Current Trends in Digester Mixing Technologies

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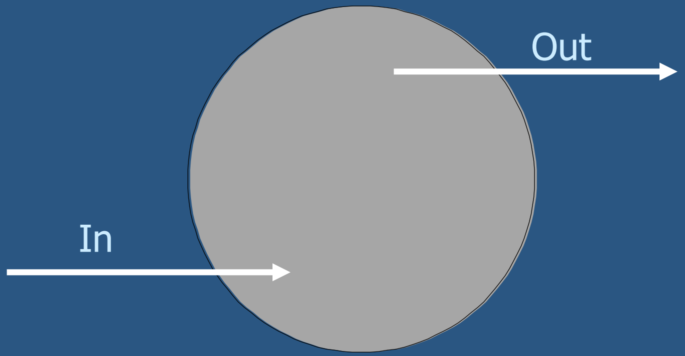
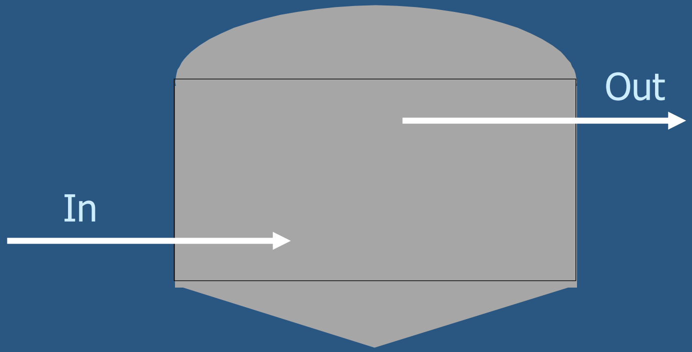
Outline

- Importance of Digester Mixing
- Digester Mixing Technologies
- Current Trends
- Case Studies
- Design Considerations
- Q & A

Digester without Mixing

- Short Circuiting
- Stratification
- Scum Mat Buildup
- Grit Accumulation





Importance of Good and Reliable Mixing in Digesters

- Provides uniform environment for microbes
- Maintains contact between active biomass and incoming feed sludge
- Enhances biological reaction rates
  - Improves VSS reduction efficiency
- Increases gas production
  - more pronounced at lower HRTs
- Reduces short-circuiting – optimizes HRT
- Reduces process upsets
- Improves operating safety margin
- Minimizes grit accumulation

Mixing Design Parameters

- Digester volume turnover time (DVTT) =(tank volume/pump capacity)

  Does not consider velocity (→ power); or viscosity

- Unit power (UP)
  = (pump horsepower/tank volume/1000)

  Inconsistent HP calculation; ignores viscosity

- RMS velocity gradient (VGT or G)
  = (pump power/tank volume/sludge viscosity)

  Better but good viscosity info hard to come by

Mixing Design Parameters

- Best approach is probably CFD modeling
- This is expensive and not definitive

Complications:

- Inlet feed and outlet hydraulics likely play a big role
- There is natural mixing that occurs due to gas production and by inlet hydraulics
- Nearly impossible to get real world side-by-side realistic comparisons

Digester Mixing Technologies

- Gas Mixing

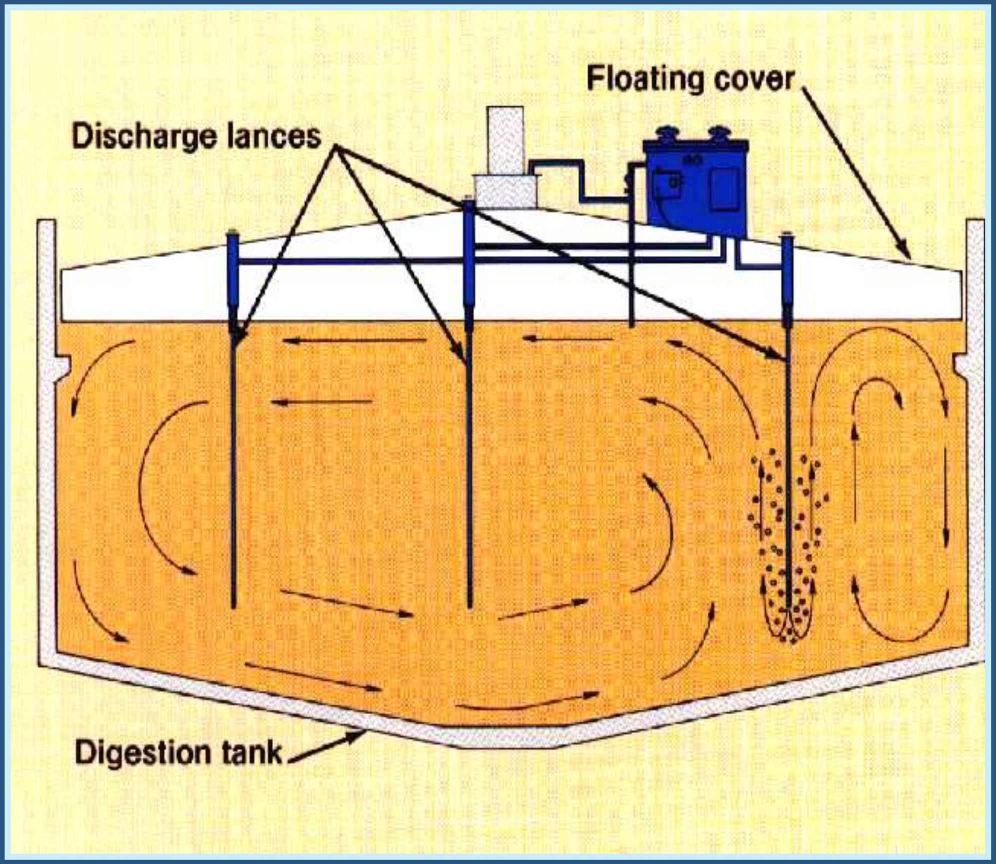
- Mechanical Mixing

- Pump Mixing

Gas Mixing

- Compressed Digester Gas Recirculated through the Digester
- "Unconfined" Mixing
  - Sequential discharge to individual lances
- "Confined" Mixing
  - Eductor tube acts as gas lift pump to recirculate digester contents
  - Bubble gun generates large bubbles that act as a gas lift pump

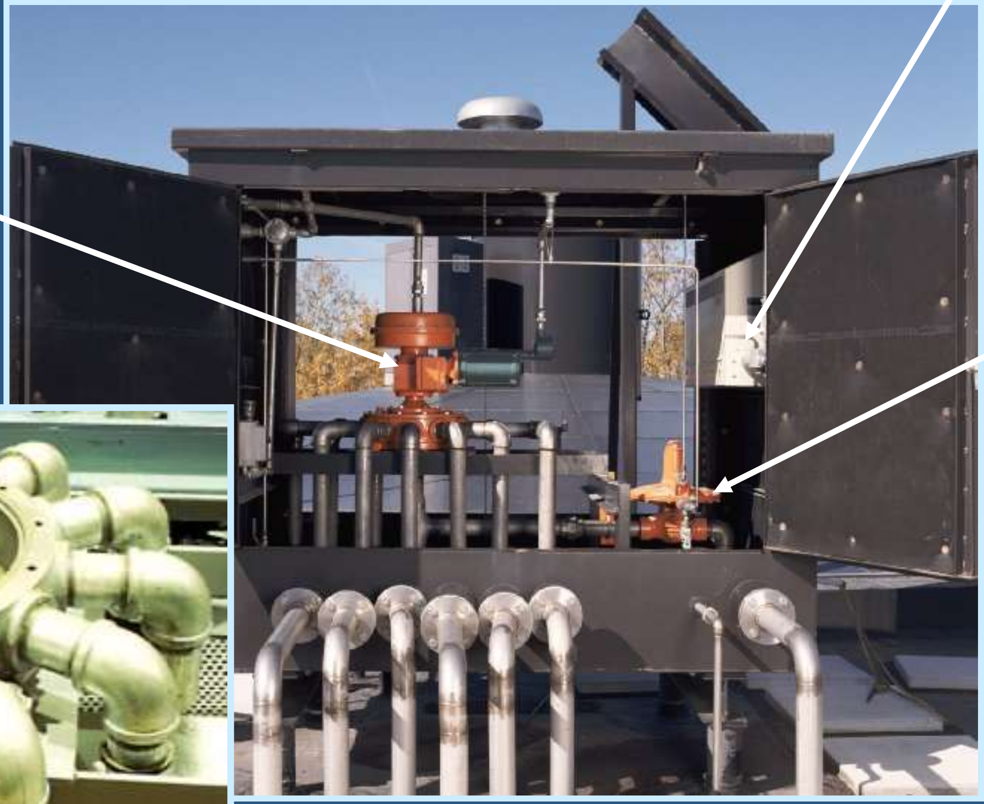
Gas Mixing – Unconfined System



- Compressed digester gas recirculated through gas lances
- Sequential discharge to individual lances using rotary valve
- Gas/liquid mixing plume increases in diameter as it rises to the surface

