Water Board Basics: Disinfection

RCAC 2015 Online Training Series

WELCOME!

This training is presented by RCAC with funding provided by the California State Water Resources Control Board Division of Drinking Water (DDW)

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Your Moderators Today…

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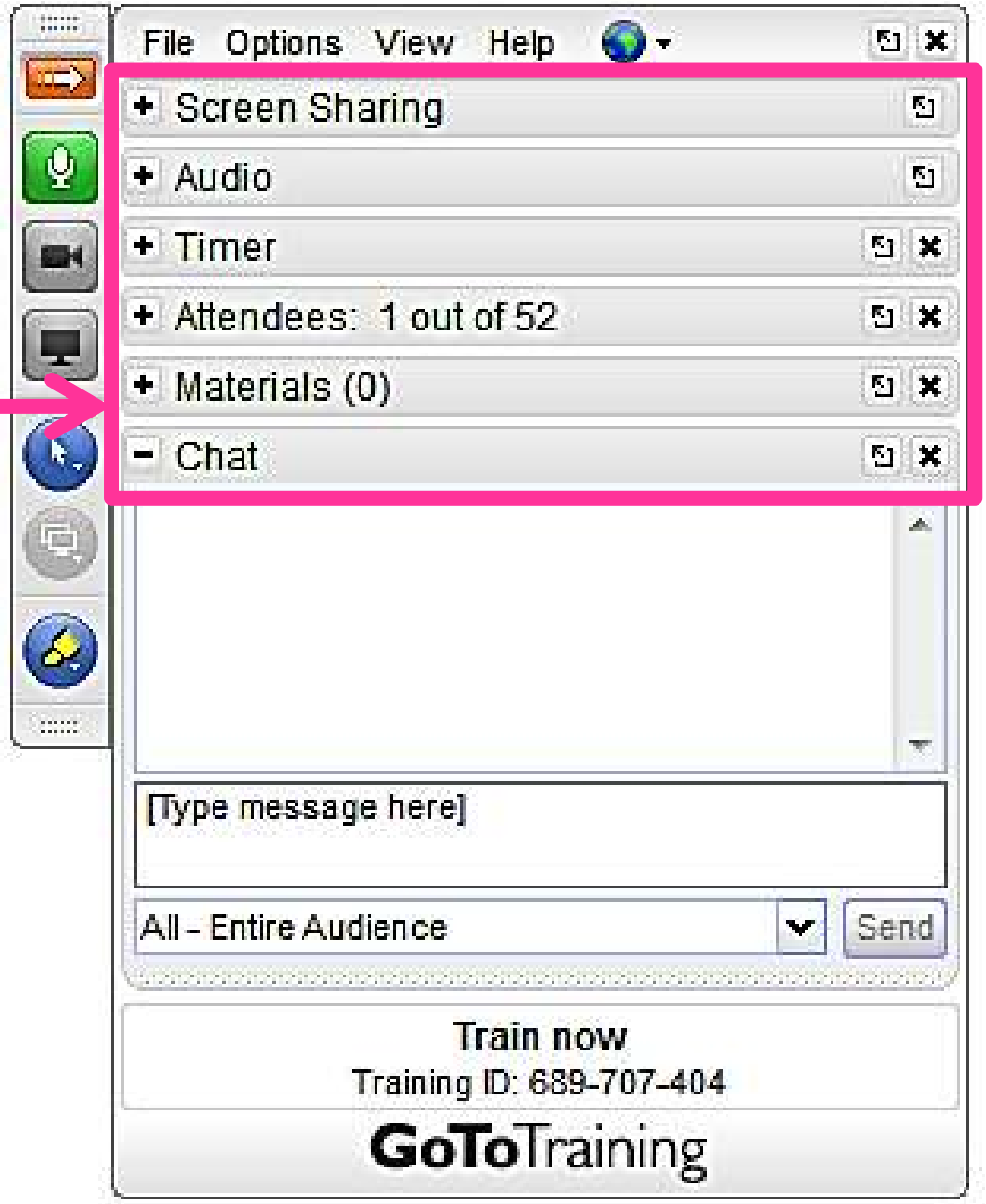
The Rural Community Assistance Partnership

RCAC Programs

- Affordable housing
- Community facilities
- Water and wastewater infrastructure financing (Loan Fund)
- Classroom and online training
- On-site technical assistance
- Median Household Income (MHI) surveys

Control Tabs



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Audio Controls

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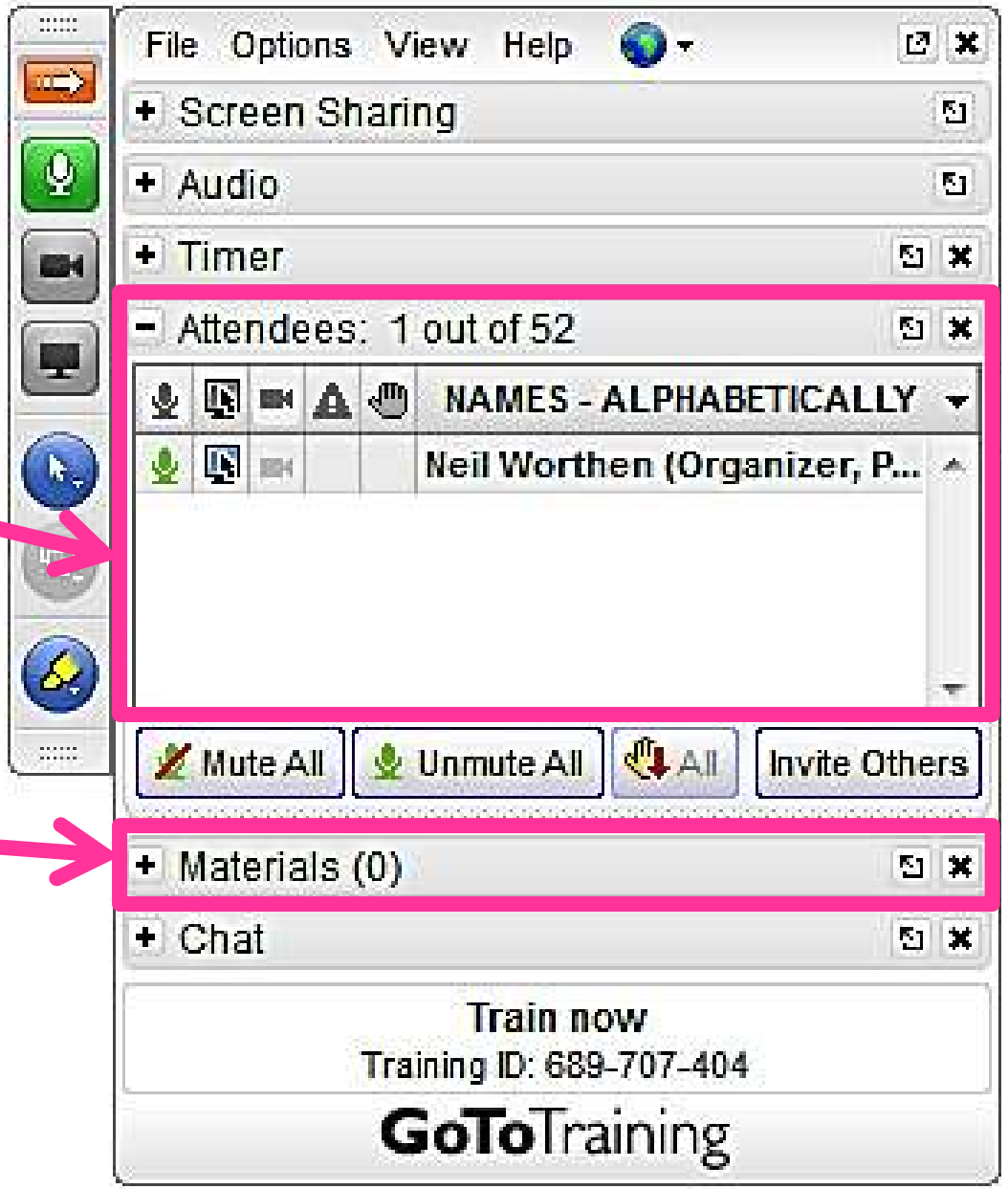
Attendee List

