CHLORINATION

Equipment and Accessories

Why Chlorinate our Water?

- Disinfection - Raw water may contain potentially dangerous materials which can be harmful if ingested. Chlorination kills these harmful materials.

  Some examples:
  - E-Coli Bacteria (O157:H7) – Walkerton, Ontario.
  - Giardia.
  - Typhoid.
  - Cholera.
- Taste and Odor Control.
- Prevention of Algal Growths (Algae).
- Iron and Manganese Removal.
- Destruction of Hydrogen Sulfide (Rotten Egg).

Why Chlorinate our Water?

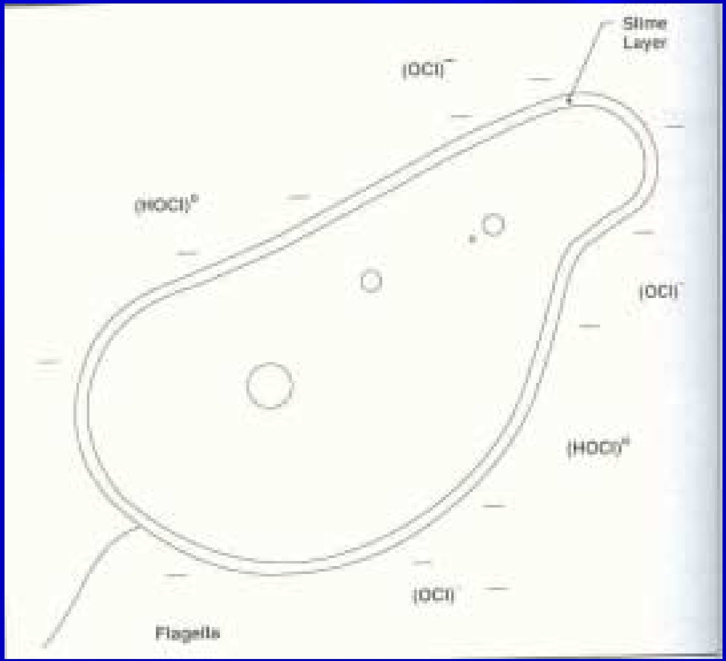
- The Government says so.
  - Most provincial bodies require a free chlorine residual of 0.2 mg/l at all points in the distribution system.
  - Residual chlorine provides a means to kill any additional dangerous substances that might contaminate the distribution system (as a result of broken mains, cross connections, backflow prevention failure, etc.).

How Does Chlorination Work?

- Chlorine Residual is a powerful oxidant existing in several states.
  - Free chlorine HOCL + OCL^- (very strong ox).
  - Combined chlorine (Nitrogenous Compound).
    - Monochloramine (NH_2Cl).
    - Dichloramine ($NHCl_2$).
    - Trichloramine (NCl_3).
- Altogether, the above is called **Total Chlorine Residual.**

How Does Chlorination Work?

- In Disinfection, chlorine residual surrounds the pathogenic organism, oxidizing its cell wall. The chlorine then penetrates the organism and upsets the natural life cycle processes or alters the cell's enzymes. The end result is the organism dies or cannot reproduce (bacteriologically safe)



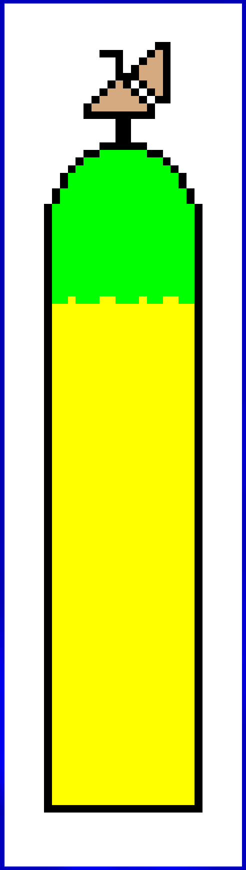
Gas Chlorination

- In a gas system we must:
  - Remove the gas from a pressurized vessel source.
  - Convert it to a vacuum.
  - Mix with water.
  - Deliver chlorine solution to Point of application.

Gas Chlorination

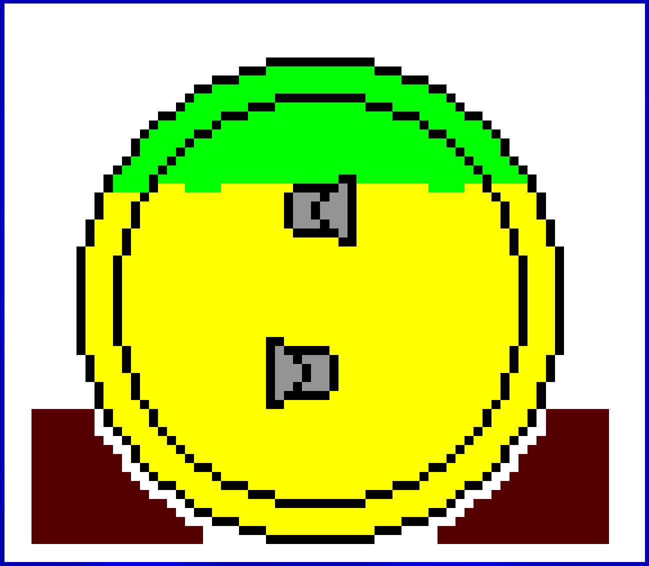
- Chlorine gas is stored under pressure.
  - Available in various sized containers.
    - 100 and 150 lb Cylinders.
    - 2000 lb (Ton) Containers.
    - Rail Car (55 – 90 ton).

100 or 150 lb. Cylinder



- Typically used in systems delivering 500 lb/24hrs or less (practical maximum 350 lb/24 hour)
- Used to deliver gas only
- Equipped with a standard Chlorine Institute Header Valve with an internal Fusible Plug which relieves at 158º - 165º F
- Approximate gas withdrawal rate is “1 lb per 24 hrs per degree F”

Ton Container (2000 lb)



- Typically used in systems delivering 600 lb/24hrs or more (or where more time between changes desired)
- Can deliver gas or liquid
- Equipped with a standard Chlorine Institute Header Valve. Six fusible plugs which relieve at 158º - 165º F are installed in the ends of the container
- Approximate gas withdrawal rate is "8 lbs. per 24 hrs per degrees F"