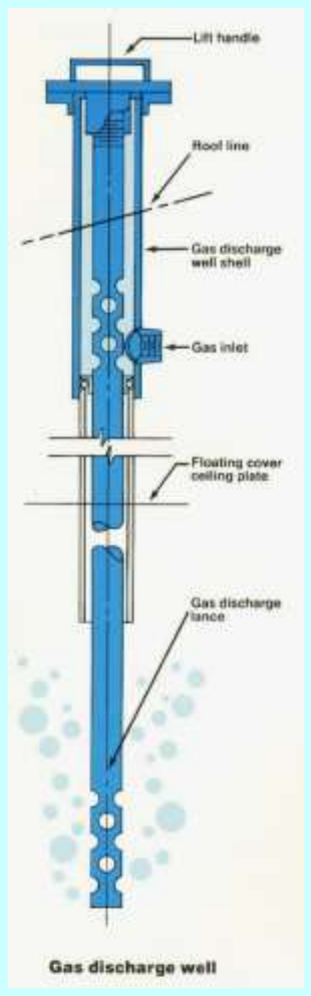
Courtesy of US Filter

Gas Mixing – Unconfined System



Courtesy of
US Filter

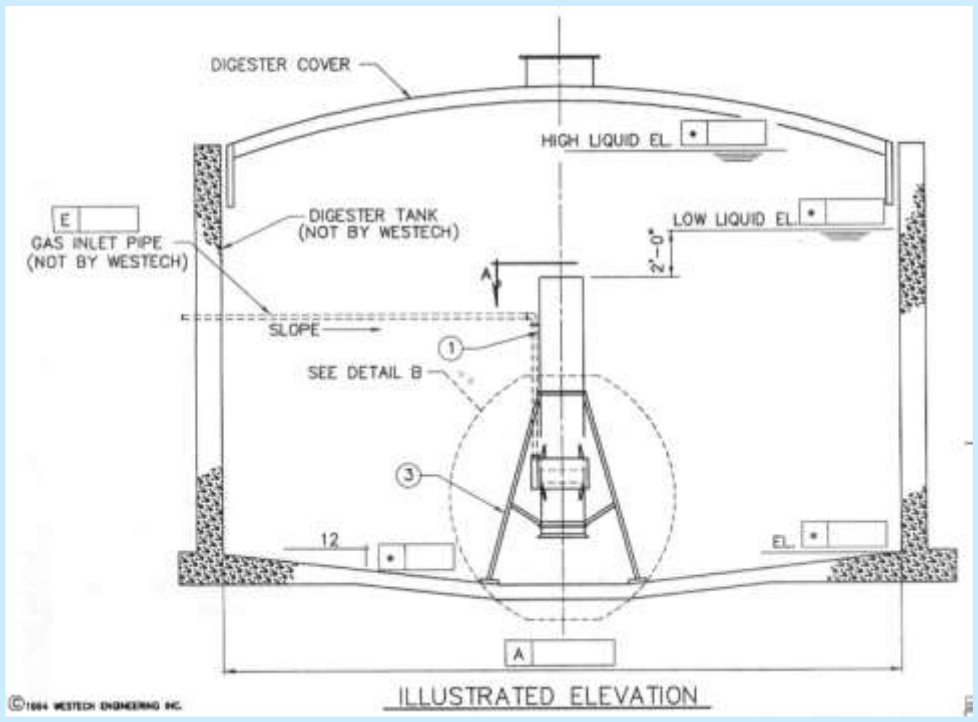
Gas Mixing – Unconfined System



- Gas discharge lance
- Removable while digester is in service

Courtesy of US Filter

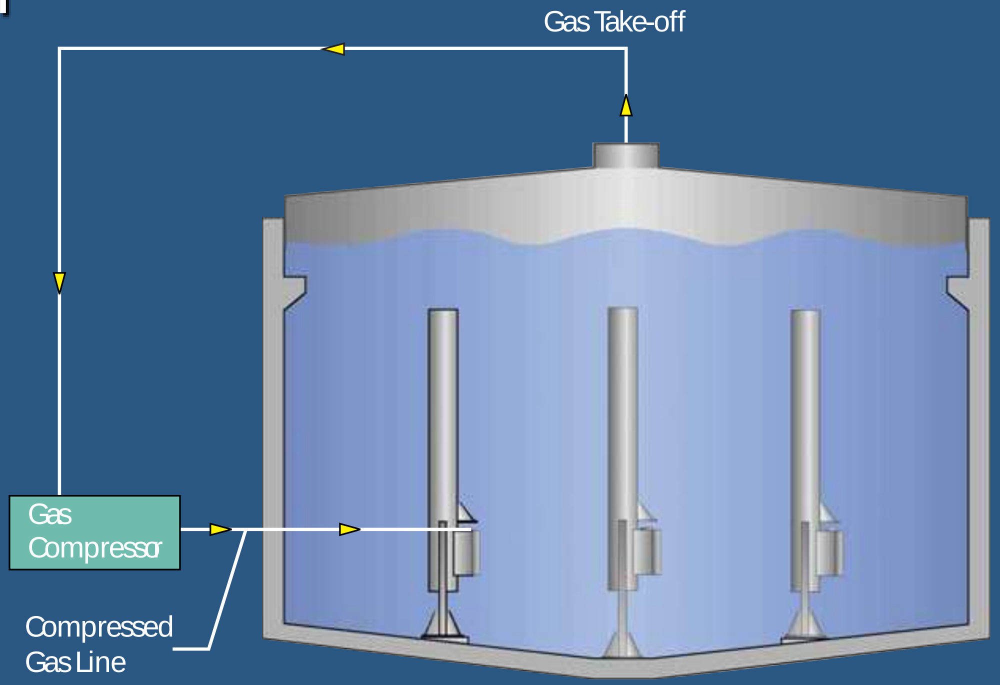
Gas Mixing – Confined System



- Eductor Tubes Release compressed gas inside digester
- Eductor tube acts as a gas lift pump
- Creates upward mixing pattern

Gas Mixing – Confined System

- Bubble Gun Generation every 3 to 4 seconds per Mixer
- Turbulence created at surface prevents scum buildup



