Training and ADdressing Operator Challenges

New England Digestion Round Table

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April 5, 2019

Agenda

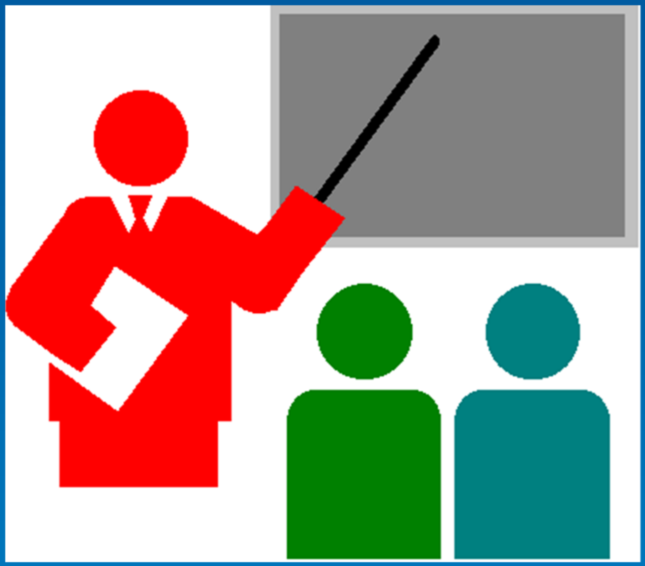
- Background
- Training
- Anaerobic Digestion Basics
- Equipment and Instrumentation
  - Mixing
  - Overflow Protection
- Operation Challenges and Lessons Learned

Background

- The best designed and built systems WILL fail without appropriate training and staff engagement.
  - "No one every told us that"
  - "Why did you do that?"
  - "That's not how we do things"

Training

- When?
- Audience
  - Assumptions
  - Learning Styles
  - Background
- Classroom/Hands on
- Repeat-Repeat-Repeat
- Cheat Sheets



TRA's Central Regional Wastewater System WWTP

- Permitted Flow: 162 mgd
- Key Processes
  - Primary Clarifiers
  - Activated Sludge
  - Final Clarifiers
  - Tertiary Filtration
  - Chlorine Disinfection
  - Discharge to Trinity River
- Class AB biosolids using GTs, GBTs, BFPs, FPs and lime

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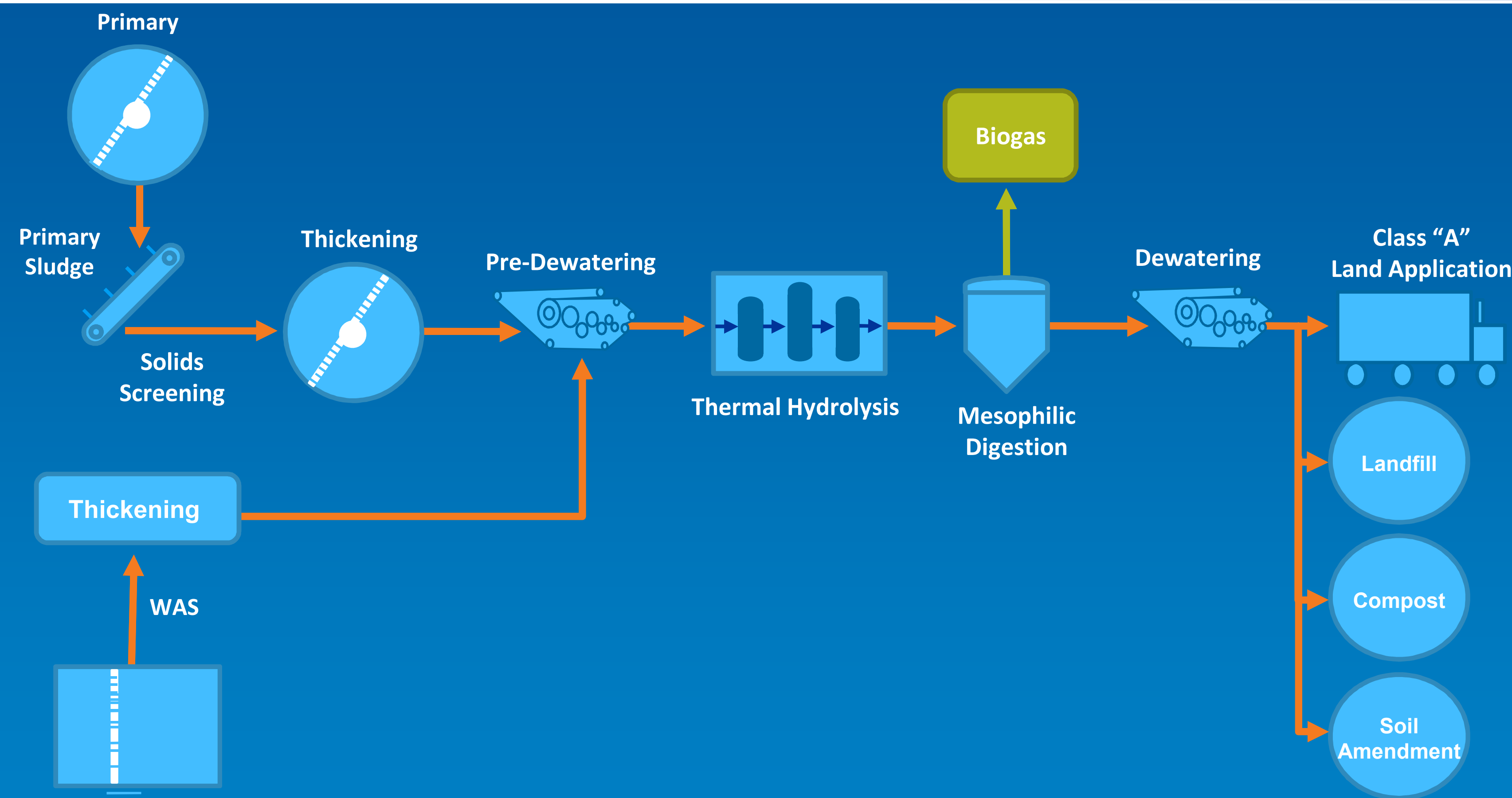
New Solids Handling Processes



