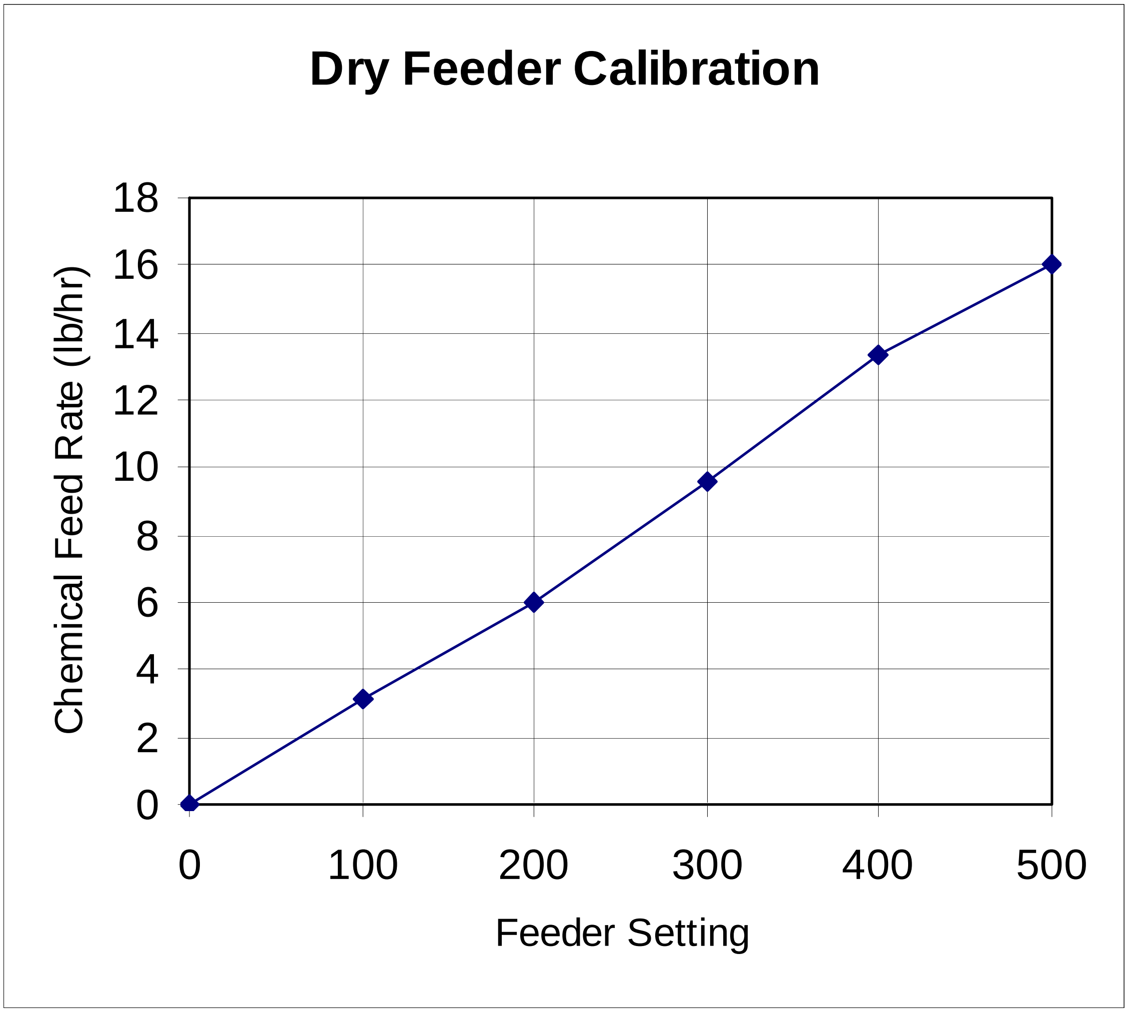

Figure 3.3 - Feeder Calibration Curve

- ❑ Determine the required feeder setting.
- ❑ Adjust feeder setting to obtain the required chemical feed rate.
- ❑ Example 3.2 on the next page will give us some practice in using the above calibration curve.

Example 3.1 – Dry Chemical Feed Calculations

Problem: Compute required feed rate in #/hr

Given: Soda Ash is used at a wastewater treatment plant to raise the pH of the plant effluent. The plant flow rate is 1.5 MGD. It has been determined that a dosage rate of 20 mg/l of soda ash is required to produce an effluent pH of 7.0. What is the required dry chemical feeder setting necessary to feed this chemical to obtain an effluent pH of 7.0, based on the feeder calibration curve above?

Feed Rate (#/hr) = Feed Rate (R) (#/day) x 0.042 (day/hr)

Solution: Step 1 – Perform calculation using the feed rate formula above.

Feed Rate (#/day) = 20 mg/l x 1.5 MGD x 8.34 #/gal = 250 #/day

Chemical Feed Rate (#/hr) = 250 #/day ÷ 24 hr/day = 10.5 #/hr

Step 2 – Determine Feeder setting from calibration chart.

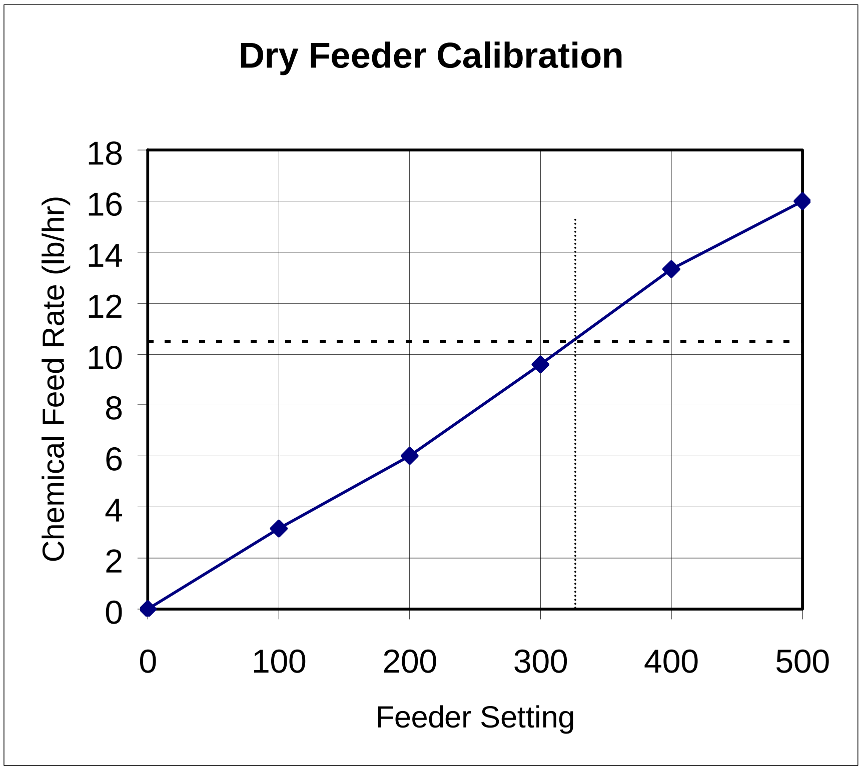

Figure 3.4 Dry Feeder Calibration

A feeder setting of 325 will be required as shown on the graph in Figure 3.4 where the vertical dashed line crosses the x-axis.

Manually Batched Solutions of Dry Chemicals

- At smaller plants, dry chemicals are routinely manually batched into solutions prior to feeding as liquids or slurries.
- To obtain the proper feed rate, the solution strength must be known and must be consistent from batch to batch.
- Solutions are batched in sufficient quantity to last from one to several days.
- Batch strength is based on the solubility of the specific dry chemical and can be obtained from the chemical supplier.

Batch Strength Equation

- Batch Strength (#/gal) = Number of pounds of chemical dissolved in number of gallons of water, or

  Batch Strength (#/gal) = Chemical (#) ÷ water (gal)
- Once the batch strength is determined, the feed pump rate is established as discussed in the next section for liquid chemicals

☑ Example 3.2 – Batching Dry Chemicals

Problem: Compute the required amount of chemical to be added in pounds (#).

Given: The wastewater plant in Sample 3.1 feeds a manually batched solution of soda ash for pH control. Determine the amount of dry soda ash which must be added to 400 gallons of water to produce batch strength of 0.25 #/gal.

Solution: Perform calculation using the batch strength equation above.

Batch strength (#/gal) = chemical (#) ÷ water (gal)

0.25 #/gal = # chemical ÷ 400 gal water

chemical = 0.25 #/gal x 400 gal = 100

Chemicals – Active Strength

- The active chemical strength is often expressed in terms of pounds per gallon. Specific gravity is also used to describe active strength.

- Active strength of liquid chemicals must be known.
  - Different strength chemicals can be purchased.
  - Example: Caustic Soda commercially available at 12 to 50% NaOH

- Active strength differs with different chemicals.
  - Example: 50% Sodium Hydroxide @ 6.38 # active/gallon
Aluminum Sulfate (Liquid Alum) @ 5.48 # active/gallon

- Active strength of same chemical may differ with different shipments.
  - Actual strength should be tested periodically.
  - Measure specific gravity and compare with known values.

Liquid Chemical Feed Pumps

Common Liquid Feeders

- Peristaltic (Tube) Pumps - Generally used for feeding small feed rates (less than 0.1 gallon per hour (gph).

- Positive displacement diaphragm pumps - Most commonly used liquid feeder, generally used for feed rates between 0.1 and 600 gph.

- Solenoid Metering Pumps - Generally used for feed rates between 0.1 and 10 gph.

- Liquid Gravity Feeder (Rotating Dipper) and Jet Pump (Eductor) are two other liquid chemical feed pumps that are less common.