Courtesy of Infilco

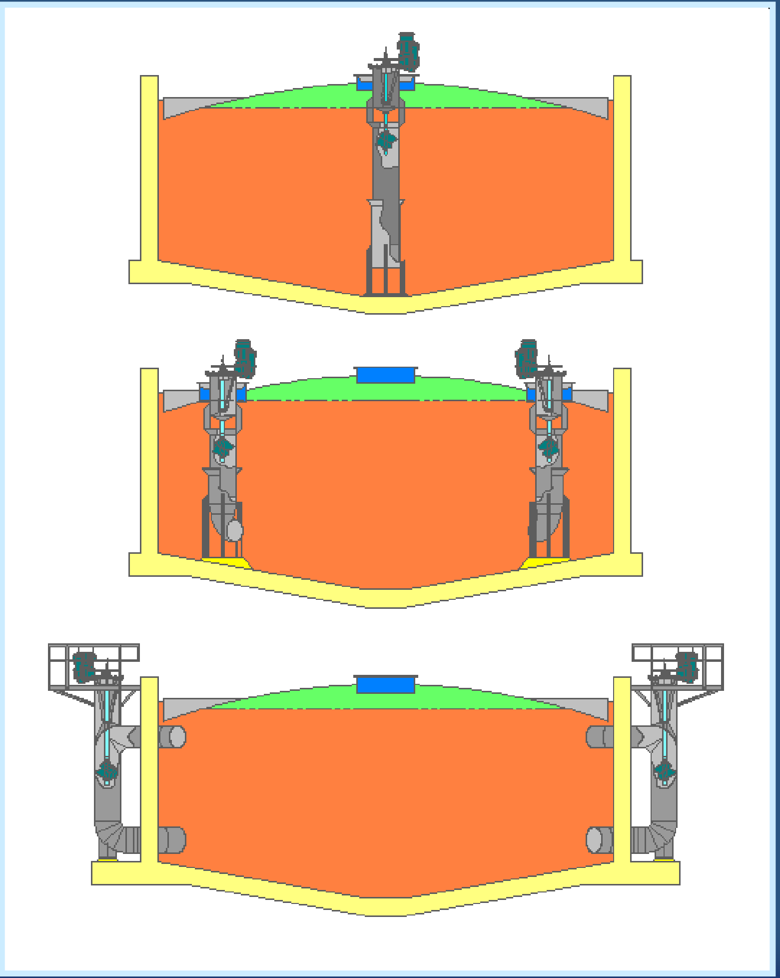
Mechanical Mixing

- Non-clog, Axial Flow Propellers
- Often Located Inside Vertical Draft Tubes (a.k.a. Draft Tube Mixing)
- Provides Tangential Mixing Pattern inside Digester
- Reversible Mixing Pattern
- Roof Mounted Equipment
- Optional Heat Exchanger Jacket

Courtesy of US Filter

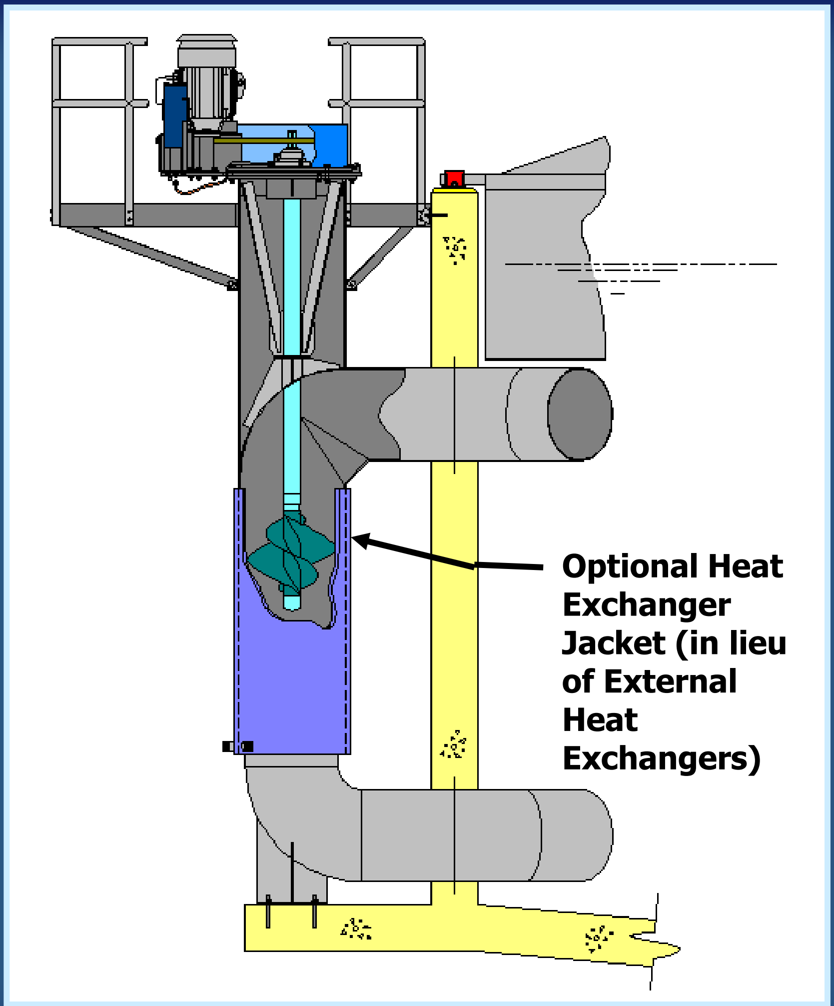
Mechanical Mixing – Draft Tubes

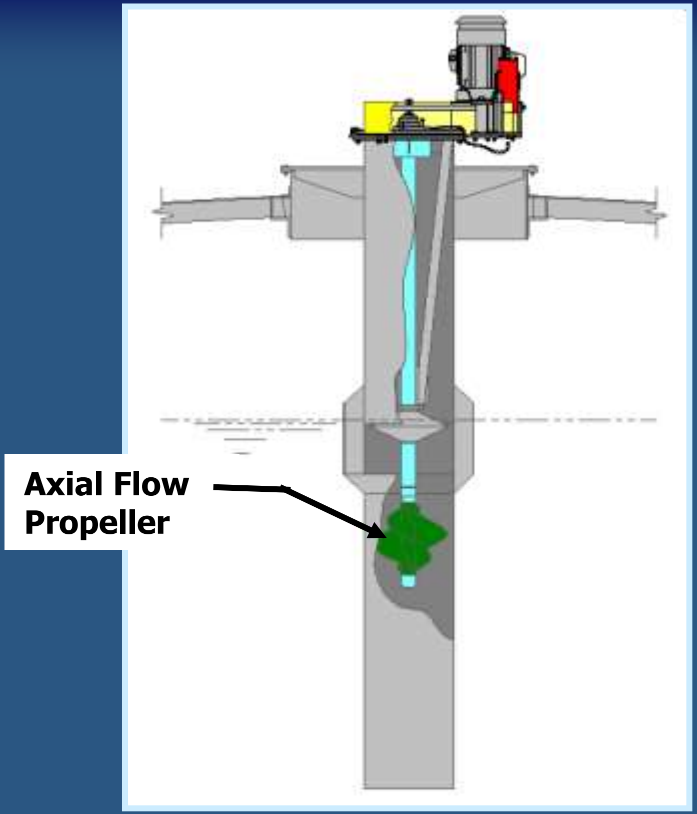
- Internal
  - Roof Mounted
- External
  - Platform Mounted