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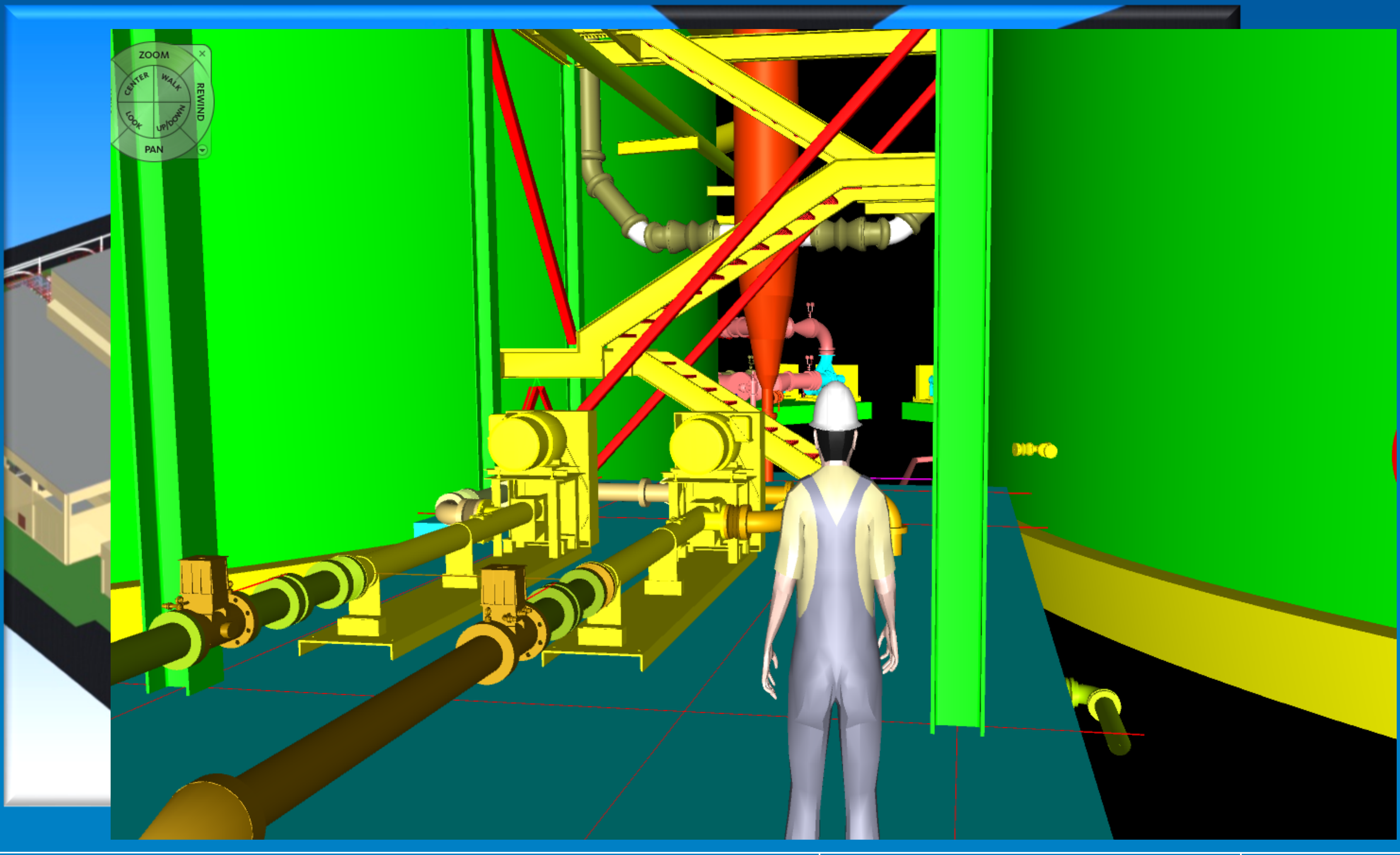
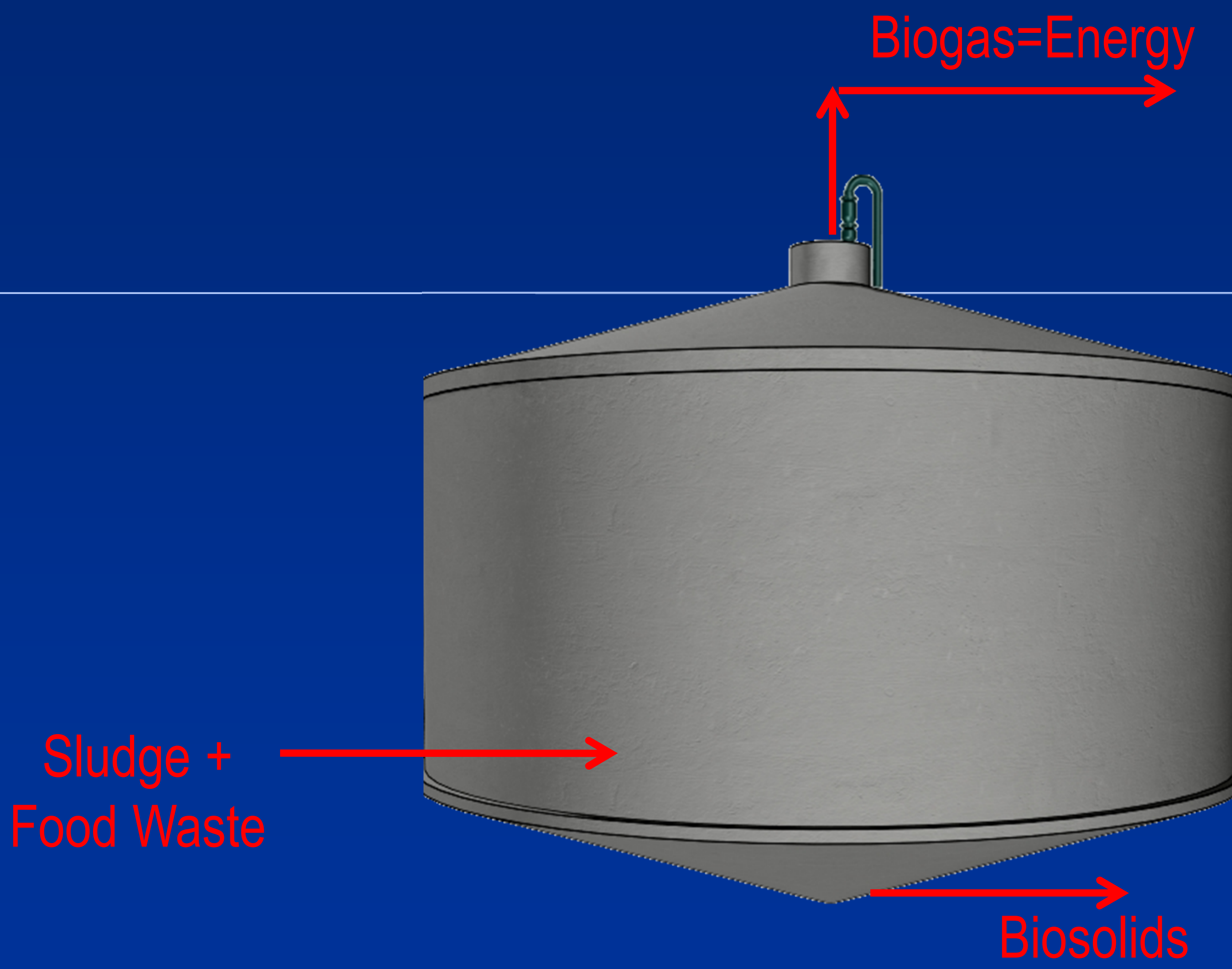


ANAEROBIC DIGESTION



Objectives of Thermal Hydrolysis and Anaerobic Digestion

- Stabilize sludge, reduce odors and reduce vector attraction
- Meet 503 regulations for Class A pathogen reduction
- Reduce volume and mass of sludge (less hauling required)
- Increase dewaterability

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Anaerobic Digestion Biology

Learning Objectives:

1. Understand the fundamentals of digestion biology
2. Explain the impact of thermal hydrolysis (TH) on anaerobic digestion

What is Anaerobic Digestion?

