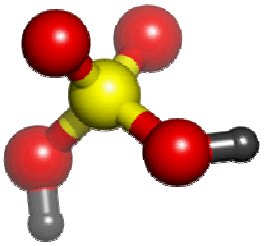


SAND2012-7064C

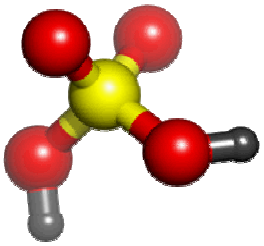
The Four Pillars of Inherent Chemical Safety / Security

Nairobi, Kenya

September, 2012

SAND No. 2012-7064C

Sandia National Laboratories



Part of formal IST definition

- IST is an iterative process that considers such options, including eliminating a hazard, reducing a hazard, substituting a less hazardous material, using less hazardous process conditions, and designing a process to reduce the potential for, or consequences of, human error, equipment failure, or intentional harm.

Pillar One

Minimize

Substitute

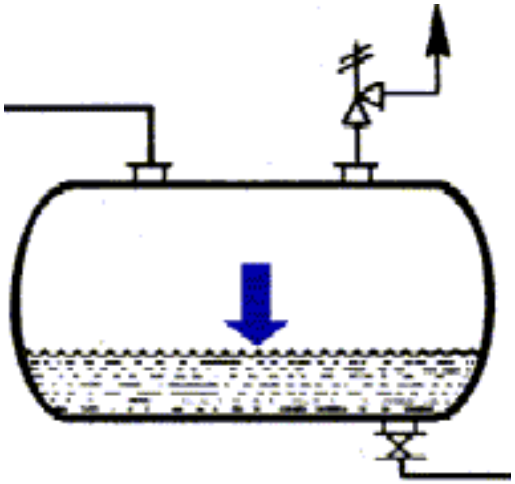
Moderate

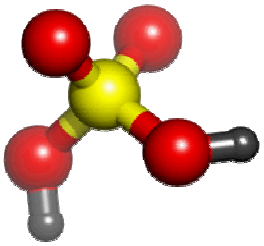
Simplify

Minimize

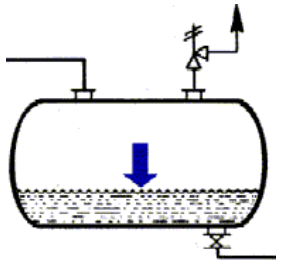
To *minimize* is to reduce the amount of potential energy present (get the system closer to a zero energy state),

this reduces the potential impacts if containment or control of the hazard is lost.



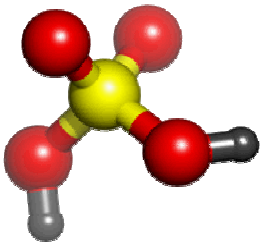


Minimize

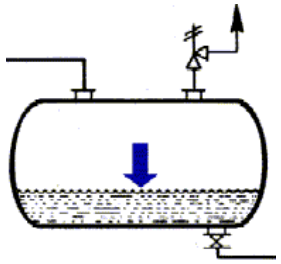


Some strategies for making a process inherently safer by ***minimization***:

- Inventory reduction:
  - less material stored ⇦ *requires administrative control*
  - fewer tanks; just-in-time delivery
  - less vapor volume
  - generate on demand (chlorine, methyl isocyante, ammonia, hydrogen...)
  - receive by pipeline instead of by truck or rail
- Process intensification
- Process operation closer to ambient conditions



Minimize



Ultimate case:

- Elimination of the hazard:
  - Eliminating use of a particular hazardous material
  - Operating the system at lower temperatures (with respect to a particular hazard)
  - Shutting down the process
  - Using another company to provide processing (risk *transfer*)

