

# Corrosion Control Treatment

## Answer Key

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## MODULE 2 - Basic Corrosion Chemistry

- The **atom** is the smallest unit of a chemical element. (Fill in the blank)
- **Electrons** are negatively charged particles which occupy the space around the nucleus. (Fill in the blank)
- An **ion** is an electrically charged atom formed by the loss or gain of electrons. (Fill in the blank)
- Some of the water molecules naturally separate (or ionize) into two ions: the **hydrogen** ion and the **hydroxide** ion. (Fill in the blanks)
- Substances that produce hydrogen ions in water are called **acids**. (Fill in the blank)
- A **base** is a substance that produces hydroxide ions in water. (Fill in the blank)
- A **salt** is the product of combining an acid and a base. (Fill in the blank)
- **pH** is the measurement of the concentration of hydrogen ions in water. (Fill in the blank)

### Exercise: Chemical Effects on pH

If I add:		The pH will be _____ (raised/lowered)
potassium hydroxide	KOH	<b>raised</b>
nitric acid	HNO <sub>3</sub>	<b>lowered</b>
lime	Ca(OH) <sub>2</sub>	<b>raised</b>
sulfuric acid	H <sub>2</sub> SO <sub>4</sub>	<b>lowered</b>
caustic soda	NaOH	<b>raised</b>
soda ash	Na <sub>2</sub> CO <sub>3</sub>	<b>raised</b>
hydrochloric acid	HCl	<b>lowered</b>

- Involves the three carbonate species: **carbonic acid**, bicarbonate, and carbonate. (Fill in the blank)
- At pH 4.5 the water contains only **carbonic acid**. (Fill in the blank)

- Above 8.3, **carbonate** begins to form and eventually excess **hydroxide** ions are formed. (Fill in the blank)
- Electron movement in water causes **electricity** which makes water corrosive to metals like lead and copper. (Fill in the blank)
- **pH** is a measure of how acidic or basic a water is. (Fill in the blank)
- One goal of corrosion control involves raising pH to **neutralize** carbonic acid. (Fill in the blank)

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### MODULE 3 - Lead and Copper Rule Overview

- Suppliers must successfully complete this course and update or develop an **Operation & Maintenance** plan to reflect CCT facilities in order to obtain an operation permit. (Fill in the blank)
- Follow-up monitoring determines if the treatment is effective and provides the data for determining CCT **performance** requirements. (Fill in the blank)
- Small and medium systems can qualify for reduced annual lead and copper tap monitoring by not **exceeding** the action levels during two consecutive six-month monitoring periods. (Fill in the blank)

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### MODULE 4 - Units and Conversions

- units of **weight** (Fill in the blank)
- units of **volume** (Fill in the blank)
- units of **time** (Fill in the blank)

Problems:

(Hint: Ask yourself if the unknown is bigger or smaller to move decimal place in the proper direction.)

1. 10 L = ? mL    2. 15 gm = ? kg    3. 14 mg = ? gm    4. 45.67 L = ? mL

**Answers:**

1. 10. L = 10 000 . mL  
                  └─┬─┘  
                  ↑

2. 15. gm = .015 kg  
                  └─┬─┘  
                  ↑

3. 14. mg = .014 gm  
                  └─┬─┘  
                  ↑

4. 45.67 L = 45 670. mL  
                  └─┬─┘  
                  ↑

- **Density** is how much a certain volume of something **weighs** (Fill in the blank).
- In the **English system**, a gallon of water weighs **8.34** pounds. (Fill in the blank).

<b>Demonstration: Density of Liquids</b>
--

**Q:** When syrup is poured into water, will it sink or float? **sink** (because specific gravity is greater than 1.0)

**Q:** Will liquids with a specific gravity of less than 1.0 (specific gravity of water) sink or float? **float** (because specific gravity is less than 1.0)

- **Concentration** is the **weight** of a substance in a **volume** of liquid. (Fill in the blank)
- **Flow** is the **volume** of water or other liquid moved during a period of **time**. (Fill in the blank)
- **Chemical feed** is the **weight** of a dry treatment chemical fed during a period of **time**. (Fill in the blank)
- The unit of dry chemical feed is **lbs/day**. (Fill in the blank)
- The density of water is **8.34** lbs/gal. (Fill in the blank)
- To determine the amount of treatment chemical to feed, you must be able to calculate dosage in **mg/L**. (Fill in the blank)
- Chemical feed pumps normally feed in **mL/min**. To perform chemical feed calculations, you must be able to convert from gal/day to mL/min. (Fill in the blank)

## MODULE 5 - Solving Problems Using Units & Conversions

### Recognizing Units

Fill in the answer with the type of unit. For example, for minute write "time" or GPM write "flow."

1. **Q:** gal  
**A:** volume

2. **Q:** mg  
**A:** weight

3. **Q:** lbs/gal  
**A:** (1)density or  
(2)concentration;

4. **Q:** mL/min  
**A:** flow

5. **Q:** mg/L  
**A:** dosage OR  
concentration

6. **Q:** MGD  
**A:** flow

7. **Q:** liter  
**A:** volume

### Vertical Formatting / Inverting Fractions Practice Problems

Write the following units in a vertical format:

10 GPD

**Answer:**  $\frac{10 \text{ gal}}{\text{day}}$

12 MGD

**Answer:**  $12 \frac{\text{MGal}}{\text{day}}$

3785 ml = 1 gal

**Answer:**  $\frac{3785 \text{ ml}}{1 \text{ gal}}$

OR

$\frac{1 \text{ gal}}{3785 \text{ ml}}$

1 day = 1440 min

**Answer:**  $\frac{1 \text{ day}}{1440 \text{ min}}$

OR

$\frac{1440 \text{ min}}{1 \text{ day}}$

Invert the following fractions:

$$694 \frac{\text{gal}}{\text{min}}$$

Answer:  $\frac{1 \text{ min}}{694 \text{ gal}}$

$$2.63 \frac{\text{ml}}{\text{min}}$$

Answer:  $\frac{1 \text{ min}}{2.63 \text{ ml}}$

## Practice Problems

### Practice Problem 1

The density of a liquid is 1gm/ml in the Metric system. What is the density in the English system (lbs/gal)?

#### Solution to Practice Problem 1.

Known Data:  $\frac{1 \text{ gm}}{\text{ml}}$

Unknown Data:  $\frac{? \text{ lbs}}{\text{gal}}$

Step 1: List unknown data including units.

$$? \frac{\text{lbs}}{\text{gal}} =$$

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

$$? \frac{\text{lbs}}{\text{gal}} = \frac{1 \text{ lb}}{454 \text{ gm}} \times$$

Step 3: To cancel unwanted denominator unit, find data with same numerator unit and place it to the right of the multiplication sign.

$$? \frac{\text{lbs}}{\text{gal}} = \frac{1 \text{ lb}}{454 \text{ gm}} \times \frac{1 \text{ gm}}{\text{ml}}$$

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

$$? \frac{\text{lbs}}{\text{gal}} = \frac{1 \text{ lb}}{454 \text{ gm}} \times \frac{1 \text{ gm}}{\text{ml}} \times \frac{3785 \text{ ml}}{1 \text{ gal}}$$

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

$$? \frac{\text{lbs}}{\text{gal}} = \frac{3785 \text{ lbs}}{454 \text{ gal}} = 8.337 \text{ or } \frac{8.34 \text{ lbs}}{\text{gal}}$$

If this number looks familiar, that's because we have just converted the density of water from the metric system to the English system.

### Practice Problem 2

How many mg/min are there in 1 lb/day?

#### Solution to Practice Problem 2

Known Data:  $\frac{1 \text{ lb}}{\text{day}}$

Unknown Data:  $\frac{? \text{ mg}}{\text{min}}$

$$? \frac{\text{mg}}{\text{min}} = \frac{1000 \text{ mg}}{1 \text{ gm}} \times \frac{454 \text{ gm}}{1 \text{ lb}} \times \frac{1 \text{ lb}}{1 \text{ day}} \times \frac{1 \text{ day}}{1440 \text{ min}} = \frac{454000}{1440} = 315.3 \frac{\text{mg}}{\text{min}}$$

### Practice Problem 3

How many hours will it take to empty a 55 gallon drum of a liquid chemical using a chemical feed pump that will pump at a rate of 30 ml/min?

#### Solution to Practice Problem 3.

Known Data: 55 gal and  $\frac{30 \text{ ml}}{\text{min}}$

Unknown Data: ? Hours

$$\frac{? \text{ Hours}}{1} = \frac{1 \text{ hr}}{60 \text{ mins}} \times \frac{\text{min}}{30 \text{ ml}} \times \frac{3785 \text{ ml}}{\text{gal}} \times \frac{55 \text{ gal}}{1} = \frac{208175}{1800} = 115.6 \text{ hrs.}$$

**Note:** The pump rate is rearranged to place the time unit in the numerator.

**Note:** If you need a few additional problems to solve, see the **Additional Unit Cancellation Problems** that follow this chapter in the workbook.

- Most mathematical problems for water treatment plant operation involve converting units. (Fill in the blank)

- Understanding which **units** of measurement are involved in performing a calculation and locating the proper conversions for those units make problem solving easier. (Fill in the blank)

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### Additional Unit Cancellation Practice Problems

1. How many mL/min are in 10 gal/hr?

**Answer:** 630.8 mL/min

2. How many gm/mL are in 1 lb/gal?

**Answer:** 0.12 gm/mL

3. How many days will it take to empty a 30 gallon drum of liquid chlorine using a chemical feed pump that's feeding at a rate of 20 mL/min?

**Answer:** 3.9 days

4. If a chlorinator is feeding at a rate of 2 lbs/day, and the well produces a flow of 75 gal/min, what is the chlorine dose (in mg/L)?

**Answer:** 2.2 mg/L

5. If a storage tank contains 1,000 gallons, and you want to disinfect the tank using chlorine to a dose of 50 mg/L, how many lbs of chlorine do you need to add?

**Answer:** 0.42 lbs

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### MODULE 6 - Water Quality Analyses - pH and Temperature

- Use **nonabrasive** towels (i.e., kim wipes) to clean electrodes. (Fill in the blank)
- **Store** electrodes in recommended storage solution. (Fill in the blank)



- Sealed gel-filled electrodes are disposable. **Discard** these electrodes when the gelled reference solution is all used up. (Fill in the blank)
- When using a refillable liquid electrode, fill to the proper level: **above** the level of the sample or storage solution. (Fill in the blank)
- Ensure injection point does not become **clogged**. A clogged junction will cause an error or drift in the reading. Some manufacturers recommend soaking the electrode in warm water to unclog the junction. (Fill in the blank)
- Buffer stock solution has a shelf-life of  $\approx$  **1 year**. Do not use after the expiration date. (Fill in the blank)
- Buffers prepared for daily use last  $\approx$  **2 or 3 days**. Do not pour used buffer back into the stock solution bottle. (Fill in the blank)

**Q:** *If you know that your raw water pH is  $\approx$  6.0, which standards would you use for pH analysis?* **(Answer: 4.00 and 7.00 buffer solutions)**

**Q:** *If your treated water pH is  $\approx$  8.0, which standards would you use?* **(Answer: 7.00 and 10.00 buffers)**

**Q:** *Why not just use 4.00 and 10.0?* **(Answer: The calibration procedure requires the use of pH 7.00 buffer to zero the meter (set the isopotential point) and the second buffer should be selected to bracket the expected sample pH. The selected buffer should not be more than two pH units away from the expected value.)**

- The two buffers used to construct this calibration curve were the pH 7.0 and 10.0 buffers. Now, use your curve to determine the pH of a sample that produced -59 mV. This time, all of us should have a pH of **8.0**. (Fill in the blank)
- Perform **two**-point calibration **daily**. (Fill in the blanks)
- Choose buffers which **bracket** the expected sample pH. (Fill in the blank)
- Analyze samples within **15 minutes** of collection. (Fill in the blank)
- Analyze samples for pH/temperature measurement within **15 minutes**. (Fill in the blank)
- Perform **two-point** calibration **daily** for accurate pH measurement. (Fill in the blanks)

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## MODULE 8 - Water Qlty Analyses: Alkalinity & Calcium

- Titration is a method of analyzing the composition of a solution by adding known amounts of a standardized solution until a given reaction or **end point** is produced. (Fill in the blank)
- The end point can be a **pH** change or a **color** change. (Fill in the blanks)
- Total alkalinity as  $\text{CaCO}_3$  is determined by titration with a sulfuric acid ( $\text{H}_2\text{SO}_4$ ) standard solution to an end point determined with a calibrated pH meter. That end point is a **pH 4.5**. (Fill in the blank)

**Q:** At what pH does the water contain only carbonic acid? (Answer: pH 4.5)

**Q:** At what pH is the alkalinity concentration  $\approx 0$ ? (Answer: pH 4.5.)

- Collect a sufficient volume (**100-200 mL** is required for either method). (Fill in the blank)
- Analyze samples **as soon as possible** after collection. (Fill in the blank)
- Analyze samples **as soon as possible** after sample collection. (Fill in the blank)
- A **QC** program is critical for accurate measurement. (Fill in the blank)

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## MODULE 10 - Wtr Qlty Analyses - Phosphorus & Silica

- Use clean, **scratch-free** sample cells. Wash cells with phosphate-free detergent and rinse thoroughly with distilled or deionized water. Rinse with 1:1 HCl when needed. (Fill in the blank)
- Extreme background **turbidity** or **color** in a sample can interfere with colorimetric analyses. (Fill in the blank)
- Colorimeters must be **zeroed** with a blank before unknown solutions can be measured. The method will specify the use of a sample blank or a reagent blank. (Fill in the blank)
- A **sample** blank is used to compensate for minimal background color inherent in the sample. To compensate, zero the instrument with the sample prior to addition of any reagents. (Fill in the blank)

- A **reagent** blank is used when the reagent itself adds color to the sample and results in a positive error. To compensate, zero the instrument with distilled or deionized water mixed with the reagents. (Fill in the blank)
- Collect  $\approx$ **100 mL** for phosphorus or silica measurement. (Fill in the blank)
- Analyze samples **as soon as possible** after collection. (Fill in the blank)
- Analyze samples for phosphorus and silica measurement **as soon as possible** after collection. (Fill in the blank)

### Day 1 Homework

Units and Conversions:

Use the conversion charts and the unit cancellation method to solve the following problems.

