Wastewater Disinfection

New Mexico Rural Water Association

Revised 2012

Purpose of Disinfection

- To destroy or inactivate pathogenic organisms

- Prevent the spread of waterborne disease
  - Protect

    Public water supplies

    Receiving waters for recreational uses

    Shellfish growing areas

- Disinfection
  - Destruction (or inactivation) of all pathogens

- Sterilization
  - Destruction of ALL microorganisms

Measure Effectiveness of Disinfection

- Presence /absence of **Coliform Bacteria** group including **total, fecal and *E. coli***

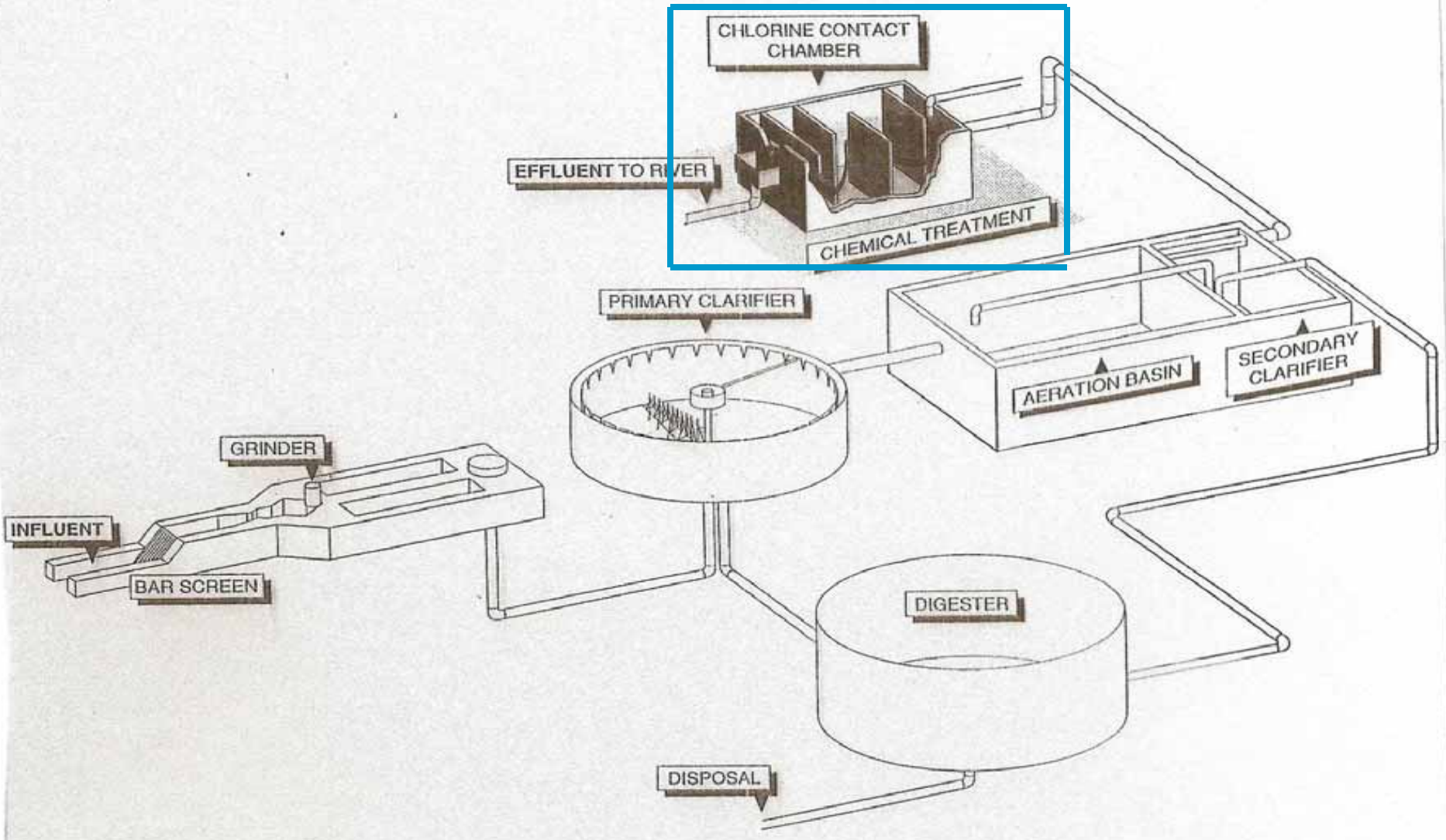
  - They survive longer than most pathogenic organisms in the water environment
  - They are easy & inexpensive to test for
  - They are less sensitive to disinfection than many pathogens
  - They exist only in the intestinal tract of warm blooded animals
  - Known as INDICATOR ORGANISMS

Chlorination

- Disinfection works because PATHOGENS are more susceptible to destruction by chlorination than nonpathogens

- Chlorine - Most widely used oxidizing agent
  - Readily available
  - Easily applied
  - Cheaper

MOST COMMON PROCESS



Other Oxidizing Agents

- Potassium permanganate ($KMnO_4$)
- Chlorine dioxide (ClO_2)
- Ozone (O_3)

Three Forms of Chlorine Used

- Chlorine **gas**/liquid – 100% chlorine (CL_2)
- Calcium hypochlorite **powder** (HTH)- up to 67% chlorine [$Ca(OCl)_2$]
- Sodium hypochlorite **liquid** (bleach) – 3 to 12 % chlorine (NaOCl) *Most expensive*

* Very effective even at low doses

Properties of Chlorine Gas

- Cl – basic element never found uncombined in nature
- 2 atoms of Cl combine to form gas- Cl_2
- As a gas is 2.5 X heavier than air
- **Greenish yellow** in color
- Slightly soluble in water
- 1 part liquid produces 450 parts gas
  - **Liquid** chlorine is **amber** in color

- Poison gas - inhalation hazard
- Threshold of odor – 0.08 to 0.4 ppm (0.2)
- 30 ppm severe coughing
- 40 ppm dangerous after 30 minutes
- 1000 ppm kills
- Classified as an irritant because it does not build up in the body

85% filled with liquid chlorine at 70 F

Chlorine is placed in the cylinder as a liquid.

150 lb
1-ton steel containers
70°F - 85 psi

The liquid boils at room temperature producing gas and pressurizing the cylinder.

Chlorine gas is cheaper per pound than the other forms of chlorine used.