Today's Materials



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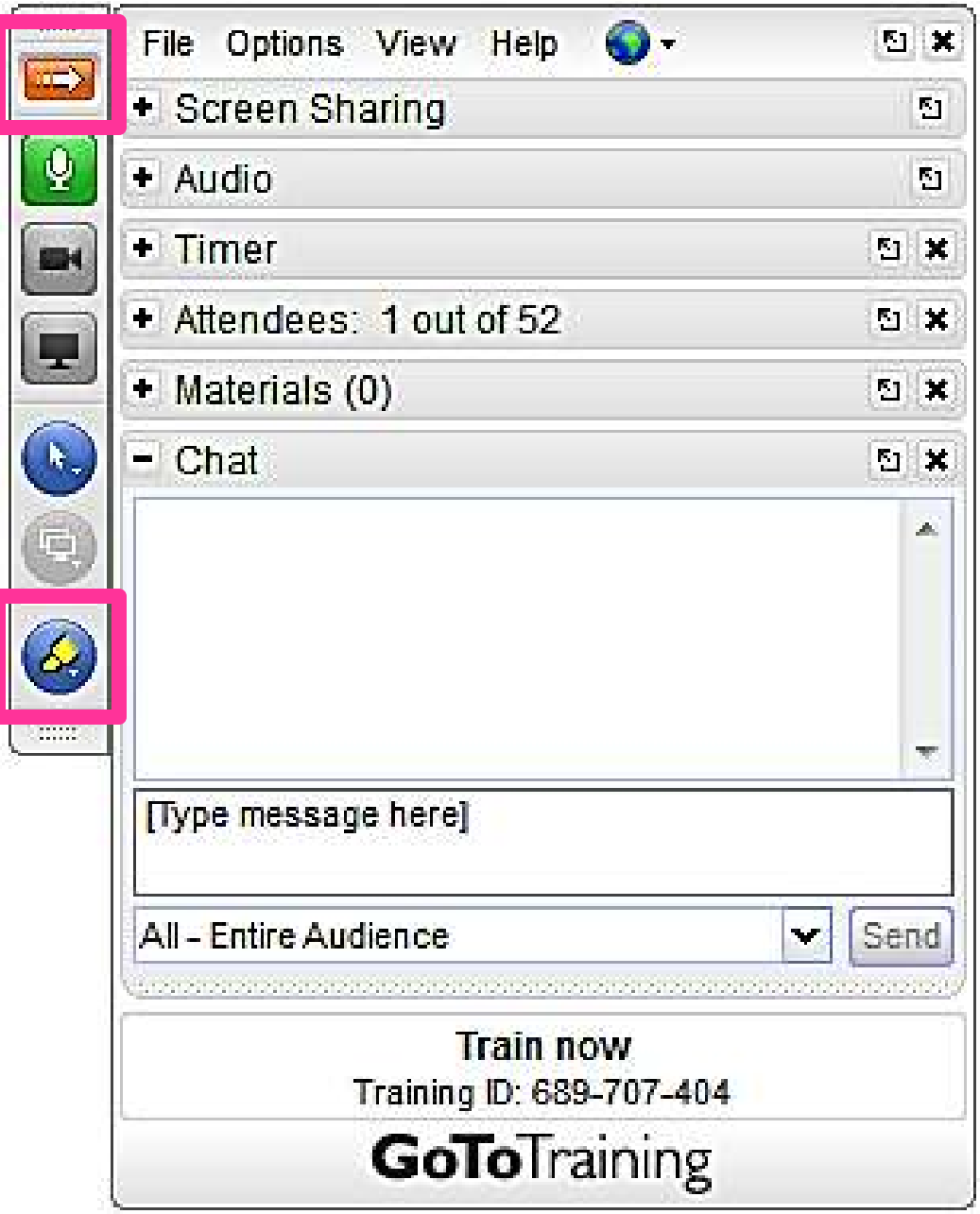
Hide/Restore Control Panel

Marking Tool



Questions?

Text your questions and comments anytime during the session

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Performance Assessment Rating Tool (PART)

- 4 to 6 weeks from today
- Email w/ today's workshop in subject line
- 3 questions – 3 minutes maximum
- How did you use the information that was presented today?
- Funders are looking for positive changes
- Help us continue these free workshops!

Your Presenter Today…

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Water Board Basics: Disinfection

RCAC 2015 Online Training Series

Sacramento, CA

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POLL QUESTION #1

Training Objectives

- Review properties of chlorine
- Factors influencing disinfection
- Disinfection process
- Points of application
- Standard Disinfection Methods
- Determining chlorine dose

Rural Community Assistance Corporation

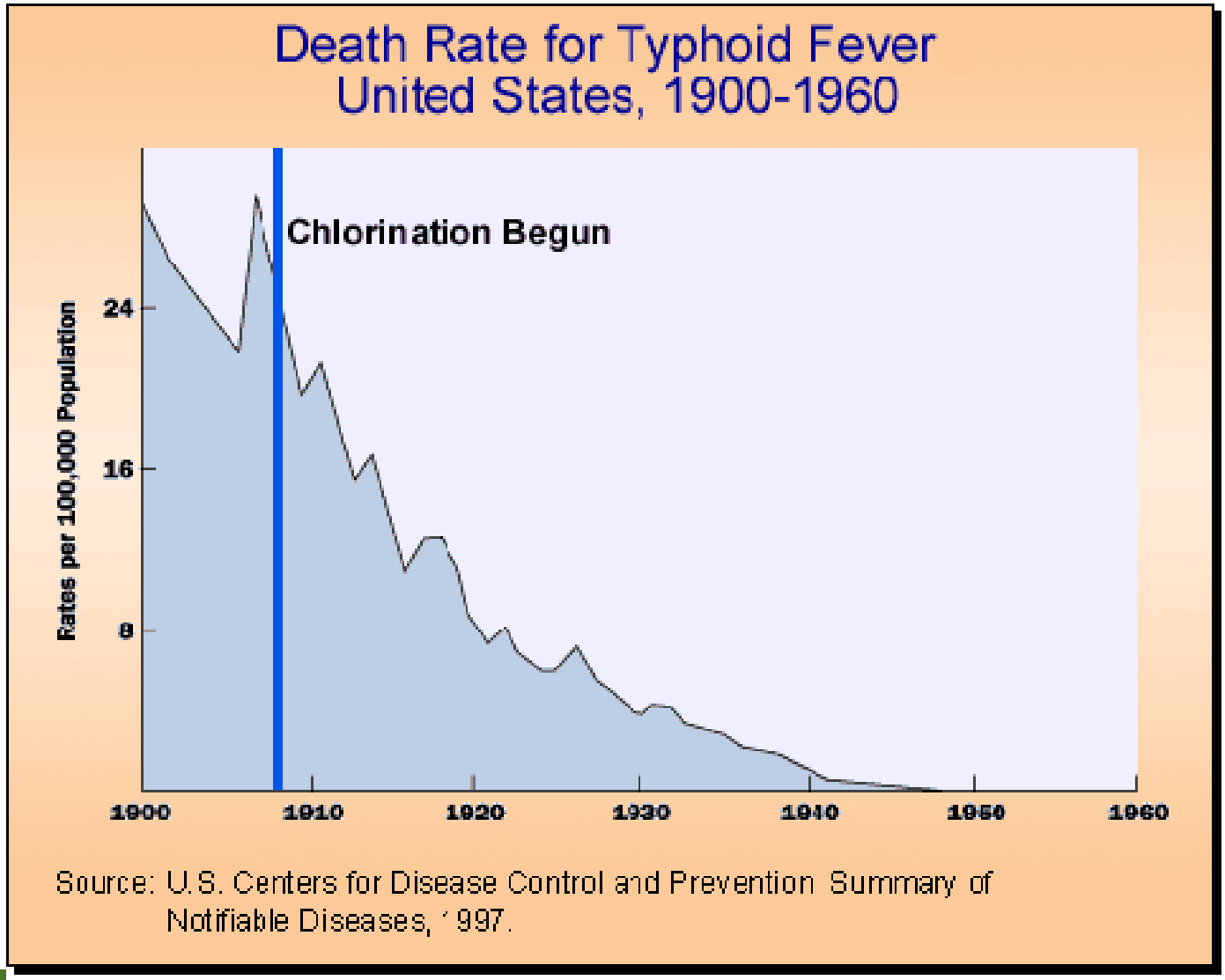
WHAT IS DISINFECTION?

- **Disinfection** - The act of destroying pathogenic organisms **(inactivation)**
  - Kill or inactivate pathogens
  - Disrupt metabolism
  - Prevent from reproducing

WHY DISINFECT?

- Between 1971 and 2000
  - 363 outbreaks of Acute Gastroenteritis
  - 126 outbreaks of Giardiasis
  - 28 outbreaks of Hepatitus A
  - 27 outbreaks of AGI, Norovirus
  - 15 outbreaks of Cryptosporidiosis
  - 11 outbreaks of AGI, E. Coli

Historical context for chlorination



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TYPES OF DISINFECTION

- **Heat** - not practical, too expensive. Used only in emergencies (boil orders). No residual
- **Ultraviolet** - exposure to UV lamps
- **Chemical Treatment**
  - Most commonly used

ULTRAVIOLET

- Effective for inactivation of pathogens (i.e. cryptosporidium cysts) which are resistant to chlorine
- Does not form Disinfection By Products (DBPs)
- *For more on LT2 and UV disinfection, go to* http://www.epa.gov/safewater/disinfection/lt2/compliance.html

CHEMICAL TREATMENT

- **Potassium permanganate ($KMnO_4$)** – Turns water purple
- Usually initial chemical added
- Taste & odor control (in conjunction with activated carbon)
- Oxidizes Iron, Manganese, Hydrogen Sulfide
- Controls Trihalomethane (THM) formation

CHEMICAL TREATMENT

- **Ozone** – a powerful oxidizing agent
  - Bluish gas/pungent odor
  - Excellent odor removal
  - Complicated production (on-site)
  - Expensive (energy consumption)
  - Harmful Disinfection Byproduct (DBP) formation if bromate is present
  - No residual

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CHEMICAL TREATMENT

- **Chlorine Dioxide** - green-yellow gas usually manufactured on-site
  - Excellent for certain taste & odor removal
  - Potential to form harmful Disinfection Byproducts (i.e. chlorite & chlorate)
  - USEPA recommends residual levels be lower than practical for most cases
  - 1 mg/L MCL in Stage 1 DBPR