Pillar Two

Minimize

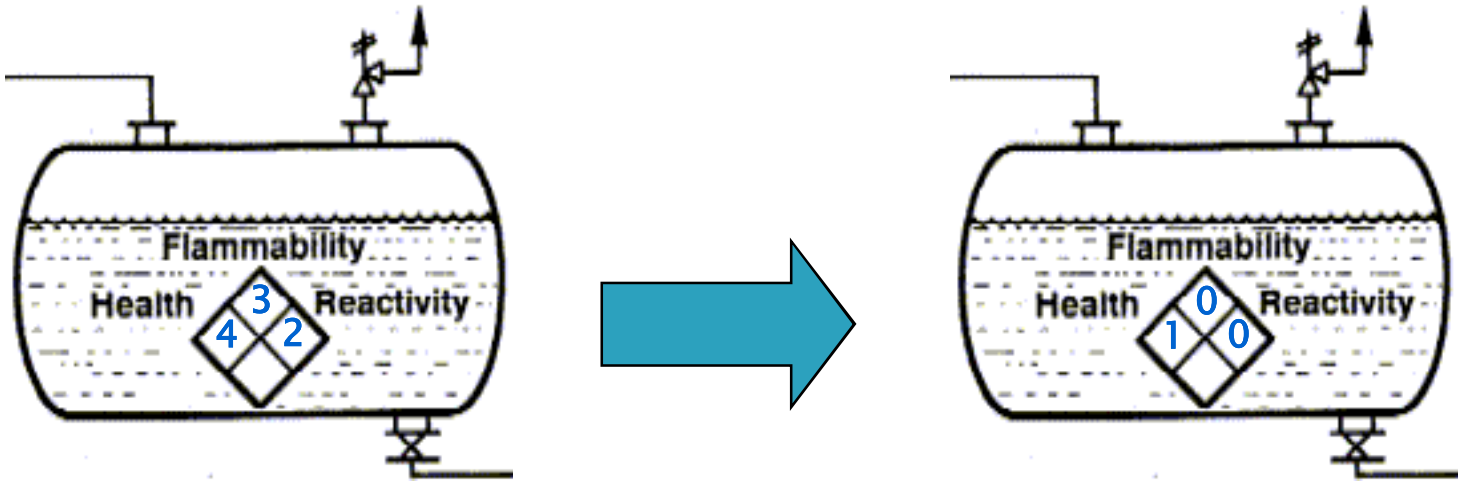
Substitute

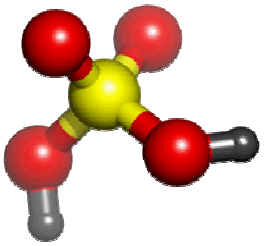
Moderate

Simplify

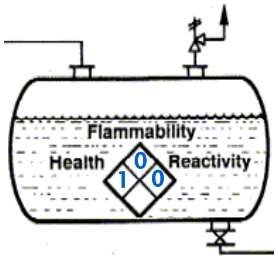
Substitute

To *substitute* is to replace with a less hazardous material or condition.



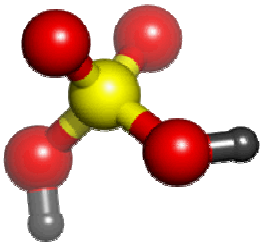


Substitute

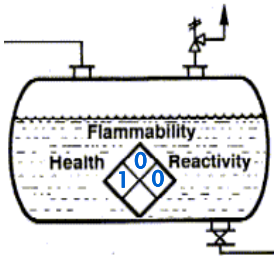


Some strategies for making a process inherently safer by *substitution*:

- Commercially available alternatives
- Alternative raw material or intermediate that can be transported and stored more safely (example ethylene glycol is toxic, propylene glycol is non-toxic)
- Alternative chemistry- Biosynthesis routes
- Oleum alternative: Sulfur burning to generate SO_3 on demand



Substitute

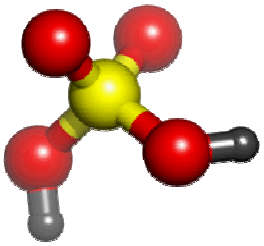


Solvent substitutes:

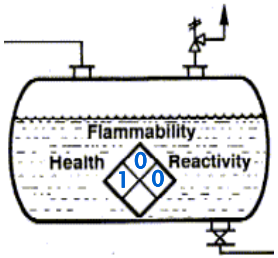
- Water-based paints, adhesives
- Aqueous cleaning systems
- Less volatile solvents; higher flash point
- Dibasic esters for paint stripping instead of dichloromethane

Web resources are available

- "Substitutes in Non-Aerosol Solvent Cleaning," www.epa.gov/ozone/snap/solvents/solvents.pdf



Substitute



Some chlorine alternatives: Cl_2

- Sodium hypochlorite
- Calcium hypochlorite
- Hydrogen peroxide
- Chlorine dioxide
- Bromine
- Mixed oxidants
- Other technologies (UV radiation)