- Anaerobic digestion is a biological process in which bacteria that live and reproduce in an environment containing no “free” or dissolved oxygen are used to treat sludge
- A simplified equation for biogas production from anaerobic digestion:

$$C_6H_{12}O_6 \longrightarrow 3CO_2 + 3CH_4$$

Carbon Dioxide + Methane

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By-Products of Anaerobic Digestion

- Biosolids (stabilized sludge)
  - Consists of inorganic solids and volatile solids that are not easily digested, but are easier to dewater and suitable for beneficial use
- Gas
  - Methane (65-70%) for fuel, carbon dioxide (30-35%) & lesser gases (hydrogen sulfide, etc).
- Foam
  - Should be controllable based on the design (surface overflow and headspace)

Anaerobic Sludge Digestion Steps

- First, complex organic compounds are converted to soluble forms.
- Second, complex soluble organic matter is changed to volatile (organic) acids.
- Third, organic acids are broken down by a different type of microorganism to form methane gas, but at a much slower rate.

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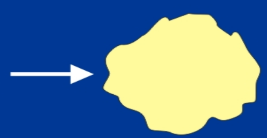
Soluble and Insoluble Material

Soluble Material

Soluble Organic

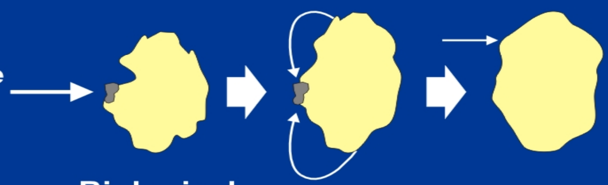


Biological Cell

Dissolved Material Passes Directly Through the Cell Wall

Insoluble Material

Insoluble Organic



Biological Cell

Solid Particle First Adheres to the Outside of Cell Wall

↓

Mirco-organisms Excretes Chemicals that Dissolve Solid Particle

↓

Solubilized Organic Passes Through Cell Wall

How Does the Transfer Work?

Acid Forming Bacteria +
Organic (Soluble & Insoluble) Matter

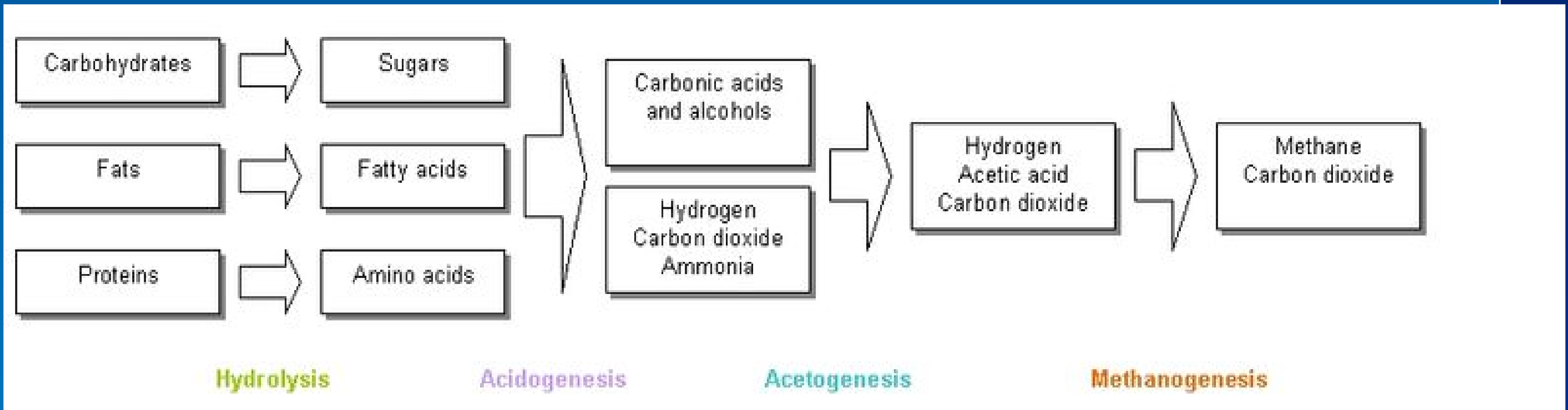
↓

Methane Forming Bacteria + Organic (Volatile) Acids

↓

Carbon Dioxide (CO_2) + Methane (CH_4) Gases

Conversion of Sludge to Biogas



- Blended Sludge
- Soluble Organic Compounds
- Organic acids and Other
- Acetic acid H_2 and CO_2
- Biogas CH_4 and CO_2

Microorganisms

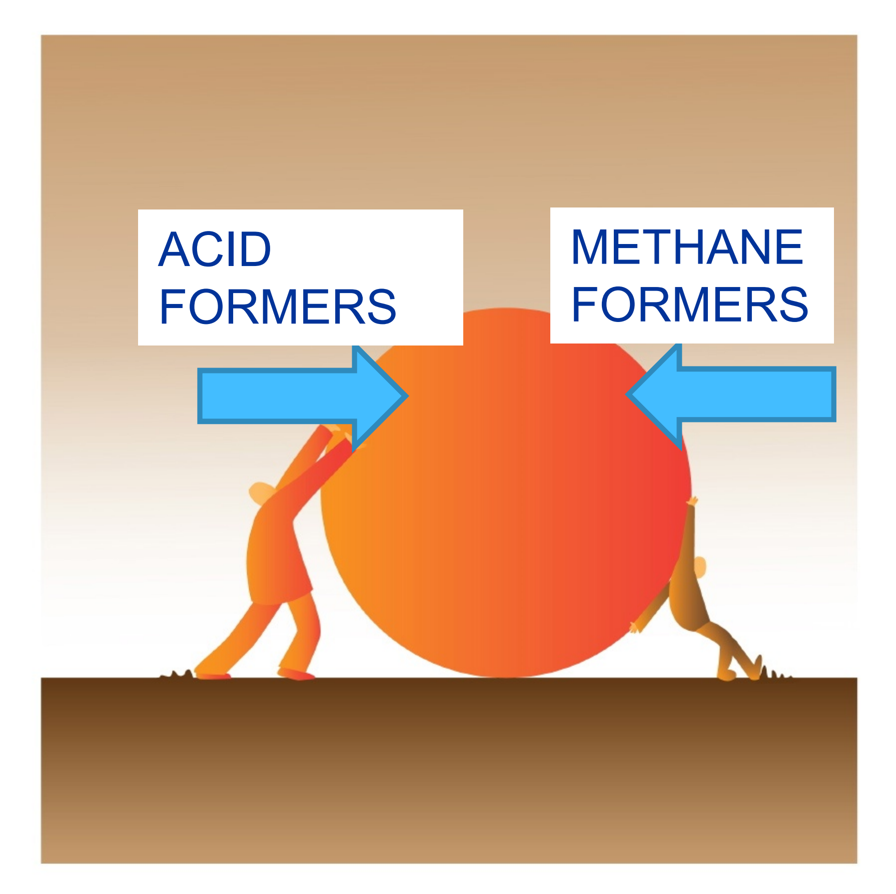
- Acid formers:
  - Convert insoluble organic solids to soluble organic solids
    - Enzymes breakdown insoluble to soluble
  - Convert soluble organic solids to organic acid
    - Alkalinity and pH tend to drop
  - High energy, rapid growing
  - Not as sensitive to environmental changes