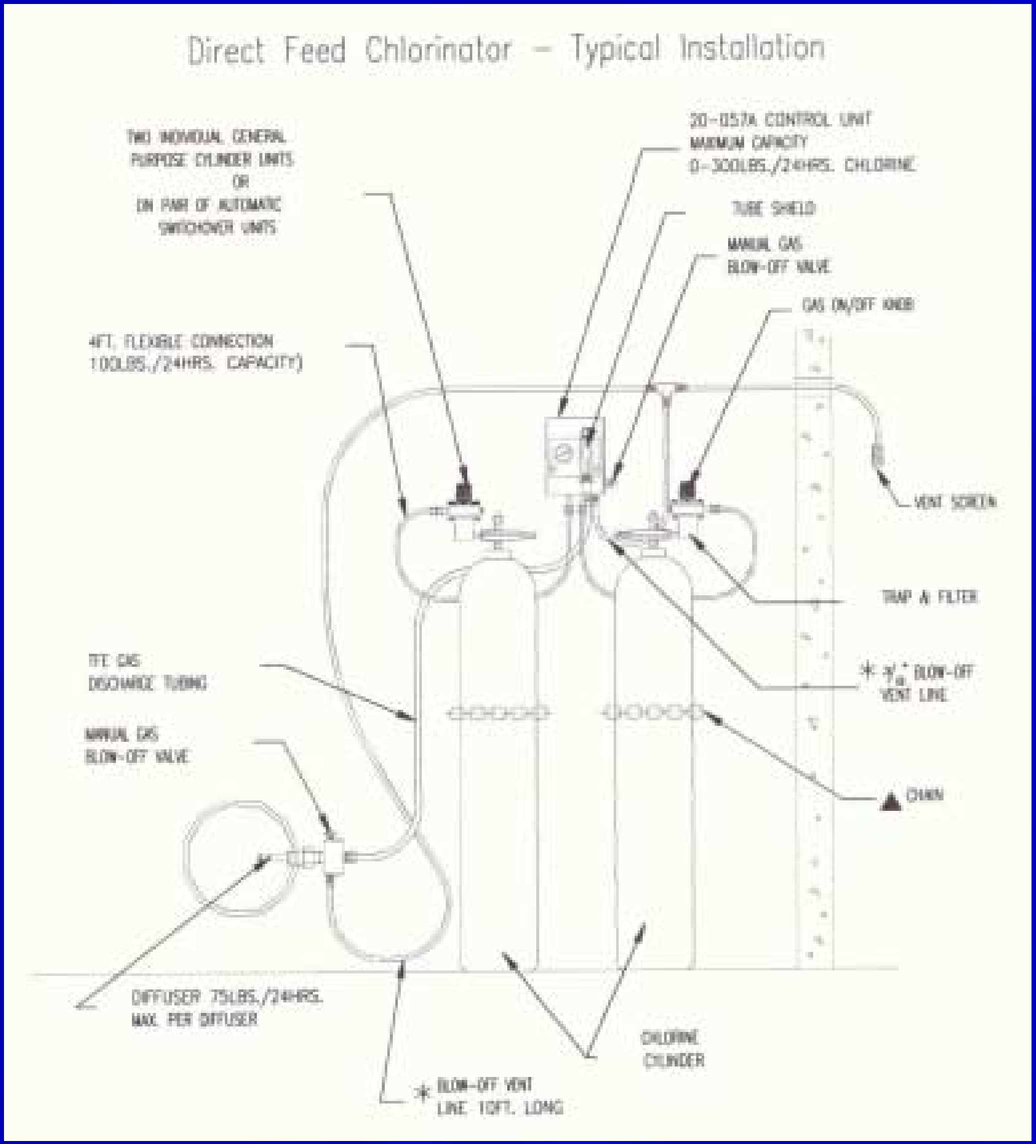
Gas Feed Chlorinators

- Two Basic Types.
  - Direct feed (Chlorine fed to POA under Pressure) – Rare.
  - Remote Vacuum Chlorinator (Solution feed).
    - Differential Regulated Gas Feeder.
    - Sonic Gas Feeder.

Direct Feed Chlorinators

- Chlorine fed to POA under pressure.
- Cylinder pressure drives gas feed – backpressure limitation 10 to 15 PSIG.
- Gas diffused through porous Kynar rods.
- Mixing results are average (CL2 gas is not very soluble in water).
- Industry has moved away from pressure based systems over safety issues.

Direct Feed Chlorinators



USFilter

Vivendi water company

Remote Vacuum Chlorinators

- Uses a Venturi style Injector (Eductor) to generate a vacuum. High pressure water in, low pressure water out – vacuum created. Alternative vacuum generation by a motorized Induction Unit.
- Uses a gas feed control unit to accurately meter chlorine gas to the injector.
- Uses vacuum regulating valves to reduce cylinder pressure gas to a vacuum and feed to gas feed control unit.

Remote Vacuum Chlorinators Differentially Regulated

- A Differentially referenced chlorinator utilizes a diaphragm type valve to maintain a continuous vacuum drop across a control orifice. This provides:
  - More accurate feed of chlorine gas by controlling external vacuum fluctuation (injector).
  - A lower operating injector suction value (differential valves reduce the injector raw suction to a lower controlled value).