CHEMICAL TREATMENT

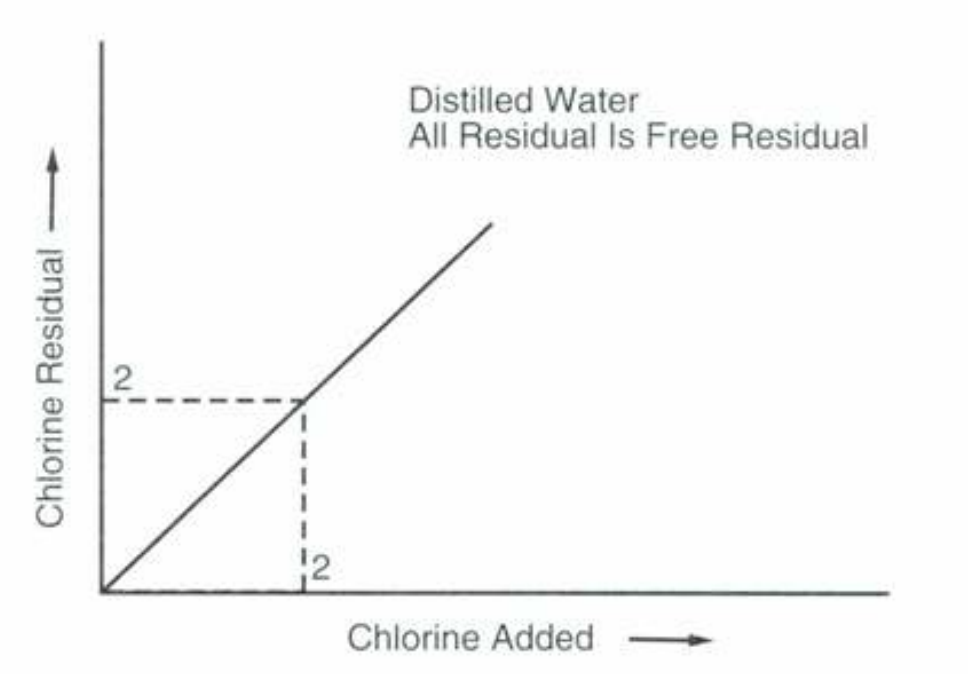
- **Chlorine** Most widely used disinfectant for water treatment in United States
- Hypochlorous acid (HOCl) and Hypochlorite ion (OCl^-) are the most effective residuals. They are derived from:
  - Chlorine, Cl_2
  - Calcium Hypochlorite, $Ca(OCl)_2$
  - Sodium Hypochlorite, NaOCl

POLL QUESTION #2

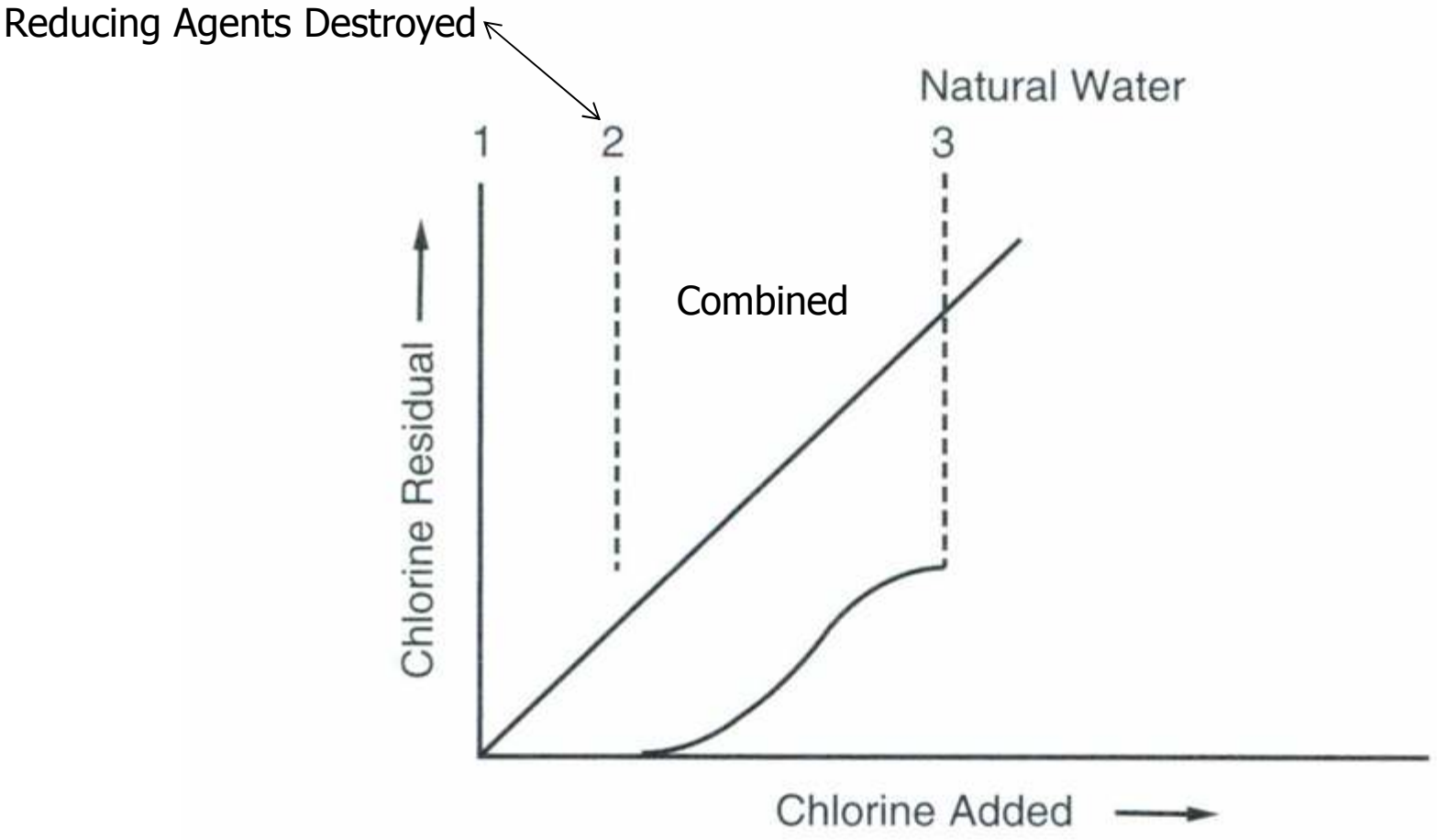
PRINCIPLES OF CHLORINATION

- **BREAKPOINT CHLORINATION**
  The amount of chlorine needed to achieve free residual chlorine

➢When chlorine is added to *distilled water* a free chlorine residual is produced. Most drinking water is not pure and the chlorine added reacts with impurities in a process called breakpoint chlorination

