PA DEP presents:

**CORROSION CONTROL**

**TREATMENT TRAINING**

**FOR OPERATORS**

# Workbook

# *Acknowledgments*

# *Statement of Intent*

All information provided in this course is believed to be accurate. This course is not the sole source of information about corrosion control treatment.  Qualified chemical and equipment sales representatives, consultants and regional DEP staff should be consulted for system-specific information regarding chemical feed. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the department.

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# MODULE 1
## *Course Introduction*

❖ **Objectives:**

- Provide a course overview

- Introduce the class participants and create a class profile

## Course Expectations

As a participant, you can expect:

- quality training

- friendly, cooperative facilitators

- answers to your questions

- an enjoyable course

- promptness in starting and ending on time

- 2.1 CEU's and 21 training hours toward certification upon successful completion of this course

Our expectations of you include:

- regular and complete attendance

- interactive participation by answering questions and sharing your knowledge
- completion of the workbook assignments

- completion of homework assignments

- successful completion of the final test

## Course Objectives

After this training program, participants will be able to:

- perform mathematical calculations for conversions and dosage feed rates

- calibrate chemical feed pumps

- perform water quality analyses (pH, alkalinity, phosphates)

- Achieve finished water stability through process control

- develop and/or update O & M plan for corrosion control treatment facilities  (operating procedures, pump calibration procedures, sampling protocol)

## Summary

## Key Points:

- Water suppliers play a major role in assuring safe and adequate water to their customers.

- Water suppliers are responsible for providing optimal corrosion control treatment at their systems.

# MODULE 2
## *Basic Corrosion Chemistry*

❖ **Objectives:**

- Explain how elements form ions.

- Explain how electron movement causes corrosion.

- Define acids, bases and salts.

- Define pH and explain its importance.

- Show how acids and bases affect pH.

- Define the major components of the carbonate system.

- Show how the addition of chemicals affects the carbonate system.

## Common Elements, Atoms and Ions

Elements are those substances found in nature like metals and gases that combine to make up everything around us.

## Important Elements in Water Chemistry

| Element | Chemical Symbol |
|---|---|
| Aluminum | Al |
| Calcium | Ca |
| Carbon | C |
| Chlorine | Cl |
| Copper | Cu |
| Fluorine | F |
| Hydrogen | H |
| Iron | Fe |
| Lead | Pb |
| Magnesium | Mg |
| Manganese | Mn |
| Nitrogen | N |
| Oxygen | O |
| Phosphorus | P |
| Potassium | K |
| Silicon | Si |
| Sodium | Na |
| Sulfur | S |

Elements are made up of atoms.

- The _____ is the smallest unit of a chemical element.

- The simplest atom is the atom for the element hydrogen.

**The Hydrogen (H) Atom**

The atom is made up of two main parts: 1) the nucleus, which contains protons and neutrons, and 2) orbiting electrons.

- Protons are positively charged particles.

- Neutrons have no charge.

- _____ are negatively charged particles which occupy the space around the nucleus.

- Atoms contain the same number of protons (positives) as electrons (negatives), making atoms electrically neutral.

Most elements are unstable, meaning they aren't satisfied with their natural state and are looking for other elements to combine with.

- Elements combine with other elements usually in one of three ways: 1) losing electrons, 2) gaining electrons or 3) sharing electrons.

- Hydrogen is one of those elements that loses electrons.

$$H \quad - \quad 1e^- \longrightarrow \quad H^+ \quad + \quad 1e^-$$

| hydrogen atom (neutral) | electron (negative) | hydrogen ion (positive) | free electron |
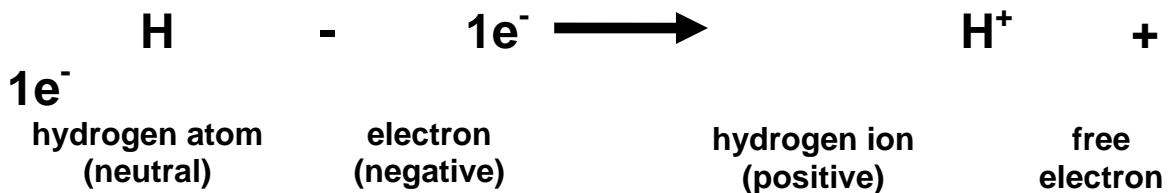
- When a neutral hydrogen atom gives up its electron, it now has one more proton than it has electrons.

- Losing one electron turns the hydrogen atom into a **hydrogen ion** with a charge of +1.

- An _____ is an electrically charged atom formed by the loss or gain of electrons.

$$Cl \quad + \quad 1e^- \quad \longrightarrow \quad Cl^-$$

**chlorine atom**        **electron**                **chloride ion**
**(neutral)**          **(negative)**               **(negative)**
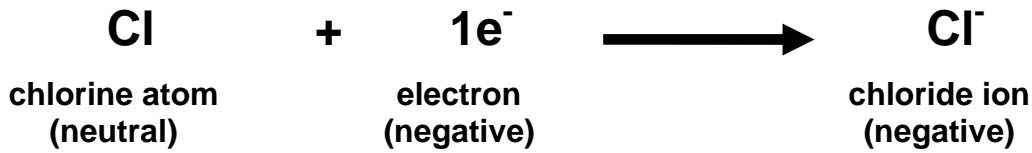
- When the neutral chlorine atom steals an electron it becomes a chloride ion with a charge of -1.

The number of electrons an element gains or loses determines the charge on the ion. For example, an element that loses two electrons would produce an ion with a charge of +2.

## Ionization

**Ionization** is the chemical process responsible for corrosion.

Sodium chloride is made up of the element sodium (Na) and the element chlorine (Cl).

$$Na \quad + \quad Cl \longrightarrow Na^+Cl^-$$
$$\underline{\quad\quad} 1e^- \longrightarrow$$
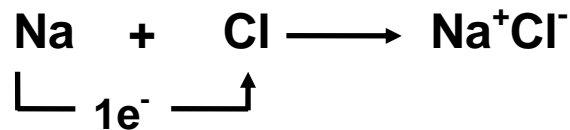
- When these two elements combine, the sodium atom loses an electron to the chlorine.

When salt is dissolved in water, the ions separate, freeing up the electrons to move. The water causes the salt to **ionize**.

$$NaCl \longrightarrow Na^+ \ + \ Cl^-$$

The ability of water to cause many compounds to dissociate into ions (ionize) gives water its unique chemical characteristics including its tendency to dissolve metals such as iron, lead and copper.

$$Pb - 2e^- \longrightarrow Pb^{+2}$$

$$Cu - 2e^- \longrightarrow Cu^{+2}$$

- In contact with water, lead and copper will lose 2 electrons and form ions.

Without the movement of electrons (electricity), which is caused by ionization, we would have no corrosion.

## The Chemistry of Water

Water is a compound that is formed when two hydrogen atoms combine with one oxygen atom.

The symbol for the water molecule "$H_2O$" is more accurately shown like this:

$$H \qquad H$$
$$\diagdown O \diagup$$
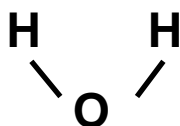
- Some of the water molecules naturally separate (or ionize) into two ions: the _____ ion and the _____ ion.

- The hydrogen ion has a charge of + 1 because it gives up its one electron.

- The hydroxide ion takes that electron, giving it a charge of - 1.

$$H_2O \longrightarrow H^+ + OH^-$$
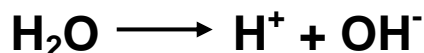
- You can see that when water ionizes, one hydrogen and one hydroxide ion are produced.

## Acids, Bases and Salts

**Acids:**

- When dissolved in water, certain substances produce hydrogen ions.

- Substances that produce hydrogen ions in water are called _____.

- Acids can usually be recognized by the "H" at the beginning of the chemical formula.

## <u>Acid</u>

$$HCl \longrightarrow H^+ + Cl^-$$

hydrochloric
acid
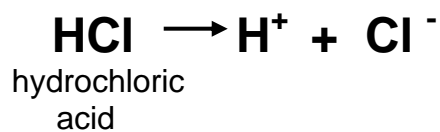
### Bases:

- A _____ is a substance that produces hydroxide ions in water.

- Bases can usually be recognized by the "OH" at the end of their chemical formula.

## Base

$$NaOH \longrightarrow Na^+ + OH^-$$
sodium hydroxide
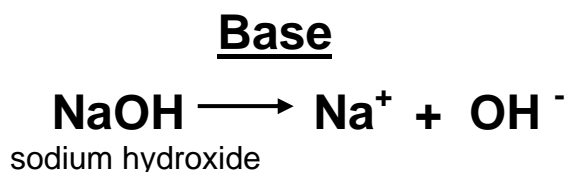
### Salts:

- When an acid and base react together, the hydrogen and hydroxide ions combine and neutralize each other, forming water together with a salt.

- A _____ is the product of combining an acid and a base.

- Salts normally do not produce either hydrogen or hydroxide ions.

## Salt

$$HCl + NaOH \longrightarrow NaCl + H_2O$$
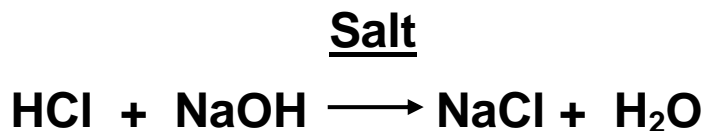
## pH

**Pure water** ionizes so that there is one hydroxide ion for every hydrogen ion produced.

- Adding an acid to pure water upsets the hydrogen-hydroxide ion balance. The water now has more hydrogen ions.

- If you add a base to pure water, there would be more hydroxide ions than hydrogen ions.

- Water that has more hydrogen ions than hydroxide ions is acidic.

- When water has excess hydroxide ions, you would say the water is basic.

- _____ is the measurement of the concentration of hydrogen ions in water.

| **H+ Concentration** | | **pH Scale** |
|---|---|---|
| 1.0 | | 0 |
| | Neutral (Pure Water) | 7 |
| 0.000 000 000 000 01 | | 14 |

## pH Scale

```
0   1   2   3   4   5   6   7   8   9   10   11   12   13   14
├───┼───┼───┼───┼───┼───┼───┼───┼───┼───┼───┼───┼───┼───┤
```

BATTERY      VINEGAR              MILK      SEA WATER        AMMONIA      LYE
ACID

         ORANGE JUICE   PURE WATER   BORAX                BLEACH

Acidic ◄───────────────        Neutral ──────────────────►
      Basic
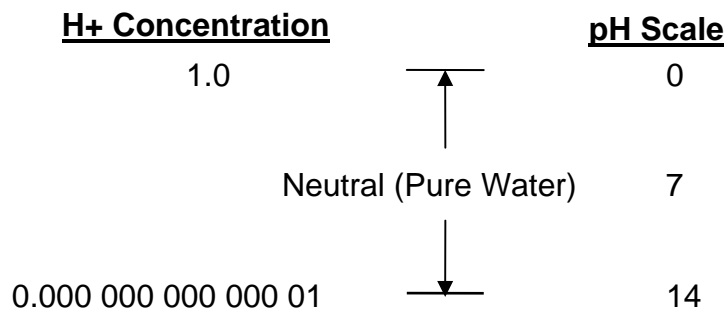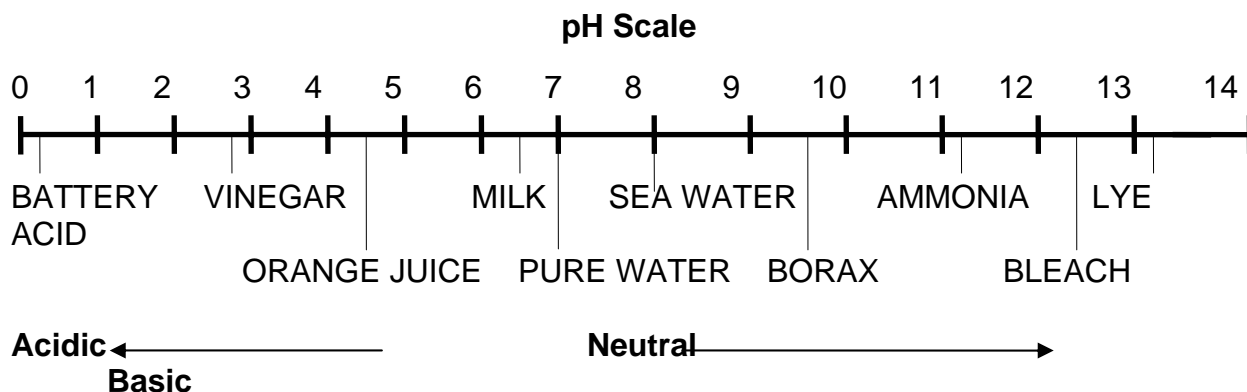
A pH of 0 is the most acidic that water can get.  On the other end of the scale, a pH of 14 is the most basic.

- Adding an acid to water **lowers** the pH.

- Adding a base **raises** it.

Exercise: Chemical Effects on pH

| If I add: | | The pH will be _____ (raised/lowered) |
|---|---|---|
| Potassium Hydroxide | KOH | |
| Nitric Acid | $HNO_3$ | |
| Lime | $Ca(OH)_2$ | |
| Sulfuric Acid | $H_2SO_4$ | |
| Caustic Soda | NaOH | |
| Soda Ash | $Na_2CO_3$ | |
| Hydrochloric Acid | HCl | |

Some salts like soda ash act similar to bases, except they are not as strong.  When you add them to water, they tend to raise pH; although it takes more chemical than it would for a strong base like caustic soda.

## The Importance of pH in Water Treatment
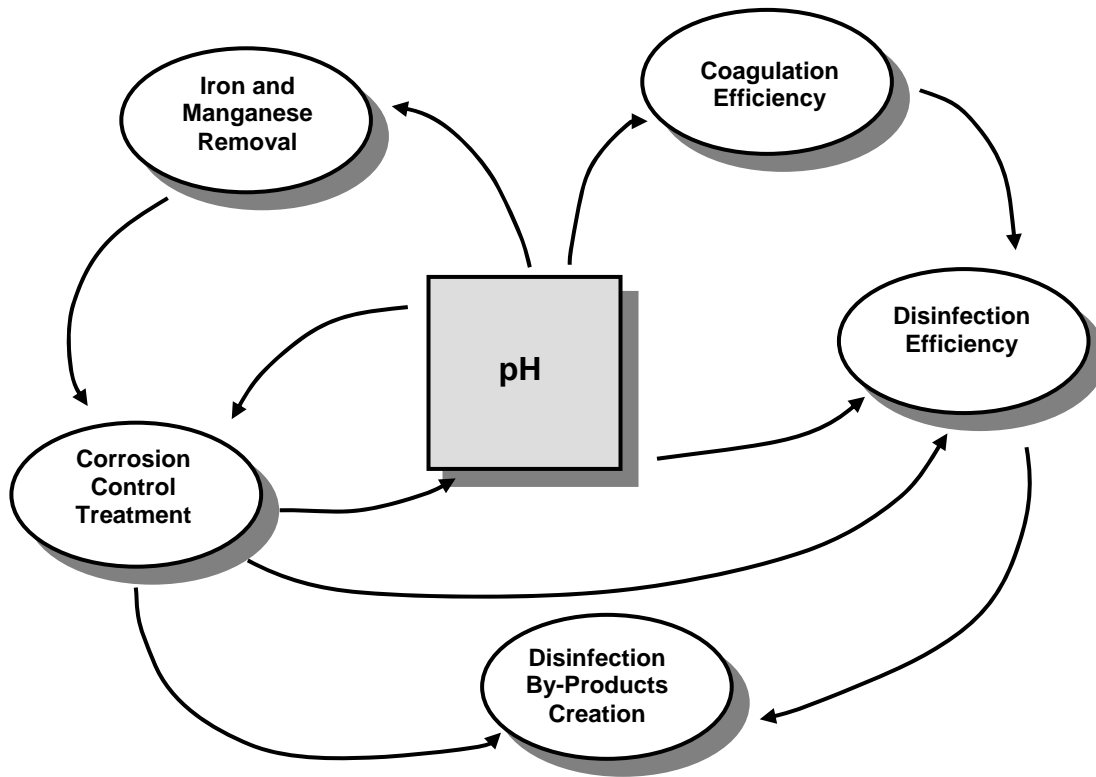


pH affects or is affected by many common water treatment processes.

## The Carbonate System

The carbonate system:

- Is a major acid/base system.

- Produces important reactions in water distribution systems.

- Involves the three carbonate species: _____, bicarbonate, and carbonate.

- Carbonic acid is mostly carbon dioxide gas ($CO_2$) dissolved in water.

$$CO_2 + H_2O \longrightarrow H_2CO_3$$
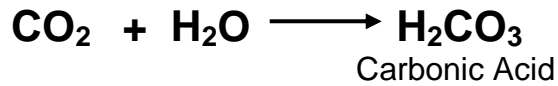
Carbonic Acid

The carbonic acid in water is a main factor contributing to corrosiveness of water.

- One of the objectives in corrosion treatment is to remove the carbonic acid.

- The two most common ways of removing carbonic acid are **aeration** and **neutralization**.

Because carbonic acid is mostly carbon dioxide gas dissolved in water, it can be removed by aeration.

$$CO_2 \text{ (gas) } \uparrow$$

Another way to remove the carbonic acid is to **neutralize** the acid by adding a base.

**(carbonic acid)  (bicarbonate) (carbonate)  (hydroxide)**

$$H_2CO_3 \longrightarrow HCO_3^- \longrightarrow CO_3^{-2} \longrightarrow OH^-$$

**Increasing pH** $\longrightarrow$
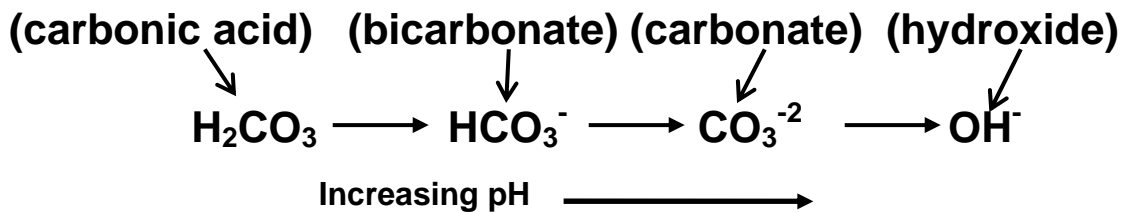
## THE CARBONATE SYSTEM
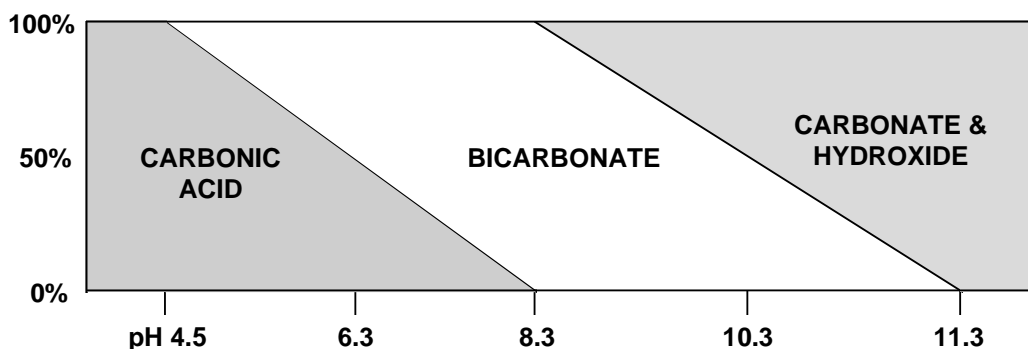


- At pH 4.5 the water contains only _____.

- As pH increases above 4.5, **bicarbonate** begins to form.

- Above 8.3, **carbonate** begins to form and eventually excess _____ ions are formed.

## Summary

## Key Points:

- Many compounds ionize when placed in a water solution.

- Electron movement in water causes _____ which makes water corrosive to metals like lead and copper.

- When placed in water, acids produce hydrogen ions; bases produce hydroxide ions.

- _____ is a measure of how acidic or basic a water is.

- pH is the most important parameter in water treatment.

- Adding an acid to water decreases its pH; adding a base increases pH.

- One goal of corrosion control involves raising pH to _____ carbonic acid.

# MODULE 3
## *Lead and Copper Rule Overview*

❖ **Objectives:**

- Introduce and provide a general overview of the LCR Guide

- Provide basic information about LCR requirements

| Summary |
| --- |

🔑 **Key Points:**

- Suppliers must successfully complete this course and update or develop an _____ plan to reflect CCT facilities in order to obtain an operation permit.

- Follow-up monitoring determines if the treatment is effective and provides the data for determining CCT _____ requirements.

- Systems must request the department to designate optimal CCT performance requirements which will be specified in the operation permit.

- Small and medium systems can qualify for reduced annual lead and copper tap monitoring by not _____ the action levels during two consecutive six-month monitoring periods.

- Use the guide to find specific information about any aspect of the Lead and Copper Rule.

# MODULE 4
## *Units and Conversions*

❖ **Objectives:**

- Explain the basic units of measurement most commonly used in water treatment
- Discuss combination units
- Review important conversion factors

Key terms:
- Density/Specific gravity
- Flow
- Concentration
- Dosage
- Chemical feed

## Basic Units of Measurement; English and Metric Systems

Basic units of measurement most often used in water treatment can be grouped into three main areas:

- Units of _____
- Units of _____
- Units of _____

### Observations about the Metric system

- It is a simple system to work in
- All units relate to each other by factors of 10 (10, 100, 1000, 0.1, 0.01)
- Need to learn the meaning of two prefixes that will cover most situations

## Basic Units in the Metric System

|                | WEIGHT | VOLUME |
|----------------|--------|--------|
| Basic Unit     | gram   | liter  |
| Abbreviation   | gm     | L      |

The basic Metric units most often used in water treatment are the **gram** and the **liter.**  The **gram** is the **basic unit for weight** and the **liter** is the **basic unit for volume**.

## Prefixes in the Metric System

|                | milli | kilo  |
|----------------|-------|-------|
| Value          | 0.001 | 1,000 |
| Abbreviation   | m     | k     |

The two Metric **prefixes** a water treatment plant operator should know are **milli** and **kilo**. Milli equals 1/1000 or 0.001; its abbreviation is "m." Kilo equals 1000; its abbreviation is "k."

## Converting in the Metric system

To convert from the basic unit of grams (gm) to milligrams (mg) or kilograms (kg), move the decimal point three (3) places.  Moving the decimal point three places is equivalent to dividing or multiplying by 1000.  Each time you move the decimal point 1 place you multiply or divide by 10.

Starting with the number 1 (or 1.0 to show the decimal point), to multiply by 10 move the decimal point one place to the right.  Now you have 10 (1x10).  To multiply 1 by 100, move the decimal point 2 places to the right. Now you have 100 (1x100) and so on.

Example:  1 gm  =  1000 mg

To convert 1 gm to mg:

1.  Show 1 gm as 1.0 gm.

2.  Move the decimal point 3 places to the right to multiply by 1000 mg/gm

3.  Add zeros to fill in blank spaces, if needed.

1 000.

Example:  500 mg = 0.5 gm

1.  Show 500 mg as 500. mg

2.  Move the decimal point 3 places to the left to divide by 1000 mg/gm

.500

Problems:

1.  10 L =  ?  mL

2.  15 gm  =  ?  kg

3.  14 mg = ? gm

4.  45.67 L = ? mL

## Observations about the English System

- System we are most familiar with
- Hard to work in
- No particular relationship between units
- Need a conversion chart or good memory

| UNITS OF WEIGHT | |
|---|---|
| English | Metric |
| pound - lb | gram - gm<br>milligram - mg<br>kilogram - kg |
| CONVERSIONS | |
| Metric/Metric | Metric/English |
| 1000 mg = 1 gm or 1000 mg/gm<br><br>1000 gm = 1 kg or 1000 gm/kg | 1 lb = 454 gm or 454 gm/lb<br><br>1 kg = 2.2 lbs or 2.2 lbs/kg |

## UNITS OF VOLUME

| English | Metric |
|---|---|
| gallon - gal<br>million gallon - Mgal<br>cubic feet - cu ft | liter - L<br>milliliter - mL |

### CONVERSIONS

| Metric/Metric | Metric/English | English/English |
|---|---|---|
| 1000 mL = 1 liter or 1000 mL/L | 1 gal = 3.785 L or 3.785 L/gal<br>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<br>hour - hr | minute - min<br>second - sec |

### CONVERSIONS

| | |
|---|---|
| 1 day = 24 hr or 24 hr/day<br><br>1 hr = 60 min or 60 min/hr | 1 min = 60 sec or 60 sec/min<br><br>1 day = 1440 min or 1440 min/day |

## Combination Units

### I. Weight/Volume Combinations - Density and Concentration

A. Density

**Density** is how much a certain volume of something _____.

| UNITS OF DENSITY | |
|---|---|
| English | Metric |
| lbs/gal<br><br>lbs/cu ft | kg/L<br><br>gm/mL |
| CONVERSIONS | |
| Metric/English | Metric/Metric |
| 1 gm/mL = 8.34 lbs/gal<br><br>1 kg/L = 62.4 lbs/cu ft | 1kg/L = 1 gm/mL |

- **The density of water** is used when performing chemical feed calculations.

- In the metric system, the density of water is 1, no matter which of the metric units are used.

- In the English system, a gallon of water weighs _____ pounds.

- **Specific gravity** is a term used in chemical feed that refers to the density of something compared to the density of water.

- In the Metric system, specific gravity is equal to density.

- In the English system, the specific gravity of a substance is calculated by dividing its density by the density of water.

### Demonstration: Density of Liquids

Weight: _____ gm                    Volume: _____ mL

Density: _____ gm/mL          Specific gravity: _____

(Density can be calculated by dividing the weight of a liquid by its volume.)

When syrup is poured into water, will it sink or float? _____

Will liquids with a specific gravity of less than 1.0 (specific gravity of water) sink or float? _____

B. Concentration

- **Concentration** is the weight of a substance in a _____ of liquid.

- This relationship can also be applied to **chemical dosage**.

| UNITS OF CONCENTRATION | |
| :---: | :---: |
| English | Metric |
| lbs/gal | mg/L |
| CONVERSION<br><br>1 lb/gal = 120,000  mg/L | |

Milligrams per liter is the most common unit used for chemical dosage.

**Chemical dosage** refers to the weight of a treatment chemical such as soda ash, alum or chlorine that you are adding to the drinking water.

Milligrams per liter is also referred to as "parts per million" or PPM.

2.  **Volume/Time Combination**

- **Flow** is the _____ of water or other liquid moved during a period of time.

| UNITS OF FLOW | |
|---|---|
| English | Metric |
| gallons per minute - gal/min - GPM<br><br>gallons per day - gal/day - GPD<br><br>million gallons per day - Mgal/day - MGD<br><br>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<br><br>1 MGD = 1.55 CFS or 1.55 CFS/MGD | 1 gal/day = 2.63 mL/min |

3. **Weight/Time Relationship**

- **Chemical feed** is the _____ of a dry treatment chemical fed during a period of time.

  Units of dry chemical feed: _____

**Operator Tips: Units and Conversions**

- The density of water is _____ lbs/gal.

- In the metric system, specific gravity is equal to density.

- Mg/L is the same as "parts per million" (PPM)

- To determine the amount of treatment chemical to feed, you must be able to calculate dosage in _____.

- To perform treatment chemical feed calculations, you may need to convert plant flow to MGD from GPM or CFS.

- Chemical feed pumps normally feed in_____.  To perform chemical feed calculations, you must be able to convert from gal/day to mL/min.

- The chemical feed in lbs/day of dry chemical is calculated from the plant flow and the dosage of chemical desired, along with the density of water.

## Summary

**Key Points:**

- A water treatment plant operator must be able to understand and work with various units of measurement and convert between units.

- Units of weight, volume and time are the units most often used in water treatment.

- Various combinations of weight, volume and time yield important water system parameters: density, concentration, flow, dosage and chemical feed.

# MODULE 5
## *Solving Problems Using Units and Conversions*

◆ **Objectives:**

- Introduce and explain a method of problem solving called unit cancellation

- Practice solving common water treatment problems using common units of measurement and related conversions discussed in the last lesson

## 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:** _____          2.  **Q:** mg     **A:** _____

3. **Q:** lbs/gal    **A:** _____ or _____

4. **Q:** mL/min     **A:** _____          5. **Q:** mg/L     **A:** _____

6. **Q:** MGD     **A:** _____          7. **Q:** liter     **A:** _____

## Problem Solving Using Unit Cancellation

**Basic rules for using unit cancellation:**

1.  Unit fractions should be written in a vertical format.  A unit fraction: one unit in the numerator (above the line) and one unit in the denominator (below the line).

    A fraction is structured like this:   $\dfrac{\text{numerator}}{\text{denominator}}$

    For example, GPM should be written as $\dfrac{\text{gal}}{\text{min}}$

2.  Any unit which appears in the **numerator** of one unit fraction and the **denominator** of another unit fraction should be canceled.

    The following is an example of how units are canceled:

    $$20 \; \frac{\text{gal}}{\cancel{\text{min}}} \quad x \quad 60 \; \frac{\cancel{\text{min}}}{\text{hr}} = 1200 \; \frac{\text{gal}}{\text{hr}}$$

3.  It may be necessary to invert data and the corresponding units.

    $$10 \; \frac{\text{gal}}{\text{min}} = \frac{1 \text{ min}}{10 \text{ gal}}$$

Caution:  When you invert, make sure to keep numerical values with their original units.  In the above example, the 10 stays with the gallons and is moved to the denominator.

## Vertical Formatting/ Inverting Fractions Practice Problems

A. Vertical Format

Write the following units in a vertical format.

10 GPD

12 MGD

3785 mL = 1 gal

1 day = 1440 min

B. Invert the following fractions:

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

2.63 $\dfrac{\text{mL}}{\text{min}}$

## Steps to solving problems using unit cancellation

Example: How many mL/min are in a flow of 5 gal/day?

**Step 1:** List all unknown data including units in vertical format
followed by an equal sign.

Example:   Unknown data:  ? mL   =
                                         min

**NOTE**:   You may need to invert data throughout the following steps.

**Step 2:** Place data (known or a conversion) that has the same
numerator unit as the unknown numerator to the right of
the equal sign.  Add a mulitiplication sign.  This positions
your numerator.

Example:          ? mL  =   3785   mL
                     min             gal

**Step 3:** To cancel unwanted denominator unit, place data (known
or a conversion) that has the same numerator unit.  Place
a multiplication sign between each piece of data.

Example:          ? mL  =   3785   mL    x          5 g̶a̶l̶
                    min         g̶a̶l̶            1 day

**Step 4:** Continue to place data (known or a conversion) into
equation to systematically cancel all unwanted units until
only the unknown units remain.

Example:  ? mL  =   3785 (mL)  x  5 g̶a̶l̶   x        1 d̶a̶y̶
          min           g̶a̶l̶       d̶a̶y̶         40 (min)

5-4

**Note 1:** All units must cancel, leaving only the units you are solving for in the unknown data.  If all units except the unknown units are **not** crossed out, check the list of known data to see if all relevant known data was used to solve the problem and all necessary conversions were made.

**Note 2:** If you need to invert the known data or conversion values and units to cancel, remember to carry the value with the appropriate unit.

**Step 5:**    Multiply the values of all numerators and place this value in the numerator of the answer.  Multiply the values of all denominators and place this value in the denominator of the answer.  Divide to calculate the final answer.

**Important:** Check the answer to verify that the value is reasonable.

Example:      $\dfrac{?mL}{min}$    $=$    $\dfrac{18{,}925 \;\; mL}{1440 \;\; min}$    $=$    $13.1 \; \dfrac{mL}{min}$

## 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)?

### Practice Problem 2

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

### Practice Problem 3

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

## Summary

## 🔑 Key Points:

- Most mathematical problems for water treatment plant operation involve _____ units.

- Unit cancellation is a good method of performing conversions to solve problems.

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

- The primary purpose of learning this method of problem solving is to help you perform chemical feed calculations for chemicals such as chlorine for disinfection and caustic soda or orthophosphate for corrosion control.

## Additional Unit Cancellation Practice Problems

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

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

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?

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)?

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?

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

❖ **Objectives:**

- Examine how pH is measured.

- Detail the specifications for acceptable pH meters.

- Outline the requirements for sample collection.

- Recommend appropriate quality control (QC) practices.

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

Monitoring pH is an essential tool for overall process control and especially for operating corrosion control treatment.

## Specifications for pH Measurement

EPA has established approved/accepted methods for water quality analyses, including pH measurement.

### SPECIFICATIONS FOR pH MEASUREMENT

Method:

Potentiometric method performed using a pH meter and electrode system.

The measuring system is composed of:

1. Two Electrodes:
   - A glass indicating electrode which develops a potential dependent on the pH of a solution.
   - A reference electrode which provides a constant potential by dispensing an electrolyte solution and completes the electrical circuit.  The reference electrode may use a silver-silver chloride, calomel or other reference element of constant potential.

2. pH Meter:
   - Range of 0 to 14.
   - Scale division of 0.01 or 0.1.
   - Accuracy of $\pm 0.05$.
   - Temperature compensation (manual or automatic) from 0 to 100°C.

3. Calibration:
   - Each meter/electrode system must be calibrated at a minimum of two points that bracket the expected pH of the sample.

# ELECTRODES

**GLASS INDICATING ELECTRODE**

Internal Reference Element
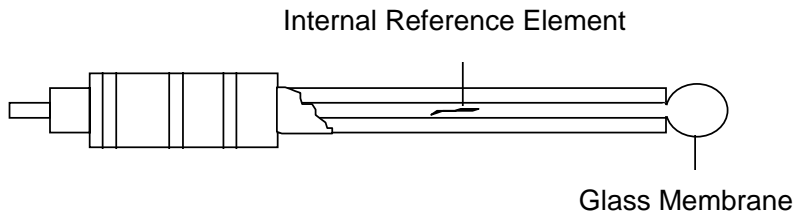
Glass Membrane

**COMBINATION ELECTRODE**

Glass Electrode

Reference Electrode

Junction

Glass Membrane

H+          H+

**REFERENCE ELECTRODE**

Reference Element

Junction

Electrolyte Filling Solution

---
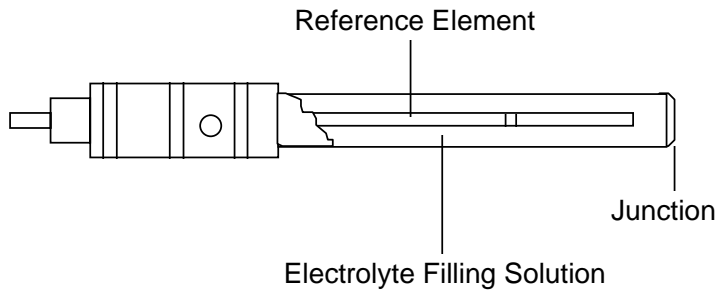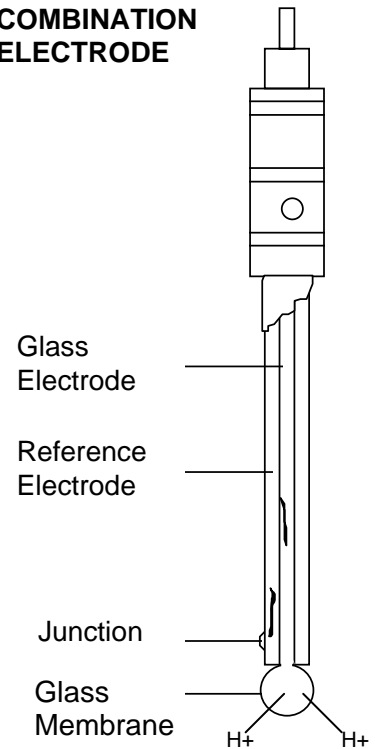
The pH Electrode:

- It is made of thin glass that is permeable only to hydrogen ions (H+).

- The internal pH of the glass electrode is 7.0.

- Its potential varies proportionately to the H+ concentration of the sample.

- Generally, electrodes fail because of scratches, deterioration, or a dirty build-up on the surface.

---

💡 **Operator Tips: pH Electrode Care**

- Use recommended procedures to clean and condition electrodes.

- Use _____ towels (i.e., kim wipes) to clean electrodes.

- Rinse electrodes with distilled or deionized water between use.

- _____ electrodes in recommended storage solution.