11. 5000 mL = ? L

= 5 L

12. 50 L = ? mL

= 50,000 mL

13. 7.990 L = ? mL

= 7,990 mL

14. 1500 mg = ? gm

= 1.5 gm

15. 5436.6 gal = ? L

$$?L = 3.785 \frac{L}{gal} \times 5436.6 gal = 20,577 L$$

16. 1.987 L = ? gal

$$? gal = \frac{gal}{3.785 L} \times 1.987 L = 0.52 gal$$

17. 50  $\frac{mL}{min}$  = ?  $\frac{L}{min}$

$$? \frac{L}{min} = \frac{L}{1000 mL} \times 50 \frac{mL}{min} = 0.05 \frac{L}{min}$$

18. 0.564  $\frac{L}{min}$  = ?  $\frac{mL}{sec}$

$$? \frac{mL}{sec} = 1000 \frac{mL}{L} \times 0.564 \frac{L}{min} \times \frac{1 min}{60 sec} = 9.4 \frac{mL}{sec}$$

$$19. \frac{765 \text{ kg}}{\text{L}} = \frac{? \text{ gm}}{\text{mL}}$$

$$? \frac{\text{gm}}{\text{mL}} = 1000 \frac{\text{gm}}{\text{kg}} \times 765 \frac{\text{kg}}{\text{L}} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 765 \frac{\text{gm}}{\text{mL}}$$

$$20. 6543 \frac{\text{L}}{\text{day}} = ? \frac{\text{gal}}{\text{min}}$$

$$? \frac{\text{gal}}{\text{min}} = \frac{1 \text{ gal}}{3.785 \text{ L}} \times \frac{6543 \text{ L}}{\text{day}} \times \frac{1 \text{ day}}{1440 \text{ min}} = 1.2 \frac{\text{gal}}{\text{min}}$$

21. A water system has an average daily plant flow of 150 gallons per minute (GPM). How much is that flow in million gallons per day (MGD).

$$a) ? \frac{\text{Mgal}}{\text{day}} = \frac{1 \text{ Mgal}}{1,000,000 \text{ gal}} \times 150 \frac{\text{gal}}{\text{min}} \times \frac{1440 \text{ min}}{\text{day}} = 0.216 \frac{\text{Mgal}}{\text{day}}$$

$$b) ? \text{ MGD} = 150 \frac{\text{GPM}}{\text{GPM}} \times \frac{1 \text{ MGD}}{694 \text{ GPM}} = 0.216 \text{ MGD}$$

22. What chemical feed pump rate in mL/min is needed to empty a 30 gallon drum of liquid chemical in three days (72 hours).

$$? \frac{\text{mL}}{\text{min}} = 3,785 \frac{\text{mL}}{\text{gal}} \times \frac{30 \text{ gal}}{3 \text{ days}} \times \frac{1 \text{ day}}{1440 \text{ min}} = 26.28 \frac{\text{mL}}{\text{min}}$$

### Bonus Questions

- A creature moves at a speed of 5 furlongs per fortnight (not a very common unit of speed) given that:

1 furlong = 220 yards

1 fortnight = 14 days

Determine the speed of the creature in yards per minute.

$$? \frac{\text{yards}}{\text{min}} = \frac{220 \text{ yards}}{\text{furlong}} \times \frac{5 \text{ furlongs}}{\text{fortnight}} \times \frac{1 \text{ fortnight}}{14 \text{ days}} \times \frac{1 \text{ day}}{1440 \text{ min}} = 0.055 \frac{\text{yards}}{\text{min}}$$

- If a person weezes 20 times per cough, how many tissues will he use per bowl of soup if:

5 weezes = 1 sneeze

3 sneezes = 1 tissue

4 coughs = 1 bowl of soup

? tissues =  
bowl

Answer: 5.33 tissues  
bowl

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## MODULE 12 - Corrosion Principles

**Q:** *Where does the lead in drinking water usually come from?* **(Answer: lead pipes, solder, brass fittings)**

**Q:** *How about copper?* **(Answer: copper pipes in home plumbing)**

- **Anode** - where electrons are lost through the metal. (Fill in the blank)
- **Cathode** - where electrons are gained and then leave the metal. (Fill in the blank)

### Factors Affecting Corrosion

- **pH:** As pH increases, corrosion **decreases.** (Fill in the blank)
- **Alkalinity:** In most cases, as alkalinity increases, corrosion **decreases.** (Fill in the blank)
- **Total dissolved solids (TDS):** So, as TDS increases, corrosion **increases.** (Fill in the blank)
- **Temperature:** In general, as temperature increases, corrosion **increases** because the rate of chemical reactions increases with increased temperature. (Fill in the blank)

- **Dissolved oxygen (DO):** As DO increases, corrosion **increases**, because oxygen accepts electrons at the cathode and allows the electrical circuit to continue. (Fill in the blank)
- **Chlorides, Sulfates, Nitrates:** As these increase, corrosion **increases**, because they all add TDS to the water increasing its conductivity. (Fill in the blank)
- **Chlorine:** As the addition of gas chlorine increases, corrosion **increases**, because it reduces pH. (Fill in the blank)

### LCR Corrosion Control Treatment Alternatives

- **pH/alkalinity** adjustment (Fill in the blank)
- Corrosion **inhibitors** (Fill in the blank)
- The **chemistry** of the water has the greatest effect on corrosion. (Fill in the blank)
- Controlling lead/copper is achieved by forming a **protective** layer on the pipe wall that eliminates the corrosion cell. (Fill in the blank)

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### MODULE 13 - Corrosion Treatment Theory

**Q:** Do you recall from earlier lessons what compounds make up the carbonate system? **(Answer: carbonic acid, bicarbonate, carbonate and we can add hydroxide since it is an important part of the chemistry)**

At pH = 6.0 raw water probably contains mostly **carbonic acid**, which makes the water corrosive. (Fill in the blank)

If we continue to add more chemical, some of the bicarbonate will be converted to **carbonate** and **hydroxide**. (Fill in the blank)

The approach is to add a **base** to the water to increase pH to reduce lead solubility. (Fill in the blank)

The key to success is to maintain a **stable** pH after treatment. (Fill in the blank)

**pH** is the most important factor. (Fill in the blank)

pH should not be less than 7; above a pH of **8.0** is best for copper reduction. (Fill in the blank)

Stable **pH** is necessary to maintain protection. (Fill in the blank)

Alkalinity should be at least **20** mg/L for pH control. (Fill in the blank)

For systems with copper problems only (no lead problems), adjust pH above **8.0**. (Fill in the blank)

Orthophosphates are by far the most widely used inhibitors for **lead** control. (Fill in the blank)

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## **MODULE 14 - CCT Chemicals: pH/Alkalinity Adjustment**

pH is the major factor that determines the **solubility** of most pipe materials. (Fill in the blank)

Most easily implemented and **least** costly. (Fill in the blank)

**Table 1 - Common pH/Alkalinity Adjustment Chemicals**

<b>Chemical Name</b>	<b>Chemical Formula</b>	<b>Common Name</b>
Sodium Hydroxide	NaOH	<u>Caustic Soda</u>
Calcium Hydroxide	Ca(OH) <sub>2</sub>	<u>Lime</u>
Sodium Bicarbonate	NaHCO <sub>3</sub>	<u>Baking Soda</u>
Sodium Carbonate	Na <sub>2</sub> CO <sub>3</sub>	<u>Soda Ash</u>

Do these chemicals act like acids or bases? **Answer: bases**

Are caustic soda and lime stronger or weaker bases than soda ash and sodium bicarbonate? **Answer: stronger**



### **Operator Tips: Lime**

- Use **flexible** pipelines to break  $\text{CaCO}_3$  deposits. (Fill in the blank)
  - Minimize length of line by placing feeder as **close** as possible to point of application. (Fill in the blank)
- 
- Lime, sodium bicarbonate, and soda ash are delivered as dry chemicals but are fed as **liquids**. (Fill in the blank)
  - Caustic soda is **dangerous** to handle. The Material Data Safety Sheet (MSDS) sheet for 50% caustic soda is 9 pages long and contains detailed information about:
    - \* health hazards
    - \* special protection
    - \* handling and storage precautions
    - \* special mixing precautions
    - \* warning label information
    - \* physical data (density, specific gravity which you will need to calculate dosages)



- pH adjustment is least costly and most **easily** implemented type of corrosion control treatment. (Fill in the blank)
- Sodium bicarbonate is used primarily to adjust **alkalinity**. (Fill in the blank)
- **Soda ash** provides both pH and alkalinity adjustment and is a safe and easy chemical to use. (Fill in the blank)
- In order to prevent freezing of **50%** caustic soda, you should keep the storage area heated. (Fill in the blank)

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## MODULE 15 - CCT Chems: Phosphate/Silicate Inhibitors

- Taste, odor, alkalinity and **pH** are not affected; hardness not increased. (Fill in the blank)
- Finished water pH is **lower**; therefore, chlorine doses and TTHM formation potential may be lower than with pH adjustment. (Fill in the blank)
- They may encourage **algal** growth in reservoirs exposed to sunlight. (Fill in the blank)
- Zinc is often added to enhance phosphate performance; however, wastewater treatment plants have **sludge** disposal problems due to the elevated zinc levels. (Fill in the blank)
- \* **Cleaning** mains by flushing or with hydraulic pigs. ( A process that removes severe tuberculation and slime build up by brushing or scraping.) (Fill in the blank)
- \* Maintaining **continuous** feed. (Interrupting feed makes corrosion worse.) (Fill in the blank)
- Phosphate/Silicate inhibitors develop a very **thin** protective insoluble metallic film on the inside of the pipes which won't clog the pipes. (Fill in the blank)
- Polyphosphates are used to sequester **iron**, manganese, and calcium. (Fill in the blank)
- Zinc orthophosphates are used primarily to control **lead** levels but are not as effective for copper. (Fill in the blank)

- Silicate inhibitors do not add **zinc** to the system and are used extensively in point-of-use applications such as buildings and industrial processes. (Fill in the blank)

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## MODULE 16 - Chemical Feed Systems

- An operator can use this information to track inventory and to verify the **dosage** of chemical being fed. (Fill in the blank)

**Q: Where should the suction assembly be installed? (Answer: Suspended just above the bottom of the tank so as not to pull in any solids that may have settled out.)**

- A calibration chamber consists of a graduated cylinder typically located on the **suction** side of the pump. (Fill in the blank)
- The valve relieves pressure if the line becomes **clogged**, a valve is inadvertently **closed**, or if the pump produces pressures higher than the piping system can withstand. (Fill in the blank)
- The valve also aids in **priming** the pump. (Provides a release for entrapped air.) (Fill in the blank)
  1. Observe its operation **daily**. (Fill in the blank)
  2. Maintain a regular schedule of **preventive** maintenance. (Fill in the blank)
- The suction assembly should be examined and cleaned on a regular basis. A clogged assembly can be cleaned with a weak acid solution (i.e., **vinegar** or 1:1 HCl). (Fill in the blank)
- Valves used with corrosive chemicals should be disassembled and inspected at least **annually**. Parts showing signs of deterioration should be replaced. (Fill in the blank)
- A ball valve caked with chemical may stick and cause **siphoning**. (Fill in the blank)
- A worn seal may form an **air leak** that could lower the pump output or cause the pump to lose prime. (Fill in the blank)
- Observe the operation of feed systems **daily**. (Fill in the blank)
- Establish a **preventive** maintenance schedule. (Fill in the blank)

- Establish and maintain proper **O&M** for stable water quality. (Fill in the blank)
- 

## MODULE 17 - Chem Feed Calc 1 - Intro & Dry Chem Feed

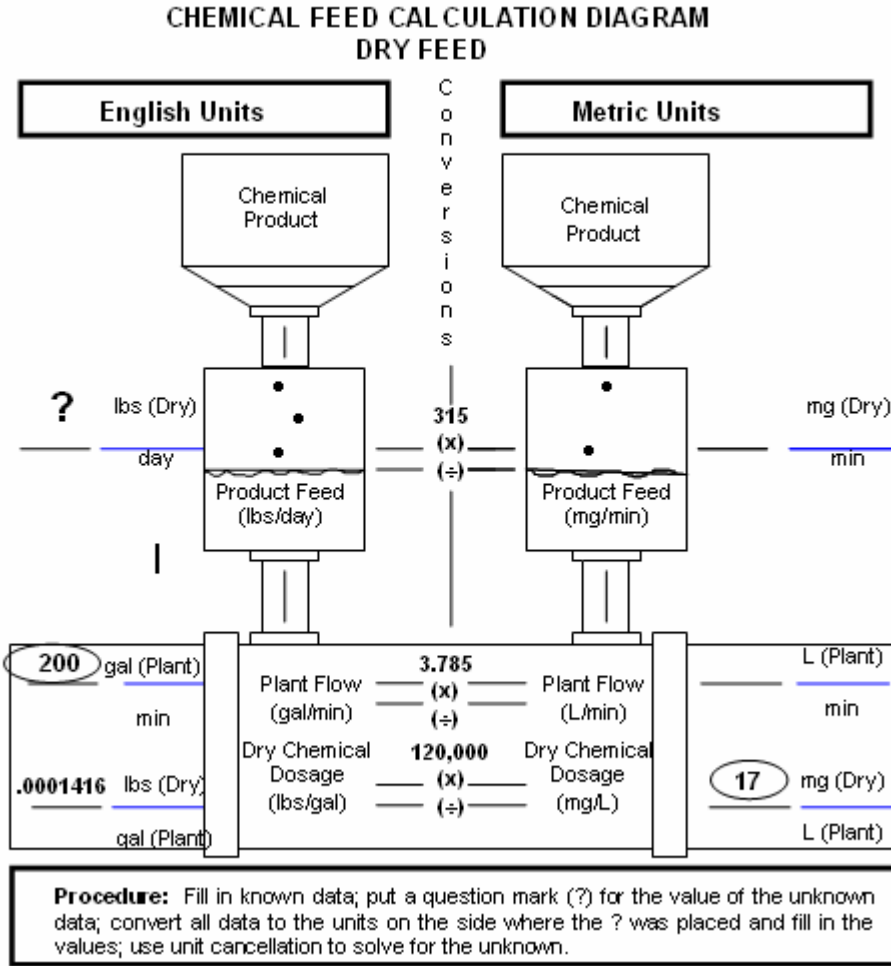
- Product Feed Rate. (Fill in the blank)
- Chemical Dosage. (Fill in the blank)
- The amount of **dry chemical** in the treated water is referred to as dosage. (Fill in the blank)
- Chemical dosage is almost always given in units of mg/L. Mg/L is also referred to as parts per million. (Fill in the blank)
- The amount of **dry chemical** in the **chemical product** is called product strength. (Fill in the blank)
- If you are feeding a liquid, the product strength is the weight of **dry chemical** in a volume of liquid product. (Fill in the blanks)
- For dry product feed, the units are usually lbs/day. Sometimes dry chemical feed is calculated in gm/min. (Fill in the blank)
- If the product is fed as a liquid, most systems will have metering pumps that feed in mL/min. Some larger systems may feed liquid chemicals at a **GPM** or **GPH** rate. (Fill in the blank)

### Chemical Feed Problem

Your water system uses a dry feed system for lime which feeds in lbs/day.

**Part 1:** How many lbs/day of lime are needed for a desired dosage of 17 mg/L when the average daily plant flow is 200 GPM?

**Part 1:**



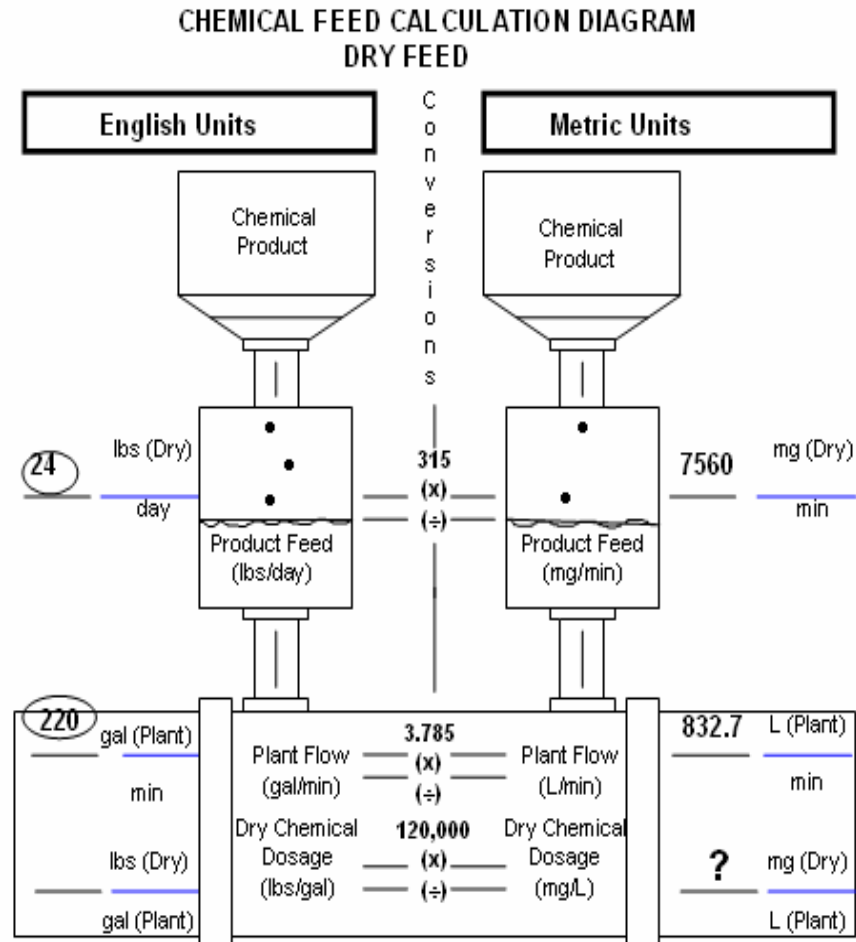
1. First, fill in the known data.
2. Put a question mark for the unknown data.
3. Convert the dosage to the English side of the diagram since our unknown, product feed, is on that side. Dosage is converted from mg/L to lbs/gal by dividing by 120,000.
4. Perform unit cancellation.

$$? \frac{\text{lbs (Dry)}}{\text{day}} = \frac{.0001416 \text{ lbs (Dry)}}{\text{gal (Plant)}} \times \frac{200 \text{ gal (Plant)}}{\text{min}} \times \frac{1440 \text{ min}}{\text{day}} = 40.78 \frac{\text{lbs (Dry)}}{\text{day}}$$

All the data we need to solve the problem is on the diagram except the conversion from minutes to days.