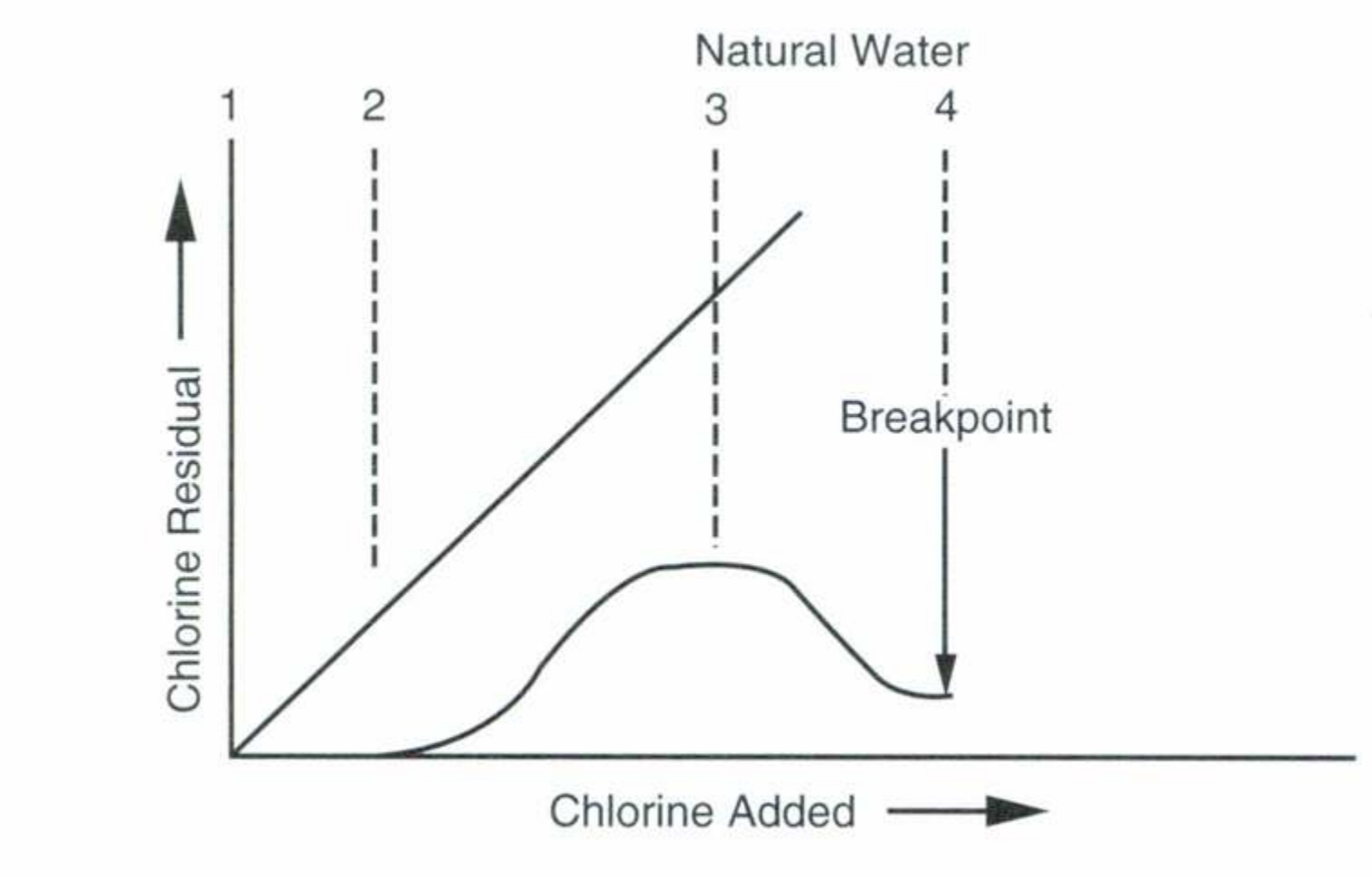


BREAKPOINT CHLORINATION



The reaction of chlorine with impurities in natural water

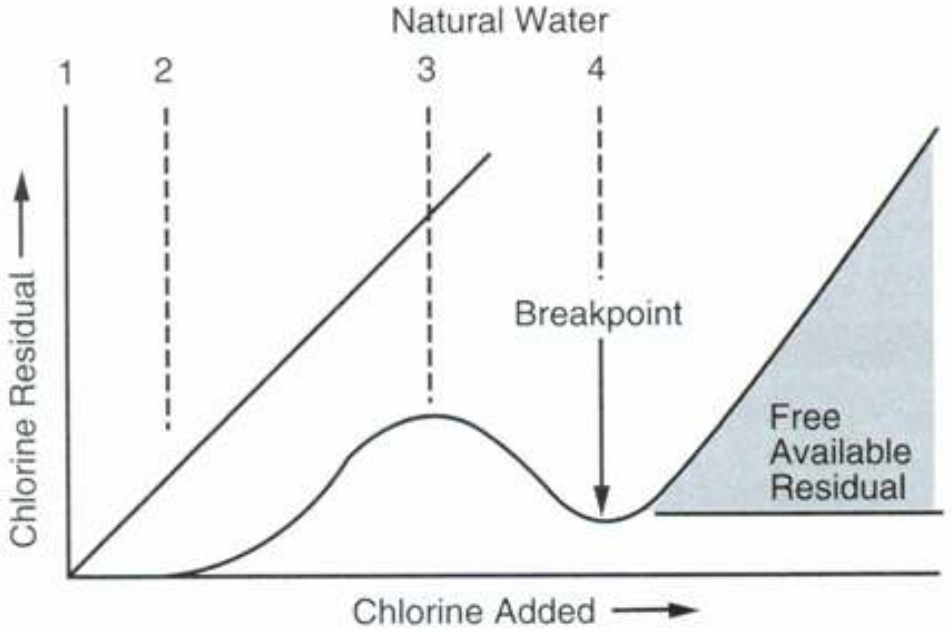
BREAKPOINT CHLORINATION



Decrease of chlorine residual

BREAKPOINT CHLORINATION

- After breakpoint, an increase in Cl_2 dose will produce a proportionate amount of free chlorine residual



The chlorine breakpoint

DOSAGE = DEMAND + RESIDUAL

- The dosage (amount of chlorine you add to water) is equal to the amount you've lost due to demand plus the amount of residual desired
  - Dosage = 5.5 mg/L
  - Demand = 5 mg/L
  - Desired residual = 0.5 mg/L

TYPES OF CHLORINE RESIDUAL

- **Free Chlorine**
  - Hypochlorous acid (HOCl)
  - Hypochlorite ion (OCl^-)
  - Free chlorine = HOCl + OCl^-
- **Combined chlorine**
  - **Chloramines** - The products of the reaction with chlorine and ammonia

EFFECTS OF pH ON FREE CHLORINE

- The amount of Hypochlorous acid (HOCl) versus Hypochlorite ion (OCl^-)

  depends on pH
- HOCl is a more powerful disinfectant than OCl^-, therefore:
- Lower pH levels = more HOCl = more effective disinfection.
- pH of 7.5 or less is most effective

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TRIHALOMETHANES (THMs)

- A byproduct of chlorine disinfection
- Formed when chlorine is added to water containing naturally occurring organic compounds, primarily **humic and fulvic acids**
- Considered to be potential carcinogens (cancer causing).

COMBINED CHLORINE RESIDUAL

- Chloramines are also called **combined residuals,** composed of:
  - Tri-chloramine
  - Di-chloramine
  - Mono-chloramine
- Di- and tri-chloramines contribute to taste and odor in finished water.
- Mono-chloramines produce the least amount of taste and odor problems.

CHLORAMINES vs FREE CHLORINE, Ph

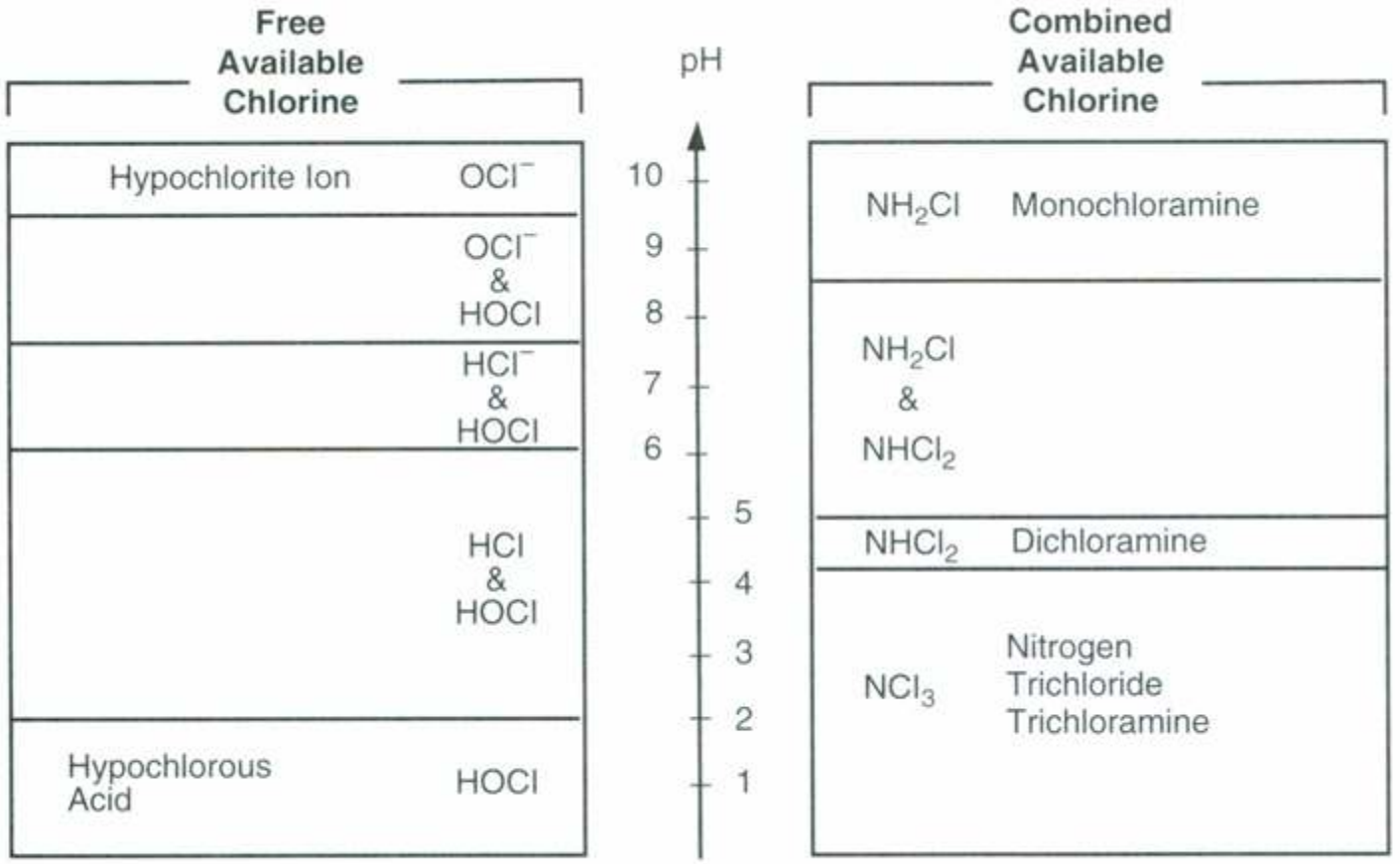


FIGURE 7–7 Effects of pH on free and combined chlorine residual

TOTAL CHLORINE

- The sum total of free chlorine plus combined chlorine.
- Free Chlorine + Combined Chlorine = Total Chlorine

USE OF FREE CHLORINE VERSUS CHLORAMINE

- Free chlorine
  - More powerful disinfectant
  - Does not persist as long as chloramines
  - Contributes to formation of tri-halomethanes (THMs)

USE OF FREE CHLORINE VERSUS CHLORAMINE

- Chloramines
  - Much weaker disinfectant than chlorine
  - Longer lasting residual than chlorine
  - Does not contribute to formation of trihalomethanes (THMs)
  - Dialysis patients?

FACTORS INFLUENCING CHLORINE DISINFECTION

1. Disinfectant concentration
2. Contact time
3. Temperature of water
4. pH of the water
5. Turbidity

NSF Certification

- www.nsf.org
- National Sanitation Foundation
- Ann Arbor Michigan
- Independent Testing Organization
- Founded in 1944
- Since 1990 NSF International
- The tell tale logo →