Microorganisms

- Methane formers:
  - In a balanced system, organic acids are consumed at the same rate as produced
  - Get little energy from the organic acids, so
  - Grow slowly compared to acid formers
  - Susceptible to pH and temperature changes
  - CO_2 and dissolved NH_3 contribute to the formation of alkalinity
  - Do the work of stabilization

Process Control Objective

- Control food supply, temperature, pH, and digested sludge feed rate to maintain a proper balance between the acid-forming and the methane-forming bacteria.



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DIGESTER MIXING

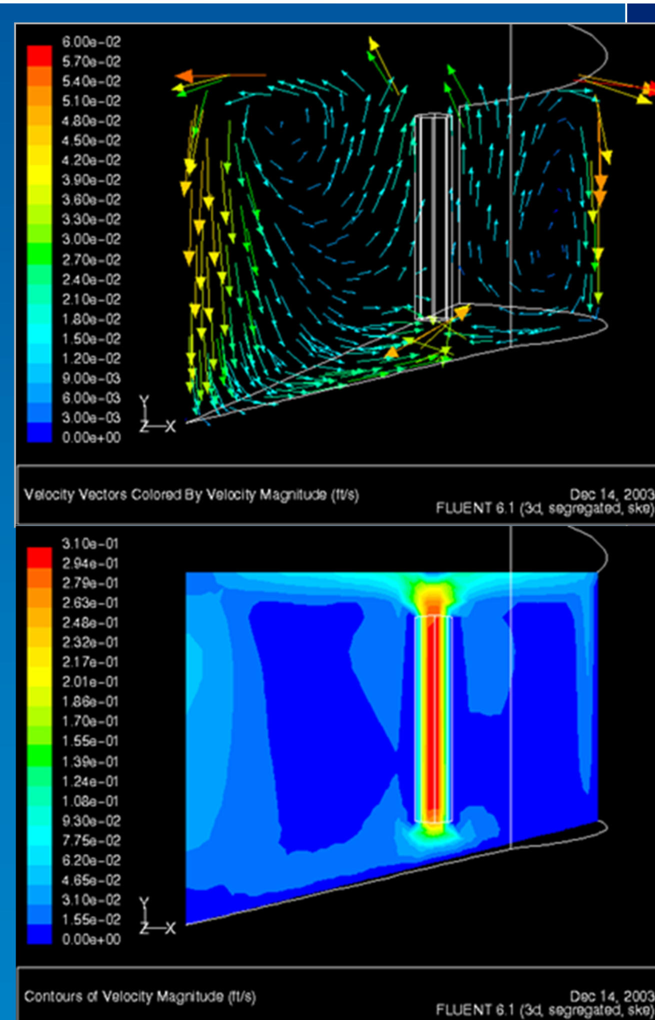
Digester Mixing

Learning Objectives:

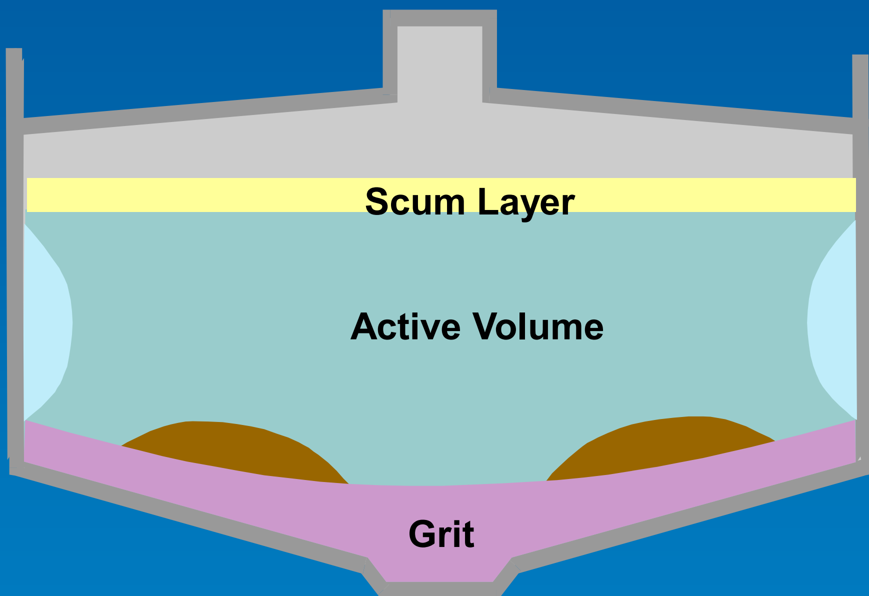
1. Understand the importance of digester mixing
2. Explain difference in THP sludge conditions that allows for mixing at higher solids concentration
3. Know the impacts of inadequate mixing

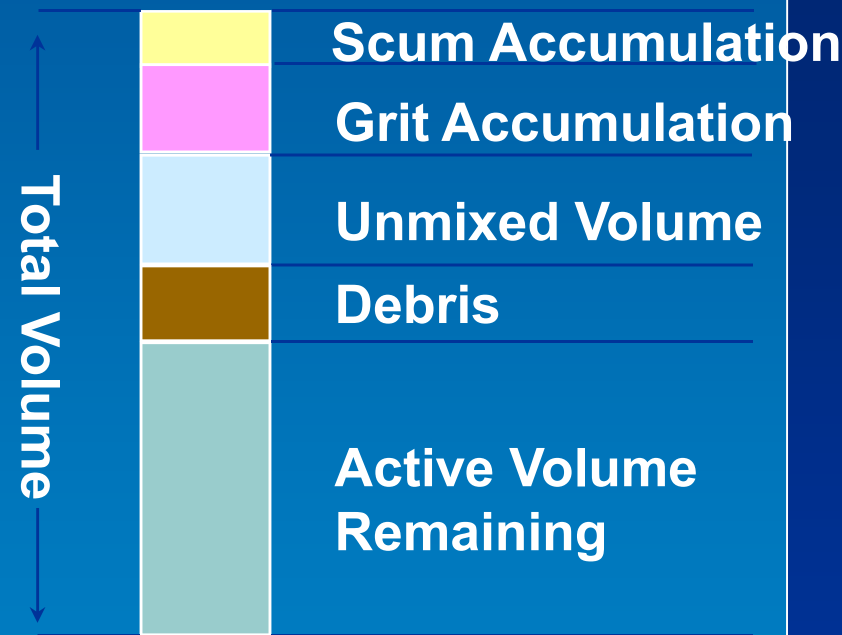
Effective Digester Mixing

- Assure effective use of entire digester
- Create uniform digester environment
- Promote contact between raw sludge and active biomass
- Evenly distribute metabolic waste products
- Reduce grit settling
- Reduce temperature stratification