---

If proper care is not taken, the electrode response time can slow, inaccurate readings can result and the life of the electrode will be shortened.

---

The Reference Electrode:

---

- Provides a constant electrode potential by allowing the flow of reference electrolyte solution into the sample.

- Reference electrodes are available in several forms (i.e., sealed, refillable, ...).

**Operator Tips:  Reference Electrode**

- Use fresh reference solution.

- Sealed gel-filled electrodes are disposable.  _____ these electrodes when the gelled reference solution is all used up.

- When using a refillable liquid electrode, fill to the proper level: _____ the level of the sample and/or storage solution.

- Ensure injection point does not become _____. A clogged junction will cause an error or drift in the reading.

The pH Meter:

- Measures the potential difference between the pH and reference electrodes.

- Results are expressed in pH units from a scale of 0 to 14.

The meter and electrodes must have some form of temperature compensation.

- pH is temperature-dependent.

- With temperature compensation, a pH meter can produce a quick and accurate response even when the electrodes, sample and reagents are all at different temperatures.

- Temperature compensation may be automatic or manual.

## pH Measurement

The test method can be summarized as follows:

1. The pH meter and electrodes are calibrated using at least two standards.

2. Then the sample pH measurement is made.

These standards are called buffer solutions and have a known pH value and associated millivolt (mV) potential.

- The buffers typically used are the pH 4.00, 7.00 and 10.00 buffer solutions.

- Buffers are available in liquid or salt form and can be color-coded for ease of use.

**Operator Tips:  Buffers**

- Buffer stock solution has a shelf-life of ≈ _____.  Do not use after the expiration date.

- Buffers prepared for daily use last ≈ _____.  Do not pour used buffer back into the stock solution bottle.

- Always cap or cover the buffer solution.

- Carbon dioxide ($CO_2$) absorption, mold growth, evaporation and contamination can cause changes in the buffer pH.

# mV Potential of Buffers
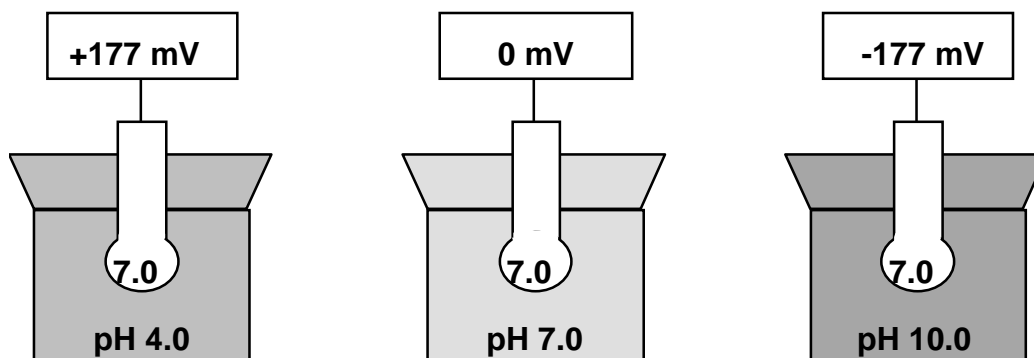


The pH electrode component has an internal pH of 7.0.


- When the pH electrode is immersed in a pH 7.0 buffer solution, the internal and external solutions are at the same pH. The electrical potential produced is 0 mV.

- The pH 7.0 buffer solution is used to zero the instrument (set the isopotential point).


For every pH unit difference, an electrical potential of ≈ 59 mV is produced.


- For example, when the pH electrode is immersed in a pH 4.0 buffer solution, the electrical potential produced = 3 x 59 mV or 177 mV.

**pH Buffers
mV vs. pH**
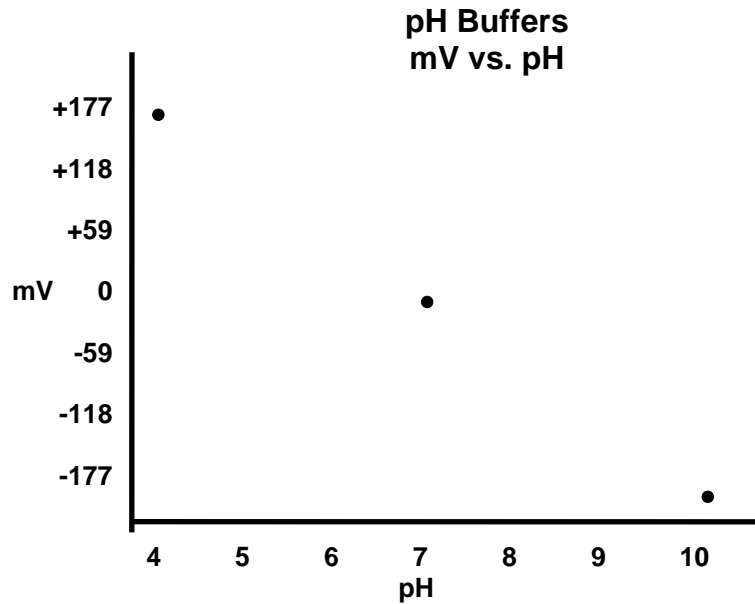


- The pH meter measures the mV potential and then converts the mV potential into pH units.


- The meter internally constructs a calibration curve for this conversion.


The calibration curve is also referred to as the slope.


- The slope is defined as the change in mV potential per pH unit.


Once the calibration curve is constructed, it then provides a reference point from which to read the pH of a sample.

---
One-Point Calibration
---

**One-Point Calibration**
**mV vs. pH**

```
        +177
        +118
         +59
mV     0              •
        -59
       -118
       -177

          4    5    6    7    8    9    10
                        pH
```
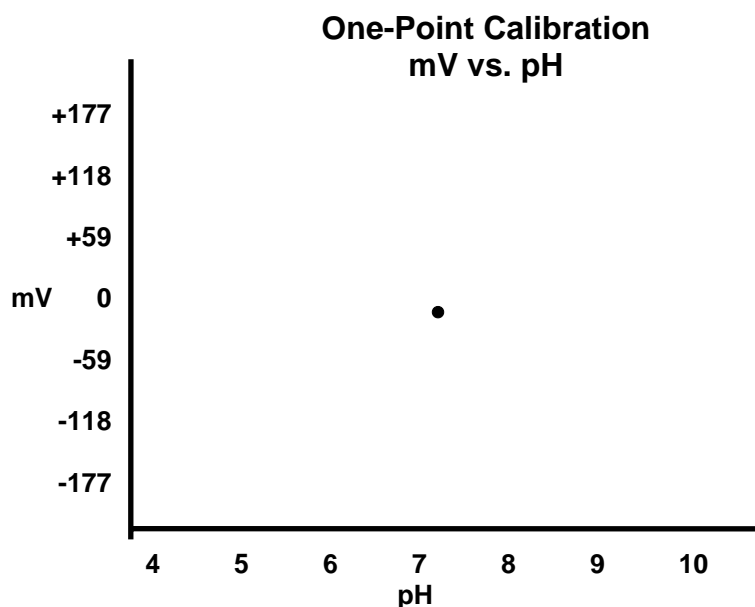
To simulate one-point calibration, assume the pH 7.0 buffer solution was measured.  Draw a calibration curve (line) through this point.

Use the calibration curve to determine the pH of a sample that produced -118 mV.  Draw a line from -118 mV over to the curve and then down to the pH axis.   The pH is _____.

One-point calibration is not accurate enough.

Two-Point Calibration

The two standards used to construct the calibration curve should be selected to bracket the expected value of the sample.

If the raw water pH is ≈ 6.0, which standards should be used for pH analysis?  _____

If the treated water pH is ≈ 8.0, which standards should be used?

_____

Why not just use 4.00 and 10.0?  _____

_____



Two-Point Calibration
mV vs. pH
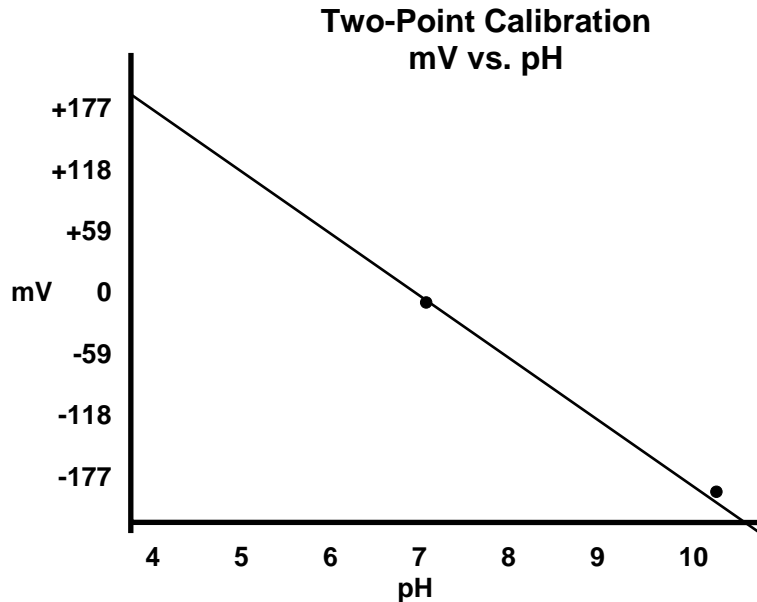
The two buffers used to construct this calibration curve were the pH 7.0 and 10.0 buffers.  Use the curve to determine the pH of a sample that produced -59 mV.  The pH is _____.

**Operator Tips:  Calibration**

- Perform _____-point calibration _____.

- Choose buffers which _____ the expected sample pH.

- Check for accuracy.  Review the slope to verify that it is acceptable.  Begin troubleshooting when the slope is outside the recommended range.

Read the instruction manual for your particular meter to determine the recommended slope.

- In some cases, the slope will be expressed as a percent (%). (example:  90% to 105%)

- Other models express the slope as a mV value.  The recommended range generally is 59 mV $\pm$ some value. (examples:  59 mV $\pm$ 5% or $\pm$ 3 mV)

## Sampling Protocol for pH

**Operator Tips:  Sampling Protocol**

- Clean and then rinse sample containers with distilled or deionized water when needed.
- Collect a sufficient volume to cover the tip of the electrode ($\approx$ 100 mL).
- Fill the sample container leaving no airspace and cap if transporting the sample back to the treatment plant or pump house for analysis.
- Analyze samples within _____ of collection.

Generally, samples must be analyzed within 15 minutes because:

- Carbon dioxide ($CO_2$) levels may change.

- Temperature changes quickly.

- pH may change significantly in a matter of minutes.

## Summary

**Key Points:**

- Use EPA approved/accepted methods for pH/temperature measurement.

- Analyze samples for pH/temperature measurement within _____.

- Perform _____ calibration _____ for accurate pH measurement.

# MODULE 7
## *Water Quality Analyses*
## *pH and Temperature*

❖❖ **Objectives:**

- Gain hands-on experience working with pH meters.

- Realize the importance of a quality control (QC) program.

## Recommended Equipment List

- A pH meter.
- A combination pH electrode (or, separate pH and reference electrodes).
- Buffer solutions (4, 7, and 10).
- 2 beakers for mixing and/or storing the buffers.
- Clippers (if using pH buffer powder pillows).
- Reference electrode solution (if needed).
- A 250 mL erlenmeyer flask (or a 250 mL beaker) used to store the electrode (s).
- Electrode storage solution.
- A wash bottle filled with distilled or deionized water.
- Kim wipes.
- A magnetic stirrer, stir bar and stir bar retriever.
- A 250 mL beaker used for measuring the sample pH.
- A beaker used for waste collection.

## Summary

**Key Points:**

- Follow manufacturer's recommendations for operation of pH meters.

- A quality control (QC) program, including two-point calibration, is critical for accurate pH measurement.

# MODULE 8
## *Water Quality Analyses*
## *Alkalinity and Calcium*

The key to optimal corrosion control is stability. A system's ability to maintain a stable water chemistry is influenced by the alkalinity concentration of its water.

❖ Objectives:

- Define alkalinity.

- Discuss the procedures for alkalinity and calcium measurement.

- Outline the requirements for sample collection.

- Recommend appropriate quality control (QC) practices.

## The Carbonate System

**THE CARBONATE SYSTEM**

| | | |
|---|---|---|
| CARBONIC ACID | BICARBONATE | CARBONATE & HYDROXIDE |

100% — 50% — 0%

pH 4.5    6.3    8.3    10.3    11.3
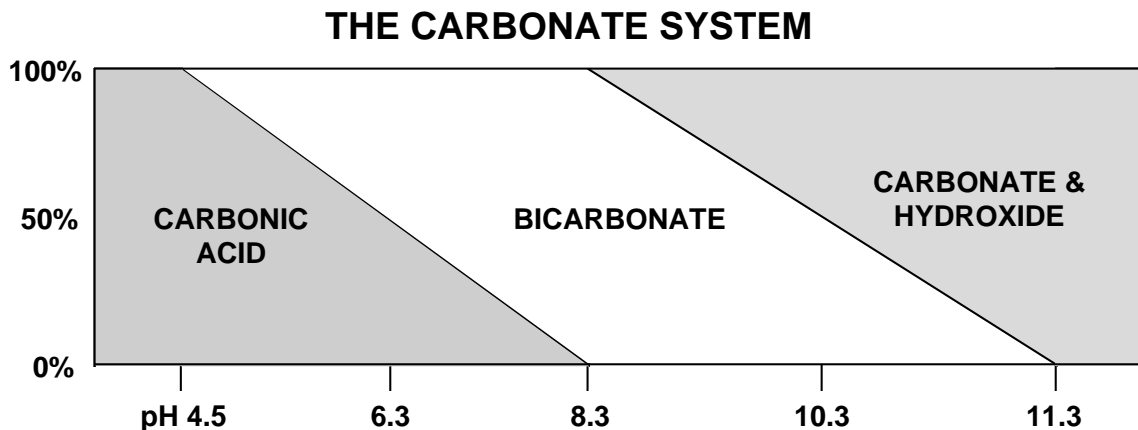
The carbonate system involves the three (3) carbonate species: carbonic acid, bicarbonate and carbonate.

As pH increases, the carbonic acid is neutralized to eventually produce hydroxide ions.

## Alkalinity

Carbonic acid (or carbon dioxide) **is not** part of alkalinity.

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

- A water's pH/alkalinity combination determines that water's tendency to dissolve lead and copper.

- Corrosion control treatment often involves adjusting pH and alkalinity to make the water less corrosive.

The amount of alkalinity in water affects its buffering ability. Buffering means how much acid or base can be added to the water without causing a great change in pH.

- Generally, alkalinity should be 20 mg/L or above to give sufficient buffering.

Low alkalinity waters produce significant pH changes when an acid or base is added.

- Without sufficient buffering, pH control is very difficult.

- The pH of a water must be stable for effective corrosion control treatment.

## Alkalinity Measurement

As we discussed in module 7, EPA has established methods for water quality analyses. The minimum requirements for alkalinity measurement are as follows:

---

### SPECIFICATIONS FOR ALKALINITY MEASUREMENT

**Apparatus:**

**Calibrated pH Meter**
   See modules 6 & 7.

**Buret or Digital Titrator**
   10 mL or 25 mL glass buret (class A).
   Digital Titrator capable of reading to 0.1 mg/L.

---

**Summary of Test Method:**

Total alkalinity as $CaCO_3$ is determined by titration with a sulfuric acid ($H_2SO_4$) standard solution to an end point determined with a calibrated pH meter. The end point is a pH of 4.5.

---

---

**Operator Tips:  Titration**

- The test method involves a titration.

- Titration is a method of analyzing the composition of a solution by adding  known amounts of a standardized solution until a given reaction or _____ is produced.

- The end point can be a _____ change or a _____ change.

- Total alkalinity as $CaCO_3$ is determined by titration with a sulfuric acid ($H_2SO_4$) standard solution to an end point determined with a calibrated pH meter.  That end point is a _____.

---

At what pH does the water contain only carbonic acid?  _____

At what pH is the alkalinity concentration $\approx 0$?  _____

At a pH of 4.5, all the alkalinity has been converted to carbonic acid, and therefore can be measured as total alkalinity.

## Calcium Measurement

Calcium as $CaCO_3$ is also determined by titration.

- An EDTA standard solution is used to titrate to an end point determined by a color change.

## Sampling Protocol for Alkalinity

**Operator Tips:  Sampling Protocol**

- Clean and rinse sample containers with distilled or deionized water between use.

- Collect a sufficient volume  (_____ is required for either method).

- Fill the sample container leaving no air-space and cap if transporting the sample back to the treatment plant or pump house for analysis.

- Analyze samples _____ after collection.

Generally, samples must be analyzed as soon as possible because:

- Carbon dioxide ($CO_2$) may be lost or gained during sampling, storage or titration.

- A change in pH will affect the endpoint determination.

## Summary

Key Points:

- Analyze samples _____ after sample collection.

- A _____ program is critical for accurate measurement.

# MODULE 9
## *Water Quality Analyses*
## *Alkalinity Lab Workshop*

❖ **Objectives:**

- Gain hands-on experience conducting titrations.

- Realize the importance of a quality control (QC) program.

## Recommended Equipment List

- A pH meter and pH electrode (s).  See the pH/Temperature section of this Appendix for more information.
- A buret/stand or a digital titrator.
- Sulfuric acid solution, 0.02 N or a $H_2SO_4$ titration cartridge for a digital titrator, 0.1600 N or 1.600 N.
- A wash bottle filled with distilled or deionized water.
- Kim wipes.
- A magnetic stirrer, stir bar and stir bar retriever.
- A 250 mL wide-mouthed Erlenmeyer flask
- A 100 mL graduated cylinder.
- A beaker used for waste collection.
- A 1.0 mL pipet and pipet bulb (used to fill the buret).

## Summary

🔑 **Key Points:**

- Alkalinity is measured by titration to an end point of pH 4.5.

- A QC program is critical for accurate measurement.

# MODULE 10
## *Water Quality Analyses*
## *Phosphorus and Silica*

◆ **Objectives:**

- Examine how phosphorus and silica are measured.

- Detail the specifications for acceptable colorimetric instruments.

- Outline the requirements for sample collection.

- Recommend appropriate QC practices.

The inhibitors used to control lead and copper act by forming a protective coating over the site of corrosion activity, thus "inhibiting" corrosion. The success of inhibitor addition depends upon your ability to provide a continuous coating throughout the distribution system.

## Specifications for Colorimetric Measurement

### SPECIFICATIONS FOR PHOSPHORUS MEASUREMENT

**Apparatus:**
Colorimetric equipment consisting of one of the following:

**Spectrophotometer:**
With an infrared phototube for use at 880 nm, providing a light path of 2.5 cm or longer.

**Filter Photometer (Colorimeter):**
Equipped with a red color filter and a light path of 0.5 cm or longer.

**Summary of Test Method:**
Phosphorus analyses involves two general steps: (a) conversion to dissolved orthophosphate, and (b) colorimetric determination of dissolved orthophosphate.

### SPECIFICATIONS FOR SILICA MEASUREMENT

**Apparatus:**
Colorimetric equipment consisting of one of the following:

**Spectrophotometer:**
For use at 410 nm, providing a light path of 1 cm or longer.

**Filter Photometer (Colorimeter):**
Providing a light path of 1 cm or longer and equipped with a violet filter having maximum transmittance near 410 nm.

**Summary of Test Method:**
Silica analyses involves two general steps: (a) addition of reagents to destroy interferences and to form a color complex, and (b) colorimetric determination of silica.

## Colorimetric Analyses

The measurement of phosphorus and silica relies on a color determination made with photometric instruments.

Photometers or colorimeters are used to measure the concentration of a constituent, like phosphorus, by measuring the intensity of a color.

Colorimetric measurement begins with reagents and a sample. Reagents are added to the sample to form a color-complex with the contaminant.

**REAGENTS**      **SAMPLE**           **COLOR- COMPLEX**
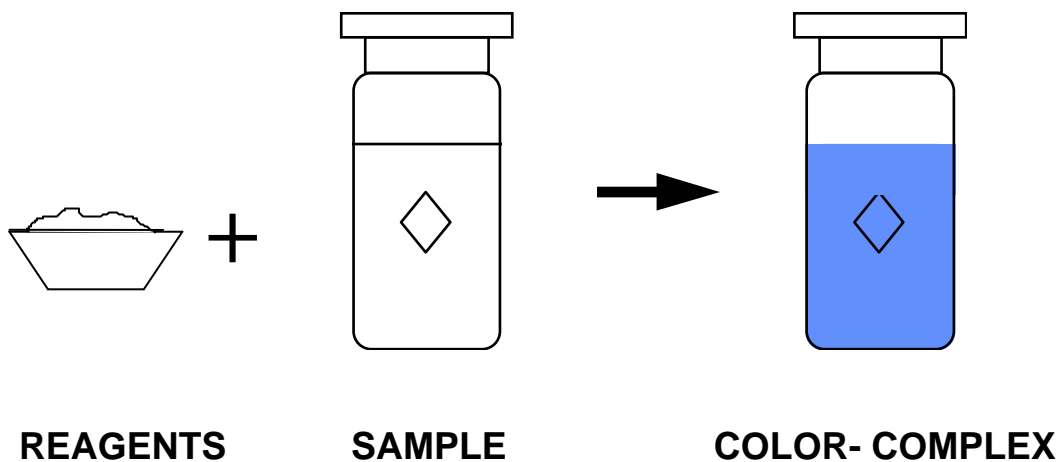
For example, addition of ascorbic acid causes the sample to turn blue if phosphorus is present.

**Operator Tips: Sample Preparation**

- Use fresh reagents.  Discard after the expiration date.

- Use clean, _____ sample cells.  Wash cells with phosphate-free detergent and rinse thoroughly with distilled or deionized water.  Rinse with 1:1 HCl when needed.

- Extreme background _____ or _____ in a sample can interfere with colorimetric analyses.

Colorimetric instruments utilize a system of separating and then selecting out a specific color or wavelength of light.

## COLORIMETRIC ANALYSES
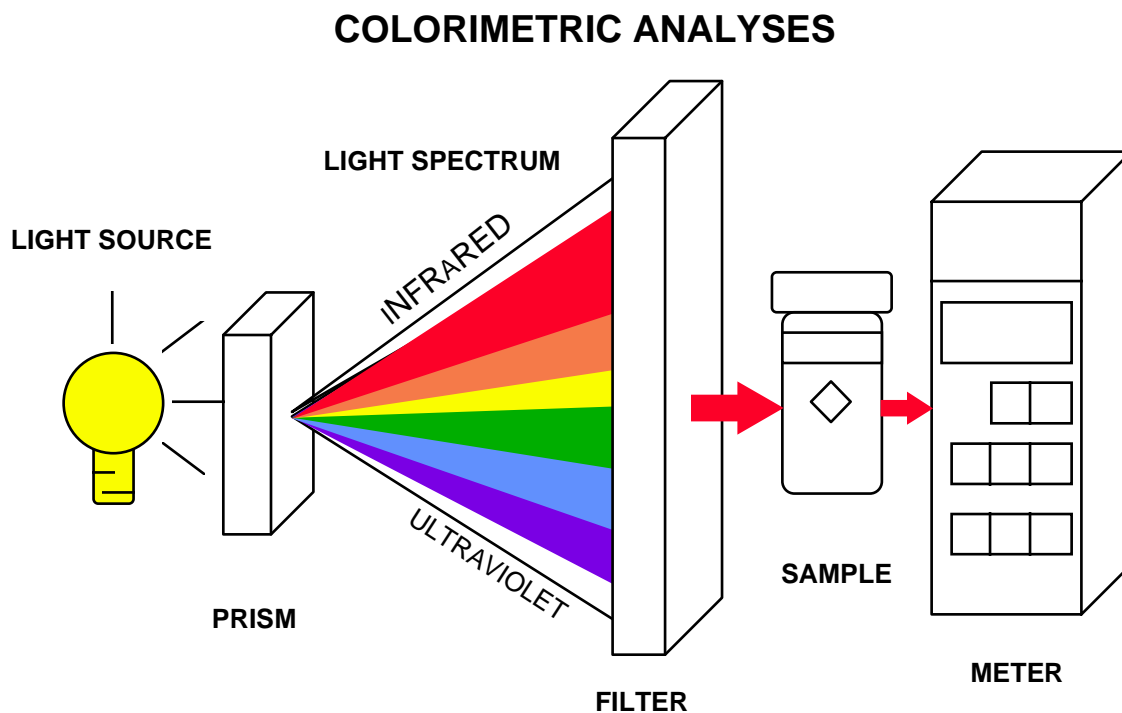
The colorimetric instrument:

- Uses a white light source.

- Provides a mechanism, like a prism, to separate the light spectrum.

- Uses a component, like a filter, to select a specific wavelength or color.

- Directs the specific wavelength through the sample.

- Detects the amount of light transmitted or absorbed with the meter.

**COLORIMETRIC ANALYSES**



100% ENTERS    30% EXITS

30% is Transmitted
70% is Absorbed
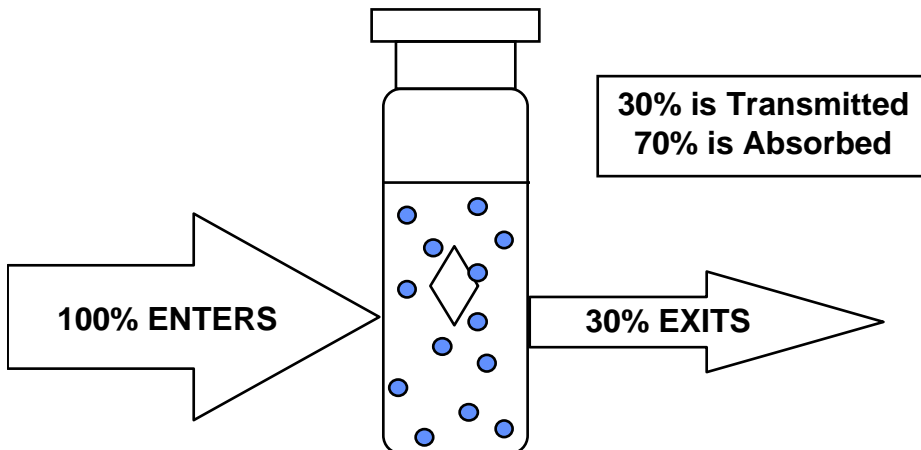
Some of the light is absorbed by the contaminant while the remainder of the light passes through the sample. The light passing through the sample is called transmitted light.

The transmitted light is detected by the meter and can be measured in percent (%) transmittance, percent (%) absorbance, or in some cases, it can be converted to a concentration as mg/L.

## Calibration

**Calibration Curve**
**Absorbance vs. Concentration**
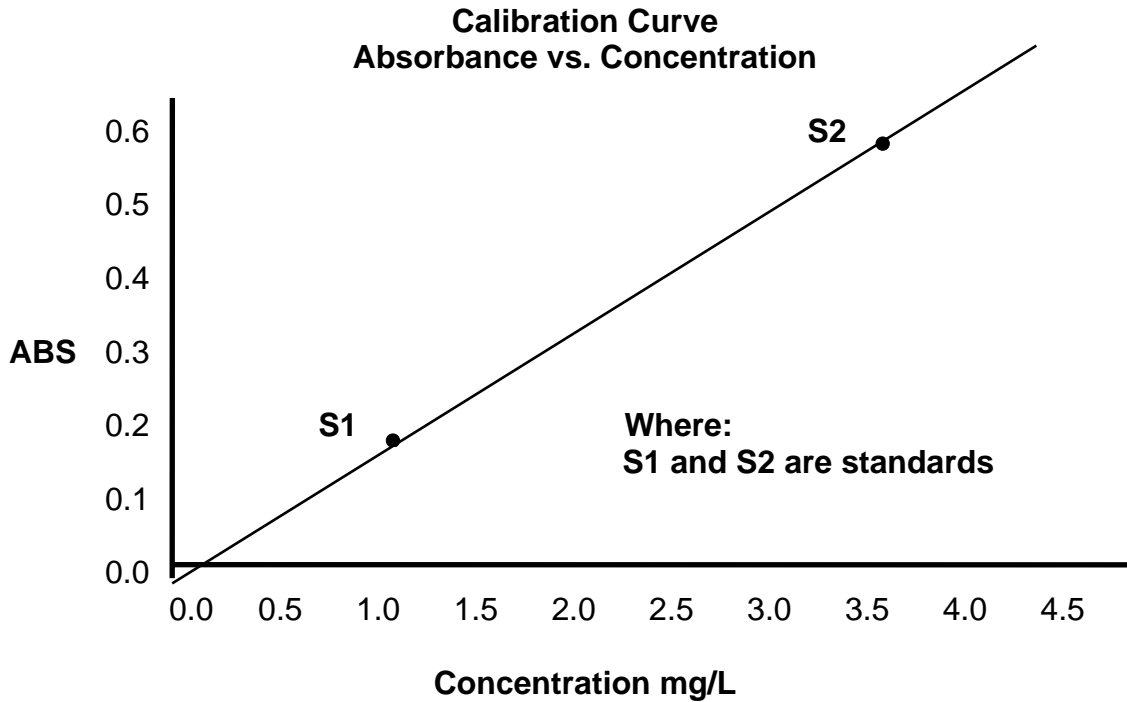


Some colorimeters can internally construct this calibration curve. They use either preprogrammed calibration points or user-generated points.

For some instruments, though, you may need to measure calibration points and then construct this type of a graph yourself.  Follow the instruction manual for information concerning calibration.

**Operator Tips: Calibration**

- Colorimeters must be _____ with a blank before unknown solutions can be measured.  The method will specify the use of a sample blank or a reagent blank.

- A _____ 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.

- A _____ 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.

- Calibration is essential for accurate colorimetric measurement.  Some colorimeters contain preprogrammed calibrations.  If the instrument is not preprogrammed, calibrate daily.

## Spiking or Standard Additions Method

Standard additions (or spiking) is a widely accepted technique for checking the validity of test results.  This technique can also be used to check the performance of the reagents and the instrument.

Standard additions is performed daily as follows:

- Analyze the sample.

- Add a small amount of a phosphate standard solution to the analyzed sample.

- Repeat the analysis - using the same reagent, instrument and technique.

- The amount of increase in the test result should equal exactly the amount of standard added as follows:


**mL Standard Added  x  Conc. of Standard, mg/L**  =  **Standard Addition, mg/L**
                 **mL of Sample**


- The final readout should = Sample Result + Standard Addition ± 0.05 mg/L.  If the sum calculated is within this error margin, the results obtained are accurate.

- If the sum calculated is greater than the margin error, begin troubleshooting.


## Sampling Protocol for Phosphorus/Silica



**Operator Tips:  Sampling Protocol**

- Collect samples for silica measurement in plastic bottles.

- Clean sample bottles and glassware with phosphate-free detergent, rinse with 1:1 HCl and then with distilled or deionized water.

- Collect ≈_____ for phosphorus or silica measurement.

- Analyze samples _____ after collection.

## Recordkeeping

Daily log sheets should be kept and maintained for all of the required water quality parameters.  In a later module, we will look at a Monthly Operational Report that can be used to record water quality analyses data.

## Summary

## 🔑 Key Points:

- Analyze samples for phosphorus and silica measurement _____ after collection.

- Maintain a QC program, including calibration, for accurate colorimetric measurement.

# MODULE 11
## *Water Quality Analyses*
## *Phosphorus/Silica Lab Workshop*

❖ **Objectives:**

- Gain hands-on experience working with colorimeters.

- Realize the importance of a QC program.

## Recommended Equipment List

- A colorimeter or spectrophotometer.
- Phosphate standard solution.
- Two (2) 10 mL sample cells.
- A 1.0 mL pipet and pipet bulb.
- A wash bottle filled with distilled or deionized water.
- PhosVer 3 Phosphate Powder Pillows or other specified reagents.
- Kim wipes.

## Summary

🔑 **Key Points:**

- Follow manufacturer's recommendations for operation of colorimeters.

- A QC program is critical for accurate measurement.

---

Units and Conversions

---

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

11.   5000 mL = ? L   12.   50 L = ? mL         13 .   7.990 L = ? mL

14.  1500 mg = ? gm         15.  5436.6 gal = ? L         16.   1.987 L = ? gal

17.   50 mL = ? _L_
         min      min

18.  0.564 L_ = ? mL
          min      sec

19.  765 kg =        ? gm_
          L              mL

20.  6543 L_ =   ? gal
          day          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).

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).

**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.

- If a person weezes 20 times per cough, how many tissues will he use per bowl of soup (which should help him feel better) if:
    5 weezes = 1 sneeze
    3 sneezes = 1 tissue
    4 coughs = 1 bowl of soup

# MODULE 12
## *Corrosion Principles*

❖ **Objectives:**

- Explain how corrosion of lead and copper occurs.

- Identify the four elements necessary for corrosion.

- Identify and discuss factors which affect corrosion.

- Explain the principles of corrosion control treatment.

- List the corrosion control treatment alternatives under the LCR.

## Basic Corrosion Theory

When most substances come in contact with water they tend to ionize or separate into ions.

Like most metals, lead and copper form positive ions which are soluble in water.

$$Pb \rightarrow Pb^{+2} + 2e^-$$

$$Cu \rightarrow Cu^{+2} + 2e^-$$

When people drink the water containing these compounds, they ingest the lead or copper.

Sources of lead/copper

_____        _____

_____        _____

# CORROSION CELL



**Anode reaction:   Pb - 2e⁻ ⟶ Pb⁺²**
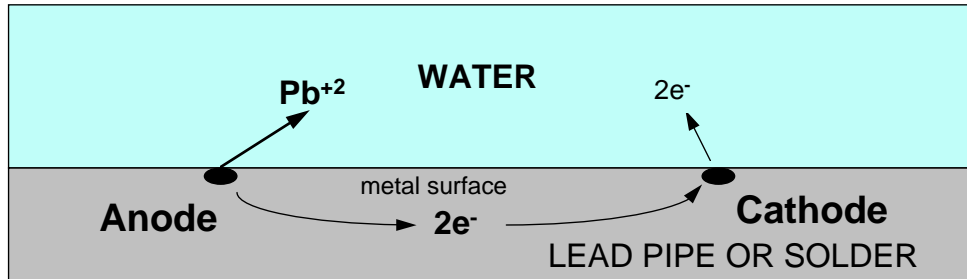
Four elements of an electrochemical cell necessary for corrosion to occur:

- _____ - where electrons are lost through the meta.l

- _____ - where electrons are gained and then leave the metal.

- Connection between the anode and cathode (pipe) - to transport the electrons.

- Electrolytic solution - (water) to conduct ions between the anode and cathode.

The anode is the part of the metal surface that is corroded.  This means that the anode is where the metal dissolves and enters the water as a $Pb^{+2}$ ion.

The anode is also the place from which electric current (electrons) flows through the metal to the other electrode, the cathode.

The cathode is the part of the metal surface where the electrons leave the metal and return to the anode through the water.

Corrosion will occur as long as this electrical circuit is complete.

**Factors Affecting Corrosion**

The chemistry of the water has usually the greatest effect on the rate of corrosion.  These are the key water chemistry factors affecting corrosion.

Insert the word "increases" or "decreases" on the lines below.

- **pH:**  As pH increases, corrosion _____.

- **Alkalinity:**  Affects the solubility of lead.  Helps in keeping a stable pH.
  In most cases, as alkalinity increases, corrosion _____.

- **Total dissolved solids (TDS):**  Increases conductivity which increases the water's ability to conduct an electrical current.   As TDS increases, corrosion _____.

- **Calcium/Hardness:**  Waters containing higher calcium/hardness are less corrosive.

- **Temperature:**  As temperature increases, corrosion _____.

- **Dissolved oxygen (DO):**  As DO increases, corrosion _____.

- **Chlorides, Sulfates, Nitrates:**  As these increase, corrosion _____ because they all add TDS to the water increasing its conductivity.

- **Chlorine:** As the addition of gas chlorine increases, corrosion _____ because it reduces pH.

## Corrosion Control Treatment

**Traditional Corrosion Control Treatment Objectives:**

- Minimize corrosion rates.
- Extend service life of plumbing materials.
- Improve hydraulic characteristics.
- Mitigate red water problems.

**CCT Objective of the LCR:**

- To protect public health by minimizing the amount of lead and/or copper dissolving in tap water.

Minimizing the dissolution of lead/copper is accomplished primarily by changing the water chemistry to favor the formation of a protective layer on the pipe walls.