Chlorine Terms

mg/l or ppm

- **Dosage**
  - Amount of chlorine added to the system
- **Demand**
  - The amount of chlorine that is used by substances like nitrogen compounds, iron, manganese, algae and microorganisms in the water
- **Residual**
  - Amount of chlorine available for disinfection AFTER the demand is satified

Types of Residuals

- Free Residual
  - Chlorine as **Cl_2 (dissolved gas)**, **hypochlorous acid** (HOCl) and the **hypochlorite ion** (OCl^-) in the water
- Combined Residual
  - Is the result of combining **free chlorine** with **nitrogen compounds** – forms chloramines, weak disinfectants requiring higher concentrations & longer detention
- Total Residual
  - Is the combination of **free and combined residuals**

****

- **Dosage - Demand = Residual**

No disinfection will take place unless the Dosage *exceeds* the Demand

Leaving a Residual

Demand + Residual = Dosage

Chlorine Chemistry

- **Two Reactions**
  - $Cl_2 + H_2O \leftrightarrow HOCl + H^+ + Cl^-$ Hydrochloric Acid
  - **$HOCl \leftrightarrow H^+ + OCl^-$**

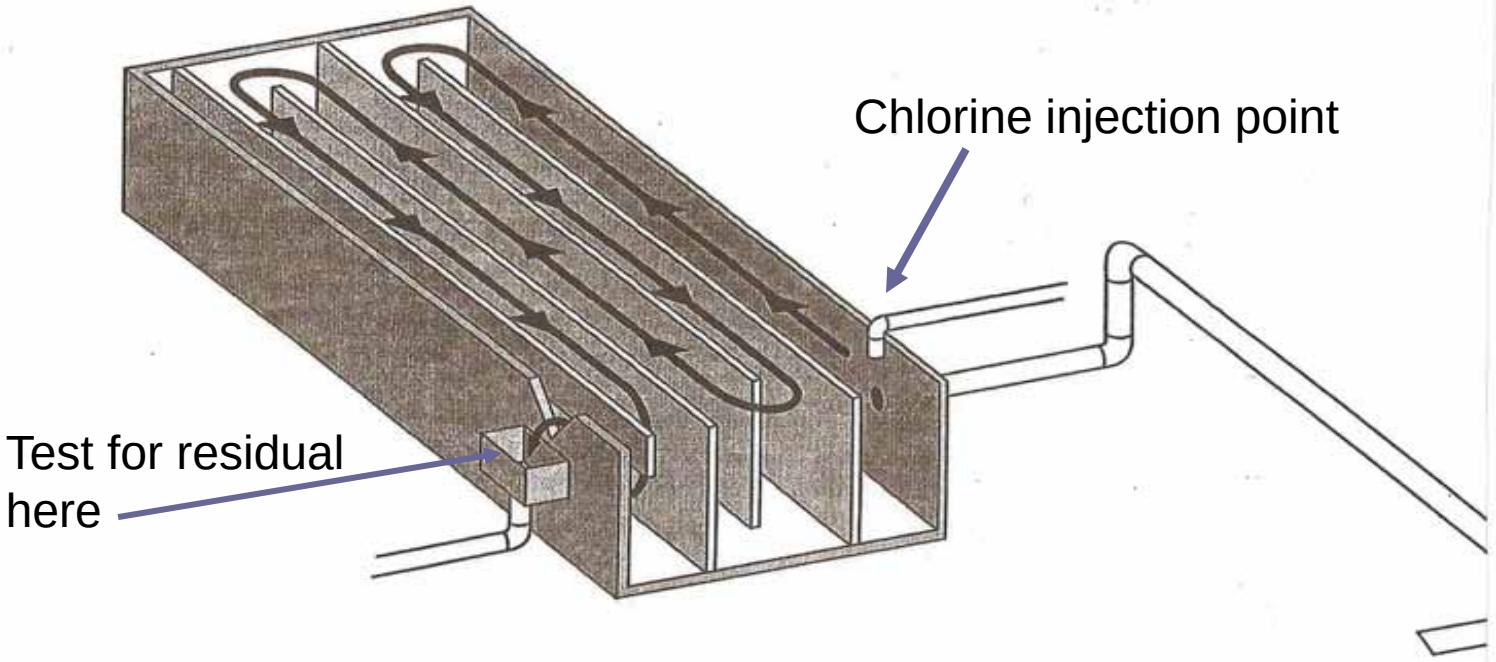
Hypochlorous Acid → ***Best disinfecting power!***

Hypochlorite Ion

Germicidal Efficiency

- **Type of residual – Free is best**
- **For wastewater use <u>Total Residual</u>**
  - Nitrogen compounds react with free chlorine so quickly in wastewater that we usually can't detect free chlorine in a test sample – high demand
- **Residual Concentration - 0.5 to 1.5 mg/l**

Detention time of 20 to 30 minutes
Good mixing - plug flow
No short circuiting
Algae growth a problem
Residuals of 0.5 to 1.5 mg/L of total




DANGER

Effects of pH and Temperature

- **pH** – Ideal range 6.5 – 7.5
  - < pH 6.0 – Hypochlorous acid doesn't breakup into the second part of the reaction – hypochlorite ion formation
  - pH 7.3 – 7.5 – Free residual is half hypochlorous acid and half hypochlorite ion
  - > pH 10 – Hypochlorous acid breaks up to form hypochlorite ion (weak disinfectant)
- **Temperature** –
  - Colder temperatures *slow* reaction times
  - Require l o n g e r detention times to achieve proper disinfection

Interfering Materials

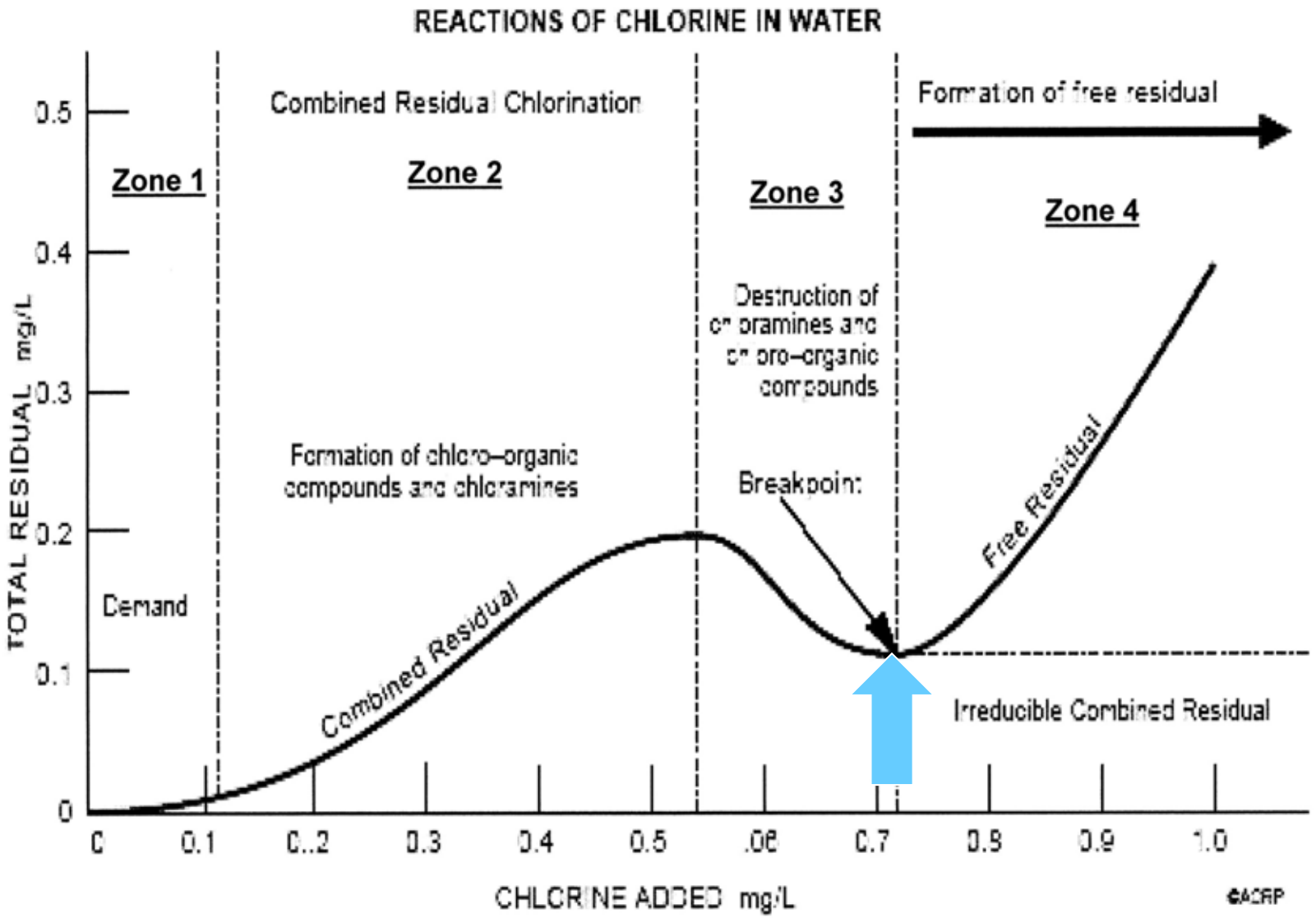
- **Turbidity**
  - Solids use chlorine
  - Provide hiding places for microorganisms

