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Mixing and Blending liquids, solids and gases into water and wastewater

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Agenda for todays seminar

- Application of Power to Fluids – Formulae
- Energy Considerations & Applications
- Illustrations & Devices used for Blending
- Static Mixers and their applications
- Mixing with Compressed Air or Liquid
- Mechanical Agitator Design
- Side, Bottom and Submersible Mixers
- Q&A – Wrap Up and CEU Certificates

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The first mixer

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Common beginnings

- Porridge and soups were first mixed from the bottom up to blend the nutrients and flavours from the meat into the new additions
- Poor folks couldn't afford to start a fresh pot every day so they blended the old into the new

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Beer and Wine kick start civilization

- Nomads got tired of travelling after discovering the secret honey bee tree and mead – sucrose & yeast = relaxation
- The success of herding and hunting gave way to agriculture and vegetarians.
- Next thing you know they all want universal health care and free college tuition

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Government takes hold

- Soon more and more nomads came to the city for free beer and wine
- Taxes were levied to pay for the wheat and barley and grapes
- Houses had to be built to protect the people ….. mortar and mud mixers were invented to augment the wooden paddle used by the brewers and cooks

Mixing 101 – History

- Food processing, mining, pulp & paper , cosmetics, pharmaceuticals, petroleum, power and chemical processing industries developed unique impellers for many applications......
- Many were for batch processes & simple blending of 2-3 components
- Continuous flow processes require some different types of agitation

Mixing Pictures

- In order to choose the right equipment , you need to understand the mixing needs and time frame.
- Develop a visual image of what needs to be done to satisfy the process goal
- Place your application into a mixing class to start the process of selection

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5 Application Classes

- Liquid – Solid
- Liquid -Gas
- Miscible Liquids
- Immiscible Liquids
- Fluid Motion

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Liquid - Solid

- Dissolving a solid into a liquid
- Suspending solids off bottom
- Describe the solids – powders,rocks,dense,fluffy,sticky,crystals
- Describe the power needed- just off bottom, ½ way up the tank til reaction or complete uniformity for continuous pumping to another tank

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Gas Liquid

- Dispersion of a gas into a liquid
- Absorption of a liquid into a gas
- Describe the density and viscosity of the liquid to understand power needs
- Describe the amount of miscibility the gas has in the liquid, whether it takes along time to effect mass transfer or if it's easy

Immiscible Liquids

- Explain the two components or more and their viscosities and rheologies vary
- Is it a blend like salad dressing or a finished end product like mayonaaissee or shampoo.....emulsions and drop size data
- Is it a mass transfer operation like hexane decaffinization of coffee or solvent extraction from oil....
- Is it mixing polymer into water for flocculation or dewatering

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Fluid Motion

- Describe pumping capacity of impeller and blend time required
- Explain the inlet and outlet port locations and side forces if velocities are high
- Is their heat transfer to accomplish like mixing cold water and warm water
- Is it chlorine contact chamber blending before a CT tank ?

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Tank and Impeller concepts

- The perfect tank is a cube – so describe how different your requirements are.....
- Tall and skinny, fat and short, round with conical bottoms, horizontal with a long side ratio ?
- Is it above ground , below ground... egress an issue, can you get to the mixer for maintenance... or not ?
- Concrete , glass, FRP, stainless or steel ???

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Impellers or is it non-contact

- Radial flow impellers pump out from the tips toward the tank walls
- Axial flow impellers pump down from the turbine or up toward the top
- Can you use a motive liquid stream or air to blend instead of sticking metal parts into the tank ?

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Tank Geometry

- Need height, length and width or diameter
- Open or closed top
- Side bottom or top entry point
- Injector locations
- Mixer location – center or offcenter
- Mixer angle for vortexing or not
- Baffle locations if any..........