Courtesy of OTI

Mechanical Mixing – Draft Tubes





Courtesy of OTI

Mechanical Mixing Installations

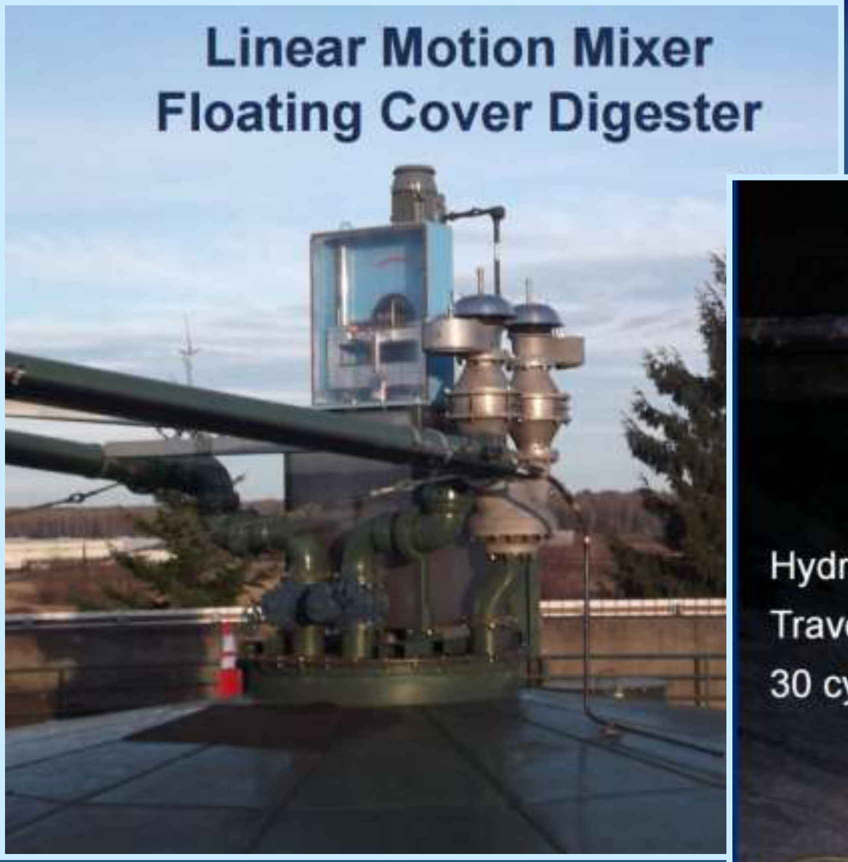
Internally Mounted

Externally Mounted

Courtesy of Westech

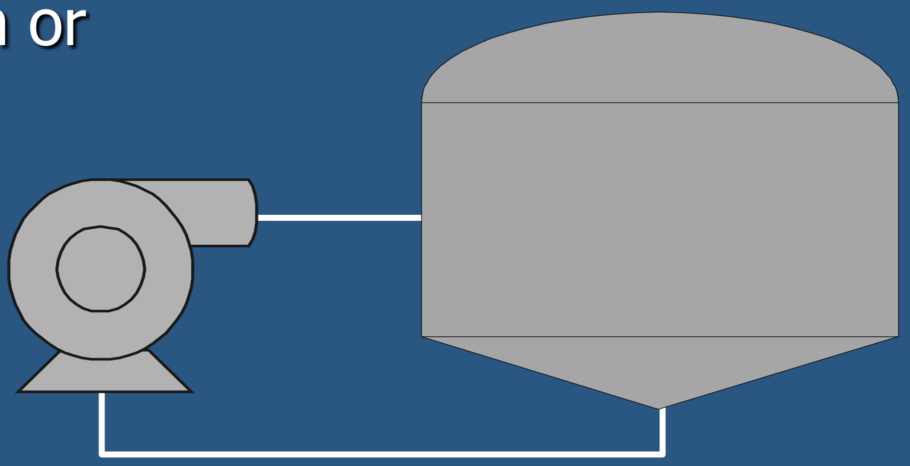
Vertical Linear Mixers (VLM)

Gresham LMM Installation



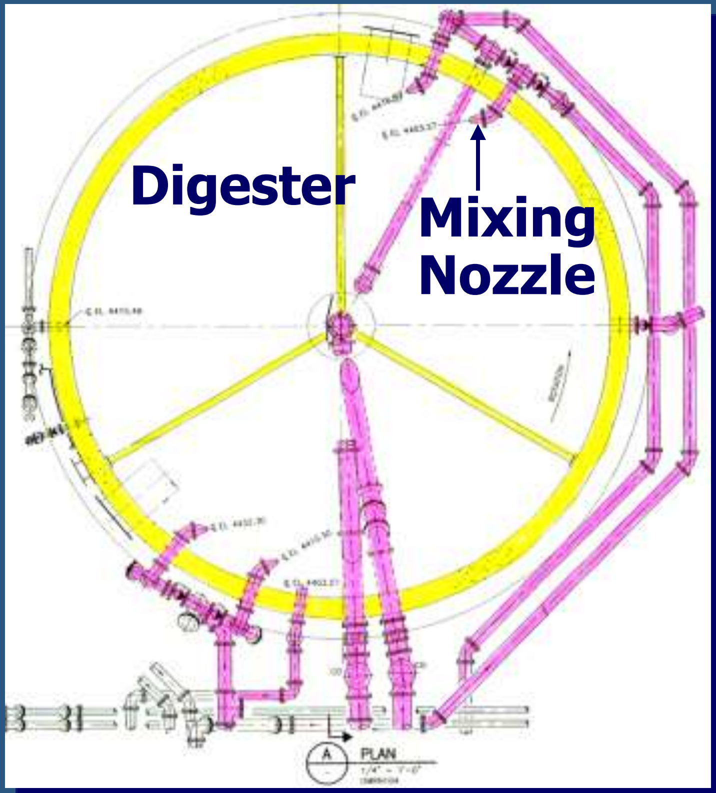
Pump Mixing

- Axial Flow, Screw Centrifugal, or Chopper Type Pumps
- Draw Sludge from Bottom or Top of Digester
- High-velocity Discharge through Nozzles
  - Perimeter Nozzles
  - Internal Nozzles
- Continuous or Intermittent Operation