- **Organic Matter**
  - Such as leaves
  - Combine with chlorine increasing demand
  - Reducing residual

Breakpoint Chlorination

- Addition of chlorine to water or wastewater until the DEMAND has been satisfied

- At this point (the breakpoint), further additions of chlorine result in a RESIDUAL that is directly proportional (1:1) to the amount of chlorine added beyond the breakpoint

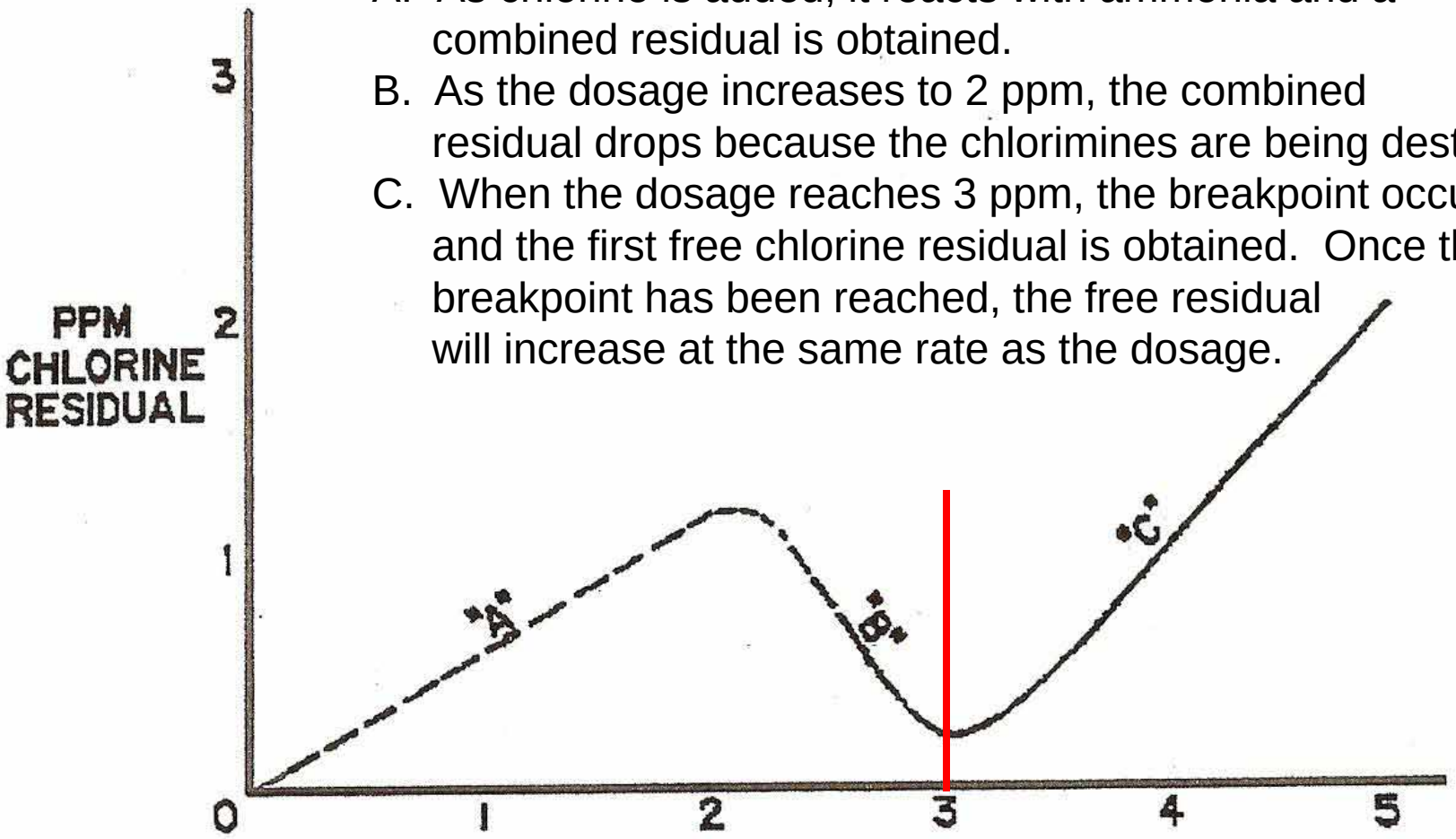


Breakpoint Chlorination Curve

A. As chlorine is added, it reacts with ammonia and a combined residual is obtained.

B. As the dosage increases to 2 ppm, the combined residual drops because the chlorimines are being destroyed.

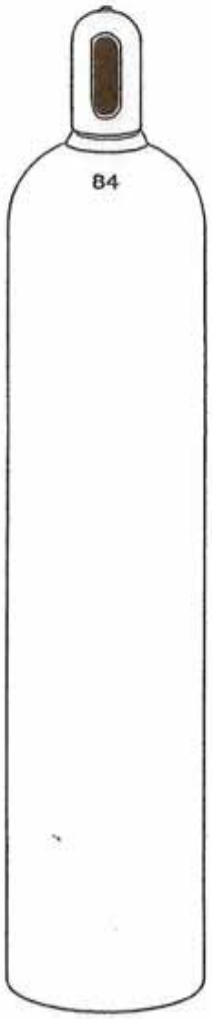
C. When the dosage reaches 3 ppm, the breakpoint occurs and the first free chlorine residual is obtained. Once the breakpoint has been reached, the free residual will increase at the same rate as the dosage.