Calculate Feed Rate

- Once chemical dosage has been determined, the feed rate can be calculated.
- Feed Rate Equation:
  - Feed Rate (R) (#/day) = Flow Rate (MGD) x Chemical Dosage (mg/l) x 8.34 #/gal
- Liquid Feed Rate Equation:
  - Liquid Feed Rate (gal/day) = Feed Rate (#/day) ÷ Active Strength (#/gal)

Determining Setting

- Determine actual feed pump output.
  - Develop feed pump calibration curve plotting feeder setting vs. feed rate in gallons per minute in the same manner as for dry chemical feeders.
    - Operate feed pump over full operating range
    - Determine actual pump output
    - Develop calibration curve
- Adjust feed pump setting to required feed rate.

Example 3.3 – Liquid Chemical Feed Calculations

Problem: Compute the feed rate in #/day

Given: A wastewater treatment plant uses liquid alum for phosphorous precipitation. At a plant flowrate of 2.0 MGD, an alum dosage of 12.5 mg/l is required. The alum has an active chemical strength of 5.48 #/gallon. Compute the required alum feed rate.

Solution: Step 1 – Perform calculation using feed rate equation.

Feed Rate (#/day) = 2.0 MGD x 12.5 mg/l x 8.34 #/gal

Feed Rate (#/day) = 208.5 #/day

Step 2 – Compute the required liquid feed rate.

Liquid Feed Rate (gal/day) = 208.5 #/day ÷ 5.48 #/gal

Liquid Feed Rate (gal/day) = 38 gal/day

Example 3.4 – Liquid Feed Calculations

Problem: Compute the pump setting required for the plant in Sample 3.3.

Given: The actual pump output of the alum feed pump at the plant in Sample 3.3 has been determined to be as follows:

Pump Setting (% Full Speed)	Alum Pumped (ml)	Time (sec)
0	0	30
20	62.6	55
40	121.1	59
60	196.8	61
80	130.7	32
100	162.9	35

Figure 3.5 Liquid Feeder Operation Test Results – Alum Feed Pump Output

Solution: Step 1 – Perform feed rate calculation.
Feed Rate (gal/min) = Feed Rate (gal/day) ÷ 1440 (min/day)
Feed Rate (gal/min) = 38 gal/day ÷ 1440 min/day = 0.026 gal/min

Step 2 – Develop feed pump calibration curve.

Pump Setting (%)	Alum Pumped (ml)	Time (sec)	Feed Rate (ml/min)	Feed Rate (gal/min)
0	0.0	30	0.00	0.000
20	65.6	55	71.56	0.019
40	141.9	59	144.31	0.038
60	249.1	61	245.02	0.065
80	195.2	32	366.00	0.097
100	267.4	35	458.40	0.121

Figure 3.6 Liquid Feeder Operation Test Results

Step 3 – Establish Alum Feed Pump setting.

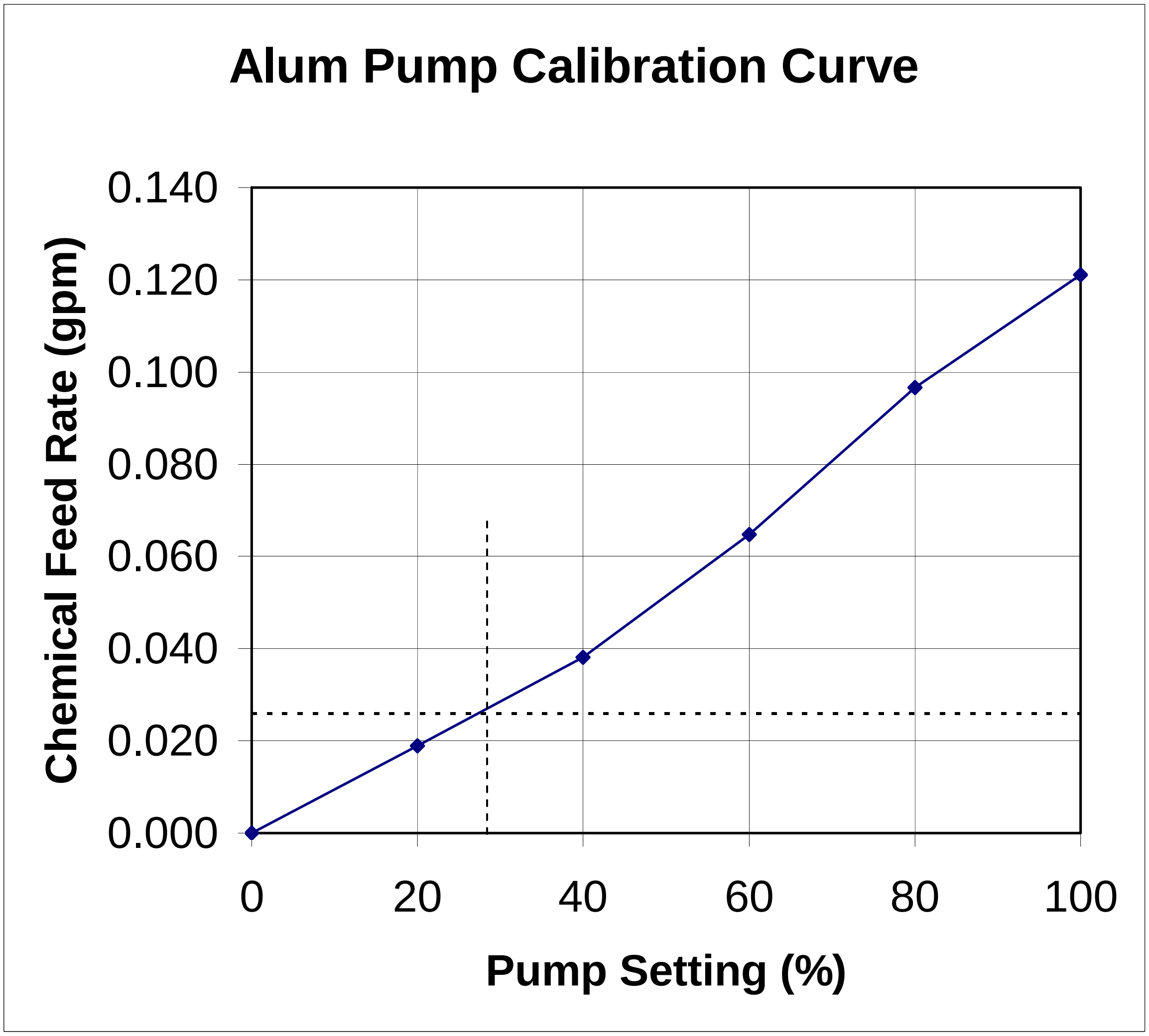

Figure 3.7 Alum Pump Calibration Curve

From where the vertical dashed line in the graph in Figure 3.7 crosses the x-axis, the Alum Feed Pump Setting = 27.5 %

Gas Feeders

Types of Gas Feeders

- ❑ Direct feed
  - o Gas is fed directly under pressure to flow stream to be treated
  - o Limited application
    - ▪ Gas is distributed under pressure
      - • Leaks in piping result in gas escape
    - ▪ Usually limited to small applications without suitable water supply for solution feed system
    - ▪ Limited feeder capacity

- ❑ Solution feed (commonly referred to as vacuum-type feeders)
  - o 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
  - o Greater available capacity than direct feed systems
  - o Requires use of ejector to create necessary vacuum for operation

Feed Rates

- Feed rate calculation for gas is the same as for other chemicals.
  - Feed Rate (#/day) = Flow Rate (MGD) x Chemical Dosage (mg/l) x 8.34 #/gal
- Chemical dosage is dependent on the desired purpose. For example, Chlorine addition serves many purposes in wastewater treatment as illustrated below.

Purpose for chlorination	Dosage Range (mg/l)
Algae Control	1.0 – 10.0
Sludge Bulking Control	2.0 – 8.0
Disinfection:	
Fresh Raw Sewage	6.0 – 12.0
Septic Raw Sewage	12.0 – 25.0
Fresh Settled Sewage	5.0 – 10.0
Septic Settled Sewage	12.0 – 40.0
Activated Sludge Plant Effluent	2.0 – 8.0
Trickling Filter Plant Effluent	3.0 – 10.0
Sand Filter Effluent	1.0 – 5.0
Odor Control	1.5 – 10.0
Slime Control	1.0 – 10.0

- Gas withdrawal from cylinders is limited.
  - 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 from cylinder and converted to gas by the evaporator.

Key Points for Unit 3 – Chemical Dosage Calculations

- Jar testing allows simultaneous testing of the coagulation, flocculation and precipitation results on your water sample with various chemical agents and dosages.
- Dry Feed rate can be expressed as either pounds per day (for a day tank) or pounds per hour (for an online process).
- In small plants, it may make sense to batch dry chemicals into solutions and feed them as liquids or slurries.
- Chemical active strength is often expressed in terms of pounds per gallon, but it can also be described as a percentage (%) or as a specific gravity value.
- Liquid chemical feed pump varieties include:
    - Peristaltic (tube)
    - Positive Displacement Diaphragm
    - Solenoid Metering
    - Liquid Gravity Feeder (Rotary Dipper)
    - Jet Pump (Eductor)

- The types of feeders for gasses such as Chlorine include:
    - Direct Feed (gas)
    - Solution Feed (liquid)

Exercise for Unit 3 – Chemical Dosage Calculation

1. A 1.0 MGD treatment facility uses 12.5 % sodium hypochlorite solution for disinfection. Laboratory testing has determined that the active chemical strength of the hypochlorite is 1.04 pounds of chlorine per gallon. The desired chemical feed rate is 2.5 mg/l.

   Determine the required chemical feed pump setting assuming that the feed pump calibration curve is identical to the alum feed pump in the class problem.

   ____

   ____

   ____

   ____

   ____

   ____

2. Use the graph in Figure 3.7 to answer this question. From the graph, determine the pump setting if you need a feed rate of 0.090 gpm.