Pillar Three

Minimize

Substitute

Moderate

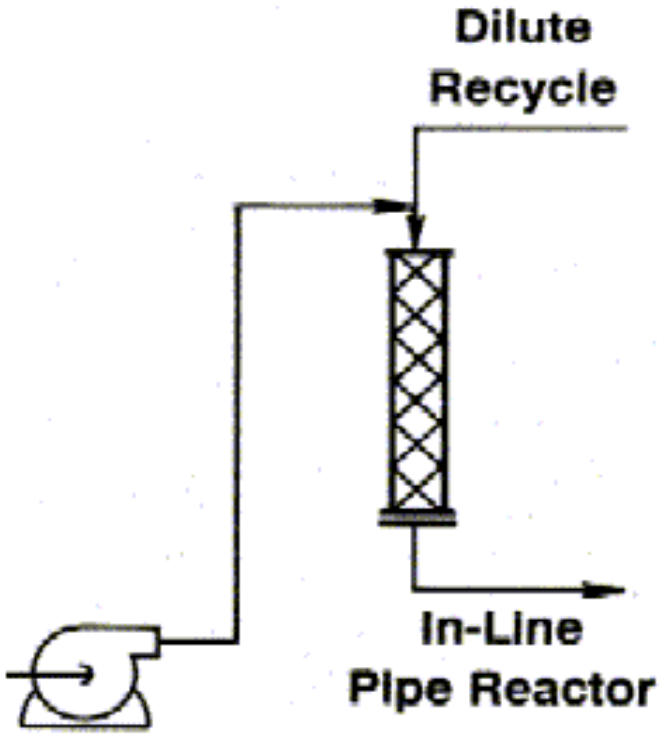
Simplify

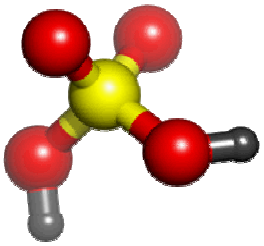
Moderate

To *moderate* (or *attenuate)* is to handle a material under less hazardous process conditions.

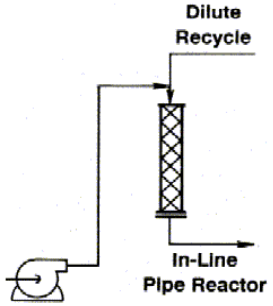
Dilution
Refrigeration
Less severe processing conditions

Note: Available energy may be the same, but potential loss event impacts can be reduced



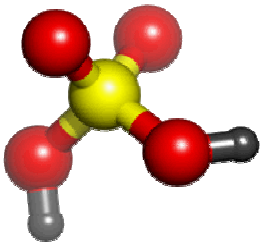


Moderate



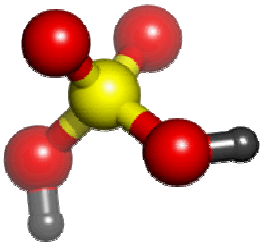
Some strategies for making a process inherently safer by *moderation* :

- **Dilution:**
  - using in aqueous instead of anhydrous form
  - Using in solution such that the solute would boil off before a runaway reaction temperature was achieved
  - Lower concentration of benzoyl peroxide in paste
  - Mixing coal dust with rock dust
- **Refrigeration:**
  - storing anhydrous ammonia as a refrigerated liquid instead of as a liquefied gas



Moderate

- Aqueous ammonia instead of anhydrous
  - Anhydrous is hazardous gas
- Aqueous HCl in place of anhydrous HCl
  - Anhydrous is a hazardous gas
- Sulfuric acid in place of oleum
  - Oleum has dissolved SO_3 (a toxic gas)
- Dynamite instead of nitroglycerine
  - The nitroglycerin in dynamite is stabilized on a solid carrier (diatomaceous earth)



Less severe processing conditions

- Ammonia manufacture
  - 1930s - pressures up to 600 atmospheres (atm)
  - 1950s - typically 300-350 atm
  - 1980s - plants operating at pressures of 100-150 atm were being built
- Result of understanding and improving the process
- Lower pressure plants are cheaper, more efficient, as well as safer