BREAKPOINT CURVE

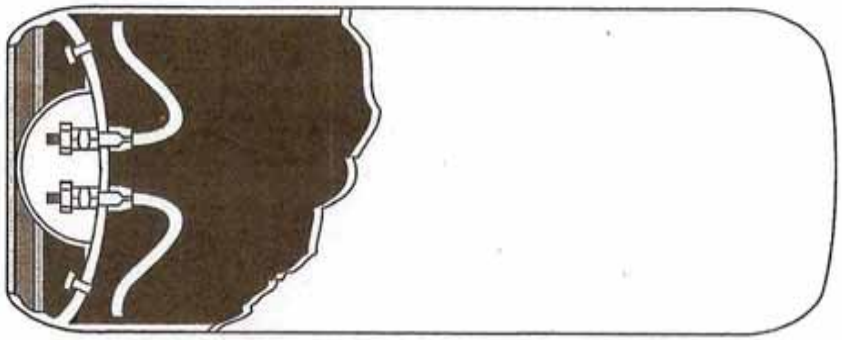
Sizes of Chlorine Cylinders Typically Found At Wastewater Treatment Facilities

Chlorine gas is drawn off the cylinder by a chlorinator and mixed with water to form a concentrated chlorine solution which is mixed with the wastewater effluent flow



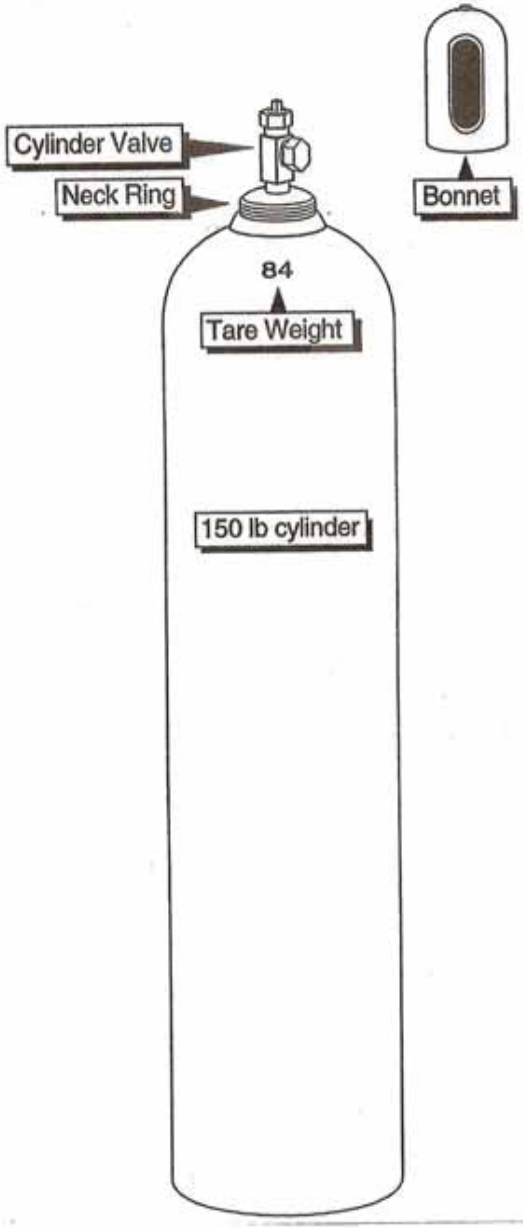
150 pound cylinder

One fusible plug



1 ton container

Three fusible plugs on each end – six total



150 lb cylinder

- Tare weight 85 to 140 pounds
- 88% full of liquid at factory (Study Guide says 85%)
- 70°F - 85 psi
- Boil at -29°F
- 158°F - 100% full - 310 psi
  (Study Guide says 157 F)

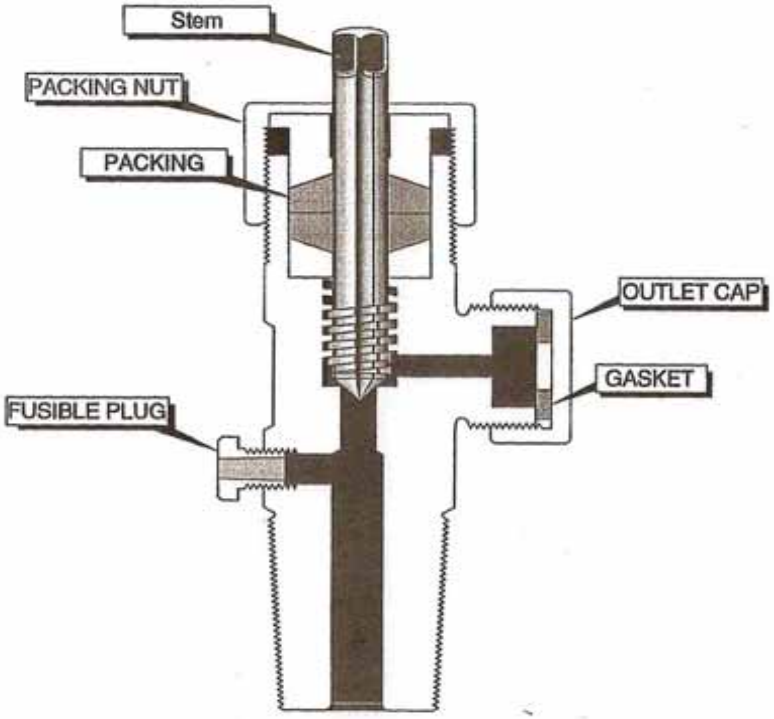
Drawoff rate based on temperature

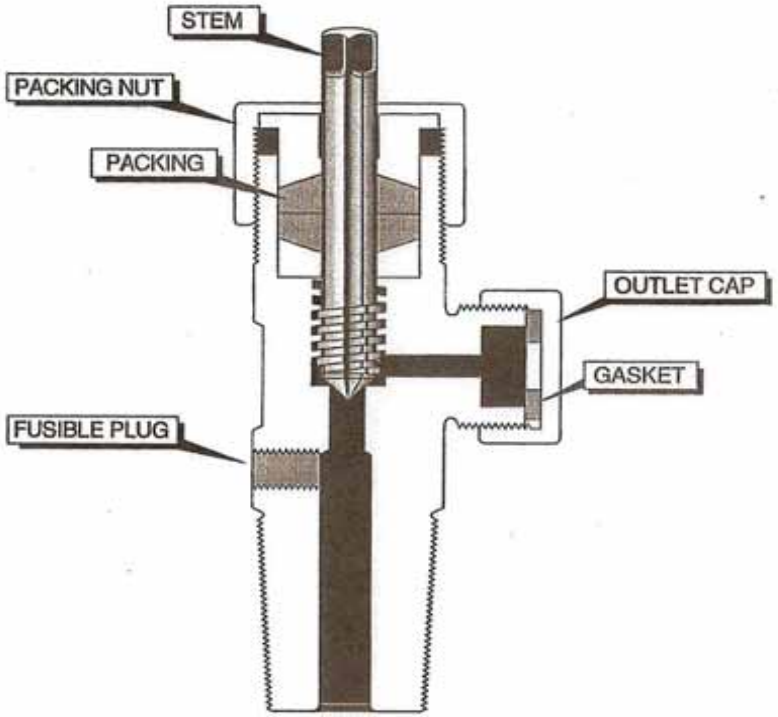
- Too high of draw off rate - frost on cylinder
- To open - 1 turn - 8" wrench

DO NOT use a longer wrench!!!