**Part 2:** For a day in which the average plant flow is 220 GPM, what lime dosage (mg/L) will the feeder deliver if it is feeding the chemical at a rate of 24 lbs/day?

**Part 2:**



**Unit cancellation:**

$$? \frac{\text{mg (Dry)}}{\text{L (Plant)}} = 7560 \frac{\text{mg (Dry)}}{\text{min}} \times \frac{\text{min}}{832.7 \text{ L (Plant)}} = 9.08 \frac{\text{mg (Dry)}}{\text{L (Plant)}}$$

You can see that because all the weight and volume units are identified as to source, there is no confusion as to which units refer to which part of the chemical feed process.

This will be particularly helpful when we perform liquid feed calculations.

Unit cancellation:

1. Chemical **Product Strength**. (Fill in the blank)
  2. Product Feed Rate.
  3. Plant **Flow**. (Fill in the blank)
  4. Chemical Dosage.
- Dosage is based on the amount of **dry** chemical fed, no matter whether the chemical is fed dry or as a liquid. (Fill in the blank)

---

## MODULE 18 – Chem Feed Calcs 2 - Liquid Chem Feed

**Q1:** *What is density?* (Density is how much a certain **volume** of something **weighs**. Density is weight/volume.)

**Q2:** *Now, what is specific gravity?* (Specific gravity is the density of something compared to the density of **water**.) 
$$\text{S.G.} = \frac{\text{Density "X"}}{\text{Density H}_2\text{O}}$$

From the conversion charts, the density of water in the English system is **8.34 lbs/gal**.

**Q3:** *If a substance has a density of 11.3 lbs/gal, what is its specific gravity?*

$$\frac{(\text{Density of substance})}{(\text{Density of water})} = \frac{11.3 \text{ lbs/gal}}{8.34 \text{ lbs/gal}} = \underline{1.35}$$

**Q4:** *What are the units of specific gravity?* (**Specific gravity has no units, the density units cancel out.**)

**Q5:** *If a liquid chemical has a specific gravity of 1.28, what is its density in metric units and in English units?* (**Metric: 1.28 gm/mL; English: 10.7 lbs/gal**)

The density in metric units (gm/mL) is the same as the specific gravity. The density in English units is 1.28 x 8.34 lbs/gal (density of water) or 10.7 lbs/gal

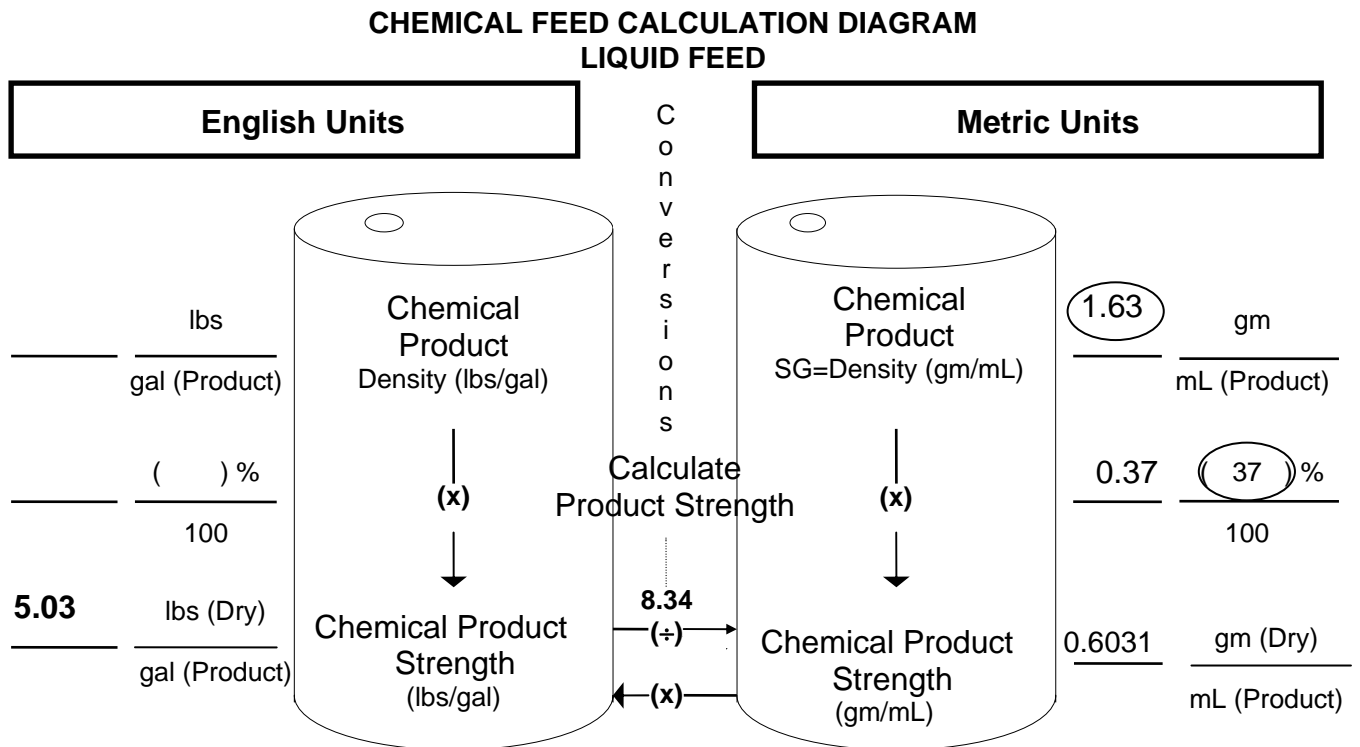
**Example Problem: Calculating Product Strength**

**Example Problem 1:** You receive a delivery of 25% caustic soda in a 55 gallon drum. The product information indicates that the density is 11.1 lbs/gal. What is the product strength? In other words, how many lbs of dry caustic soda are in a gallon of liquid product?

$$\begin{aligned} \text{Product Strength (lbs/gal)} &= \text{Product Density (lbs/gal)} \times \frac{\text{Percent Strength}}{100} \\ &= 11.1 \text{ lbs/gal} \times \frac{25}{100} \\ &= 11.1 \times 0.25 = \mathbf{2.775 \text{ lbs (dry)/gal (product)}} \end{aligned}$$

**Example Problem Using the Diagram**

**Example Problem 2:** You are using a zinc orthophosphate solution for corrosion control. The manufacturer's data gives the product's specific gravity as 1.63. Your supplier has recommended a feed rate assuming the product contains 37% PO<sub>4</sub>. What is the product strength in lbs/gal?



Solution Steps:

1. This problem involves specific gravity; so you fill in the density on the Metric (right ) side of the diagram. In the Metric system, specific gravity equals density.
2. Fill in the percent/100 or 0.37 and multiply.
3. Since the problem asks for product strength in lbs/gal, the diagram directs you to multiply the Metric value by 8.34, which yields 5.03 lbs (dry)/gal (product).

Like the dry feed problems, the diagram accomplishes the same calculations as the formulas without having to memorize the formulas.

**Liquid Chemical Feed Problem 1**

A treatment plant is feeding caustic soda at a dosage of 32 mg/L. The plant flow is 347 GPM. The caustic soda is a 50% solution and has a density of 12.8 lbs/gal. What is the feed pump rate in mL/min?

Solution Steps - Problem 1

1. Fill in the known data.
2. Put a question mark (?) for the value of the unknown data.
3. Calculate chemical product strength.
4. The unknown data is on the Metric side (mL/min). Using the conversions provided, move each piece of known data across to the metric side
5. Use unit cancellation to solve for the product feed rate in the space provided at the bottom of the diagram.

**Data from Diagram**

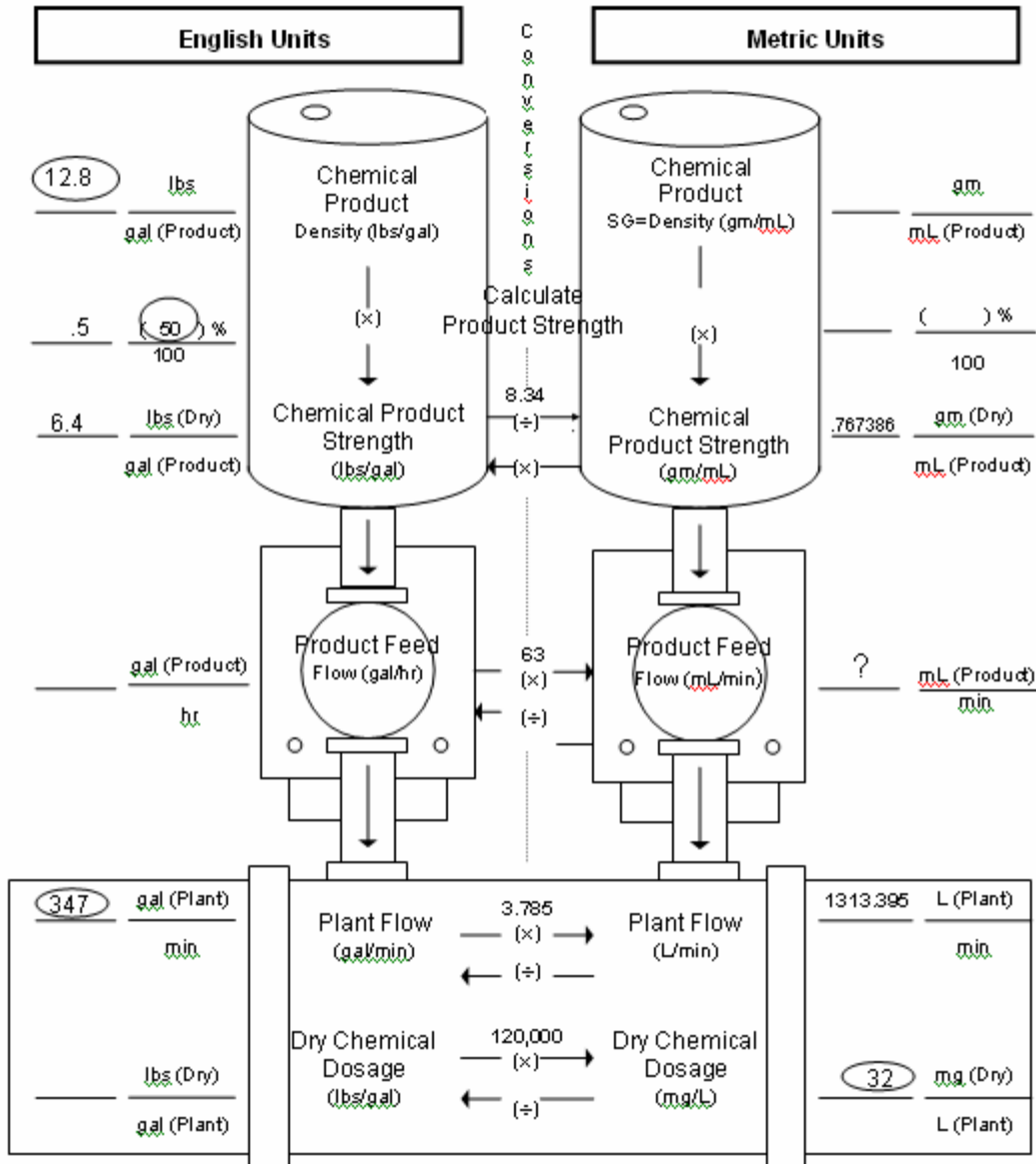
$$\begin{aligned} ? \frac{\text{mL (Product)}}{\text{min}} &= \frac{\text{mL (Product)}}{.767386 \text{ gm (Dry)}} \times \frac{\text{gm}}{1000 \text{ mg}} \times 32 \frac{\text{mg (Dry)}}{\text{L (plant)}} \times 1313.395 \frac{\text{L (Plant)}}{\text{min}} \\ &= \mathbf{54.77 \text{ mL/min}} \end{aligned}$$

**Data from Conversion Chart**

(see diagram on next page)



**CHEMICAL FEED CALCULATION DIAGRAM  
LIQUID FEED**

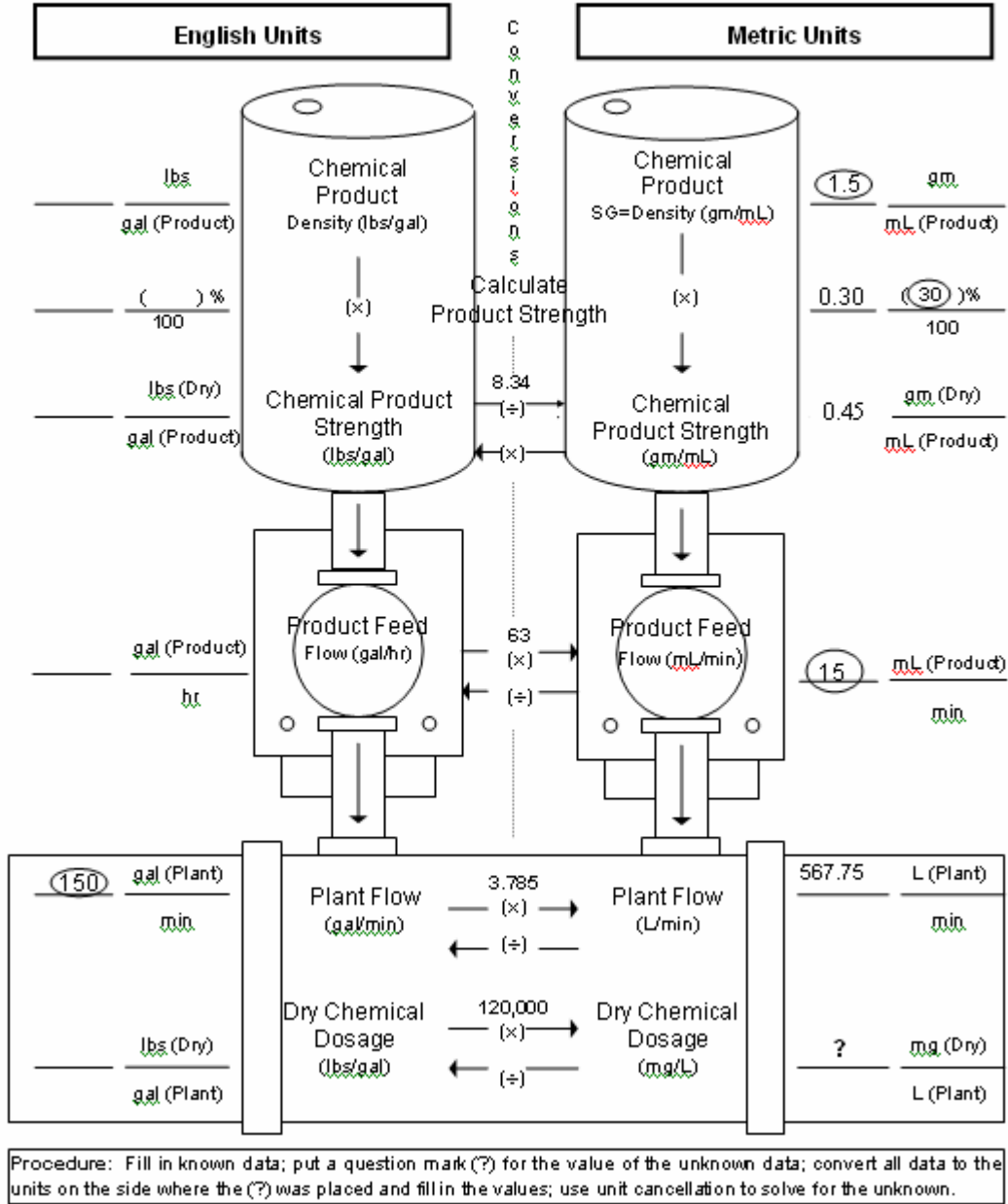


Procedure: Fill in known data; put a question mark (?) for the value of the unknown data; convert all data to the units on the side where the (?) was placed and fill in the values; use unit cancellation to solve for the unknown.