   ____

3. Match the common liquid feeders below with the range of feed rates needed.

<u>Feeding Pump</u>	<u>Feed Rate</u>
A. ____ Positive Displacement	a. 0.1 to 10 gph
B. ____ Solenoid Metering	b. less than 0.1 gph
C. ____ Peristaltic Pump	c. 0.1 to 600 gph
D. ____ Jet Pump	d. Not defined in our workbook

4. A multi-station Jar Test Stirrer lab equipment station usually has 6 beakers for simultaneous testing of various strengths of coagulant chemicals.

   a. ____ True   b. ____ False

5. The two common types of gas feed equipment are __________ feed and _________ feed.

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Unit 4 – Chemical Feed Systems

Learning Objectives

- Describe the appropriate storage facilities, feed equipment, and accessory equipment for dry, liquid, and gas chemical feed systems.
- Identify the components of a typical dry, liquid or gas chemical feed system.
- List and describe two types of leak detection equipment.
- Describe the special activation requirements of polymers.

Repair

Operators should maintain the proper tools and an inventory of spare parts necessary to repair chemical feed equipment in the event of a malfunction.

Adequate Supply

Wastewater plants should provide sufficient chemicals in storage to insure an adequate supply at all times. As a general guideline it would be a minimum chemical storage of 10 day's supply.

Storage Areas

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

All liquid chemicals should be stored in spill containment areas. These are areas designed to retain the contents of the largest storage tank should that tank burst and release the contents into the room. Spill containment areas have special coatings which are not affected by the stored chemical so that in the event of a major spill, the entire chemical spill 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.

Storage Facilities

A 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 a 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 airborne dust from feed area. Helps to provide clean, healthy, safe work area.
- Dissolving Tank Float Valve – maintains a constant water level in the dissolving tank.
- Mixer – aids dissolving of the chemical in the dissolving 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.

