Chemical Removal of H_2S: ***Iron Sponge***

- Chemical reaction bonds sulfur to iron oxide
- Reaction occurs at ambient temperatures
- Must be in alkaline conditions, pH > 7.5 w/ 8-10 preferred; caustic soda added as needed
- Temperature < 110F

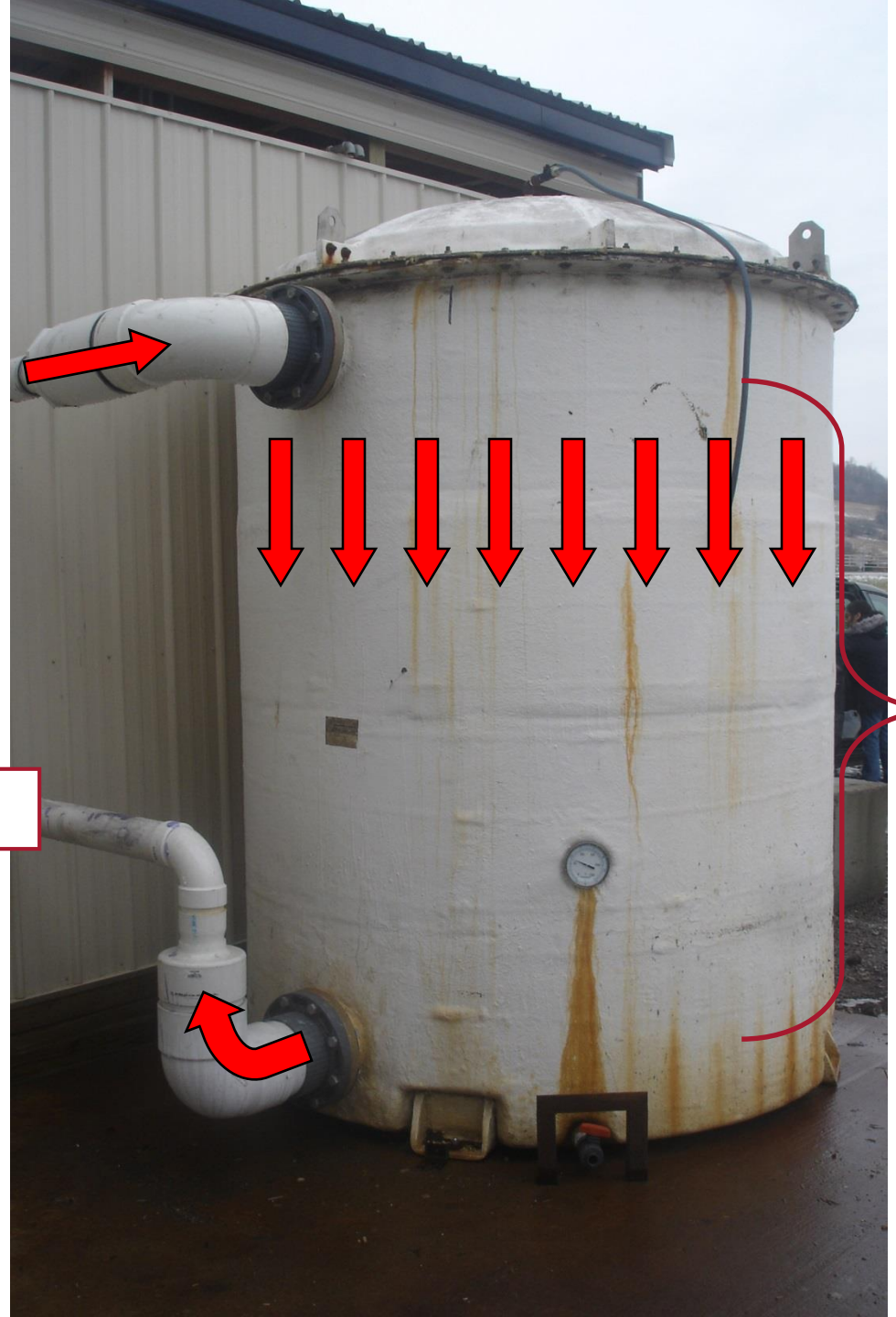
Chemical Removal of H_2S: *Iron Sponge* (con't)

- Each pound of Fe_20_3 can remove 0.56 lbs. sulfide

- Iron oxide is impregnate in wood bark: 15 lbs. Fe_20_3 per bushel of bark (1 bushel in-place = 1 cu. ft.)