**Liquid Chemical Feed Problem 2**

A treatment plant is feeding an inhibitor for corrosion control treatment. The plant flow is 150 GPM. The inhibitor contains 30% orthophosphate and has a specific gravity of 1.5. A check of the feed rate indicates that the pump is delivering 15 mL/min. What dosage (mg/L) is being added at this feed rate?

**CHEMICAL FEED CALCULATION DIAGRAM  
LIQUID FEED**



Unit Cancellation:

$$\frac{? \text{ mg (Dry)}}{\text{L (Plant)}} = \frac{1,000 \text{ mg}}{\text{gm}} \times \frac{0.45 \text{ gm (Dry)}}{\text{mL (Product)}} \times \frac{15 \text{ mL (Product)}}{\text{min}} \times \frac{\text{min}}{567.75 \text{ L (Plant)}}$$

$$= 11.89 \text{ mg/L}$$

- Understanding and using **chemical product** information is the most difficult and confusing part of liquid feed calculations. (Fill in the Blank)
- Dosage is based on how much **dry** chemical is fed, even for liquid chemicals. (Fill in the Blank)

## MODULE 19 - Pump Calibration Workshop



### 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? (Answer: Pump output is different going up the scale than it is going down the scale. Output from 30 - 40 is different than 40 - 30.)**

- Conduct a pump calibration to determine the pump's **feed rate**.
- Perform calibrations at least **once per year**.

## Day Two Homework

### Plant Data - Practice Borough Water Authority

- Average plant flow = 80 GPM
- pH adjustment chemical - 25 percent caustic soda; S.G. 1.27
- Target finished water pH is 8.5

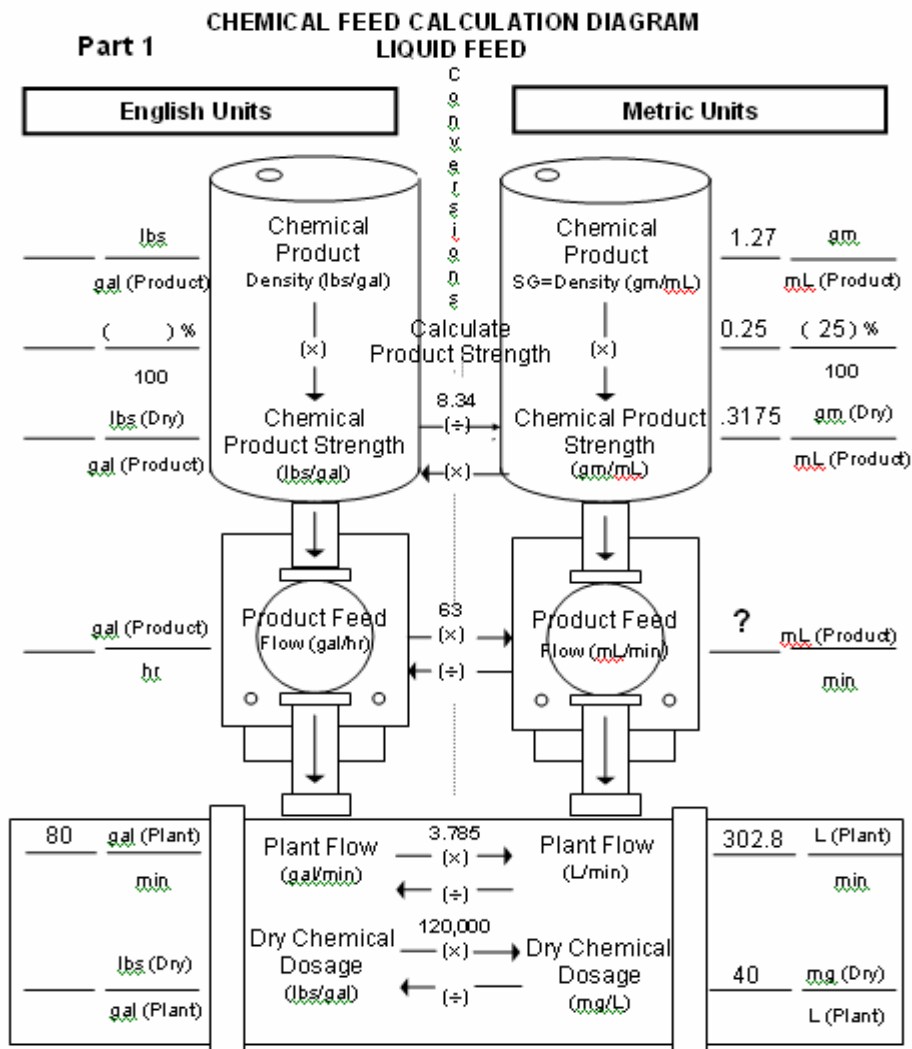
### Operator Tools

- Liquid Chemical Feed Calculation Diagrams (Part 1- page 2; Part 2 - page -4)
- Pump Calibration Curve (page 3, use for Part 1)

**Part 1:** Under the current pump calibration, what chemical feed pump setting is needed to deliver a caustic soda dosage of 40 mg/L?

**Speed Setting = 58**

Tools needed: diagram (page 2) and pump calibration curve (page 3).



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.

Put unit cancellation work here:

$$? \frac{\text{mL (Prod)}}{\text{min}} = \frac{\text{mL (Prod)}}{.3175 \text{ gm (Dry)}} \times \frac{\text{gm}}{1,000 \text{ mg}} \times \frac{40 \text{ mg (Dry)}}{\text{L (Plant)}} \times \frac{302.8 \text{ L (Plant)}}{\text{min}} = 38.15 \frac{\text{mL}}{\text{min}}$$

## Liquid Metering Pump Calibration Curve

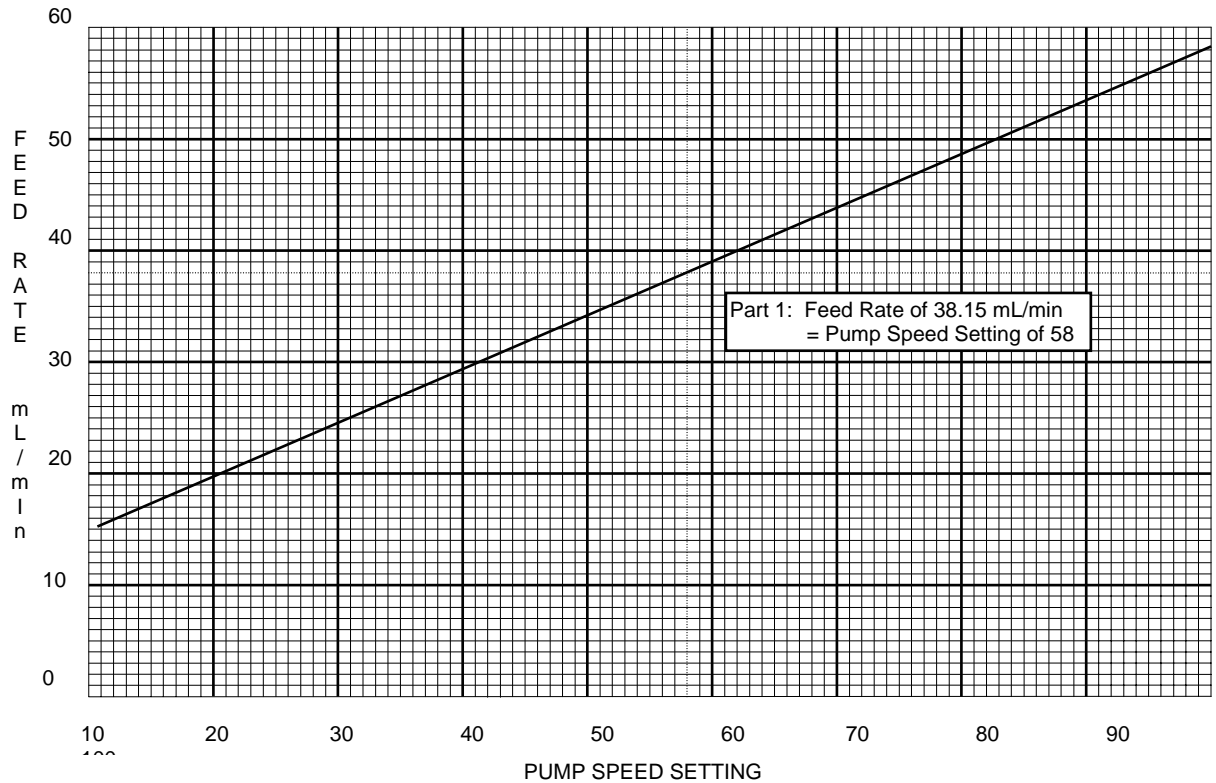
(Use for Part 1)

PUMP: 25 % caustic

STROKE: 80%

CALIBRATION CURVE

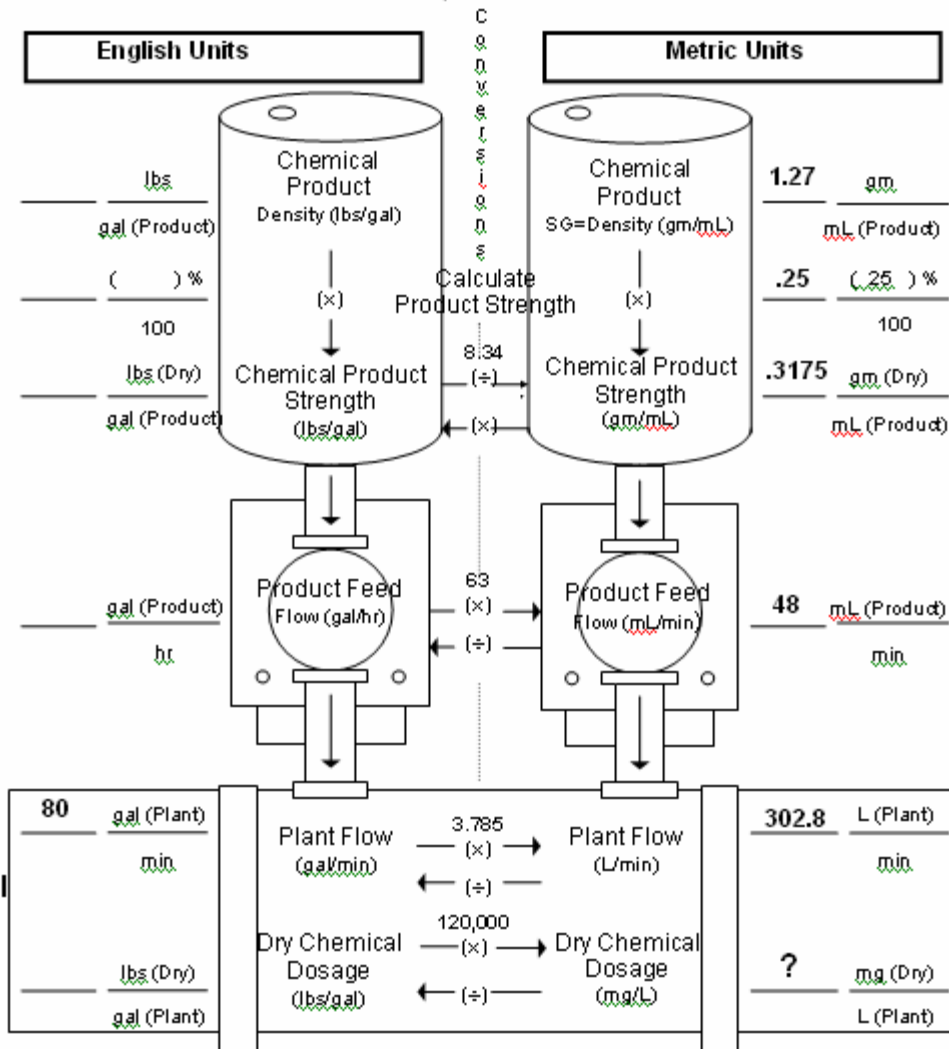
DATE: 9/10/95



**Part 2:** The plant operator comes in one day and begins his daily stability routine. He measures entry point pH and finds that it is 8.9. A spot check of the feed pump determines that the feed rate is 48 mL/min. What caustic soda dosage is being delivered at that time? Tools needed: diagram (page 4).

**Dosage = 50.33 mg/L**

**Part 2 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.

Put unit cancellation work here:

$$\frac{? \text{ mg (Dry)}}{\text{L (Plant)}} = \frac{1,000 \text{ mg}}{\text{gm}} \times \frac{.3175 \text{ gm (Dry)}}{\text{mL (Prod)}} \times \frac{48 \text{ mL (Prod)}}{\text{min}} \times \frac{\text{min}}{302.8 \text{ L (Plant)}} = 50.33 \frac{\text{mg}}{\text{L}}$$

**Bonus Problem**

The following information is available from your feasibility study.

- pH = 6.5
- Alkalinity = 14 mg/L
- Target EP pH = 7.5
- Target Soda Ash Dosage = 19 mg/L
- Target EP Orthophosphate Residual = 1 mg/L

Based on the raw water quality data, an engineer has determined that your system should use pH/alkalinity adjustment followed by orthophosphate inhibitor addition for lead control. pH/alkalinity adjustment is needed to increase your pH because phosphate inhibitors usually work best for corrosion control in the pH range of 7.2 to 7.8.

You will be feeding soda ash from a day tank. Your engineer has specified a chemical product strength of 0.83 lbs (dry)/gal (product).

Your average plant flow is 75 GPM. The target soda ash dosage is 19 mg/L. What feed rate (mL/min) is needed to deliver the target dosage? Use the Chemical Feed Calculation Diagram on the next page.

**54.2 mL/min (See Diagram)**

You need to purchase a new feed pump for the soda ash solution. Which of the following pumps should be purchased (using the feed rate from above)? **Feed Rate needed is 54.2 mL/min.**

- a. 18 GPD (**Undersized: operating range 0.72 to 11.52 gal/day**)
- b.** 48 GPD (**Good mid-range pump: operating range 1.92 to 30.72 gal/day**)
- c. 600 GPD (**Oversized: operating range 24 to 384 gal/day**)
- d. none of the above

$$\frac{? \text{ gal}}{\text{day}} = \frac{1 \text{ gal}}{3785 \text{ mL}} \times \frac{54.2 \text{ mL}}{\text{min}} \times \frac{1440 \text{ min}}{\text{day}} = \frac{20.6 \text{ gal}}{\text{day}}$$

How to determine operating range for 18 GPD pump. (See module 19)

$$\frac{? \text{ gal}}{\text{day}} = \frac{18 \text{ gal}}{\text{day}} \times \% \text{ Stroke} \times \% \text{ Speed}$$

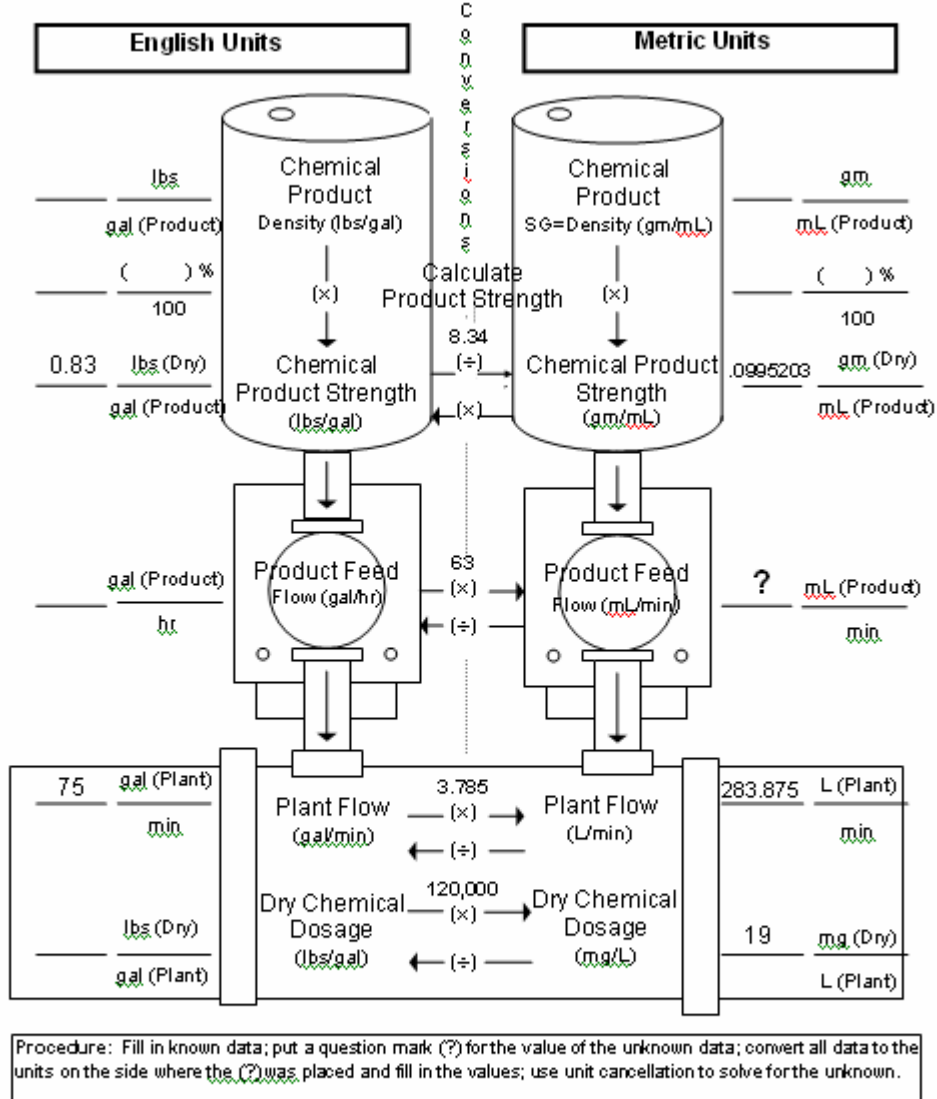
If minimum = 20% Stroke and 20% Speed, then:

$$\frac{? \text{ gal}}{\text{day}} = \frac{18 \text{ gal}}{\text{day}} \times 0.2 \times 0.2 = \frac{0.72 \text{ gal}}{\text{day}}$$