(Study Guide says 157 F)

Fusible plug melt - 158°F - 165°F





Lead or pressed fiber cap gasket
1 new with each cylinder change

Clean connection with steel wool

Transportation & Storage

- Keep bonnet on when moving or storing
- Never lift by bonnet!
- Chain up 2/3 from the bottom
- Secure at bottom in earthquake area
- Use hand truck to move
- Transportation requires special training

- Do NOT store with other chemicals such as
  - Compressed gases
  - Hydrocarbons, gas, diesel
  - Floor sweeping compounds
- Keep in an upright position
- Maintain temperature between 60 -120 F using indirect heat
- Steel burns with chlorine at 483 F
- Separate full from empty cylinders – mark
- Post proper signs

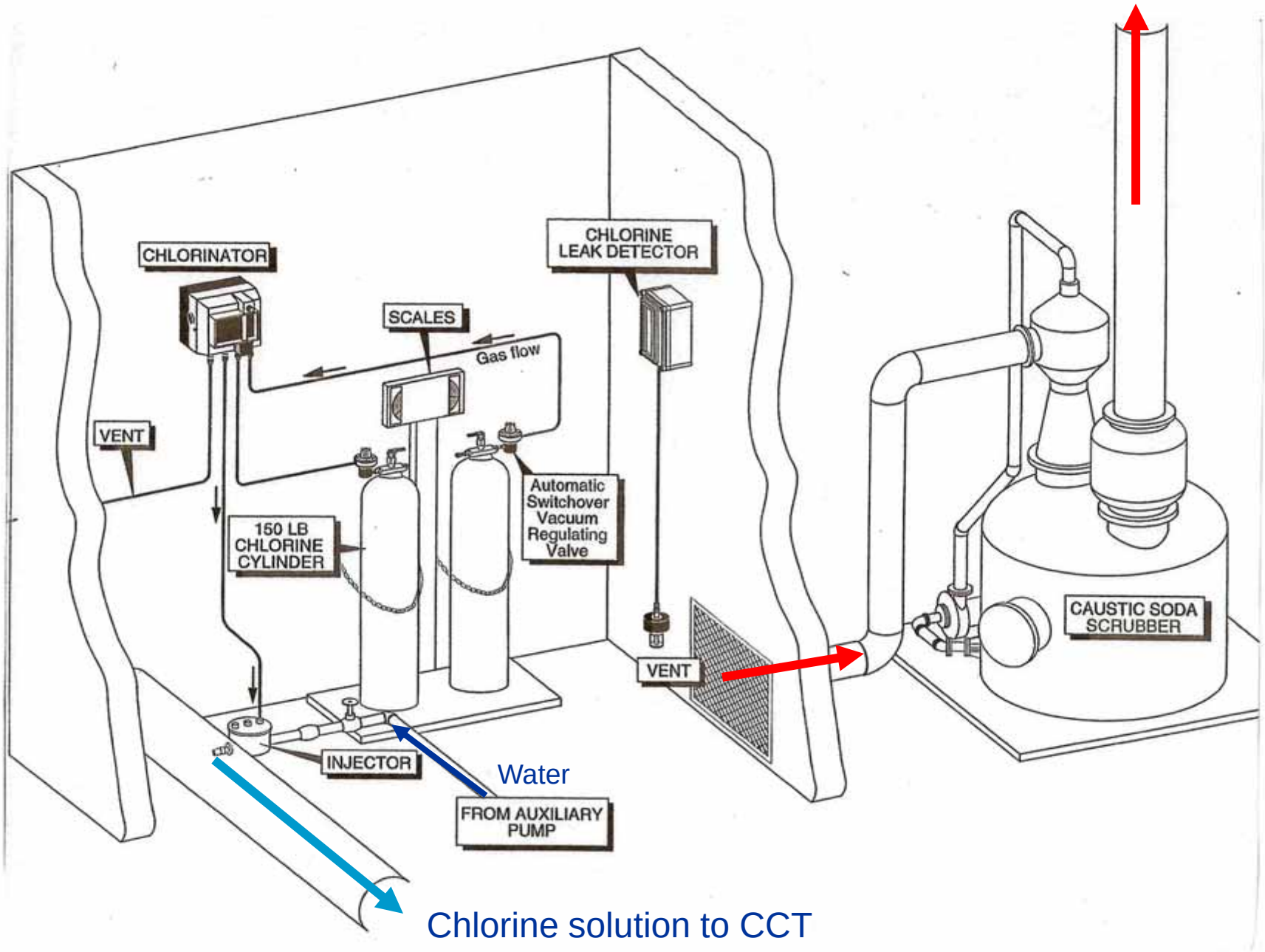

LEAK DETECTOR

Chlorine Building

- Should contain a leak
- Door open out
- Two doors are desirable
- Window to reduce entry
- Electrical equipment NEMA 4X – corrosion proof
- Exterior light and ventilation fan switch
  - Run 3-4 minutes prior to entry