$$3H_2S + Fe_20_3 + H_2O \rightarrow 4H_2O + Fe_20_3$$

$[H_2S]_{in}$ = 1k to 4k ppm

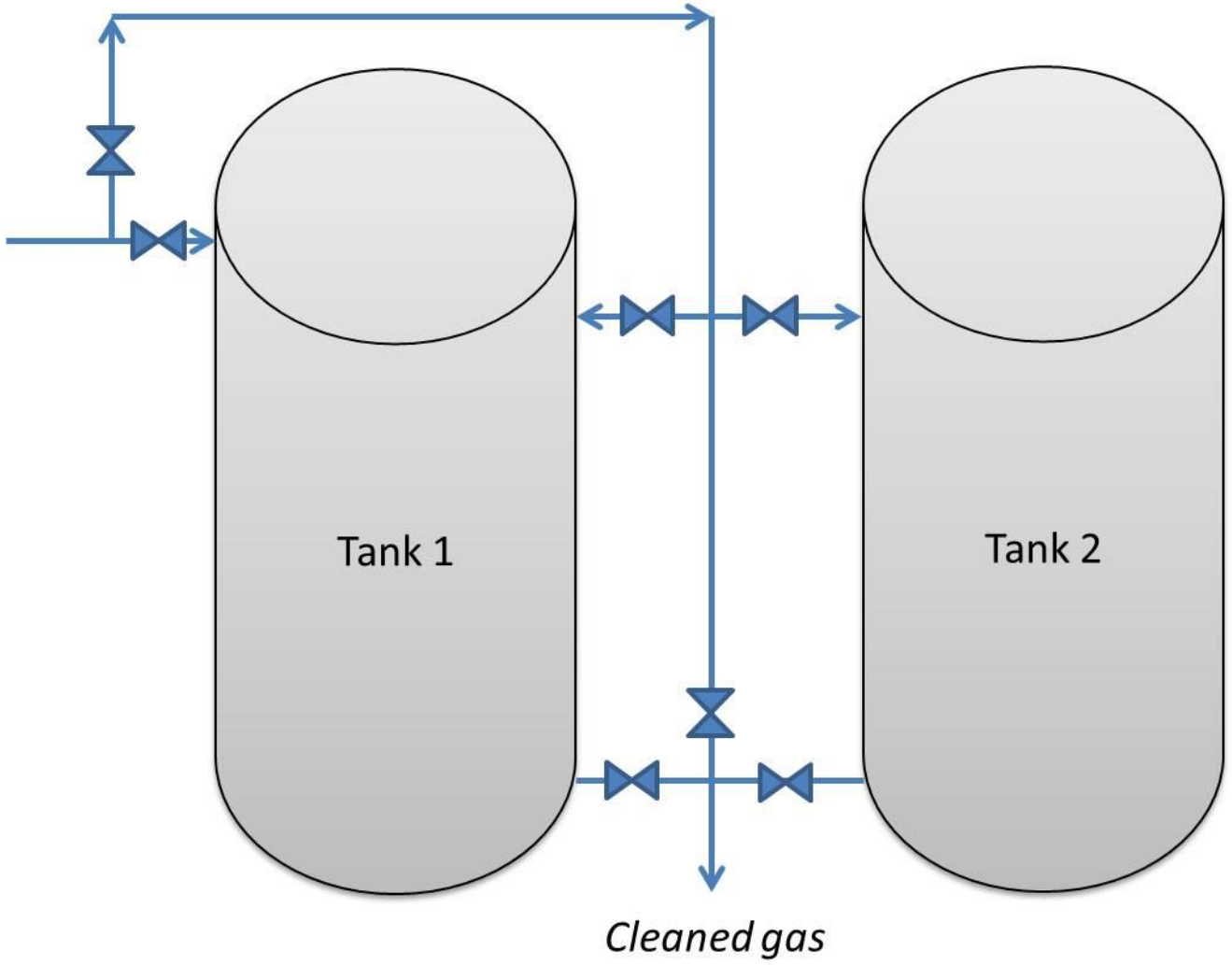


$[H_2S]_{out}$ = 50 ppm

<u>Δp:</u>
2 - 3” wc initially
8 - 10” over time

Iron Sponge – MSU AD System

Two Tank System for Biogas Clean-up



Iron Sponge Scrubbers – Janesville WWTP, Janesville, WI

Chemical Removal of H_2S: *Iron Sponge* (con't)

- Iron oxide can be regenerated by adding air (0_2)
  - prolong life by 3 to 4x
  - sulfide is changed to elemental sulfur

$$2Fe_2S_3 + 30_2 + 2H_2O \rightarrow 2Fe_20_3 + 2H_2O + 6S + Heat$$

Spent iron sponge (no longer when H_2S is removed and/or when bark has deteriorated into fine particles) can be burned (caution: can self combust), land filled, or spread on ag. land.