Typical System Schematics

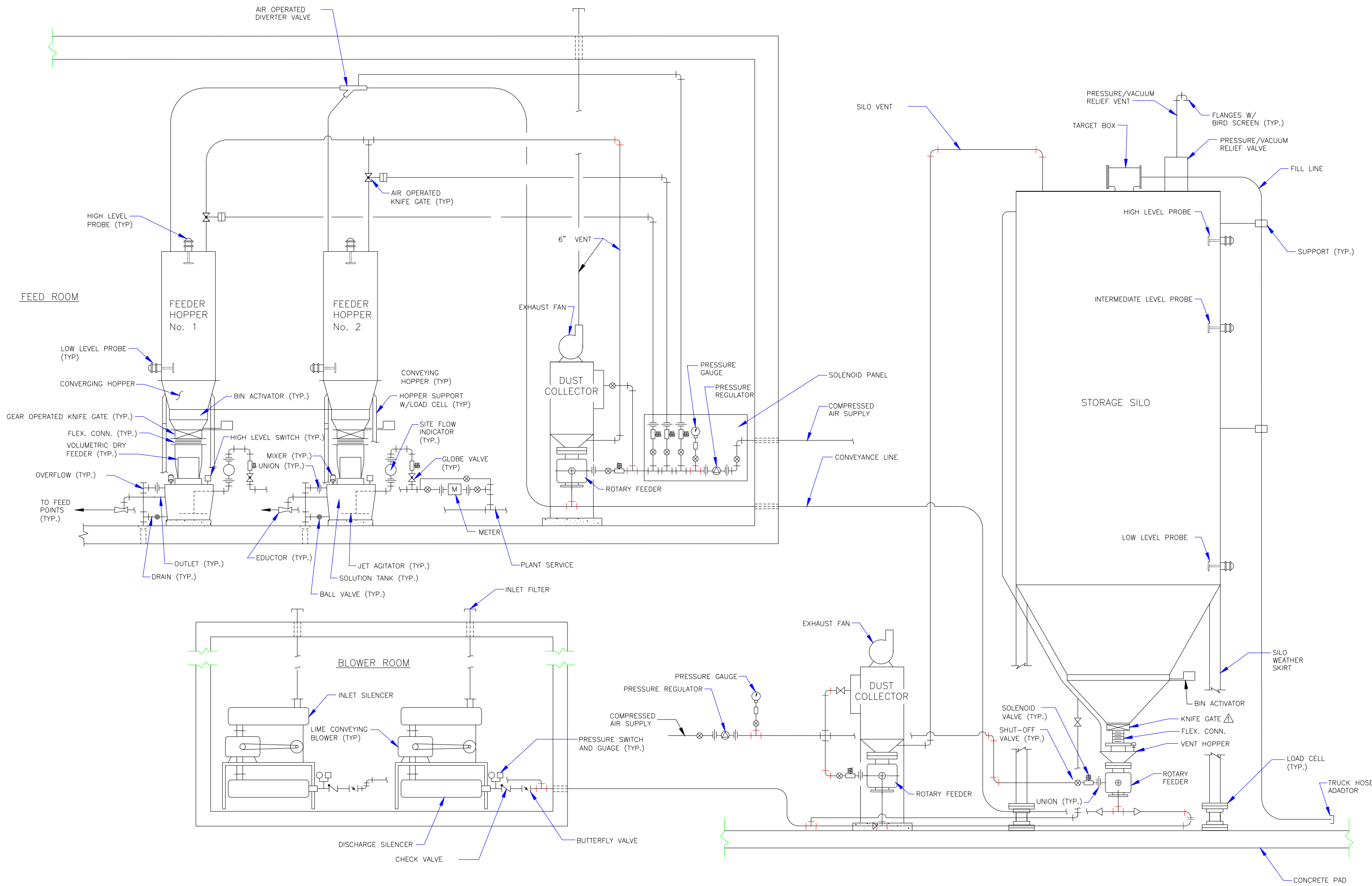


Figure 4.1 – Typical Bulk Dry Chemical Feed System

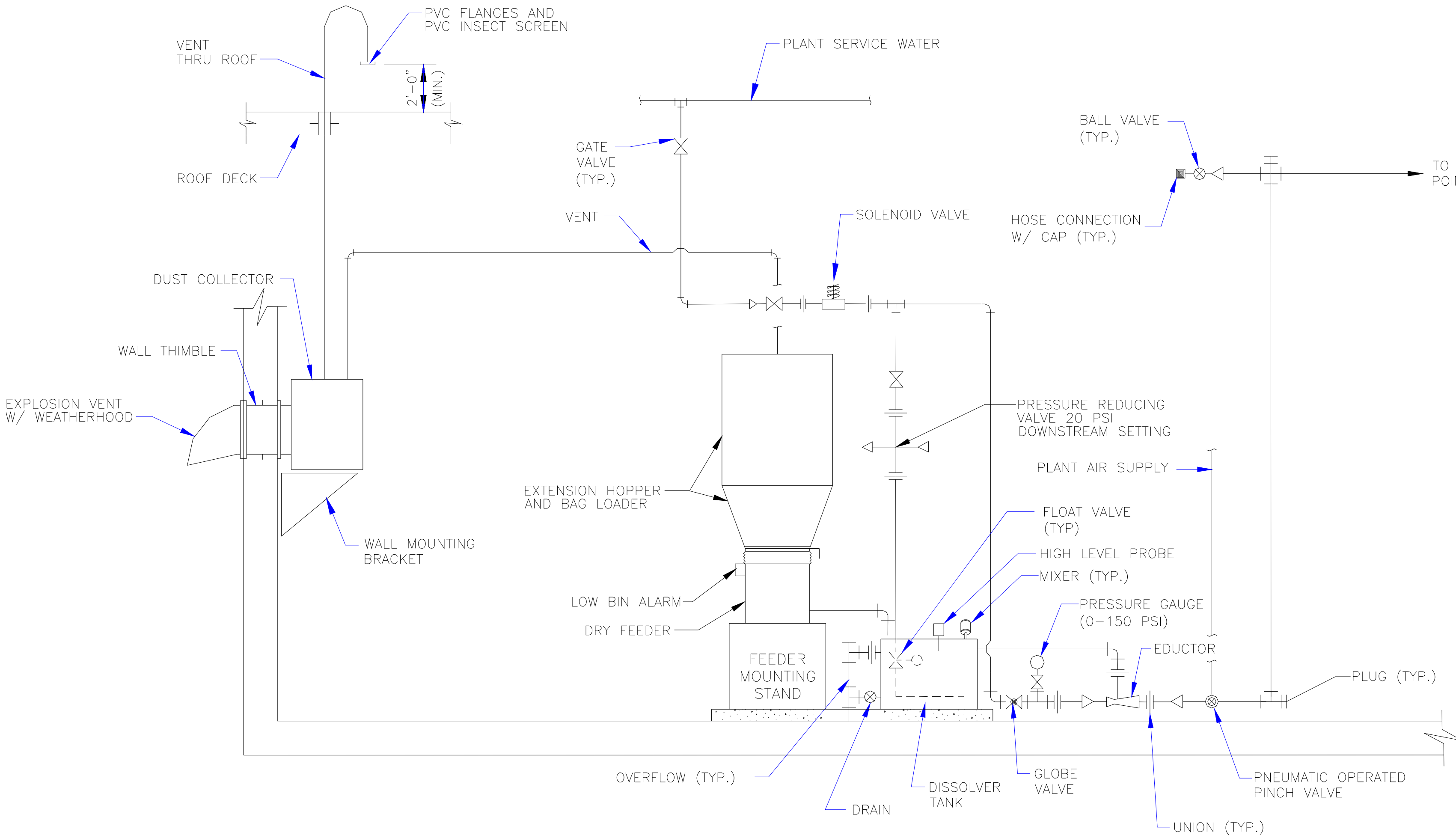


Figure 4.2 – Typical Bag Dry Chemical Feed System

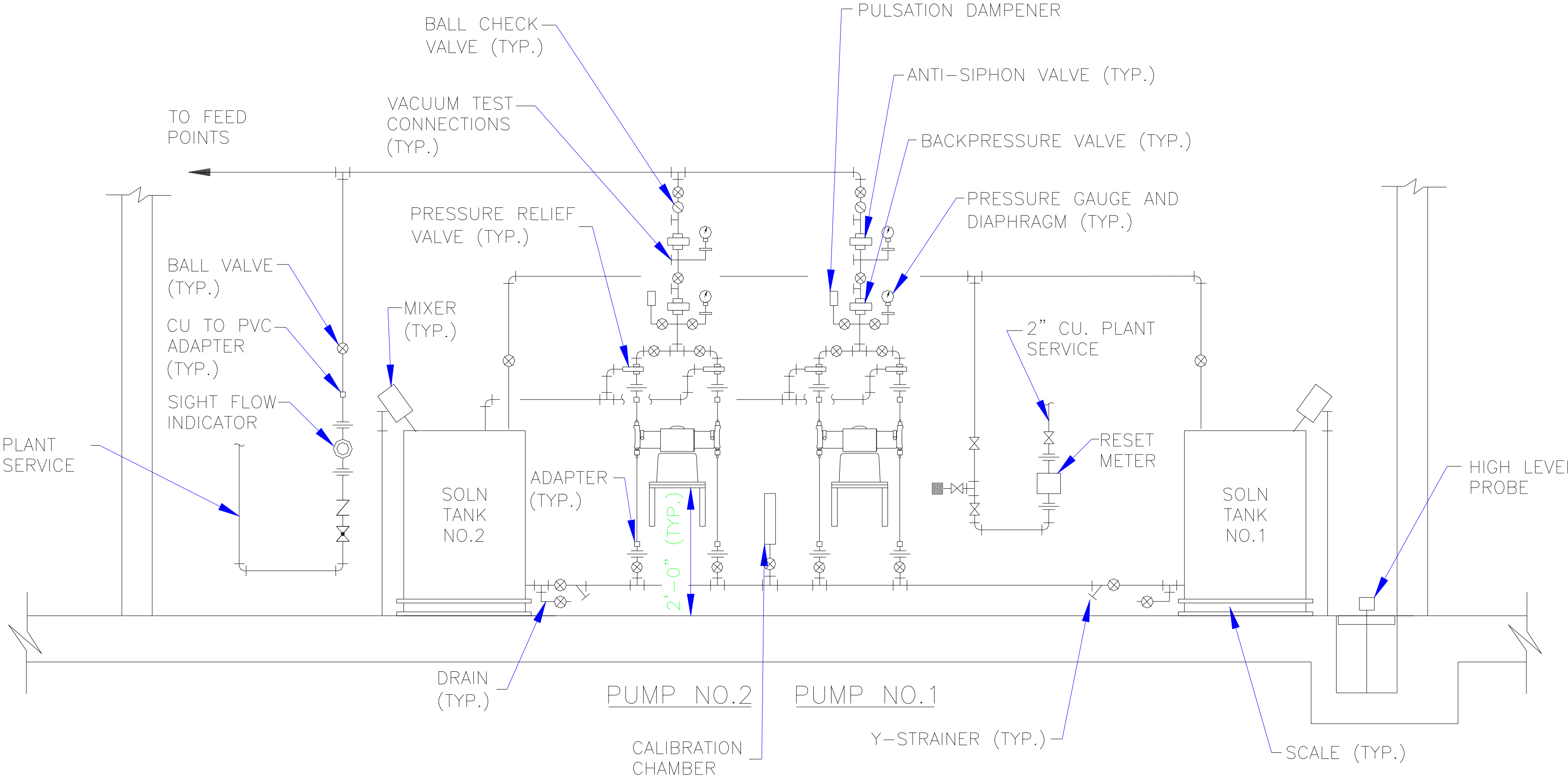


Figure 4.3 – Typical Batch Dry Chemical Feed System

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 – feeds 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.