POLL QUESTION #3

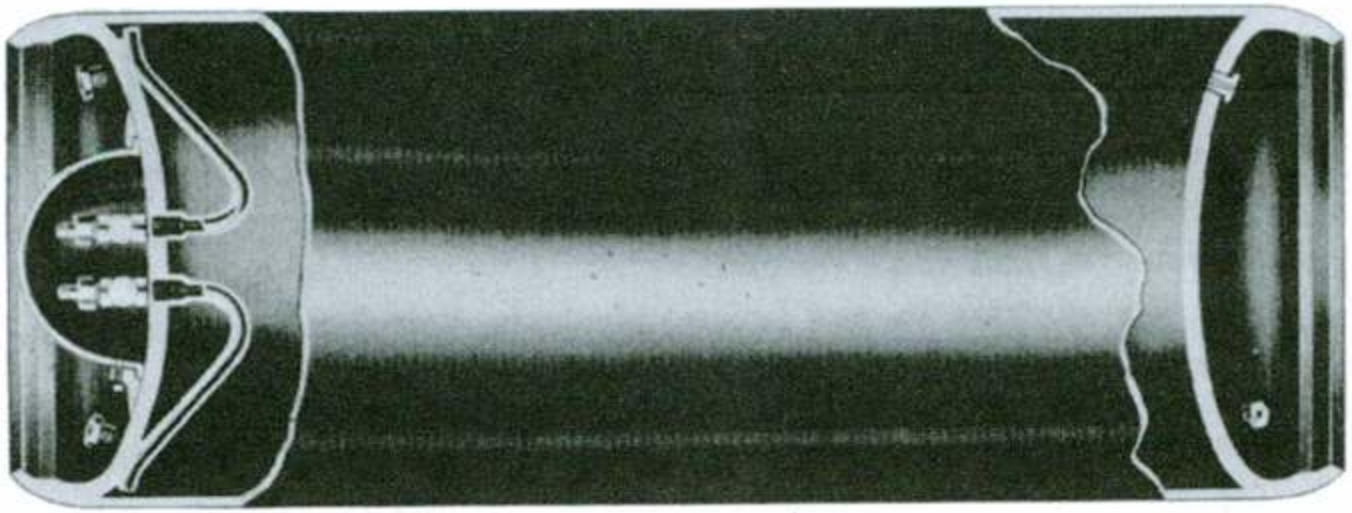
FORMS OF CHLORINE

- **Liquified chlorine gas**
  - 100 & 150lb cylinders
  - One ton containers
  - Tank car @ 55-90 tons

FORMS OF CHLORINE

- **Properties of chlorine gas**
  - yellowish green in color
  - 2.5 times as dense as air
  - has pungent odor
  - one volume of liquid chlorine will expand to about 450 volumes of gas
  - is highly irritating
  - can kill within a few breaths

LIQUIFIED GAS



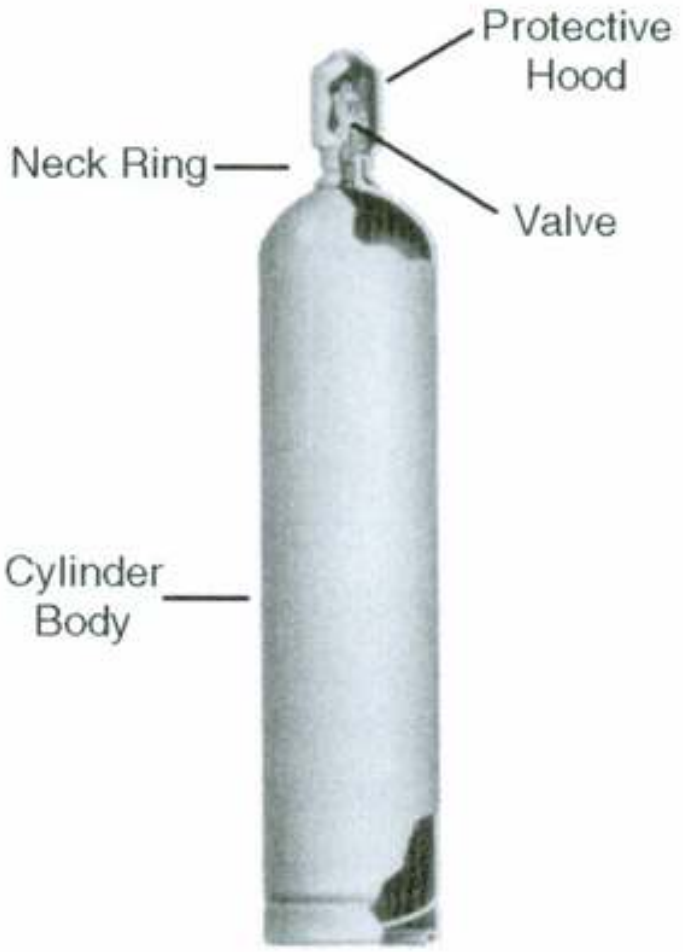
Courtesy of The Chlorine Institute

FIGURE 7–12 Chlorine ton container

LIQUIFIED GAS

Courtesy of US Filter/Wallace & Tiernan

FIGURE 7–19 Two-cylinder scale



LIQUIFIED GAS

- Liquified chlorine gas is most economical, it is also **difficult & dangerous to handle**
- May reduce the pH and alkalinity of water

HYPOCHLORITES

- Chlorine compounds that are available in either dry or liquid form.
  - React with water to produce free chlorine
  - Hypochlorite will lose strength over time, especially sodium hypochlorite.
  - Hypochlorites will raise the pH and alk.
  - Safer to handle than liquified gas

DRY- CALCIUM HYPOCHLORITE

- Granular or tablet form
- 65-70% available chlorine
- Must be thoroughly mixed with water to form a hypochlorite solution
- Solution fed via hypochlorinator
- Relatively more expensive than other forms of chlorine
- Can lead to scale formation

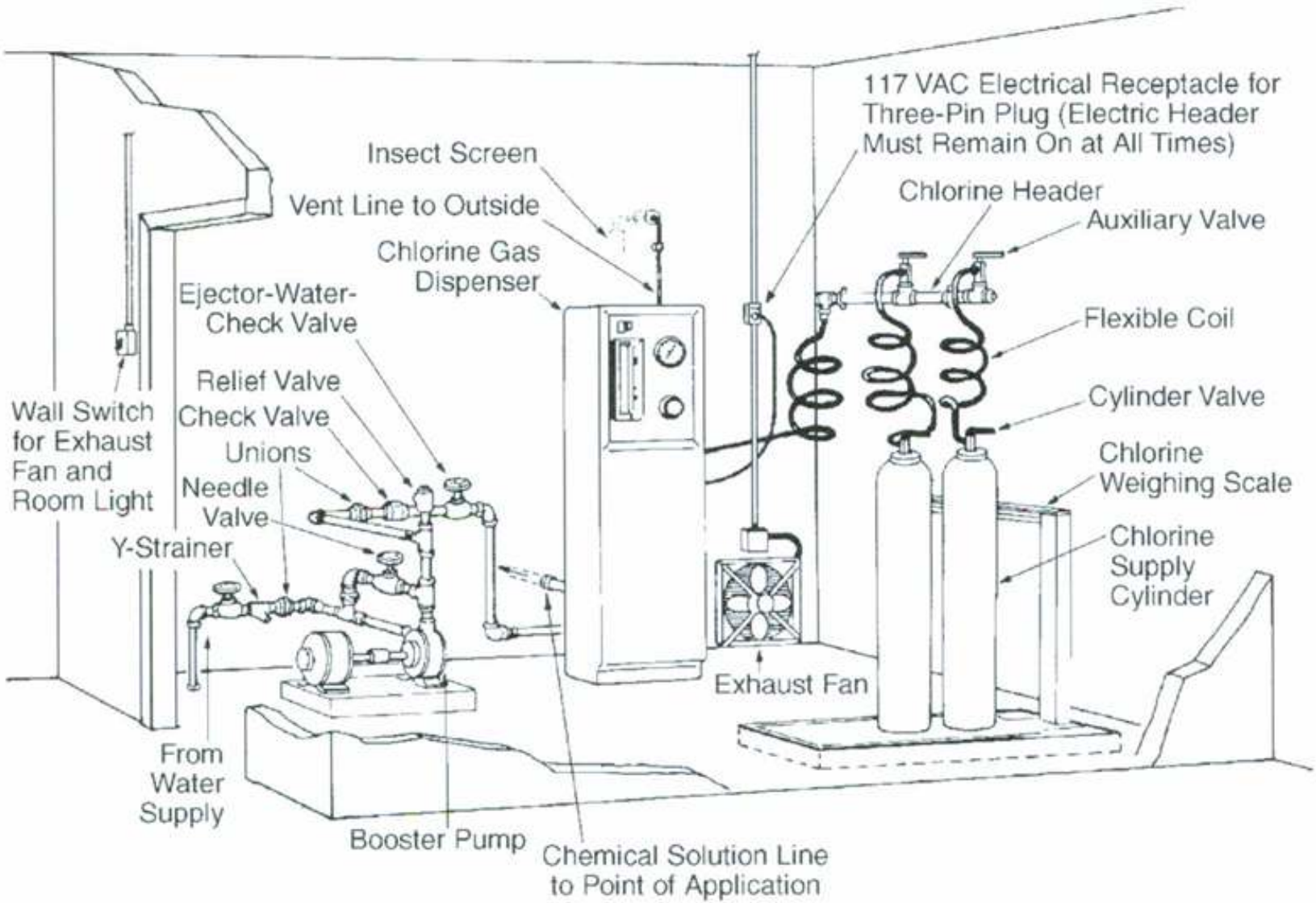
LIQUID – SODIUM HYPOCHLORITE

- Also referred to as liquid bleach
- Available in a range of strengths from 5% (household bleach) to 15% (industrial)
- Solution fed via hypochlorinator

POLL QUESTION #4

USING CHLORINE GAS

- 150 lb Cylinders
  - Should always be stored (chained) in an upright position
  - Move with hand truck
  - Store in well ventilated, protected areas
  - Keep protective hoods on whether full or empty