If maximum = 80% Stroke and 80% Speed, then:

$$\frac{? \text{ gal}}{\text{day}} = \frac{18 \text{ gal}}{\text{day}} \times 0.8 \times 0.8 = \frac{11.52 \text{ gal}}{\text{day}}$$

### CHEMICAL FEED CALCULATION DIAGRAM LIQUID FEED



Put unit cancellation work here:

$$\frac{? \text{ mL (Prod)}}{\text{min}} = \frac{\text{mL (Prod)}}{0.995203 \text{ gm (Dry)}} \times \frac{\text{gm}}{1,000 \text{ mg}} \times \frac{19 \text{ mg (Dry)}}{\text{L (Plant)}} \times \frac{283.875 \text{ L (Plant)}}{\text{min}} = 54.2 \frac{\text{mL}}{\text{min}}$$



---

## MODULE 20 - Chemical Feed Calculations 3 - Practice Problems/Mixing Day Tanks

**Q:** What are the four values that can be calculated on the chemical feed calculation diagram? **Answer:** 1) chemical product strength, 2) feed rate, 3) plant flow and 4) dosage.

### Liquid Chemical Feed Practice Problem

**Background information:** You are the operator of a small water treatment plant. The plant operates on a 12 hour-per-day basis. During the operating day, the plant raw water pump runs on cycles of about 20 minutes each. This pump is metered and flow is measured in gallons. You are feeding 25% caustic soda (density = 10.5 lbs/gal) to raise pH. The target pH is 8.4. The chemical feed pump comes on and shuts off with the raw water pump.

This is a fairly common situation at small water systems. Let's go over this three-part problem.

**Part 1:** What is the average plant flow in GPM?

#### Solution

1. The first step is to measure the gallons pumped during the pump cycle. Since flows and cycle times will vary somewhat during different cycles, it is best to measure several cycles and calculate the average. You decide to measure 5 cycles during different times of the day. Then you construct the following table.

Cycle Number	Cycle Time (min)	Gallons Pumped
1	22	1553
2	24	1590
3	21	1546
4	20	1540
5	17	1521
<b>average</b>	<b>21</b>	<b>1550</b>

- The average plant flow in GPM is calculated by dividing the average gallons pumped (1550 gal) by the cycle time (21 min).

**Q:** What is this answer? Answer: **73.8 GPM**

Now let's move on to Part 2 of the problem.

**Part 2:** To maintain the target pH, the caustic soda dosage ranges from 20 to 30 mg/L. Construct a feed rate vs. dosage table.

Solution

- Fill the known plant data (including the plant flow determined in Part 1) in the proper blanks on the Chemical Feed Calculation Diagram (page 20-5). Start with a dosage of 20 mg/L.

**Note:** The known data is circled on the diagram.

- Calculate product strength on the diagram.
- The unknown data (product feed) is on the Metric side. Using the conversions provided, move the known data (product strength and plant flow) across to the metric side.
- Use unit cancellation to solve for the product feed.

$$? \frac{\text{mL (Prod)}}{\text{min}} = \frac{\text{mL (Prod)}}{\text{min}} \times \frac{1 \text{ gm}}{1,000 \text{ mg}} \times \frac{20 \text{ mg (Dry)}}{\text{L (Plant)}} \times \frac{279.333 \text{ L (Plant)}}{\text{min}} = 17.75 \frac{\text{mL}}{\text{min}}$$

- Place the product value on the Feed Rate vs. Dosage Table on page 20-6. Fill in the chemical and plant flow information.
- To complete the table for the dosage range, you decide to pick steps at 2 mg/L intervals and calculate the pump rate for each dosage step. Each feed rate can be calculated using the diagram or you can calculate one feed rate and then use a proportion to complete the table.

Example of the use of proportion:

A feed rate of 17.8 mL/min will give a dosage of 20 mg/L. To calculate the feed rate for a dosage of 22 mg/L, a proportion is set up like this:

$$\frac{17.8}{20} = \frac{?}{22} ; \text{ Solving for the unknown } ? = 0.89 \times 22 = 19.6 \frac{\text{mL}}{\text{min}}$$

7. Finish the Feed Rate vs. Dosage Table on page 20-6 for each dosage value.

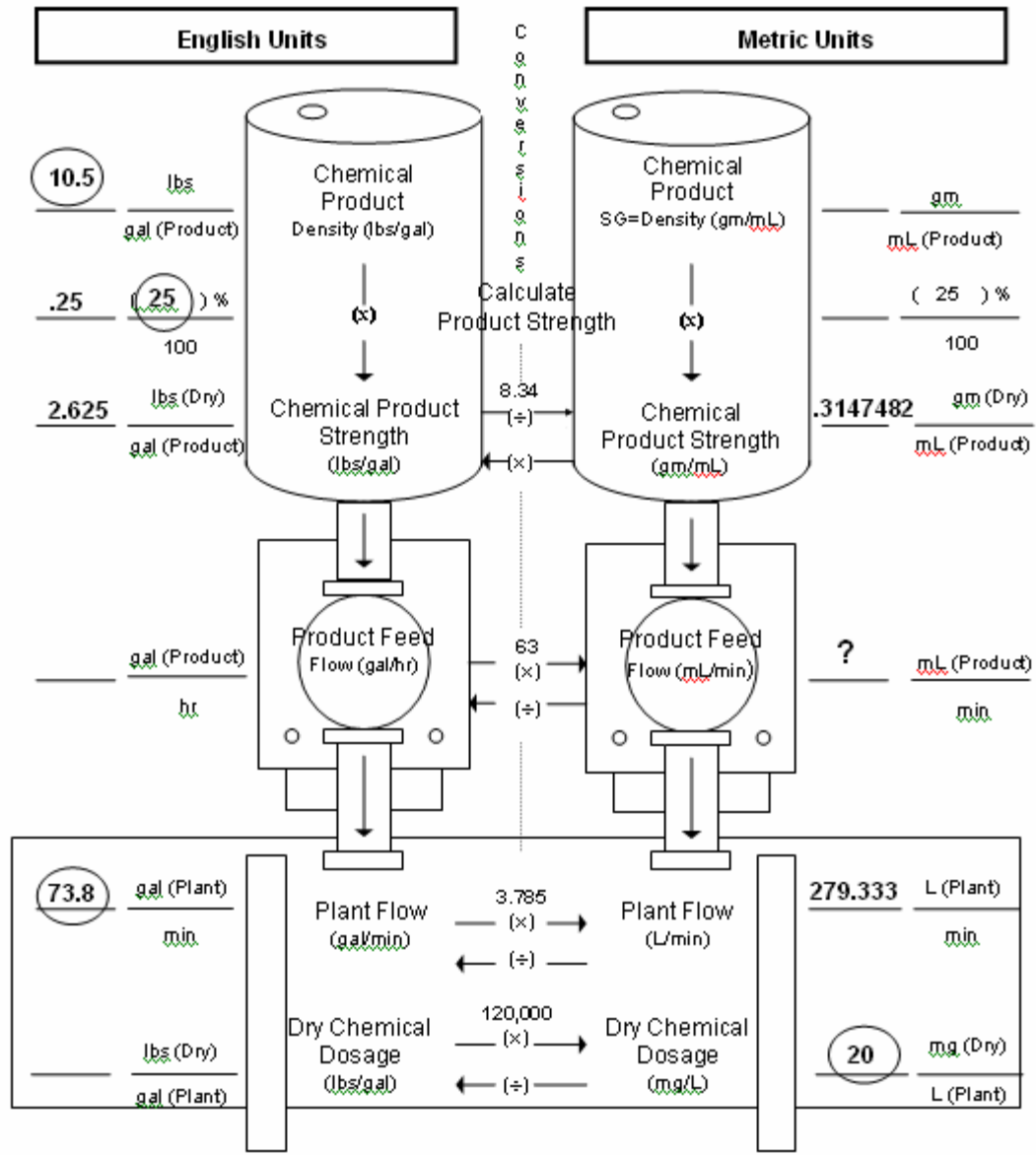
**FEED RATE VS. DOSAGE TABLE**

**Chemical:** 25% Caustic Soda      **Plant Flow:** 73.8 GPM

<b>FEED RATE (mL/min)</b>	<b>DOSAGE (mg/L)</b>
17.8	20
19.6	22
21.3	24
23.1	26
24.9	28
26.7	30

Part 2

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.

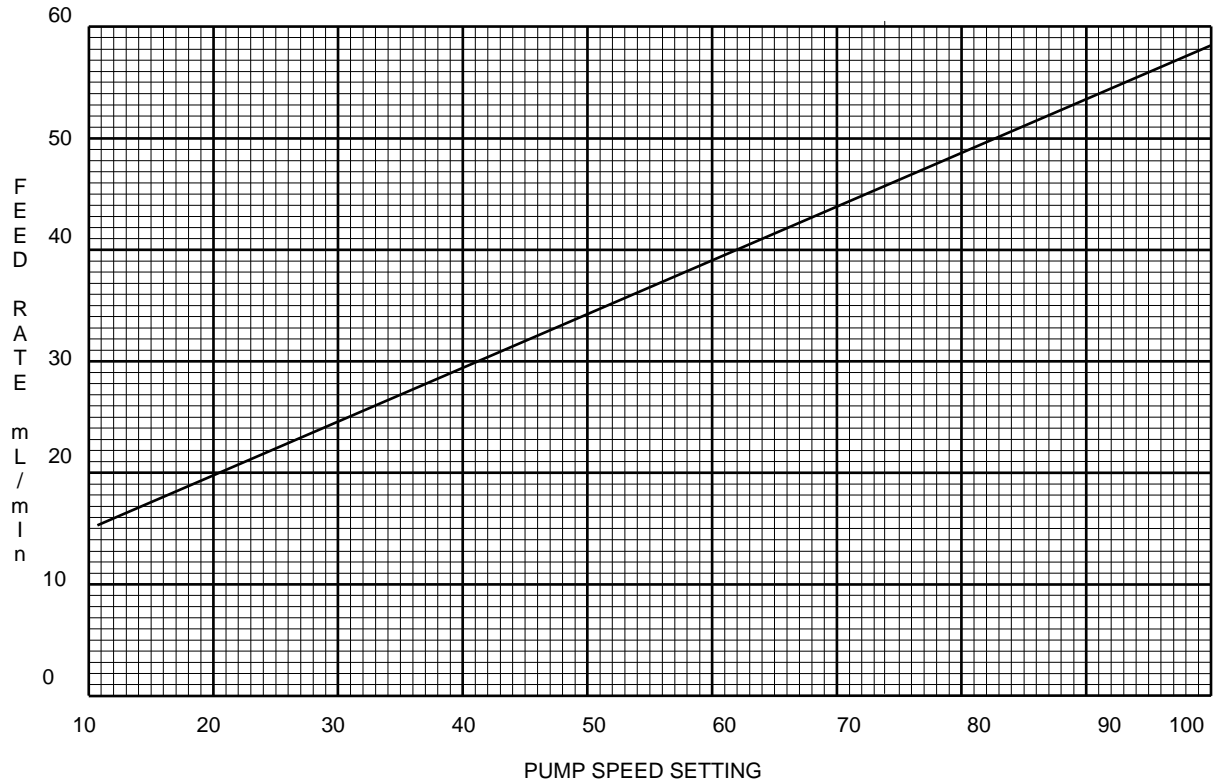
**Part 3: What pump settings will give the desired feed rates?**

Solution

1. You perform a pump calibration and produce a curve for a stroke of 80%. The curve is shown on page 20-7.

**Liquid Metering Pump Calibration Curve**

PUMP: caustic STROKE: 80% CALIBRATION CURVE DATE: \_\_\_\_\_



2. For each feed rate on the Feed Rate vs. Dosage Table, find the corresponding pump speed setting using the calibration curve. As a time saver, you can construct the table on the bottom of page 20-7 showing the pump speed for each dosage and attach it to the pump calibration curve. Complete the table. Keep the table with the calibration curve as a reminder that a new pump calibration will require a new table.

Dosage (mg/L)	Pump Setting
20	16
22	20
24	23
26	27
28	31
30	34

## Mixing a Day Tank

**Example:** You have a new chemical feed system at your plant that you want to start up. The chemical feed system has been designed to feed a soda ash solution with a product strength of 0.2 lbs(dry)/gal(product). How many pounds of dry soda ash do you need to mix with water to start up your 50 gallon day tank?

Solution: We will use unit cancellation to solve this problem. Fill in the blanks.

**Q:** *What is your unknown?* (Answer: lbs (dry) chemical)

**Q:** *When the day tank is full, you will have 50 gal of what?* (Answer: chemical product)

$$? \text{ lbs (dry)} = \frac{0.2 \text{ lbs (dry)}}{\text{gal (product)}} \times 50 \text{ gal (product)} = 10 \text{ lbs dry soda ash}$$

Once the day tank is filled initially, you will need to refill it before it is empty. The easiest way to do this is to use a smaller container like a 5 gallon bucket and make up the product in that container. Then you will always be pouring product into the tank at the correct product strength no matter how empty the tank is.

How much soda ash would you add to water to fill a 5 gallon bucket?

$$? \text{ lbs (dry)} = \frac{0.2 \text{ lbs (dry)}}{\text{gal (product)}} \times 5 \text{ gal (product)} = 1 \text{ lb dry soda ash}$$

## Liquid Feed Problem Involving a Day Tank

### Problem

You are the water treatment plant operator at the Sunset Nursing Home. Your average plant flow is 10 GPM. You have switched to soda ash for corrosion control, but you are using the existing chemical feed equipment. Your feed pump operates most efficiently at or near an output of 63 mL/min. How many pounds of soda ash do you need to dilute with water to fill a 25 gallon day tank if your target dosage is 65 mg/L?