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Process Requirement

- 10 minute blend time – or 30 seconds
- Uniform temp at outlet within 30 min
- pH within +/- 0.1 log
- Conductivity or dissolved solids concentration
- Streaming current value stable
- UV level correct

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Feed Characteristics

- Density or specific gravity of components
- Temperature
- Viscosity
- Corrosivity / pH level
- Volume ratios
- % solids level
- Settleability
- %Volatile solids
- Ash content

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Degree of Mixing

- Mild, moderate or violent agitation.....
- How to define these terms, swirling , splashing moving rippling, vortexing......
- How about a Scale from 1-10
- Call it Chemscale & define it a the range from 6-60 feet per minute
- Bulk Fluid Velocity ~ tank motion for many turbulent flow applications

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Computational Fluid Mechanics

- CFM is a powerful tool that is used to mathematically model fluid flows of different agitator/impeller designs in mixing tanks.
- Mixing of single and multi-phase fluids in stirred tank reactors is a common operation in many industries.
- Understanding the fluid flow in these tanks is critical for equipment design, scale-up, process control and economic factors.
- CFM models allow you to see what is taking place in the mixing vessel. The results enable an engineer to select the best agitator design to obtain the desired process performance.
- Rectangular and side-entering agitated tanks as well as turbulent and laminar flow static mixers can all be successfully evaluated

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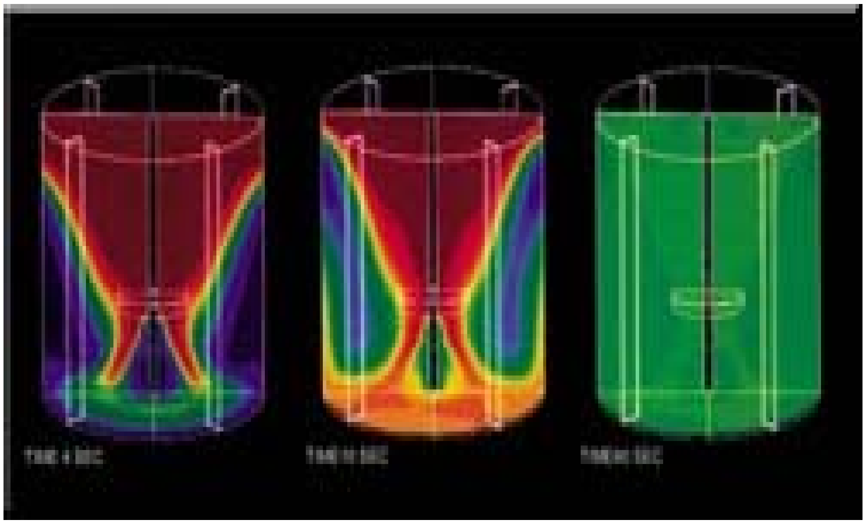
Graphic Analysis



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Digital Particle Image Velocimetry (DPIV)

- An Argon-Ion laser light sheet illuminates fluorescent, neutrally buoyant particles. A CCD camera captures the images, then an advanced timing system and a computer with image board freezes and digitizes the images. The picture below shows the motion of fluorescent particles illuminated by a sheet of Argon-Ion laser light.
- The particles (60 micrometers) are small and neutrally buoyant, so they follow the liquid flow. The tank is equipped with a pitched-blade turbine. The particle motion is filmed with a CCD camera. The velocity field is then extracted from the digitized images using cross-correlation software. Armed with this information, engineers can better design agitators.
- DPIV technology has the capability of measuring the entire fluid velocity field in a tank almost instantaneously making it possible to study large-scale, time-dependent phenomena in the tank.
- The color shows the local, time-averaged velocity. Fast-moving regions are colored red and slow-moving regions are colored blue. The pitched-blade turbine creates a mixed axial/radial flow pattern. The highest velocities are found at the impeller blade tip. The velocities at the liquid surface are an order of magnitude lower.

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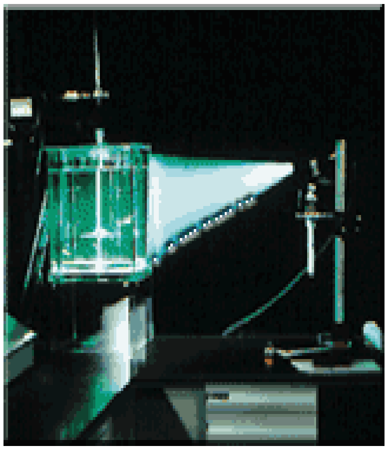
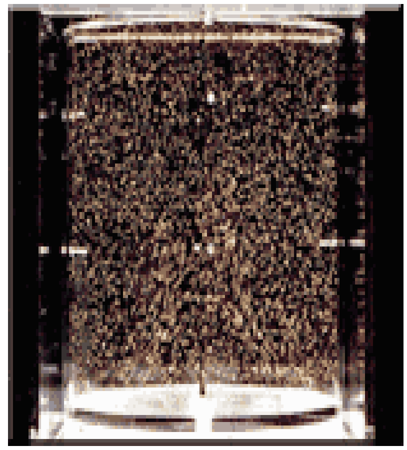
DPIV images