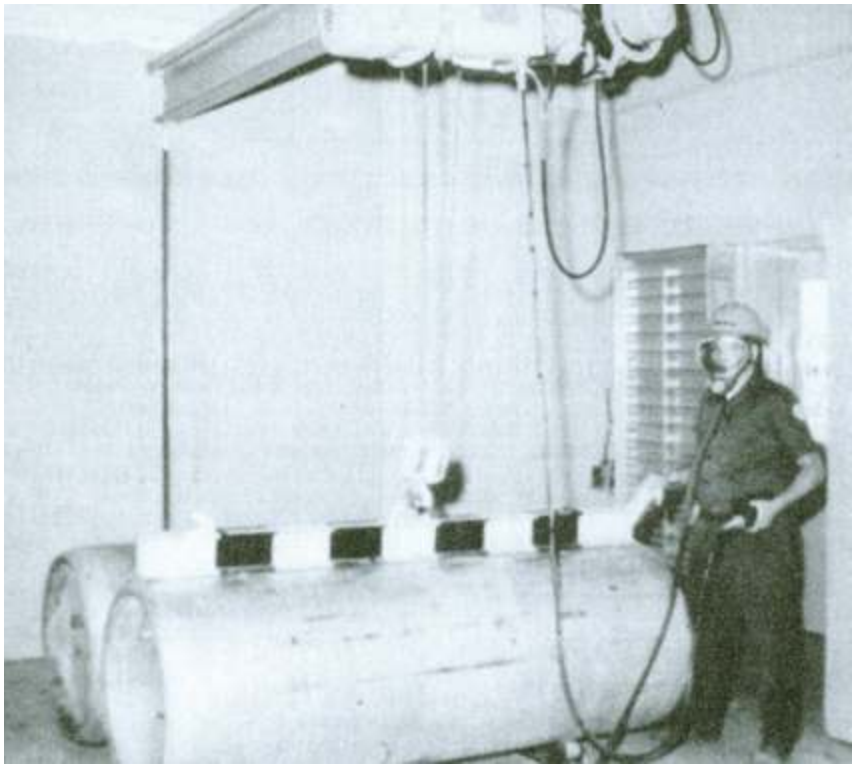


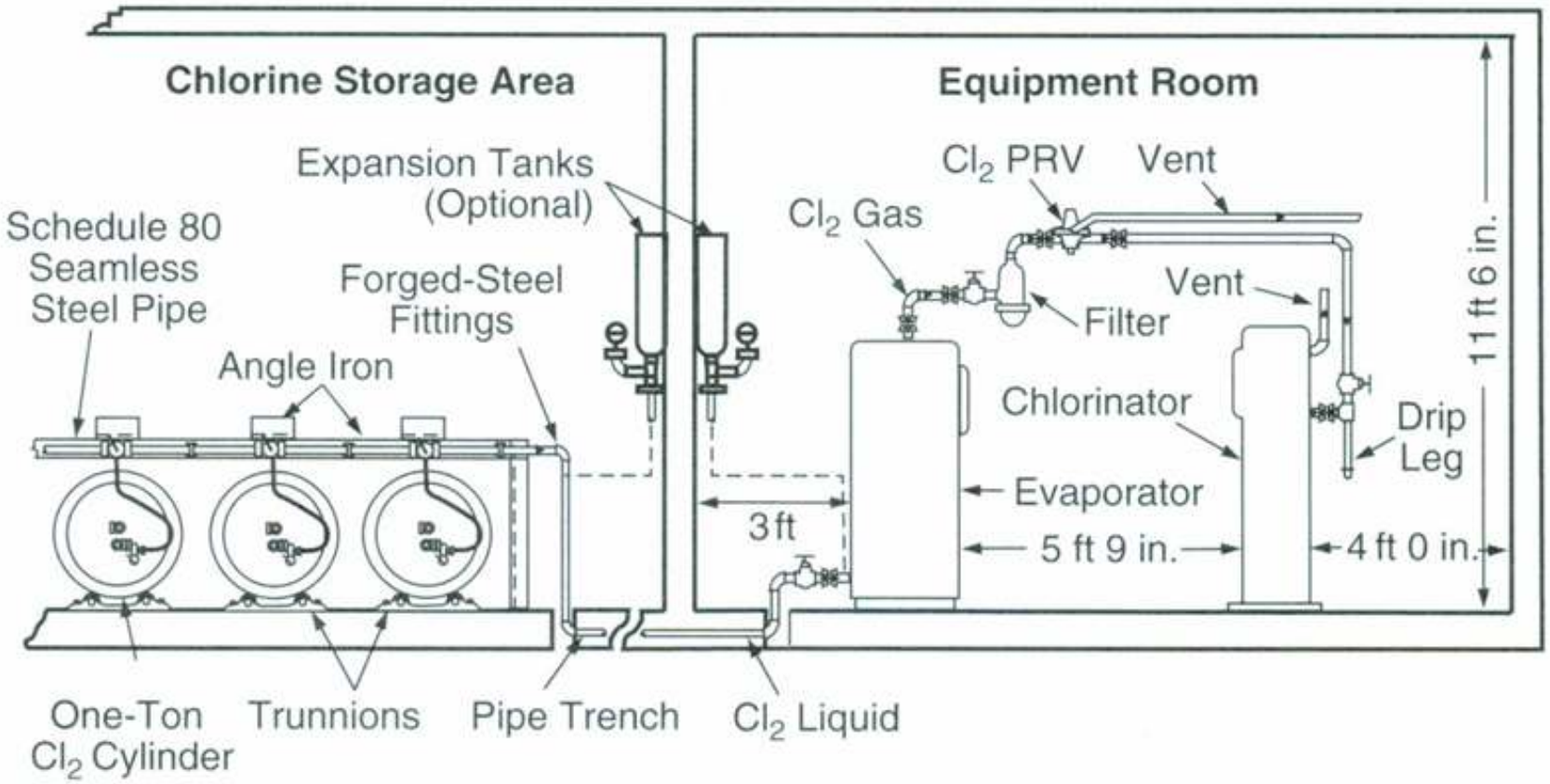
Courtesy of The Chlorine Institute

FIGURE 7–49 Schematic of a well-designed chlorine room

USING CHLORINE GAS

- Ton cylinders
  - Stored horizontally
  - Moved by mechanical means
  - Bowl shaped hood covers the valves
  - Can draw from bottom valve (liquid) or top valve (gas)





From Handbook of Chlorination and Alternative Disinfectants. *4th ed. by Geo. Clifford White, copyright © 1998. Reprinted by permission of John Wiley & Sons, Inc.*

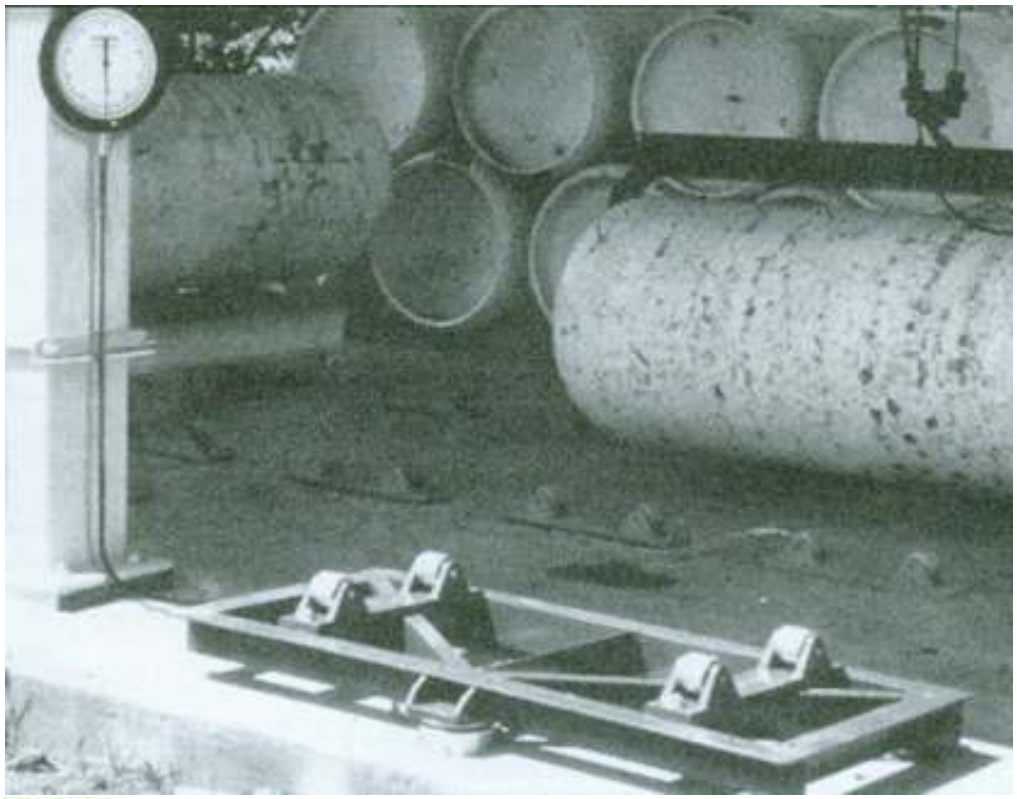
FIGURE 7–18 Chlorination feed equipment located in a separate room