### Solution

1. Fill in plant data in the chemical feed calculation diagram (page 20-10).

- The unknown (chemical product strength) is on the English side of the diagram. Use conversions to move the data to that side.
- Use unit cancellation to solve for **chemical product strength**.

$$? \frac{\text{lbs (Dry)}}{\text{gal (Prod)}} = \frac{0.0005416 \text{ lbs (Dry)}}{\text{gal (Plant)}} \times \frac{10 \text{ gal (Plant)}}{\text{min}} \times \frac{60 \text{ min}}{1 \text{ hr}} \times \frac{1 \text{ hr}}{1 \text{ gal (Prod)}} = 0.325 \frac{\text{lbs (dry)}}{\text{gal (Prod)}}$$

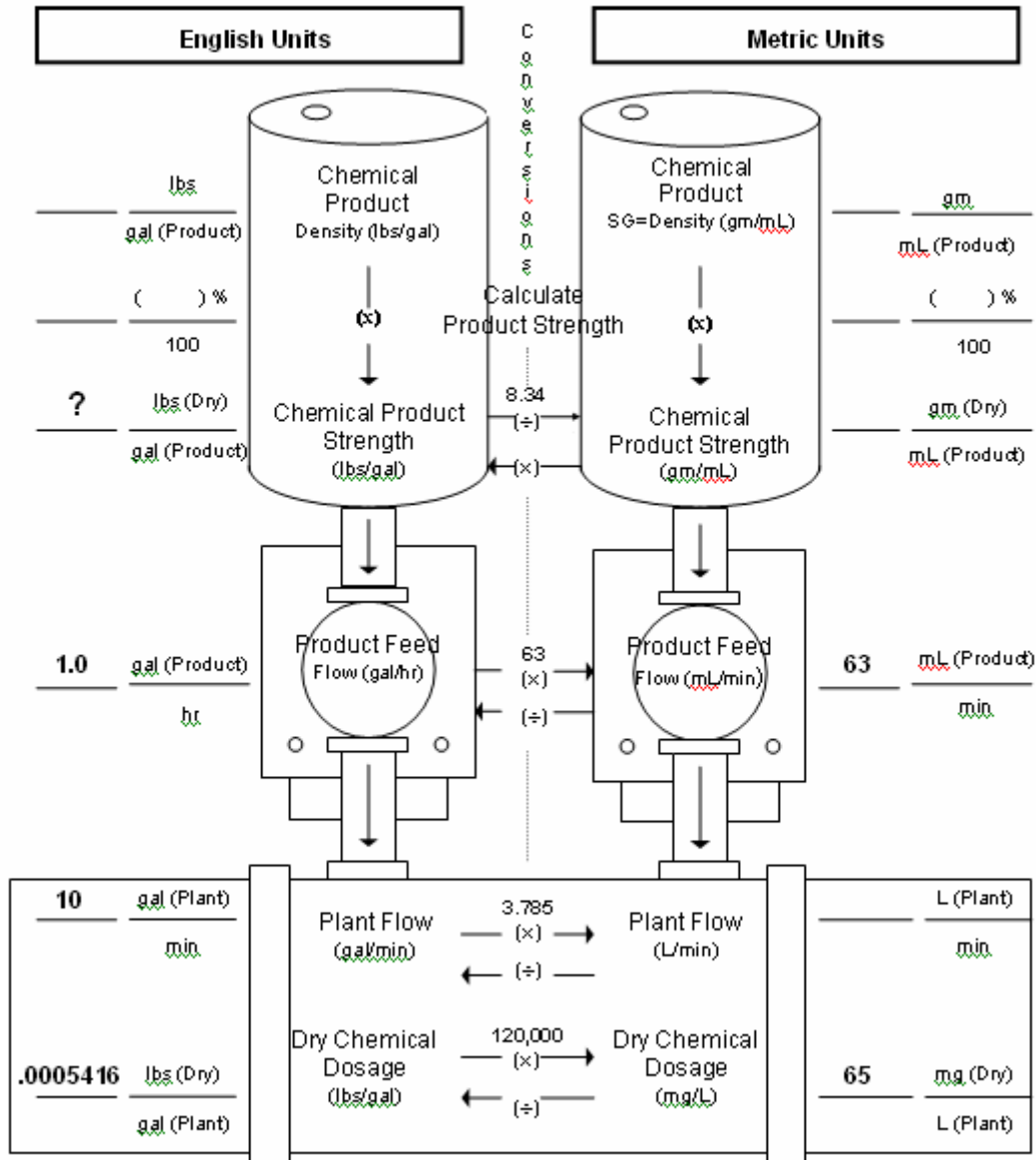
- Calculate pounds of soda ash to add to the day tank.

$$? \text{ lbs (dry)} = \frac{.325 \text{ lbs (dry)}}{\text{gal (product)}} \times 25 \text{ gal (product)} = 8.1 \text{ lbs dry soda ash}$$

**Answer: You would add 8 pounds of soda ash to the day tank.**

(see diagram on next page)

**Day Tank 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.



## MODULE 21 - Operational Constraints/Startup

### Small Group Questions (& Answers)

**Note:** The parenthesis behind the answers (i.e., pH #1, In #2) explains which numbered bullet from pp. 21-2 through 21-4 in the workbook applies to each answer.

#### Questions:

- 1) Describe 2 ways that pH adjustment impacts the disinfection process.
  - a) **Disinfection effectiveness is reduced as pH increases** (pH #1)
  - b) **Greater potential for higher total plate counts, confluent growth or presence of total coliforms.** (pH #6)
  
- 2) Why do silicates affect the useful life of hot water heaters?  
**They precipitate rapidly at higher temperatures** (In #6)
  
- 3) If you are using a phosphate-based inhibitor, what other treatment process could be affected?  
**Disinfection** (In #1)  
  
How is it affected?  
**Residual may be depleted due to biofilms** (In #1)
  
- 4) Name 2 precipitates that could cause turbidity to increase as a result of increasing the pH  
**lime, alum, calcium carbonate, iron, manganese** (pH #2)
  
- 5) What impacts are applicable to both pH/alkalinity adjustment chemicals and inhibitors?
  - a) **Users should be advised of treatment changes** (pH #11, In #4)

- b) **Sodium-based chemicals will increase total sodium levels.** (pH #8, In #5)
- 6) Name 3 impacts that result from raising the pH before disinfection or the coagulation process.
- a) **high THM concentrations** (pH #3)
- b) **alum or poly aluminum won't work as well above pH of 7.0** (pH #4)
- c) **increased aluminum concentrations in finished water if using alum.**(pH #4)
- d) **reduces effectiveness of some coagulants for THM precursor removal** (pH #5)
- 7) Why is it difficult to produce an acceptable coating of calcium carbonate in large distribution systems?
- a) **Too much coating clogs the pipe but if dosage is not high enough, coating may not extend to the ends of distribution system.** (pH #10)
- 8) Name the optimum location for pH adjustment for :
- Systems using lime: **Added prior to filtration so inert material does not accumulate in the clearwell or enter the distribution system.** (pH #1 asterisk)
- Systems not using lime: **After disinfection and near the entrance to the distribution system.** (pH #1 asterisk)
- NOTE: Systems using greensand filtration to remove iron and manganese might disinfect before filtering to oxidize iron and manganese.
- 9) What causes “white water”?
- Excessive calcium carbonate precipitation** (pH #9)
- 10) What adverse effects may occur during the initial phase of adding a phosphate-based inhibitor?
- Customer complaints about red water, dirty water, color and sediment** (In #2)

What can you do to minimize these effects?

- a) **Flush the lines prior to and during the initial pre-treatment phase**  
(Phosphate module)
- b) **Notify customers about the temporary negative effects prior to start up** (common sense)
- 11) Why should commercial users with specific needs be advised of water treatment changes?
- a) **Users may have consumers who shouldn't have excessive levels of some additives (ie. sodium levels for hospital or nursing home residents)** (In #4)
- b) **Industries may have to adjust their own "pretreatment" before they use the water in boilers, laundries, restaurants, etc...** (In #4)
- 12) Name an element in some phosphate-based inhibitors that is regulated in wastewater facilities permits.
- Zinc OR phosphorus** (In #3)



## Key Points:

- The effectiveness of free chlorine is reduced as pH **increases**. (Fill in the blank)
  - The optimum location for pH adjustment is after disinfection, unless **lime** is used. (Fill in the blank)
  - During the initial phase of treatment with phosphate-based inhibitors, you may receive customer complaints about red water, dirty water, color, and sediment. You should **flush** water lines and keep your customers informed about the initial negative impacts to minimize these complaints. (Fill in the blank)
-

## MODULE 22 - Stock Solution/Jar Test Workshop

### Dry Chemicals

Making a stock solution using a dry chemical (i.e., soda ash) is fairly easy. We can use unit cancellation.

Let's look at an example.

#### Example #1:

Prepare 1 L of a 1,000 mg/L stock solution using sodium bicarbonate. How much sodium bicarbonate is needed?

$$\begin{aligned}
 \text{Unknown:} & & \text{Known:} \\
 ? \text{ mg sodium bicarbonate} & = & \frac{1,000 \text{ mg (Dry)}}{\text{L (Stock)}} \times 1 \text{ L (Stock)} \\
 & = & 1,000 \text{ mg}
 \end{aligned}$$

And, if your scale only reads in grams, we can convert mg to grams:

$$\begin{aligned}
 ? \text{ gm sodium bicarbonate} & = & 1,000 \text{ mg (Dry)} \times \frac{\text{gm}}{1,000 \text{ mg}} \\
 & = & 1 \text{ gm (Dry)}
 \end{aligned}$$

Stock Solution Concentration (Dry Chemicals)			
Stock Solution (% Strength)	Stock Solution Concentration (mg/L)	Grams of Dry Chemical Added to a 1 Liter Flask	mg/L Dosage Per mL of Stock Solution Added to a 1 Liter Sample
0.1	1,000	1	1
0.2	2,000	2	2
0.4	4,000	4	4
1.0	10,000	10	10

Notice the highlighted column.

**Q:** If we wanted to mix 1 liter of a 4,000 mg/L stock solution using alum, how much alum would we need? **(Answer: 4 grams)**

## Liquid Chemicals

As we've already discussed, calculations for liquid chemicals are not as simple.

Why? We have to deal with varying chemical product strength.

So, we've developed a diagram similar to the one used for chemical feed to calculate stock solutions using liquid chemicals.

Let's try an example.

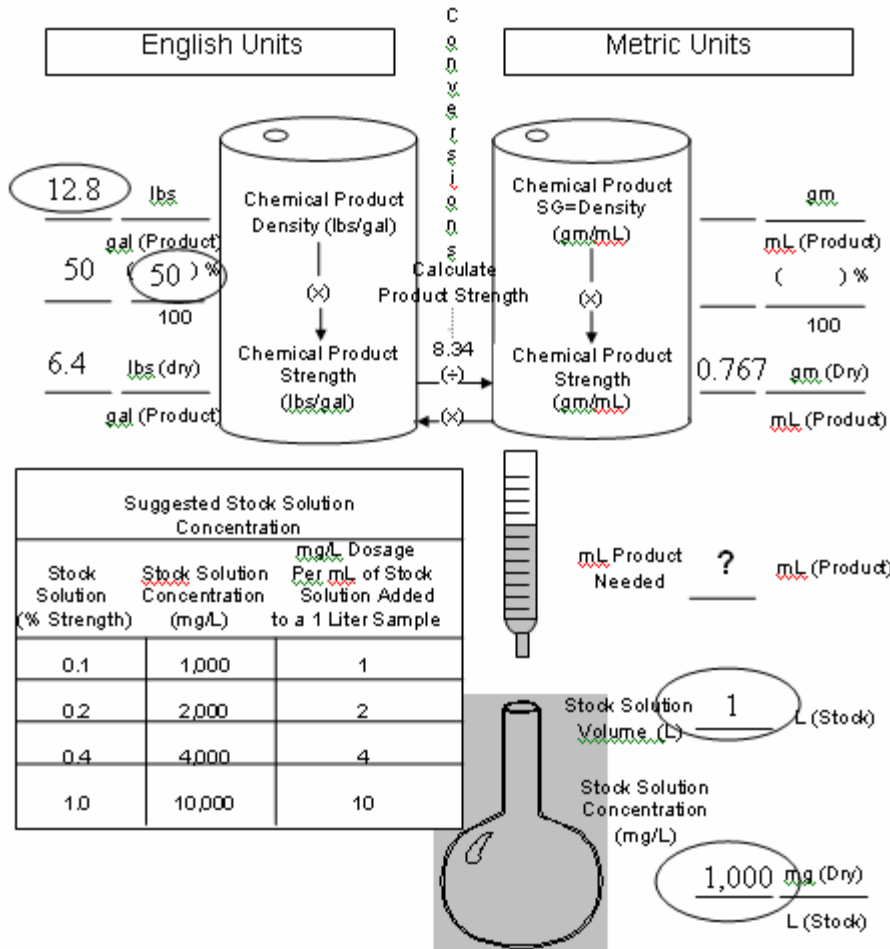
### Example #2:

Prepare 1 L of a 1,000 mg/L stock solution using caustic soda. The caustic soda has a commercial strength of 50% and a density of 12.8 lbs/gal. How much caustic soda is needed?

1. Using the diagram on page 22-4, let's fill in the known data. (see diagram next page)
2. Next, calculate the chemical product strength.
3. Convert all units to the side where the ? is.
4. Then, use unit cancellation to solve for ?.

# Liquid Chemicals

## STOCK SOLUTION DIAGRAM LIQUID CHEMICAL



Procedure: Fill in known data; the question mark (?) is the unknown data; convert all chemical product data to the units on the side where the ? is, and fill in the values; use unit cancellation to solve for the unknown.

Unit Cancellation:

$$\begin{aligned}
 (?) \text{ mL (Product)} &= \frac{\text{mL (Product)}}{0.767 \text{ gm (Dry)}} \times \frac{\text{gm}}{1,000 \text{ mg}} \times \frac{1,000 \text{ mg (Dry)}}{\text{L (Stock)}} \times 1 \text{ L (Stock)} \\
 &= 1.30 \text{ mL}
 \end{aligned}$$

Once we know how much chemical to add, we can prepare the stock solution.



### Operator Tips: Preparing a Stock Solution

- Use care when handling and mixing chemicals. Read all information supplied by your chemical manufacturer, including MSDS sheets. (Fill-in the blank)
- Use fresh stock solution. Stock solution has a shelf-life of ≈2-4 weeks. The solution may deteriorate with time due to mold or algae growth, CO<sub>2</sub> absorption or contamination. (Fill-in the blank)



### Operator Tips: Baseline Water for CCT

- At surface water systems - baseline water is collected just past the filters, but before any post treatment addition. (Fill-in the blank)
- At ground water systems without filtration - baseline water is collected from the raw water tap. (Fill-in the blank)



### Operator Tips: Conducting a Jar Test

- Ensure the sample temperature does not change during the jar test. The jar test should be completed immediately following collection of the baseline water sample.

## Stock Solution/Jar Test Workshop

The workshop has two parts. First, we will prepare a stock solution using soda ash. Then we will perform a jar test using our stock solution.

Let's look at the calculation for soda ash.

## Workshop Exercise Part 1 - Prepare a Stock Solution

Prepare 1 L of a 1,000 mg/L stock solution using soda ash. How much soda ash is needed?

**Q:** Using the stock solution table or unit cancellation someone tell us how much soda ash is needed? (1,000 mg or 1 gram)

**Instructor Note:** Perform the calculation on the whiteboard, if needed.

$$\begin{aligned} ? \text{ mg soda ash} &= \frac{1,000 \text{ mg (Dry)}}{1 \text{ L (Stock)}} \times 1 \text{ L (Stock)} \\ &= 1,000 \text{ mg (Dry)} \\ ? \text{ gm soda ash} &= 1,000 \text{ mg (Dry)} \times \frac{1 \text{ gm}}{1,000 \text{ mg}} \\ &= \mathbf{1 \text{ gm (Dry)}} \end{aligned}$$

## Workshop Exercise Part 2 - Perform a Jar Test

**Q:** Why is alkalinity important? (Answer: Alkalinity is a measure of a water's buffering capacity. For high alkalinity waters, more chemical is needed to increase pH. For low alkalinity waters (< 20 mg/L), great changes in pH can occur when a chemical is added.)

Here is some background plant information.

- Plant Flow (average) = 100 gpm
- Chemical: soda ash; chemical product strength =  $\frac{1.0 \text{ lbs (dry)}}{\text{gal (product)}}$
- Target EP pH = 8.0

The operator determines that baseline water quality has changed. Jar test results indicate that the dosage needs to be adjusted to **30 mg/L** to maintain the target EP pH of 8.0. What pump speed setting is needed? Tools needed: feed rate vs. dosage table and pump calibration curve.

Our first step is to determine the feed rate required to deliver a dosage of 30 mg/L. Let's look at the Feed Rate vs. Dosage Table for this system.