Typical System Schematics

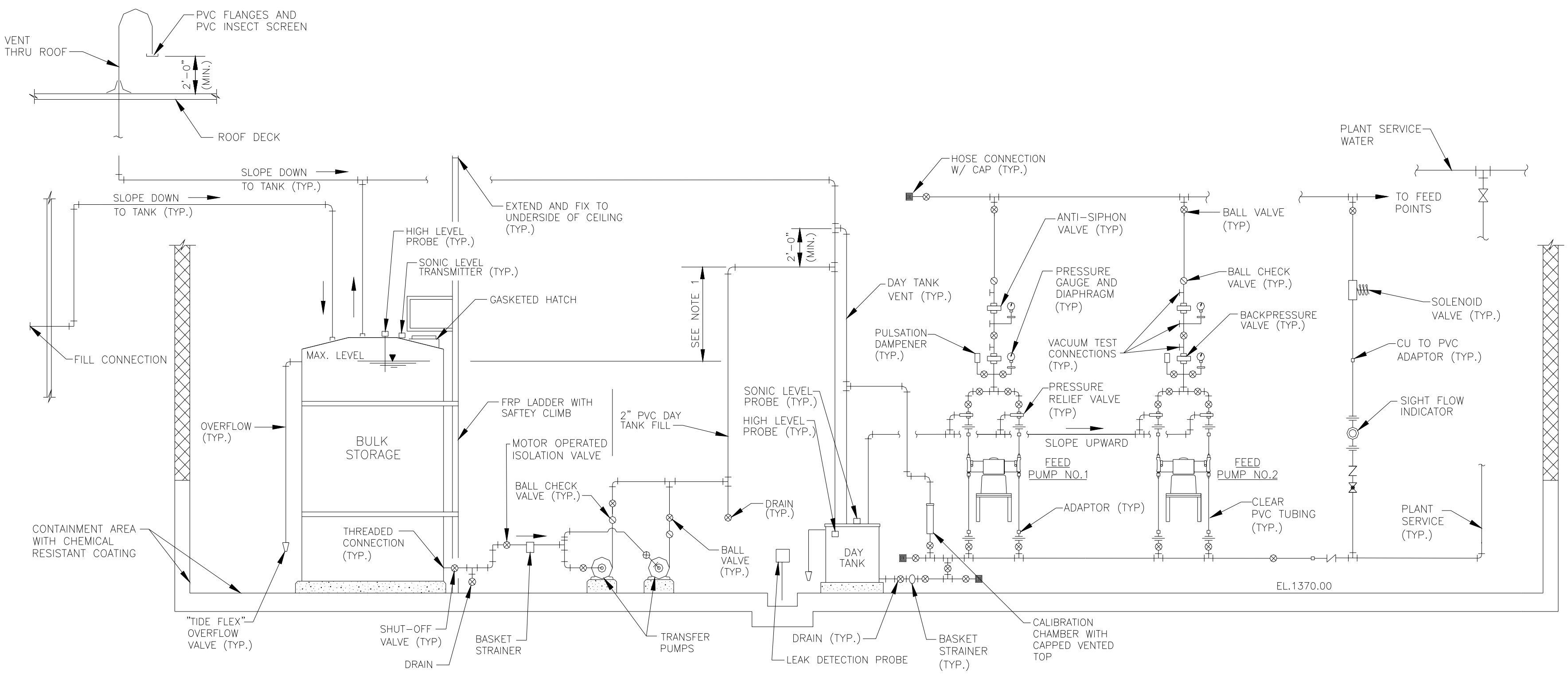


Figure 4.4 – Typical Bulk Liquid Chemical Feeder

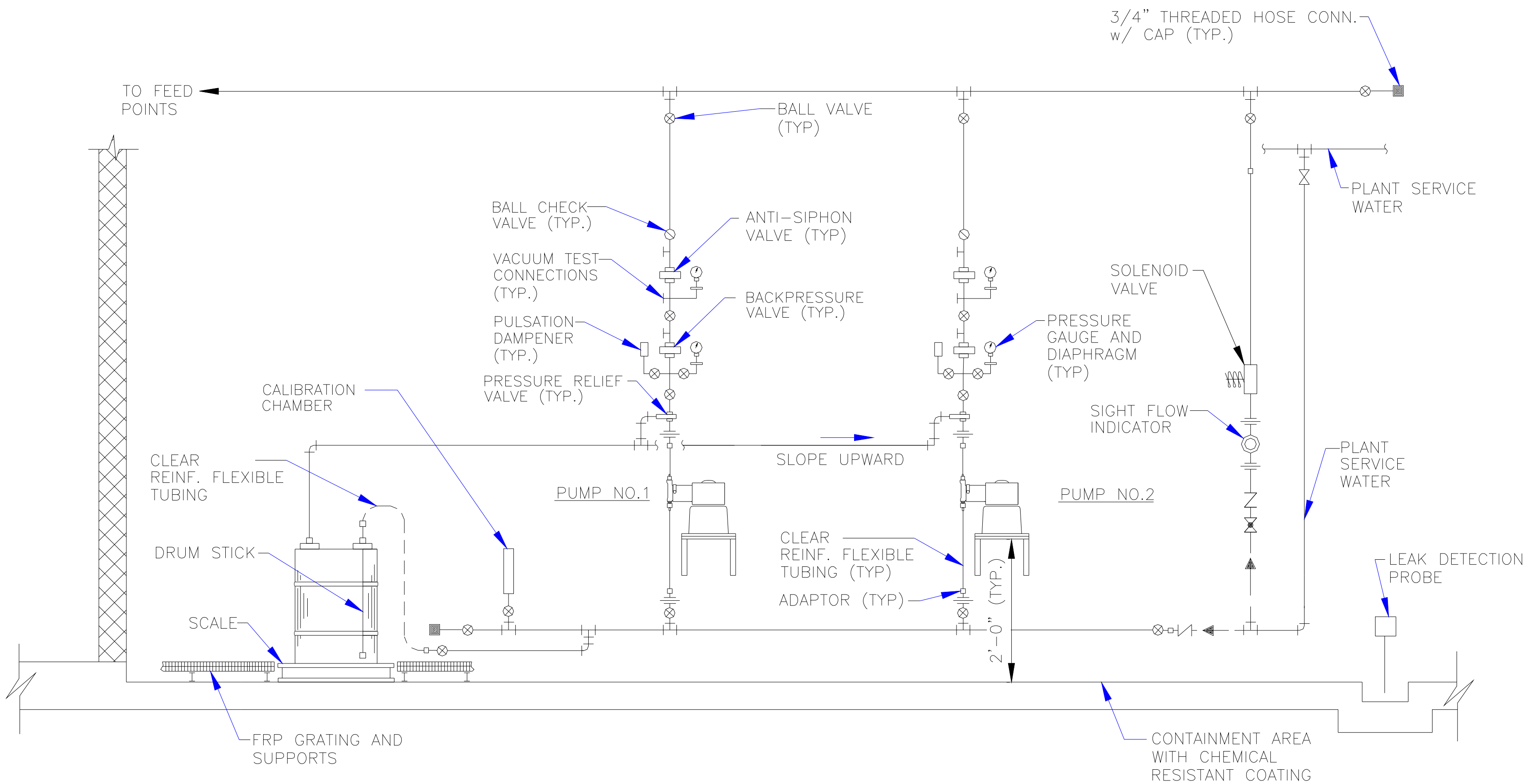


Figure 4.5 – Typical Drum Storage Liquid Chemical Feed System

Storage Facilities

Polymer is shipped either dry (bags) or as liquid (drums). Therefore storage facilities need to be the same as for 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.

Typical System Schematics

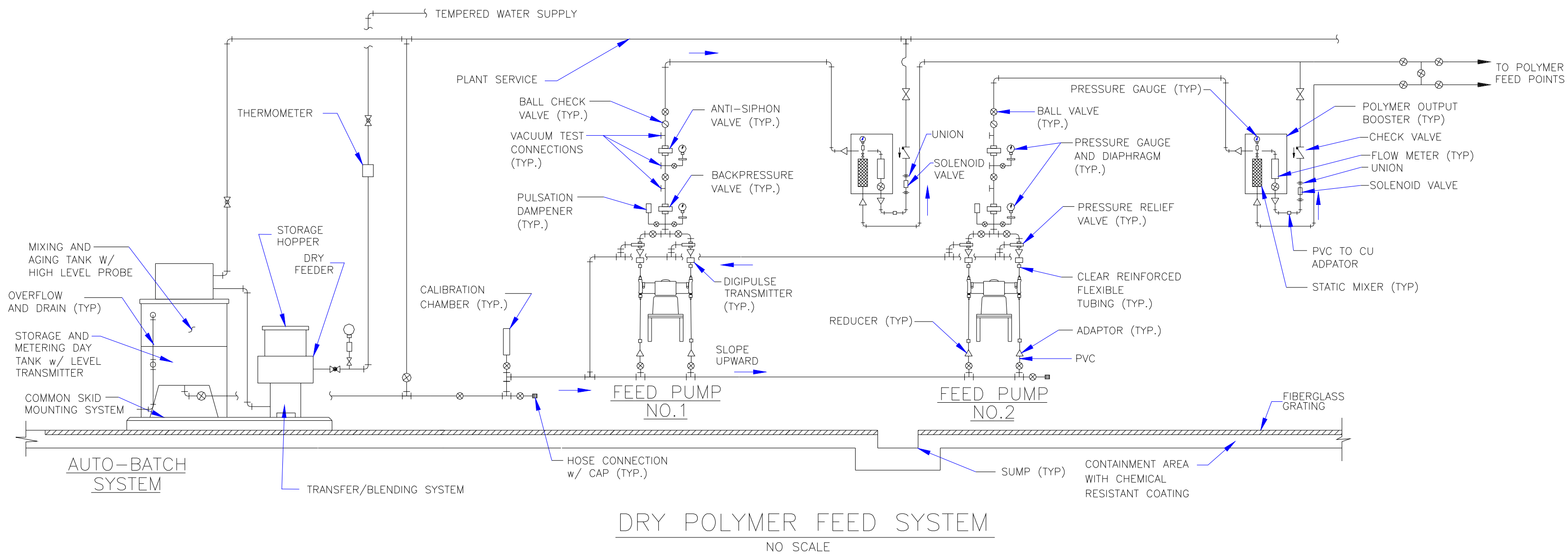


Figure 4.6 – Typical Dry Polymer Feed System

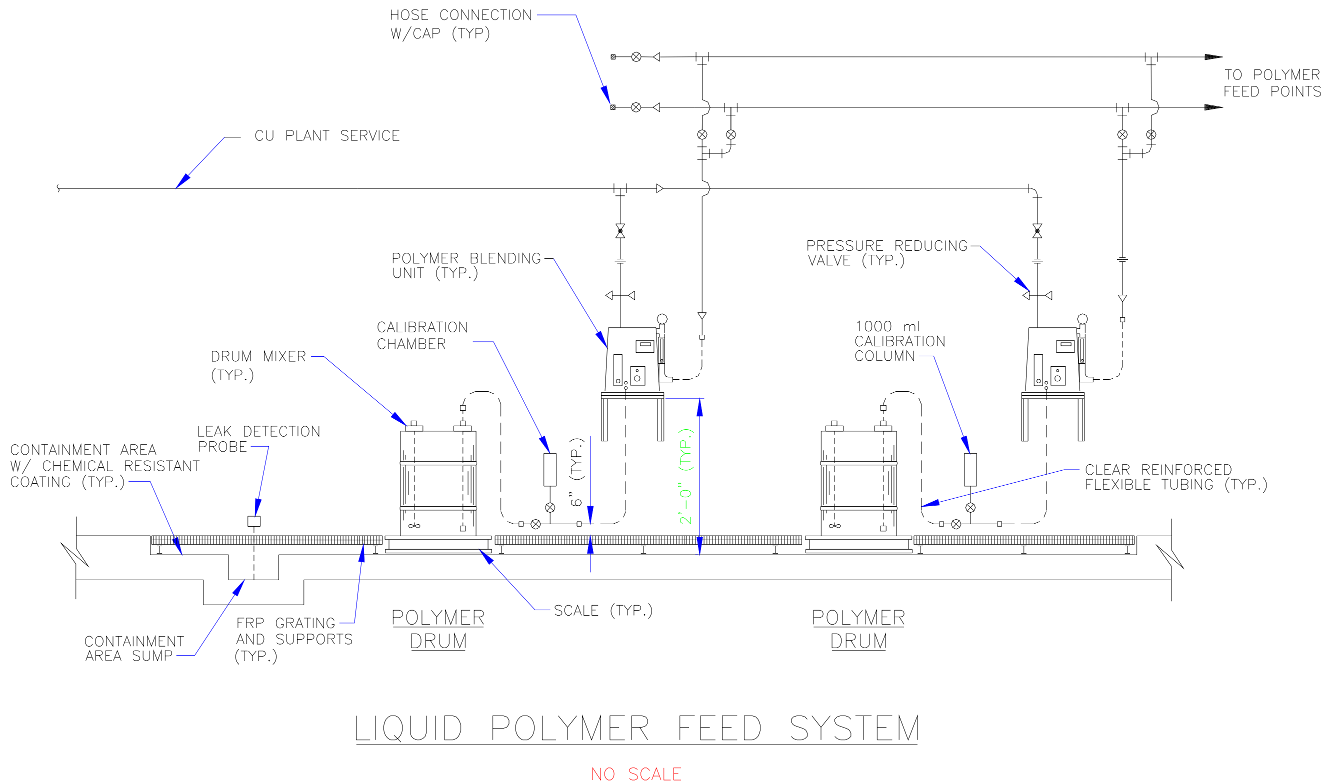


Figure 4.7 – Typical Liquid Polymer Feed Systems

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.
- Plants which use large amounts of Chlorine typically use a evaporator to change the Chlorine from a liquid state in two ton containers into the gaseous state for use in the plant.[3]

Accessory Equipment

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

- Evaporator – used at large installations to convert compressed 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 an unacceptable level of the gas is 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).