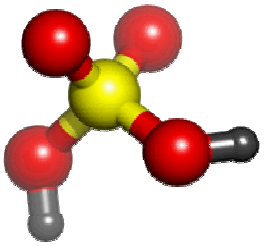
Pillar Four

Minimize

Substitute

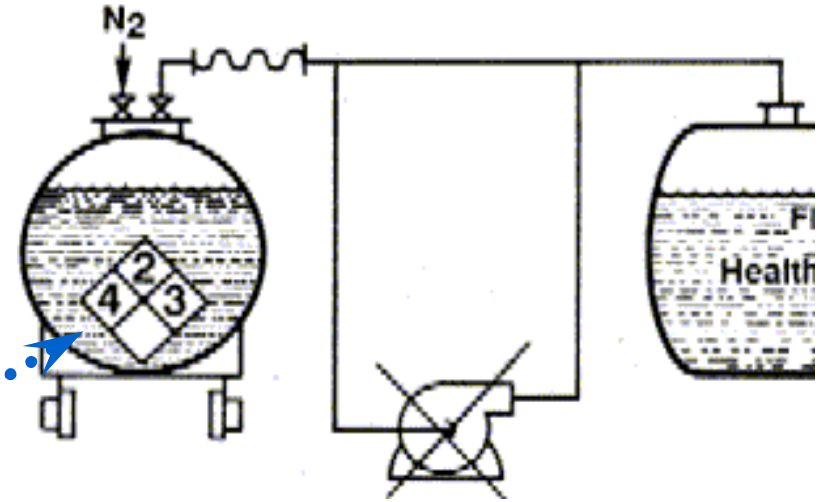
Moderate

Simplify

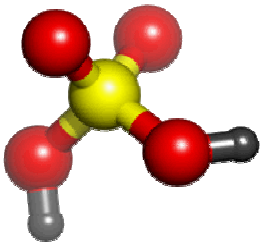


Simplify

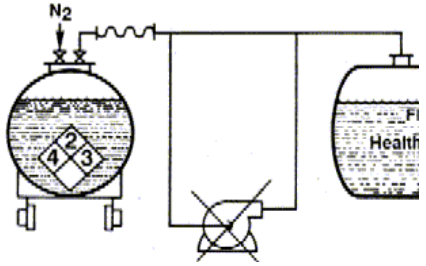
To ***simplify*** is to eliminate unnecessary complexity.



(Not "first-order" inherent safety, since the underlying hazard is still there.)