Poor Internal Conditions Reduce Active Volume





Poor mixing can lead to reduced active volume, digester overload, gas entrainment and rapid rise, and ultimately digester failure

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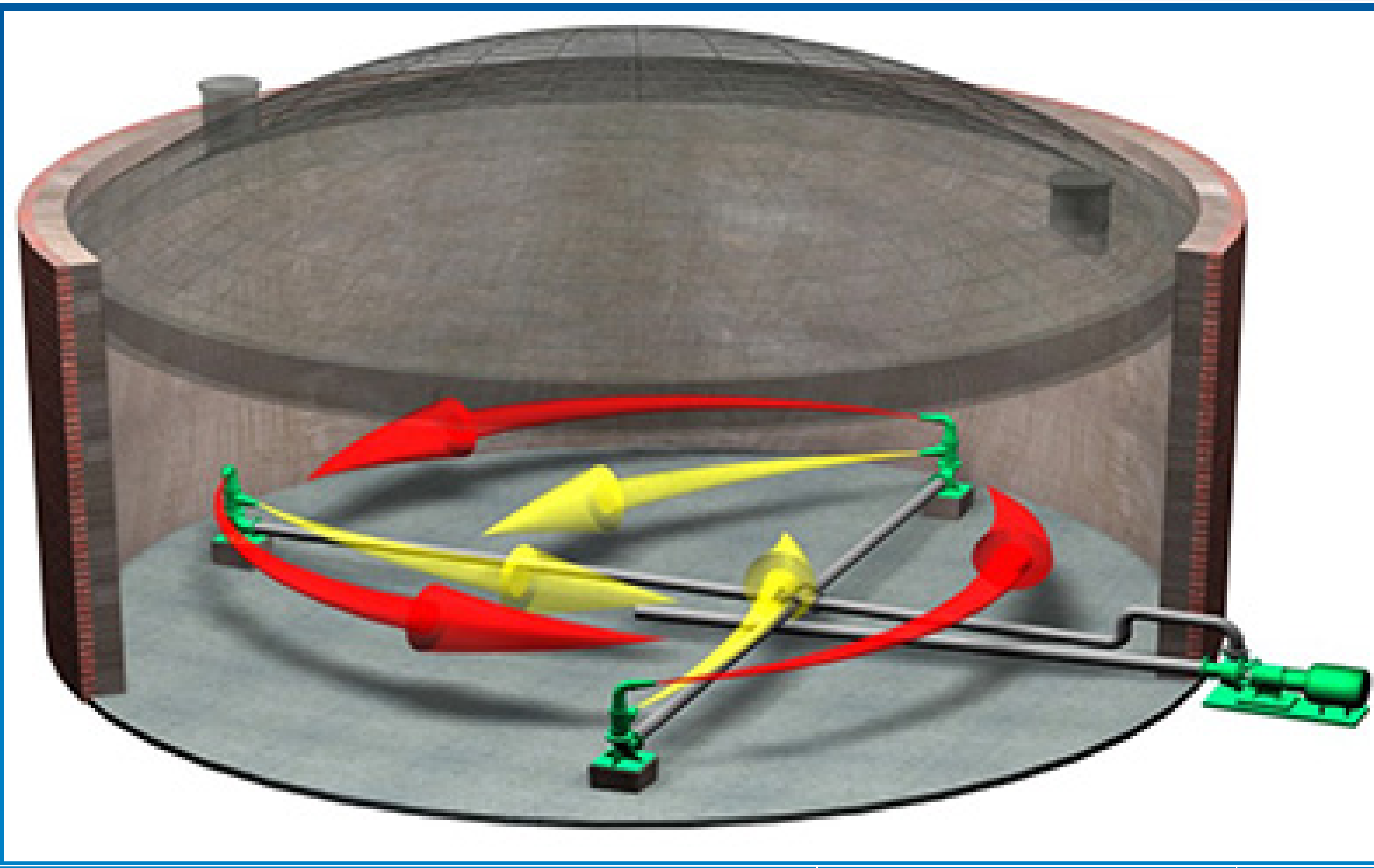
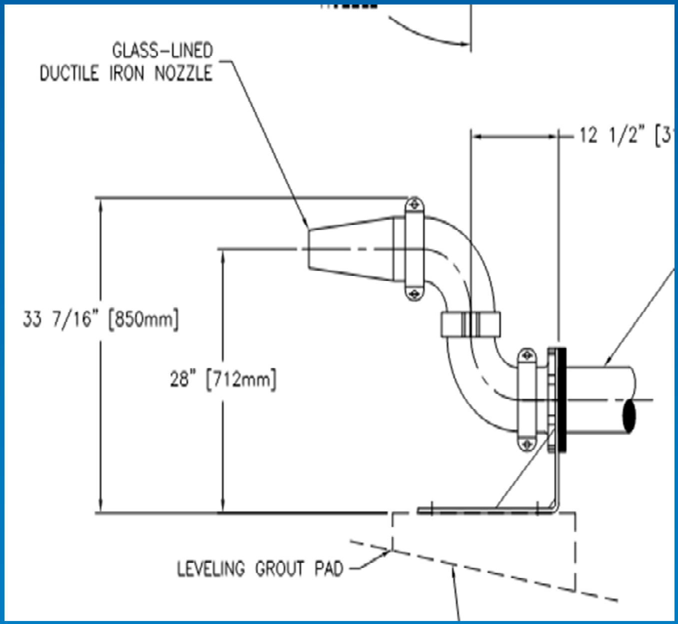
Mixing Pattern