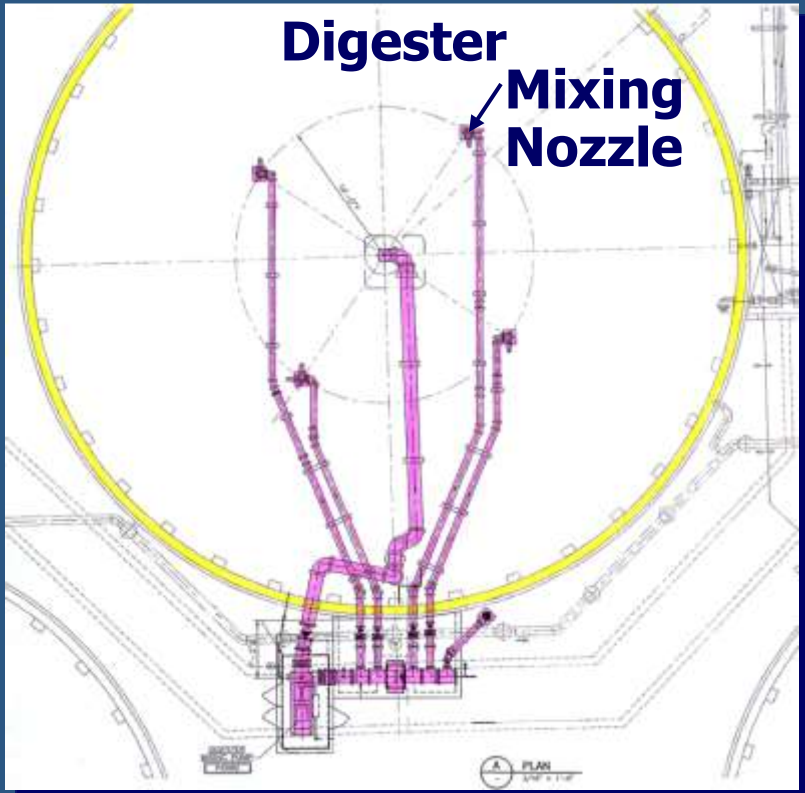


Courtesy of Vaughan/Rotamix

Pump Mixing Nozzle Design Alternatives



Perimeter-Mounted Nozzles



Internal Floor-Mounted Nozzles

Pump Mixing – Perimeter Nozzles

Pump Mixing – Internal Nozzles

- Chopper Pump with Internal Mixing Nozzles

Courtesy of Vaughan/Rotamix

Pump Mixing – Internal Nozzles

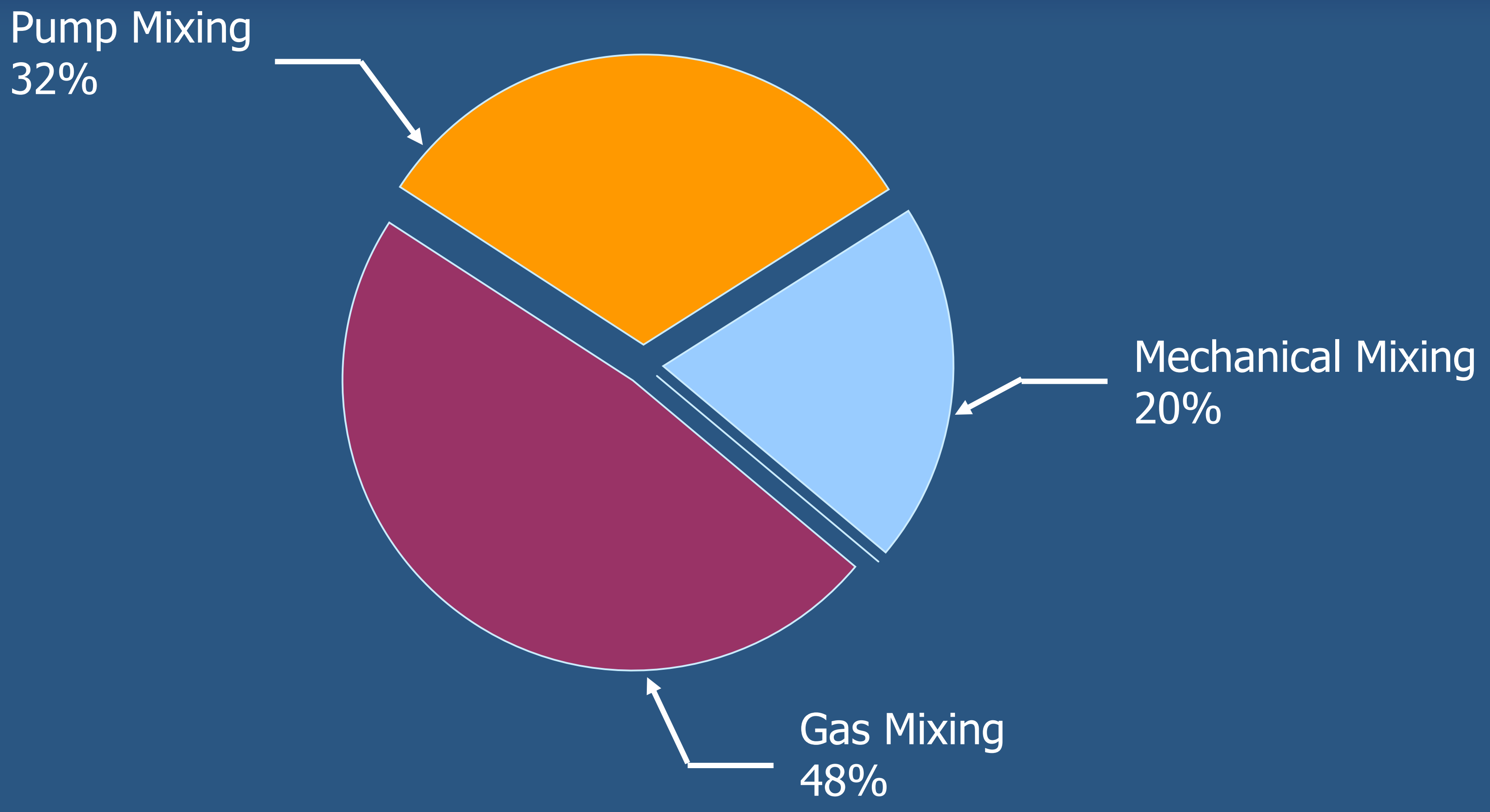
Courtesy of Vaughan/Rotamix

Current Trends

1983 ASCE Nationwide Survey of Anaerobic Digesters

- 90 WWTPs from 39 states responded
- Active mixing was found to be the most significant factor in reducing volatile solids
  - 13 WWTPs reported "Inadequate" Mixing but still reported >50% VSS Reduction