FEEDING CHLORINE GAS

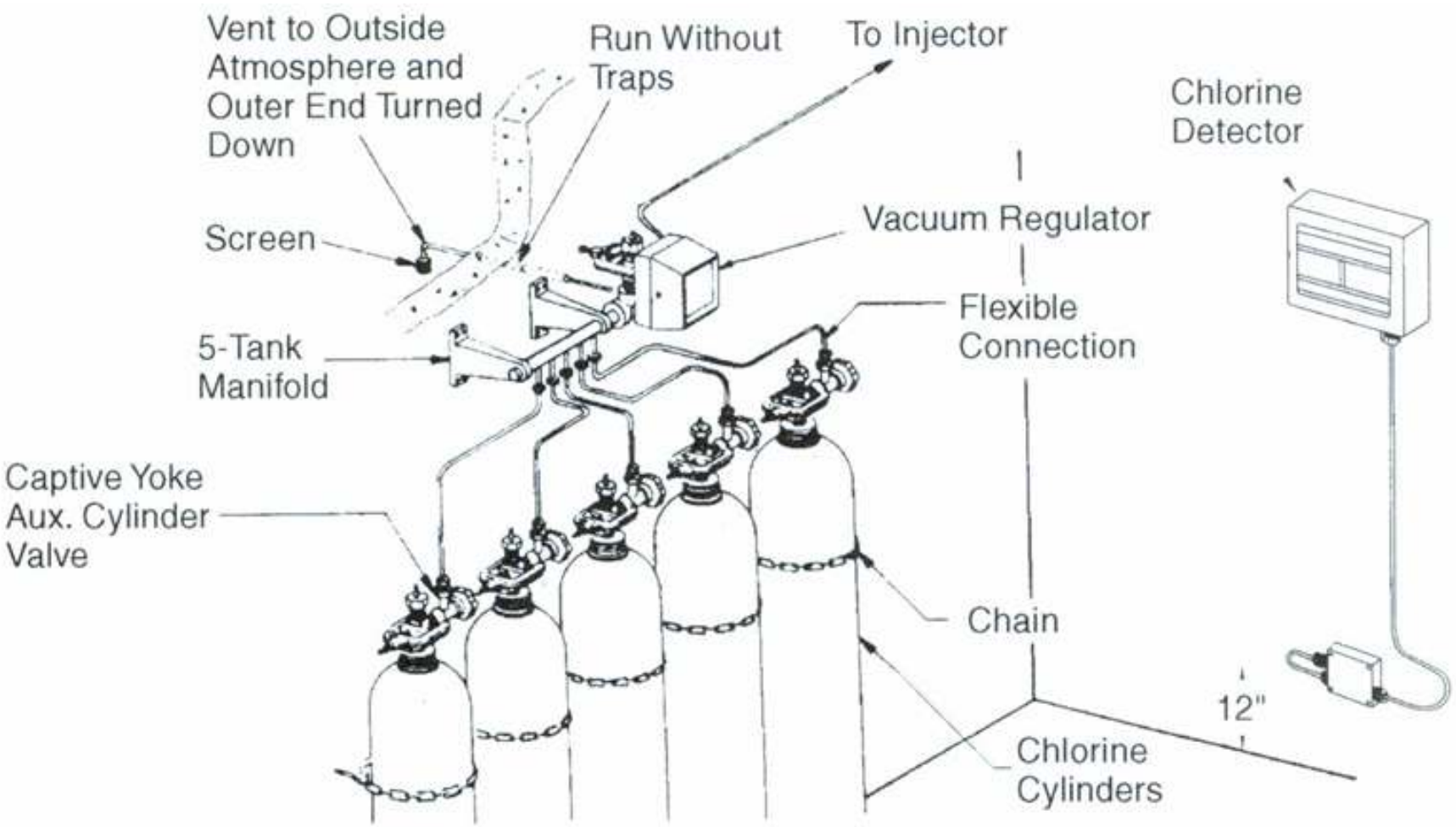
- The main component of the feed system are:
  - Weighing scale
  - Valves and piping
  - Chlorinator
  - Injector or diffuser

GAS FEED SYSTEM

- Weighing scale

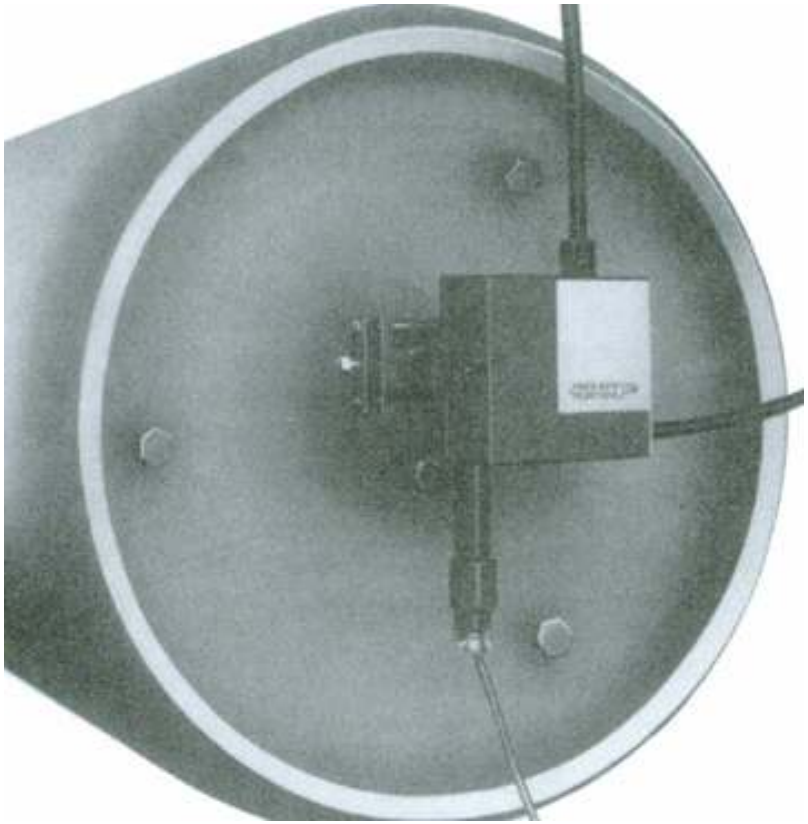


GAS FEED SYSTEM



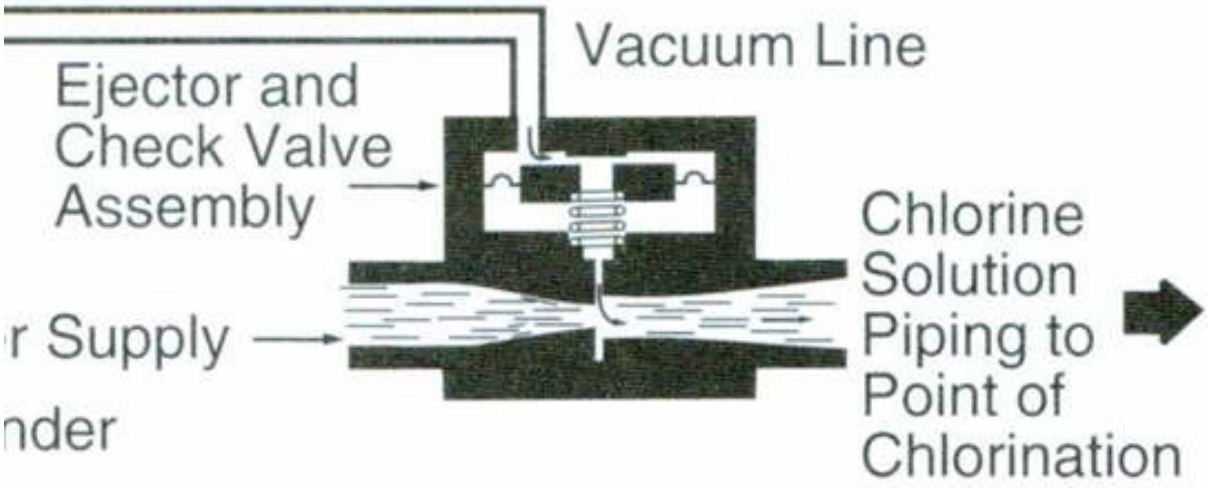
GAS FEED SYSTEM

- Chlorinator
  - Meters gas safely and accurately from the cylinder
  - Delivers a set dosage
  - Rate adjusted by setting rotameter



GAS FEED SYSTEM

- Injector
  - Venturi device
  - Creates the vacuum needed to operate



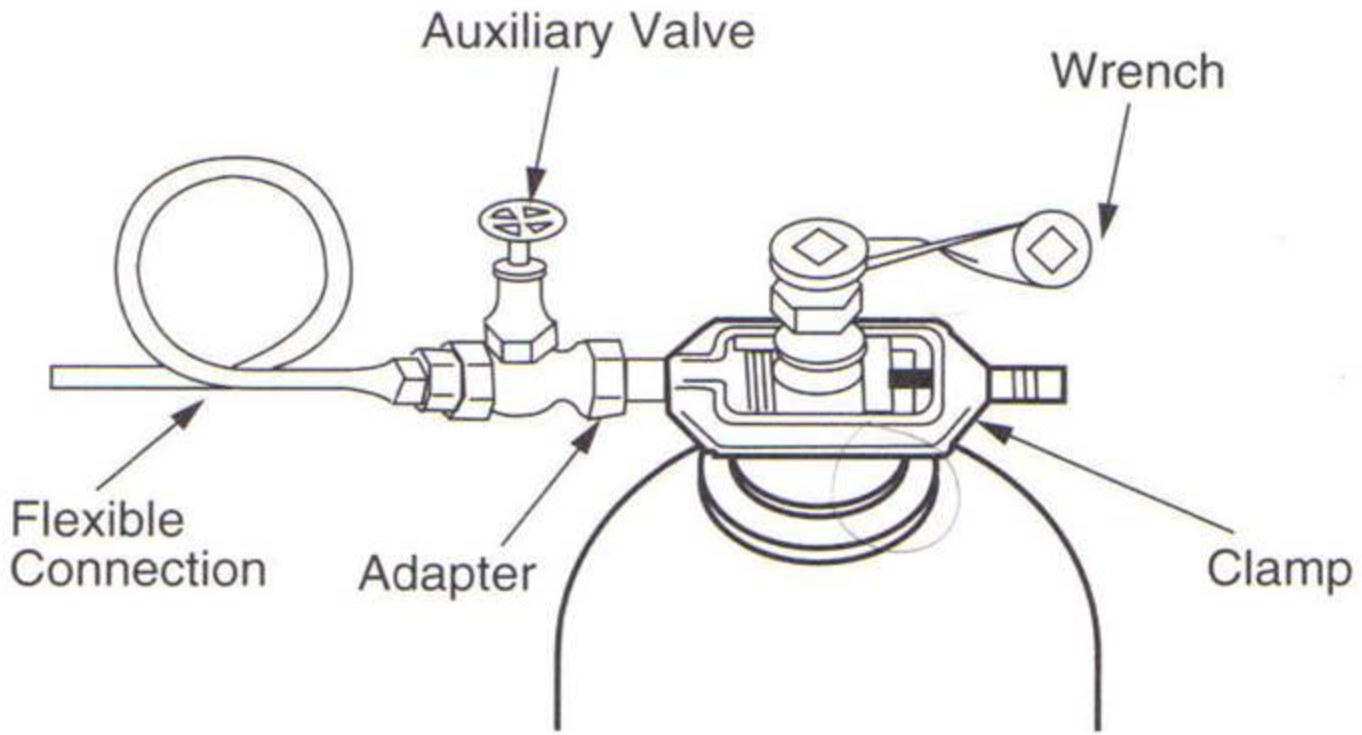
GAS FEED SYSTEM

- Maximum withdrawal rate for cylinders 40-42 lbs/day
- Maximum withdrawal rate for ton containers (gas valve) 450-460 lbs/day
- Maximum withdrawal rate for ton containers connected to an evaporator (liquid valve) 9,600 lbs/day