Typical System Schematic

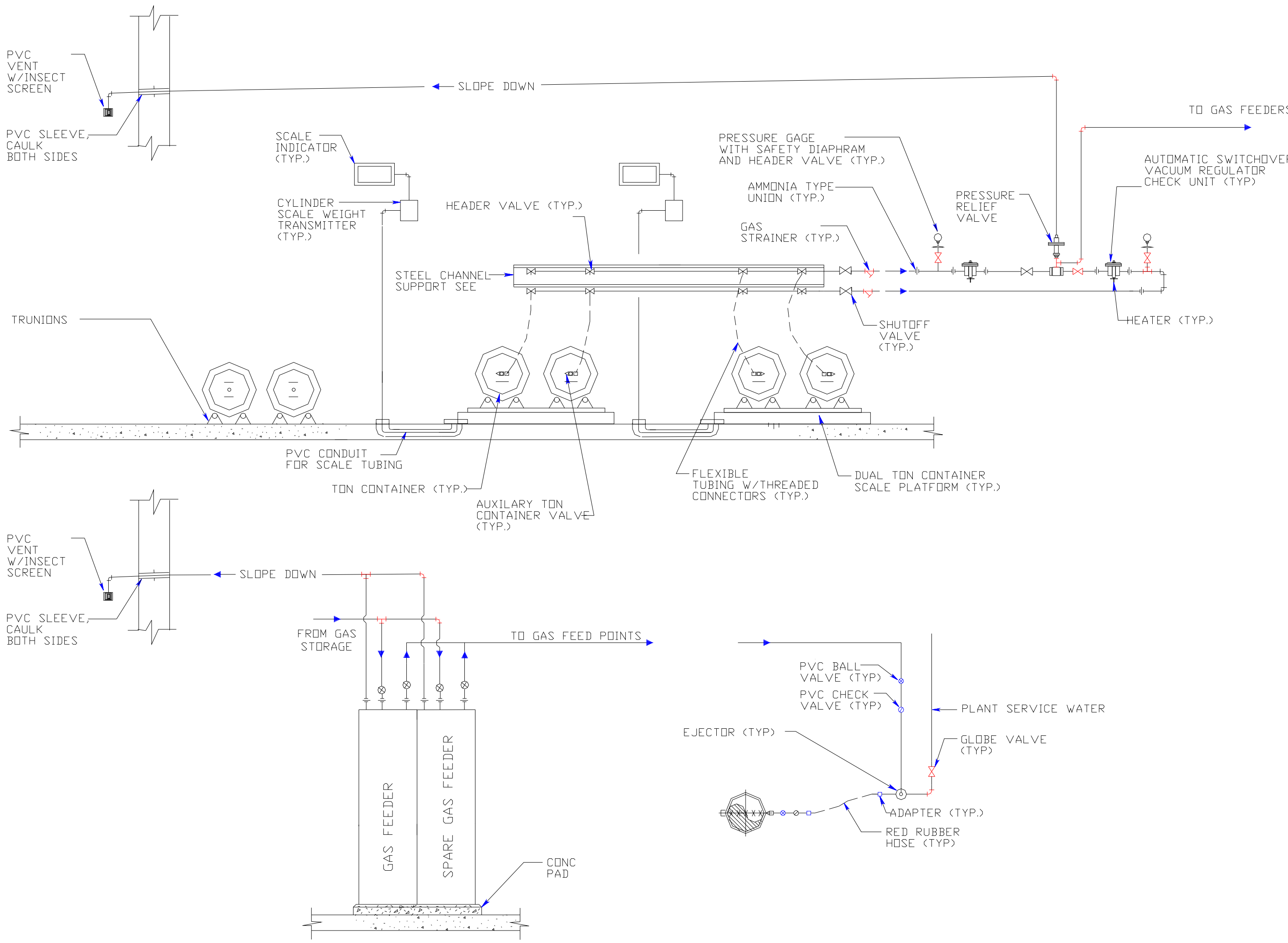


Figure 4.8 – Typical Gas Chemical Feed System (Ton Containers)

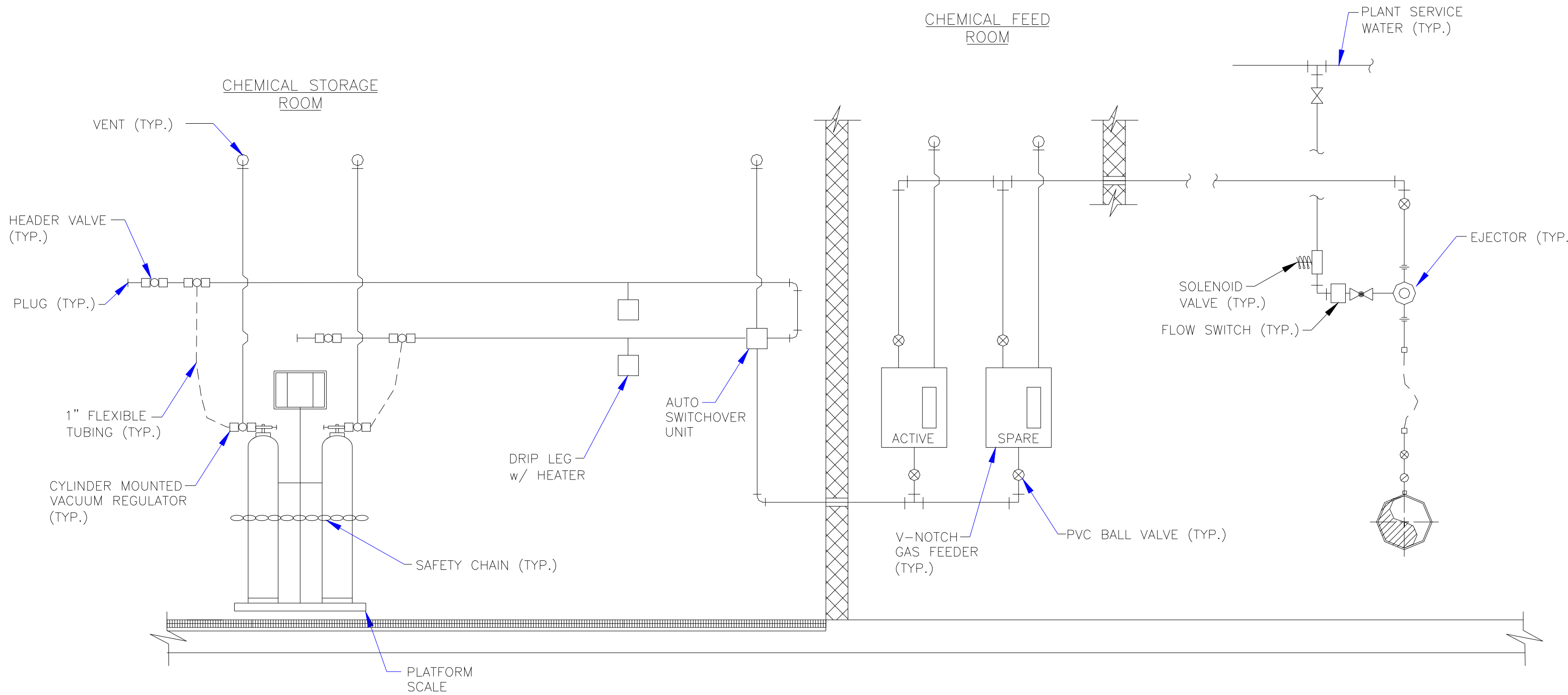


Figure 4.9 – Typical Small Gas Chemical Feed System

Key Points for Unit 4 – Chemical Feed Systems

- In General, a wastewater plant should keep at least 10 days supply of chemicals and appropriate tools or spare parts for common repairs on hand at all times.
- Take proper precautions when storing and handling chemicals. Follow specific instructions on the manufacturer's MSDS information.
- Use recommended and procedures for dry, liquid, gaseous and polymer chemicals.
- Polymers may require special mixing and activation or aging procedures before they are ready to use.
- Gas detectors, self contained breathing equipment, emergency repair kits and other specialized equipment and/or training may be needed before using gaseous chemicals.

☑ Exercise for Unit 4 – Chemical Feed Systems

A. Identify each of the following statements with a T for true or F for false.

_____ 1. Chemical storage should be in the vicinity of feeders to avoid unnecessary handling.

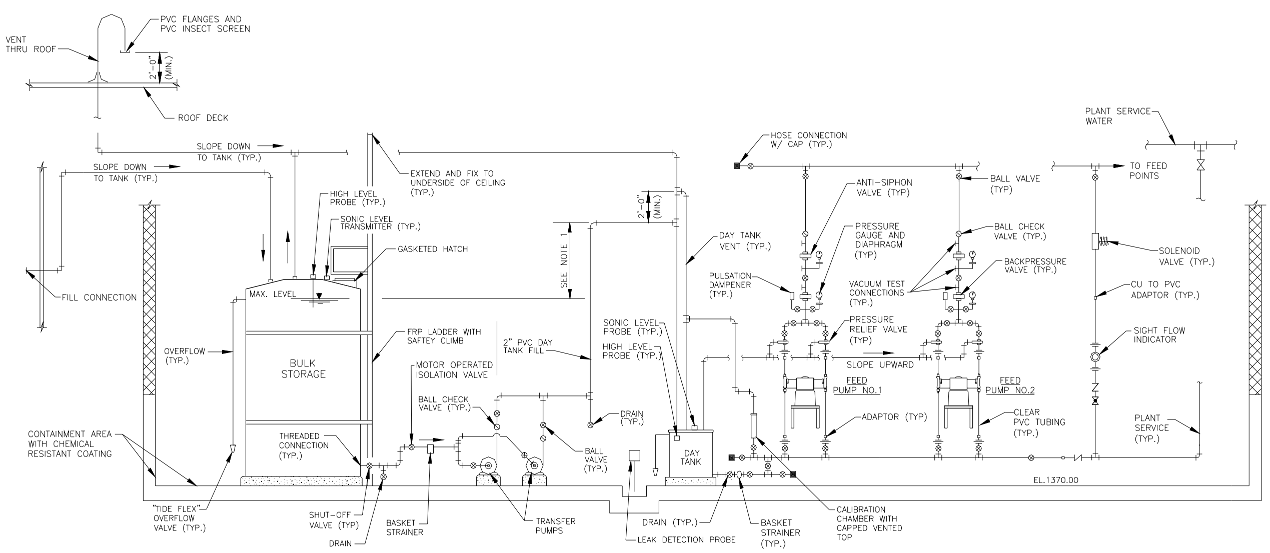
_____ 2. All chemicals should be stored in spill containment areas.

_____ 3. Gaseous chemical storage is usually in an adjacent room or outside building at a location close to the feed room.

_____ 4. The minimum amount of chemical storage is the quantity required for 30 days supply at average use.

B. What type of Chemical Feed System is represented by the following schematic? Write your answer in the space provided.

____



C. List the two Feed Systems that require leak detection equipment.

____

____

[1] The MSDS is available at www.deltachemical.com

[2] John Brady and Ross Gudgel, "Chapter 11: Activated Sludge" in *Operation of Wastewater Treatment Plants, Volume II,* (Sacramento, CA: California State University, Sacramento Foundation, 2003) p. 103.

[3] Leonard W. Hom, J. L. Beals, and Tom Ikesaki, "Chapter 10: Disinfection and Chlorination" in *Operation of Wastewater Treatment Plants, Volume I*, (Sacramento, CA: California State University, Sacramento Foundation, 2004) p. 392.

Appendix A

Note to the participant: The following may be done as a class activity if time permits. Your instructor will indicate if you should work on it during class. It fits into the course in Unit 3 at page 3-13.