Forming a protective layer on the pipe wall interrupts the flow of electrons by eliminating either the cathode or the anode, or both. Also, changing the water chemistry can make the water less effective in conducting electricity.

# CORROSION CELL

**WATER**

Anode     metal surface     Cathode

LEAD PIPE OR SOLDER
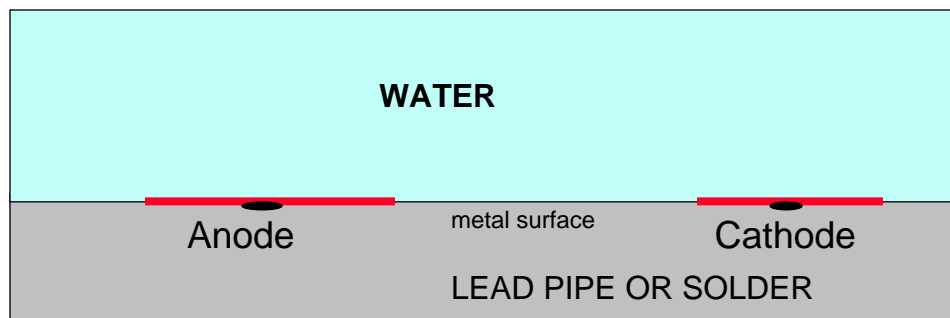
# LCR Corrosion Control Treatment Alternatives

- _____ adjustment

- Calcium hardness adjustment (calcium carbonate precipitation)

- Corrosion _____

## Summary

## Key Points:

- Pipe metals dissolve in water (corrode) because they give up electrons.

- Corrosion of pipes occurs because an electrochemical cell is formed.

- The _____ of the water has the greatest effect on corrosion

- Corrosion control treatment under the Lead and Copper Rule is intended to minimize the dissolution of lead/copper into tap water.

- Controlling lead/copper is achieved by forming a _____ layer on the pipe wall that eliminates the corrosion cell.

- The Lead and Copper Rule lists 3 corrosion control treatment alternatives.

# MODULE 13
## *Corrosion Treatment Theory*

❖ Objectives:

- Explain how the three types of corrosion control treatment work

- Discuss the important factors affecting each type of treatment

## pH/alkalinity adjustment

- pH/alkalinity adjustment involves adding a base or similar chemical to the water to increase pH to a level where the lowest practical lead or copper solubility is achieved.

*What compounds make up the carbonate system?*

_____        _____

_____        _____

- In pH/alkalinity adjustment, lead forms lead carbonate-hydroxide compounds and copper forms copper carbonate-hydroxide compounds.

Lead $\longrightarrow$ $Pb_3(CO_3)_2(OH)_2$ $\longleftarrow$ hydroxide

$\longleftarrow$ carbonate

Copper $\longrightarrow$ $Cu_2(OH)_2CO_3$ $\longleftarrow$
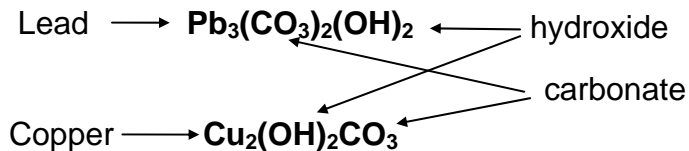
- When these compounds are formed on the pipe surface, they become a protective layer that keeps the metal in the pipe from dissolving because it interrupts the flow of electricity in the corrosion cells.

- The objective of pH/alkalinity adjustment is to neutralize carbonic acid and favor the formation of the insoluble metal compounds.

## THE CARBONATE SYSTEM

| 100% | | | |
|---|---|---|---|
| 50% | CARBONIC ACID | BICARBONATE | CARBONATE & HYDROXIDE |
| 0% | | | |

pH 4.5     6.3     8.3     10.3     11.3
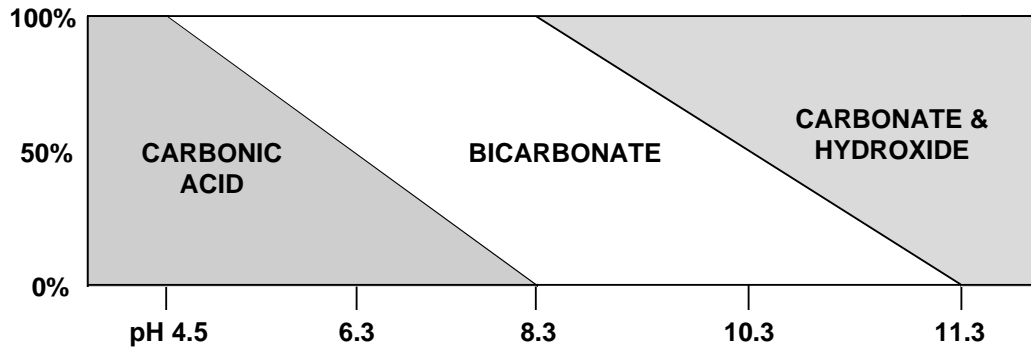
**Example:** A water system exceeded the lead action level and the pH of the raw water is 6.0.

At pH = 6.0 raw water probably contains mostly _____ which makes the water corrosive.

If we add a base, the carbonic acid will be converted to bicarbonate as the pH increases.

If we continue to add more chemical, some of the bicarbonate will be converted to _____ and hydroxide.

Carbonate and hydroxide are the compounds needed to combine with the lead to form the desired compound.

- For many systems, pH/alkalinity adjustment involves operating at fairly high pH's, often above 8.5

# Pb Solubility vs. pH

**Solubility, mg/L Pb**
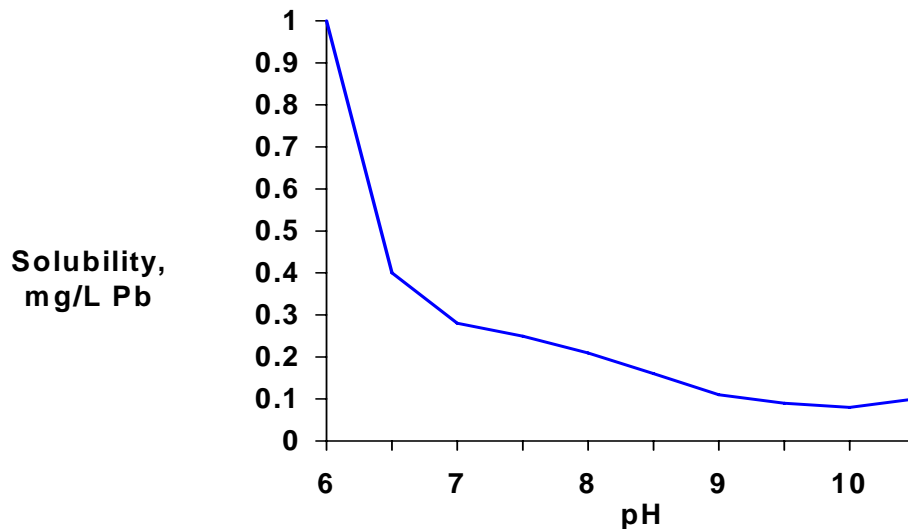


[1] This graph was developed from information in "Lead Control Strategies," AWWARF, pages 122 and 123. The pH and lead solubility points were obtained from the solubility curves shown as Figures 6.5 and 6.6 at a DIC of 12 mg/L as C.

- This graph shows the effect of pH on lead solubility under laboratory conditions.

- As pH increases, lead solubility, or the amount of lead dissolving in the water, decreases.

- For effective lead reduction, many systems will need to adjust pH to the 8.0 - 8.5 range or above.

- Caution: under certain raw water conditions, adding a chemical to raise pH may cause calcium carbonate to precipitate in the distribution system

**Operator Tips:**

**pH/Alkalinity Adjustment
Considerations for Lead**

- It is the simplest type of corrosion treatment (adding one chemical).

- The approach is to add a _____ to the water to increase pH to reduce lead solubility.

- The operator should maximize reduction of lead considering other treatment such as disinfection, disinfection byproducts or iron removal.

- The key to success is to maintain a _____ pH after treatment.

- Raising pH may cause $CaCO_3$ to precipitate.

- If a system has exceeded **both** lead and copper, treatment should focus on lead reduction. Copper levels will usually be lowered also.

If a system has exceeded the copper action level only, the following operator tips should be considered.

**Operator Tips:**

**pH/Alkalinity Adjustment
Considerations for Copper**

- It is the simplest type of corrosion treatment.

- _____ is the most important factor.

- 98 percent of copper problems can be solved by pH adjustment.

- pH should not be less than 7; above a pH of _____ is best for copper reduction

# Corrosion Inhibitors

- Inhibitors are specially formulated chemicals that form a protective layer on the pipe wall.

- **Phosphates** are by far the most common inhibitors used in water treatment for corrosion control.

- **Silicates** have a more limited application and may be most suitable for small systems with iron and manganese problems.

Lead = Pb
Phosphate = $PO_4$

Phosphate

Lead → **$Pb_5(PO_4)_3(OH)$**
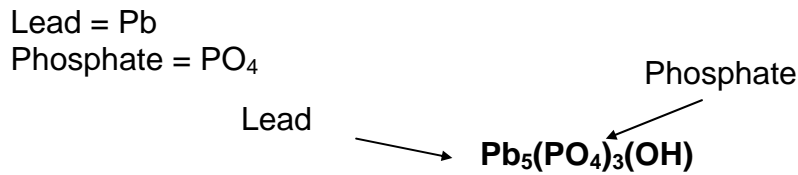
- When a phosphate inhibitor is used for corrosion control, the protective coating is formed from the pipe metal combined with the phosphate.

- The control of lead using a phosphate inhibitor occurs when a **lead-phosphate** compound is formed.

- Orthophosphates are primarily used to control lead, not copper.

- Under optimal conditions, orthophosphate treatment is usually **more effective** in reducing lead than pH/alkalinity adjustment.

---

**Operator Tips: Orthophosphate Treatment**

- Stable _____ is necessary to maintain protection.

- Optimal pH is 7.2 to 7.8.

- Alkalinity should be at least _____ mg/L for pH control.

- Orthophosphate residual must be maintained in the distribution system.

---

- Systems that have raw water naturally in the optimal pH range of 7.2 to 7.8 can treat with orthophosphate alone, provided the water has sufficient alkalinity for a stable pH.

- If pH and/or alkalinity are not in the optimal ranges, pH/alkalinity adjustment is needed in addition to the inhibitor.

**Treatment Summary for pH/alkalinity Adjustment and Corrosion Inhibitors**

| Treatment Approach→ | pH/Alkalinity Adjustment | Corrosion Inhibitor |
|---|---|---|
| **Key Water Quality Parameters** → | pH, alkalinity, temperature | pH, alkalinity, temperature, metals, hardness, inhibitor residual |
| **Appropriate Chemical Feed Systems** → | Caustic Soda<br>Lime<br>Soda Ash<br>Sodium Bicarbonate | Orthophosphate<br>Polyphosphate<br>Ortho-poly blends<br>Silicates |

Calcium Carbonate Precipitation

- Precipitation forms a layer of calcium carbonate ($CaCO_3$) precipitate that coats the pipe.

- Like pH/alkalinity adjustment, you add a base or similar chemical - caustic soda, lime, soda ash, or sodium bicarbonate- to increase pH.

- Some systems which are trying to control corrosion using pH adjustment will precipitate calcium carbonate.  This may occur when the raw water chemistry has some or all of these characteristics:

  - Low pH (usually below 6.5)
  - High carbon dioxide levels
  - Moderate or higher alkalinity (50 mg/L or higher)
  - Moderate or higher calcium hardness

## Summary

### 🔑 Key Points:

- For most systems with lead/copper corrosion, pH/alkalinity adjustment is the treatment of choice.

- pH/alkalinity adjustment is the simplest treatment - adding a chemical to raise pH.

- For systems with copper problems only (no lead problems), adjust pH above _____.

- Corrosion inhibitors should be used when pH adjustment alone is insufficient or raw water is naturally in the optimal pH range for the inhibitor.

- Orthophosphates are by far the most widely used inhibitors for _____ control.

- A system using pH/alkalinity adjustment has the potential to precipitate calcium carbonate.

- Calcium carbonate precipitation is not a recommended treatment unless pH adjustment and inhibitors are not feasible.

- Corrosion control treatment requires pH control and finished water stability to be effective.

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

❖ **Objectives:**

- Identify common pH/alkalinity adjustment chemicals

- Discuss characteristics and operational considerations of these chemicals

## pH Adjustment

- pH is the major factor that determines the _____ of most pipe materials

- most common method of reducing corrosion in water distribution systems

- most easily implemented  and _____ costly

- pH adjustment alone is often insufficient in waters that are low in carbonate and bicarbonate alkalinity

## Common Chemical Names

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

| Chemical Name | Chemical Formula | Common Name |
|---|---|---|
| Sodium Hydroxide | NaOH | _____ |
| Calcium Hydroxide | $Ca(OH)_2$ | _____ |
| Sodium Bicarbonate | $NaHCO_3$ | _____ |
| Sodium Carbonate | $Na_2CO_3$ | _____ |

Do these chemicals act like acids or bases?  _____

Are caustic soda and lime stronger or weaker bases than soda ash and sodium bicarbonate? _____

Chemical Characteristics

**Table 2 - Summary of Chemicals Typically Used in pH/Alkalinity
and Calcium Adjustment Corrosion Control Treatment**

| Chemical | Use | Notes |
|---|---|---|
| Caustic Soda | Raise pH. Convert excess $CO_2$ to alkalinity species | pH control is difficult when applied to low alkalinity  water (<20 mg/L)<br>no increase in calcium<br>adds sodium |
| Lime | Raise pH.  Increases alkalinity and calcium content | Slurry feed can cause excess turbidity<br>O & M intensive |
| Sodium bicarbonate | Increases alkalinity with little increase in pH | Good alkalinity adjustment choice, but very expensive<br>adds sodium |
| Soda ash | Increases alkalinity with moderate increase in pH | More pH increase caused as compared to sodium bicarbonate, but less costly<br>adds sodium |

- Caustic soda,  lime, and soda ash raise pH

- Sodium bicarbonate is primarily used to increase alkalinity

- Caustic soda causes the pH to rise dramatically and quickly when the alkalinity is low

- Lime requires more operational attention than other chemicals

**Operator Tips:  Lime**

- Use _____ pipelines to break $CaCO_3$ deposits apart.

- Minimize length of line by placing feeder as _____ as possible to point of application.

## Operational Considerations

**Table 3 - Operational Considerations
for pH/Alkalinity Adjustment Chemicals**

| Chemical | Available Forms | Feed Equipment | Storage | Safety Considerations |
|---|---|---|---|---|
| Caustic Soda | 50 % or 25% solution | Proportioning pump or rotameter | 50% solution requires heated storage room to prevent freezing | dangerous to handle protective clothing, rubber gloves, rubber apron, face shield control mists with good ventilation |
| Lime | powder in 50 or 100 lb bags; bulk | Hydrated lime-solution tank, and feed pump with erosion-resistant lining as eductor | Dry storage with slurry feed | positive ventilation, protective clothing, gloves, face shield, neck cloth, respirator |
| Sodium Bicarbonate | powder; 25 lb drums, 100 lb bags | Solution tank, proportioning pump or rotameter | Dry storage with solution feed | positive ventilation, protective clothing, gloves, goggles, respirator |
| Soda Ash | powder in 50 and 100 lb bags;  bulk | Solution tank, proportioning pump or rotameter | Dry storage with solution feed | positive ventilation, protective clothing, gloves, goggles, respirator |

- Lime, sodium bicarbonate, and soda ash are delivered as dry chemicals but are fed as _____.

- Soda ash and sodium bicarbonate are safe and easy chemicals to handle.

- Caustic soda is _____ to handle.   Refer to the Material Data Safety Sheet (MSDS) sheet  for detailed safety and handling precautions.

---

**Operator Tips:  Caustic Soda**

- Because 50% caustic soda freezes at 54° F,  you must keep the storage room and feed lines warm.

---

## Summary

**Key Points:**

- pH adjustment is least costly and most _____ implemented type of corrosion control treatment.

- Caustic soda, lime, and soda ash are common pH adjustment chemicals.

- Sodium bicarbonate is used primarily to adjust _____.

- Lime feed requires more operational attention because it clogs the lines.

- _____ provides both pH and alkalinity adjustment and is a safe and easy chemical to use.

- Caustic soda is dangerous to handle so refer to the MSDS sheet for detailed safety and handling instructions.

- In order to prevent freezing of _____% caustic soda, you should keep the storage area heated.

# MODULE 15
## *CCT Chemicals*
## *Phosphate/Silicate Inhibitors*

❖ **Objectives:**

- Identify common phosphate/silicate inhibitors.

- Discuss characteristics and operational considerations of these chemicals.

Circumstances that favor the use of inhibitors include:

- Raw water pH is in the optimal range for inhibitors.

- High iron and/or manganese levels.

- High TTHM formation potential.

## Phosphate Inhibitors

- Phosphate inhibitors develop a very thin protective insoluble metallic film on the inside of the pipes.

- They are used to control scale build up.

## Advantages

- Protective film won't clog pipes so flow and pump efficiencies remain high.

- Taste, odor, alkalinity and _____ not affected.

- Hardness not increased.

- Finished water pH  is _____ so chlorine doses and TTHM formation potential may be lower than with pH adjustment.

## Disadvantages

- They may encourage _____ growth in reservoirs exposed to sunlight.

- Phosphates can act as fertilizers on bacterial growth in distribution systems so you need to maintain adequate chlorine residuals

- Zinc is often added to enhance phosphate performance; however, wastewater treatment plants have _____ disposal problems due to the elevated zinc levels.

**Operator Tips:  Inhibitors**

- The choice of the particular type of phosphate depends on the specific water quality.

- Compositions are proprietary so the chemical distributor establishes dosage rates and minimum inhibitor concentrations in the distribution system.

- Some phosphate feed programs should include:

    ∗ _____ mains by flushing or with hydraulic pigs

    ∗ Pre-treating for a short term with high dosages

    ∗ Maintaining _____ feed

# Inhibitor Fact Sheets

## Group #1 - Polyphosphates

Polyphosphates are primarily sequestering agents.

Bimetallic polyphosphates contain zinc.  Zinc enhances the polyphosphate by forming a film faster and increases the effective pH range.

**Use**:

Scale control
Sequester iron and manganese and calcium

**Available Forms**:

liquid, granular, or glassy form

**Examples**: C-2  (liquid pyrophosphate)        **RS-2 (dry blend of poly)
            C-5  (liquid polyphosphate)           *TG-10 (glassy zinc poly)
                 **C-6  (granular zinc metaphosphate)
                   V937 (granular zinc metaphosphate)
                   Nalco 7393 (zinc polyphosphate)

**Suitable Materials for Handling**:

For storage tanks, feed systems, and piping:  polyethylene, fiberglass or epoxy or vinylester lined steel.

For pump liquid ends and piping:  PVC, CPVC, Kynar$^\bullet$, 316 stainless steel, Viton$^{\circledR}$ or Hypalon$^{\circledR}$

$^{\circledR}$ Trademark of Du Pont
$^\bullet$ Trademark of Pennwall

**Storage/Feed Considerations**:

Solution drums or day tanks should be located in a heated building or use heat-traced tank to prevent freezing; keep liquid container closed when not in use
Dry storage (granular or glassy forms) should be on pallets in a cool, dry area to avoid moisture absorption

Glassy forms have sharp edges

*TG-10 requires an electric mixer and dissolving tank
**C-6 and RS-2 require vigorous mechanical stirring

**Safety Equipment Required**:  goggles, gloves

**Notes**:

- Polyphosphates degrade to orthophosphates depending on time and temperature

- pH conflict exists between sequestering iron and manganese which requires a pH of less than 7 vs. lead/copper control requires a pH of greater than 7

- Bimetallic polyphosphates often perform better than other polyphosphates in the following ways:
    * with lower dosages
    * in more mineralized and harder water
    * extend their effectiveness to a pH of at least 8
- 
- 
- 

## Group #2 - Orthophosphates

Orthophosphates form the insoluble metal film we mentioned earlier.

**Use:**

reduces lead solubility
do not sequester
not very effective for copper

**Available Forms:**

liquid delivered in plastic drums, disposable liquibins, and bulk

**Examples:**  C-9 (liquid zinc ortho)      C-14 (liquid zinc ortho)
C-9L (liquid zinc ortho)      C-15 (liquid zinc ortho)
C-10 (liquid zinc ortho)      V932 (liquid zinc ortho)
C-11 (liquid zinc ortho)

**Suitable Materials for Handling:**

For storage tanks, feed systems, and piping:  polyethylene, fiberglass
or epoxy or vinylester lined steel.

For pump liquid ends and piping:  PVC, CPVC, Kynar•, 316 stainless
steel, Viton® or Hypalon®

• Trademark of Pennwall
® Trademark of Du Pont

**Storage/Feed Considerations:**

Heated building or heat-traced tank to prevent freezing;
Keep liquid container closed when not in use

**Safety Equipment Required:**  goggles, gloves, face shield, and
protective clothing

**Notes:**

- most effective when a stable pH between 7.4 and 7.8 is
  maintained
- intended for low hardness waters (below 50 mg/L total hardness)

- low alkalinity water may require pH stabilization for optimal lead and copper reduction
- need to prevent $CaCO_3$ scale precipitation in high alkaline water because they contain little or no scale inhibition properties
- 
- 
- 

## Group #3 - Ortho/Poly Blends

Ortho/poly blends sequester and form films.  They are used to sequester iron and manganese in addition to reducing lead and copper levels.

**Use:**

corrosion control
finished water stabilization
distribution protection without limitations of poly or orthos

**Available Forms:**

liquid delivered in plastic container or bulk

**Examples:**    AQUA MAG (liquid sodium ortho/polyphosphate)
                C-4 (liquid blended phosphate)

**Storage/Feed Considerations:**

Store product in a clean dry area protected from freezing and extreme heat.
Keep container closed when not in use.

**Suitable Materials for Handling:**  PVC, teflon, polyethylene, stainless steel

**Safety Equipment Required:**    goggles

**Notes:**

- Varying proportions of sodium and potassium phosphates in portions that vary from 10 - 30% ortho to polyphosphate ratio.
- They are dependent upon reacting with calcium to form a calcium orthophosphate protective film.
- Exhibit tubercle and scale removal properties
- Initial increased high passivation dosage not needed
- Operate best in pH range of 7.2 to 7.8
- 
- 
- 

## Group #4 - Silicates

Silicates form a metal silicate barrier on top of and interlatticed with a metal hydroxide structure.

**Uses**:

Lead and Copper control
Fe/Mn removal
point-of-use for buildings and industrial processes

**Available Forms:**

known as "water glass"
liquid delivered in plastic drums or bulk

**Examples:**   PQ Corporation N$^®$ (liquid sodium silicate)
PQ Corporation D$^®$ (for water with pH < 6.0)

**Storage/Feed Considerations:**

Store product in a heated building to prevent freezing.

Wet spills are slippery and dehydrate to form glass-like films; therefore, rinse minor spills with water immediately.  Dried deposits may form sharp edges

**Suitable Materials for Handling:**  For piping:  PVC, carbon steel, stainless steel

**Safety Equipment Required:**  Goggles or face shield, alkali-resistant gloves

**Notes:**

- limited use in Pennsylvania
- best when raw water is in the pH range between 8 and 9.5
- no scale properties
- process is self-limiting; requires corrosion products to form and stops when corrosion products are no longer available
- protection is lost if dosage is stopped
- higher cost than phosphate inhibitors
- less effective in stagnant water
- 
- 
- 

## Summary

**Key Points:**

- Phosphate/silicate inhibitors develop a very _____ protective insoluble metallic film on the inside of the pipes which won't clog the pipes.

- Phosphate inhibitors may encourage algal growth in reservoirs exposed to sunlight.

- Polyphosphates are used to sequester _____, manganese, and calcium.

- Zinc orthophosphates are used primarily to control _____ levels but are not as effective for copper.

- Ortho/poly blends should be used when you need to sequester iron and manganese in addition to reducing lead levels.

- Silicate inhibitors do not add _____ to the system and are used extensively in point-of-use applications such as buildings and industrial processes.

- Follow safety and handling procedures on the MSDS sheets, especially when handling "glass" forms of phosphates and silicates.

# MODULE 16
# *Chemical Feed Systems*

## ❖ Objectives:

- Examine chemical feed systems used for corrosion control.

- Detail necessary components for optimal control of feed systems.

- Recommend appropriate operation and maintenance (O&M) of feed systems.

## Liquid Feed System

Distribution

**LIQUID FEED SYSTEM**

1. Chemical Storage
2. Suction Assembly
3. Pump
4. Calibration Chamber
5. Pressure Relief Valve
6. Pulsation Dampener
7. Backpressure Valve
8. Anti-siphon Valve
9. Injection Assembly
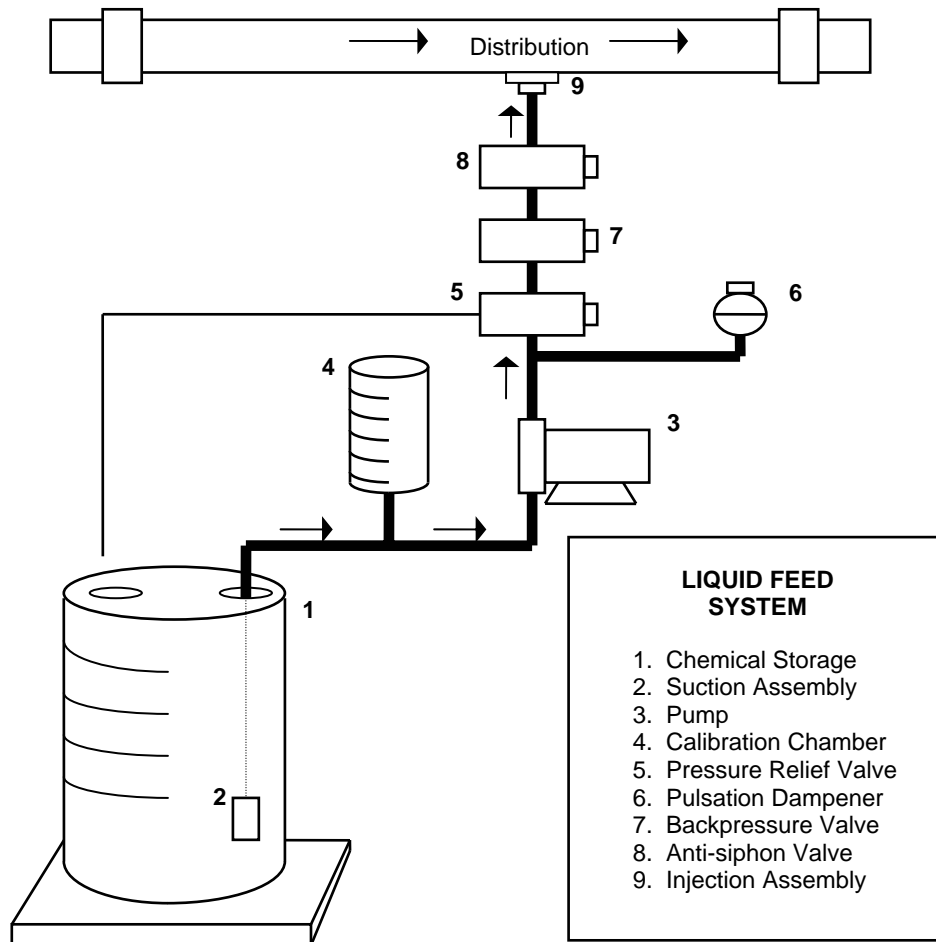
## 1. Chemical Storage

Liquid chemicals may be stored and fed from a chemical drum supplied by the manufacturer or from a day tank.

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

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

Storage tanks may be equipped with the following:

- Fill line.          • Drain.

- Vent line.          • Discharge connection.

- Overflow.          • Mixer.

Storage tanks should also have provisions for measuring the liquid level.

---

**Operator Tips:  Chemical Storage**

- Continuous measurement of the liquid level or volume is necessary for determining the quantity of chemical fed.

- An operator can use this information to track inventory and to verify the _____ of chemical being fed.

---

Level indicating devices include the following:

- A continuous level probe.

- A sight glass.

- Weighing scales.

- Increments (gallons or liters) marked on the day tank.

- A yard stick used to dip the tank.

## 2. Suction Assembly

The suction assembly consists of:

- A strainer to protect the internal components of the pump.

- A foot valve (check valve) to prevent the pump from losing prime.

Where should the suction assembly be installed? _____
_____

## 3. Pump

Pumps can range in price from $400.00 and up.

A mechanical diaphragm metering pump is used in nearly 99 percent of all feed systems.

Figure 1    Mechanical Diaphragm Pump

Outlet

Diaphragm

Closes Discharge Valve

Plunger

Expands Pump Chamber

Opens Suction Valve

Inlet

Pulls in Chemical
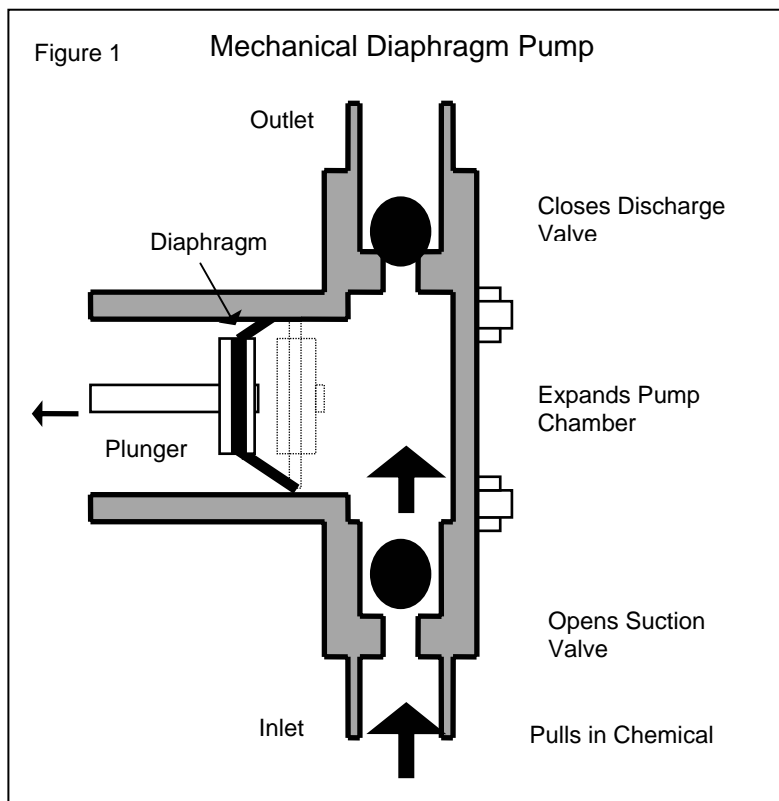
In figure 1, as the plunger moves backward, it creates vacuum: the pump chamber expands, the discharge valve closes, the suction valve opens, and chemical is pulled in.

Figure 2    Mechanical Diaphragm Pump

Pushes Out
Chemical

Outlet

Diaphragm

Opens Discharge
Valve

Compresses
Pump Chamber

Plunger

Closes Suction
Valve

Inlet
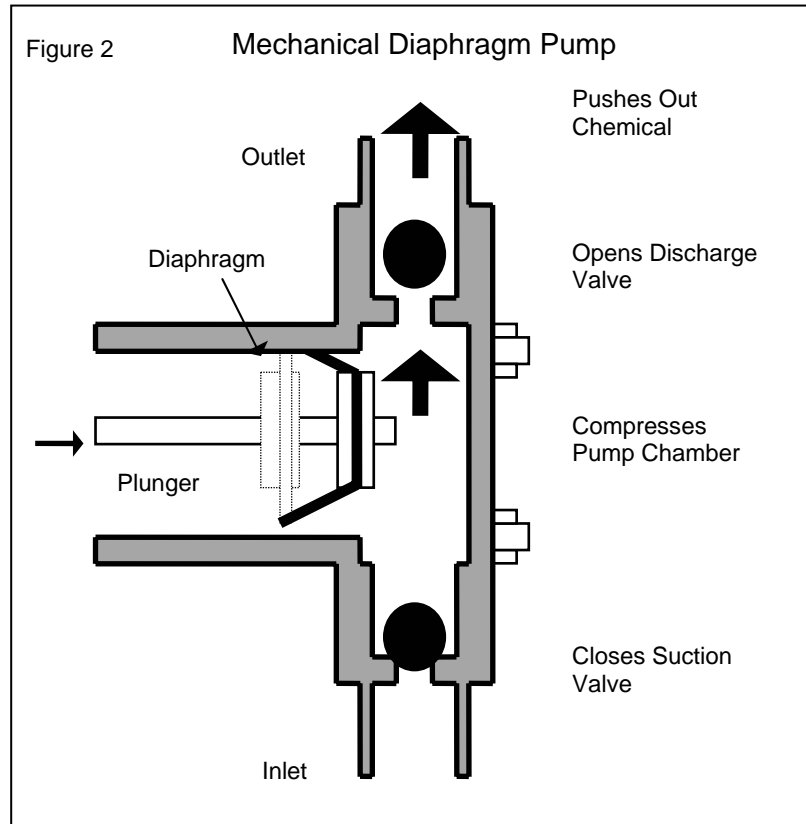
In figure 2, the plunger moves forward and creates pressure: the pump chamber compresses, the suction valve closes, the discharge valve opens, and chemical is pushed out.

Mechanical diaphragm metering pumps are positive displacement pumps.

- The output of the pump is controlled by the length of the plunger stroke and the number of repetitions of the stroke.

- The pump displaces a fixed volume of chemical per stroke.

Flow-paced control units are available for systems with varying plant flow.

Other types of metering pumps include:

- Hydraulic diaphragm pumps.

- Peristaltic pumps.

- And several other types.

## 4.  Calibration Chamber

**Operator Tips:  Calibration Chamber**

- A calibration chamber consists of a graduated cylinder typically located on the _____ side of the pump.

- A calibration chamber is necessary for accurate determination of the pump's feed rate.

## Valves

By definition, a valve is a device that controls the flow of liquids. Valves can control not only the flow, but the rate, the volume, the pressure, or the direction.

## 5.  Pressure Relief Valve

**Operator Tips:  Pressure Relief Valve**

- The valve relieves pressure if the line becomes _____, a valve is inadvertently _____, or if the pump produces pressures higher than the piping system can withstand.

- The valve incorporates a connection to discharge the liquid back into the chemical storage tank or to waste.

- The valve also aids in _____ the pump.

## 6.  Pulsation Dampener

A pulsation dampener:

- Is installed between the pump and the pressure relief valve.

- Offsets surges created by the pulsating discharge pressure encountered when using either a piston or diaphragm metering pump.

- Combats water hammer.

## 7.  Backpressure Valve

A backpressure valve:

- Maintains a steady backpressure to ensure accurate delivery.

- Prevents overpumping when little or no backpressure is present.

- Provides some anti-siphon action.

- Cannot be used for slurries.

## 8.  Anti-siphon Valve

An anti-siphon valve prevents siphoning of the chemical storage tank into the distribution system.

This valve should be located as close as possible to the point of chemical injection.  Some chemical injection assemblies contain an anti-siphon valve.

## Multi-Function Valves

A multi-function valve can provide:

- Anti-siphon protection.

- Backpressure (25 psi).

- Priming function.

- Pressure relief.

## 9.  Injection Assembly

- Installation is determined by the chemical being fed.

- Location of the assembly is important for proper mixing. For some applications, the assembly is attached to the bottom of the main.

- The order of chemical addition is important and should be specified for your system.

## O & M Liquid Feed

If 3 factors are considered, chemical feed systems will give years of trouble-free operation.

**Operator Tips:  O & M Liquid Feed**

1. Observe its operation _____.

2. Maintain a regular schedule of _____ maintenance.

3. Follow manufacturer's instructions.

## Preventive Maintenance

The preventive maintenance schedule that you follow depends on the manufacturer's recommendations and your own experience with the chemical feed system.

**Operator Tips:  Preventive Maintenance**

- 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., _____ or 1:1 HCl).

- Valves used with corrosive chemicals should be disassembled and inspected at least _____.  Parts showing signs of deterioration should be replaced.

- Pumps should be inspected regularly for signs of wear and damage.  Wetted parts (ball valves, diaphragms, ...) should be replaced on a regular basis.