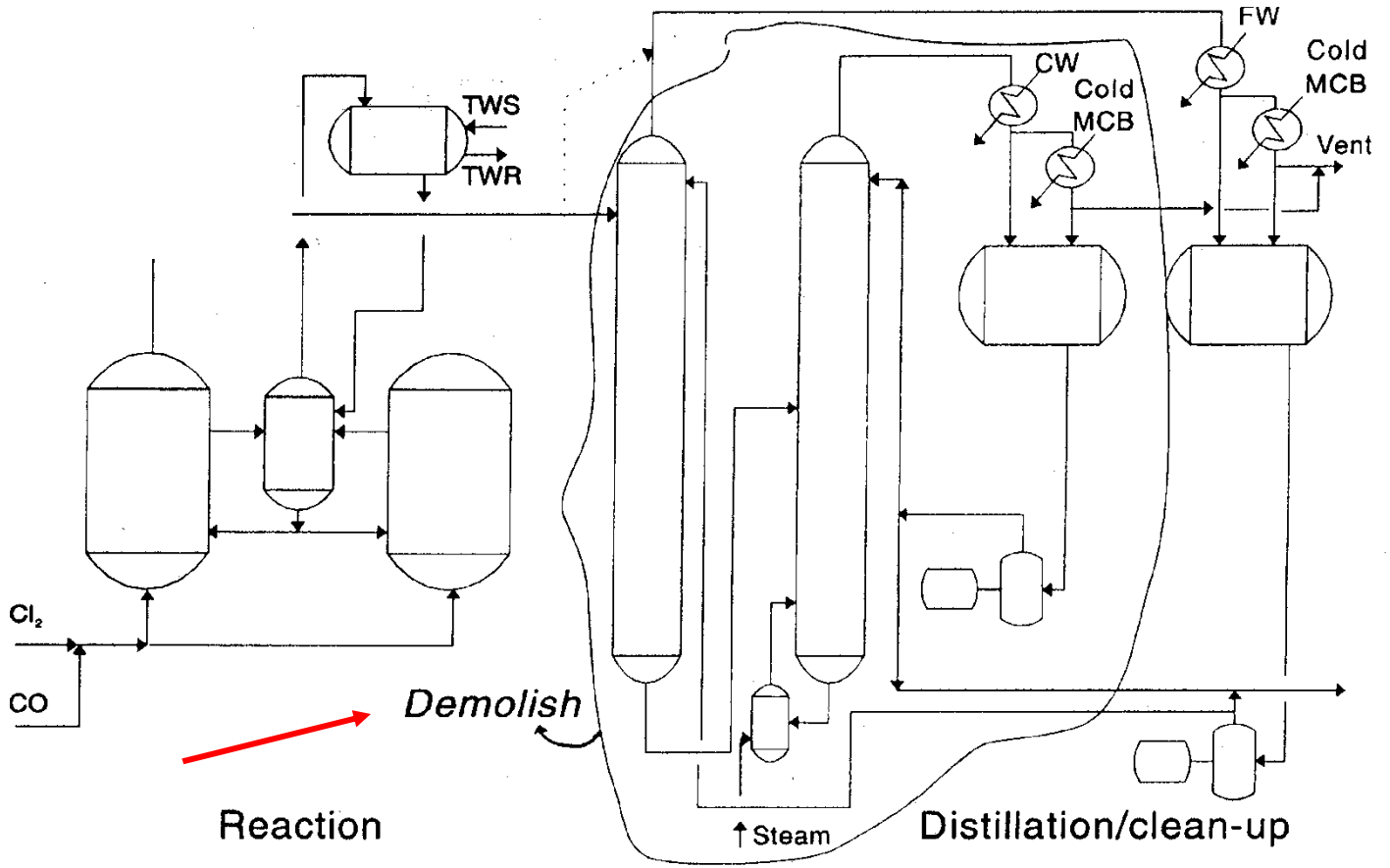
Simplify



Some ***simplification*** strategies:

- **Use simpler equipment arrangement:**
  - Gravity flow instead of pumping
  - Natural convection
  - Collocation of shutoff valves
- **Eliminate interconnections** to reduce the likelihood of inadvertent mixing
- **Minimize number of flanges, connections, and other potential leak locations**

Simplify…

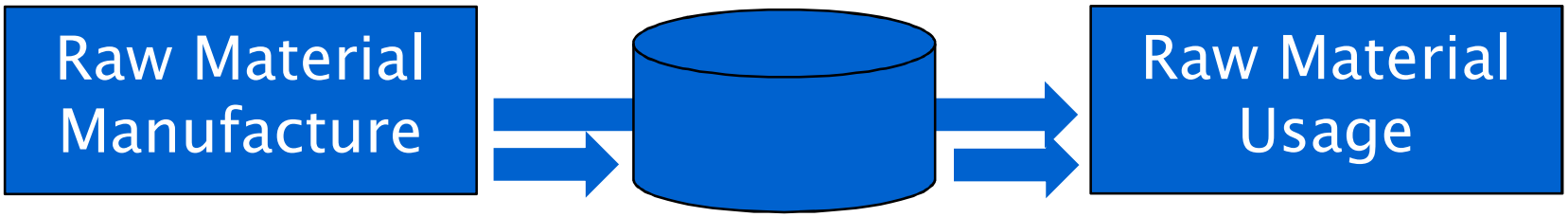


Simplification of Dow Phosgene Unit for MDI Production

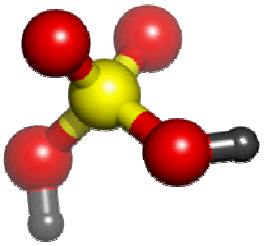
R. Gowland, "Applying Inherently Safer Concepts to a Phosgene Plant Acquisition," *Process Safety Progress 15*(1), 57

DISCUSSION

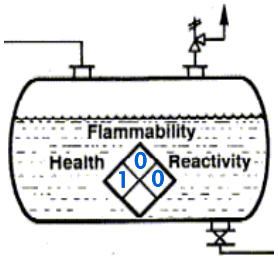
- An inherent safety review recommends eliminating intermediate storage of a hazardous raw material:



- What are the inherent safety benefits?
  -
- What are the possible drawbacks?
  -