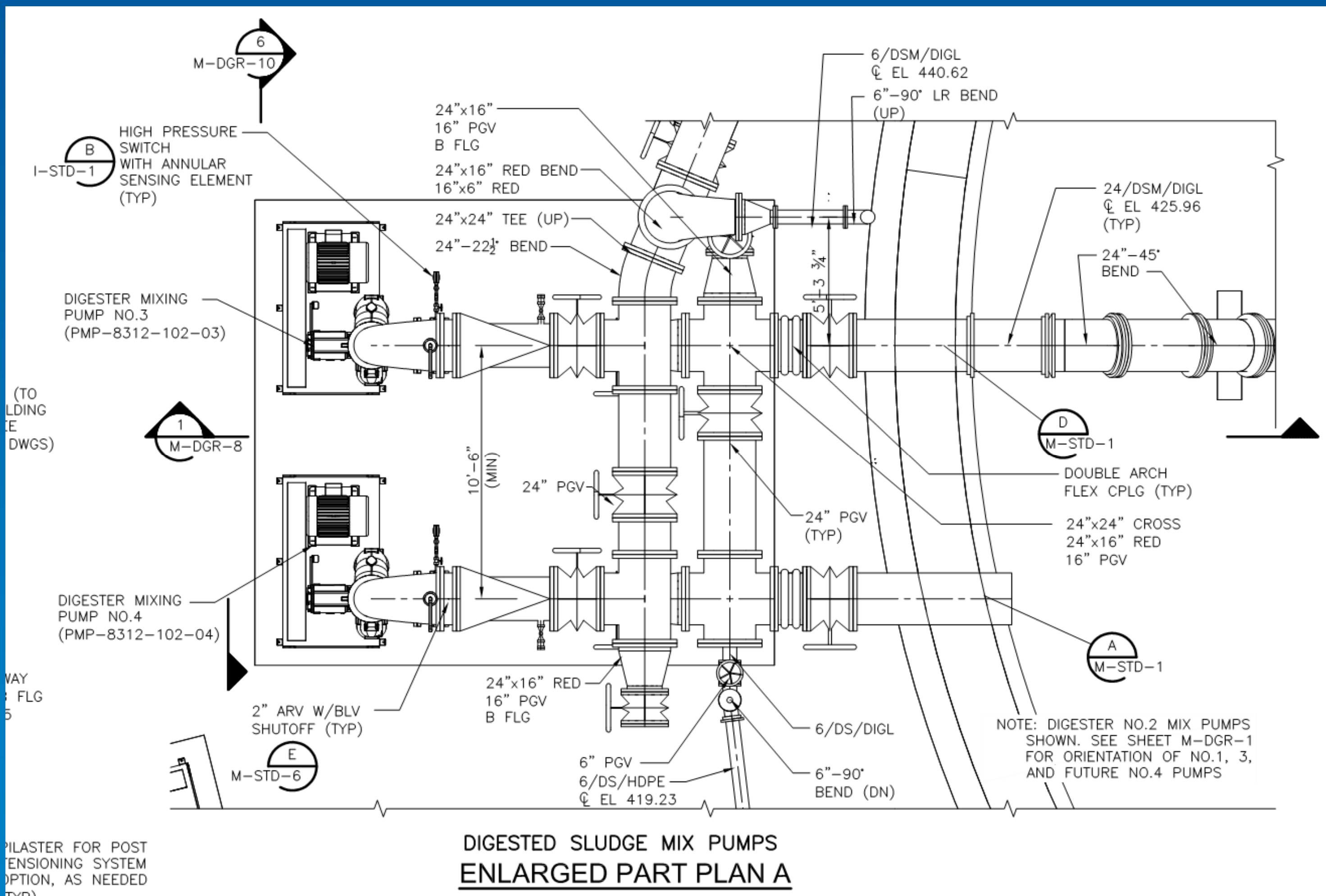


Rotamix System



Floor Mounted Mix Nozzles (RotaMix®)

Sludge Mix Pumps



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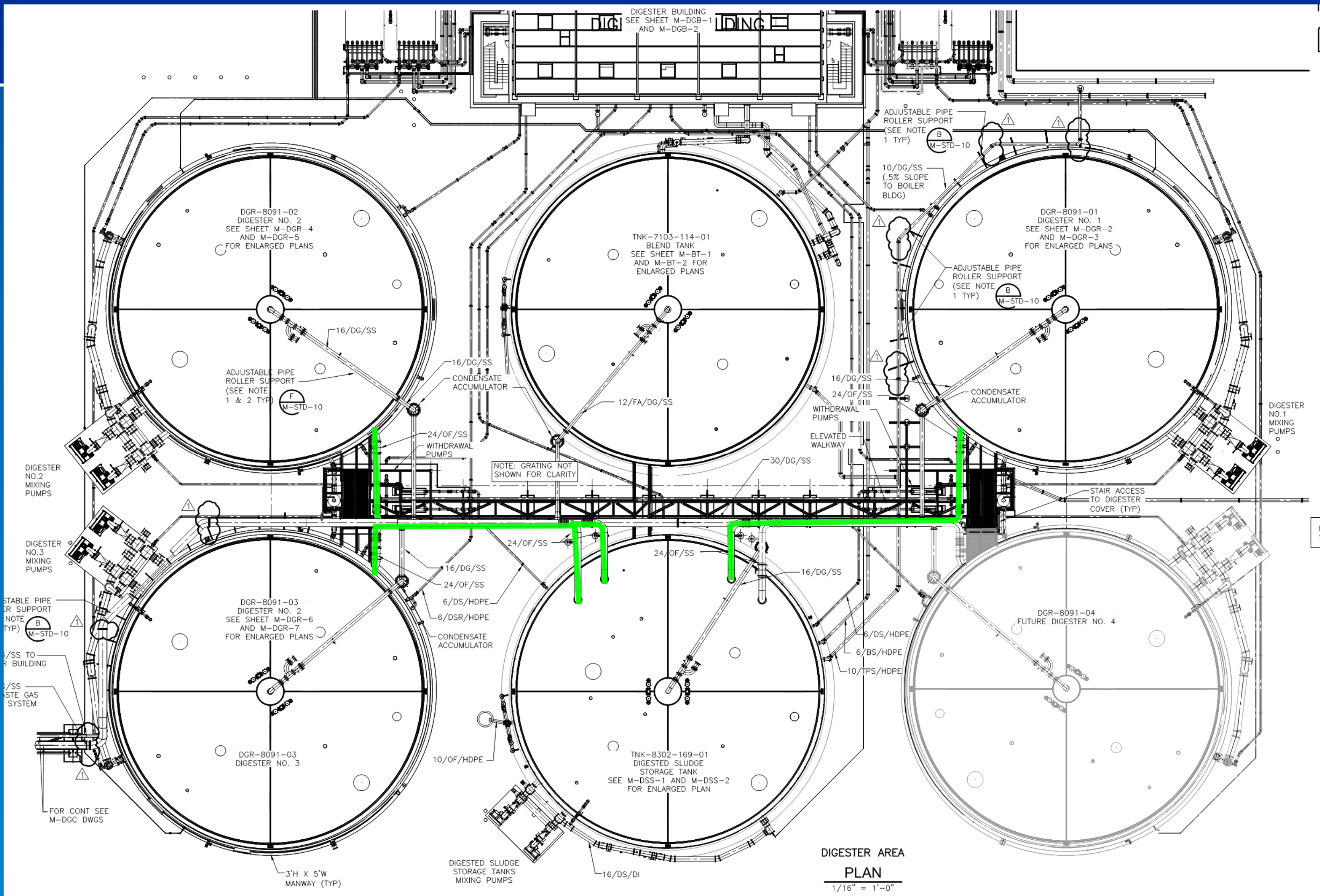
Overflow and Emergency Overflow – Purpose/Objective