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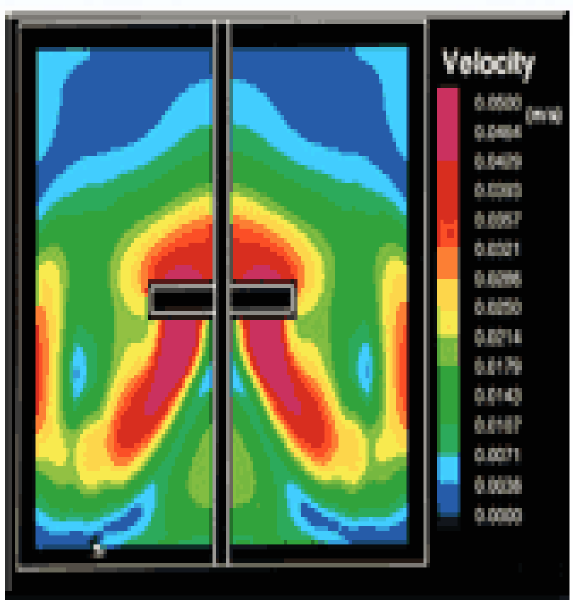
DPIV graph



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Laser Doppler Anemometry

- (LDA) is widely recognized as the best method of non-intrusively determining mean velocity and turbulence data with pinpoint accuracy using the Dantec FlowLite turnkey measurement system to determine velocities in stirred tanks and static mixers.
- The measurement technique relies on the physical fact that when two laser beams of the same wavelength cross, an interference pattern of bright and dark fringes is formed.
- As a single particle passes through the intersection of two such laser beams, it reflects light at certain frequencies which depends only on the velocity of the particle and the fringe spacing.
- Appropriate optical collection and data analysis enable highly accurate velocity measurements within extremely small volumes of fluid. Within minutes, thousands of particles may pass through the measurement volume, enabling an accurate determination of velocity at that point

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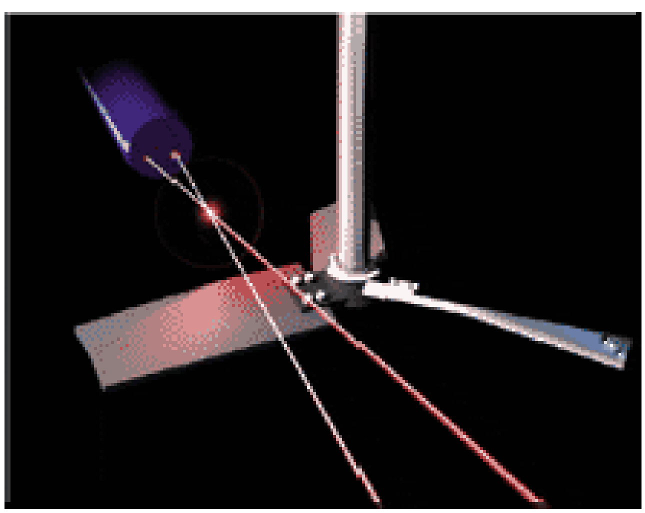
Laser Doppler Anemometry



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Laser Induced Fluorescence

- One of the most challenging problems in fundamental diagnostics is directly measuring mixedness.
- Limiting factors in traditional mixing systems include the intrusion of probes and the number of probes required to statistically determine mixedness.
- Laser Induced Fluorescence (LIF) is a measurement technique which enables the user to gain a fundamental understanding of mixing in a straightforward fashion.
- Materials such as rhodamine or uranine will fluoresce when struck by light of certain wavelengths. We use this property to track the path and diffusion of injectants in agitated vessels and static mixers.
- A laser beam is spread into a sheet of coherent light which is projected through a clear pipe or vessel. When fluorescent material is struck by the light, it scatters light at a higher wavelength than the laser wavelength. The scattered light may be captured on video or on a CCD camera directly linked to a computer. These digital images may be analyzed to determine uniformity.
- One of the benefits of such an analysis is that both qualitative and quantitative assessment of mixing may be gained simultaneously.
- In static mixer systems, we have used this information to calculate a coefficient of variation while in stirred tanks, blend times have been measured. In either circumstance, the user also gains a general understanding of the mixing mechanisms.