Remote Vacuum Chlorinators Differentially Regulated

Industry Examples of Floor Mounted Units

Remote Vacuum Chlorinators Differentially Regulated

Industry Examples of Wall Mounted Units

USFilter

VIVENDI water company

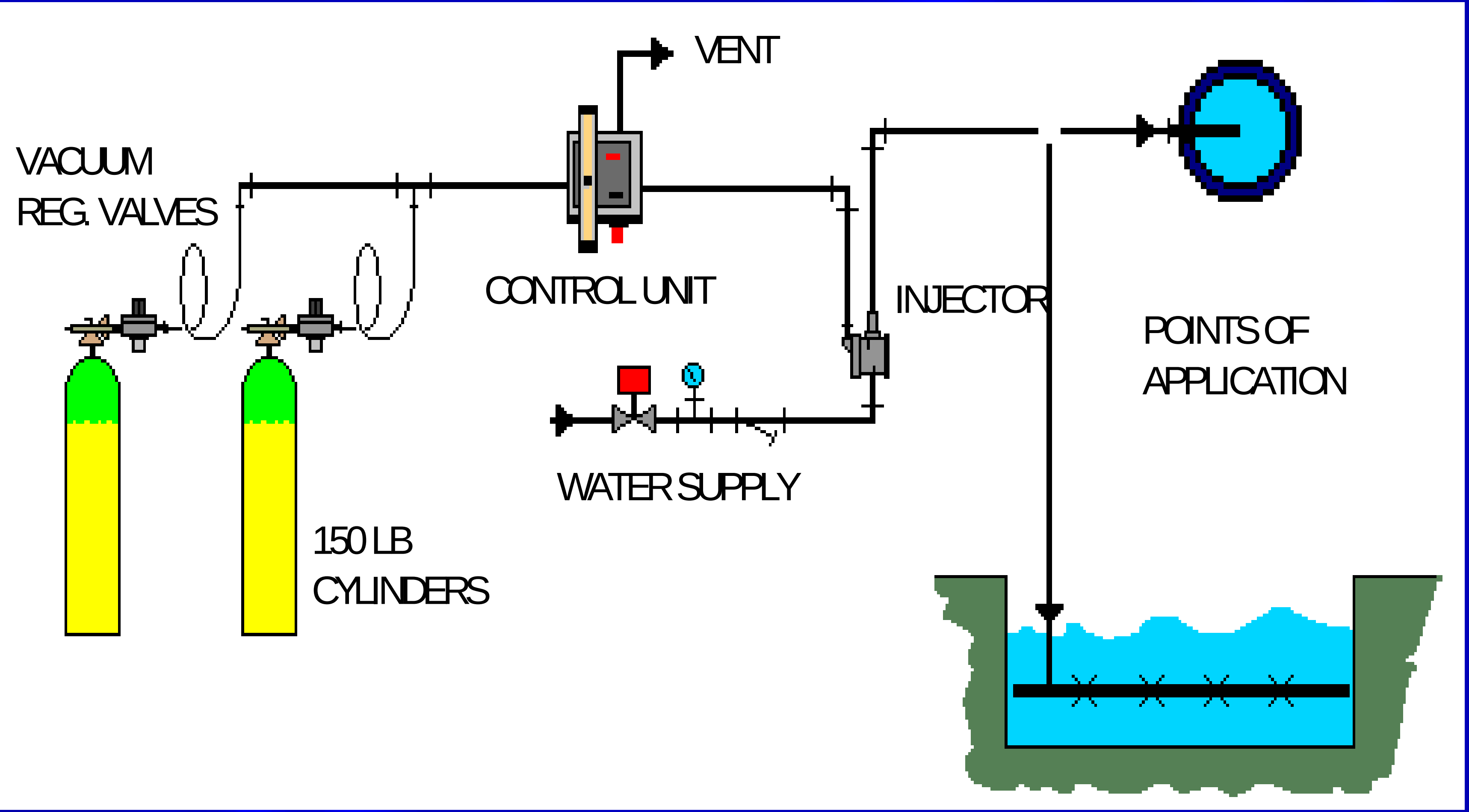
Remote Vacuum Chlorinators Sonic Regulated

- A Sonically referenced chlorinator requires enough injector suction to accelerate the gas to the speed of sound (Sonic) through a control orifice, after which the gas feed rate is constant (typically 16” Hg injector suction required).
- By eliminating the need for differential regulation, the chlorinator becomes less expensive but more susceptible to injector performance fluctuation.
- Typically used up to 500 lb/24hr gas feed rate.

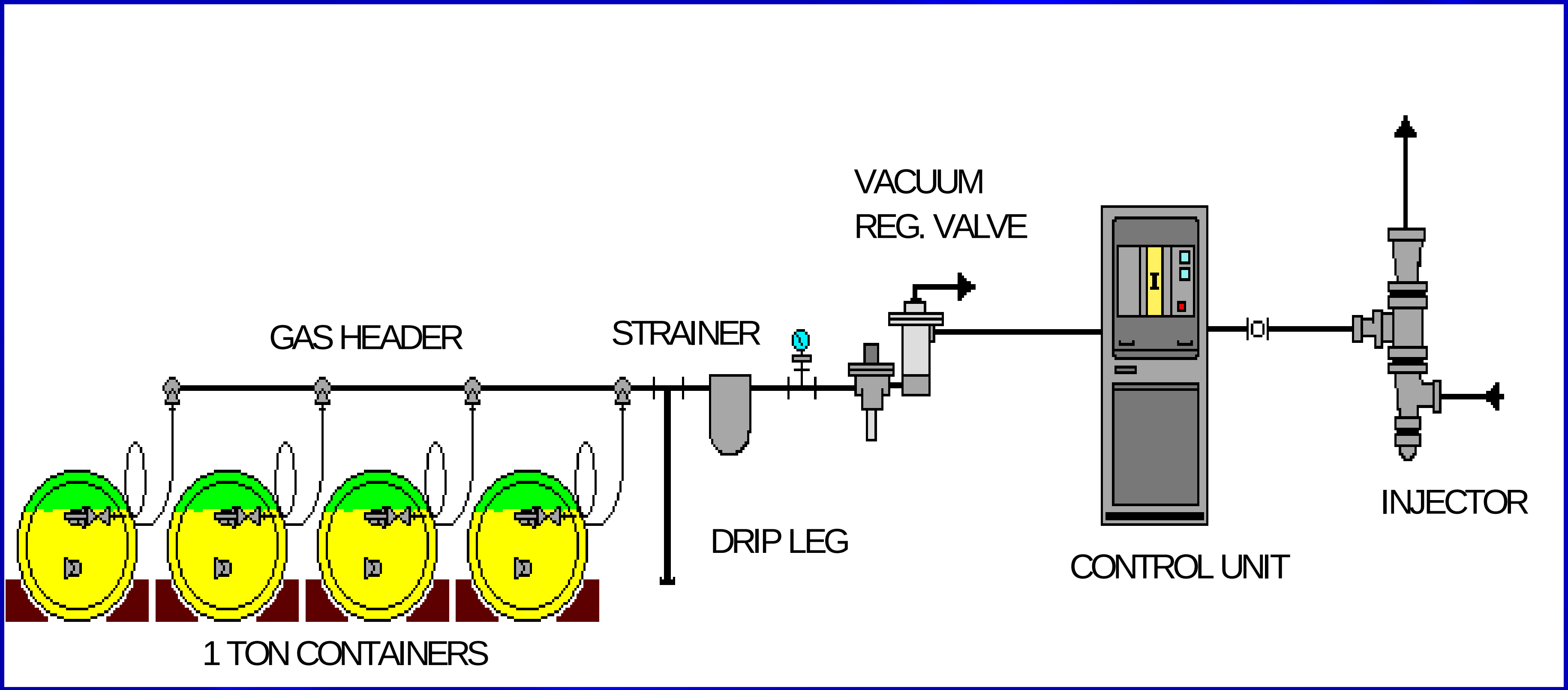
Remote Vacuum Chlorinators
Sonic Regulated

Industry Examples

Typical Small Chlorine Feed System



Typical Medium Chlorine Feed System



System Piping Requirements

- Chlorine Gas & Liquid Under Pressure.
  - Schedule 80 seamless carbon steel pipe with 3000# CWP forged steel fittings or two bolt ammonia unions (generally large systems).
  - Cadmium Coated Flexible Copper line.
  - Avoid reliquification.
  - Pitch lines uphill from gas source.
  - Provide for increase in temperature from source to vacuum regulator.
  - Keep number of valves to a minimum.
  - Keep containers at the same temperature.