Chemical Removal of H_2S: *Activated Carbon*

- Activated carbon impregnated with potassium iodine or sulfuric acid
- Air injected into biogas to promote carbon adsorption of H_2S
- Carbon also regenerated with injected air
- $H_2S \rightarrow$ elemental S

Microbial Removal of H_2S
Biological Fixation

Sulfur oxidizing bacteria

$H_2S + 2O_2 + 2OH \rightarrow SO_4^{2-} + 2H_2O$

Requires ~2% oxygen injection,
~10% air so some dilution,
$[H_2S] < 100$ ppm

Step 1: $H_2S + 0.5\ O_2 \rightarrow S + H_2O$

Step 2: $S + 1.5\ O_2 + H_2O \rightarrow SO_4^{2-} + H^+$

Microbial Removal of Biogas H_2S
Biological Fixation

Two Possible Locations (Strategies):

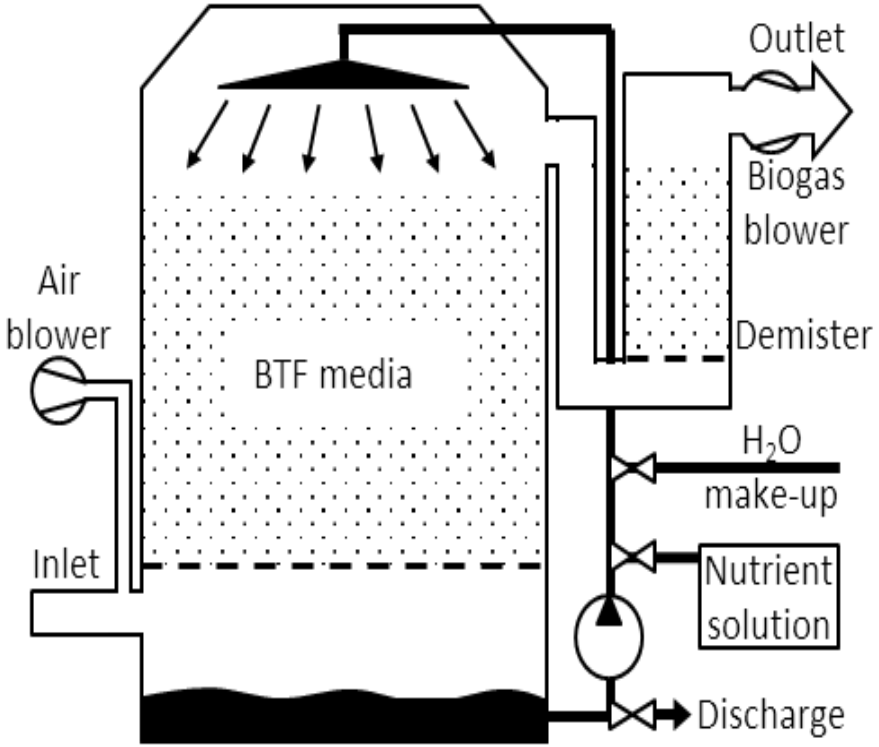
Digester Biogas Head Space
(In situ)

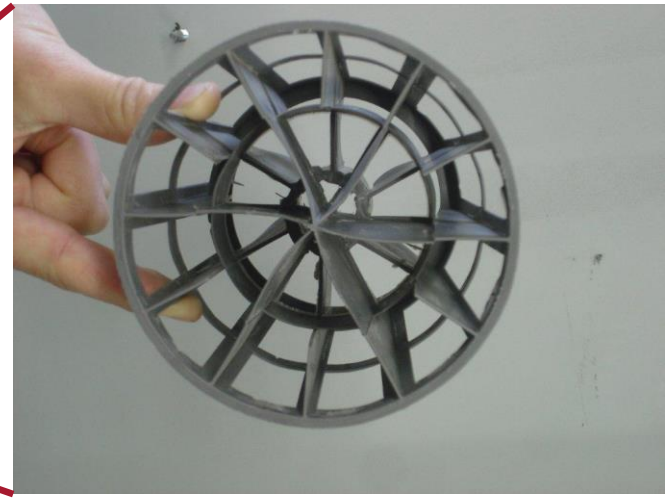
Separate Vessel
(Biotrickling Filter (BTF))

In situ H_2S removal

- Should be part of original design
- Sulfur accumulation, flocs into AD vessel, though cleaning may be required

Biotrickling Filters





Other BTFs

Biofouling in BTF vessels

Biogas Cleanup – Level 3 of 3

CO_2 Reduction/Removal

1. Regenerative Water Wash
2. Regenerative Amine Wash (Amine)
3. Pressure Swing Adsorption (PSA)
4. Membrane Separation

Chemical Removal of CO_2: *Regenerative Water Wash*

- Based on the principle of that CO_2 is more dissolvable in pressurized water than CH_4
- Counter flow technology used and absorption scrubber contains media to ↑ contact between biogas and water
- Important to remove H_2S (also soluble in water) prior to regenerative water wash system since it will foul pipes
- Purified biogas harvested from the top of the pressure vessel and CO_2 and dissolved CH_4 removed from wash water in a flash tank were water pressure is reduced