FEED RATE VS. DOSAGE TABLE
----------------------------

Chemical: Soda Ash

Flow: 100 gpm

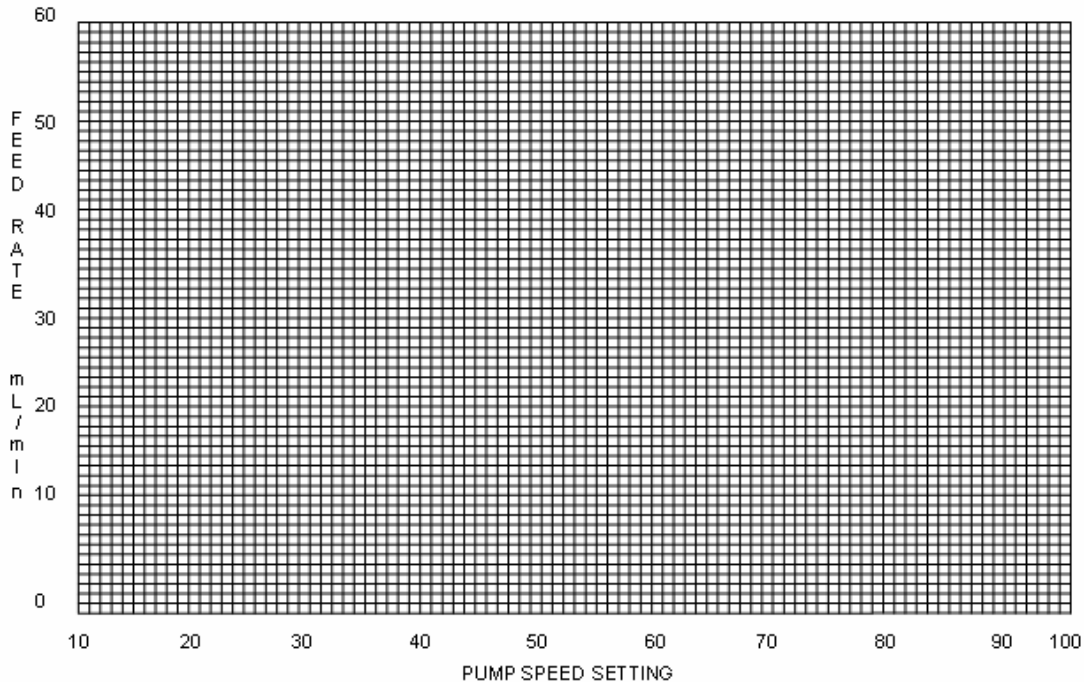
FEED RATE (mL/min)	CHEMICAL DOSAGE (mg/L)
36.8	28
38.1	29
<b>39.4</b>	30
40.7	31
42.1	32

**Q:** What feed rate do we need? (Answer: 39.4 mL/min)

(Chart on next page)

PUMP: \_\_\_\_\_ CALIBRATION CURVE DATE: \_\_\_\_\_

% Stroke: 60%



**Q:** *What pump speed setting is needed? (76)*

This practice problem should help you to understand how these tools are used to adjust chemical feed in response to changing baseline water quality.



### Key Points:

The key points of this module are:

- Perform a jar test to determine optimal dosages. (Fill in the blank)
- The Chemical Dosage Chart is used to adjust chemical feed when the baseline water quality changes. (Fill in the blank)
- Jar testing may be necessary to maintain a stable water quality. (Fill in the blank)

## MODULE 23 - Process Control and Stability

**Q:** *What is finished water stability for corrosion control treatment? (Answer: It means that the distribution system pipe interior sees a consistent water quality.)*



### **Operator Tips: Daily Stability Routine for pH/alkalinity adjustment**

- Your most important task is to maintain a **stable** entry point pH.
- Measure your entry point pH at least **daily** using a calibrated pH meter.
- Use **jar testing** to determine proper chemical dosage for changing baseline water quality.



### **Operator Tips: Daily Stability Routine for Phosphate Inhibitor**

- Measure entry point **orthophosphate** residual daily to assure that it is within the desired range.
- Check the validity of each daily phosphate residual measurement by running a **standard additions** test.

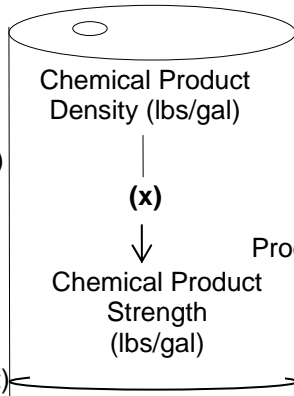
# MODULE 24 - PROCESS CONTROL WORKSHOP

First Week on the New Job @  **Awesome Water, Inc.**

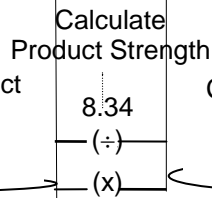
## Step 1

### STOCK SOLUTION DIAGRAM LIQUID CHEMICAL

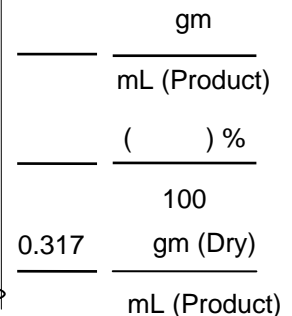
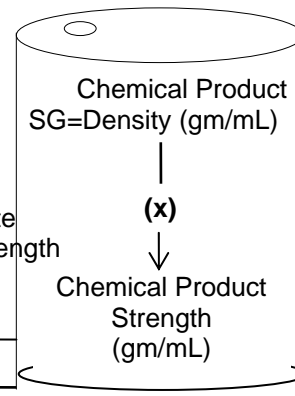
#### ENGLISH UNITS



C  
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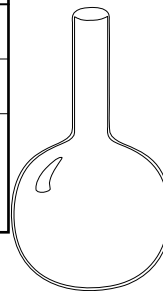
#### METRIC UNITS



Suggested Stock Solution Concentration		
Stock Solution (% Strength)	Stock Solution Concentration (mg/L)	mg/L Dosage Per mL of Stock Solution Added to a 1 Liter Sample
0.1	1,000	1
0.2	2,000	2
0.4	4,000	4
1.0	10,000	10



mL Product Needed ? mL (Product)



Stock Solution Volume (L) 1 L (Stock)

Stock Solution Concentration (mg/L) 1,000 mg (Dry)  
L (Stock)

Procedure: Fill in known data; the question mark (?) is the unknown data; convert all chemical product data to the units on the side where the ? is and fill in the values; use unit cancellation to solve for the unknown.

**Q:** How many mL of caustic soda are needed? (3.15 mL)

$$\begin{aligned}
 ? \text{ mL (Product)} &= \frac{\text{mL (Product)}}{0.317 \text{ gm (Dry)}} \times \frac{\text{gm}}{1,000 \text{ mg}} \times \frac{1,000 \text{ mg (Dry)}}{\text{L (Stock)}} \times \frac{1 \text{ L (Stock)}}{1} \\
 &= 3.15 \text{ mL}
 \end{aligned}$$

<b>Step 2</b>
---------------

**CHEMICAL:** 25 % Caustic Soda                      **DATE** \_\_\_\_\_

**TARGET EP pH** 8.5                      **TARGET EP ALKALINITY** \_\_\_\_\_

**CHEMICAL DOSAGE CHART FOR  
pH/ALKALINITY ADJUSTMENT**

pH→ Alk.↓	6.8	6.9	7.0	7.1	7.2	7.3	7.4	7.5
20								
21								
22								
23								
24								
25								
26								
27								
28	9							
29	9	7						
30		8	6	5				
31				5				
32			7	6				
33		9						
34	11		8		4			
35								
36								
37								
38								
39								
40								

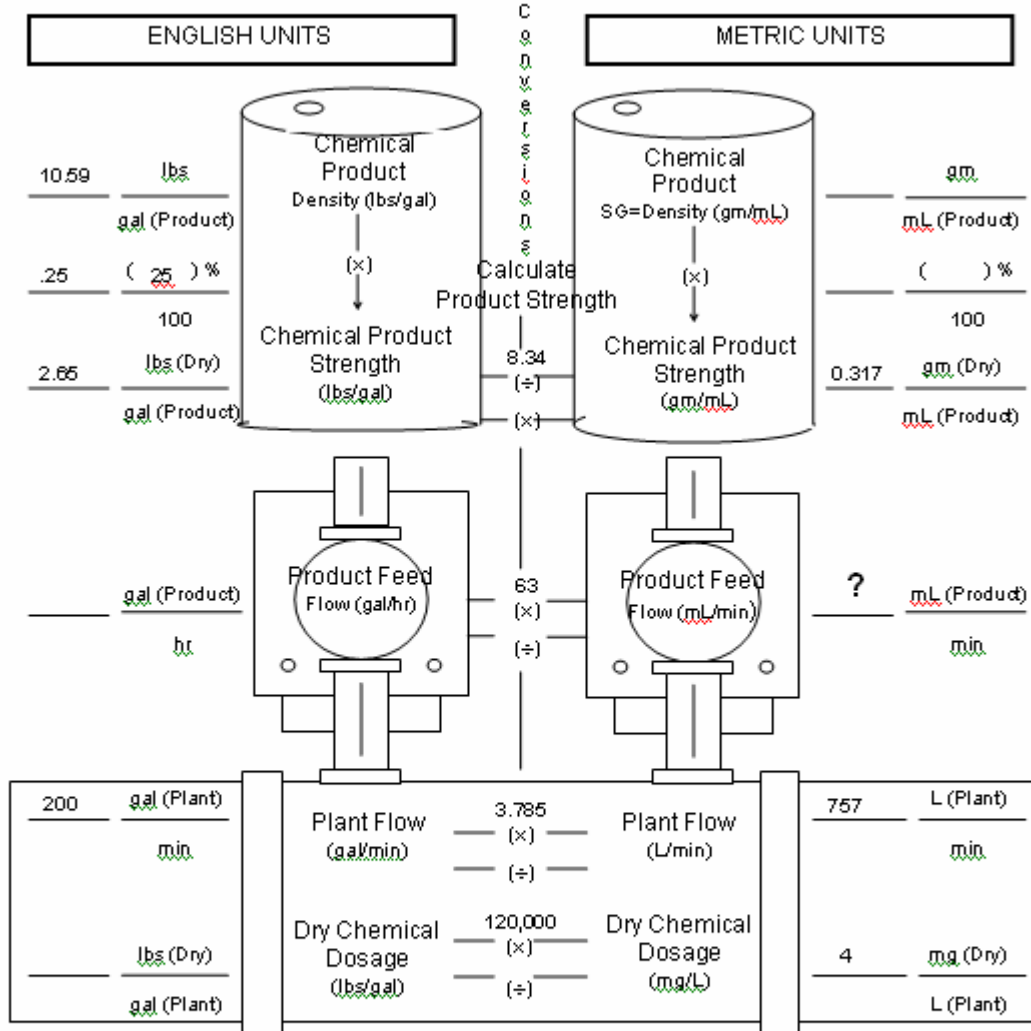
### Step 3

Construct a Feed Rate vs. Dosage Table.

Use the Chemical Feed Calculation Diagram (p. 24-6) to calculate the feed rate for the dosage value of \_\_\_\_\_.

(see diagram next page)

### CHEMICAL FEED CALCULATION DIAGRAM LIQUID FEED



Procedure: Fill in known data; the question mark (?) is the unknown data; convert all chemical product data to the units on the side where the ? is and fill in the values; use unit cancellation to solve for the unknown.

$$\frac{? \text{ mL (Product)}}{\text{min}} = \frac{\text{mL (Product)}}{0.317 \text{ gm (Dry)}} \times \frac{\text{gm}}{1,000 \text{ mg}} \times 4 \frac{\text{mg (Dry)}}{\text{L (Plant)}} \times \frac{757 \text{ L (Plant)}}{\text{min}} = 9.6$$

Ex. for 4 mg/L. Substitute remaining dosage values and solve for mL/min.

As we go around the room, tell us your dosage value and the resulting feed rate you calculated. Fill in the data on the table.

**FEED RATE VS. DOSAGE TABLE**

**Chemical:** 25% Caustic

**Plant Flow:** 200 GPM

FEED RATE (mL/min)	CHEMICAL DOSAGE (mg/L)
9.6	4
11.9	5
14.3	6
16.7	7
19.1	8
21.5	9
23.9	10
26.3	11

Once you have the feed rate determined, you can continue on to the next step.

**Step 4**

Calibrate the pump and construct a pump calibration curve. So, you calibrate your pump and construct a calibration curve.

Use the curve to fill in the chart showing the pump setting needed to deliver each dosage value.



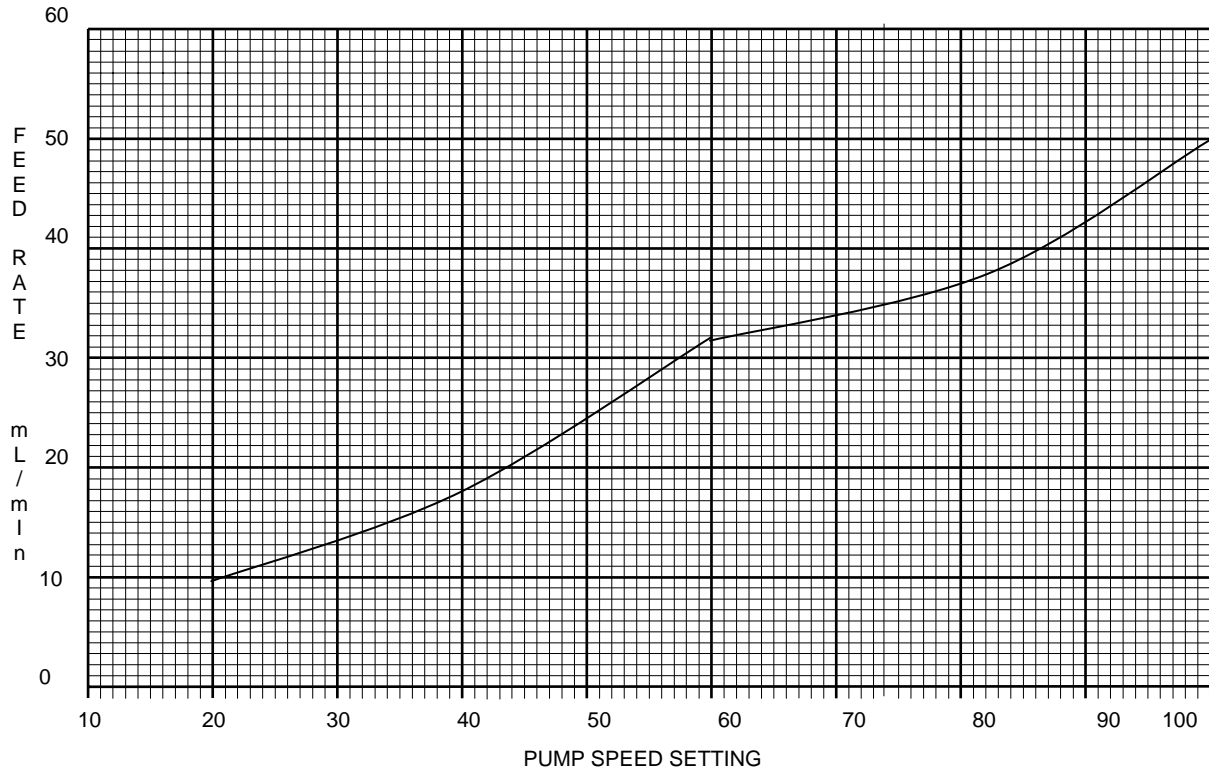
## FEED PUMP CALIBRATION CURVE

% Stroke: 60%

Pump: \_\_\_\_\_

% Stroke: 60%

Pump: \_\_\_\_\_



Dosage (mg/L)	Pump Setting
4	20
5	25
6	30
7	37
8	41
9	46
10	48
11	51

## Workshop

To begin, we will assume that this is the second day of operation. Here is some data from Day 1.

### Information from Day 1

- Baseline pH = 7.1
- Baseline alkalinity = 30 mg/L
- EP pH = 8.5
- Feed Rate = 12 mL/min
- Dosage = 5 mg/L

This information tells us that the EP pH was right on target at 8.5. The operator used a feed rate of 12 mL/min to deliver a dosage of 5 mg/L.

## DAY 2 - PART 1

You begin your daily stability routine. You perform a two-point calibration and then measure the entry point pH.