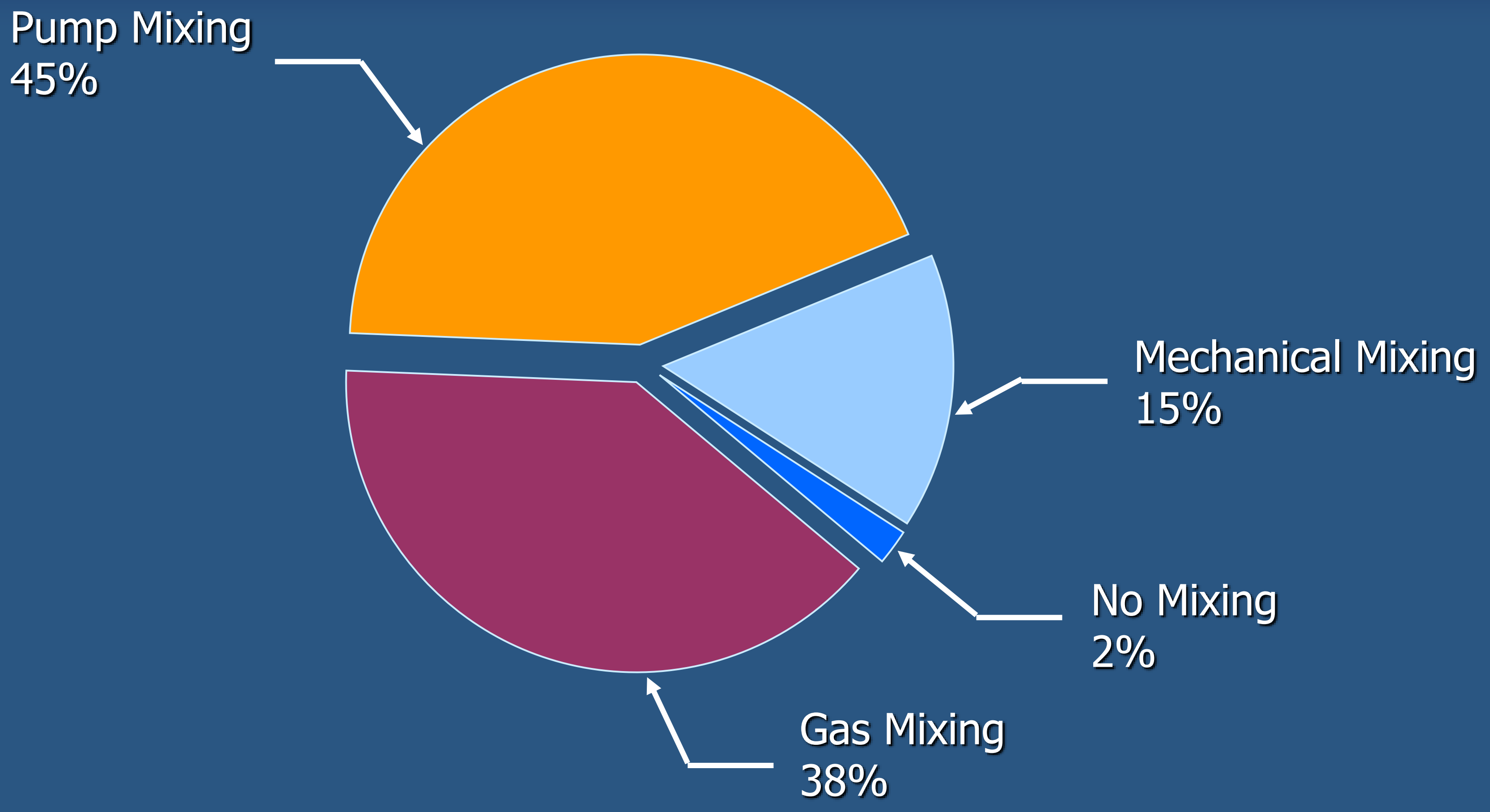
1983 Survey Results



2005/06 Carollo Survey

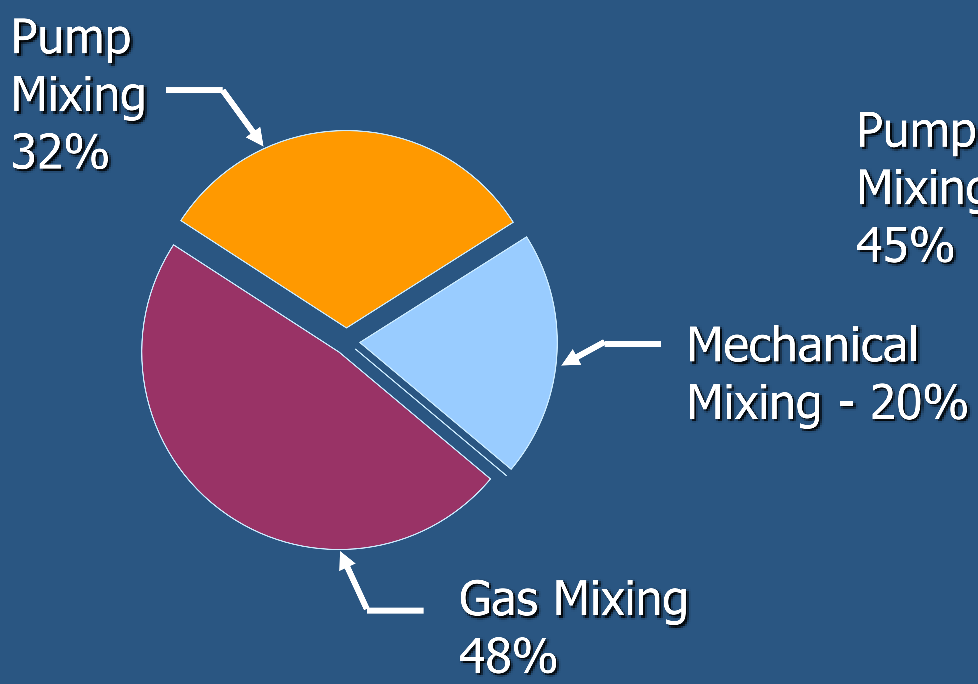
- 55 WWTPs in 6 Western States Responded
- WWTP Capacities Between 3 and 320 mgd
- PS/TWAS was Most Common Feed Sludge
- VSS Reduction Varied Between 44 and 68% (50 to 55% Most Common)
- HRT Varied Between 15 and 45 Days (Median was 20 Days)

2005/06 Survey Results

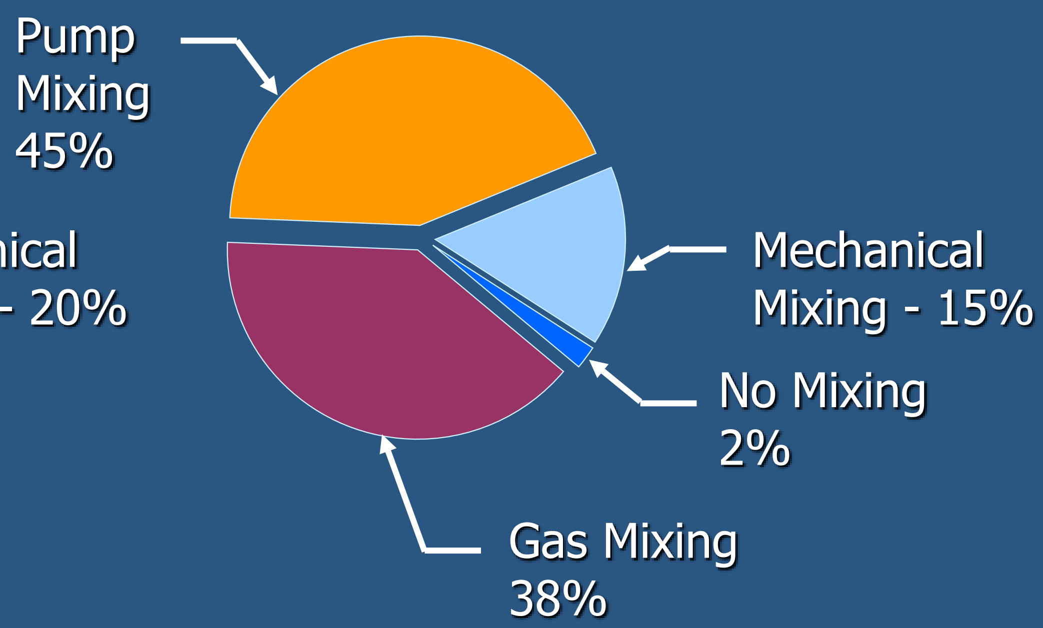


Survey Comparison

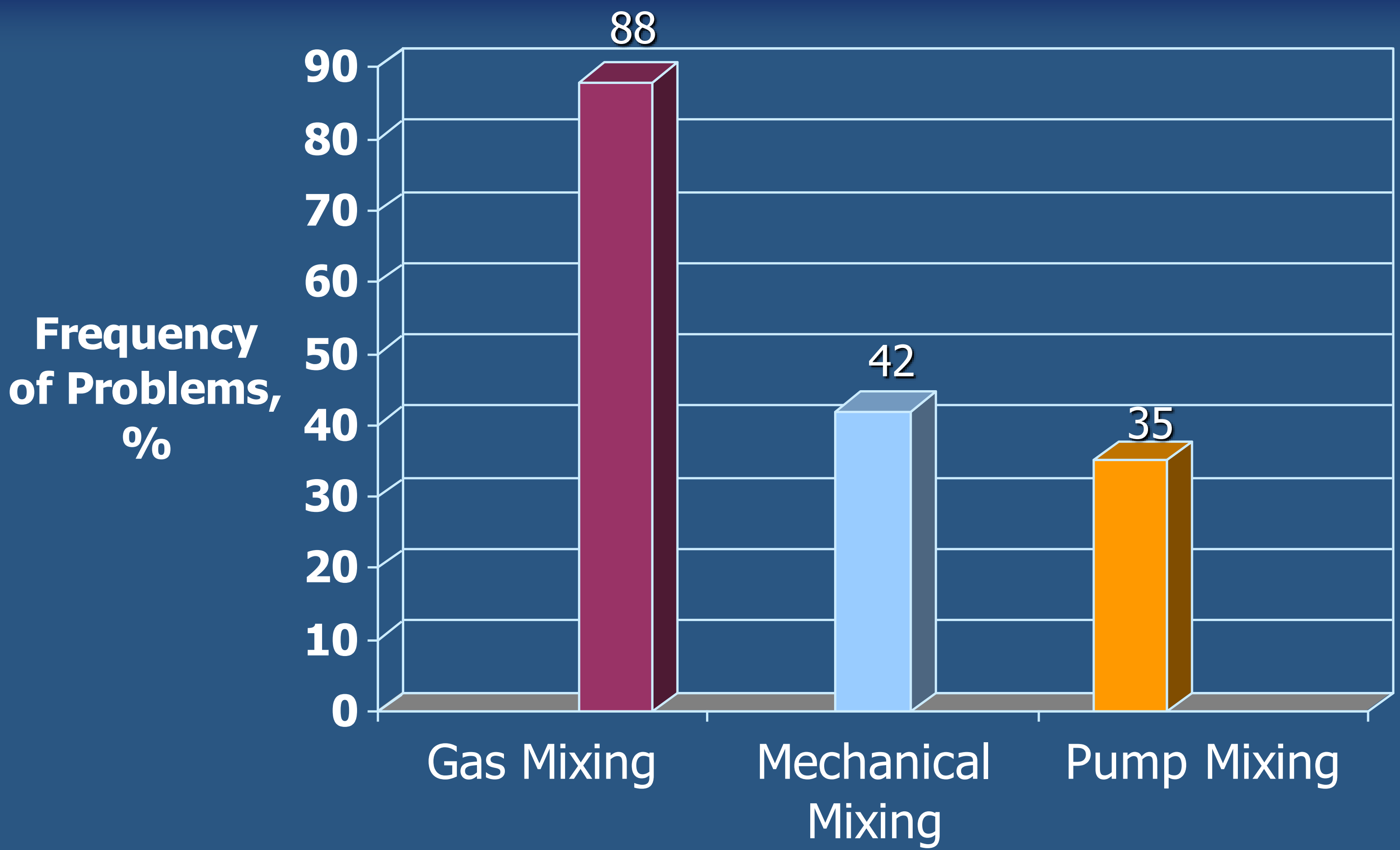
1983 Survey



2005/06 Survey



2005/06 Survey – Frequency of Problems



2005/06 Survey – Reported Problems

- Gas Mixing
  - Compressor failure/extensive maintenance
  - Pipe leaking
  - Pipe plugging
  - Digester foaming
  - Poor mixing