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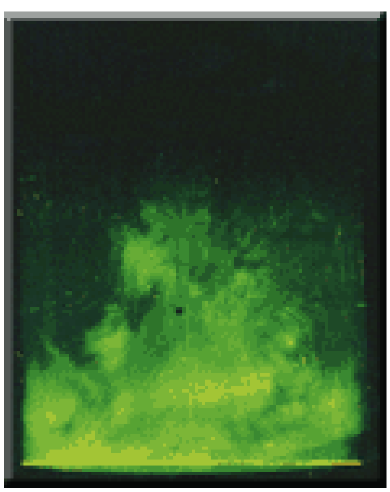
L.I.F. images



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Shear Rate and Impeller style

- Impeller type and size affect tip speed
- Blade ratio & angle of attack affect shear
- RPM obviously controls this effect the most
- Time for an equation ?

- P ~ Q x H x density
- P = powerdraw
- Q = flow or pumping capacity
- H = Velocity head

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Power draw vs Speed

- $P \sim N^3$ where N = RPM
- $P \sim D^5$ where D = impeller diameter
- $P = N^3 \times D^5 \times s.g.$

- All of the above vary with impeller type

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Impeller Types

- Rake type (picket fence)
- Gate type (large paddle floc)
- Anchor style (with cross members)
- Helix type (screw or ribbon)
- Propeller ….. as in cast , like boats
- Radial turbine (2,4,6 bladed)
- Axial flow (pitched blades)
- Aerofoil (twisted improved axial blades)

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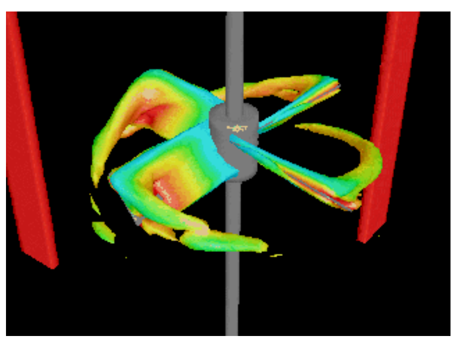
Impellers + Dynamic Models

- high computer speeds and software now allows us to simulate performance in tanks



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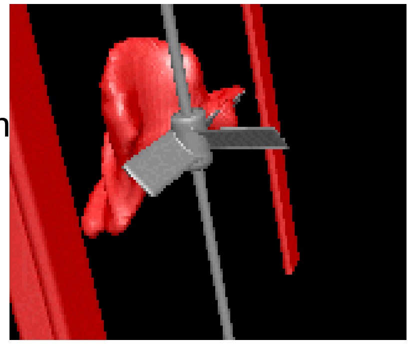
Time Release design review

- Dropping red dye into a pitched blade turbine with baffles in a circular tank



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Power Number

- Each impeller design has a unique flow vs power draw character
- Blades 12 inch long and 4 inches high
- Attached to hub at 45 degrees, 30 degrees or 90 degrees will have different Hp draw at the same RPM
- Measure and back calculate N^P
- Power # = 1.523 $x10^{13}$x P / N^3 D^5 x s.g.

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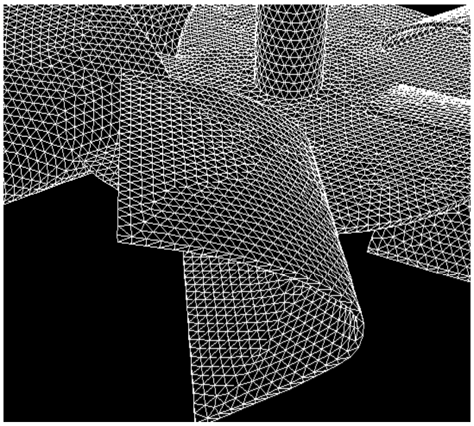
Blade design optimization