System Piping Requirements

- Chlorine Gas Under Vacuum
  - PVC, CPVC pipe
  - Polyethylene tubing
- Chlorine Solution
  - PVC, CPVC
  - Rubber lined pipe
  - Polyethylene tubing or chemical duty hose

Chlorine Supply Accessories Gas Systems

- Chlorine Container Scales
  - Two-cylinder (150 lb Cylinder)
  - Dial Scales (2000 lb Cylinder)
  - Load Cell Scales (2000 lb Cylinder)

- Trunnions
- Ton-cylinder lifting bar

Chlorine Supply Accessories Gas Systems

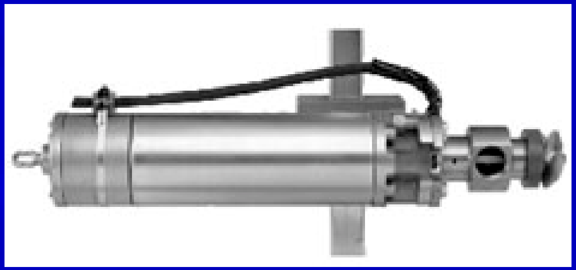
- Gas filters
- Header and shut-off valves
- Gas and liquid supply pressure gauges
- Gas Manifolds
- Flexible Connections
- Auxiliary Container Valves
- Chlorine Gas Detectors

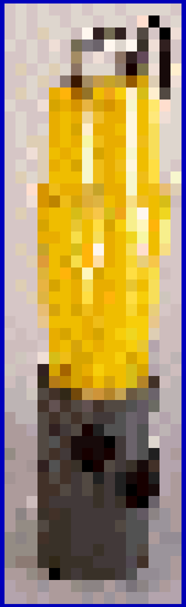
Chlorine Solution Design Considerations

- Calculate back pressures accurately (3 Components).
  - The pressure at the point of application.
  - The difference in elevation between the p.o.a. and the chlorinator Injector.
  - The friction loss in the solution line.
- Keep solution lines short.
- If possible, use a regulated supply for injector water (Sonic Regulation especially).

Chlorine Solution Design Considerations

- Diffusers
  - Provide a quick and uniform dispersion
  - Should not hamper flow being treated
  - Must be able to withstand strain due to flow
  - Must be easily removable
  - Gas induction units may be considered





Hypochlorination

- In a hypochlorite injection system we must:
  - Mix a dry chemical (Calcium Hypochlorite) into solution or obtain liquid hypochlorite (Sodium Hypochlorite).
  - Dilute chemical (if necessary) to desired strength.
  - Meter Hypochlorite via metering pump or other means to point of application.

Hypochlorination

- Hypochlorite is available in two forms:
  - Calcium Hypochlorite - dry powder or crystals stored in cans, barrels, or drums. Commercial grade can be as high as 70% available chlorine. This must be mixed with water and allowed to settle. The solution should be siphoned off to a plastic metering tank before use.
  - Sodium Hypochlorite – liquid form available in 5 gallon pails, 45 gallon drums, totes, bulk truck delivery. Concentrations available to 15% available chlorine (most common commercial grade is 12%). This can be metered neat or diluted to a desired concentration.

Hypochlorite Feed Methods

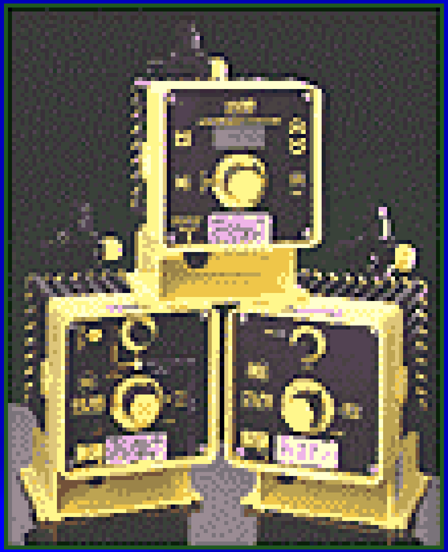
- Metering Pumps
  - Solenoid Actuated
  - Motor Driven
  - Peristaltic
- Chemical Induction Unit
  - Liquid V-notch
  - Venturi Control (Injector)

Solenoid Metering Pumps

- Typically used in low feed rate processes (0.1-20 usgph) – pressure ratings drop off as feed ratings increase.
- Positive displacement metering pump using ball check valves and diaphragm. Shaft is driven by a magnetic solenoid.
- Inexpensive capital costs and relatively inexpensive to maintain.
- Mid range life expectancy compared to motor driven pumps (depends on maintenance).

Solenoid Metering Pumps

Industry Examples



USFilter

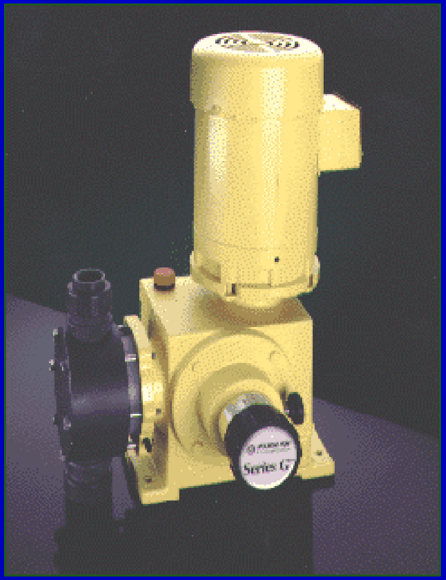
a VIVENDI water company

Motor Driven Metering Pumps

- Used over a very wide range of feed rates (approx 1-300usgph) – pressure ratings drop off as feed ratings increase but much better than solenoid pumps.
- Positive displacement metering pump with ball checks and diaphragm. Shaft is driven by motor driven cam unit.
- More expensive than solenoid pumps but one can expect a longer life cycle (depends on maintenance).

Motor Driven Metering Pumps

- Industry Examples



Peristaltic Metering Pumps

- Used over a very wide range of feed rates.
- Positive displacement metering pump with tube and rollers. Tube is pressed against inner housing of pump “head” by multiple rollers.