☑ Optional Activity - Class Problem

Problem: A. How much dry aluminum sulfate is required to batch 400 gallons of solution?

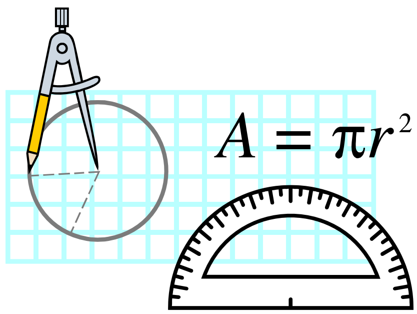
B. How long will 400 gallons of solution last?

Given: A wastewater treatment plant is required to achieve a minimum phosphorous reduction of 85%. Jar testing has indicated that the addition of 10 parts of aluminum sulfate per part of phosphorous will result in a 90% reduction. The plant operator manually batches dry aluminum sulfate at a concentration of 0.5 pounds aluminum sulfate per gallon of water. Using the feed pump calibration curve for the feed pump in Sample 3.4, determine the setting required when the plant flow is 1.0 MGD and the influent phosphorous is 10 mg/l.

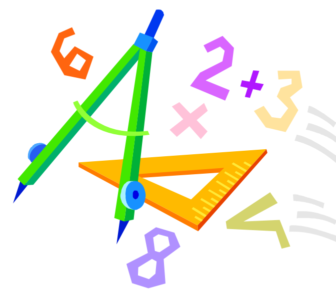
Commonwealth of Pennsylvania
Bureau of Water Supply and Wastewater Management

3/15/2005

Formulas, Conversions, and Common Scientific Units



ABC Formulas, Conversions & Abbreviations



DEP Dry and Liquid Chemical Feed Diagrams

Unit Cancellation Steps

Units of Weight, Volume,Time, Density, Concentration & Flow

Formulas & Conversions

Formulas

The symbol ∏ = Pie = 3.14

Alkalinity = $\frac{\text{(mL of Titrant) (Acid Normality) (50,000)}}{\text{mL of Sample}}$

Area of Circle = (.785) (Diameter^2) or (∏) (Radius^2)

Area of Cylinder Surface = [(.785) (Diameter^2)] + [(∏) (Diameter) (Height)]

Curved Surface Area of a Cylinder = 2 (Π) (Radius) (Height)

End Surface areas of a Cylinder (both ends) = 2 (Π) (Radius^2)

Volume of a Cylinder = (Π) (Radius^2) (Height)

Area of Rectangle = (Length) (Width)

Area of Triangle = $\frac{\text{(Base) (Height)}}{2}$

Circumference of Circle = (∏) (Diameter) or (2) (∏) (Radius)

Chlorine Demand (lbs/day) =
lbs of Chlorine Fed/day – [(Chlorine Residual, mg/l) (Flow, MGD) (8.34)]

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

Discharge = $\frac{\text{Volume}}{\text{Time}}$

Dosage, lbs/day = (mg/L) (8.34) (MGD)

Efficiency, % = $\frac{\text{(Mass In – Mass Out) (100\%)}}{\text{Mass In}}$ May substitute weight for mass

Feed Rate, lbs/day = (Plant Capacity, MGD) (Dosage, mg/L) (8.34 lbs/gal)

Filter Backwash rate = $\frac{\text{Flow (gpm)}}{\text{Filter surface area (ft}^2\text{)}}$

Food/Microorganism Ratio = $\frac{\text{Influent BOD, lbs/day}}{\text{Aeration System MLVSS, lbs}}$

Gallons/Capita/Day = $\frac{\text{Gallons Per Day}}{\text{Population}}$

Hardness = $\frac{\text{(mL of Titrant) (1,000)}}{\text{mL of Sample}}$ (for 0.2 N EDTA)

Horsepower (hp):

$$\text{theoretical hp} = \frac{(\text{Flow, gpm})\ (\text{Total Water Head, ft})}{3960}$$

$$\text{brake hp} = \frac{\text{theoretical hp}}{\text{pump efficiency}}$$

$$\text{Hydraulic Surface Loading Rate (gpd/ft}^2\text{)} = \frac{\text{Flow Rate (gpd)}}{\text{Surface Area (ft}^2\text{)}}$$

Loading rate (lbs/day) = (Concentration, mg/l) (Flow, MGD) (8.34)

Mean Cell Residence Time (MCRT):

$$\frac{\textit{(lbs of Suspended Solids in Aeration System)}}{\textit{(lbs of Suspended Solids Wasted/Day + lbs of Suspended Solids Lost in Effluent/Day}}$$

$$\text{Organic Loading Rate} = \frac{\text{Organic Load, lbs BOD/day}}{\text{Volume in 1000 ft}^3}$$

$$\text{Oxygen Uptake} = \frac{\text{Oxygen Usage (mg/L)}}{\text{Time (min)}}$$

$$\text{Population Equivalent} = \frac{(\text{Flow, MGD})\ (\text{BOD, mg/L})\ (8.34\ \text{lbs/gal})}{0.18\ \text{lbs BOD/day/person}}$$

$$\text{Reduction in Flow, \%} = \frac{(\text{Original Flow - Reduced Flow})\ (100\%)}{\text{Original Flow}}$$

$$\text{Slope} = \frac{\text{Drop or Rise}}{\text{Distance}}$$

$$\text{Sludge Volume Index} = \frac{(\text{Settleable Solids, \%})\ (10{,}000)}{\text{MLSS, mg/L}}$$

Solids Applied (liquid), lbs/day = (Flow, MGD) (Concentration, mg/l) (8.34 lbs/gal)

$$\text{Solids Loading, lbs/day/sq ft} = \frac{\text{Solids Applied, lbs/day}}{\text{Surface Area, sq ft}}$$

$$\text{Solids, mg/L} = \frac{(\text{Dry Solids, grams})\ (1{,}000{,}000)}{\text{mL of Sample}}$$

$$\text{Surface Loading Rate (GPD/ft}^2\text{)} - \frac{\text{Flow Rate, GPD}}{\text{Surface Area, ft}^2}$$

$$\text{Velocity} = \frac{\text{Flow}}{\text{Area}} \text{ or } \frac{\text{Distance}}{\text{Time}}$$

$$\text{Volatile Solids, \%} = \frac{(\text{Dry Solids – Ash Solids})\ (100\%)}{\text{Dry Solids}}$$

Volume of Rectangular Tank (ft^3) = (Length) (Width) (Height)

Volume of Cone (ft^3) = (1/3) (.785) (Diameter^2) (Height)

Volume of Cylinder (ft^3) = (.785) ($Diameter^2$) (Height) or
(Π) ($Radius^2$) (Height)

Waste Milliequivalents = (mL) (Normality)

$$\text{Waste Normality} = \frac{\text{(Titrant Volume) (Titrant Normality)}}{\text{Sample Volume}}$$

Note: Volumes are in same units

$$\text{Weir Overflow Rate} = \frac{\text{Flow (gpm)}}{\text{Weir Length, (ft)}}$$

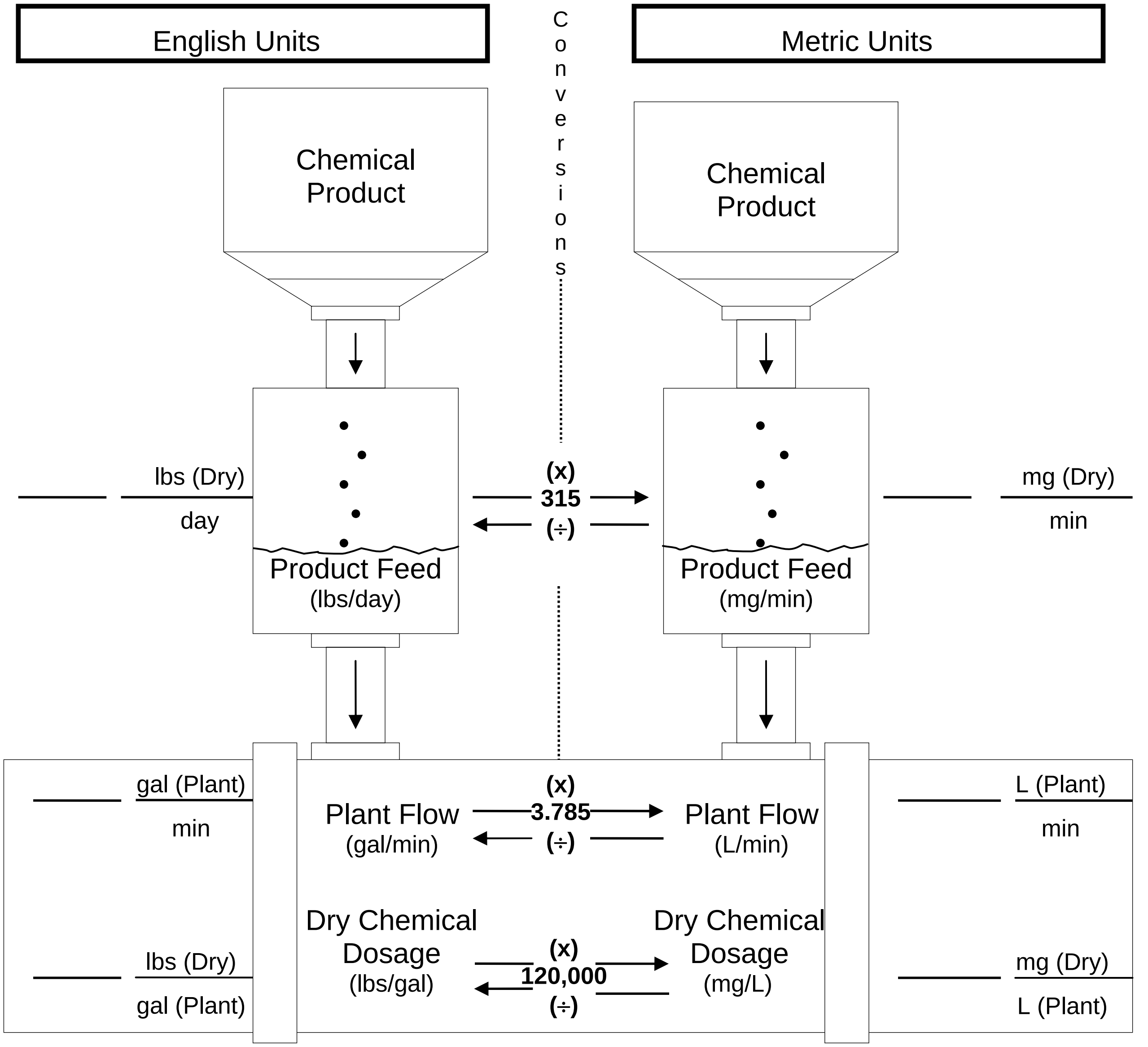
Conversion Factors:

1 acre = 43,560 square feet	1 horsepower = 0.746 kilowatts
1 cubic foot = 7.47 Gallons	1 million gallons per day = 694 gallons per minute
1 foot = 0.305 meters	1 pound = 0.454 kilograms
1 gallon = 3.79 liters	1 pound per square inch = 2.31 feet of water
1 gallon = 8.34 pounds	Degrees Celsius = (Degrees Fahrenheit – 32) (5/9)
1 grain per gallon = 17.1mg/L	Degrees Farenheit = (Degrees Celsius) * 1.8 + 32
1 mg/l = 1 ppm	1 Ft of water column = 0.43 psi

Abbreviations:

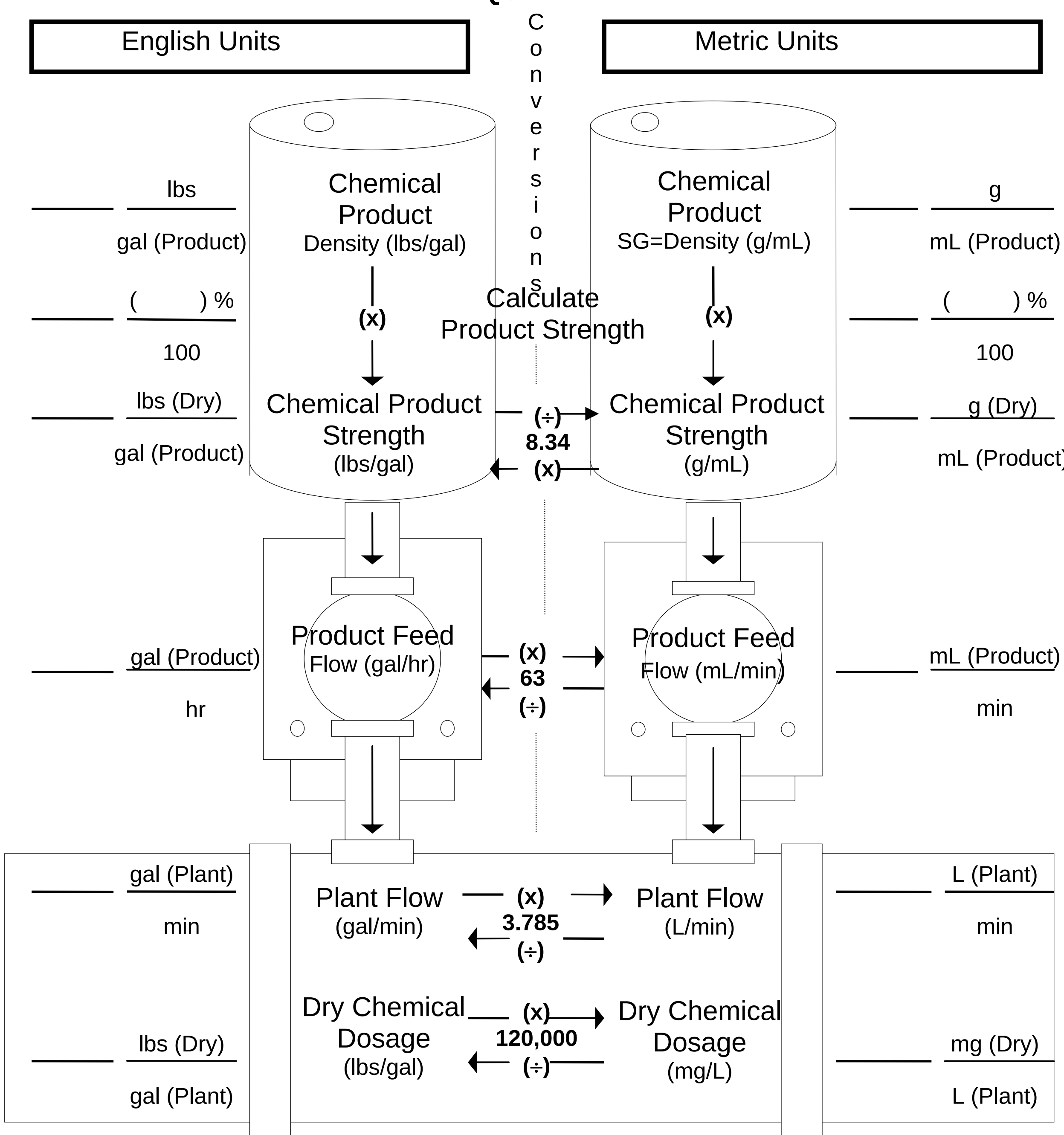
BOD	Biochemical Oxygen Demand
ft	feet
gpd	gallons per day
gpg	grains per gallon
gpm	gallons per minute
lbs	pounds
mg/L	milligrams per Liter
MGD	million gallons per day
mL	milliliter
MLSS	mixed liquor suspended solids
MLVSS	mixed liquor volatile suspended solids
ppm	parts per million

CHEMICAL FEED CALCULATION DIAGRAM
DRY FEED



Procedure: Fill in known data; put a question mark (?) for the value of the unknown data; convert all data to the units on the side where the (?) was placed and fill in the values; use unit cancellation to solve for the unknown.

CHEMICAL FEED CALCULATION DIAGRAM
LIQUID FEED



Procedure: Fill in known data; put a question mark (?) for the value of the unknown data; convert all data to the units on the side where the (?) was placed and fill in the values; use unit cancellation to solve for the unknown.

Unit Cancellation Steps

Step 1: List unknown data as a question mark (?) including units, followed by an equals sign (=).

Sept 2: Place data with same numerator unit to the right of the equal sign followed by a multiplication sign.

Step 3: To cancel unwanted denominator unit, next place data with same numerator unit.

Step 4: Continue to place data into equation to systematically cancel all unwanted units until only the unknown units remain.

Step 5: Do the math (multiply all numerator values, multiply all denominator values; then divide numerator by the denominator.)

Example: $? \frac{\text{lbs}}{\text{gal}} = \frac{1\ \text{lbs}}{454\ \cancel{\text{g}}} \times \frac{1\ \cancel{\text{g}}}{\cancel{\text{mL}}} \times \frac{3785\ \cancel{\text{mL}}}{1\ \text{gal}} = 8.34 \frac{\text{lbs}}{\text{gal}}$

Helpful Hints:

$\frac{\text{Numerator}}{\text{Denominator}}$

Vertical format: $5\ \text{gal} = \frac{5\ \text{gal}}{1}$

1 g = 1000 mg is written: $\frac{1\ \text{g}}{1000\ \text{mg}}$ OR $\frac{1000\ \text{mg}}{1\ \text{g}}$

“per” means divided by: Example: $5\ \text{gpm} = 5 \frac{\text{gal}}{\text{min}}$

Inverting: $\frac{5\ \text{gal}}{\text{min}} = \frac{1\ \text{min}}{5\ \text{gal}}$

NITS OF WEIGHT	
English	Metric
pound - lb	gram - g milligram - mg kilogram - kg
CONVERSIONS	
Metric/Metric	Metric/English
1000 mg = 1 g or 1000 mg/g 1000 gm = 1 kg or 1000 g/kg	1 lb = 454 g or 454 g/lb 1 kg = 2.2 lbs or 2.2 lbs/kg

UNITS OF VOLUME	
English	Metric
gallon - gal million gallon - Mgal cubic feet - cu ft	liter - L milliliter - mL

CONVERSIONS		
Metric/Metric	Metric/English	English/English
1000 mL = 1 liter or 1000 mL/L	gal = 3.785 L or 3.785 L/gal 1 gal = 3785 mL or 3785 mL/gal	7.48 gal = 1 cu ft or 7.48 gal/cu ft

UNITS OF TIME	
day - day hour - hr	minute - min second - sec
CONVERSIONS	
1 day = 24 hr or 24 hr/day 1 hr = 60 min or 60 min/hr	1 min = 60 sec or 60 sec/min 1 day = 1440 min or 1440 min/day

UNITS OF DENSITY	
English	Metric
lbs/gal lbs/cu ft	kg/L g/mL
THE DENSITY OF WATER	
English	Metric/Metric
8.34 lbs/gal 62.4 lbs/cu ft	1 kg/L 1 g/mL

UNITS OF CONCENTRATION	
English	Metric
lbs/gal	mg/L
CONVERSION	
1 lb/gal = 120,000 mg/L	

UNITS OF FLOW	
English	Metric
gallons per minute - gal/min - GPM gallons per day - gal/day - GPD million gallons per day - Mgal/day - MGD cubic feet per second - cu ft/sec - CFS	milliliters per minute - mL/min
CONVERSIONS	
English/English	English/Metric
1 MGD = 694 GPM or 694 GPM/MGD 1 MGD = 1.55 CFS or 1.55 CFS/MGD	1 gal/day = 2.63 mL/min