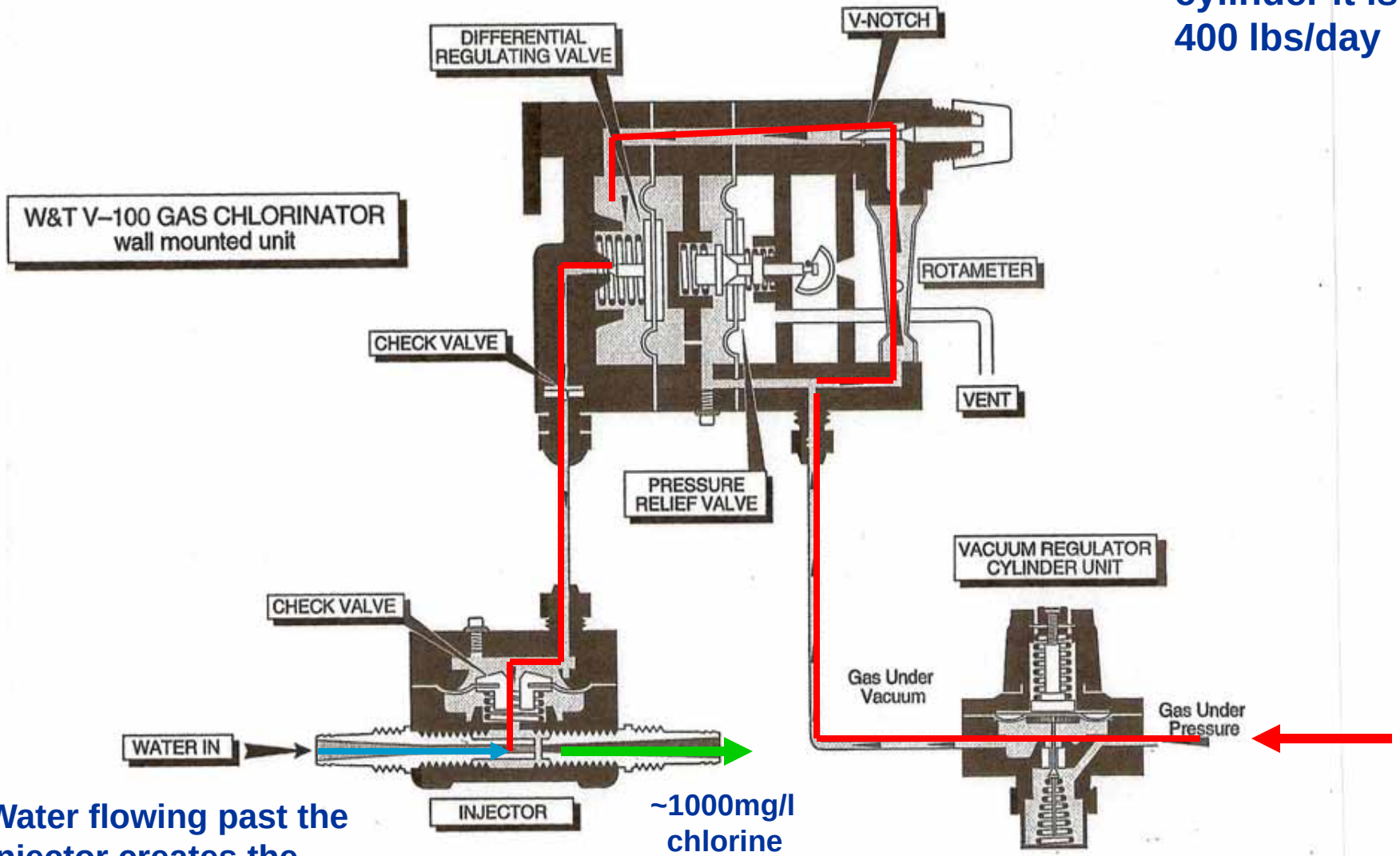
- No other electrical equipment in room
- Ventilation system near floor
- Remove air in 3 to 4 minutes
- Allow fresh air to enter near ceiling
- New facilities must have a caustic soda air scrubber system
  - Treat air to below 15 ppm –release to atmosphere

- Maintain negative pressure in room
- Tepid water eye wash & shower
- Floor drains protected
- Fire sprinkler system
- Emergency power
- Leak detector alarm at 1 ppm chlorine
- Vandal resistant
- Scales to weigh cylinders daily


CHLORINATOR
CHLORINE LEAK DETECTOR
SCALES
Gas flow
VENT
Automatic Switchover Vacuum Regulating Valve
150 LB CHLORINE CYLINDER
CAUSTIC SODA SCRUBBER
VENT
INJECTOR
Water
FROM AUXILIARY PUMP
Chlorine solution to CCT

Maximum feed rate from a 150 lb cylinder is 40 lbs per day

For a ton cylinder it is 400 lbs/day



Water flowing past the injector creates the vacuum that draws gas into the system

~1000mg/l chlorine

Vacuum operated for safety

A break in any component will cause vacuum to be lost shutting down the system and preventing escape of chlorine gas

Evaporators

- Installed at large plants that use a lot of chlorine
- Hot water heater surrounding a steel tank
- Heat in water is transferred to liquid chlorine in inner steel tank
- Heat causes liquid chlorine to vaporize
- Chlorine gas flows from evaporator to gas manifold