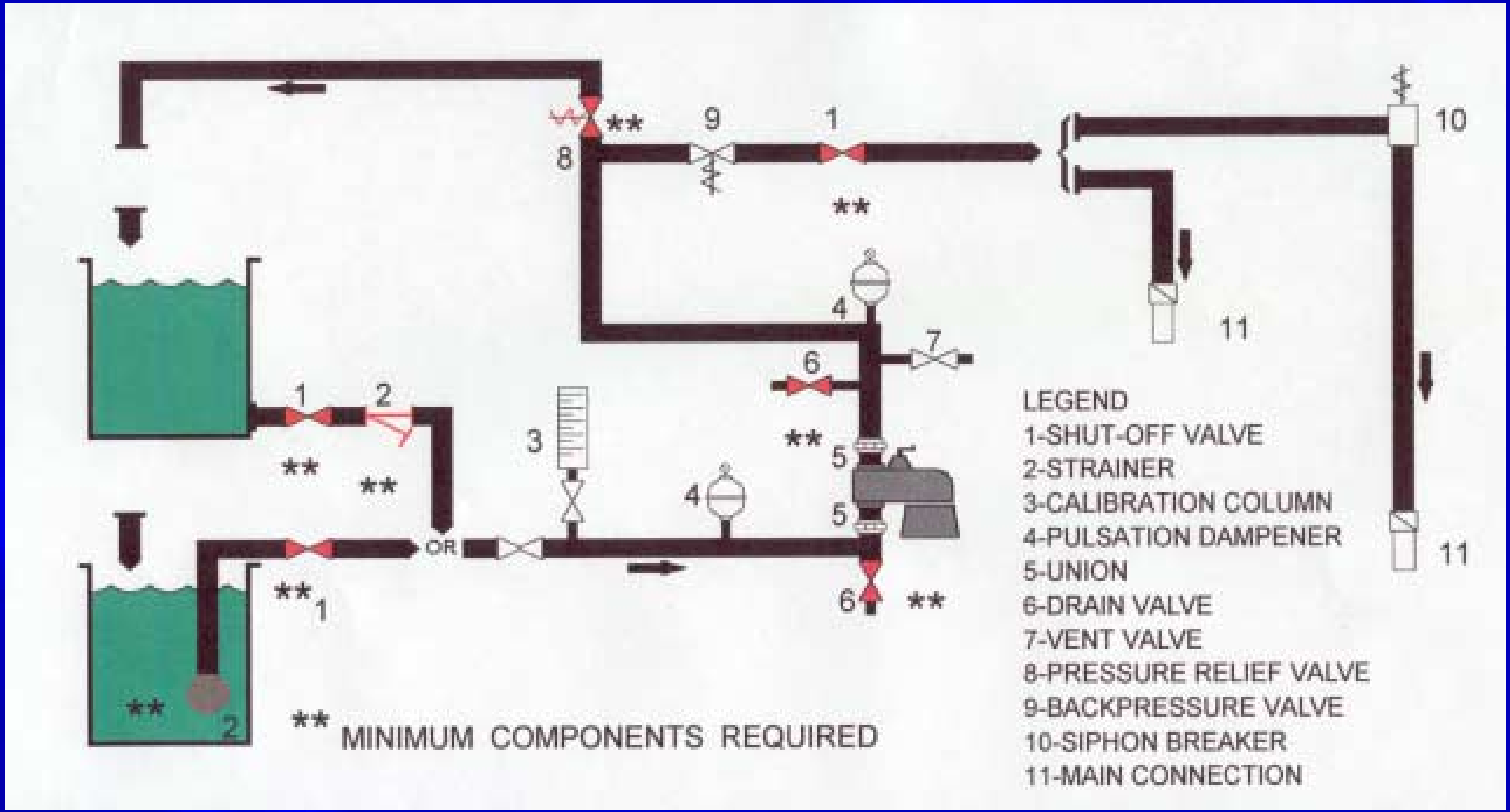
Peristaltic Metering Pumps

- Industry Examples.

USFilter

a VIVENDI water company

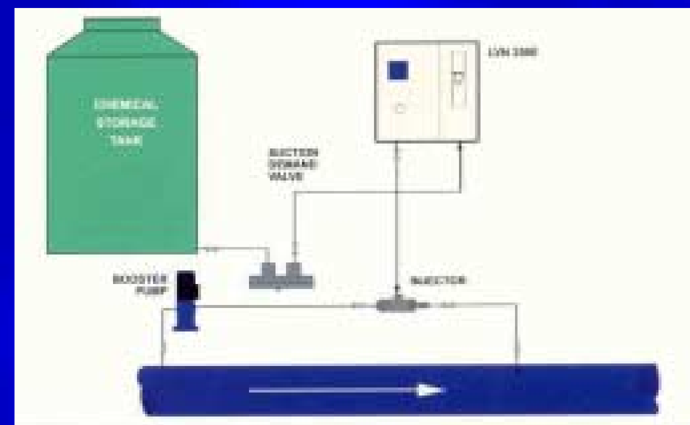
Metering Pump
Typical Installation

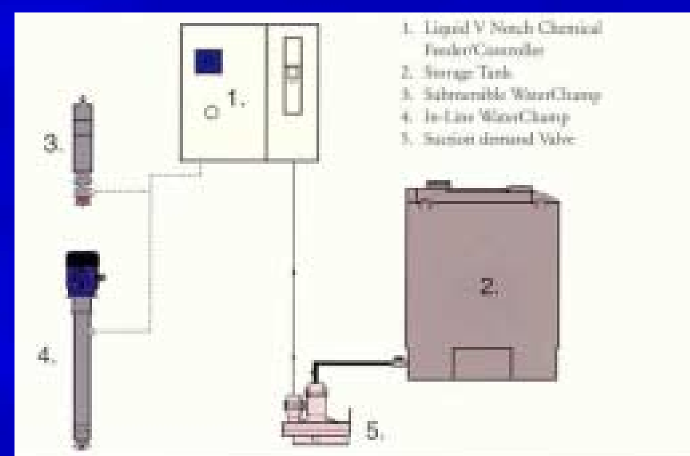


Liquid V-notch

- Similar to a gas chlorinator but liquid hypochlorite is fed rather than gas.

Industry Example.





Gas vs Hypochlorination

Gas.

- Capital cost Higher.
- Material cost lower.
- More capacity per volume (100% CL2).
- No carbonate problems.
- No vapor locking.
- Can run without power if necessary.
- Requires greater care to transport and store.