2005/06 Survey – Reported Problems

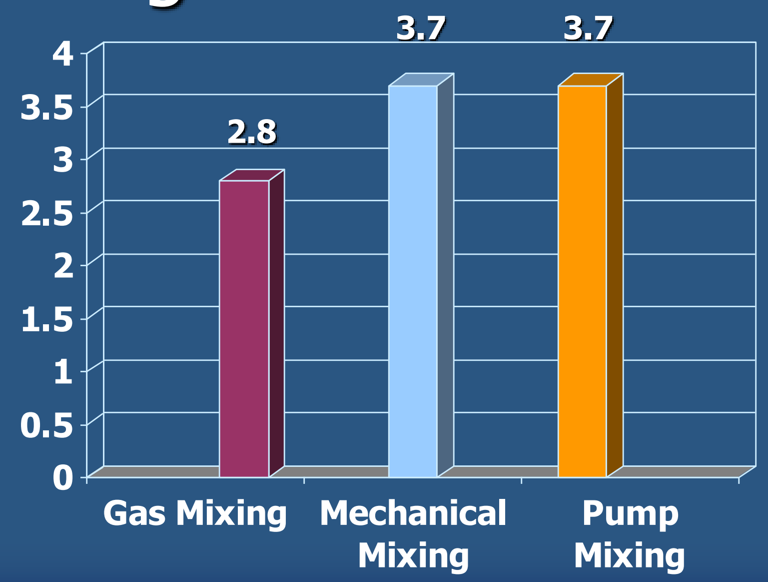
- Mechanical Mixing
  - Impeller ragging
  - Vibration problems

2005/06 Survey – Reported Problems

- Pump Mixing
  - Foaming
  - Pump Clogs

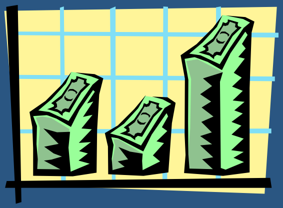
Digester Mixing Rating

- Rating System
  - Score of 1 to 5 (1 = worst, 5 = best)
- Average Ratings



Survey Summary

- Increasing Trend in Use of Pump Mixing
- Pump Mixing is Often the Simplest Retrofit Alternative
  - Lowest cost alternative in most cases
- O&M Concerns are Key Drivers for Selection of Mixing Technology



Case Studies

Case Studies

- Monterey, CA
  - 30 mgd design ADWF
  - 4 86-ft diameter digesters
  - Unconfined gas mixing system using discharge lances

Case Studies – Monterey, CA

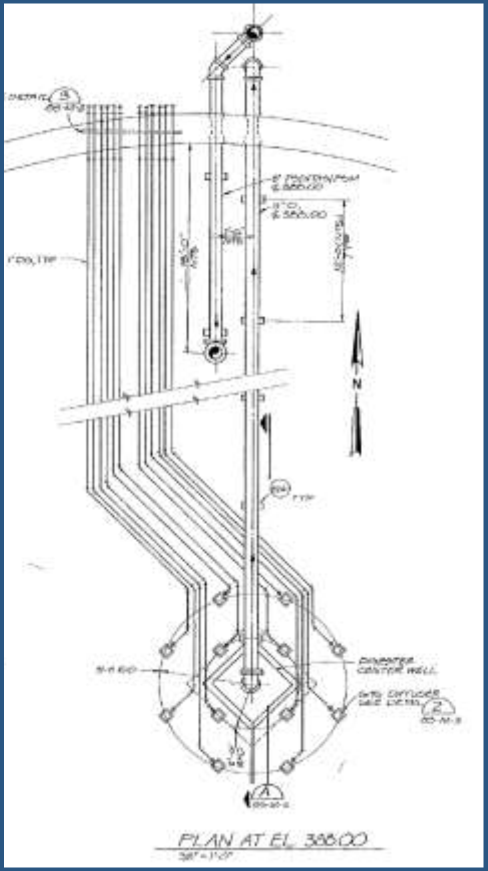
- Concerns with existing system
  - Routine and unexpected leaks in digester gas piping
  - Significant maintenance requirements on digester gas compressors
  - High water requirement on digester gas compressors (50,000 gallons per day)
  - Outdated electrical system
    - Replacement parts were difficult to find
  - Improper mixing resulted in significant solids accumulation at bottom of digesters
    - Required frequent cleaning

Case Studies

- Eugene, OR
  - 49 mgd design ADWF
  - 3 85-ft diameter digesters
  - Unconfined gas mixing system using diffuser rings

Case Studies – Eugene, OR

- Concerns with existing system
  - Incomplete mixing
    - active volume of digesters only 63% of total volume based on tracer study
  - Replacement parts for the compressed digester gas system are difficult to obtain



Case Studies – Economic Comparison

- Installed Cost
  - Similar for the three systems (±10%)
- Maintenance Cost
  - Highest for gas mixing system
    - Based on operator input and results from 2005/06 survey
  - Can vary based on plant-specific factors
- Power cost
  - Lowest for pump mixing system operated intermittently

Case Studies – Non-Economic Comparison

Mixing Technology	Advantages	Disadvantages
Gas Mixing	• No moving equipment submerged	• Explosive gas hazard • Compressor operation and maintenance • Potential for gas leaks • [illegible] • [illegible] efficiency
[illegible]	• [illegible] hazard • Mixer can reverse pump flow • Multiple mixers provide added reliability	• Large wall penetrations • Roof mounted motors are more difficult to maintain • Prone to clogging with rags
External Pump Mixing	• Low explosive hazard • Easier equipment access • Chopper pumps macerate rags and debris • Lower maintenance	• Piping/nozzles inside digester (difficult to access)

Favors mechanical and pump mixing systems

Case Studies – Plant Specific Factors

- Struvite (NH_4MgPO_4) build-up
  - Precipitation can lead to clogged pipes
  - Struvite deposits most often occur at locations of local turbulence (pipe fittings, valves, pumps)

- Energy Costs
  - Peak demand charges can influence equipment's life cycle cost

Case Studies

- Monterey, CA
  - High energy cost shifted economic to favor the use of intermittent pump mixing
  - Rotamix system has been installed in one of four digesters

- Eugene, OR
  - Struvite concerns shifted the analysis to favor the use of external draft tubes
  - 3 digesters were converted

Design Considerations

Pump Mixing Design Considerations

- Provide 1 or 2 Pumps per Digester
- Size Pump based on 8 Turnovers per day (or 1 turnover every 3 hours)
- Pump Venting needed for Intermediate Operation
- Provide 1 to 2 Mixing Nozzles per 100,000 cf of Volume
- Size Nozzle for discharge velocity between 20 to 30 fps
- Size Digester Piping between 5 to 8 fps
- Check Pump hp is within 0.2 to 0.3 hp/1,000 cf

Mechanical Mixing (Draft Tubes) Design Considerations

- Provide minimum of 4 External Mixers on Digesters greater than 70 ft in diameter
- Consider Both Upflow and Downflow Mixing in Design of Draft Tubes
- Consider Insulating Exposed External Draft Tubes
- Provide Mixer Motors rated for Class I Div 1 service
- Check Total Mixer hp is within 0.2 to 0.3 hp/1,000 cf

Gas Mixing Design Considerations

- Don’t do it unless you have to!
- Consider Pump Mixing or Mechanical Mixing Systems instead

Q & A

Digester Mixing Selection

- Factors affecting selection of digester mixing technology
  - Digester size
  - Digester shape
  - Sludge type (primary, secondary, or mixed)
  - Mixing system reliability

Digester Mixing Technology Cost Comparison

	Gas Mixing	Mechanical Mixing	Pump Mixing
Equipment Cost	$97,000	$300,000	$147,000

Notes:

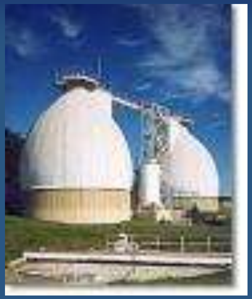
(1) Based on vendor quotes for an 80-foot diameter digester

(2) Includes associated piping costs.