- A cracked diaphragm may leak chemical, damage the pump  or cause the pump to lose prime.

- A ball valve caked with chemical may stick and cause _____.

- A worn seal may form an _____ _____ that could lower the pump output or cause the pump to lose prime.

- Repairs or replacement should be made before the machine breaks down.

## Spare Parts

Spare parts kits range from $\approx$ $30.00 - $60.00.

Maintain a sufficient stock of spare parts.  Most manufacturers offer a spare parts kit containing o-rings, ceramic balls or poppits, gaskets, seals and a diaphragm.

## Leaks

Leaks in and around the discharge line of a solution feeder can affect the quantity of a solution delivered. Even a small leak can result in damage to the feeder and surroundings.

## Dry Feed Systems

The two basic types of dry feeders are volumetric and gravimetric dry feeders.

## Volumetric Dry Feeders

Volumetric dry feeders are:

- Easier to operate.

- Less expensive to purchase and maintain.

- The most common type of dry feeder.

The feed mechanism (rolls or screws) delivers exactly the same **volume** of dry chemical to the dissolving tank with each complete revolution. Varying the speed of rotation varies the feed rate.

## Gravimetric Dry Feeders

Gravimetric dry feeders are:

- Extremely accurate.

- More expensive.

- Readily adapted to automatic control and recording.

The belt-type feeder delivers a certain **weight** of material with each revolution of the conveyor belt. Because gravimetric feeders control the weight of material, not the volume, variations in **density** have no effect on feed rate. This accounts for the extreme accuracy of this type feeder.

The dry chemical is discharged from a dry feeder and falls into a solution chamber or tank where it is dissolved in water to form a slurry.

- The tank is usually equipped with a mixer to aid in dissolving the chemical.

- The resulting solution either flows by gravity into the clear well or is pumped into a pressurized line.

## Summary

## Key Points:

- Begin with a properly designed chemical feed system.

- Observe the operation of feed systems _____.

- Establish a _____ maintenance schedule.

- Follow manufacturer's instructions.

- Establish and maintain proper _____ for stable water quality.

# MODULE 17
## *Chemical Feed Calculations 1*
## Introduction and Dry Chemical Feed

❖ **Objectives:**

- Explain chemical feed calculation considerations for each of the four components of a chemical feed system.

- Explain the difference between dry feed and liquid feed calculations.

- Demonstrate a new method of performing chemical feed calculations.

- Explain and practice dry chemical feed calculations.

## Introduction: Four Components of a Chemical Feed System

- Chemical Product Strength.

- Product _____ _____.

- Plant Flow.

- Chemical _____.

# CHEMICAL FEED DIAGRAM

Chemical Product:
- Density
- Specific Gravity
- Product Strength
  lbs (dry)/gal (product)

**Chemical Product**

Product Feed Rate:
- Dry Feed
  lbs/day; gm/min
- Liquid Feed
  GPM; GPH; mL/min

**Product Feed**

**Plant Flow**

MGD; GPD; GPM

**Chemical Dosage**

mg(dry)/L(plant)
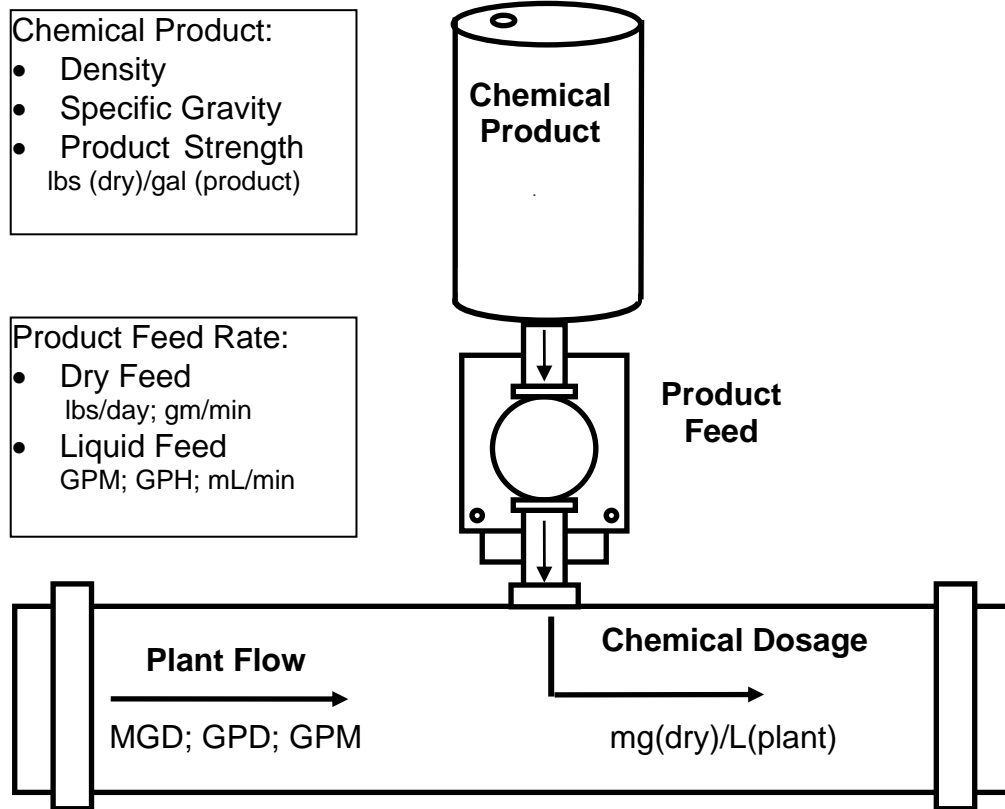
Chemical Dosage:

**Question 1:** How much dry chemical is needed in the treated water?

- The amount of **dry chemical** in the treated water is known as _____.

- Chemical dosage is almost always given in units of _____.

- The amount of dry chemical in the dosage is its weight in milligrams.

- It doesn't matter what form the chemical is in, dry or liquid, it is the amount of **dry chemical** we are interested in.

## Plant Flow:

**Question 2:** What (or how much) is the plant flow?

- Meters measure the plant flow in million gallons per day (MGD), gallons per day (GPD), or gallons per minute (GPM).

## Chemical Product:

**Question 3:** How much dry chemical is in the chemical product?

| **WAYS TO FEED CHEMICAL PRODUCT** |
| :--- |
| • Dry chemical feed (i.e., lime).<br><br>• Dry chemical mixed with water (i.e., soda ash).<br><br>• Liquid chemical fed neat - undiluted (i.e., caustic soda, inhibitors).<br><br>• Liquid chemical diluted with water (i.e. sodium hypochlorite for disinfection). |

- The amount of **dry chemical** in the **chemical product** is called _____ _____.

- If we know how much dry chemical is in the **product**, we can calculate how much dry chemical will be in the **dosage**.

- If you are feeding a liquid, the product strength is the weight of _____ chemical in a volume of liquid _____.

- Product strength for a liquid chemical is calculated from the **product density** (how much a volume of the liquid product weighs) and **percent strength** (the percentage of the product which is dry chemical).

## Product Feed:

**Question 4:** How much product must be fed to get the desired dosage?

- For dry product feed, the units are usually _____.

- If the product is fed as a liquid, most systems will have metering pumps that feed in _____.

## Difficulties of Chemical Feed Calculations

1. Converting between English and Metric units.

    - Chemical product units can be pounds, gallons, grams or milliliters.
    - Product feed is either gallons or milliliters.
    - Dosage units are mg/L.
    - Plant flow is in gallons.

2. Understanding which units are correct.

    - Pounds of what - dry chemical or liquid chemical?
    - Gallons or liters of what- chemical product or plant flow?

3. Understanding product information and how to use it.

    - Product density or specific gravity.
    - Commercial purity.
    - Percent strength.

## Dry Chemical Feed

- Corrosion control chemicals normally fed dry are lime and soda ash.

- **Product Strength:** Lime and soda ash can be considered essentially full strength ($\approx$ 100%). **Exception**: "Light" soda ash has a product strength of about 90%.

- **Commercial purity**: Some products such as certain grades of lime may contain significant amounts of impurities.

- Refer to the Chemical Feed Calculation section of the Appendix for more information on dry chemicals with less than full product strength.

## Chemical Feed Calculations for Dry Chemicals

## Dosage Formula

**Dry Chemical Feed (lbs/day) = Plant Flow (MGD) x Dosage (mg/L) x 8.34**

- More information on the dosage formula is located in the Chemical Feed Calculation section of the Appendix.

## CHEMICAL FEED CALCULATION DIAGRAM
## DRY FEED
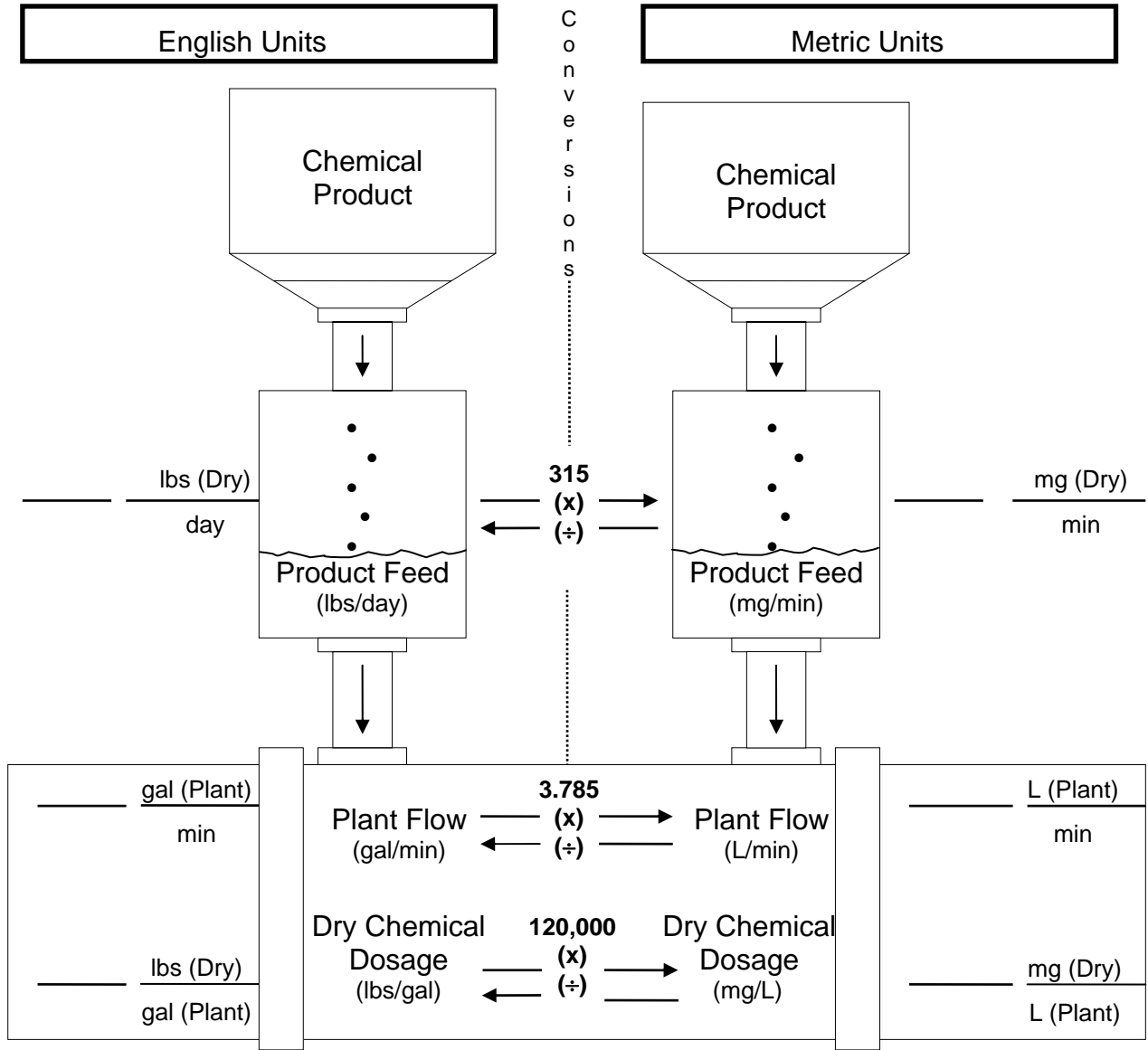
| English Units | Conversions | Metric Units |
|---|---|---|

Chemical Product

Chemical Product

_____ lbs (Dry) / day

**315**
**(x)**
**(÷)**

Product Feed (lbs/day)

Product Feed (mg/min)

_____ mg (Dry) / min

_____ gal (Plant) / min

**3.785**
Plant Flow **(x)** Plant Flow
(gal/min) **(÷)** (L/min)

_____ L (Plant) / min

_____ lbs (Dry) / gal (Plant)

Dry Chemical **120,000** Dry Chemical
Dosage **(x)** Dosage
(lbs/gal) **(÷)** (mg/L)

_____ mg (Dry) / L (Plant)

**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.

- The diagram starts with **chemical product**, followed by **product feed** and then **plant flow** and **dosage.**

- The diagram contains the units needed to solve chemical feed problems.

- In the middle of the diagram are the conversions needed to get from English to Metric or vice versa.

The procedure at the bottom of the diagram explains how you use this diagram to solve a problem.

## 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 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 1**

## CHEMICAL FEED CALCULATION DIAGRAM
## DRY FEED
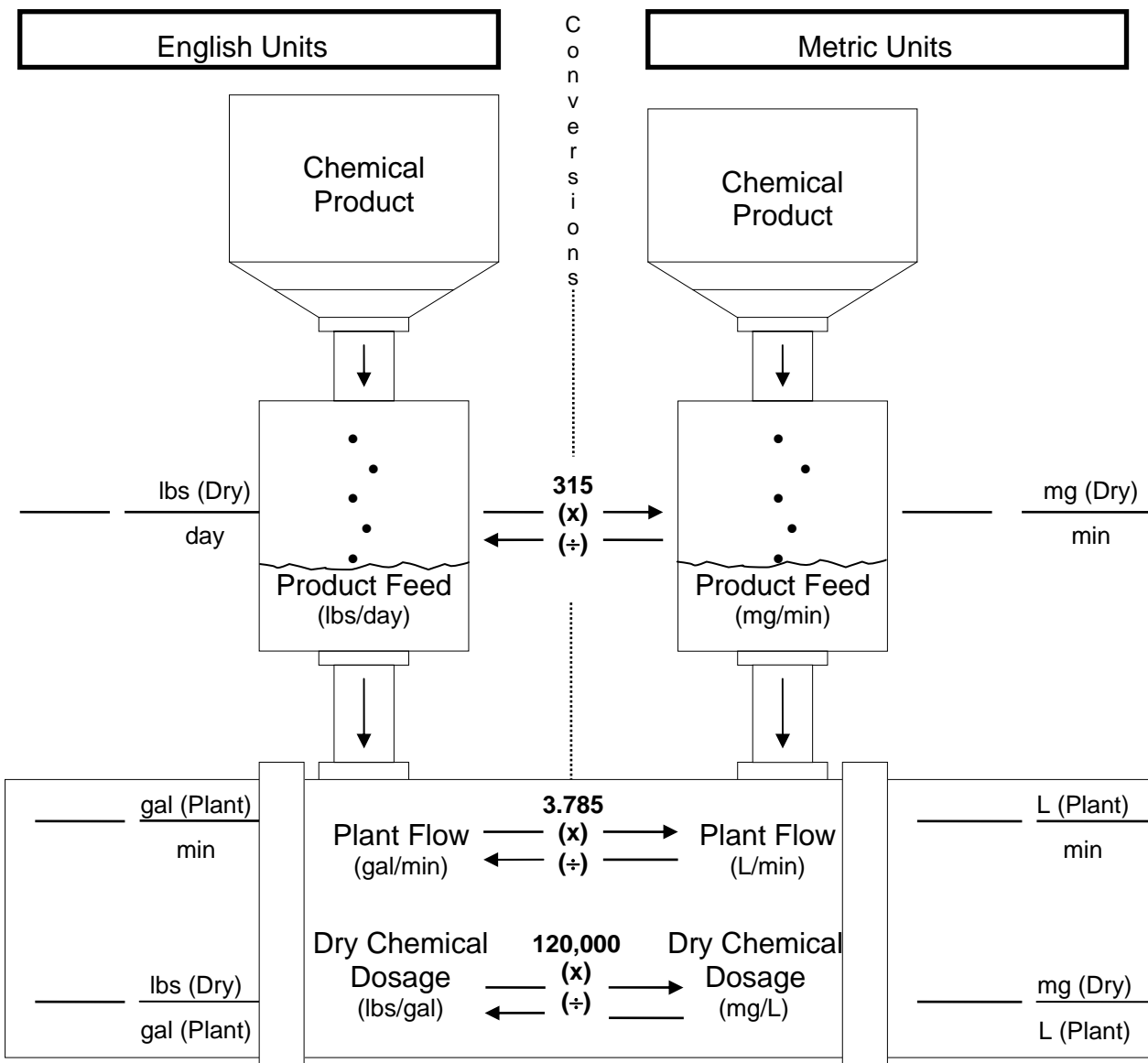


| English Units | Conversions | Metric Units |

Chemical Product

Chemical Product

lbs (Dry) / day

**315 (x) (÷)**

mg (Dry) / min

Product Feed (lbs/day)

Product Feed (mg/min)

gal (Plant) / min

Plant Flow (gal/min) **3.785 (x) (÷)** Plant Flow (L/min)

L (Plant) / min

lbs (Dry) / gal (Plant)

Dry Chemical Dosage (lbs/gal) **120,000 (x) (÷)** Dry Chemical Dosage (mg/L)

mg (Dry) / L (Plant)

**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 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?

Unit cancellation:

## CHEMICAL FEED CALCULATION DIAGRAM
## DRY FEED

C o n v e r s i o n s

| English Units | | Metric Units |
|---|---|---|

Chemical Product

Chemical Product

$$\frac{lbs\ (Dry)}{day}$$

**315**
**(x)**
**(÷)**

$$\frac{mg\ (Dry)}{min}$$

Product Feed (lbs/day)

Product Feed (mg/min)

$$\frac{gal\ (Plant)}{min}$$

**3.785**
Plant Flow **(x)** Plant Flow
(gal/min) **(÷)** (L/min)

$$\frac{L\ (Plant)}{min}$$

Dry Chemical **120,000** Dry Chemical
$$\frac{lbs\ (Dry)}{gal\ (Plant)}$$ Dosage **(x)** Dosage $$\frac{mg\ (Dry)}{L\ (Plant)}$$
(lbs/gal) **(÷)** (mg/L)

**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 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?

Unit cancellation:

## Summary

 **Key Points:**

- Chemical feed calculations involve four primary considerations:

1.   Chemical _____ _____.

2.   Product Feed Rate.

3.   Plant _____.

4.   Chemical Dosage.

- Dosage is based on the amount of _____ chemical fed, no matter whether the chemical is fed dry or as a liquid.

- The chemical feed calculation diagram is a useful tool for operators.

A working knowledge of unit cancellation is beneficial.

# MODULE 18
## *Chemical Feed Calculations 2*
## *Liquid Chemical Feed*

❖ **Objectives:**

- Explain chemical product considerations for liquid chemicals.

- Calculate chemical product strength.

- Demonstrate and practice liquid feed calculations using the diagram method.

## Introduction to Liquid Chemical Feed

- Liquid feed calculations are more complex than dry feed calculations.

- Understanding and using **chemical product** information is the most difficult and confusing part of liquid feed calculations.

- **Dosage** is based on how much **dry chemical** is fed, even for liquid chemicals.

- The diagram method will help operators understand liquid chemical feed.

## Liquid Chemical Product Considerations

- Feeding the product neat or mixing it with water.

- Density/specific gravity of the product.

- Percent strength of the product.

- Calculation of the product strength.

## Feeding Liquid Product Neat

When these products are delivered from the chemical supplier, two important pieces of information must be obtained:

- Product density or specific gravity.
- Percent strength (sometimes called concentration).

This information can be found on the **MSDS** sheets and the **invoice**.

## Density/Specific Gravity

**Q1:** What is **density**?  Density is how much a certain _____ of something _____.

**Q2:** What is **specific gravity**?  Specific gravity is the density of something compared to the density of _____.

The density of water in the English system is _____.

In the metric system, the density of water is 1 gm/mL or 1 kg/L.

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

**Q4:** What are the units of specific gravity? _____

**Q5:** If a liquid chemical has a specific gravity of 1.28, what is its density in Metric units and in English units?

Metric: _____          English: _____

The density of your treatment chemical product is needed to calculate **product strength**.

Percent Strength (Concentration)

Percent strength may be found on the MSDS sheet or product invoice.

Chemical Product Strength

- In evaluating the chemical product, finding **product strength** is the goal.

- Product strength is defined as the weight of **dry chemical** in a certain volume of **liquid product**.

**Chemical Product Strength = <u>Weight (Dry) Chemical</u>**
$$\text{Volume (Product)}$$

- The most common unit for product strength is **lbs/gal**.

**Product density** and **percent strength** are used to calculate the chemical product strength.   To calculate product strength from product density and percent strength you can use the following formula:

**Product Strength (lbs/gal) =  Product Density (lbs/gal)  x  <u>Percent Strength</u>**
$$\text{100}$$

---

## 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?

Product Strength (lbs/gal) = Product Density (lbs/gal)  X  <u>Percent Strength</u>
$$\text{100}$$

# Chemical Feed Calculation Diagram

**CHEMICAL FEED CALCULATION DIAGRAM**
**LIQUID FEED**

| English Units | | | C o n v e r s i o n s | | Metric Units |
|---|---|---|---|---|---|

$$\frac{lbs}{gal\ (Product)}$$

Chemical
Product
Density (lbs/gal)

Chemical
Product
SG=Density (gm/mL)

$$\frac{gm}{mL\ (Product)}$$

$$\frac{(\quad)\ \%}{100}$$

**(x)**

Calculate
Product Strength

**(x)**

$$\frac{(\quad)\ \%}{100}$$

$$\frac{lbs\ (Dry)}{gal\ (Product)}$$

Chemical Product
Strength
(lbs/gal)

**8.34**
—(÷)→

←(x)—

Chemical
Product Strength
(gm/mL)

$$\frac{gm\ (Dry)}{mL\ (Product)}$$
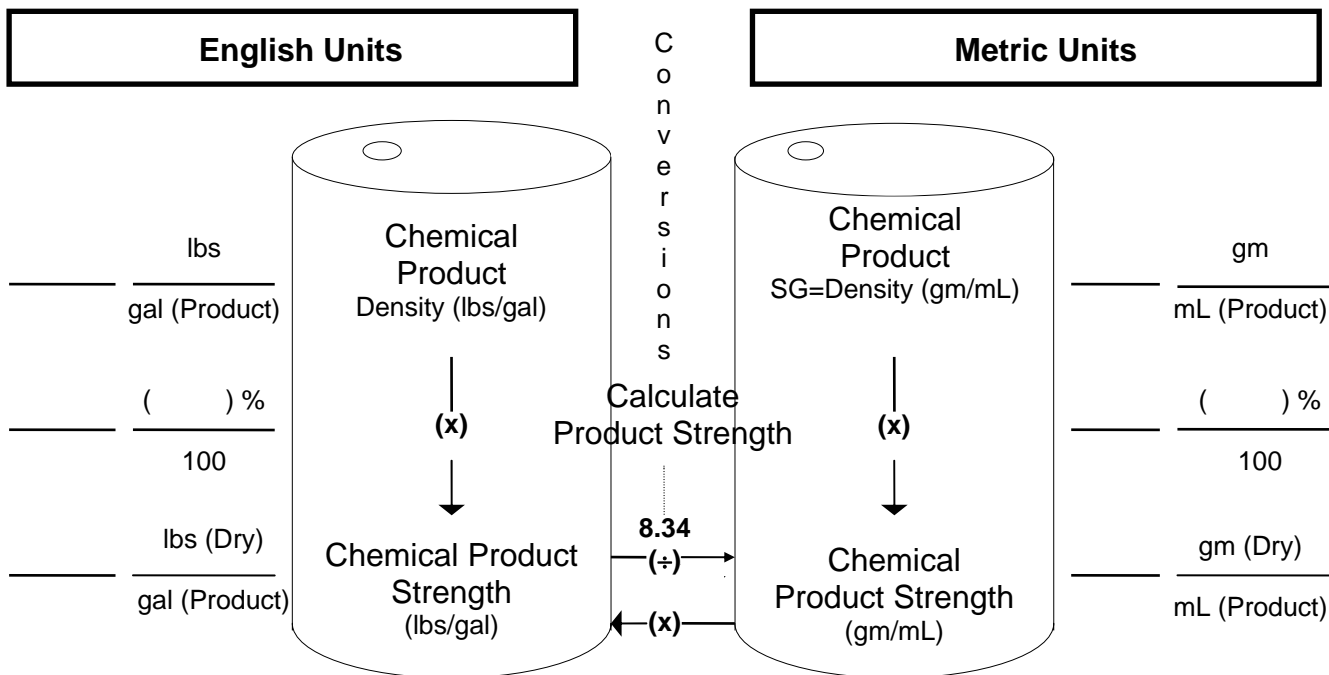
The chemical product portion helps you calculate chemical product strength from product density and percent strength.

What is shown in the product container and beside the container is essentially the equation for product strength we just used.

- **Density**.

- **Percent Strength** is given as a decimal.

- **Product Strength** is obtained by multiplying the density by the percent strength.

## 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% $PO_4$. What is the product strength in lbs/gal?

**CHEMICAL FEED CALCULATION DIAGRAM**
**LIQUID FEED**
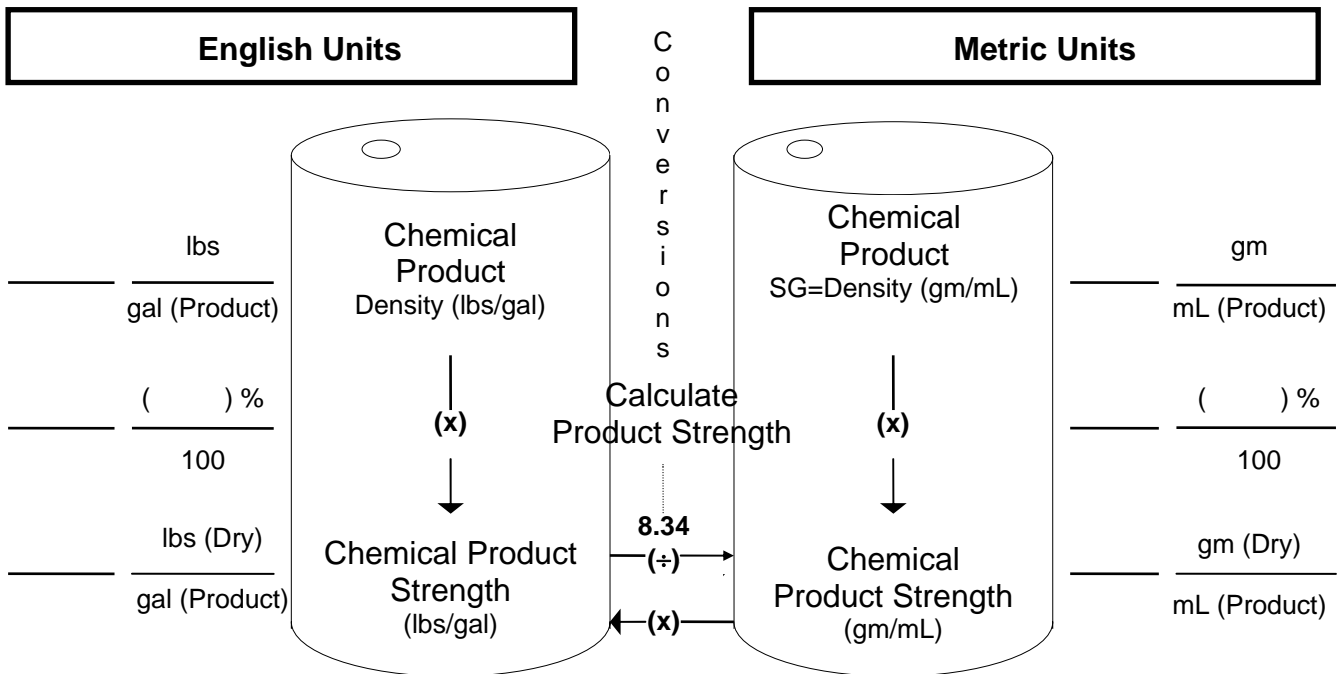


## Liquid Product Feed Considerations

Most small and medium systems will calibrate metering pumps in flow units of **mL/min**. Larger systems may use pumps that are calibrated in gal/min or gal/hr.

## Plant Flow/Chemical Dosage Considerations

Plant flow and dosage considerations are the same as for dry chemical feed.

- Dosage is in mg/L, that is, milligrams of **dry chemical** in a liter of **plant flow.**

- Plant flow must be measured.

## Liquid Chemical Feed Problem Using the Diagram

**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? Use the Diagram on page 18-8.

Solution Steps

1. Fill in the known data.

2. Put a question mark (?) for the value of the unknown data.

3. Calculate chemical product strength.

4. Convert all data to the units on the side where the ? is.

5. Use unit cancellation to solve for the unknown.

## CHEMICAL FEED CALCULATION DIAGRAM
### LIQUID FEED
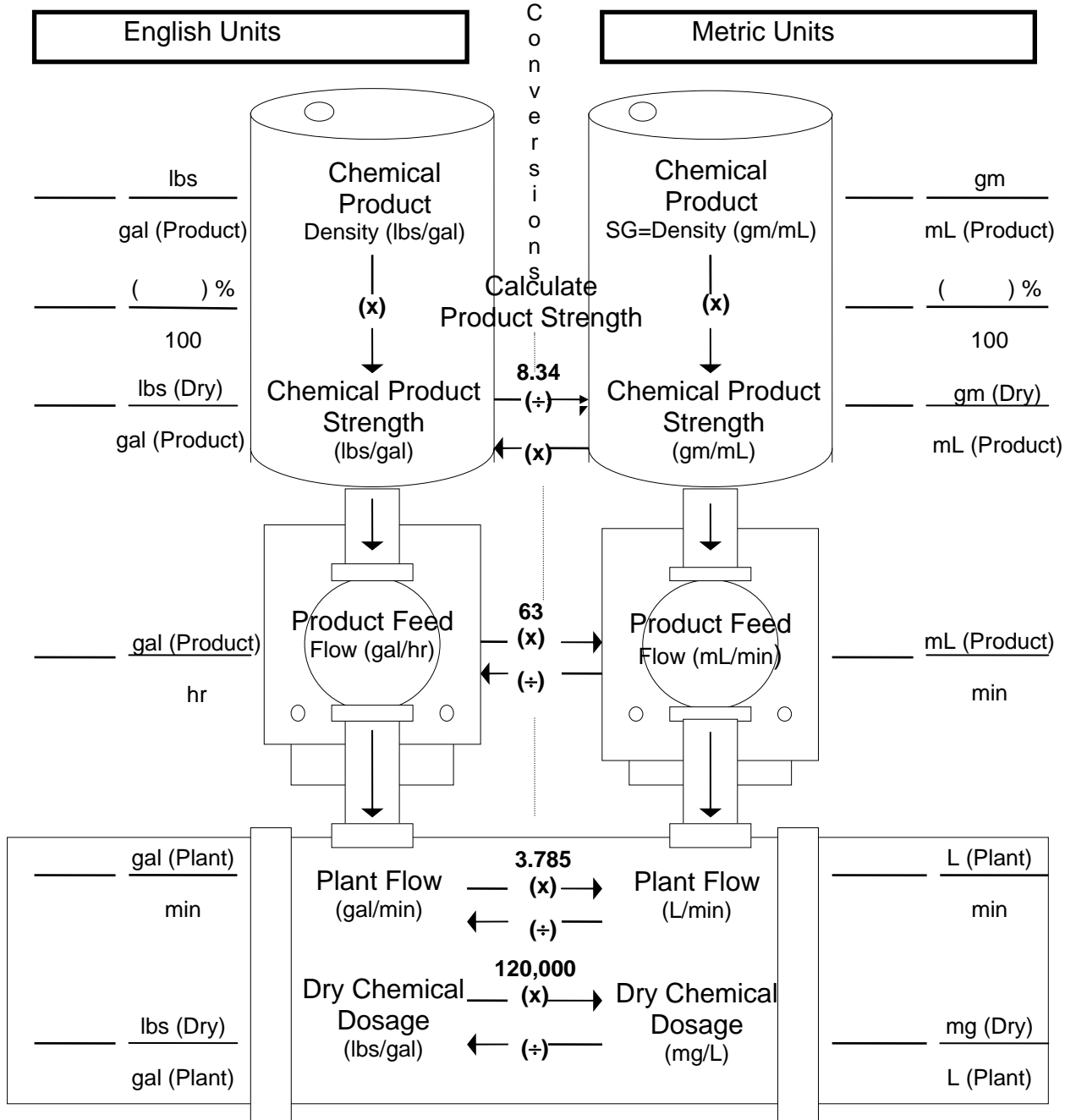
C
o
n
v
e
r
s
i
o
n
s

| English Units | | Metric Units |

_____ lbs / gal (Product)

**Chemical Product**
Density (lbs/gal)

**Chemical Product**
SG=Density (gm/mL)

_____ gm / mL (Product)

_____ ( ___ ) % / 100

Calculate
Product Strength

**(x)**

**(x)**

_____ ( ___ ) % / 100

_____ lbs (Dry) / gal (Product)

**Chemical Product Strength**
(lbs/gal)

**8.34**
**(÷)→**
**←(x)**

**Chemical Product Strength**
(gm/mL)

_____ gm (Dry) / mL (Product)

_____ gal (Product) / hr

**Product Feed**
Flow (gal/hr)

**63**
**(x)**
**(÷)**

**Product Feed**
Flow (mL/min)

_____ mL (Product) / min

_____ gal (Plant) / min

**Plant Flow**
(gal/min)

**3.785**
**(x)→**
**←(÷)**

**Plant Flow**
(L/min)

_____ L (Plant) / min

_____ lbs (Dry) / gal (Plant)

**Dry Chemical Dosage**
(lbs/gal)

**120,000**
**(x)→**
**←(÷)**

**Dry Chemical Dosage**
(mg/L)

_____ mg (Dry) / L (Plant)

**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:

## Liquid Chemical Feed Problem Using the Diagram

**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? Use the Diagram on page 18-10.

## CHEMICAL FEED CALCULATION DIAGRAM
## LIQUID FEED
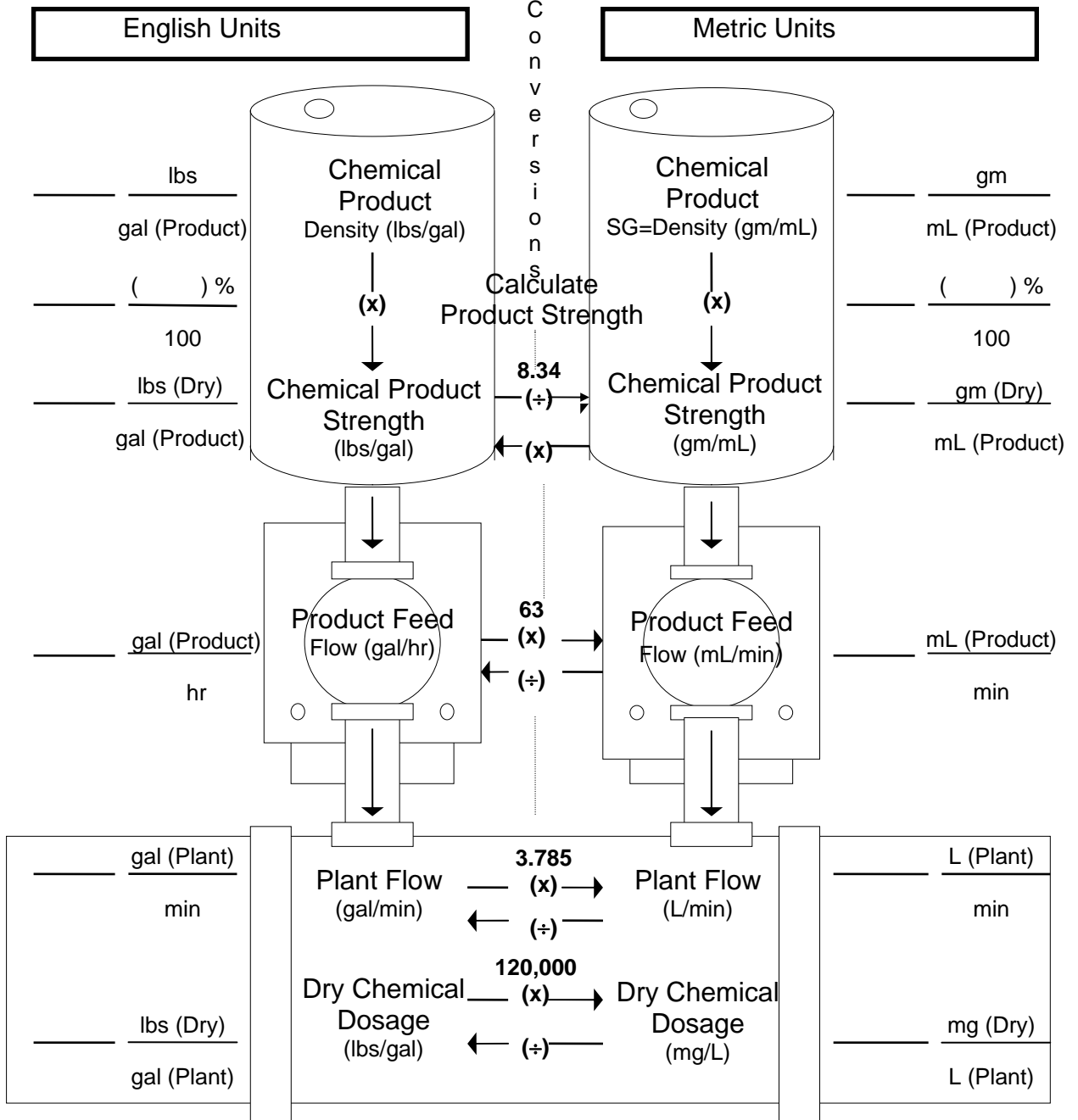
| English Units | | Metric Units |
|---|---|---|