Hypochlorite.

- Capital cost Lower.
- Material cost higher.
- Require more storage (12% available chlorine).
- Carbonate build-up at POA.
- Vapour locking possible (except for Peristaltic).
- Requires power for pump.
- Safer to transport and store.

Chlorine Residual Analyzers

Total Chlorine

= Free Chlorine ($HOCL + OCL^-$)

+ NH_2CL (Monochloramine)

+ $NHCL_2$ (Dichloramine)

+ NCL_3 (Trichloramine)

Chlorine Residual Analyzers

Different Technologies Available:

- Amperometric Measurement – Bare electrode.
- Amperometric Measurement – Membrane covered electrode.
- Oxidation/Reduction Potential (ORP).
- Colorimetric.

Amperometric – Bare Electrode

- Analyzer measures chlorine residual using the small current generated by Hypochlorous acid (or iodine for total) in water sample. May use buffer and/or KI solutions.

Industry Examples.

Amperometric - Membrane

- Analyzer measures chlorine residual using the small current generated by hypochlorous acid (or Iodine for total). A thin membrane covers the electrode so that only a small amount of sample reaches the electrode. Uses special electrolyte solutions rather than reagents.

Industry Examples.

ORP Analyzers

- Analyzer measures the oxidation/reduction potential generated by chlorine/sulfite in sample. With pH correction, the mV potential is proportional to chlorine residual.

Industry Example.

Colorimetric Analyzers

- Analyzer injects a chemical reagent to a fixed sample and measures color change to determine chlorine residual.

Industry Example.

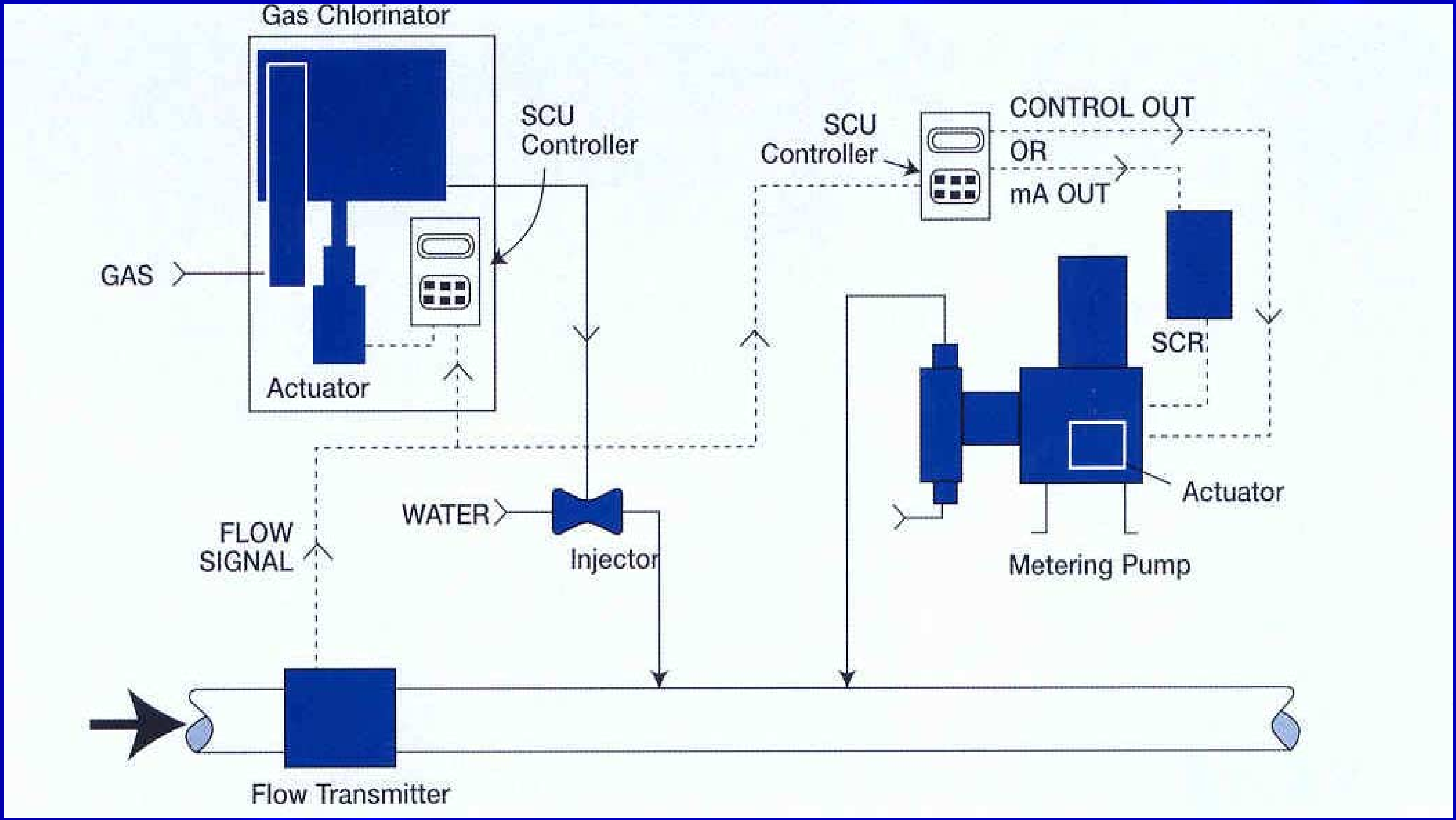
Manual Residual Testers

- Amperometric (measures reduction of chlorine by monitoring current decrease).
- Colorimetric (measures color change with chemical reactant (DPD).