(3) Does not include installation costs.

Other Observations

- Use of Mechanical Mixing in Egg-Shaped Digesters
- Difficult to Retrofit Using Draft Tubes
  - Large sidewall penetrations
- Selection of Pump Mixing for Cylindrical Digesters



Comparison of Digester Pump Mixing Alternatives

Perimeter-Mounted Nozzles	Internal Floor-Mounted Nozzles
• Three nozzles located around each tank perimeter to create spiral mixing pattern	• Four floor-mounted nozzles inside each tank to produce a dual-zone mixing pattern
• Five side wall penetrations per tank	• Two sidewall penetrations per tank
• Requires more piping and larger diameter piping	• Requires less piping and smaller diameter piping
• Proven Carollo design	• Vendor guarantee on mixing
• $904,000 w/outdoor pumps	• $714,000 w/outdoor pumps

Mixing Pump Location Evaluation

	Advantages	Disadvantages
Outdoor Installation (adjacent to each digester)	• Simplifies construction sequencing (shorter construction period) • Less piping required • Readily accessible for O&M needs	• Aesthetics and noise concerns • Electrical equipment needs to be Class I, Div 2 minimum when located adjacent w/in 10′ of digester
Indoor Installation (w/in digester control building)	• Equipment protected from weather • All pumps centrally located in one area	• More complex construction sequencing (longer construction period) • More piping required in tunnel areas • Electrical equipment needs to be Class I, Div 2 minimum when located inside building • May trigger upgrade of electrical equipment inside building to meet Class I, Div 2 requirements ($50,000 to $250,000)

Pump Mixing

- Axial Flow, Screw Centrifugal, or Chopper Type Pumps
- Draw Sludge from Bottom or Top of Digester
- High-velocity Discharge through Nozzles
  - Perimeter Nozzles
  - Internal Nozzles
- Continuous or Intermittent Operation

Courtesy of Vaughan/Rotamix

Digester Mixing Cost Comparison

Item	Confined Gas Mixing	Mechanical Mixing	Pump Mixing
Installed Cost	$880,000	$785,000	$745,000
Present Worth of O&M Cost	$268,000	$209,000	$89,000
Total Present Worth Cost	**$1,148,000**	**$994,000**	**$834,000**

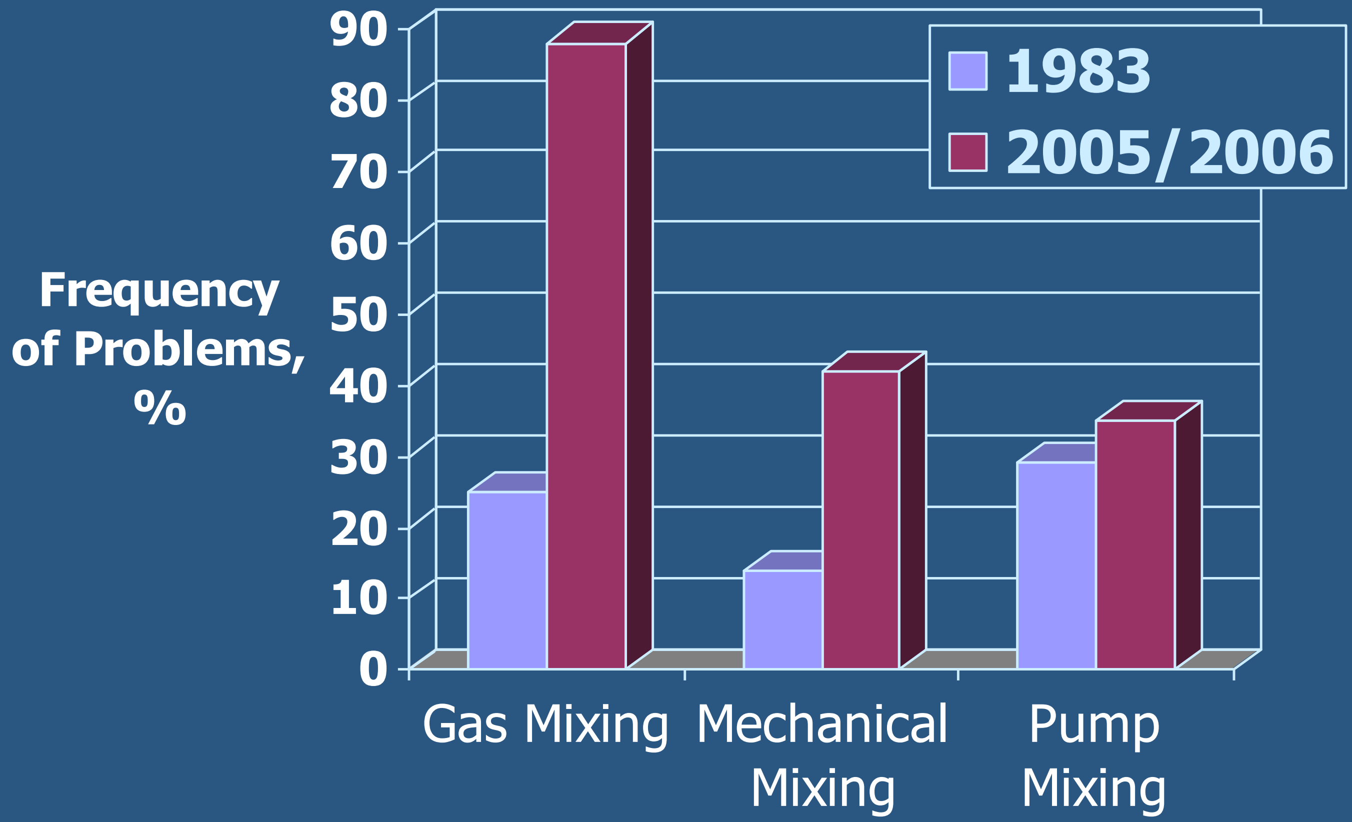
Notes:

(1) Based on vendor quotes for an 85-foot diameter digester.

(2) Based on present value of 20 years of annual costs at 6% interest.

(3) Based on an estimated O&M labor week of $50/hour depending on complexity of the equipment: 9 hrs/week for gas mixing, 7 hrs/week for mechanical mixing, 3 hrs/week for pump mixing.

Comparison of Surveys – Frequency of Problems



Design Criteria Comparison for an 85-ft Diameter Digester with 27-ft SWD

Item	Confined Gas Mixing	Mechanical Mixing	Pump Mixing
Manufacturer	Infilco	OTI	Vaughan/Rotamix
Number of Compressors	1	N/A	N/A
Number of Mixers	N/A	4	N/A
Number of Pumps	N/A	N/A	1
Energy, hp (total)	32	40[(1)]	37.5[(2)]
Energy Input, hp/1,000 cf	0.20	0.26	0.24[(2)]
Turnover Rate, minutes	29	28	30[(3)]

Notes:

(1) Based on equipment manufacturer's design for continuous operation using four mixers at rated 10 hp.

(2) Based on equipment manufacturer's design for intermittent operation (2 hours on/off cycle), which is equivalent to 50% of the rated 75 hp mixing pump.

(3) Adjusted value considering nozzle entrained flow velocity of 40 fps.