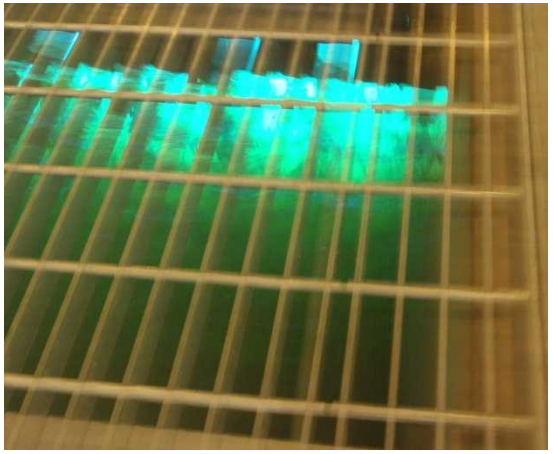


Case Study - Substitute Wastewater Plant



Chlorine alternative : Cl_2

- **Alternative Disinfection (UV radiation)**

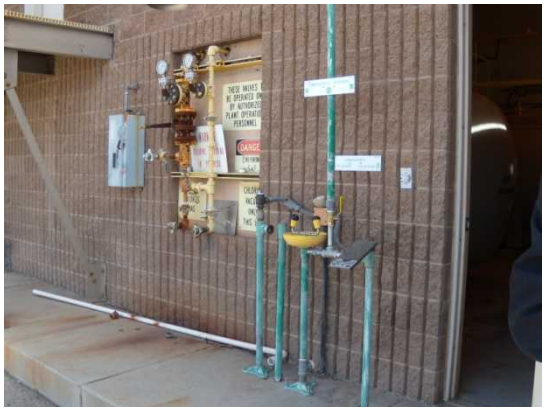


Wastewater plant chlorination process- Substitute

2-25 ton Cl_2

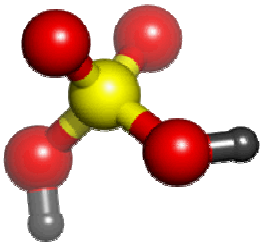
Cl_2 Evaporators

Chlorinator



Shower/Eyewash

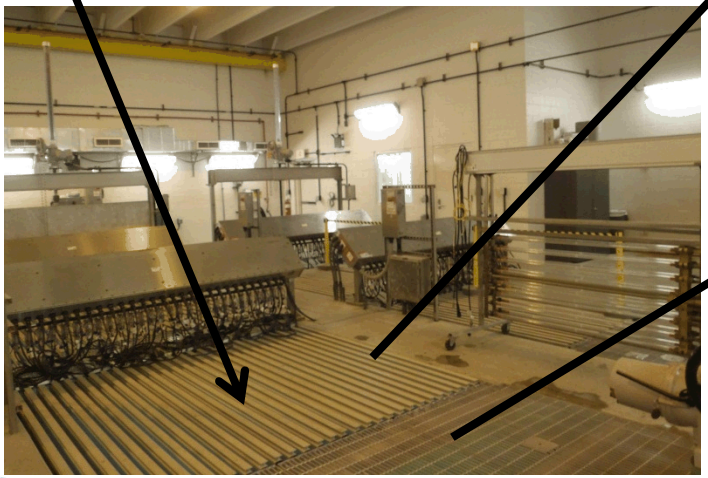
Chlorine contactor

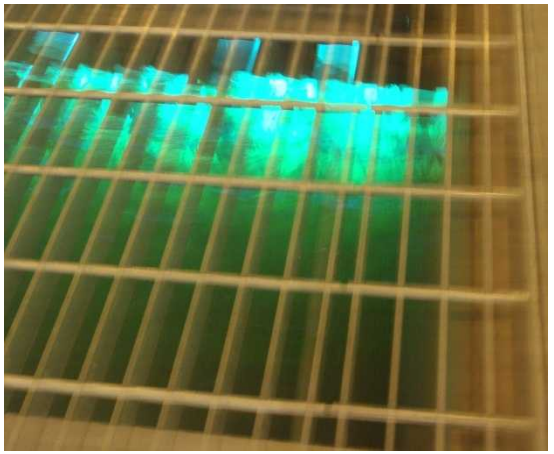


SO_2 used to remove excess chlorine before discharge - Substitute

Two 15 ton SO_2

Ultraviolet disinfection replaces both Cl_2 and SO_2- Substitute

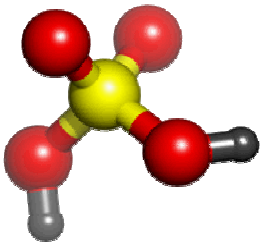




Bulk chemical removed from process - Substitute

2-25 ton Cl_2

2-15 ton SO_2



Discussion

- Can you think of applications of substitution to chemical management?
- What role does regulation play in the selection of technology?
- What may make it difficult to mandate Inherent Safety?