Chemical Removal of CO_2: *Regenerative **Water Wash***

- Wash water system can result in more water vapor in the processed biogas than in the raw biogas
- Electrical energy use ~ 6.2 kWh per ft^3 of cleaned gas
- Process is ~ 98.5 percent efficient
- Used wash water requires proper handling

Chemical Removal of CO_2: *Regenerative **Amine Wash***

- Similar to the regenerative water wash system but Amine is used to adsorb CO_2

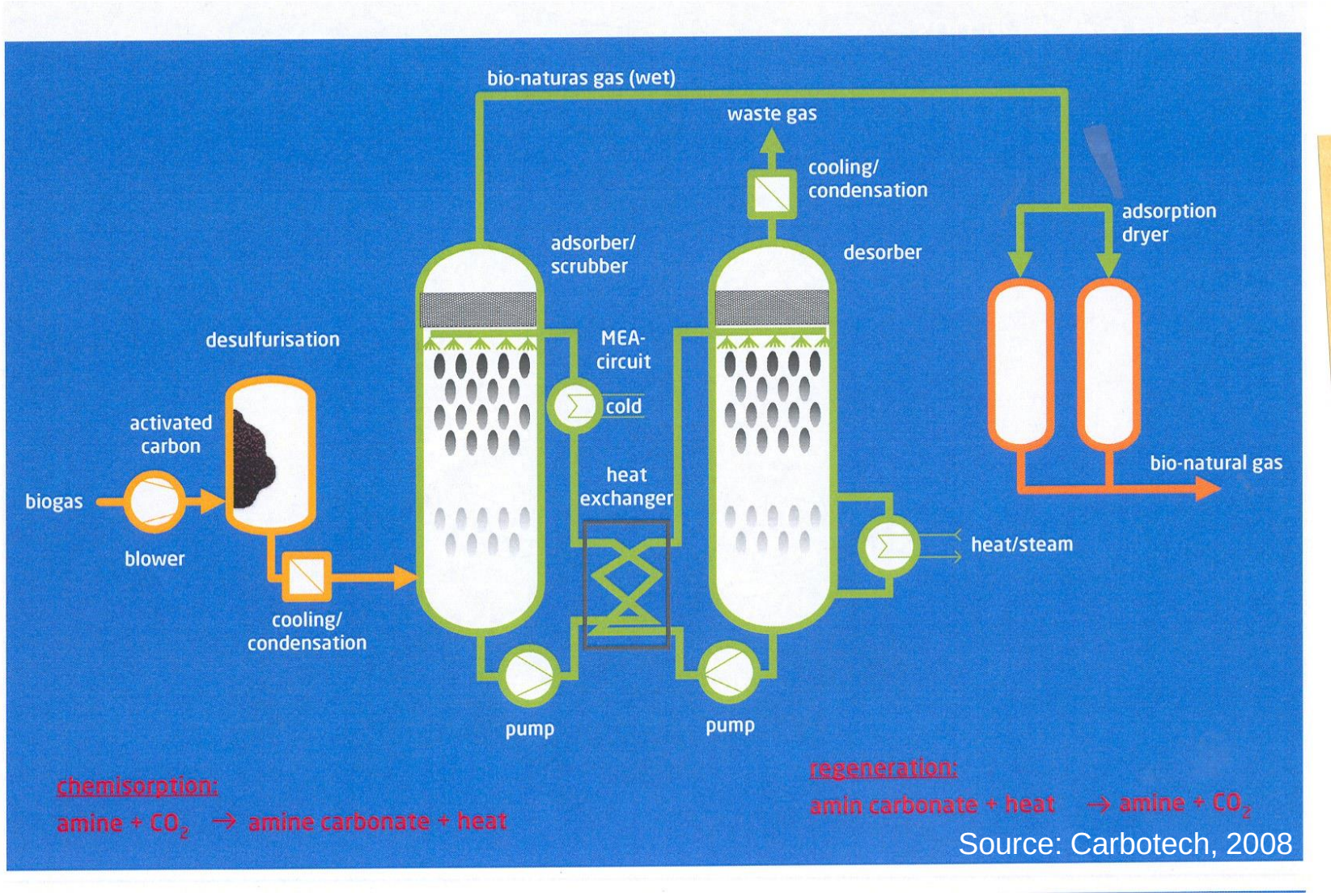
- Amine chemicals are very affective of CO_2 removal resulting in almost pure *biomethane* and little loss in tailgas

- Amine chemicals are toxic to humans and the environment

- Process is high in parasitic power needed for regeneration

- Biogas moisture contaminates amine chemicals reducing efficiency

Biogas Clean Up – Amine System



Source: Carbotech, 2008

Amine System – Pilot Plant Schwandorf, Germany; 7,100 ft^3/hr