AUTOMATIC SWITCHOVER VALVE
LEAK DETECTOR


AUTOMATIC SWITCHOVER VALVE

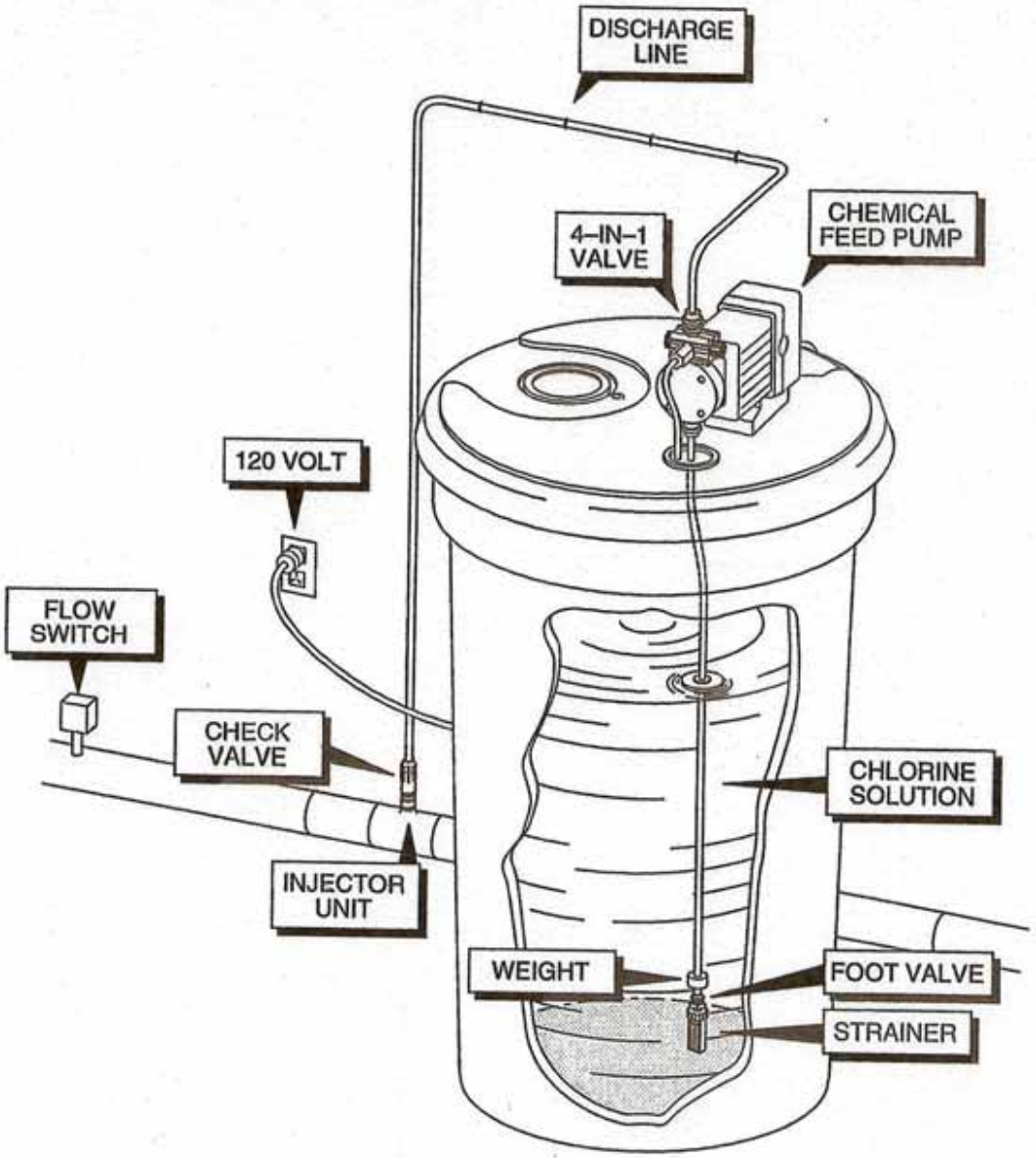
Safety Equipment

- **Respiratory Protection**
  - SCBA – Enough air for ~ 30 minutes
  - Gas masks for quick escape **ONLY**
- **Regulation Requirements**
  - An evaluation of hazards
  - Written policy and procedures
  - Initial training including respirator fitting
  - Monthly inspection of the devices
  - Annual retraining on use of devices
  - Documentation of the training and the evaluation
- **Emergency Response**
  - 29 CFR 1910-40 hour hazardous materials response training (HAZMAT) – usually firefighters

- **Repair Kits**
  - Kit A - For 150 lb cylinders
  - Kit B - For 1 ton containers
  - Kit C - For Tank cars and trucks
- **Use of the kits**
  - Part of an official HAZMAT response team
- **Finding Leaks**
  - A strong ammonia solution is used/squirted
  - A white vapor or cloud will form

Hypochlorite Systems

- **Common System**
  - 20-50 gal tank/drum
  - Chemical Feed Pump
    - LMI
    - Wallace & Tiernan
    - Stenner
- **Protect pump**
  - Strainer at end of suction line
- **Weight & Foot valve**
  - Weight to keep line in solution
  - Foot valve to help maintain prime
  - Discharge side has check valve


DISCHARGE LINE
4–IN–1 VALVE
CHEMICAL FEED PUMP
120 VOLT
FLOW SWITCH
CHECK VALVE
CHLORINE SOLUTION
INJECTOR UNIT
WEIGHT
FOOT VALVE
STRAINER

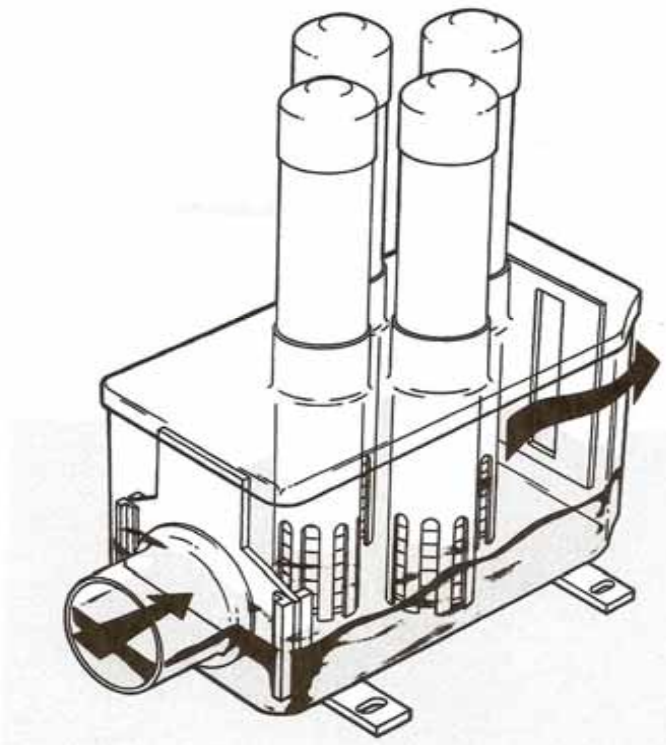
Mixing Calcium Hypochlorite (HTH)

- **Wear**
  - Safety goggles
  - Cartridge respirator
  - Rubberized gloves
- Partially fill tank with water ***before*** adding powder to avoid an **explosion**
- **Store HTH**
  - In a cool, dry room
  - Away from oil, gas, other organic matter
  - Keep lid tightly closed
  - Check for cracks

Tablet Feeders

1. Tubes must be in proper position
2. Invert unused tubes
3. Spacers can be used to fine-tune feed rate
4. Tubes must be kept free of solids and debris
5. Changing weir plates is another way to control dosing
6. Tablets must be flat in the stack and all tubes must be in contact with feeder bottom

Use calcium hypochlorite tablets



Using Sodium Hypochlorite

Wear

- Safety goggles
- Rubberized gloves

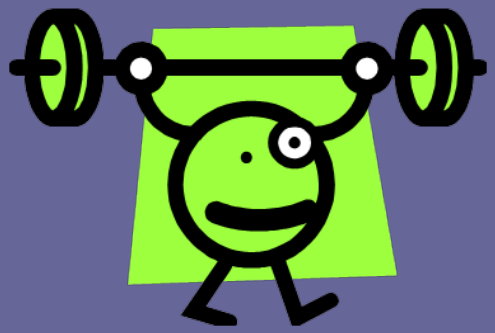
Solution Strength

2.5% - 10%

Example Strength

6% Chlorine means

- 6 parts per 100
- 60 parts per 1,000
- 600 parts per 10,000
- 6,000 parts per 100,000
- 60,000 parts per 1,000,000 **OR**
- **60,000 ppm or 60,000 mg/l**



Routine Operations & Records

- **Daily**
  - Check chlorine residual
  - Determine quantity of chlorine used
  - Determine chlorine dosage
- **Annually**
  - Rebuild pump
  - Clean and replace gaskets
  - Replace foot and diffuser check valves

Mixed Oxidant Systems

- Utilize an electrolytic cell to generate oxidant solution
  - Sodium chloride
  - Water
  - Electricity
- Produces a stream of very aggressive mixed oxidants
- Very effective in disinfection

MIOX and Chlor-Tech are examples

Process

- Add dry salt to brine tank
- Add water to form saturated brine solution
- Feed brine to electrolytic cell

- Liquid mixed oxidant solution produced
- Collected in a storage tank

- Solution is injected into wastewater stream at an appropriate concentration
- Chlorine residual can be measured using DPD test equipment

Safety

- Safer to use than chlorine
- Hydrogen gas is produced during the reaction
- Must be safely vented from the system
- HAZMAT training and Risk Management Plan not necessary

Ultraviolet (UV) Systems

- UV radiation is absorbed by microorganism cells damaging the genetic material in such a way that the organisms are no longer able to grow or reproduce

- They are “inactivated”

Source of UV

- Low pressure mercury vapor lamps
- Multi lamp assemblies
- A quartz sleeve protects each lamp
- Lamp assemblies mount on racks
- Racks are immersed in waste stream
- In open channel or closed vessel