- Maximize digester useable volume
- Accommodate rapid rise
- Contain sludge
- Protect digester cover

Rapid Rise Contingencies



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Emergency Overflow – Double U-Tube Assembly

Emergency Overflow - Double U-Tube Assembly

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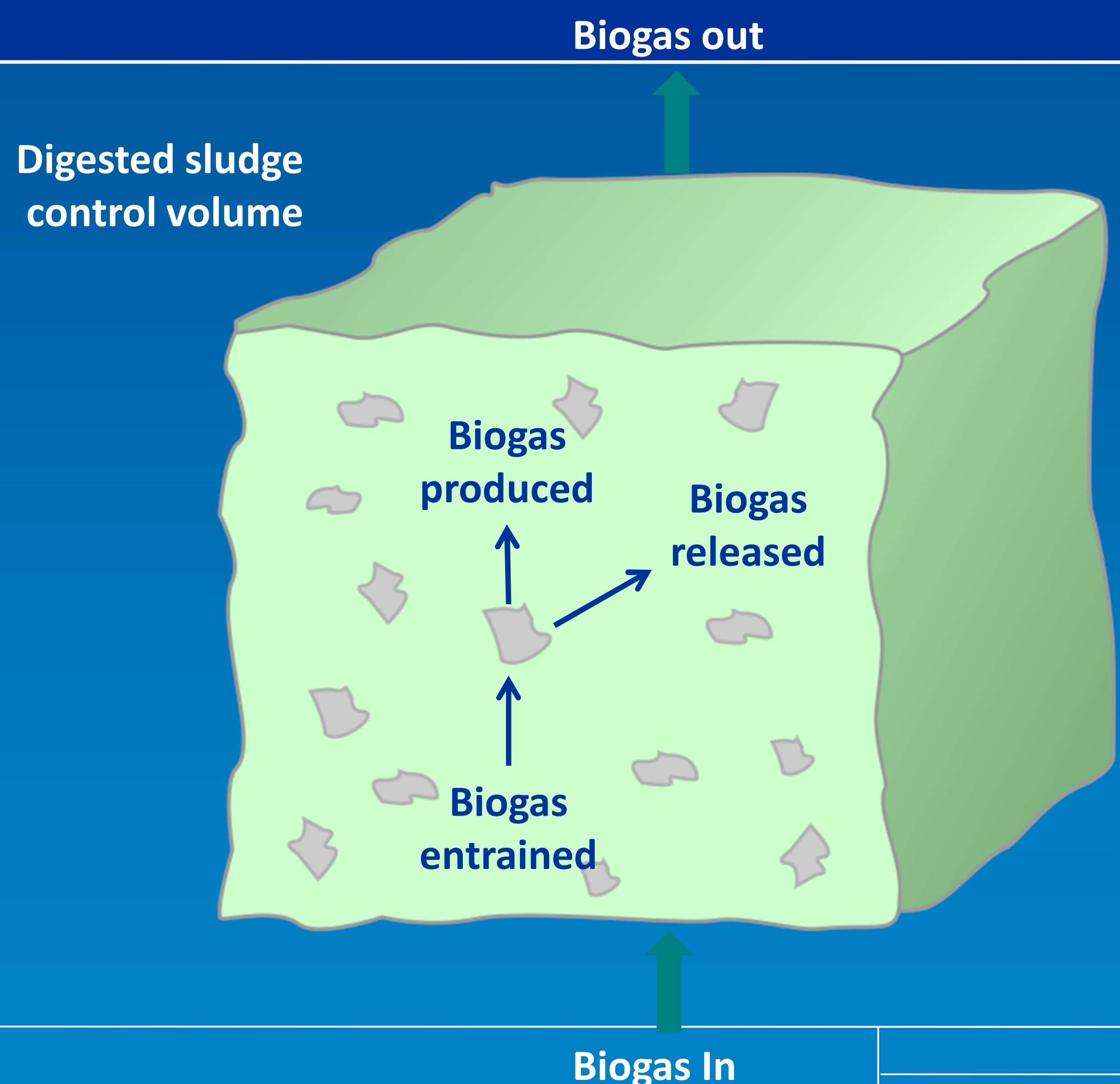
Digested Sludge Density Fundamentals



Sludge density is inversely proportional to the amount of entrained biogas

Avoiding Rapid Rise and Emergency Overflows

- Avoid sudden loss of mixing
- Avoid sudden start of mixing
- Avoid sudden drop in gas pressure
- Avoid sudden increase in sludge feed and consequent gas production
- Avoid too high of solids concentration (higher concentrations are possible with THP)

DIGESTER OPERATION

Digester Operation

Learning Objectives:

1. Understand key aspects of digester operation
2. Explain methods to maintain stable digestion operation
3. Know warning signs of an upset digester

Anaerobic Digestion Challenges

- Grit deposition
- Struvite, vivianite deposition
- Surface accumulation
- Loading rate
- Foaming
- Rapid rise
- Start up
- Digester upset

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Digestion Performance Measurements

- Sludge solids (%TS, %VS)
- Loading rates
  - Hydraulic retention time
  - Volatile solids loading rate
  - Specific energy loading rate
- Biogas
  - Specific gas production
  - Composition: Methane, Carbon dioxide

Digestion Performance Measurements

- Acid/Alkalinity Ratio
  - Volatile Fatty Acids (VFAs)
  - Alkalinity as $CaCO_3$
- Ammonia as N
- pH
- Foaming
- Dewatering
  - Capture, %Solids, Polymer consumption
  - Sidestream characteristics

Temperature Control

- Ideal digestion temperature of 95°F (range: 93°F to 100°F), supports mesophilic microorganisms.
- Digestion can proceed at lower temperatures (85°F to 90°F) with fairly good effectiveness
  - Requires additional digestion time to allow for the slower breakdown of organics.
- Methane forming bacteria are adversely affected by rapid temperature changes of 2°F
  - Limit and control to 1°F per day

pH; What is it and Why does it Matter?