C
o
n
v
e
r
s
i
o
n
s

_____ $\dfrac{\text{lbs}}{\text{gal (Product)}}$

**Chemical Product**
Density (lbs/gal)

_____ $\dfrac{(\quad) \%}{100}$

Calculate Product Strength

**(x)**

_____ $\dfrac{\text{lbs (Dry)}}{\text{gal (Product)}}$

**Chemical Product Strength** (lbs/gal)

**8.34**
**(÷)** →

**(x)** ←

**Chemical Product**
SG=Density (gm/mL)

**(x)**

**Chemical Product Strength** (gm/mL)

_____ $\dfrac{\text{gm}}{\text{mL (Product)}}$

_____ $\dfrac{(\quad) \%}{100}$

_____ $\dfrac{\text{gm (Dry)}}{\text{mL (Product)}}$

_____ $\dfrac{\text{gal (Product)}}{\text{hr}}$

**Product Feed** Flow (gal/hr)

**63**
**(x)** →
**(÷)** ←

**Product Feed** Flow (mL/min)

_____ $\dfrac{\text{mL (Product)}}{\text{min}}$

_____ $\dfrac{\text{gal (Plant)}}{\text{min}}$

**Plant Flow** (gal/min) —

**3.785**
**(x)** →
**(÷)** ←

**Plant Flow** (L/min)

_____ $\dfrac{\text{L (Plant)}}{\text{min}}$

_____ $\dfrac{\text{lbs (Dry)}}{\text{gal (Plant)}}$

**Dry Chemical Dosage** (lbs/gal)

**120,000**
**(x)** →
**(÷)** ←

**Dry Chemical Dosage** (mg/L)

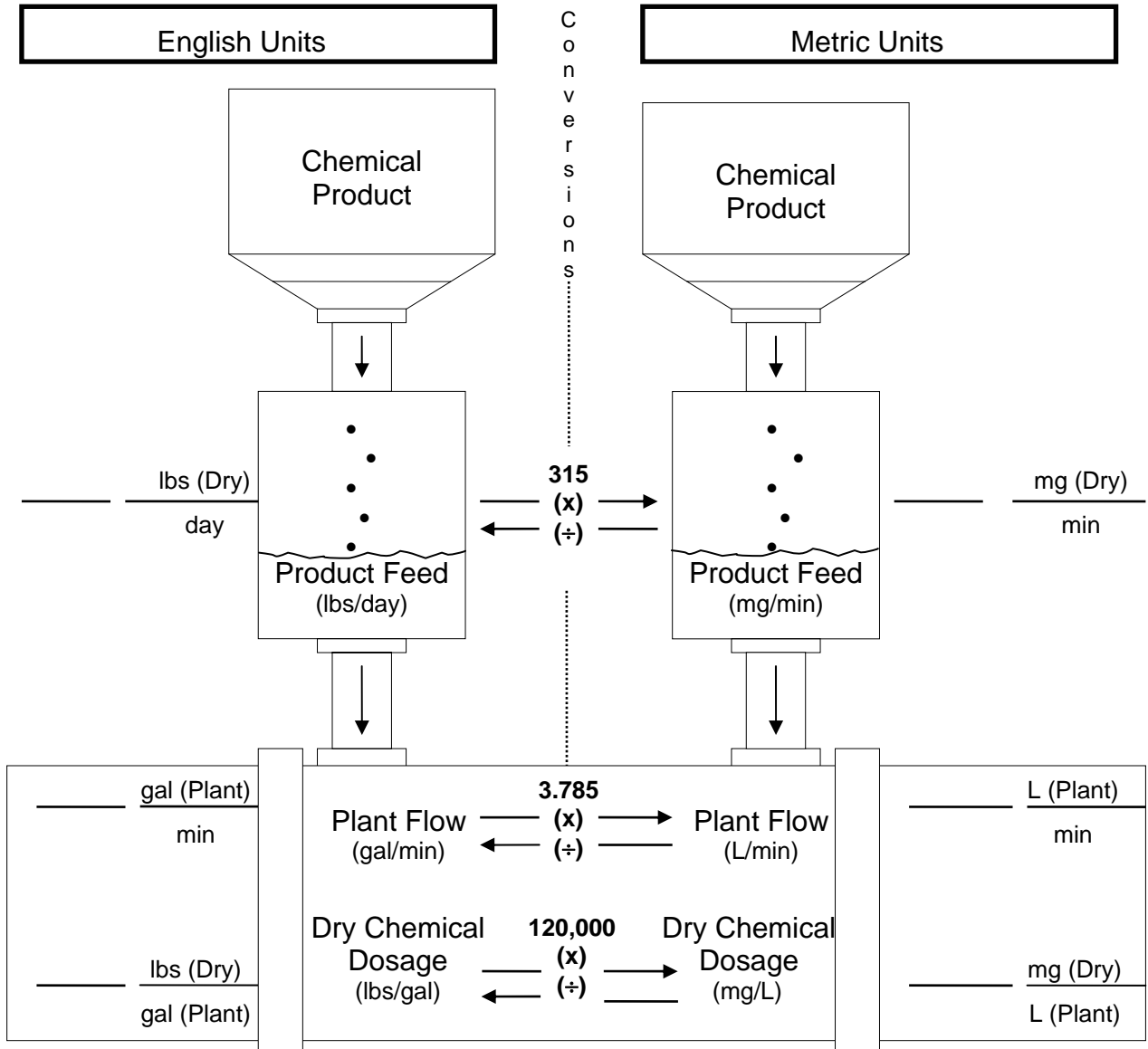_____ $\dfrac{\text{mg (Dry)}}{\text{L (Plant)}}$

**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:

## Summary

**Key Points:**

- Liquid feed calculations are more complex than dry feed calculations.

- Understanding and using _____ _____ information is the most difficult and confusing part of liquid feed calculations.

- Dosage is based on how much _____ chemical is fed, even for liquid chemicals.

- The diagram method will help operators understand liquid chemical feed.

# MODULE 19
## *Pump Calibration Workshop*

❖ **Objectives:**

- Gain hands-on experience conducting liquid metering pump calibrations.

- Illustrate the usefulness of a pump calibration curve.

To achieve accurate chemical feed, it is first necessary to make a decision on the desired chemical dosage in mg/L.

The chemical feed pump must then be adjusted to deliver the selected dosage.  This is referred to as the **feed rate**.

The feed rate determines how the chemical will be added to the water and could be expressed in terms of mL/min, gal/day, or lbs/day.

Feed pumps are adjusted with the use of a pump calibration curve.

## Mechanical Diaphragm Pump

There are two adjustments that can be made to control the output:

1. Length of the stroke.

2. Number of repetitions.

Chemical feed pumps should be calibrated during start-up to determine the optimal pumping range.

With time, a pumps output will change due to wear and tear of the moving parts.

A new pump calibration curve should be constructed:

- At least once per year.

- If troubleshooting points to the need for a new pump calibration.

- If any maintenance is performed on the pump.

## Liquid Feed Pump Calibration Workshop

## 1.  Pump Calibration Equipment

### Pump Calibration Chamber

A pump calibration chamber:

- Is typically located on the suction side of the pump.

- Consists of a graduated cylinder.

- Should be properly sized.

### Alternate Method Using a 1,000 mL Beaker

Materials needed include:

- Suction tubing.

- A 1,000 mL beaker.

- A 100 mL graduated cylinder.

- A 250 mL beaker.

The beaker method is an alternate method. The best way to conduct a pump calibration is with a calibration chamber. Calibration using a chamber is much easier to perform, is safer, and requires only one person to complete.

## 2. Prime the Pump

To prime the pump:

1. Fill the calibration chamber or a 1,000 mL beaker with water.

2. Turn on the pump. Set the "Percent of Full Stroke" to **80%** and the speed to **100**. (For many pumps, the dial settings can only be adjusted while the pump is on.)

3. Allow the pump to run until water is pumped through the discharge tubing. Then, turn the pump off. The pump is now primed.

Many pumps are self-priming provided the suction lift is five (5) feet or less. If the pump will not prime:

1. Open the pressure relief valve to bleed off the entrapped air until water is exiting through the valve. Then, close the valve.

2. Allow the pump to run until water is pumped through the discharge tubing. Then, turn the pump off. The pump is now primed.

## 3. Pump Calibration Procedure

### Pump Calibration Using a Calibration Chamber

1. Refill the chamber with water.

2. Check that the "Percent of Full Stroke" setting is at **80%.**

3. Note or record the starting volume in the calibration chamber.

4. Turn the pump on, set the speed to **20**, and allow the pump to run for **three (3) minutes**.  Then, turn the pump off.

5. Note or record the ending volume in the chamber and determine the volume of water pumped.

6. Record the mL of water pumped and the time the pump was allowed to run on the Liquid Feed Pump Calibration Table.

| LIQUID FEED PUMP CALIBRATION TABLE |
|---|

% Stroke:       _____

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

7. Repeat steps 1-6 at speed settings of **40, 60, 80 and 100**. Record the results on the table.  **Note:**  Allow the pump to run for **two (2) minutes** at the speed setting of **40**.  For all others **(60, 80 and 100)**, allow the pump to run for **one (1) minute**.

8. When all of the results have been recorded on the table, perform the following calculation to determine the feed rate, mL/min.

    Calculate the feed rate (mL/min) by dividing the volume pumped by the elapsed time.

For example, if 80 mL was pumped in two (2) minutes, the feed rate would be:

Feed Rate (mL/min)  =  $\underline{80 \text{ mL}}$  =  40 mL
                                2 min

Record the feed rates on the table.

Proceed to the section on Construction of a Calibration Curve.

Pump Calibration Using a 1,000 mL Beaker

1. Refill the 1,000 mL beaker with water.

2. Check that the "Percent of Full Stroke"  setting is at **80%.**

3. Note or record a starting mark or volume.

4. Turn the pump on, set the speed to **20**, and allow the pump to run for **three (3) minutes**.  Then, turn the pump off.

5. To determine the volume of water pumped, use a 100 mL graduated cylinder filled with water to the 100 mL mark.  Pour water from the graduated cylinder into the 1,000 mL beaker until the water level is back up to the starting mark or volume.  Then, measure the volume of water poured from the graduated cylinder to fill the 1,000 mL beaker.  This is the volume of water pumped.  **Note:**  This step is necessary to accurately determine the volume of water pumped.  A 1,000 mL beaker does not contain small enough increments to determine the mLs pumped.

6. Record the mL of water pumped and the time the pump was allowed to run on the Liquid Feed Pump Calibration Table.

| LIQUID FEED PUMP CALIBRATION TABLE |
|---|

% Stroke:     _____

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

7. Repeat steps 1-6 at speed settings of **40, 60, 80 and 100**. Record the results on the table. **Note:** Allow the pump to run for **two (2) minutes** at the speed setting of **40**. For all others **(60, 80 and 100)**, allow the pump to run for **one (1) minute**.

8. When all of the results have been recorded on the table, perform the following calculation to determine the feed rate, mL/min.

   Calculate the feed rate (mL/min) by dividing the volume pumped by the elapsed time.

   For example, if 80 mL was pumped in two (2) minutes, the feed rate would be:

   Feed Rate (mL/min)  =  $\underline{80\ mL}$  =  40 mL
   　　　　　　　　　　　　　2 min

   Record the feed rates on the table.

Proceed to the section on Construction of a Calibration Curve.

## 4. Construction of a Calibration Curve

1. Plot each Feed Rate (mL/min) vs. Pump Speed setting on the graph.

2. Connect each of the points together with a straight line.

PUMP: _____      PUMP CALIBRATION CURVE     DATE: _____

% STROKE: _____



FEED RATE mL/min

PUMP SPEED SETTING
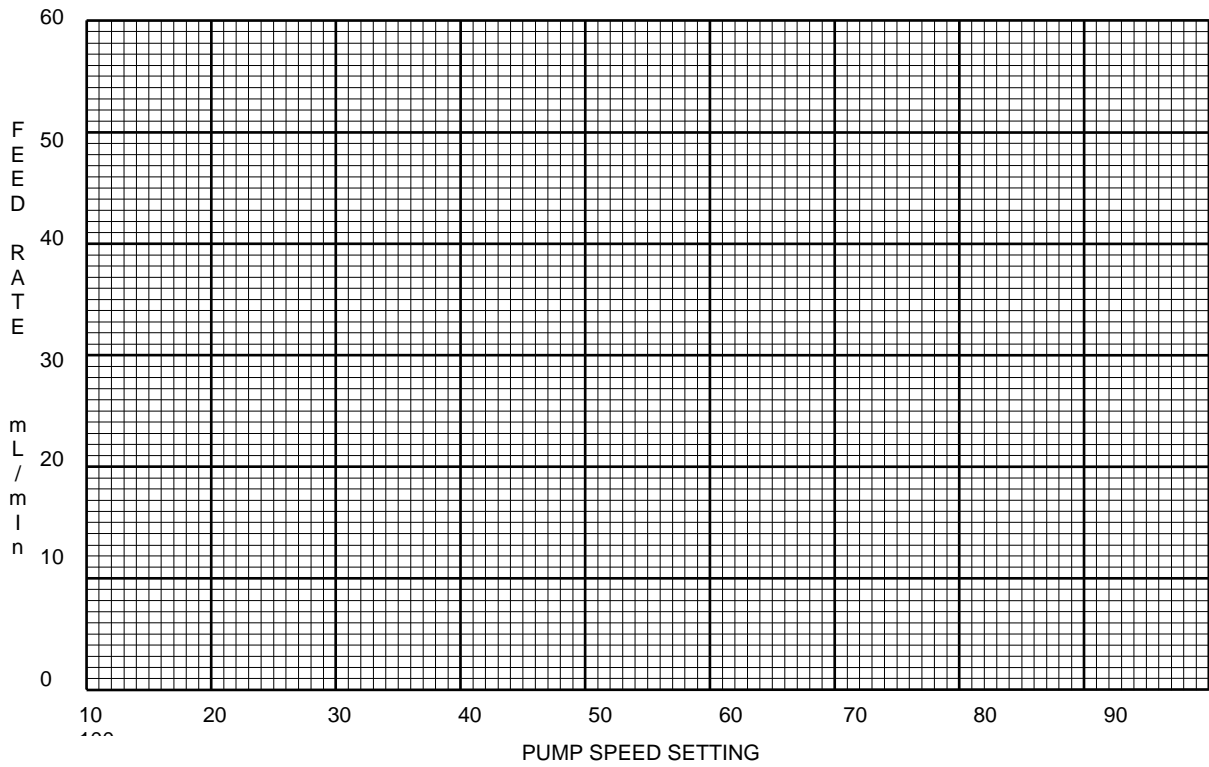
## Discussion Following Pump Calibration Workshop

This is only a simulation of a pump calibration.

An actual calibration would be conducted using a chamber (typically) on the suction side of the pump so that calibration could be conducted while the pump was on-line, under normal operating conditions (normal pressures, ...).

**Operator Tips:  Pump Calibration**

- Pump calibration is conducted to determine the pump's _____.

- 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 _____ 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 _____ the desired setting and then slowly increased to the appropriate setting.

Theoretical Pump Output:

PUMP OUTPUT = MAXIMUM PUMP OUTPUT X % SPEED X % STROKE

The maximum pump output can be found on the dataplate on the pump control panel.

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

$$\frac{24.0 \text{ gal}}{\text{day}} \text{ X } .80 \text{ X } 1.0 = \frac{\textbf{19.2 gal}}{\textbf{day}}$$

$$\frac{19.2 \text{ gal}}{\text{day}} \text{ X } \frac{\text{day}}{1440 \text{ min}} \text{ X } \frac{3785 \text{ mL}}{\text{gal}} = \frac{\textbf{50.5 mL}}{\textbf{min}}$$

The formula should only be used as an estimate because the output will change with wear and tear on the pump.

Pump calibration is still the most accurate tool used to determine the pump's output.

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

The optimal setting would take into account:

- The dosage required.

- The manufacturer's recommendations for minimum and maximum settings.

- The linearity of the "curves".  A more linear (straight) curve is better.

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

| Spot Check |
| --- |

In addition to complete calibrations, spot checks should be performed on the pump.

A spot check is used to compare the current feed rate and corresponding dosage against the most recent  calibration curve.

It is a tool used to determine when a new, full pump calibration is needed.

Use the following guidelines:

- Determine the current feed rate by filling the calibration chamber and allowing the pump to run for a few minutes.

- Then, calculate the dosage using the feed rate and the Chemical Feed Calculation Diagram.

  - If the dosage is within $\pm$ 10% of the expected value, the current pump calibration curve is good and nothing more is needed.

  - If the dosage is outside this range, the pump may need to be recalibrated.

## Dry Feeder Calibration

Calibration is equally important for dry feeders. For information concerning the calibration of dry feeders, see the Pump Calibration section in the Appendix.

## Summary

## Key Points:

- Conduct a pump calibration to determine the pump's _____.

- Construct a pump calibration curve to provide a tool for quickly adjusting chemical feed in response to varying water quality or chemical demand.

- Perform calibrations at least _____.

- Typically, locate the calibration chamber on the suction side of the pump.

## Liquid Chemical Feed Practice Problem

Complete Part 1 and Part 2 using the tools provided.  Show all your work.

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?

Tools needed: diagram (page 2) and pump calibration curve (page 3).
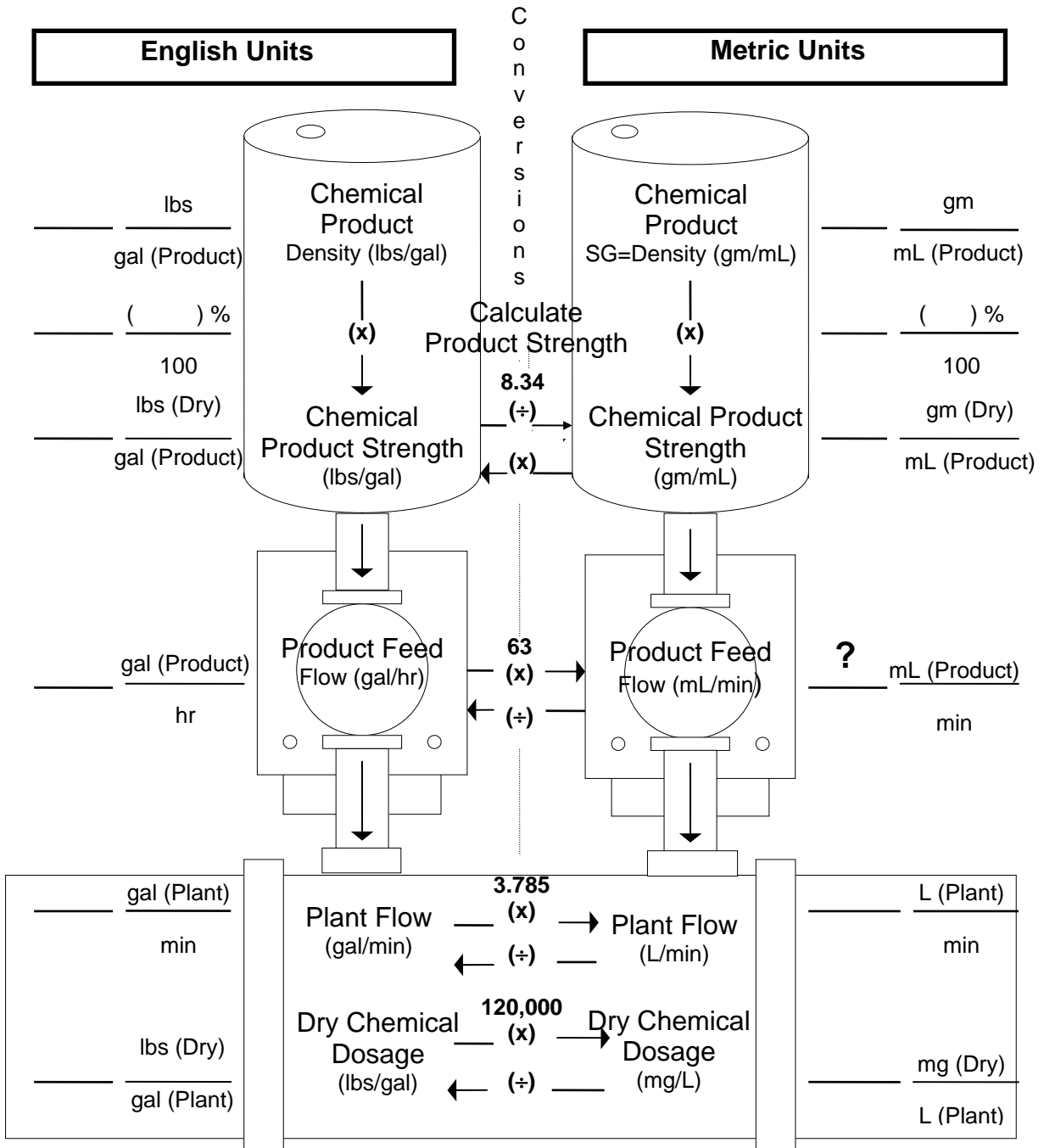
# CHEMICAL FEED CALCULATION
## DIAGRAM

**Part 1**

Conversions

| **English Units** | | **Metric Units** |
|---|---|---|

_____ lbs / gal (Product)

Chemical Product
Density (lbs/gal)

**(x)**

_____ ( _____ ) % / 100

**(x)**

_____ lbs (Dry) / gal (Product)

Chemical Product Strength (lbs/gal)

Calculate Product Strength

**8.34**
**(÷)**
**(x)**

Chemical Product
SG=Density (gm/mL)

**(x)**

Chemical Product Strength (gm/mL)

_____ gm / mL (Product)

_____ ( _____ ) % / 100

**(x)**

_____ gm (Dry) / mL (Product)

_____ gal (Product) / hr

Product Feed Flow (gal/hr)

**63**
**(x)**
**(÷)**

Product Feed Flow (mL/min)

**?** _____ mL (Product) / min

_____ gal (Plant) / min

Plant Flow _____ (gal/min)

**3.785**
**(x)**
**(÷)** _____

Plant Flow _____ (L/min)

_____ L (Plant) / min

_____ lbs (Dry) / gal (Plant)

Dry Chemical Dosage _____ (lbs/gal)

**120,000**
**(x)**
**(÷)** _____

Dry Chemical Dosage _____ (mg/L)

_____ mg (Dry) / L (Plant)

---

**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:

Day Two Homework

**Liquid Metering Pump Calibration Curve**

(Use for Part 1)

PUMP: _25 % caustic_     STROKE: _80%_   **CALIBRATION CURVE**
DATE: _7/1/01_



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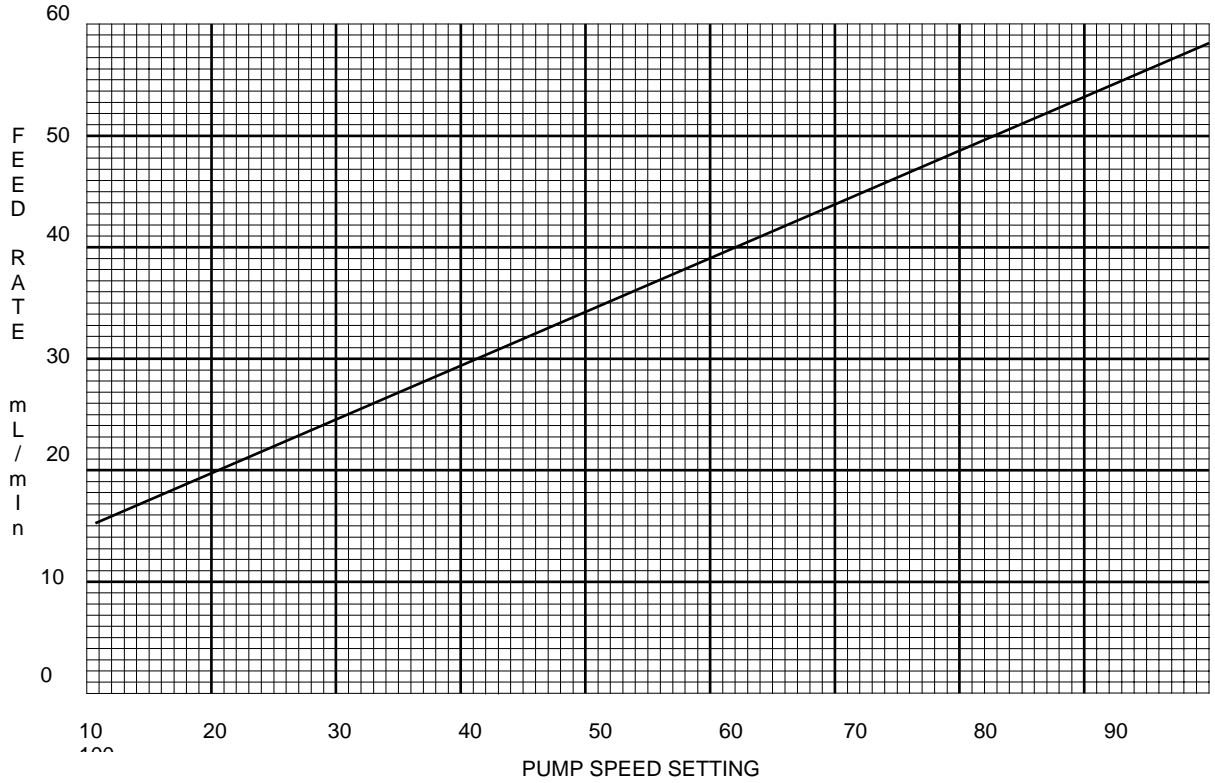
**Part 2:** The plant operator comes in one day and begins his daily stability routine. He measures entry point pH and finds that it is 8.9. A spot check of the feed pump determines that the feed rate is 48 mL/min. What caustic soda dosage is being delivered at that time? Tools needed: diagram (page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

**Part 2**   **CHEMICAL FEED CALCULATION DIAGRAM**
**LIQUID FEED**

C
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s

| English Units | | Metric Units |

_____ lbs / gal (Product)

Chemical Product
Density (lbs/gal)

Chemical Product
SG=Density (gm/mL)

_____ gm / mL (Product)

_____ ( ) % / 100

**(x)**

Calculate Product Strength

**(x)**

_____ ( ) % / 100

_____ lbs (Dry) / gal (Product)

Chemical Product Strength (lbs/gal)

**8.34 (÷)**
**(x)**

Chemical Product Strength (gm/mL)

_____ gm (Dry) / mL (Product)

_____ gal (Product) / hr

Product Feed
Flow (gal/hr)

**63 (x)**
**(÷)**

Product Feed
Flow (mL/min)

_____ mL (Product) / min

_____ gal (Plant) / min

Plant Flow
(gal/min)

**3.785 (x)**
**(÷)**

Plant Flow
(L/min)

_____ L (Plant) / min

_____ lbs (Dry) / gal (Plant)

Dry Chemical Dosage
(lbs/gal)

**120,000 (x)**
**(÷)**

Dry Chemical Dosage
(mg/L)

**?** _____ mg (Dry) / L (Plant)

**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:

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.




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)?

a. 18 GPD
b. 48 GPD
c. 600 GPD
d. none of the above

Day Two Homework

# CHEMICAL FEED CALCULATION
## DIAGRAM
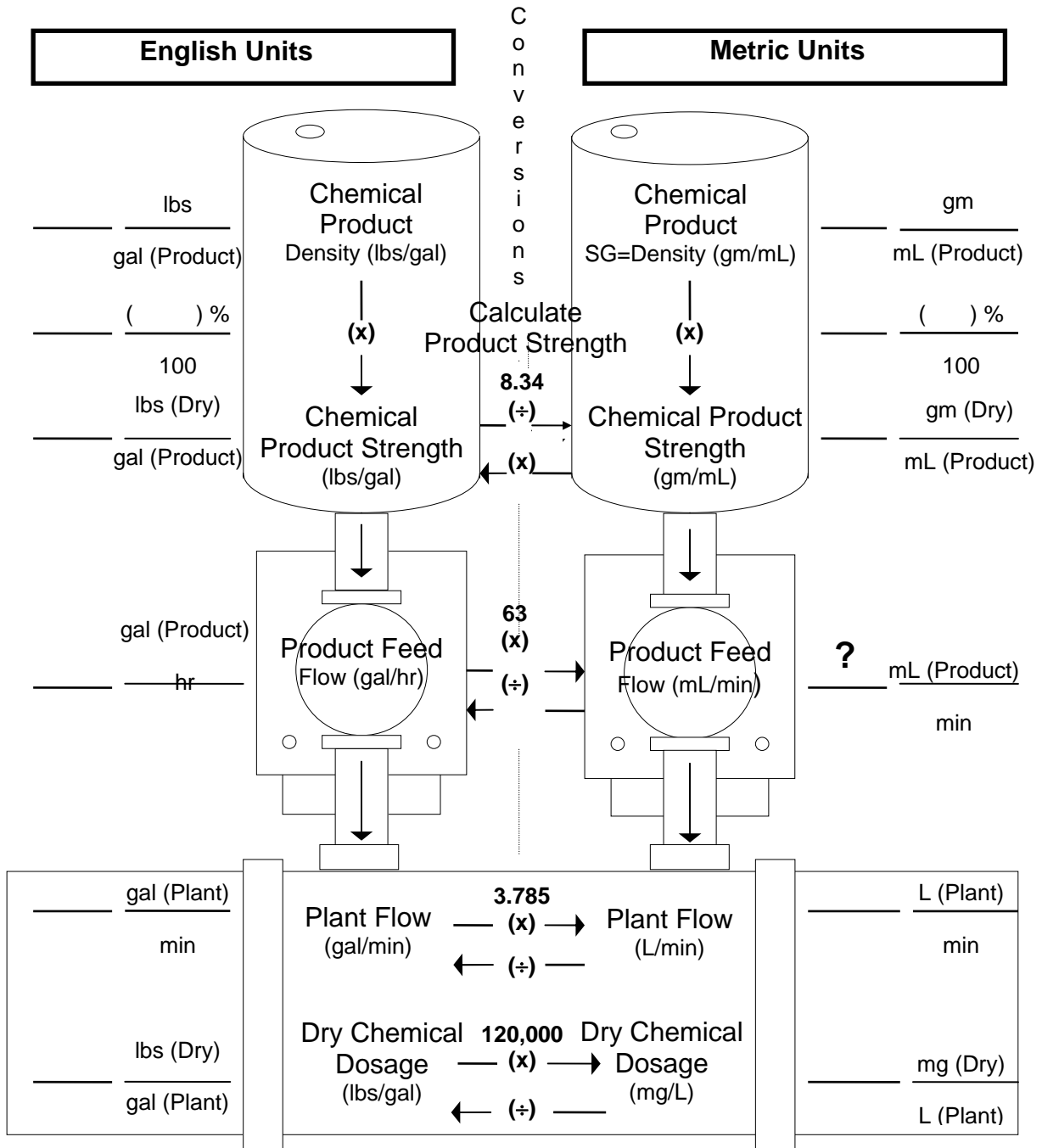
C
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| English Units | | Metric Units |
|---|---|---|

_____ lbs / gal (Product)

Chemical Product
Density (lbs/gal)

Chemical Product
SG=Density (gm/mL)

_____ gm / mL (Product)

_____ ( ___ ) % / 100

**(x)**

Calculate
Product Strength

**(x)**

_____ ( ___ ) % / 100

_____ lbs (Dry) / gal (Product)

Chemical Product Strength (lbs/gal)

**8.34**
**(÷)**

**(x)**

Chemical Product Strength (gm/mL)

_____ gm (Dry) / mL (Product)

_____ gal (Product) / hr

Product Feed Flow (gal/hr)

**63**
**(x)**

**(÷)**

Product Feed Flow (mL/min)

**?** _____ mL (Product) / min

_____ gal (Plant) / min

Plant Flow (gal/min)

**3.785**
**(x)**
**(÷)**

Plant Flow (L/min)

_____ L (Plant) / min

_____ lbs (Dry) / gal (Plant)

Dry Chemical Dosage (lbs/gal)

**120,000**
**(x)**
**(÷)**

Dry Chemical Dosage (mg/L)

_____ mg (Dry) / L (Plant)

**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:

6

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

❖ **Objectives:**

- Practice liquid chemical feed calculations using the techniques you have learned.
- Show how good recordkeeping tools can save time while improving operation.
- Demonstrate and practice the calculation of mixing a day tank.

Constructing a Feed Rate vs. Dosage Table

An important recordkeeping tool for operators feeding corrosion control chemicals is the **Feed Rate vs. Dosage Table.**

FEED RATE VS. DOSAGE TABLE

**Chemical:** _____        **Plant Flow:**
_____

| FEED RATE (mL/min) | DOSAGE (mg/L) |
|---|---|
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |

- This table is completed using the Chemical Feed Calculation Diagram.

*Q: What are the four values that can be calculated on the chemical feed calculation diagram?*

      1. _____
      2. _____
      3. _____
      4. _____

- To complete this table, pick various **dosage** values within the anticipated dosage range and solve for the **feed rate** necessary to deliver each particular dosage.

- The average **plant flow** and the **product strength** must be constant.

- Once you have completed this table, it remains valid as long as the average plant flow and product strength don't change.

- The average plant flow for many systems can be considered constant if the chemical feed pump operation is tied to plant water pump operation and the plant flow rate does not vary significantly during the pump cycle or from one cycle to another.

- The values on the table are **independent of the pump calibration** and are tied in through the pump calibration curve where feed rates are given for various pump settings.

- Systems that are unable to maintain a constant average plant flow will have to use the chemical feed calculation diagram and recalculate the dosage each time the plant flow changes.

| 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 about a 20 minute cycle. 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.

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

<u>Solution</u>

1.  Measure the gallons pumped during the pump cycle.  Since flows and cycle times will vary somewhat during different cycles, 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 |
| **average** | **21** | **1550** |

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

**Part 2:**  A caustic soda dosage range of 20 to 30 mg/L is needed to maintain the target pH.  Construct a Feed Rate vs. Dosage Table.

<u>Solution</u>

1. 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.

2. Calculate product strength on the diagram.

3. 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.

4. Use unit cancellation to solve for the product feed.

5. Place the product feed value on the Feed Rate vs. Dosage Table on page   20-6.  Fill in the chemical and plant flow information.