Operation

- Water level over lamps must be maintained at appropriate level
- Monitor lamp output intensity
- Replace lamps that no longer meet design standards
- Do NOT exceed maximum turbidity design standards
- Lack of residual disinfection means no protection against recontamination
- When treated water is exposed to visible light, microorganisms can be ***reactivated***

UV Safety

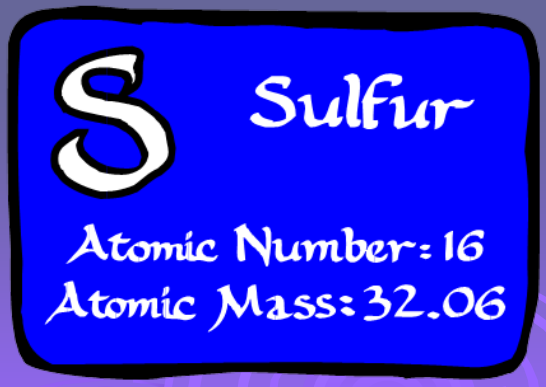
- UV light can cause serious burns to eyes and skin
- NEVER look directly into the uncovered parts of the UV chamber without protective glasses
- Do NOT plug a UV unit into an electrical outlet without properly securing the unit first
- Handle lamps with care-mercury vapor is a hazardous substance
- Be prepared to clean up any spills

De-chlorination

- **Physical** or **chemical** removal of all traces of residual chlorine ***after*** the disinfection process and ***before*** discharge of the effluent

Sulfur Compounds Commonly Used to *Chemically* Remove Residual

- Sulfur dioxide (gas)
- Sodium sulfite
- Sodium metabisulfite
- Sodium bisulfite



Other Means of De-chlorination

- Long detention periods - residual will dissipate
- Aeration - bubbling air thru chlorinated water
- Sunlight - chlorine is destroyed by sunlight (shallow water)
- Activated carbon - adsorption of chlorine onto activated carbon

Sulfur Dioxide – SO_2

- Colorless gas
- Heavier than air – settles in low areas
- Non-flammable
- **DEADLY**, affects central nervous system
- Pungent (sharp, biting odor)
- May be cooled and compressed to a liquid
- Liquid is colorless

Sulfur Dioxide Gas cont'

- In presence of moisture, forms sulfuric acid (H_2SO_4)
- Is extremely corrosive
- More soluble in water than chlorine
- As temperature *increases*, SO_2 solubility in water *decreases*
- **Density** of SO_2 is similar to that of chlorine

- Sulfonators and Chlorinators are **NOT** interchangeable

- Sulfonator diaphragms are manufactured of special materials to handle SO_2 rather than chlorine

- SO_2 reacts instantaneously with chlorine on an approximately 1:1 basis
  (1 mg/l SO_2 removes 1 mg/l chlorine)

Chemical Reaction of De-chlorination

- All *active positive* **chlorine** ions are converted/reduced to *non-active negative* **chloride** ions

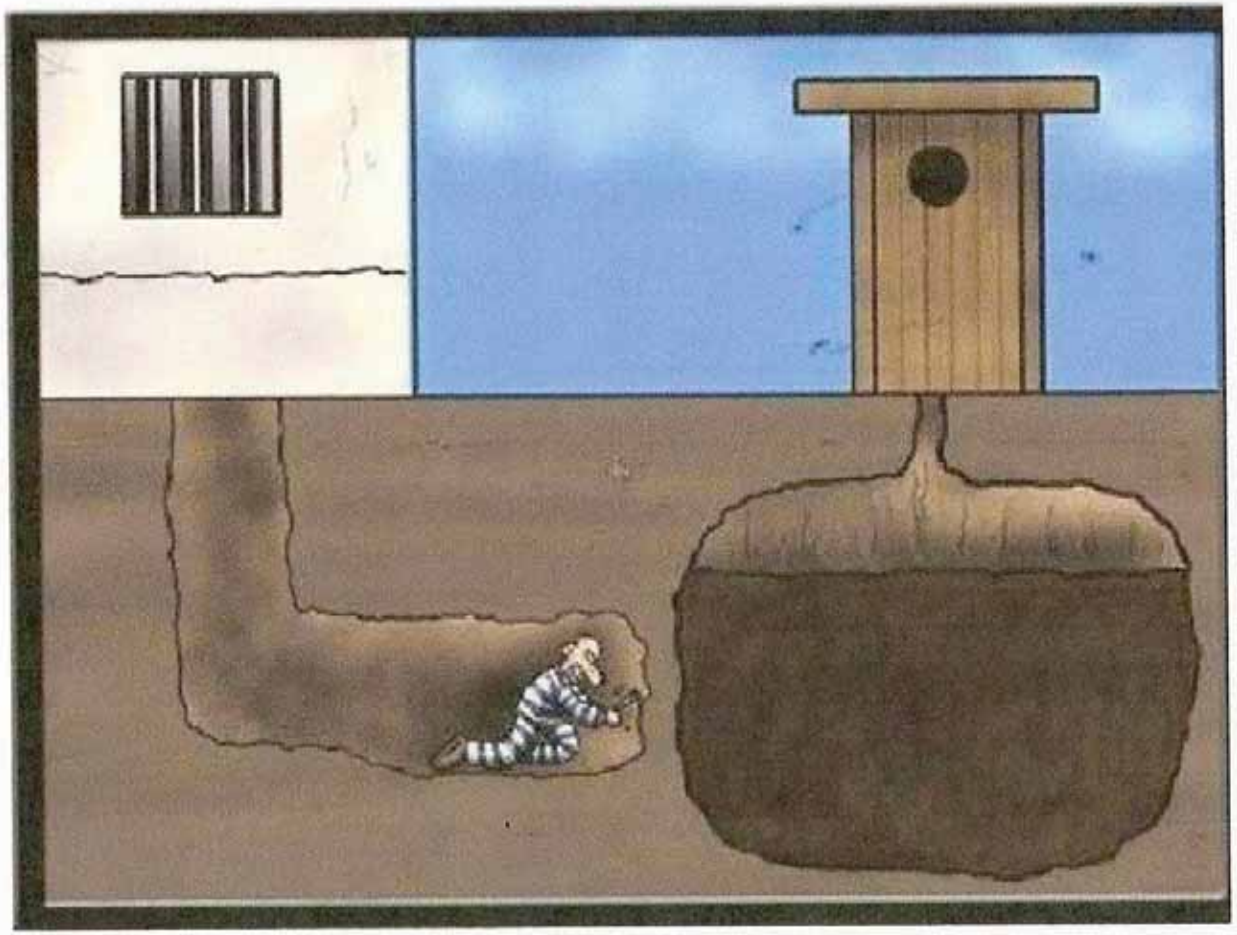
- **Sulfur** is converted to **sulfate**
- Sulfur dioxide = 1.1 to 1 mg/l Total Residual Chlorine

Do **NOT** Overfeed Sulfur Compounds

Wasteful

In Effluent:

- Can result in DO reduction
- Increase in BOD
- Drop in pH



It Can Always Be Worse