CONNECTING CYLINDERS AND TON CONTAINERS

- Always wear respirator when changing
- Never lift a cylinder by the hood
- Secure in upright position with chain
- Remove protective hood
- Remove brass outlet cap and any foreign matter in valve outlet
- Use a new lead washer and supplied cylinder wrench

TANK AND AUXILIARY VALVE



OPENING THE VALVE

- Place supplied wrench on stem
- Grasp valve firmly, and give wrench a sharp blow in a counterclockwise direction with palm
- Open valve and close immediately
- Check all joints and connections for leaks with ammonia
- If no leaks are found, open valve one complete turn
- Leave wrench on the valve for easy shutoff

CHLORINATION OPERATING PROBLEMS

- Chlorine leaks
- Stiff container valves
- Hypochlorinator problems
- Tastes and odors
- Sudden residual changes
- THM formation

CHLORINATION OPERATING PROBLEMS

- Leak prevention
  - New gasket each time cylinder is changed
  - Clean threads with wire brush
  - Replace supply line valves annually

HYPOCHLRINATOR PROBLEMS

- Clogged equipment - scale ($CaCO_3$) buildup in the suction or discharge line, or at the injector
  - 5 % hydrochloric acid
- Broken diaphragms
  - Monitor for drops in outflow from pump

CHLORINATION OPERATING PROBLEMS

- Taste and odors
  - “Swimming pool” odor usually caused by too little chlorine
- Sudden residual changes
  - Possible cross connection
  - Increase residual immediately, then analyze and correct problem

CONTROL TESTS

- Bacteriological tests (Bac T)
  - Determines the effectiveness of disinfection
  - Indicator organisms must:
    - Always be present in contaminated water
    - Always be absent when fecal is absent
    - Survive longer in water than pathogens
    - Be easy to identify
  - Coliform bacteria are the “indicator organism”

POLL QUESTION #5

CHLORINE SAFETY

- Proper safety equipment
  - Self Contained Breathing Apparatus (SCBA)
  - Emergency repair kits
  - Adequate ventilation equipment

CHLORINE SAFETY

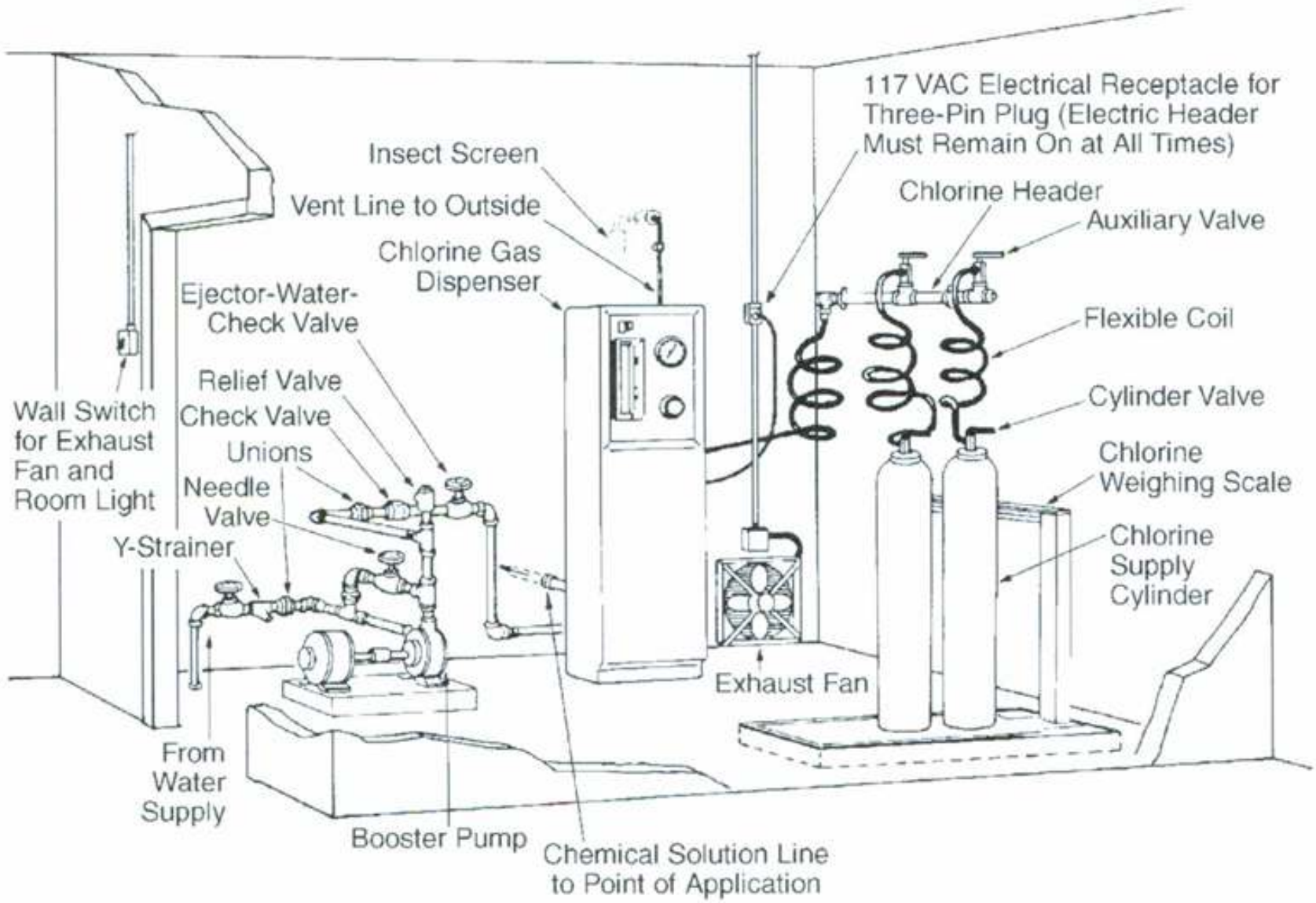
- Self Contained Breathing Apparatus (SCBA)

CHLORINE SAFETY

- Emergency repair kits
  - Kit A for 150 lb. cylinders
  - Kit B for ton containers

CHLORINE SAFETY

- Adequate ventilation equipment
  - Should be able to completely change the volume of air in the room every one to four minutes
- Chlorine detector
  - Early warning of small leaks, before they grow bigger



Courtesy of The Chlorine Institute

FIGURE 7–49 Schematic of a well-designed chlorine room

CHLORINE SAFETY PROCEDURES

- Storing/handling containers
- Connecting/disconnecting cylinders
- Emergency procedures if leaks threaten nearby residential areas
- First aid for persons exposed to chlorine
- North American Chlorine Emergency Plan - (800) 424-9300
- https://www.chlorineinstitute.org/emergency-preparedness/chlorep/index.cfm

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ALTERNATIVE OXIDANT FEED SYSTEMS

- Ozone system consists of the following:
  - Air compression/drying unit or oxygen source
  - Ozone generator or ozonator
  - Contactor to introduce ozone into the water
  - Residual ozone destruction unit

ALTERNATIVE OXIDANT FEED SYSTEMS

- Chlorine dioxide system
  - Uses chlorine and sodium chlorite to generate ClO_2 onsite
  - Small applications add chlorine to water, then add chlorinated water to hydrochloric acid/sodium chlorite solution
  - Larger systems inject chlorine gas into a stream of chlorite solution

Safety; no matter what!

- Gas chlorine is very dangerous
- More accidents occur with liquid
- Always wear the proper PPE
- Never think you're invincible

Determining Chlorine Dose

- Always do the math!

$$\text{Liq. Gal.} = \frac{\text{MG x ppm dose x 8.34 lbs}}{\text{\% Strength x Chemical Weight}}$$

Example Using Sodium Hypo.

A tank containing 250,000 gallons of water, needs to be hand dosed at 1 ppm, with 12.5% strength liquid chlorine. (chemical weight is 10 lbs) How many gallons are required?

$$\text{Liq. Gal.} = \frac{0.25\ \text{MG} \times 1\ \text{ppm dose} \times 8.34\ \text{lbs}}{0.125 \times 10\ \text{lbs}}$$

Answer: 1.67 Gallons of Liquid 12.5 %

Same Scenario Using 65% HTH

$$\text{HTH Lbs} = \frac{0.25\ \text{MG} \times 1\ \text{ppm dose} \times 8.34\ \text{lbs}}{0.65}$$

Answer: 3.2 Lbs 65% HTH

Questions?

Resources

- SWRCB Operator Certification Page
  http://www.waterboards.ca.gov/drinking_water/certlic/occupations/DWopcert.shtml
- Water Board Web Site
  http://www.waterboards.ca.gov/drinking_water/programs/index.shtml

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To contact the trainers…

- kbaughman@rcac.org
- mboyd@rcac.org

5 minute break

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