- Using a novel hexographic contour plot system to model the impeller …..
- Run the simulation and **shazam** ….
- out comes the perfect turbine for your application

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Laboratory analysis

- Once the system is selected, you can take the impeller to the lab to confirm the simulation with actual torque, thrust, speed and power draw measurements

Sizing guidelines

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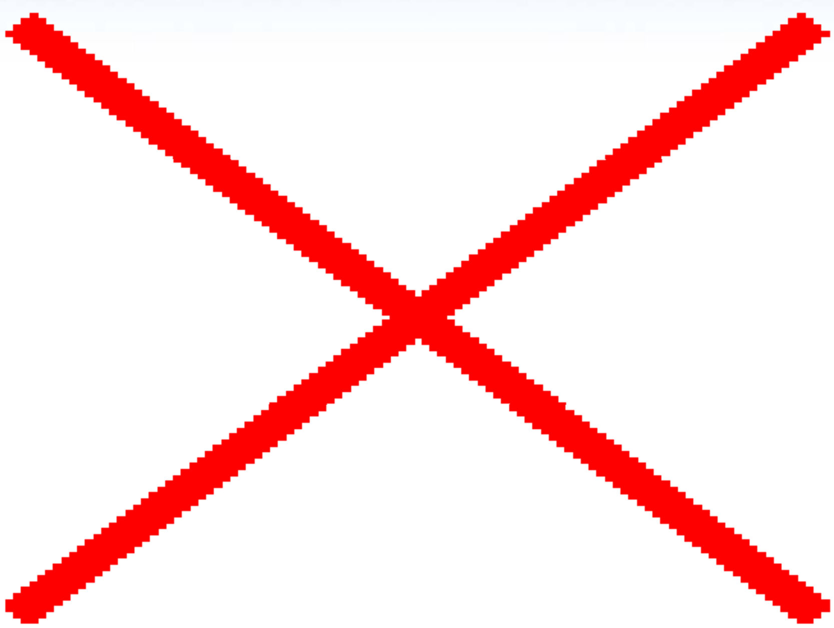

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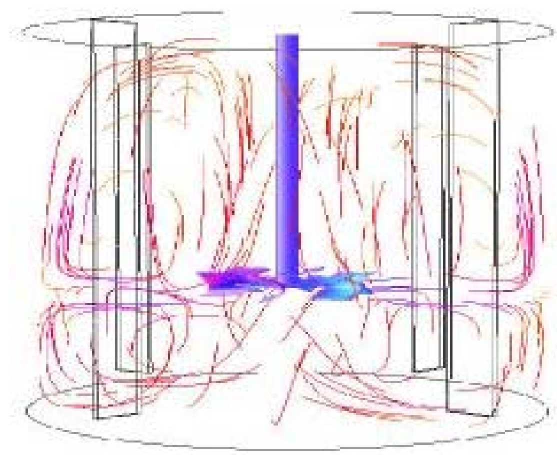
Laser Light Spectrum Velocimetry



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Reynolds Number / Flow Regime

- Laminar , transitional & turbulent flow
- Viscosity effect increases drag on impeller tank walls and baffles > H[draw
- Viscosity ratios 1000/1
- Volume ratios 100/1
- $N^{re} = 10.754 \times N \times D^2 \times s.g. / u$

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Impeller Power #s

- Rushton turbine ~ 5.75
- Bar turbine ~ 0.61
- Anchor impeller ~ 52
- 1.5/1 pitch prop ~ 0.87
- 45^o pitch blade ~ 0.53
- Hydrofoils ~ 0.2 – 0.3 (3 or 4 blade)

Reynolds number values

- N re < 10 = laminar creeping flow
- Honey dripping or molasses pouring
- N re 10-100 = smooth laminar flow without striations
- **toothpaste extrusion**
- N re >100 = transitional flow
- Cl2 contact chamber with swirls + eddies
- N re > 1000 = turbulent flow
- Splashing brook / whitewater

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Various types of mixers

- Top entering – overhung shaft
- Side entering – angled mount
- Portable - air driven clamp on
- Bottom entering – stub shaft
- Submersible gear driven – banana blade
- Submersible direct drive – wall pump
- Static or mechanical - in-line types
- Jet mixers – pod or manifold style
- Pumped recirc flow mixer / aspirators
- Pneumatic draft tube or bubble plate airlift
- Fluted and ragless circulators – direct drive shaft mount
- Engineered pipe grid /check valve hydraulic designs
- Hyperbolic bottom mount circulators
- Rotating arm or ball spray type agitators
- Screw auger counter - rotating double drives