- pH measurement data:
  - Slope = -58.5
  - Entry point pH = 8.2

Is the EP pH within the target range? **NO (8.4 - 8.6)**

Use the Daily Stability Routine Flowchart (wb p. 24-10) to determine your plan of action. **(OH 24-6)**

You should: **SPOT CHECK THE FEED PUMP OUTPUT AND DETERMINE  
THE FEED RATE.**

## DAY 2 - PART 2

The slope is within the acceptable range of -56 to -62.

### Action Plan

- You should spot check the feed pump output and determine the feed rate.

You perform a spot check and determine the following:

At a 60% stroke and speed of 25, the feed rate is 12 mL/min

You refer to the Feed Rate vs. Dosage Table (wb p. 24-7) and determine the dosage to be **5 mg/L**. (OH 24-4)

Compared to the last correct dosage, is the dosage as expected ( $\pm 10\%$ )? **YES**

Use the Flowchart (wb p. 24-10) to determine your plan of action. (OH 24-6)

You should: **MEASURE THE BASELINE WATER FOR pH, ALKALINITY AND TEMPERATURE.**

## DAY 2 - PART 3

The feed rate and dosage are correct but the entry point pH is still out of the range.

### Action Plan

- You should measure the baseline pH, alkalinity, and temperature for change.

You measure the baseline water and determine the following:

- pH = 7.0
- Alkalinity = 30

The baseline water quality has changed. You must adjust the chemical feed.

You need to determine the dosage required to raise the pH of this baseline water to the target pH = 8.5.

Using the Flowchart (wb p. 24-10), what is your plan of action? **LOCATE BLOCK ON CHEMICAL DOSAGE CHART.** (OH 24-6)

## DAY 2 - PART 4

### Action Plan:

- You should locate the block on the Chemical Dosage Chart (wb p. 24-5). **(OH 24-2)**

The new dosage required is **6 mg/L**.

What feed settings are required to deliver the new dosage? **STROKE = 60%,  
SPEED = 30.** **(OH 24-5)**

You adjust the feed settings and then measure the entry point pH. Now the entry point pH is 8.5.

Is the entry point pH within the target range? **YES**

Is the daily routine finished? **YES**

Record the data on the Monthly Operational Report (wb p. 24-15, 24-16).

**\*\*\*Day 2 is finished\*\*\***

Our next step would be to record the data. To illustrate how the information is recorded, look at page 24-15. The data for Days 1 and 2 is already filled in.

## DAY 3 - PART 1

You begin your daily stability routine. You perform a two-point calibration and then measure the entry point pH.

- pH measurement data:
  - Slope = -58.5
  - Entry point pH = 8.0

Is the EP pH within the target range? **NO**

Use the Flowchart (wb p. 24-10) to determine your plan of action. **(OH 24-6)**

You should : **SPOT CHECK THE FEED PUMP OUTPUT AND DETERMINE THE FEED RATE.**

## DAY 3 - PART 2

The slope is within the acceptable range of -56 to -62.

### Action Plan

- You should spot check the feed pump output and determine the feed rate.

You perform a spot check and determine the following:

- At a 60% stroke and speed of 30, the feed rate is 10 mL/min.

You refer to the Feed Rate vs. Dosage Table (wb p. 24-7) and determine the dosage to be **4 mg/L**. (OH 24-4)

Compared to the last correct dosage, is the dosage as expected ( $\pm 10\%$ )? **NO**

$$(6 \pm 10\% = 5.4 - 6.6)$$

Use the Flowchart (wb p. 24-10) to determine your plan of action. (OH 24-6)

You should: **TROUBLESHOOT, REPAIR AND RECALIBRATE**

## DAY 3 - PART 3

The feed rate was determined to be 10 mL/min and it should have been 14.3 mL/min. Because the feed rate was off, the dosage being delivered was 4 mg/L instead of the required 6 mg/L.

### Action Plan

- You should troubleshoot the feed pump and other feed system components and make any necessary repairs.
- You should then recalibrate the feed pump at 60% stroke and speed settings of 20, 40, 60, 80 and 100.
- You should construct a new calibration curve.

The mechanical components check out O.K.

You perform a calibration of the feed pump and construct a new calibration curve (wb p. 24-20). **(OH 24-9)**

Use the new calibration curve (wb p. 24-20) to determine the appropriate feed settings to deliver 14.3 mL/min. **STROKE = 60%, SPEED = 32.**

You adjust the feed settings and then measure the entry point pH. Now, the entry point pH is 8.5.

Is the entry point pH within the target range? **YES**

Is the daily routine finished? **YES**

Record the data on the Monthly Operational Report (wb p. 24-15, 24-16).

**SPOT CHECKED THE FEED PUMP OUTPUT, CHECKED THE FEED SYSTEM, RECALIBRATED THE PUMP, ADJUSTED THE PUMP SETTING.**

# NEW LIQUID FEED PUMP CALIBRATION CURVE

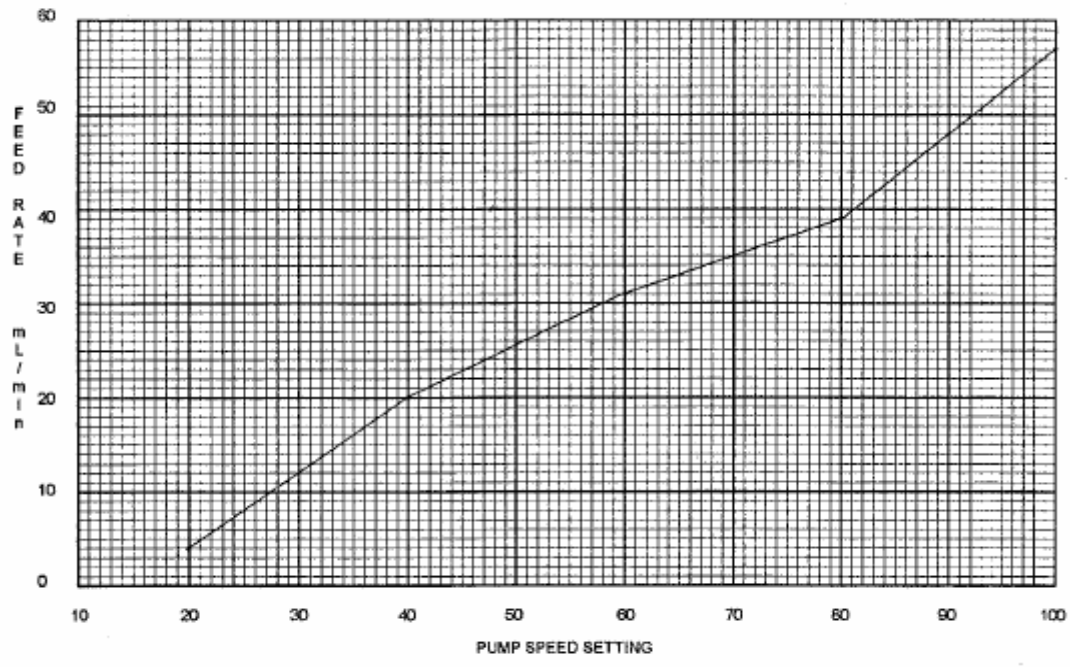
% Stroke: 60%

Pump: \_\_\_\_\_

## NEW LIQUID FEED PUMP CALIBRATION CURVE

% Stroke: 60%

Pump: \_\_\_\_\_



Dosage (mg/L)	Pump Setting
4	27
5	30
6	33
7	36
8	39
9	43
10	47
11	51

## Summary



### Key Points:

- The Daily Stability Routine Flowchart is a tool used to maintain a stable water quality. (Fill in the blank)
  - The Feed Rate vs. Dosage Table provides a quick reference for adjusting chemical feed to deliver a new dosage. The Table remains constant as long as the plant flow does not vary and the chemical product strength remains the same. (Fill in the blanks)
  - The Chemical Dosage Chart is used to adjust chemical feed when the baseline water quality changes. (Fill in the blank)
- 

## Chemical Feed Calculation Practice Problems

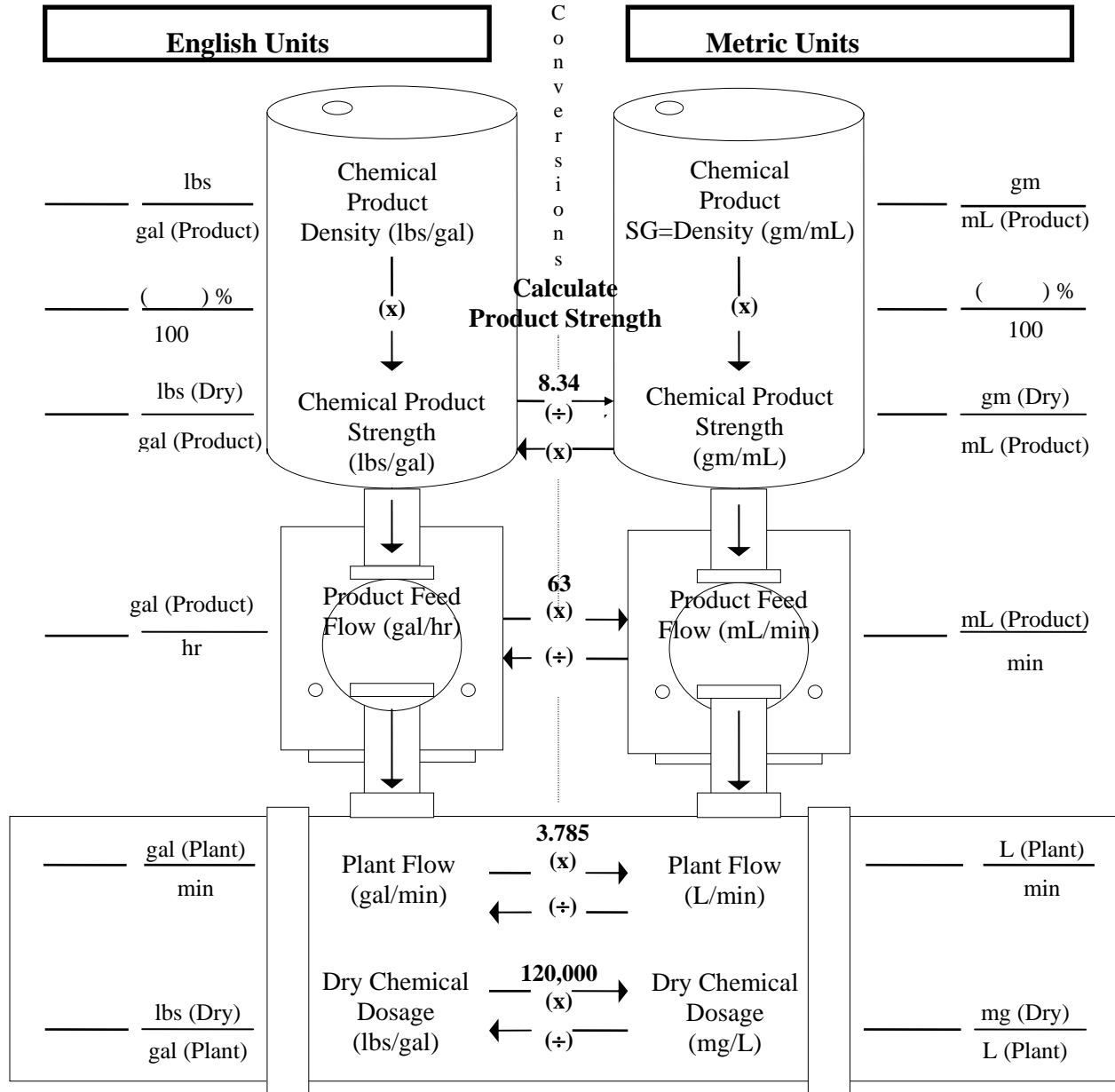
1. A treatment plant wants to feed sodium hypochlorite (12%, density = 10.4 lbs/gal) at a dosage of 1.5 mg/L. The plant flow is 700 GPM. What feed pump rate in mL/min is needed to deliver this dosage?

(Diagram on next page)





## CHEMICAL FEED CALCULATION DIAGRAM



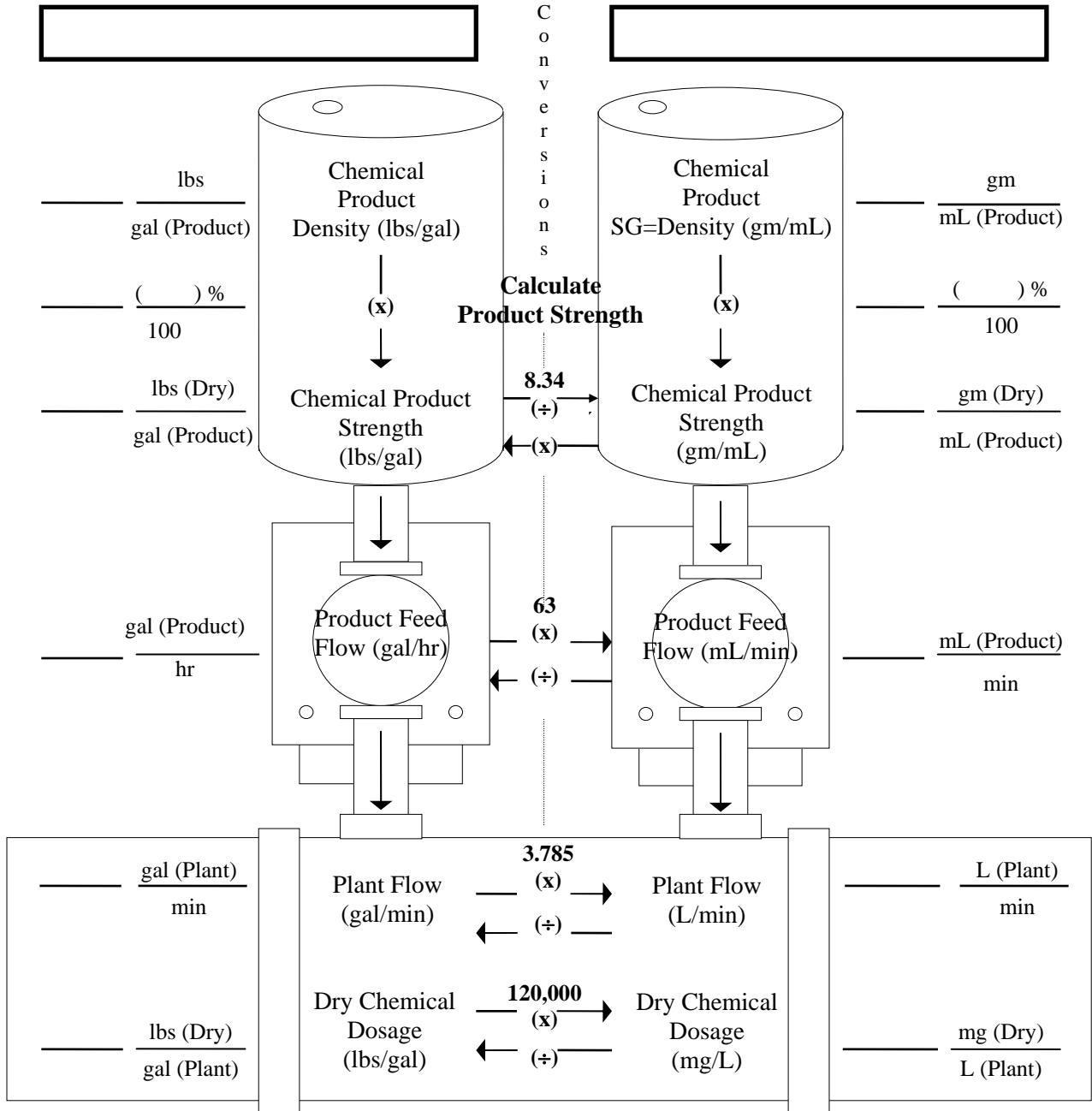
**Procedure:** Fill in known data; put a question mark (?) for the value of the unknown data; convert all data to the units on the side where the (?) was placed and fill in the values; use unit cancellation to solve for the unknown.

**Answer: 26.6 mL/min**

2. A treatment plant is feeding sodium hypochlorite (15%, specific gravity = 1.2). The plant flow is 650 GPM. A check of the feed rate indicates that the pump is delivering 12 mL/min. What dosage (mg/L) is being added at this feed rate?



### CHEMICAL FEED CALCULATION DIAGRAM



**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.

**Answer: 0.88 mg/L**