6. To complete the table for the dosage range, you decide to pick steps at             2 mg/L intervals and calculate the pump feed 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:

$$\frac{17.8}{20} = \frac{?}{22}$$

   Solving for the unknown   ? =  0.89 x 22 = 19.6 $\underline{\text{mL}}$
                                                                    min

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

**Part 2**
**CHEMICAL FEED CALCULATION DIAGRAM**
**LIQUID FEED**
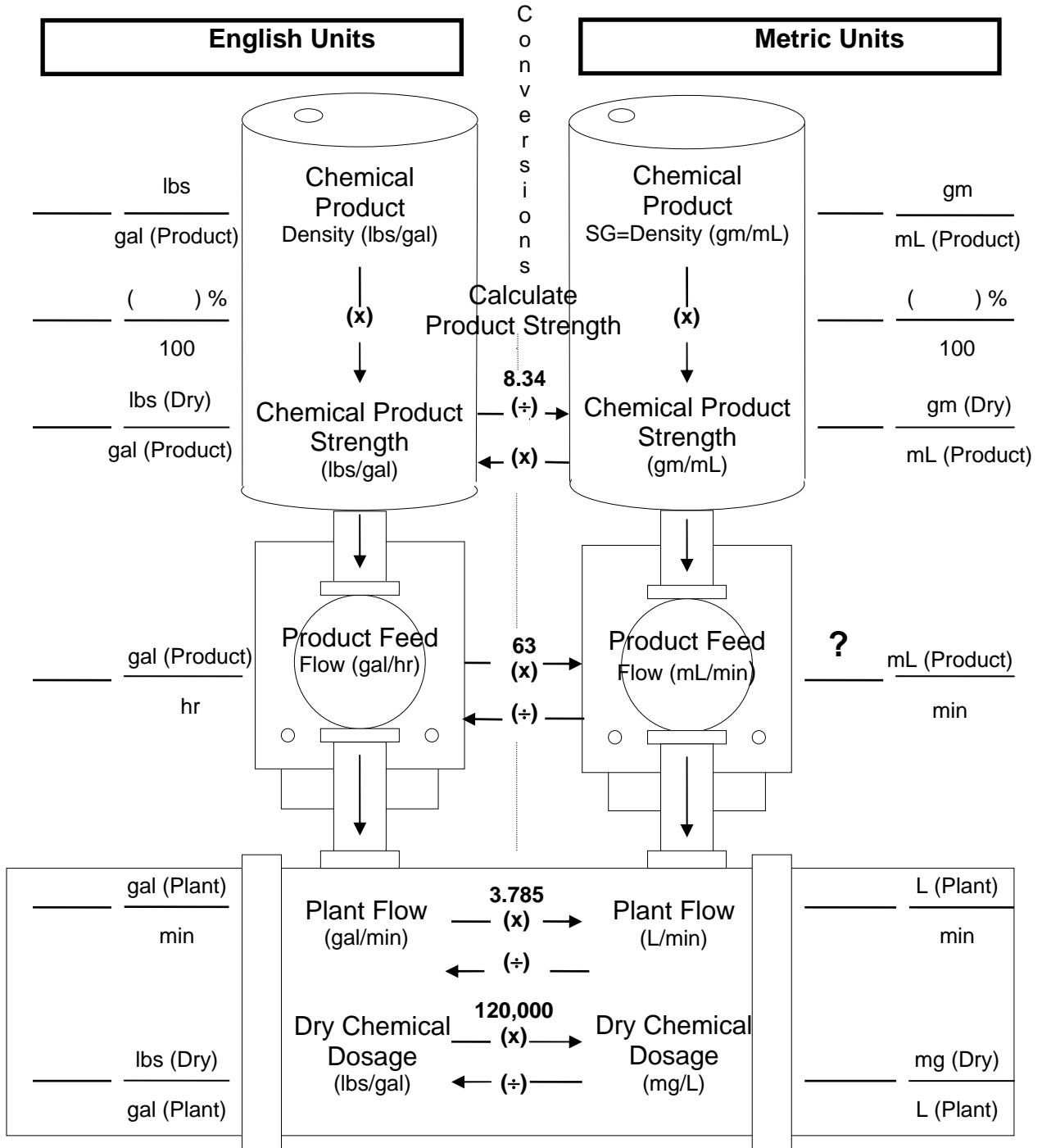
C
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| **English Units** | | **Metric Units** |
|---|---|---|

_____ lbs
gal (Product)

Chemical
Product
Density (lbs/gal)

Chemical
Product
SG=Density (gm/mL)

_____ gm
mL (Product)

_____ ( ) %
100

Calculate
Product Strength

**(x)**

**(x)**

_____ ( ) %
100

_____ lbs (Dry)
gal (Product)

**(x)**

Chemical Product
Strength
(lbs/gal)

**8.34**
**(÷) →**

**← (x) —**

Chemical Product
Strength
(gm/mL)

_____ gm (Dry)
mL (Product)

_____ gal (Product)
hr

Product Feed
Flow (gal/hr)

**63**
**(x) →**

**← (÷)**

Product Feed
Flow (mL/min)

**?** mL (Product)
min

_____ gal (Plant)
min

Plant Flow
(gal/min)

**3.785**
**(x) →**

**← (÷) —**

Plant Flow
(L/min)

_____ L (Plant)
min

_____ lbs (Dry)
gal (Plant)

Dry Chemical
Dosage
(lbs/gal)

**120,000**
**(x) →**

**← (÷) —**

Dry Chemical
Dosage
(mg/L)

_____ mg (Dry)
L (Plant)

**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:

## FEED RATE VS. DOSAGE TABLE

**Chemical:** _____          **Plant Flow:**

_____

| FEED RATE (mL/min) | DOSAGE (mg/L) |
|---|---|
| | 20 |
| | 22 |
| | 24 |
| | 26 |
| | 28 |
| | 30 |

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

Solution

1. You perform a pump calibration and use the curve for a stroke of 80%.

## Liquid Metering Pump Calibration Curve

PUMP: __25% caustic____ STROKE: __80%__ **CALIBRATION CURVE** DATE: __7/1/01_____
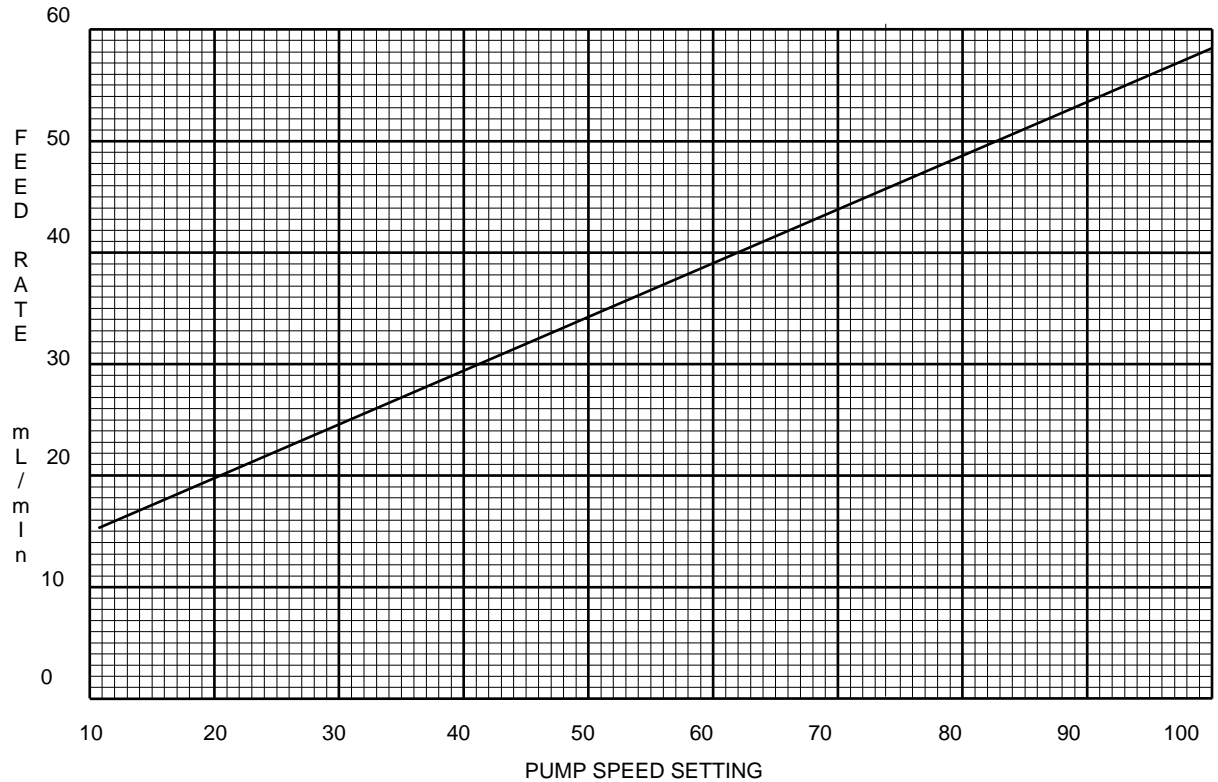


2. For each feed rate on the Feed Rate vs. Dosage Table, find the corresponding pump speed setting using the calibration curve. As a time saver, construct a table showing the pump speed for each dosage and attach it to the pump calibration curve. Keep the table with the calibration curve as a reminder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

| Dosage (mg/L) | Pump Setting |
|---------------|--------------|
| 20 | |
| 22 | |
| 24 | |
| 26 | |
| 28 | |
| 30 | |

---
Mixing a Day Tank
---

- For mixing dry chemicals with water, we are concerned with only one thing: **product strength.**

## Product strength = lbs (dry)/gal (product)

Normally, mixing the chemical will be accomplished in a day tank using plant water. What you will feed through your metering pump will be a liquid chemical product. In figuring what to mix, you want to know how many **pounds of dry chemical** you should add to produce a **chemical product of a certain strength**.

Product strength information should be provided by your engineer or chemical supplier. The chemical feed system will be designed to deliver a chemical product of a certain strength. The following examples are based on chemical product strength given in lbs/gal. Sometimes, product strength may be provided as percent solution. Refer to the Chemical Feed Calculation section of the appendix for information on converting from percent solution to lbs/gal.

**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

*Q: What is your unknown?* _____

*Q: When the day tank is full, you will have 50 gal of what?*

_____

Use unit cancellation to solve this problem in the space below.

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?

## Liquid Feed Problem Involving a Day Tank

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?

Tool needed: diagram page 20-10.

a) What chemical product strength do you calculate from the diagram?

b) Calculate lbs of soda ash to add to the day tank.

## CHEMICAL FEED CALCULATION DIAGRAM
## LIQUID FEED
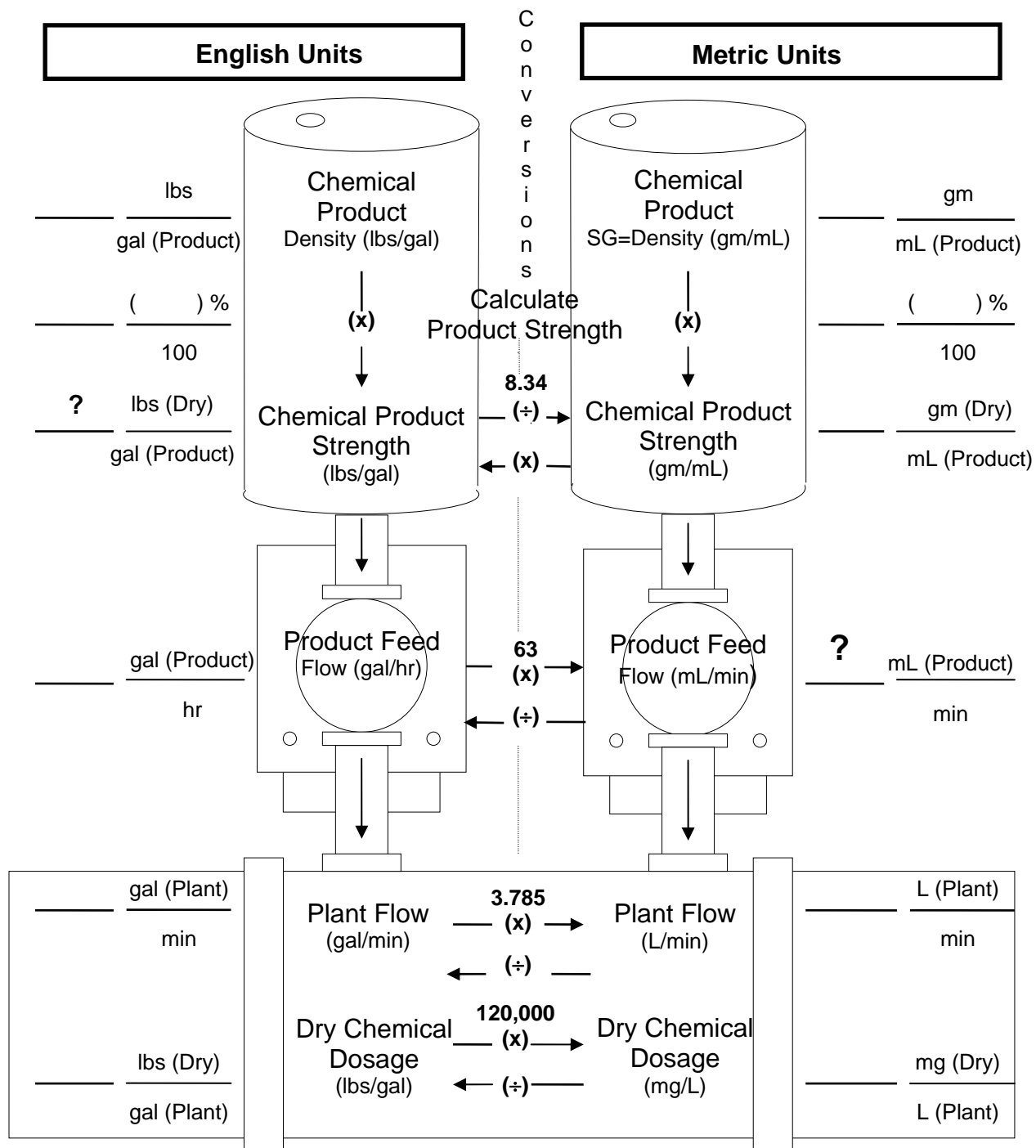
Conversions

| English Units | | Metric Units |
|---|---|---|

English Units side:

$$\frac{\quad\quad lbs}{gal\ (Product)}$$

Chemical Product
Density (lbs/gal)

$$\frac{(\quad)\ \%}{100}$$

**(x)**

$$\frac{?\quad lbs\ (Dry)}{gal\ (Product)}$$

Chemical Product Strength (lbs/gal)

**8.34**
**(÷)** →

**← (x)**

Metric Units side:

Chemical Product
SG=Density (gm/mL)

$$\frac{\quad\quad gm}{mL\ (Product)}$$

$$\frac{(\quad)\ \%}{100}$$

**(x)**

Chemical Product Strength (gm/mL)

$$\frac{\quad\quad gm\ (Dry)}{mL\ (Product)}$$

Calculate
Product Strength

Product Feed
Flow (gal/hr)

$$\frac{\quad\quad gal\ (Product)}{hr}$$

**63**
**(x)** →

**← (÷)**

Product Feed
Flow (mL/min)

$$\frac{?\quad mL\ (Product)}{min}$$

$$\frac{\quad\quad gal\ (Plant)}{min}$$

Plant Flow
(gal/min)

**3.785**
**(x)** →

**← (÷)**

Plant Flow
(L/min)

$$\frac{\quad\quad L\ (Plant)}{min}$$

$$\frac{\quad\quad lbs\ (Dry)}{gal\ (Plant)}$$

Dry Chemical Dosage
(lbs/gal)

**120,000**
**(x)** →

**← (÷)**

Dry Chemical Dosage
(mg/L)

$$\frac{\quad\quad mg\ (Dry)}{L\ (Plant)}$$

**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:

20-10

## Summary

### Key Points:

- The Chemical Feed Calculation Diagram, pump calibration curve, and Feed Rate vs. Dosage Table are helpful tools for process control of chemical feed.

- Mixing a day tank involves calculating how much dry chemical is needed to produce a liquid chemical product with specific product strength.

# MODULE 21
## *Operational Constraints/Startup*

❖ **Objectives:**

- Discuss operational constraints of corrosion control treatment methods.

- Discuss how adjusting pH and using inhibitors can affect other aspects of a water system's treatment.

- Discuss CCT startup considerations.

## Optimal Corrosion Control Treatment

- Treatment that minimizes lead and copper concentrations at user's taps while insuring that the treatment does not cause the water system to violate any national primary drinking water regulations.

- When applying corrosion control treatment, a substantial amount of time may elapse between the time treatment changes are made and their effects are detected through the analysis of tap water samples.

- Because you are changing the chemistry of the water, conditions may get worse before they get better.

# Impacts/Constraints Fact Sheets

## Impacts and Constraints of pH/Alk Adj. or CaCO$_3$ Precip.

1. Reduces inactivation effectiveness of free chlorine if pH is raised before disinfection.***

   ***Unless operating restraints dictate otherwise, the optimum location for pH adjustment is after disinfection and near the entrance to the distribution system. If lime is used to adjust pH, for example, it needs to be added prior to filtration so inert material does not accumulate in the clearwell or enter the distribution system.

2. May increase turbidity from post-filtration precipitation of lime, aluminum, iron, or manganese

3. High trihalomethane (THM) concentrations from chlorination if pH is raised before disinfection

4. Raising pH levels before the coagulation process reduces the effectiveness of alum and poly aluminum chloride.  For examples, increasing the pH above 7.0 before the coagulation process hinders turbidity removal and may increase the aluminum concentration in the finished water.

   It is preferable to adjust pH levels after coagulation.  Otherwise, a different coagulant should be used that will work effectively at higher pH levels.

5. Reduced effectiveness of some coagulants for THM precursor removal if pH is raised before coagulation.

6. Potential for higher total plate counts, confluent growth, or presence of total coliform when chlorination is practiced

7. Removal of radionuclides during softening may be linked to the degree of softening.  Modifying softening practices to achieve corrosion control could interfere with removals.

8. The use of sodium-based chemicals will increase total sodium levels in the finished water

9. Excessive calcium carbonate precipitation may produce "white water" problems in portions of the distribution system

10. It may be difficult to produce an acceptable coating of calcium carbonate on interior piping for large distribution systems. Too much coating may lead to reduced hydraulic capacities in lines near the treatment facility, whereas too little coating may not provide adequate corrosion protection in the extremities of the distribution system.

11. Users with specific water quality needs, such as health care facilities, should be advised of any treatment changes

## Impacts and Constraints of Inhibitors

1. Phosphate-based inhibitors may stimulate biofilms in the distribution system; the biofilms may deplete disinfectant residuals within the distribution system

2. Consumer complaints regarding red water, dirty water, color, and sediment may result from the action of the inhibitor on existing corrosion byproducts within the distribution system.

3. The use of zinc orthophosphate may present problems for wastewater facilities with zinc or phosphorus limits in their NPDES permits.

4. Users with specific water quality needs, such as health care facilities, should be advised of any treatment changes.

5. The use of sodium-based chemicals will increase total sodium levels in the finished water.

6. The use of silicates may reduce the useful life of domestic hot water heaters due to "glassification"; silicates precipitate rapidly at higher temperatures.

7. For systems using alum or other products containing aluminum: if aluminum breakthrough occurs, the aluminum will bind with the orthophosphate at a ratio of 1:4 and interfere with maintaining an effective inhibitor film. This means that 1 part of aluminum will bind 4 parts of orthophosphate. According to the Calgon Corporation, orthophosphate that is "bound" with aluminum will still create an orthophosphate residual, but the part that is bound won't be contributing to the corrosion control treatment coating. (For example, if your target orthophosphate residual is 0.5 mg/l and you have 0.1 mg/l of aluminum, only 0.1 mg/l of the orthophosphate will be used to coat your pipes while 0.4 mg/l will be bound to the aluminum.) To account for this problem, aluminum readings should be taken at the entry point, multiplied by 4 and added to the operating orthophosphate residual to obtain an effective residual of orthophosphate needed for corrosion control in the system.

## Small Group Questions

1) Describe 2 ways that pH adjustment impacts the disinfection process.

   _____

   _____

2) Why do silicates affect the useful life of hot water heaters?

   _____

3)  If you are using a phosphate-based inhibitor, what other treatment process could be affected?

_____

How is it affected?

_____

4)  Name 2 precipitates that could cause turbidity to increase as a result of increasing the pH

_____          _____

5)  What impacts are applicable to both pH/alkalinity adjustment chemicals and inhibitors?

_____

6)  Name 3 impacts that result from raising the pH before disinfection or the coagulation process.

_____

_____

_____

7)  Why is it difficult to produce an acceptable coating of calcium carbonate in large distribution systems?

_____

_____

8) Name the optimum location for pH adjustment for :

Systems using lime: _____

Systems not using lime: _____

9) What causes "white water"?

_____

10) What adverse effects may occur during the initial phase of adding a phosphate-based inhibitor?

_____

What can you do to minimize these effects?

_____

_____

11) Why should commerical users with specific needs be advised of water treatment changes?

_____

12) Name an element in some phosphate-based inhibitors that is regulated in wastewater facilities permits.

_____

## Startup Considerations

- During the year prior to startup, you'll want to gather and record baseline water data (groundwater - raw; surface water - filtered) for pH, alkalinity and temperature.

- Take lead/copper tap samples at critical taps (3 to 4 sites, including exceedance sites).

---

**Operator Tips: Startup and Initial Operation of CCT**

- Establish treatment goals; target entry point (finished water) pH; inhibitor concentration.
    (from feasibility study, consulting engineer, chemical supplier)

- Take lead/copper tap samples at critical taps monthly for at least the first 6 months.

- Consult with your engineer and/or chemical supplier concerning start-up procedures and target water quality parameter values.

- Establish and add startup procedures to your O&M Plan based on manufacturers' recommendations:

    - Calibrate chemical feed pump/ metering equipment.
    - Spot check feed rates as needed (calibration chamber).
    - If mixing a day tank, establish your mixing procedure and measurements.

---

## Summary

To summarize this module:

## 🔑 Key Points:

- When applying corrosion control treatment, a substantial amount of time may elapse between the time treatment changes are made and their effects are detected through the analysis of tap samples.

- When the water chemistry changes, conditions often get worse before they get better.

- The effectiveness of free chlorine is reduced as pH _____.

- The optimum location for pH adjustment is after disinfection, unless _____ is used.

- 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 _____ water lines and keep your customers informed about the initial negative impacts to minimize these complaints.

- It's important to look at how treatment processes affect each other to avoid a serious negative impact. Remember Milwaukee!

- Use the time prior to follow-up monitoring to gather good baseline water data and perform testing and calibration.

# MODULE 22
## *Stock Solution/Jar Test Workshop*

❖ **Objectives:**

- Examine how a jar test is used to simulate the effects of chemical treatment on water quality.

- Gain hands-on experience preparing stock solutions and conducting a jar test for pH adjustment.

## What is a Jar Test?

In general, a jar test for pH/alkalinity adjustment is conducted to determine the dosage of chemical required to reach a target pH.

A jar test for pH/alkalinity adjustment involves essentially two steps.

1. Prepare a stock solution using your CCT chemical.

2. Simulate chemical feed using a titration to determine the optimal dosage.

## Preparing a Stock Solution

Stock solutions for jar testing can be prepared using this table.

| 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 |

"% Strength" or "Concentration, mg/L" can be calculated using the following conversion:

$$1.0\% \ = \ 10,000 \text{ mg/L}$$

Note there is a decimal move of four places to the right when converting from percent to mg/L.

$$1.0\% \ = \ 10,000. \ \text{ mg/L}$$

The concentrations from the table are designed such that **addition of the stock solution results in an easily measured increase in dosage** as indicated in the last column.

Stock solutions for pH/alkalinity adjustment are normally 0.1% (or 1,000 mg/L) in concentration.

So, when we prepare a stock solution:

1.  Determine the desired stock solution concentration.

2.  Then ask the following:  How much of my chemical must be added to water to make the desired stock solution?

## Dry Chemicals

For dry chemicals, use unit cancellation.

## Example #1:

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

? mg sodium bicarbonate      =

| 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 |

## Liquid Chemicals

### STOCK SOLUTION DIAGRAM
### LIQUID CHEMICAL

Conversions

| English Units | Metric Units |

$$\frac{\_\_\_\_ \text{ lbs}}{\text{gal (Product)}}$$

Chemical Product
Density (lbs/gal)

Chemical Product
SG=Density
(gm/mL)

$$\frac{\_\_\_\_ \text{ gm}}{\text{mL (Product)}}$$

$$\frac{(\quad)\,\%}{100}$$

(x)

Calculate
Product Strength

(x)

$$\frac{(\quad)\,\%}{100}$$

$$\frac{\_\_\_\_ \text{ lbs (dry)}}{\text{gal (Product)}}$$

Chemical Product
Strength
(lbs/gal)

8.34
(÷)→

←(x)

Chemical Product
Strength
(gm/mL)

$$\frac{\_\_\_\_ \text{ gm (Dry)}}{\text{mL (Product)}}$$

| 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 **?** $\frac{\_\_\_\_}{}$ mL (Product)

Stock Solution Volume (L) $\_\_\_\_$ L (Stock)

Stock Solution Concentration (mg/L)

$$\frac{\_\_\_\_ \text{ mg (Dry)}}{\text{L (Stock)}}$$

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.

Unit Cancellation:

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?

(?) mL Caustic Soda  =

---

**Operator Tips:  Preparing a Stock Solution**

- Use care when handling and mixing chemicals. Read all information supplied by your chemical manufacturer, including _____ sheets.

- Use fresh stock solution. Stock solution has a shelf-life of ≈_____. The solution may deteriorate with time due to mold or algae growth, $CO_2$ absorption or contamination.

- Mix the stock solution using distilled or deionized water.

- Measure accurately and prepare using a volumetric flask.

- Mix properly. Add ≈ 1/2 the volume of water to the volumetric flask. Add the chemical. Stir or swirl to mix. Add water to the mark. (Note:  When caustic soda is mixed with water, heat is generated. So, allow the solution to cool to room temperature prior to topping off to avoid expansion of the solution in the flask.)

- Cover the stock solution.

## Conduct a Jar Test for pH/Alkalinity Adjustment

A jar test is used to adjust chemical feed when the baseline water quality changes.

---

**Operator Tips:  Baseline Water for CCT**

- At surface water systems - baseline water is collected just _____ the filters, but _____ any post treatment addition.

- At ground water systems with filtration (i.e., greensand, sand, etc.) - again, baseline water is collected just past the filters, but before any post treatment addition.

- At ground water systems without filtration - baseline water is collected from the _____ water tap.

---

**Operator Tips:  Conducting a  Jar Test**

- Jar testing for pH/alkalinity adjustment is similar to the titration process.  Refer to operator tips in module 8.

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

## 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?

? mg soda ash   =


                =


? gm soda ash   =



## Procedure:

1. Use the scale to weigh out the required amount of soda ash.

    - Turn on the scale.

    - Place the weigh boat on the scale and press the tare button.

    - Add the desired amount of soda ash to the weigh boat.

    - Turn off the scale (hold down the off button).

2. Add ≈ 500 mL of deionized water to the 1 L volumetric flask.

3. Add the soda ash to the water and swirl (or stir, if needed) to mix. Rinse all chemical from the weigh boat into the volumetric flask.

4. Add deionized water to the 1 L mark.  (Use a wash bottle filled with deionized water to accurately reach the 1 L mark.)

5. Cap the volumetric flask and invert to mix.

## Workshop Exercise Part 2 - Perform a Jar Test

Determine the dosage of soda ash required to adjust the baseline water to the target pH of _____.

### Procedure:

1. Fill a 1,000 mL beaker to the 1,000 mL mark with the **baseline** water sample.  Place the beaker on a stirrer and begin stirring the sample.

2. Use a calibrated pH meter to measure the sample pH and temperature.

   - Record the pH:            _____

   - Record the temperature:  _____ ° C

   - Record the alkalinity:     _____ mg/L

3. Fill a 10 mL pipet with the prepared stock solution.  Record the starting volume.

   Starting volume:                     _____

4. Begin adding stock solution in small increments. (Do not submerge the tip of the pipet into the sample.)  Continue to add stock solution until the target pH is reached.  Record the ending volume.

   Ending volume:                      _____

5. Record the volume (mL) of stock solution added to reach the target pH.

Total volume:                    _____

6. Calculate the dosage (mg/L) added (i.e., if every mL = 1 mg/L ... then 5 mL = 5 mg/L).

Dosage:                    _____

## Recordkeeping

Record the results of each jar test and maintain the records to serve as a quick reference should you experience these baseline water characteristics again.

**CHEMICAL** _____          **DATE** _____

**TARGET EP pH** _____  **TARGET EP ALKALINITY** _____

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

| pH→ Alk.↓ | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| | | | | | | | | |
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Directions:

1. Construct a chemical dosage chart for each chemical added.

   - Record the target EP pH and/or alkalinity.

   - Record the pH range of the baseline water in the top row.

   - Record the alkalinity range of the baseline water in the first column.

2. Monitor the EP parameters on a daily basis (monitor baseline parameters when needed).

3. Complete a block on the chemical dosage chart when baseline water quality changes.

   - Conduct a jar test to determine the dosage needed to obtain the target EP pH.

   - Locate the appropriate block and record the dosage.

4. Complete additional blocks on the chart as varying baseline water quality conditions are experienced.

5. Use the chart as a quick reference to adjust chemical feed when the same water quality occurs again.

Collect baseline water quality data as early as possible. Data collected during the year prior to start-up will provide you with the knowledge of how often and when your baseline water quality might change.

By gaining an understanding of the magnitude of this change, you will have a better picture of what process control might mean at your system.

## Practice Problem

Background plant information:

- Plant Flow (average) = 100 gpm
- Chemical:  soda ash; chemical product strength = $\dfrac{1.0 \text{ lbs (Dry)}}{\text{gal (Product)}}$
- 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.

## 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 |
| 39.4 | 30 |
| 40.7 | 31 |
| 42.1 | 32 |

PUMP: _____      PUMP CALIBRATION CURVE      DATE: _____

% STROKE: _____60%_____



PUMP SPEED SETTING
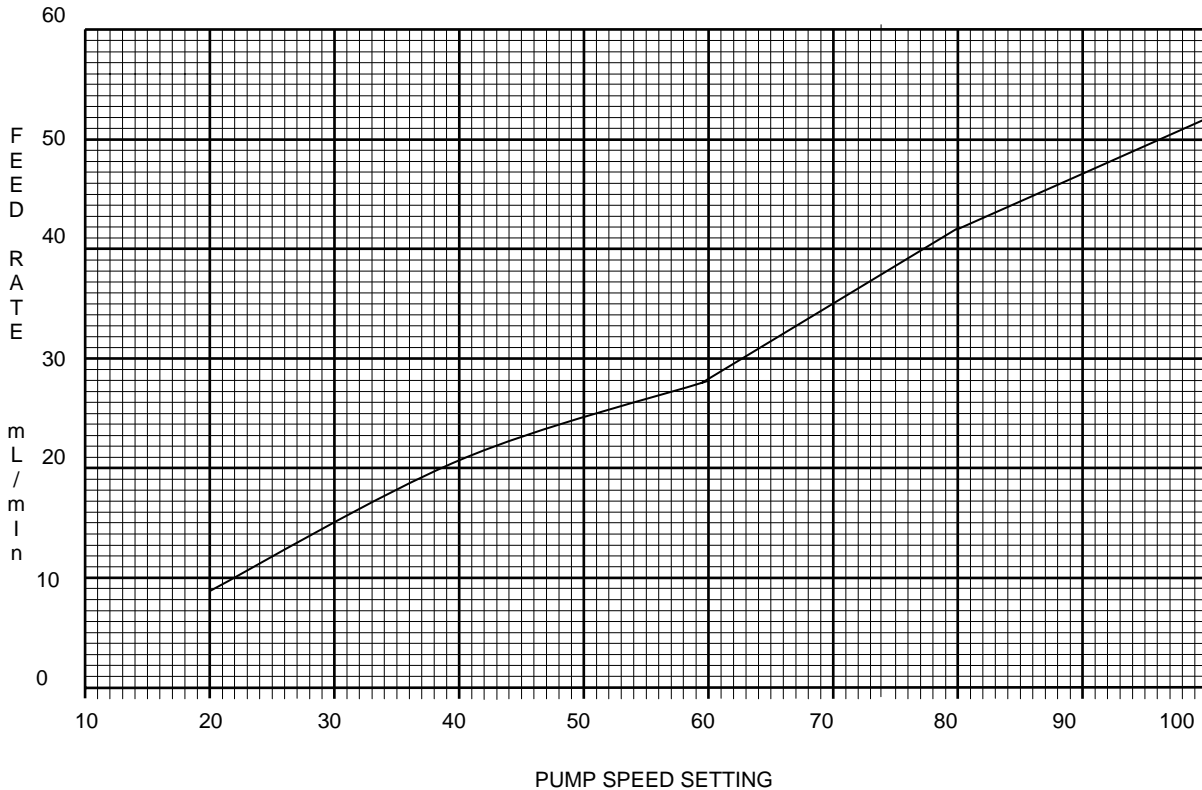
## Summary

## Key Points:

- Conduct a jar test to simulate the effects of chemical treatment.

- Perform a jar test to determine optimal _____.

- The Chemical Dosage Chart is used to adjust chemical feed when the _____ water quality changes.

- Jar testing may be necessary to maintain a _____ water quality.

# MODULE 23
## *Process Control and Stability*

❖ **Objectives:**

- Discuss the importance of process control and stability.

- Define finished water stability for different CCT approaches.

- Discuss daily stability routine.

## Finished Water Stability

*Q: What is finished water stability?*

_____
_____
_____

How is finished water stability maintained?

- Finished water stability is achieved and maintained by adjusting chemical feed to control the water chemistry of the finished water.

- Stability is maintained regardless of variations in baseline water quality. **Process control** is needed to accomplish this.

**Finished Water Stability**

**Baseline Water ***

**Finished Water ***

**Process Control**

* **Fluctuations in**
  - **pH**
  - **alkalinity**
  - **CO$_2$**
  - **temperature**

*****Target Ranges**
  - **pH**
  - **inhibitor conc.**
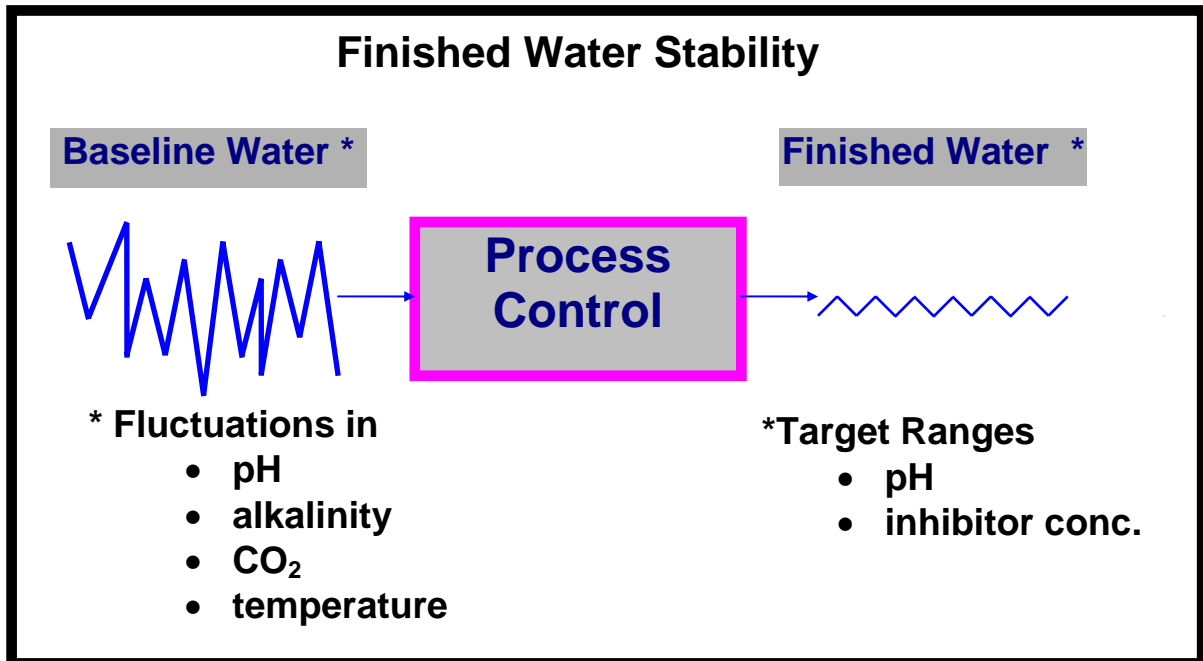
- Often, baseline water, even ground water, may have widely changing chemistry.