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Applications and Energy considerations

- Efficiency is now..... time to consider all options including biogas fed direct drive engines in lieu of electric motors
- Solar powered circulator mixers for water storage tanks in the distribution system
- Impeller conversions to reduce Hp or enhance process performance
- Installation modifications to improve maintenance and optimize equipment life

Simple blending example

- 1975 Cl2 Contact chamber has a 5 Hp top entering mixer with drip feed lines
- Opt A) Convert to larger HE-3 impeller
- Opt B) Change to same size A 310 turbine
- Opt C) Convert to aspirating wet mixer
- Opt D) Add static inline mixer before tank
- Opt E) Use jet reactor mixer tube instead
- Opt F) Go to contract operations - retire

Applications for water and wastewater plants

- Rapid mixers
- Flocculators
- Carbon, soda ash or lime slurry makedown
- Lime softening clarifloc tanks
- Inline finished water adjustment
- Ferric chloride and polymer storage
- Draft tube ballast recirc systems
- Anaerobic digestor mixing
- Mudwell and sludge storage tanks
- Anoxic tank/ Fermentor stage BNR blending
- PH adjustment
- Surface Aeration or submerged turbine oxygenation
- Chlorine contact / CT basins

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Specialized Services

- ATTADs mixer aerators
- SBR systems
- Pre-Oxidation of Fe/Mn/As
- Lagoon & Oxyditch Mixer Aerators
- Sidestream Ozonation Reactors
- Scum Storage & Homogenizers
- Foam Entrainment Mixers
- Dewatering Feed Mixers

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TOP ENTERING

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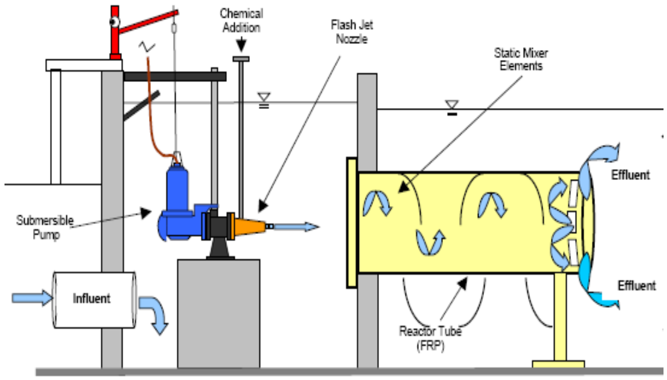
JET MIXER



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Aspirating Mixer

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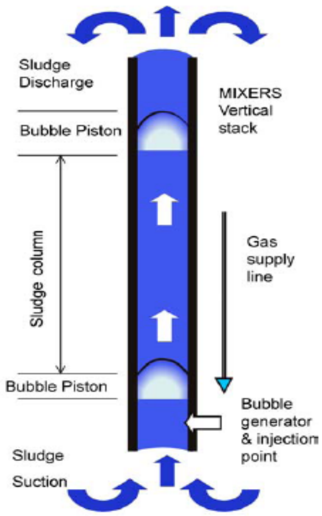
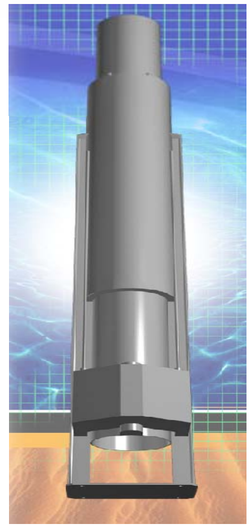
Draft Tube Mixer