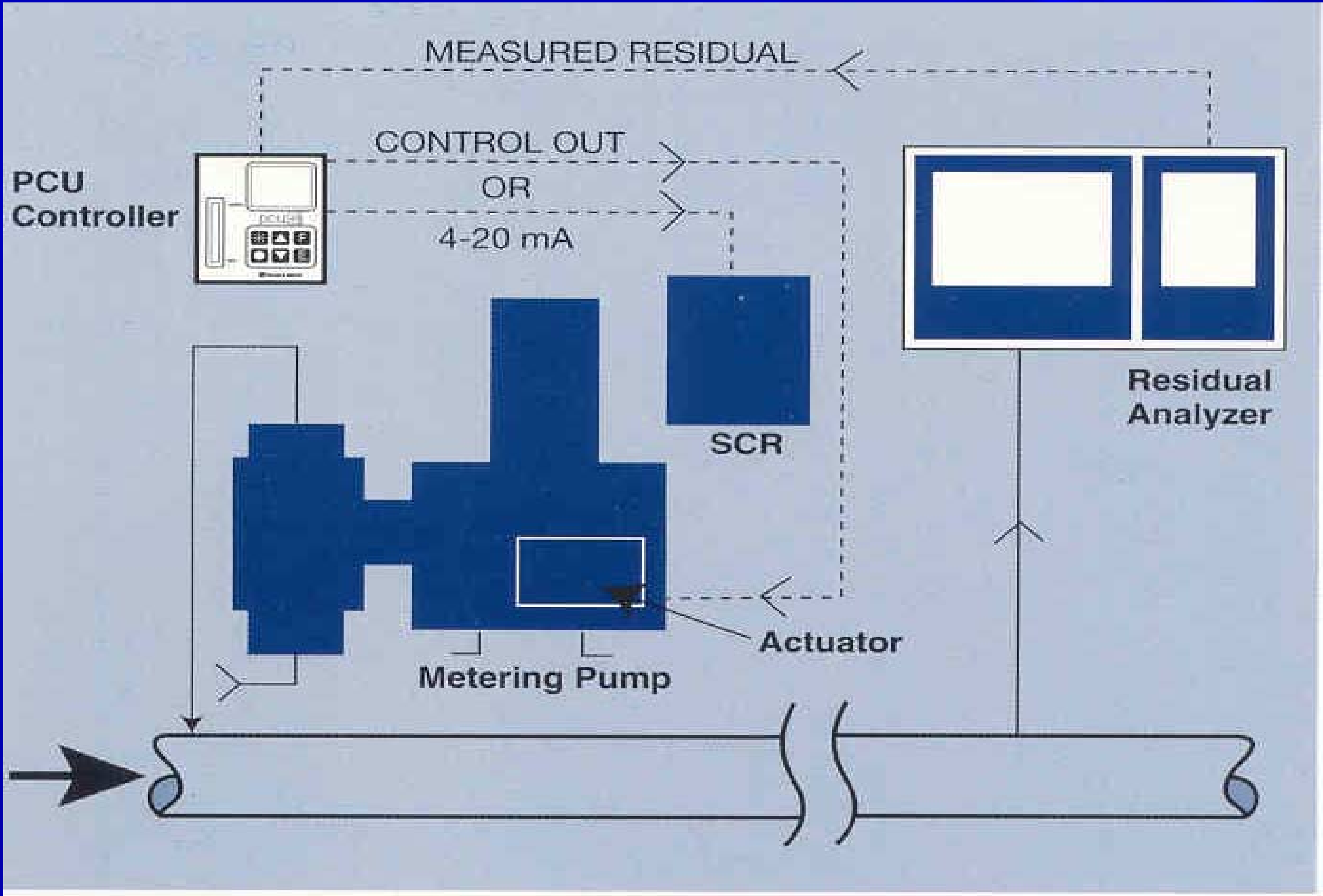
Chlorination Control Types

• Continuous, Uniform Rate of Flow	• Manually Set Feedrate
• Intermittent, Uniform Rate of Flow	• Intermittent Start Stop
• Variable Rate, Constant Demand	• Flow Proportional Control
• Constant Rate, Variable Demand	• Direct Residual
• Variable Rate, Variable Demand	• Compound Loop

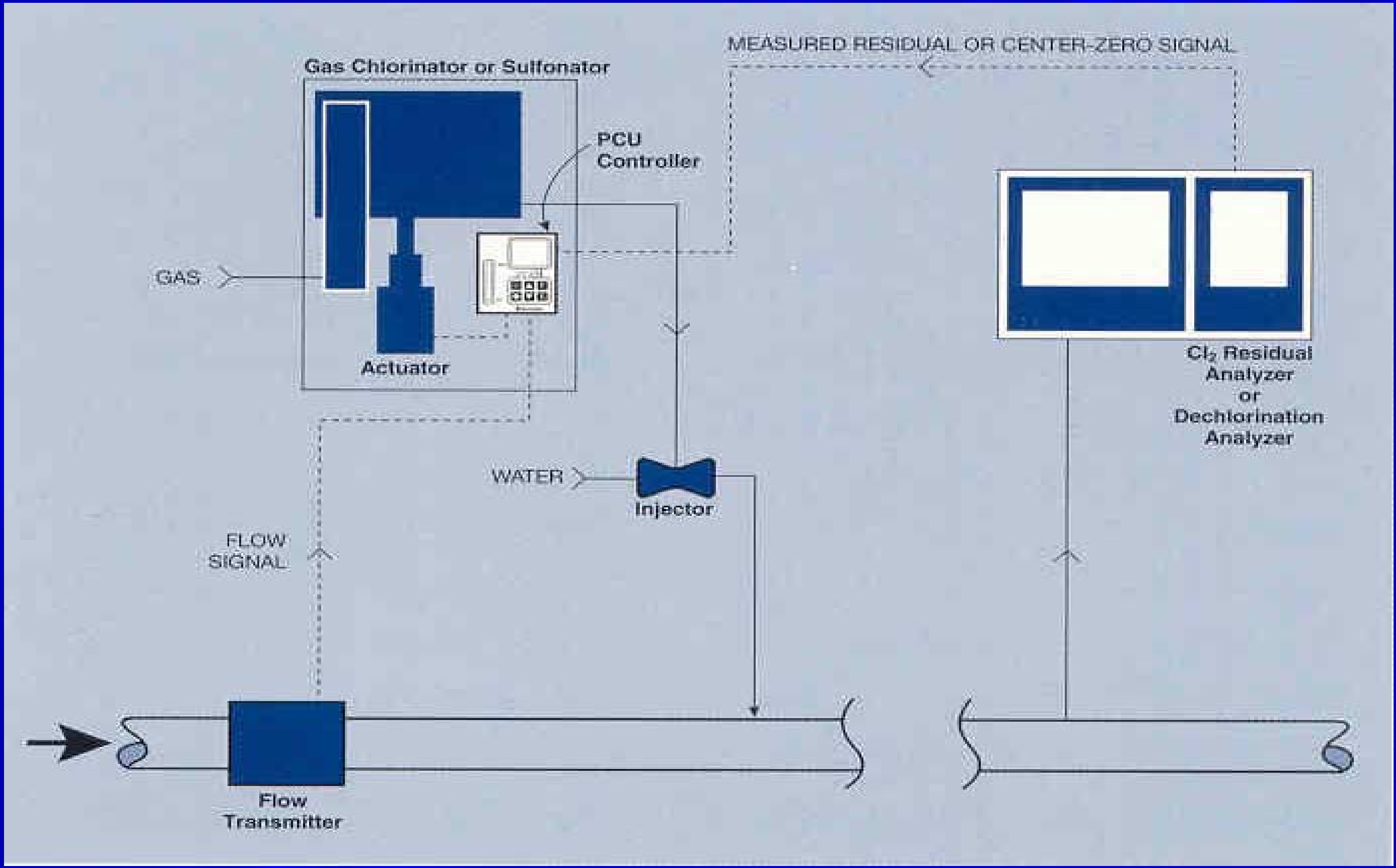
Flow Proportional Control



Direct Residual Control



Compound Loop Control



Alternate Chlorine Based Disinfection Systems

- Chloramination
- Chlorine Dioxide
- On Site Electrolytic Chlorination (OSEC)