- For corrosion control treatment, we are particularly interested in variations in pH and alkalinity, which may be caused by fluctuations in carbon dioxide levels, and variations in temperature.

- Through process control, meaning controlling chemical feed, you can maintain a stable chemistry in the finished water.

- For pH/alkalinity adjustment and inhibitor addition, maintaining a stable pH is the most critical process control objective.

- Also, for inhibitor treatment, it is important to maintain a consistent inhibitor residual.

**Finished Water Stability**



Pipe Wall → pH / PO$_4$

| Stable pH | Stable PO$_4$ |
|---|---|
| ± 0.1 pH Unit | ± 0.1 mg/L |
| (Example) | (Example) |
| 8.5 ← 8.6 → 8.7 | 0.4 ← 0.5 → 0.6 |
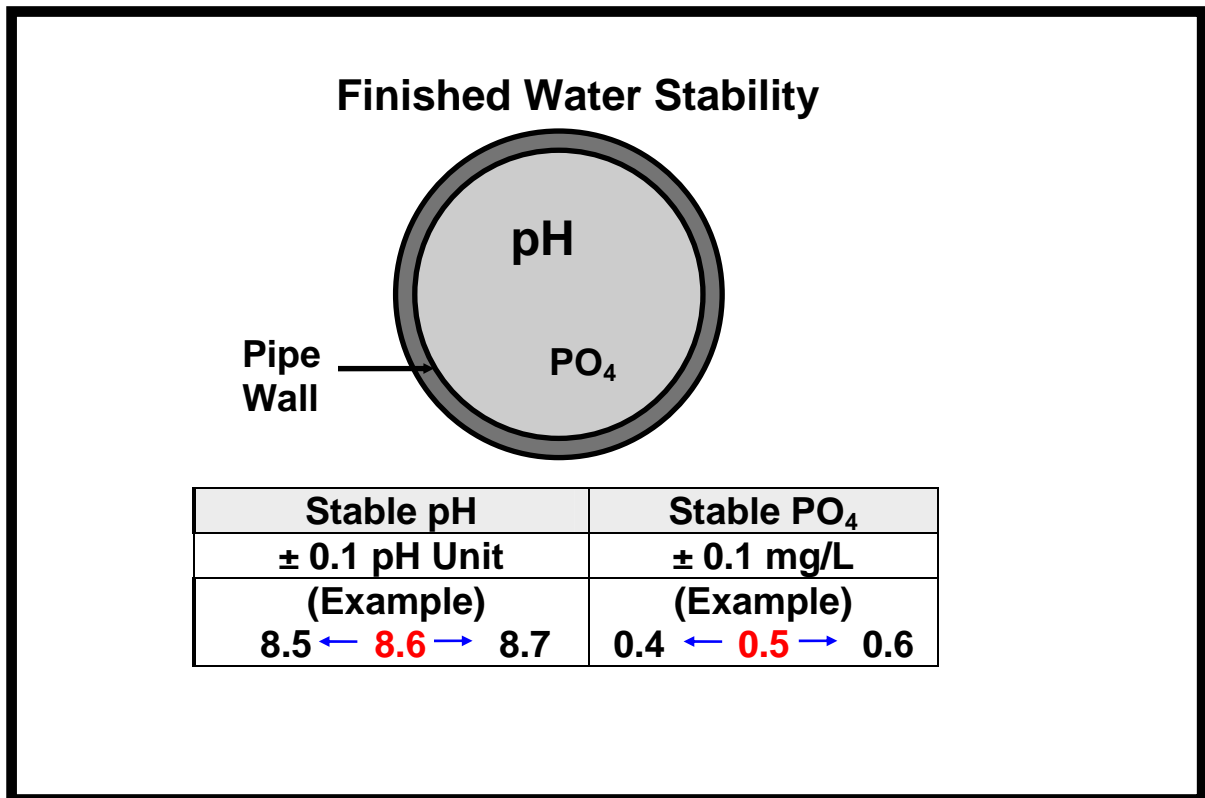
- Specifically, a stable pH range usually means that daily finished water pH fluctuations are no greater than 0.1 above or below the desired pH value. For example, if the desired pH value is 8.6, a stable finished water is one that remains between pH 8.5 and 8.7 on any given day.

- A stable orthophosphate residual is one that does not fluctuate more than 0.1 mg/L above or below the desired residual. If the desired phosphate residual is 0.5 mg/L, stability is achieved when the residual remains between 0.4 mg/L and 0.6 mg/L PO$_4$.

---

### Essential Tools for Startup and Process Control

- Water Quality Analyses
    - pH meter  *(Modules 6 and 7)*
    - titration for alkalinity  *(Modules 8 and 9)*
    - colorimeter for phosphate  *(Modules 10 and 11)*

- Feed Pump Calibration  *(Module 19)*

- Chemical Feed Calculations  *(Modules 17,18 and 20)*

- Feed Rate vs. Dosage Table  *(Module 20)*

- Chemical Dosage Chart  *(Module 22)*

- Jar Testing  *(Module 22)*

- Chemical handling/safety  *(Modules 14 and 15)*

- Good recordkeeping  *(Modules 20, 22, and 24)*

---

### Daily Stability Routine for pH/alkalinity Adjustment

Achieving and maintaining finished water stability through process control takes, as a minimum, **daily** operator attention.

Once the routine is established, process control will not normally be time consuming.

The following flow chart shows the activities involved in a daily stability routine.

# Daily Stability Routine
# pH/Alkalinity Adjustment

Calibrate
pH meter.

*Note: If entry point pH is still outside the target range, check chemical product.

Measure
entry point pH.

Spot check feed
pump output
and determine
feed rate.

No ← Is pH
within target
range? → Yes

Finished with daily routine
(Complete daily/monthly
records).

Verify plant flow.
Determine dosage
and compare to last
correct dosage.

*Water Chemistry Considerations*

Is dosage
comparison
within range
(±10%)? → Yes

Measure baseline
pH, alkalinity, temp
for change.

Locate dosage block
on Chemical
Dosage Chart.

No

Conduct jar test
to determine
dosage.

No ← Is dosage
value recorded
on chart?

*Mechanical Considerations*

Troubleshoot/repair
feed pump & other
system components.

Fill dosage
value in chart.

Yes

Recalibrate
pump/develop
new pump curve.

Adjust chemical
feed pump to
correct dosage. *

| Daily Stability Routine Activities for pH/Alkalinity Adjustment |
|---|

| **Activity Number** | **Activity Description** |
|---|---|
| 1 | The first step in the daily routine is to calibrate the pH meter. |
| 2 | Measure entry point (finished water) pH. |
| 3 | If pH is within the target range, daily stability routine is finished.  Complete daily and monthly records. |
| 4 | If pH is outside the target range, spot check feed pump output and determine feed rate. |
| 5 | Verify plant flow rate.  If plant flow is constant, use the Feed Rate vs. Dosage Table to determine the dosage.  If plant flow is variable, determine the plant flow rate and calculate the dosage using the Chemical Feed Calculation Diagram.  Compare this dosage with the last correct dosage value (i.e., the dosage that produced the target entry point pH).  The dosage comparison is within range if it is within $\pm 10\%$  - example: if the last correct dosage was 20 mg/L,  the dosage would be acceptable within a range of 18-22 mg/L. |
| 6 | If the dosage comparison is outside the acceptable range, check the feed pump and other system components for:<br>• Ruptured diaphragm<br>• Trapped air or air leak<br>• Clogged feed line<br>• Malfunctioning valve, etc<br><br>Repair feed pump and/or other feed system components. |

7           After completing feed system repair, recalibrate the feed pump and construct new calibration curves.

8           If the dosage comparison made in activity 5 is within range, measure the baseline water quality (pH, alkalinity, temperature) to see if it has changed.

9           Use the baseline water quality data to locate the appropriate block on the Chemical Dosage Chart.

10          If there is no dosage value recorded in the appropriate block of the Chemical Dosage Chart, conduct a jar test to determine the proper dosage value for that baseline water quality.

11          Write the dosage value obtained from the jar test in the appropriate block on the Chemical Dosage Chart.

12          After completing activities in response to **water chemistry considerations**, use the dosage value obtained either from the Chemical Dosage Chart or jar test along with the pump calibration curve to adjust the chemical feed pump to deliver the correct dosage.  If it was necessary to conduct activities in response to **mechanical considerations**, use the newly developed pump calibration curve to adjust the chemical feed pump to deliver the correct dosage.

13          Measure entry point pH again (allow sufficient time for finished water change to occur).

**Caution:** at this point, if the entry point pH is still outside the acceptable range, the problem is likely with your chemical product. Check the invoice to see if the current shipment has not exceeded its expiration date and has the same **product strength** as previous shipments.  A change in chemical product strength will render all chemical feed calculations invalid.

| Why is performing a daily stability routine important? |
| --- |

- It assures optimal operation and lower lead/copper levels.

- It saves time.  Once the Chemical Dosage Chart has been filled in for the various baseline water quality changes, you can estimate the chemical dosage needed within a few minutes of knowing the baseline water quality.

  The alternative: play "crank and wait"  (to see the effect on the finished water).  The crank and wait method is not good for stability (over-crank or under-crank) and can be time consuming (guessing and waiting around for results).

- It saves money.  The daily stability routine regulates chemical usage, which means feeding the right amount chemical to do the job.

- It has other benefits.  Beyond CCT, benefits of stability include fewer dirty water complaints, fewer taste and odor problems, and, in some cases, improved disinfection.

| Stability Effects on Lead and Copper Levels |
| --- |

Actual system results:

- This system exceeded both the lead and copper action levels.

- The system already had pH adjustment treatment for corrosion control.   The target pH was 7.6.   Higher pHs caused dirty water problems.

Lead Levels Before and After pH Stabilization
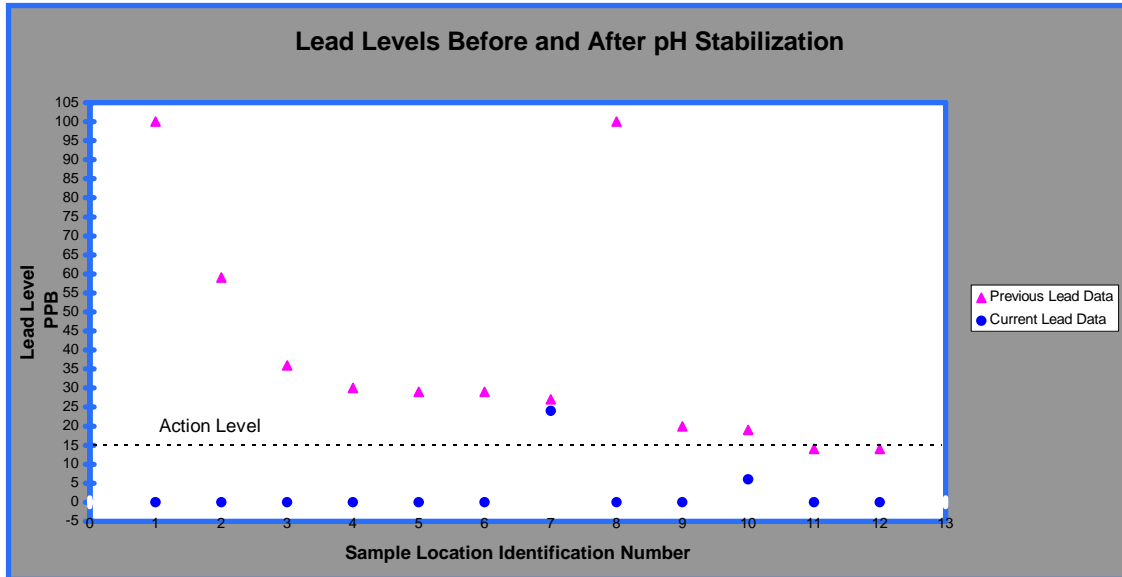
- This system had fairly high levels at several locations. These high levels were not caused by improper treatment, but by a fluctuating finished water pH.

- After DEP Small Water System Outreach Program staff worked with the operator to achieve a stable finished water pH, the lead levels decreased dramatically.



Copper Levels Before and After pH Stabilization
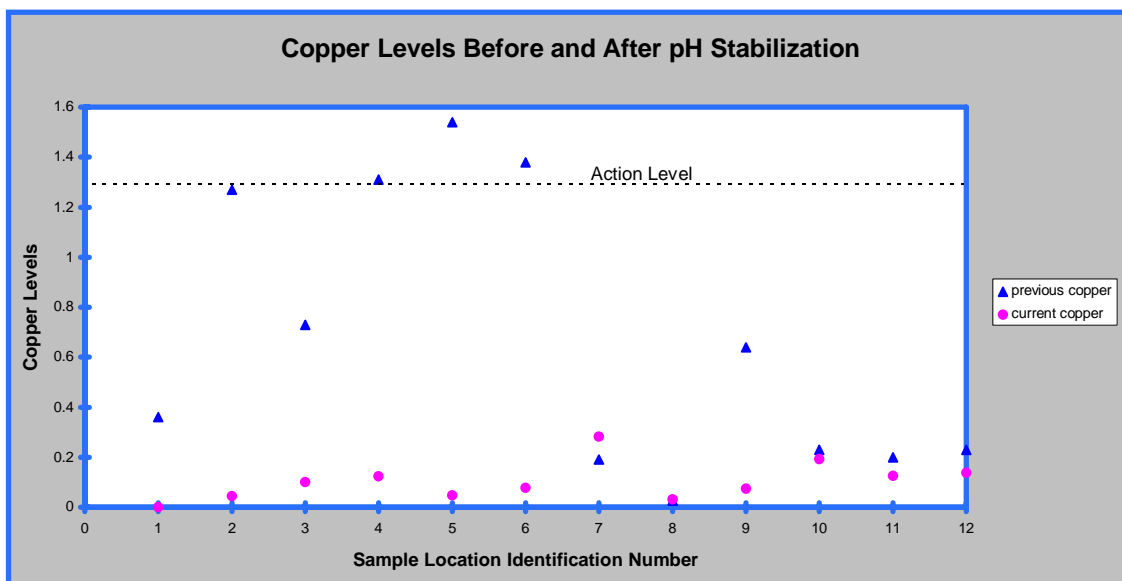
- Similar results occurred with the copper levels. After finished water stability was achieved, the copper levels decreased to well below the action level.

- Stabilizing the finished water pH optimized the corrosion control treatment.

---

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

- Your most important task is to maintain a _____entry point pH.

- Measure your entry point pH at least _____ using a calibrated pH meter.

- Keep good records of pH adjustment chemical dosage for changing baseline water quality (pH, alkalinity, temperature).

- Use _____ _____ to determine proper chemical dosage for changing baseline water quality.

---

## Daily Stability Routine for Phosphate Inhibitor

- The daily stability activities for phosphate inhibitor are similar to those for pH/alkalinity adjustment, but are much simpler.

- Inhibitor stability is simpler because variations in baseline water quality normally do not have a major effect on the orthophosphate levels.

- If you are adjusting pH as well as adding a phosphate inhibitor, you will need to perform both daily stability routines.

| Activity Number | Activity Description |
| --- | --- |
| 1 | The first step in the daily routine is to measure the entry point (finished water) orthophosphate residual. The **orthophosphate** residual is measured even if a polyphosphate or ortho-poly blend is used because the orthophosphate component is the effective ingredient for corrosion control. |
| 2 | Run a standard to verify the result. |
| 3 | If the orthophosphate residual is within the acceptable range, the daily phosphate stability routine is finished. Complete daily and monthly records. |
| 4 | If the orthophosphate residual is outside the target range, spot check the feed pump output, determine the feed rate and calculate the dosage. |
| 5 | If the dosage is as expected, the problem may be with the chemical product. Check with the product representative for assistance. |
| 6 | If the dosage is not as expected, check the feed pump and other system components for:<br>• Ruptured diaphragm<br>• Trapped air or air leak<br>• Clogged feed line<br>• Malfunctioning valve, etc<br><br>Repair feed pump and/or other feed system components. |
| 7 | After completing feed system repair, recalibrate the feed pump, construct new |

calibration curves and adjust the feed pump to deliver the correct dosage.

Complete the following.

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

- If you are adjusting pH, follow the daily stability routine for pH/alkalinity adjustment as well as the routine for phosphate.

- Measure the entry point _____ residual daily to assure that it is within the desired range.

- Check the validity of each daily phosphate residual measurement by running a _____ test.

- If you are having trouble keeping a consistent residual, check your feed pump and other system components or check for temperature effect on polyphosphate breakdown.

- Consult with your phosphate chemical supplier if stability problems continue.

## Summary

**🔑 Key Points:**

- The most important task in CCT is to maintain a stable finished water chemistry, particularly a stable entry point pH.

- To maintain finished water stability, conduct critical water quality analyses daily and keep good records.

- In this lesson we have discussed process control and stability to achieve optimal operation and lowest lead/copper levels.  These procedures and target ranges may be more stringent than what is needed to achieve compliance with the Lead and Copper Rule.

# MODULE 24
# PROCESS CONTROL WORKSHOP

❖   **Objectives:**

- Practice using process control and recordkeeping tools.

- Become more familiar with the Daily Stability Routine Flowchart for pH/alkalinity adjustment.

- Utilize the Flowchart to determine the process control activities required to achieve and maintain a stable water quality.

---

## Background Information

You are the newly hired operator at Awesome Water, Inc.  The water system exceeded the lead action level during initial monitoring.

The system owner hired an engineering firm to conduct the feasibility study and design the treatment facilities.   The engineer recommended pH/alkalinity adjustment as the best treatment.   A chemical feed system for caustic soda has been installed and initial operation has begun.  The engineer recommended a target EP pH of 8.5 and told the former operator that a dosage of $\approx$ 7 mg/L would achieve the target pH.

The former part-time operator operated the new system for about six months.  When a new round of lead tap monitoring was conducted, the system still exceeded the lead action level.  The operator quit and one of the maintenance crew has been looking after the plant every now and then to see that everything is running.

You have been hired by the owner to improve the system operation and achieve acceptable lead levels. Currently, you work six hours a day, six days a week.

The following information is available from the feasibility study.

---

**Awesome Water, Inc.**

**Plant Data**

- Plant flow (average)  =  200 GPM

- Baseline water quality ranges:

    - pH  =  6.8 - 7.5
    - Alkalinity  =  20 - 40 mg/L

- CCT chemical - 25% caustic soda  (Density = 10.59 lbs/gal)

- Target EP pH  =  8.5

- Target dosage ≈ 7 mg/L

---

## First Week on the New Job:

You find that the former operator kept very sparse records.   You calibrate the pH meter and determine that the calibration is good. You measure the entry point pH and it reads 7.8.  You then measure the baseline water and find that the pH is 6.8 and alkalinity is 29 mg/L.

## Step 1

Begin measuring baseline water daily and begin jar testing to determine the proper dosage needed to reach the target pH.

Use the Stock Solution Diagram (p. 24-3) to determine how many mLs of caustic soda are needed to prepare 1 L of stock solution.

# STOCK SOLUTION DIAGRAM
# LIQUID CHEMICAL

C
o
n
v
e
r
s
i
o
n
s

| English Units | | Metric Units |

Calculate
Product Strength

**English Units side:**

_____ lbs / gal (Product)

( ____ ) % / 100

_____ lbs (dry) / gal (Product)

Chemical Product
Density (lbs/gal)

(x)

Chemical Product
Strength
(lbs/gal)

**Conversion center:**

8.34
—(÷)→

←(x)—

**Metric Units side:**

Chemical Product
SG=Density
(gm/mL)

(x)

Chemical Product
Strength
(gm/mL)

_____ gm / mL (Product)

( ____ ) % / 100

_____ gm (Dry) / mL (Product)

| 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) ——— _____ L (Stock)

Stock Solution Concentration (mg/L)

_____ 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.

**? mL (Product) =**

You conduct daily baseline water testing for two weeks. You perform jar testing on each new baseline water. The following is the record of your results.

| Day | Baseline Water Data | | Jar Test Results |
| --- | --- | --- | --- |
| | pH | Alkalinity | Caustic Soda Dosage |
| 1 | 6.9 | 30 | 8 |
| 2 | 7.2 | 34 | 4 |
| 3 | 7.1 | 30 | 5 |
| 4 | 7.1 | 31 | 5 |
| 5 | 7.0 | 32 | 7 |
| 6 | 6.8 | 28 | 9 |
| 7 | 6.9 | 29 | 7 |
| 8 | 6.8 | 29 | 9 |
| 9 | 7.0 | 30 | 6 |
| 10 | 7.0 | 32 | 7 |
| 11 | 6.9 | 33 | 9 |
| 12 | 6.8 | 34 | 11 |
| 13 | 7.0 | 34 | 8 |
| 14 | 7.1 | 32 | 6 |

Step 2

Construct a Chemical Dosage Chart.

Complete the Chart (p. 24-5) using the above data.

**CHEMICAL:**   25 % Caustic Soda          **DATE** _____

**TARGET EP pH** ____8.5____    **TARGET EP ALKALINITY** _____

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

| pH→<br>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 | | | | | | | | |
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| 33 | | | | | | | | |
| 34 | | | | | | | | |
| 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 _____.

## CHEMICAL FEED CALCULATION DIAGRAM
## LIQUID FEED
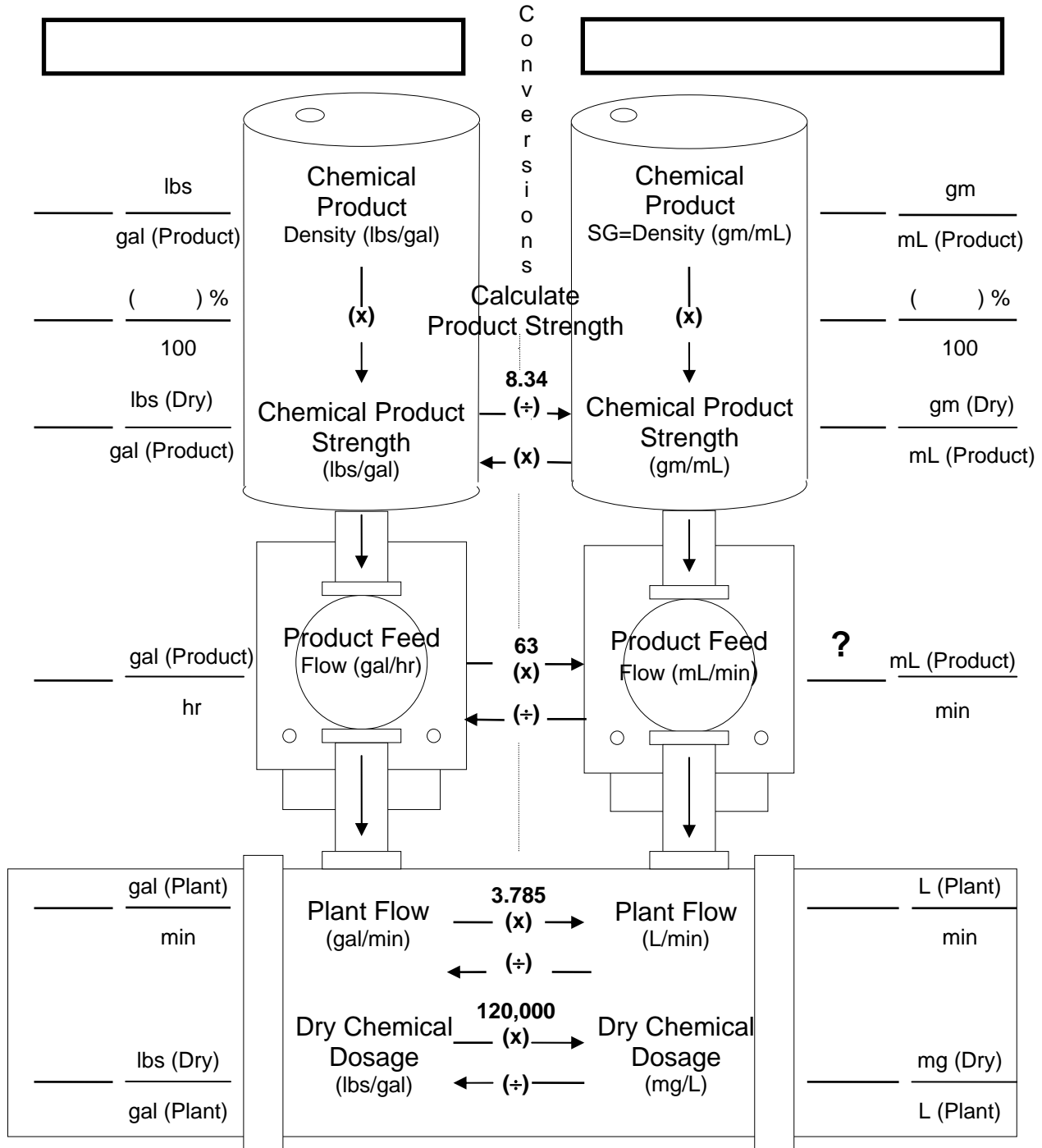
Conversions

_____ lbs / gal (Product)

( _____ ) % / 100

_____ lbs (Dry) / gal (Product)

Chemical Product Density (lbs/gal)

**(x)**

Chemical Product Strength (lbs/gal)

Calculate Product Strength

**8.34 (÷)** →

← **(x)** —

Chemical Product SG=Density (gm/mL)

**(x)**

Chemical Product Strength (gm/mL)

_____ gm / mL (Product)

( _____ ) % / 100

_____ gm (Dry) / mL (Product)

_____ gal (Product) / hr

Product Feed Flow (gal/hr)

**63 (x)** →

**(÷)** ←

Product Feed Flow (mL/min)

**?** mL (Product) / min

_____ gal (Plant) / min

Plant Flow (gal/min)

**3.785 (x)** →

← **(÷)** _____

Plant Flow (L/min)

_____ L (Plant) / min

_____ lbs (Dry) / gal (Plant)

Dry Chemical Dosage (lbs/gal)

**120,000 (x)** →

← **(÷)** _____

Dry Chemical Dosage (mg/L)

_____ mg (Dry) / L (Plant)

**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.

**? mL (Product) =**
**min**

Complete the Feed Rate vs. Dosage Table.

## FEED RATE VS. DOSAGE TABLE

**Chemical:** 25% Caustic          **Plant Flow:**      200 GPM

| FEED RATE (mL/min) | CHEMICAL DOSAGE (mg/L) |
|---|---|
| | |
| | |
| | 4 |
| | 5 |
| | 6 |
| | 7 |
| | 8 |
| | 9 |
| | 10 |
| | 11 |
| | |
| | |

## Step 4

Calibrate the pump and construct a pump calibration curve.

Complete the chart on page 24-8.

## LIQUID FEED PUMP CALIBRATION CURVE

% Stroke: ___60%___          Pump: _____
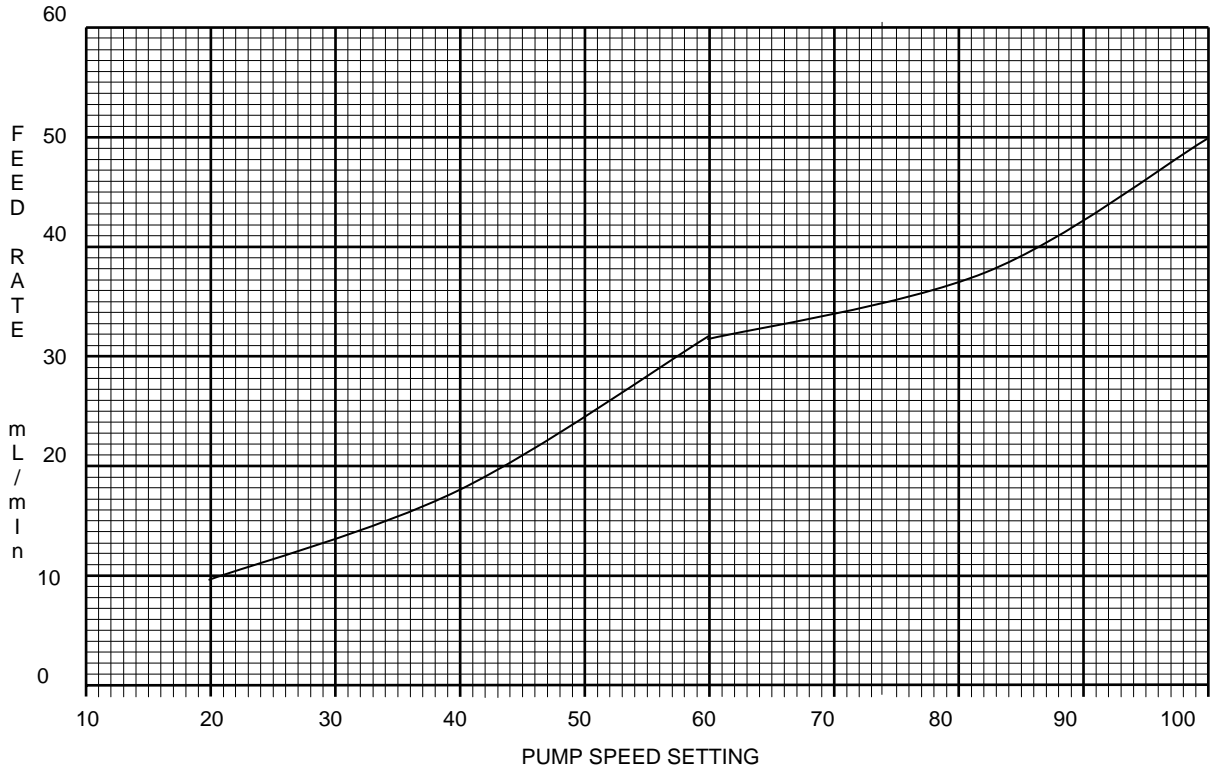


| Dosage (mg/L) | Pump Speed Setting |
|:---:|:---:|
|  |  |
|  |  |
| 4 |  |
| 5 |  |
| 6 |  |
| 7 |  |
| 8 |  |
| 9 |  |
| 10 |  |
| 11 |  |
|  |  |
|  |  |

## Workshop

### Directions

- Use the background information and the tools we've just compiled to answer the following scenarios.

- Refer to the Daily Stability Routine Flowchart (p. 24-10) to determine the appropriate plan of action for each step.

- Once the correct plan of action has been determined, continue on to the next step until the scenario is completed.

- Following completion of each day, we will go over the answers before continuing on to the next day.

To begin, we will assume that this is the second day of operation.

**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.

# Daily Stability Routine
# pH/Alkalinity Adjustment

Calibrate pH meter.

*Note: If entry point pH is still outside the target range, check chemical product .

Measure entry point pH.

Spot check feed pump output and determine feed rate.

Is pH within target range?

No → (to Spot check feed pump output)

Yes → Finished with daily routine (Complete daily/monthly records).

Verify plant flow. Determine dosage and compare to last correct dosage.

Is dosage comparison within range (±10%)?

Yes → (Water Chemistry Considerations)

No → (Mechanical Considerations)

## *Water Chemistry Considerations*

Measure baseline pH, alkalinity, temp for change.

Locate dosage block on Chemical Dosage Chart.

Conduct jar test to determine dosage.

Is dosage value recorded on chart?

No → (Conduct jar test)

Yes → (Adjust chemical feed pump)

Fill dosage value in chart.

## *Mechanical Considerations*

Troubleshoot/repair feed pump & other system components.

Recalibrate pump/develop new pump curve.

Adjust chemical feed pump to correct dosage. *

## 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:
  - Entry point pH = 8.2

Is the EP pH within the target range? _____

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

You should: _____

_____

Complete this part before continuing on.

## 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 (p. 24-7) and determine the dosage to be  _____.

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

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

You should: _____

_____

Complete this part before continuing on.

## 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 (p. 24-10), what is your plan of action? _____

_____



Complete this part before continuing on.

## DAY 2 - PART 4

<u>Action Plan:</u>

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

The new dosage required is  _____.

What feed settings are required to deliver the new dosage?  _____

_____

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?  _____

Is the daily routine finished?  _____

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

Day 2 is finished.

# Process Control Workshop

## MONTHLY OPERATION RECORD

**Month** _____   **Year** _____

| | Plant Flow | | Chemical Feed | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | Source Used | Flow (TGD) | Chemical: 25% Caustic | | | Chemical: | | | Parameter: pH | | | Parameter: Alkalinity | | | Parameter: | | |
| | | | Feed Rate (mL/min) | Dose (mg/L) | Used (gal or lbs) | Feed Rate (mL/min) | Dose (mg/L) | Used (gal or lbs) | Raw | EP | Dist | Raw | EP | Dist | Ra | EP | Dist |
| 1 | | 288 | 12 | 5 | | | | | 7.1 | 8.5 | | 30 | | | | | |
| 2 | | 288 | 14.3 | 6 | | | | | 7.0 | 8.5 | | 30 | | | | | |
| 3 | | | | | | | | | | | | | | | | | |
| 4 | | | | | | | | | | | | | | | | | |
| 5 | | | | | | | | | | | | | | | | | |
| 6 | | | | | | | | | | | | | | | | | |
| 7 | | | | | | | | | | | | | | | | | |
| 8 | | | | | | | | | | | | | | | | | |
| 9 | | | | | | | | | | | | | | | | | |
| 10 | | | | | | | | | | | | | | | | | |
| 11 | | | | | | | | | | | | | | | | | |
| 12 | | | | | | | | | | | | | | | | | |
| 13 | | | | | | | | | | | | | | | | | |
| 14 | | | | | | | | | | | | | | | | | |
| 15 | | | | | | | | | | | | | | | | | |
| 16 | | | | | | | | | | | | | | | | | |
| 17 | | | | | | | | | | | | | | | | | |
| 18 | | | | | | | | | | | | | | | | | |
| 19 | | | | | | | | | | | | | | | | | |
| 20 | | | | | | | | | | | | | | | | | |
| 21 | | | | | | | | | | | | | | | | | |
| 22 | | | | | | | | | | | | | | | | | |
| 23 | | | | | | | | | | | | | | | | | |
| 24 | | | | | | | | | | | | | | | | | |
| 25 | | | | | | | | | | | | | | | | | |
| 26 | | | | | | | | | | | | | | | | | |
| 27 | | | | | | | | | | | | | | | | | |
| 28 | | | | | | | | | | | | | | | | | |
| 29 | | | | | | | | | | | | | | | | | |
| 30 | | | | | | | | | | | | | | | | | |
| 31 | | | | | | | | | | | | | | | | | |

Note: "EP" = entry point to the distribution system; "Dist" = distribution system; "TGD" = thousand gallons per day.

24-15

Process Control Workshop

| Day | Comments |
|---|---|
| 2 | Spot checked the feed pump output, measured the baseline water, adjusted the pump settings |
| 3 | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |

## 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:
  - Entry point pH = 8.0

Is the EP pH within the target range?  _____

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

You should :  _____

_____

  Complete this part before continuing on.

## 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 (p. 24-7) and determine the dosage to be _____.

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

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

You should: _____

_____

Complete this part before continuing on.

# 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 pump calibration curve (p. 24-20).

Use the new calibration curve (p. 24-20) to determine the appropriate feed       settings       to       deliver       14.3       mL/min. _____

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?  _____

Is the daily routine finished?  _____

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

Day 3 is finished.