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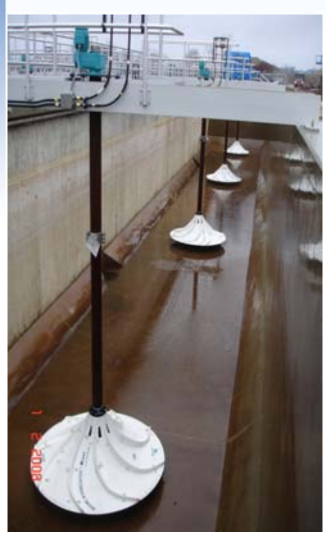
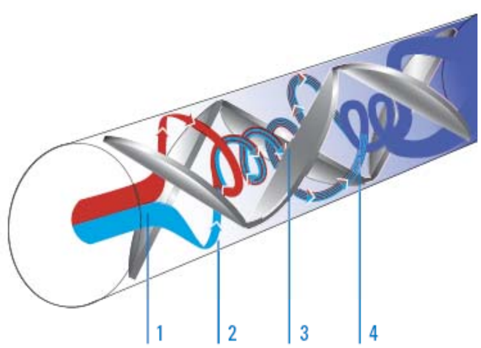
Hyperbolic Mixer



Submersible Mixer

Static Mixer



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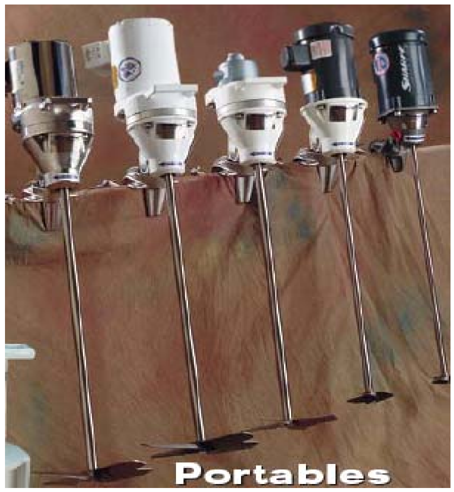
Portable Mixers



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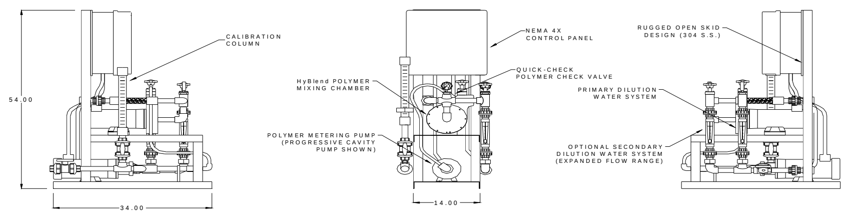
Mechanical Inliner

Polymer makedown systems

TYPICAL LAYOUT



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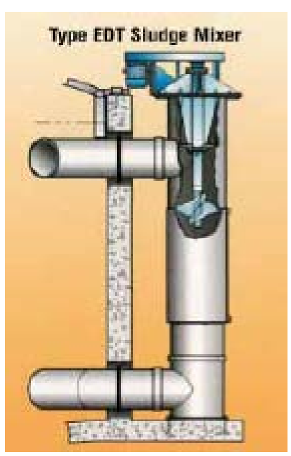
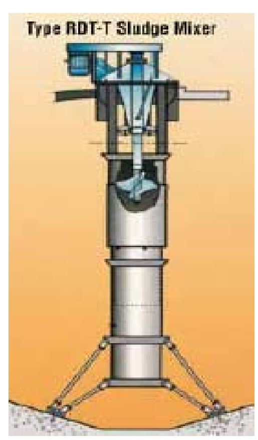
Sludge Recirculators





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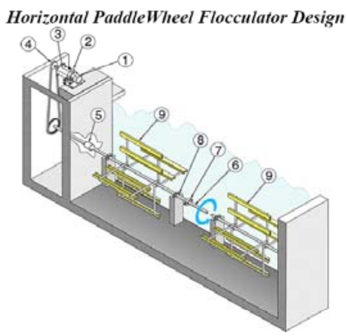
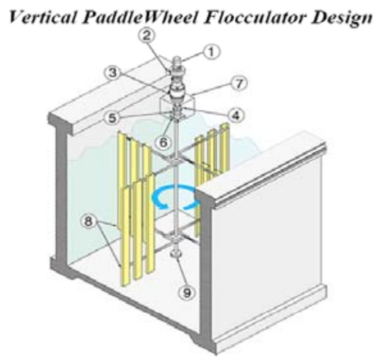
Flocculators