- Measurement of hydrogen ion concentration of a solution indicating the relative degree of acid or base.
  - Digestion Range: 6.6 to 7.2;
  - Preferred Range: 6.8 to 7.0
  - Above 8.0, un-ionized ammonia is toxic to methane formers.
  - Below 6.0, un-ionized volatile acids are toxic to methane formers
  - Below 4.5, digestion ceases.
- Un-ionized molecules pass through the methane formers cell wall easily causing toxicity.
  - How do you respond: change the pH which changes the un-ionized concentration preventing toxicity
    - (i.e., adding bicarbonate alkalinity)

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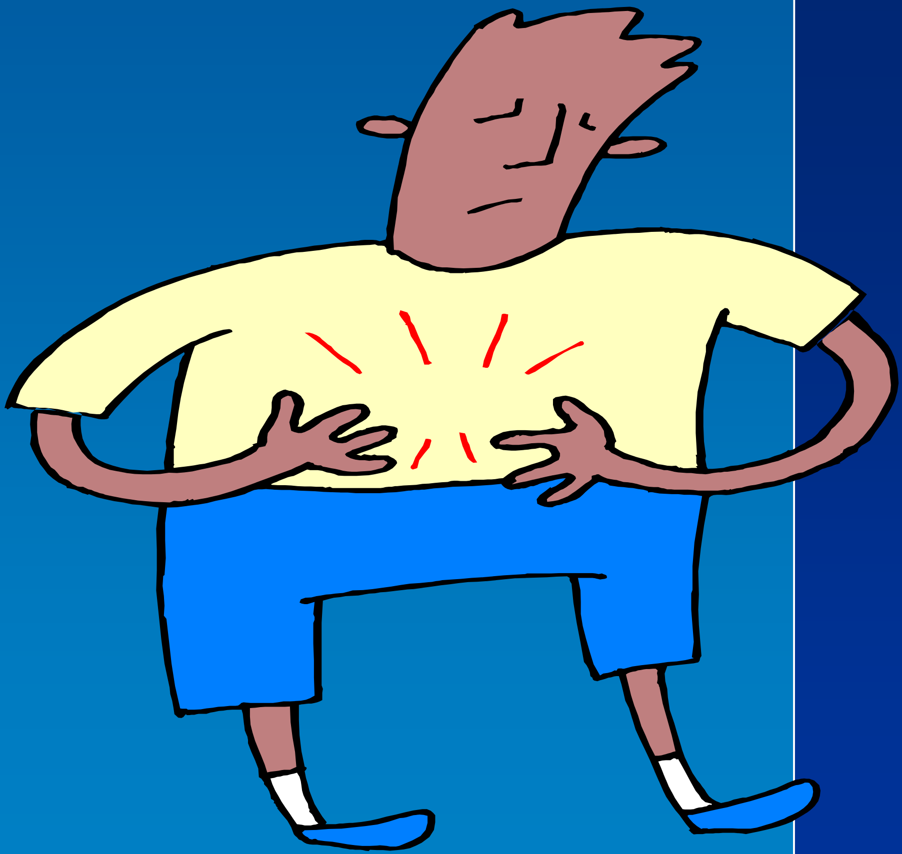
Digester Upset

- Failure of the digestion process (souring) may result from a number of causes, including:
  - Overloading the Digester
  - Fluctuations in Digester Temperature
  - Toxic Wastes
  - Poor or Over Mixing
  - Air Leakage (detrimental to methane formers)



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Digester Upset

- Low pH, low alkalinity, and high volatile acids are the result, rather than the cause, of the problem.
- Address the cause(s)
- Add alkalinity
- Anti foam addition

Volatile Acids (VA)

- Volatile acid production is largely dependent on the volume of sludge fed to the digester.
  - It should be held relatively constant.
- In healthy digesters, acids will be used by the methane formers at the rate they're produced.
  - Severe changes in conc. indicates that acid-producing organisms are multiplying at a rate faster than the methane producing organisms.
  - Staff must monitor the relative change in the proportionality of the VA/Alk ratio.

Alkalinity (Alk)

- Sufficient alkalinity must be present to “buffer” the volatile acids formed during digestion.
- Alkaline buffers come from two sources:
  - Present and concentrated in the feed sludge.
    - Hard water, alkaline industrial wastes
  - Produced by the methane formers
    - Bicarbonates, carbonate and ammonia
  - Typically 2,000 to 5,000 mg/l expressed as bicarbonate alkalinity (mg/L $CaCO_3$)
- Alkalinity (fed and produced) must be in equilibrium with acid production to prevent upset.

VA/Alk

- Indicates the progress of digestion, its stability, and is used for process control.
- The results of the volatile acids and alkalinity tests are expressed as a ratio. Example:
  - Volatile acids = 300 mg/l
  - Alkalinity = 2,000 mg/l
  - VA/Alk = 300 / 2,000 = 0.15
- The range of VA/Alk ratio is 0.1 to 0.35, 0.1 to 0.25 is ideal.
- VA/Alk ratio of 0.5 indicates a sour digester
- Parameters must be sampled and tested daily at start-up, no less than a minimum of three times per week during stable operation.
  - If unstable conditions are beginning to occur, or are present (trending above 0.25), test daily.

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What is the proper ratio of volatile acids to alkalinity?

1. Ideally, the VA/ALK ratio should range between 0.1 and 0.25, once it goes beyond 0.25 the operator is cautioned to back off on the feed and monitor very closely.

2. Within this range, the digester is considered healthy with good digestion taking place.

3. When the ratio begins to change, it is an indication of a potential digester upset. Trending towards 0.35 is entering the danger zone. A ratio of 0.5 indicates a sour digester.

Volatile Acids/Alkalinity Ratio

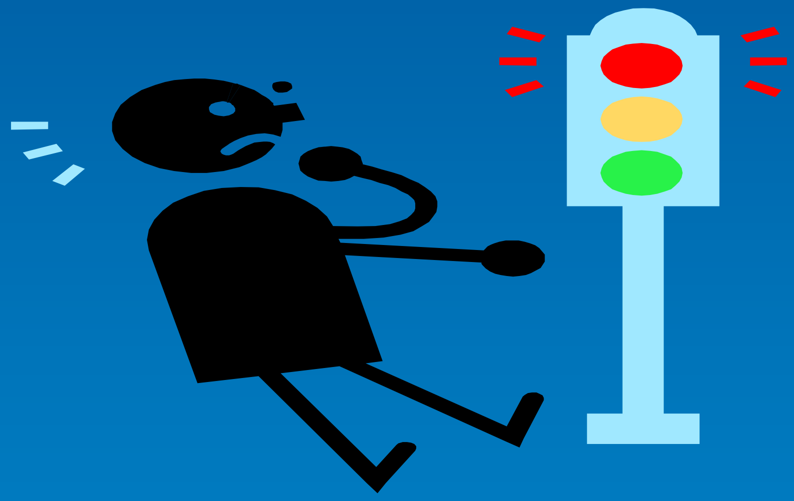
0.1 – 0.25 **green light**

0.25 + **yellow caution light**

0.35 + **red warning danger light**

0.55 **FLASHING RED LIGHT!**

HEADING TOWARDS A SOUR DIGESTER !!!



Control Parameters

Parameter	Approximate Value
Alkalinity	10,000 to 15,000 mg/l
Volatile Fatty Acids	500 to 5000 mg/l
VA/Alkalinity Ratio	0.1 to 0.35
pH	7.5 to 8.3
Carbon Dioxide	35 to 45% by volume
Methane	55 to 65% by volume
Temperature	100°F (97°F to 103°F)

Questions???