## NEW LIQUID FEED PUMP CALIBRATION CURVE

% Stroke:  60%                    Pump: _____



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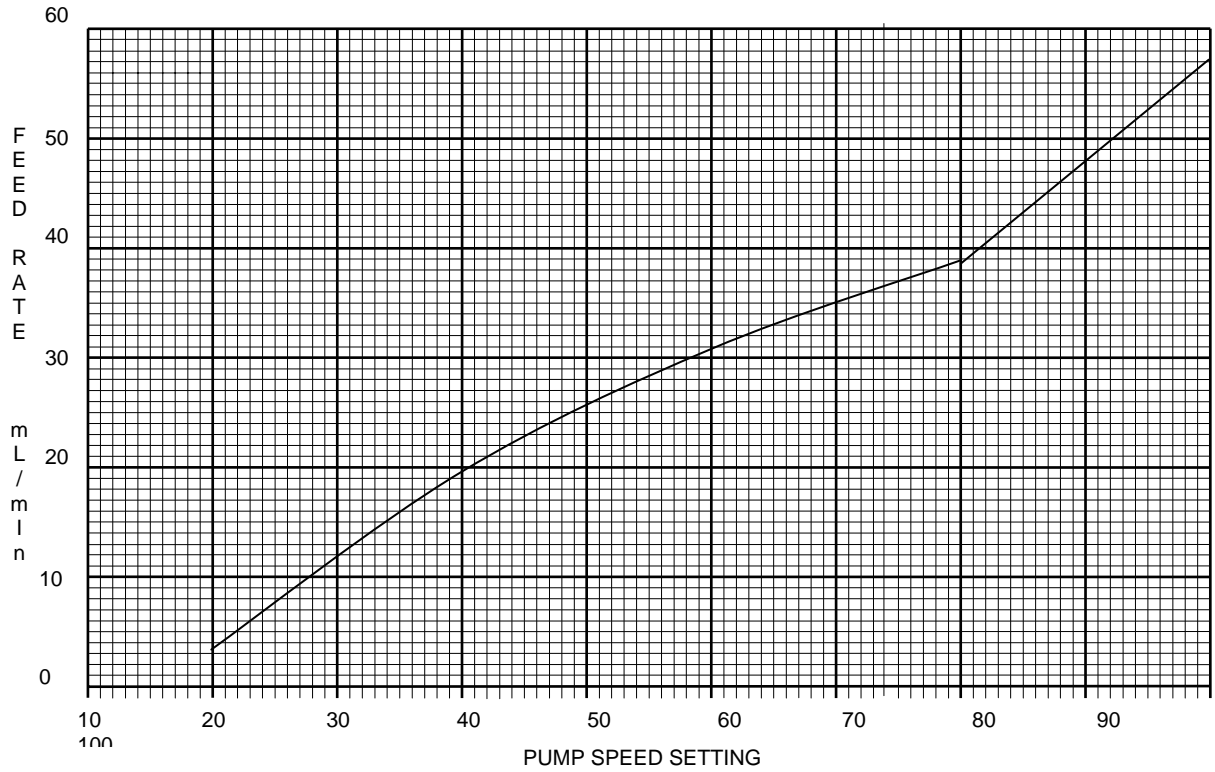
| Dosage (mg/L) | Pump Setting |
|---|---|
|  |  |
|  |  |
| 4 | 27 |
| 5 | 30 |
| 6 | 33 |
| 7 | 36 |
| 8 | 39 |
| 9 | 43 |
| 10 | 47 |
| 11 | 51 |
|  |  |
|  |  |

## Summary

**Key Points:**

- The Daily Stability Routine Flowchart is a tool used to maintain a _____ water quality.

- 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 _____ does not vary and the chemical product _____ remains the same.

- The Chemical Dosage Chart is used to adjust chemical feed when the _____ water quality changes.

- Jar testing is required only when a value is missing on the Chemical Dosage Chart.

# MODULE 25
# *CCT Course Summation*

❖ **Objectives:**

- Summarize the top ten key points of the entire course.

- Identify contacts for additional assistance.

- Answer questions and address concerns of class before final exam.

## Summary:  Top Ten Key Points

🔑 **Key Points:**

1. The most important task in corrosion control treatment is to maintain a stable finished water chemistry, particularly a stable entry point pH.

2. Observe the operation of feed systems daily.

3. Use the LCR Guide to find information about the Lead and Copper Rule.

4. Quality control procedures, including two-point calibration, are critical for accurate pH measurement.

5. Analyze samples as soon as possible after sample collection.

6. Establish and maintain proper operation and maintenance activities for stable water quality.

7.  The chemical feed calculation diagram, pump calibration curve and chemical dosage chart are necessary tools for process control of chemical feed systems.

8.  It's important to look at how treatment processes affect each other to avoid a serious negative impact.

9.  Perform a generous amount of testing and calibration during startup.

10. Controlling lead/copper is achieved by forming a protective layer on the pipe wall that eliminates the corrosion cell.

# Tab 1: Chemical Feed Calculations - Additional Practice Problems

Tab 1 - 1

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?

**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.

Tab 1 - 2

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**
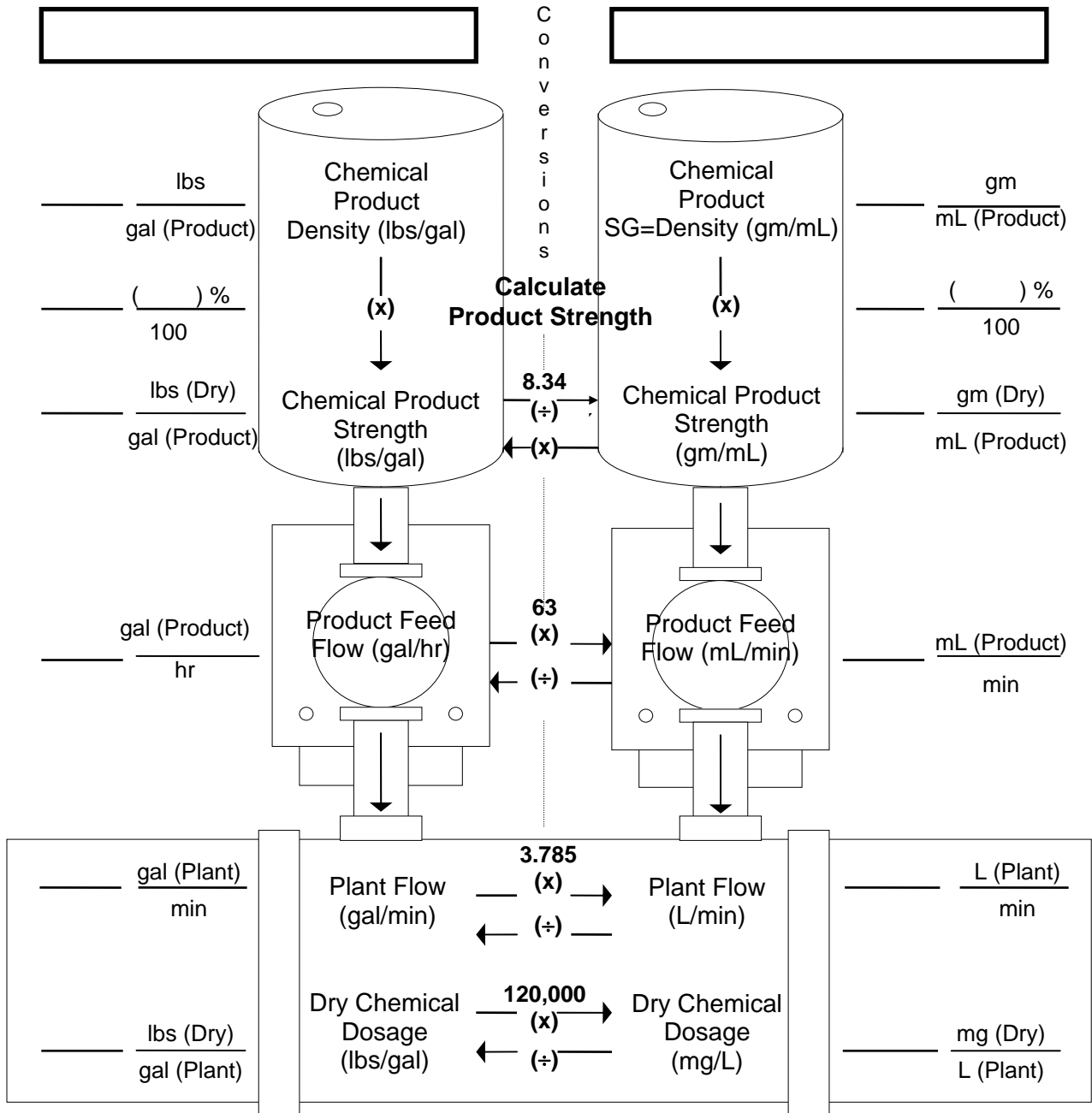
| | | |
|---|---|---|
| _____ lbs / gal (Product) | Chemical Product Density (lbs/gal) | Chemical Product SG=Density (gm/mL) |
| _____ ( ___ ) % / 100 | **(x)** | **(x)** |
| _____ lbs (Dry) / gal (Product) | Chemical Product Strength (lbs/gal) | Chemical Product Strength (gm/mL) |

**Calculate Product Strength**

**8.34 (÷)** ?
**(x)**

_____ gm / mL (Product)

_____ ( ___ ) % / 100

_____ gm (Dry) / mL (Product)

| _____ gal (Product) / hr | Product Feed Flow (gal/hr) | **63 (x) →** **(÷) ←** | Product Feed Flow (mL/min) | _____ mL (Product) / min |

| _____ gal (Plant) / min | Plant Flow (gal/min) | **3.785 (x) →** **(÷) ←** | Plant Flow (L/min) | _____ L (Plant) / min |

| _____ lbs (Dry) / gal (Plant) | Dry Chemical Dosage (lbs/gal) | **120,000 (x) →** **(÷) ←** | Dry Chemical Dosage (mg/L) | _____ mg (Dry) / L (Plant) |

**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.

Tab 1 - 3

# Terms and Definitions

Tab 3 - 1

## CORROSION CONTROL TRAINING FOR OPERATORS
## TERMS AND DEFINITIONS

**ACID:** A chemical that lowers the pH of water by producing hydrogen ($H^+$) ions.

**ALKALINITY:** The capacity of water to neutralize acids. This capacity is caused by the water's content of carbonate, bicarbonate and hydroxide. Alkalinity is expressed in mg/L of equivalent calcium carbonate. Alkalinity is a measure of how much acid or base can be added to a liquid without causing a great change in pH.

**ANION:** A negatively charged ion formed when an atom or molecule gains electrons.

**ANODE:** The positive electrode of a corrosion cell. Oxidation occurs (electrons are lost) at the anode of a corrosion cell.

**ATOM:** The smallest unit of a chemical element. An atom is composed of protons, neutrons and electrons.

**BASE:** A chemical that raises the pH of water by consuming hydrogen ions ($H^+$). A base produces hydroxide ions ($OH^-$) in solution.

**BUFFERING CAPACITY:** The measure of the capacity of water for offering a resistance to changes in pH.

**CALCIUM CARBONATE EQUIVALENT:** An expression of the concentration of a substance in water in terms of its equivalent value to calcium carbonate. For example, the hardness in water which is caused by calcium, magnesium and other ions is usually described as calcium carbonate equivalent.

**CATHODE:** The negative electrode of a corrosion cell. The cathode attracts positively charged ions. Reduction occurs (electrons are gained) at the cathode of a corrosion cell.

**CATION:** A positively charged ion formed when an atom or molecule loses electrons.

**COMPOUND:** A substance composed of two or more elements whose compostion doesn't change.

**CONDUCTANCE:** The measurement of the capacity of water to carry an electrical current, which is related to the concentration of ionized substances in the water.

Tab 3 - 2

**CORROSION:** The process by which metals are oxidized in the atmosphere. Corrosion causes the gradual decomposition or destruction of the metal by chemical action, often involving an electrochemical reaction. Corrosion starts at the surface of the material and moves inward.

**CORROSION INHIBITOR:** A substance that slows the rate of corrosion by coating the anode or cathode of a corrosion cell.

**CORROSIVITY:** An indication of the corrosiveness of a water. Corrosivity is determined by a water's pH, alkalinity, hardness, temperature, total dissolved solids and other factors.

**DENSITY:** A measure of how heavy a substance is for its size. Density is expressed in terms of weight per unit volume such as grams per cubic centimeter or pounds per cubic foot.

**DISSOLVED INORGANIC CARBONATE (DIC):** The dissolved inorganic carbon in water. DIC has a direct relationship to how corrosive a water is to lead and copper. DIC is expressed in mg/L of either carbon or calcium carbonate equivalent. DIC is normally calculated from the pH and alkalinity of a water at a given temperature.

**ELEMENT:** A substance that cannot be broken down into simpler substances.

**ELECTRON:** An extremely small, negatively charged particle that occupies the space around the nucleus of an atom. The electron is the part of the atom that determines its chemical properties.

**HARDNESS:** A characteristic of water caused mainly by the presence of calcium and magnesium. The calcium and magnesium react with bicarbonate, sulfate, chloride and soaps to form scales.

**ION:** An electrically charged (positive or negative) atom or molecule formed by the loss or gain of one or more electrons.

**IONIZATION:** The splitting or separation of molecules into negatively or positively charged ions.

**METAL:** An element that gives up electrons easily.

**MOLE:** The molecular weight of a substance, usually expressed in grams.

**MOLECULAR WEIGHT:** The sum of the weights of all atoms in a molecule.

Tab 3 - 3

**MOLECULE:** The smallest division of a compound that still retains all the properties of the substance. A molecule of water is composed of two hydrogen atoms and one oxygen atom ($H_2O$).

**OXIDATION:** The removal or loss of electrons from an element or compound, producing a cation. Oxidation occurs most readily in metals.

**OXIDIZING AGENT:** Any substance that can steal electrons. Oxidizing agents are usually non-metals.

**pH:** The measurement of the acidity (concentration of hydrogen ions) of a water. The pH scale is a log scale based on 10 that represents small concentrations on a scale of 0 to 14.

**PRECIPITATION:** A chemical reaction that transforms a substance in solution into an insoluble solid called a precipitate. Precipitation is a corrosion control treatment in which a base is added to the water to raise the pH until calcium carbonate precipitates on the pipe wall.

**PROTON:** A positively charged particle in the nucleus of an atom.

**REDUCING AGENT:** Any substance that will readily give up electrons. Reducing agents are usually metals.

**REDUCTION:** The addition of electrons to an element or compound, producing an anion. Reduction occurs most readily in non-metals.

**SALT:** A product formed when an acid and a base react together. Water is the other product formed in the reaction.

**SOLUBILITY:** The amount of a substance that dissolves in a solution.

**SPECIFIC GRAVITY:** Weight of a substance in relation to the weight of water. Water has a specific gravity of 1.0 no matter what units of measurement are used for density.

**TOTAL DISSOLVED SOLIDS (TDS):** All of the dissolved solids in a water.

Tab 3 - 4

## WATER ABBREVIATIONS

| | | | |
|---|---|---|---|
| amp | ampere | km | kilometer |
| °C | degrees Celsius | L | liter |
| cfm | cubic feet per minute | lb | pound |
| cfs | cubic feet per second | lbs/sq in | pounds per square inch |
| cm | centimeter | m | meter |
| cu ft | cubic feet | M | million |
| cu in | cubic inch | mg | milligram |
| cu m | cubic meter | mg/L | milligram per liter |
| cu yd | cubic yard | MGD | million gallons per day |
| °F | degrees Fahrenheit | mL | milliliter |
| ft | feet or foot | min | minute |
| gal | gallon | mm | millimeter |
| gal/day | gallon per day | pCi | picoCurie |
| gm | gram | psf | pounds per square foot |
| GPD | gallons per day | psi | pounds per square inch |
| GPM | gallons per minute | ppb | parts per billion |
| HP | horsepower | ppm | parts per million |
| hr | hour | sec | second |
| in | inch | sq ft | square feet |
| k | kilo | sq in | square inch |
| kg | kilogram | | |

Tab 3 - 5

# Conversions

Tab 3 - 1

Conversions

| UNITS OF WEIGHT | |
|---|---|
| English | Metric |
| pound - lb | gram - gm<br>milligram - mg<br>kilogram - kg |
| CONVERSIONS | |
| Metric/Metric | Metric/English |
| 1000 mg = 1 gm or 1000 mg/gm<br>1000 gm = 1 kg or 1000 gm/kg | 1 lb = 454 gm or 454 gm/lb<br>1 kg = 2.2 lbs or 2.2 lbs/kg |

| UNITS OF VOLUME | | |
|---|---|---|
| English | Metric | |
| gallon - gal<br>million gallon - Mgal<br>cubic feet - cu ft | liter - L<br>milliliter - mL | |
| CONVERSIONS | | |
| Metric/Metric | Metric/English | English/English |
| 1000 mL = 1 liter or 1000 mL/L | 1 gal = 3.785 L or 3.785 L/gal<br>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<br>hour - hr | minute - min<br>second - sec |
| CONVERSIONS | |
| 1 day = 24 hr or 24 hr/day<br>1 hr = 60 min or 60 min/hr | 1 min = 60 sec or 60 sec/min<br>1 day = 1440 min or 1440 min/day |

Tab 3 - 2

Conversions

| UNITS OF DENSITY | |
|---|---|
| English | Metric |
| lbs/gal<br>lbs/cu ft | kg/L<br>g/mL |
| THE DENSITY OF WATER | |
| English | Metric |
| 8.34 lbs/gal<br>62.4 lbs/cu ft | 1kg/L<br>1 gm/mL |

| UNITS OF CONCENTRATION | |
|---|---|
| English | Metric |
| Pounds per gallon — lbs/gal | Milligrams per liter — mg/L |
| CONVERSION<br>1 lb/gal = 120,000 mg/L | |

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

Tab 3 - 3

# Math Process for Calculating Chemical Dosages and Feed Rates

Tab 4 -1

# Math Process for Calculating Chemical Dosages and Feed Rates

---

## *Introduction:*

Some water treatment plant operators lack the basic math skills necessary to control chemical feed (i.e., perform process control).

The PA Department of Environmental Protection created the following math process to assist operators when calculating chemical dosages and feed rates. The department created several tools, including:

- A Chemical Feed Calculation Diagram for liquid and dry feed
- Conversion Charts
- Helpful hints for performing unit cancellation

Use of these tools is described and demonstrated below.

---

## *Sample Problem:  Liquid Chemical Feed Calculation Diagram*

**A treatment plant is feeding caustic soda for pH adjustment.  Results of a jar test indicate a dosage of 32 mg/L is needed to reach the target pH.  The plant flow is 347 GPM.  The caustic soda is a 50% solution and has a density of 12.8 lbs/gal.  What feed pump rate (in mL/min) is needed to deliver this dosage?**

Tab 4 -2

| Solution Steps: |
|---|

## *To complete the diagram:*

**Step 1.** Fill in the known data.

**Step 2.** Put a question mark (?) for the value of the unknown data.

**Step 3.** Calculate chemical product strength (top 1/3$^{rd}$ portion of diagram).

**Step 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.

**Step 5.** Use unit cancellation to solve for the product feed rate, as follows.

## *To perform unit cancellation:*

**Step 1:** List ? unknown data (including units) followed by an = sign.

**Step 2:** Place data (either known data or a conversion) with the 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 the same numerator unit.

**Step 4:** Continue to place data into the 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).

---

**Unit Cancellation Helpful Hints**

<u>Numerator</u>                                        "per" means divided by
Denominator

Vertical format:        5 gpd = <u>5 gal</u>
                                              day

    1 g = 1000 mg   is written as:    <u>1   g</u>        OR      <u>1000 mg</u>
                                                        1000 mg                        1 g

Invert, when necessary:  <u>5 gal</u>   is the same as:   <u>1 min</u>
                                                min                                5 gal

---

Tab 4 -3

## CHEMICAL FEED CALCULATION DIAGRAM
### LIQUID FEED

Conversions

| English Units | | Metric Units |
|---|---|---|

**English Units**

12.8 lbs / gal (Product)

Chemical Product Density (lbs/gal)

0.5 ( 50 )% / 100

(x)

Calculate Product Strength

6.4 lbs (Dry) / gal (Product)

Chemical Product Strength (lbs/gal)

8.34 (÷)
(x)

Product Feed Flow (gal/hr)

gal (Product) / hr

63 (x) (÷)

347 gal (Plant) / min

Plant Flow (gal/min)

3.785 (x) (÷)

lbs (Dry) / gal (Plant)

Dry Chemical Dosage (lbs/gal)

120,000 (x) (÷)

**Metric Units**

g / mL (Product)

Chemical Product SG=Density (g/mL)

( )% / 100

(x)

Chemical Product Strength (g/mL)

0.767386 g (Dry) / mL (Product)

Product Feed Flow (mL/min)

? mL (Product) / min

Plant Flow (L/min)

1313.395 L (Plant) / min

Dry Chemical Dosage (mg/L)

32 mg (Dry) / L (Plant)

**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.

Tab 4 -1

Sample Problem Solution:

**Data from Diagram**

**?** mL (Product) = mL (Product) x   g   x 32 mg (Dry) x 1313.395 L (Plant)
      min     .767386 g (Dry)  1000 mg     L (Plant)           min

**Data from
Conversion Chart**

= **54.77 mL/min**

Tab 4 -2

# Forms

Tab 5 -1

PUMP: _____   CALIBRATION CURVE   DATE: _____

% STROKE: _____



PUMP SPEED SETTING

FEED RATE mL/min

Tab 5 -2
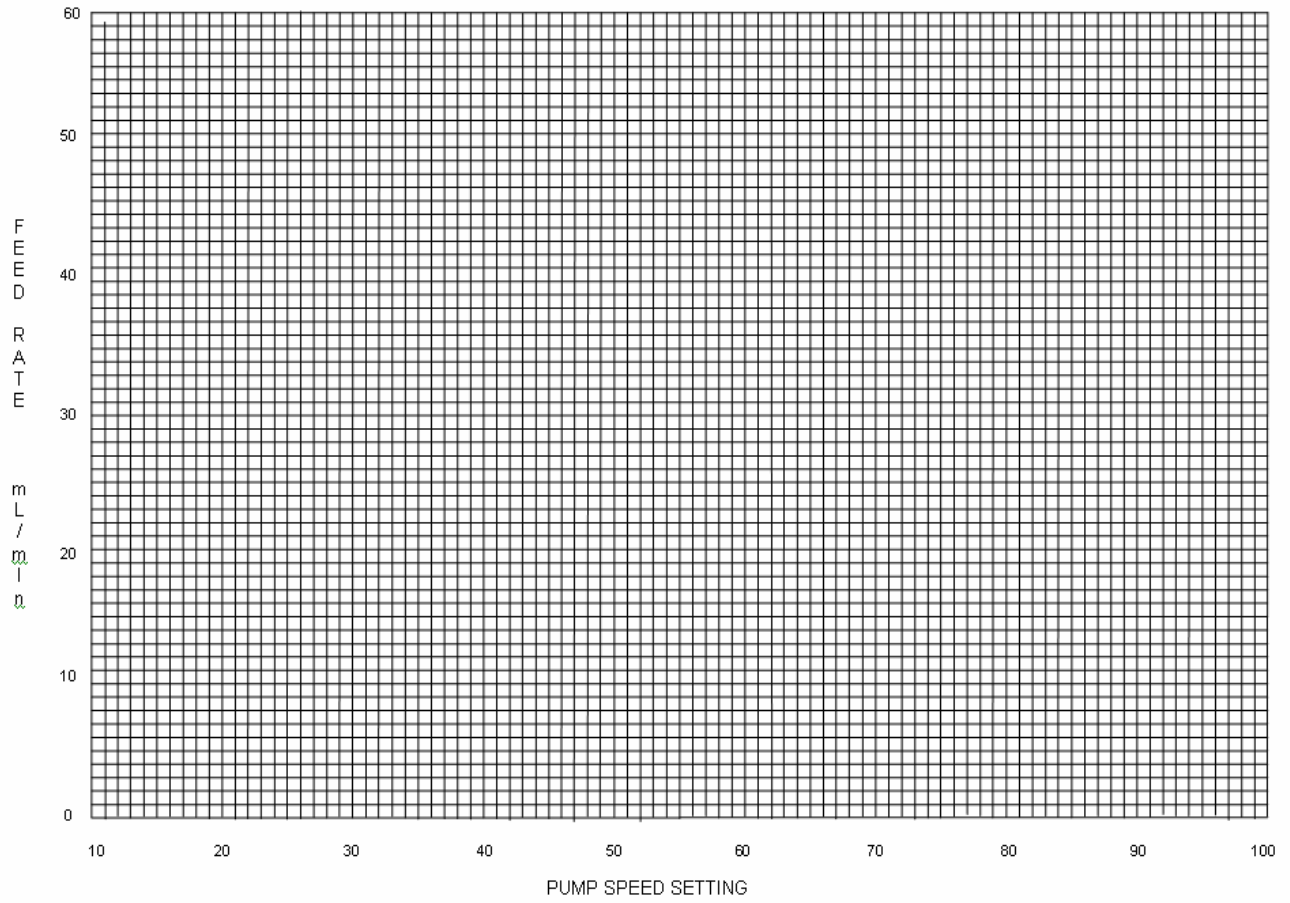
Forms

## MONTHLY OPERATION RECORD

Month _____    Year _____

| Date | Plant Flow | | Chemical Feed | | | | | | Water Quality Analyses | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Source Used | Flow (TGD) | Chemical: | | | Chemical: | | | Parameter: | | | Parameter: | | | Parameter: | | |
| | | | Feed Rate (mL/min) | Dose (mg/L) | Used (gal or lbs) | Feed Rate (mL/min) | Dose (mg/L) | Used (gal or lbs) | Raw | EP | Dist | Raw | EP | Dist | Raw | EP | Dist |
| 1 | | | | | | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | | | | | | |
| 4 | | | | | | | | | | | | | | | | | |
| 5 | | | | | | | | | | | | | | | | | |
| 6 | | | | | | | | | | | | | | | | | |
| 7 | | | | | | | | | | | | | | | | | |
| 8 | | | | | | | | | | | | | | | | | |
| 9 | | | | | | | | | | | | | | | | | |
| 10 | | | | | | | | | | | | | | | | | |
| 11 | | | | | | | | | | | | | | | | | |
| 12 | | | | | | | | | | | | | | | | | |
| 13 | | | | | | | | | | | | | | | | | |
| 14 | | | | | | | | | | | | | | | | | |
| 15 | | | | | | | | | | | | | | | | | |
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| 19 | | | | | | | | | | | | | | | | | |
| 20 | | | | | | | | | | | | | | | | | |
| 21 | | | | | | | | | | | | | | | | | |
| 22 | | | | | | | | | | | | | | | | | |
| 23 | | | | | | | | | | | | | | | | | |
| 24 | | | | | | | | | | | | | | | | | |
| 25 | | | | | | | | | | | | | | | | | |
| 26 | | | | | | | | | | | | | | | | | |
| 27 | | | | | | | | | | | | | | | | | |
| 28 | | | | | | | | | | | | | | | | | |
| 29 | | | | | | | | | | | | | | | | | |
| 30 | | | | | | | | | | | | | | | | | |
| 31 | | | | | | | | | | | | | | | | | |

Tab 5 -3

Forms

| Day | Comments |
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Tab 5 -4

**CHEMICAL FEED CALCULATION DIAGRAM**
**DRY FEED**

| English Units | | Metric Units |
|---|---|---|

Chemical Product

Conversions

Chemical Product

lbs (Dry) / day

Product Feed (lbs/day)

(x) 315
(÷)

Product Feed (mg/min)

mg (Dry) / min

gal (Plant) / min

Plant Flow (gal/min)

(x) 3.785
(÷)

Plant Flow (L/min)

L (Plant) / min

lbs (Dry) / gal (Plant)

Dry Chemical Dosage (lbs/gal)

(x) 120,000
(÷)

Dry Chemical Dosage (mg/L)

mg (Dry) / L (Plant)

**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.

Tab 5 -5

# CHEMICAL FEED CALCULATION DIAGRAM
## LIQUID FEED

| English Units | | Metric Units |
|---|---|---|

**Conversions**

### English Units

_____ lbs / gal (Product)

Chemical Product
Density (lbs/gal)

_____ ( ____ ) % / 100

(x)

_____ lbs (Dry) / gal (Product)

Chemical Product Strength
(lbs/gal)

_____ gal (Product) / hr

Product Feed Flow (gal/hr)

_____ gal (Plant) / min

_____ lbs (Dry) / gal (Plant)

### Metric Units

_____ g / mL (Product)

Chemical Product
SG=Density
(g/mL)

_____ ( ____ ) % / 100

(x)

_____ g (Dry) / mL (Product)

Chemical Product Strength
(g/mL)

_____ mL (Product) / min

Product Feed Flow (mL/min)

_____ L (Plant) / min

_____ mg (Dry) / L (Plant)

### Conversions (center)

Calculate Product Strength

Chemical Product Strength: (÷) 8.34 (x)

Product Feed Flow: (x) 63 (÷)

Plant Flow (gal/min) — (x) 3.785 / (÷) — Plant Flow (L/min)

Dry Chemical Dosage (lbs/gal) — (x) 120,000 / (÷) — Dry Chemical Dosage (mg/L)

**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.

Tab 5 -6

**Daily Stability Routine
pH/Alkalinity Adjustment**

Calibrate
pH meter.

*Note: If entry point pH is
still outside the target
range, check chemical
product .

Measure
entry point pH.

Spot check feed
pump output
and determine
feed rate.

Is pH
within target
range?

No

Yes

Finished with daily routine
(Complete daily/monthly
records).

Verify plant flow.
Determine dosage
and compare to last
correct dosage.

**Water Chemistry Considerations**

Is dosage
comparison
within range
(±10%)?

Yes

Measure baseline
pH, alkalinity, temp
for change.

Locate dosage block
on Chemical
Dosage Chart.

No

**Mechanical Considerations**

Conduct jar test
to determine
dosage.

No

Is dosage
value recorded
on chart?

Troubleshoot/repair
feed pump & other
system components.

Fill dosage
value in chart.

Yes

Recalibrate
pump/develop
new pump curve.

Adjust chemical
feed pump to
correct dosage. *

Tab 5 -7

**STOCK SOLUTION DIAGRAM**
**LIQUID CHEMICAL**

| English Units | | Metric Units |
|---|---|---|

Conversions

**English Units**

lbs / gal (Product)

( ) % / 100

lbs (dry) / gal (Product)

Chemical Product
Density (lbs/gal)

(x)

Chemical Product Strength
(lbs/gal)

**Metric Units**

Chemical Product
SG=Density
(gm/mL)

(x)

Chemical Product Strength
(gm/mL)

gm / mL (Product)

( ) % / 100

gm (Dry) / mL (Product)

Calculate Product Strength

8.34
(÷) →
(x) ←

mL Product Needed   ?   ___ mL (Product)

Stock Solution Volume (L)   ___ L (Stock)

Stock Solution Concentration (mg/L)   ___ mg (Dry) / L (Stock)

| 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 |

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.

Tab 5 -8

## FEED RATE VS. DOSAGE TABLE

**Chemical:** _____     **Plant Flow:** _____

| FEED RATE<br>(mL/min) | DOSAGE<br>(mg/L) |
| --- | --- |
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Tab 5 -9

CHEMICAL _____          DATE _____

TARGET EP pH _____          TARGET EP ALKALINITY _____

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

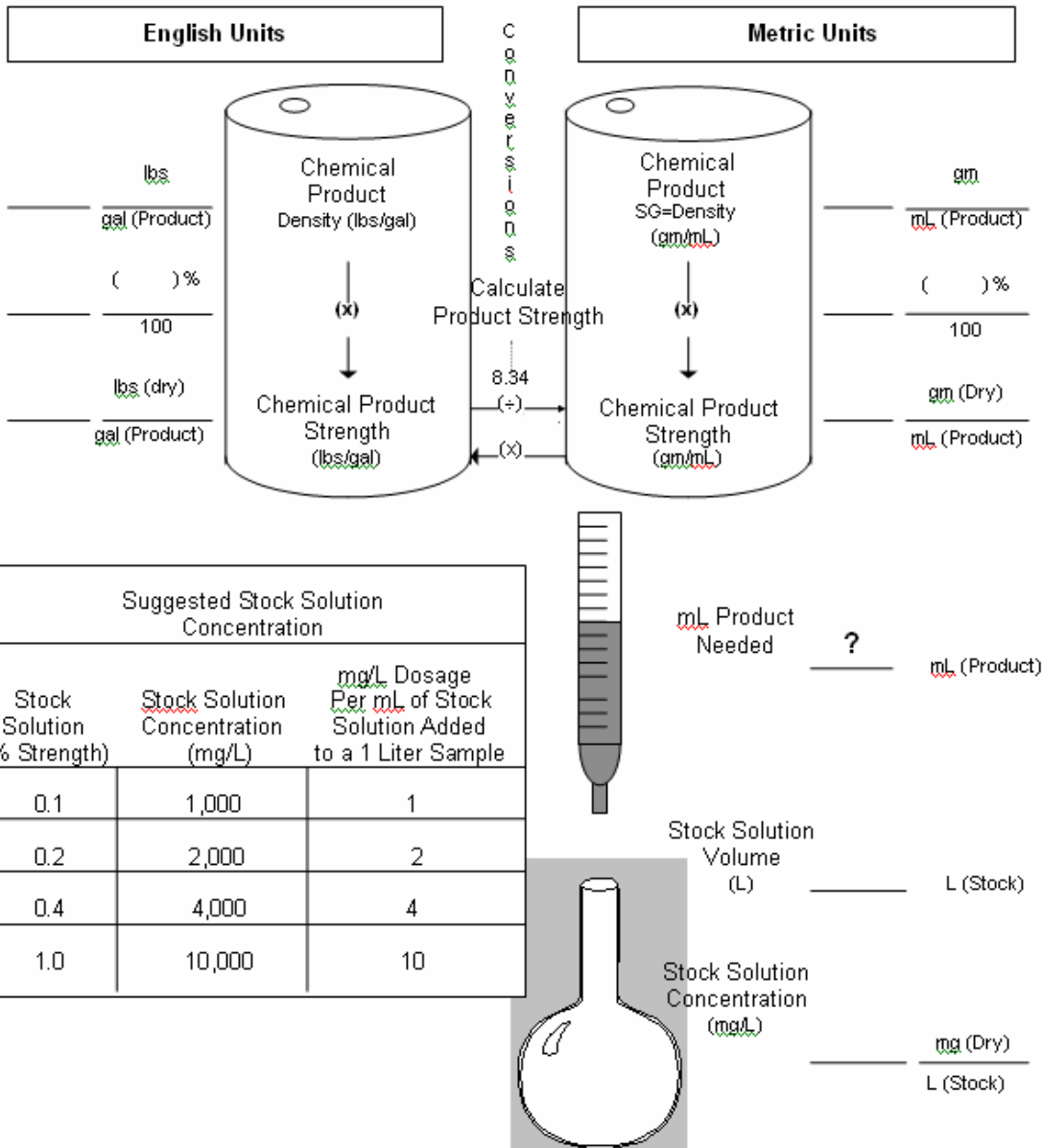| pH→<br>Alk.↓ | | | | | | | |
|---|---|---|---|---|---|---|---|
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**Directions:**

1. Construct a chemical dosage chart for each chemical added.
   - Record the pH range of the baseline water in the top row.
   - Record the alkalinity range of the baseline water in the first column.
2. Monitor the EP parameters on a daily basis (monitor baseline parameters when needed).
3. Complete a block on the chemical dosage chart when baseline water quality changes.
   - Conduct a jar test to determine the dosage needed to obtain the target EP pH.
   - Locate the appropriate block and record the dosage.
4. Complete additional blocks on the chart as varying water quality conditions are experienced.
5. Use the chart as a quick reference to adjust chemical feed when the same water quality occurs again.

Tab 5 -10

Forms

## LIQUID FEED PUMP CALIBRATION TABLE

**% Stroke:** _____

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

Tab 5 -11

## Unit Cancellation Steps

**Step 1:** List ? unknown data including units followed by an = sign

**Step 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 systemically 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:** ? lbs =   1 lb   x   1 gm   x   3785 mL   = 8.34 lbs

gal     454 gm        mL        1 gal

gal

**Helpful Hints:**

Numerator
Denominator

Vertical format:   5 gal =   5 gal
                                    1

1 gm = 1000 mg    is written:            1 gm   OR    1000 mg
                                               1000 mg              1 gm

"per" means divided by:    Ex.   5 gpm = 5 gal
                                                      min

Inverting:  5 gal  =  1 min
                  min        5 gal

Tab 5 -12

Commonwealth of Pennsylvania
Department of Environmental Protection
7/31/98

**Equal Opportunity Employer**

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