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Walking Beam & Turbine Type

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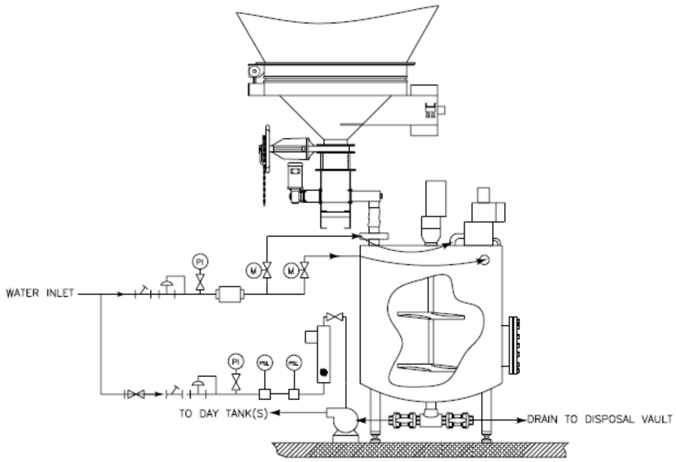
Lime Slurry Makedown Mixers



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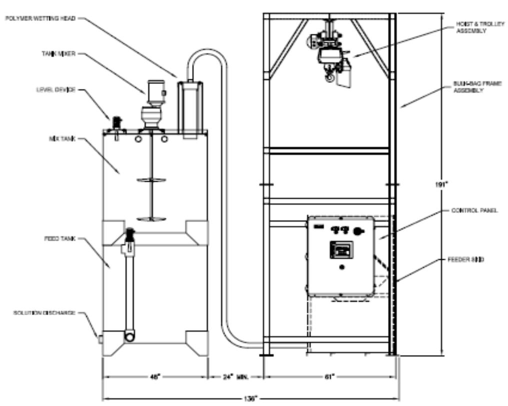
Soda Ash or Carbon system mixers



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Silo feeding a dry chemical make-down tank

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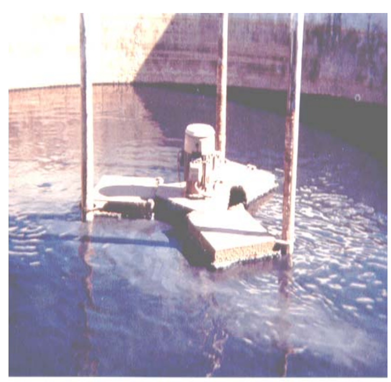
Floating scum control mixers



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2 speed SBR mixer aerator

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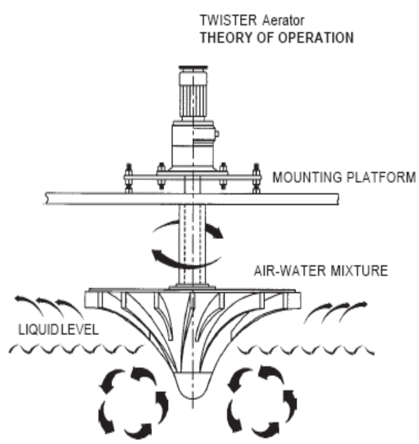
Pure Oxygen Mixing



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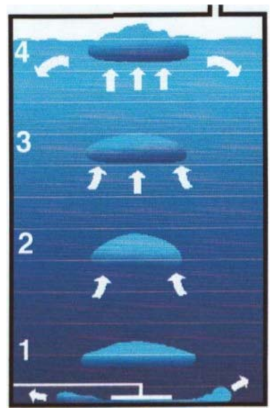
Airlift mixing

- Compressed air injected to accumulator plate forms large bubbles to lift and mix tank contents



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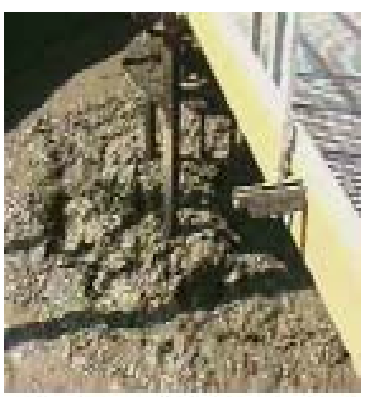
TWAS Shear-tube Mixer



Draft Tube Installation - Mixing 4% Solids

MEDT Installation - 31 ft. Deep Basin

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Inline sludge mixers