Chloramination

- Ammonia is added to a process to convert free chlorine deliberately to monochloramine residual (pH and mixing ratio dependent).
- Addition can done with either ammonia gas or aqueous ammonia (Typically 25%).
- Benefits.
  - Monochloramine contributes least to taste and odor problems.
  - Provides a longer lasting residual in distribution system (though not as powerful).
  - Monochloramine does not form THMs.

Chloramination Sequence of Addition

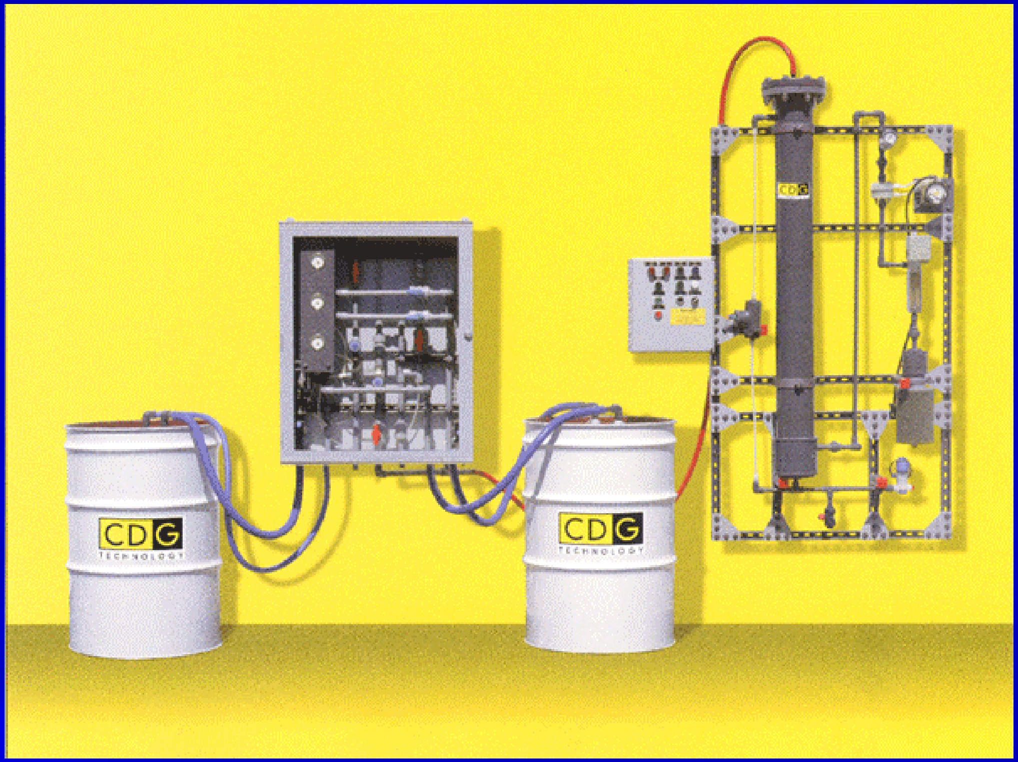
- Ammonia after Chlorine addition
  - THM function of time
  - In most cases short period of free chlorine exposure can be tolerated
- Ammonia before Chlorine addition
  - No free chlorine contact can be tolerated
  - When significant bromide concentration is found

Chlorine Dioxide – CLO_2

- A powerful oxidant formed by mixing chlorine solution (usually from chlorinator) with sodium chlorite solution (mixed from powder and metered by pump).
- Can be done with chlorinator,metering pump(s) and reaction chamber, or industrial pre-packaged systems available.
- Resulting solution can be metered by pump, induction unit, or fed by chlorinator solution line in simple style installation.

Chlorine Dioxide – CLO_2

Industry Examples of pre-packaged systems.

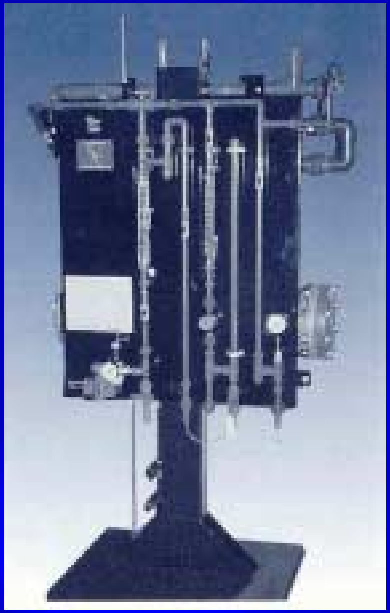
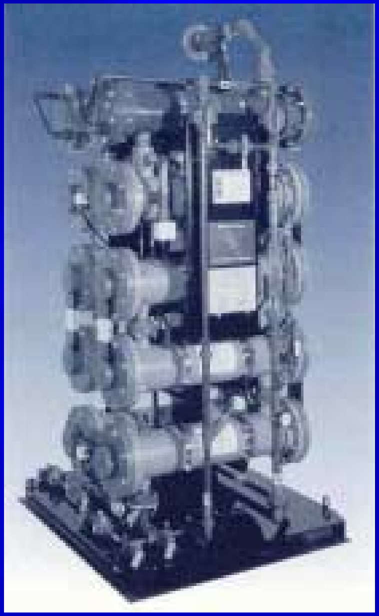


OSEC
On Site Electrolytic Chlorination

- A process that uses Brine (salt) solution and electricity to produce Sodium Hypochlorite (0.9% max solution strength).
- Available in various capacities from 5 to 2000 lb/day equivalent chlorine.
- Available in pre-engineered packages.

OSEC
On Site Electrolytic Chlorination

Industry Examples.


Questions and Answers