University of California, Los Angeles

Aeration Systems
25 Years of Experience

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Outline

- Aeration system types
- Terminology
- Mechanical (surface) aerators
- Combined (jets and turbines)
- Diffused aeration
  - Coarse
  - Fine pore
    - Ceramic
    - Plastic
    - Membranes

Terminology

- Efficiency
  - Standard oxygen transfer efficiency (SOTE) (percent oxygen transferred)
  - Standard oxygen transfer rate (SOTR) (mass transferred per unit time)
  - Standard aeration efficiency (SAE) (mass transferred per unit time per unit power)

Terminology Cont

- SOTE - percent
- SOTR – lb O2/hr or kg O2/hr
- SAE – lb O2/hp-hr or kg O2/kW-hr
- All above at standard conditions (e.g. 20^{o}C, clean water, etc.)
- OTE, OTR, AE – at process conditions

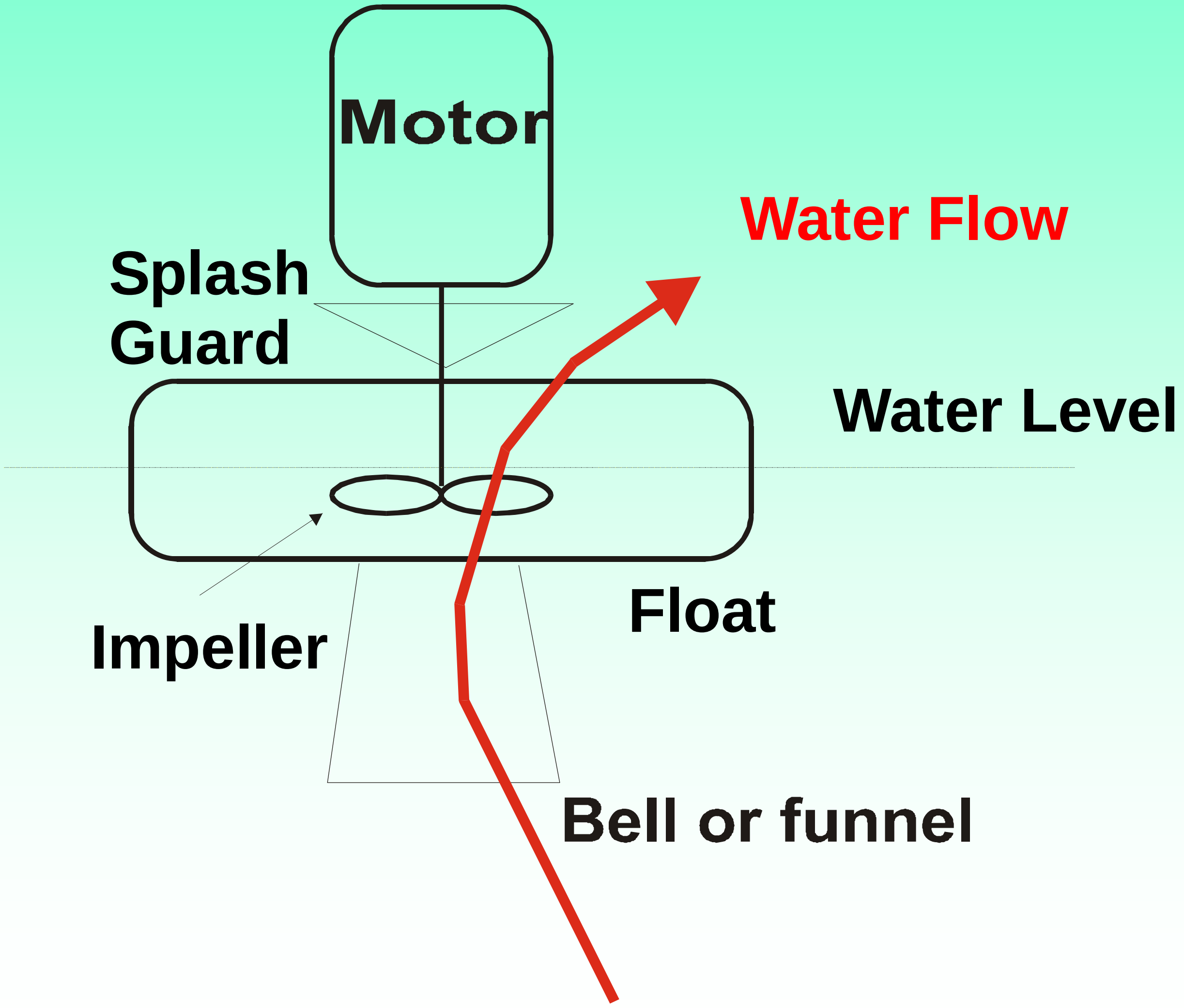
Standard and Process Conditions

- Adustment formulas based upon driving force, temperature, barometric pressure, water quality, saturation concentration, etc.
- Driving force and water quality the most significant
- Driving force = $(DO_S – DO)/DO_S$
- Water quality – alpha factor, 0 to 1 !
- Total correction can result in process water transfer of only 30 to 80% of clean water transfer

Mechanical Aerators

- Two types
  - High speed (900-1200 RPM)
  - Low speed (30-80 RPM)
- Operate at the surface
- Modest efficiency
- High heat loss
- Mist, spray
- Often simple to install, especially high speed
- Higher alpha factors (0.6 to 0.9) depending upon energy density

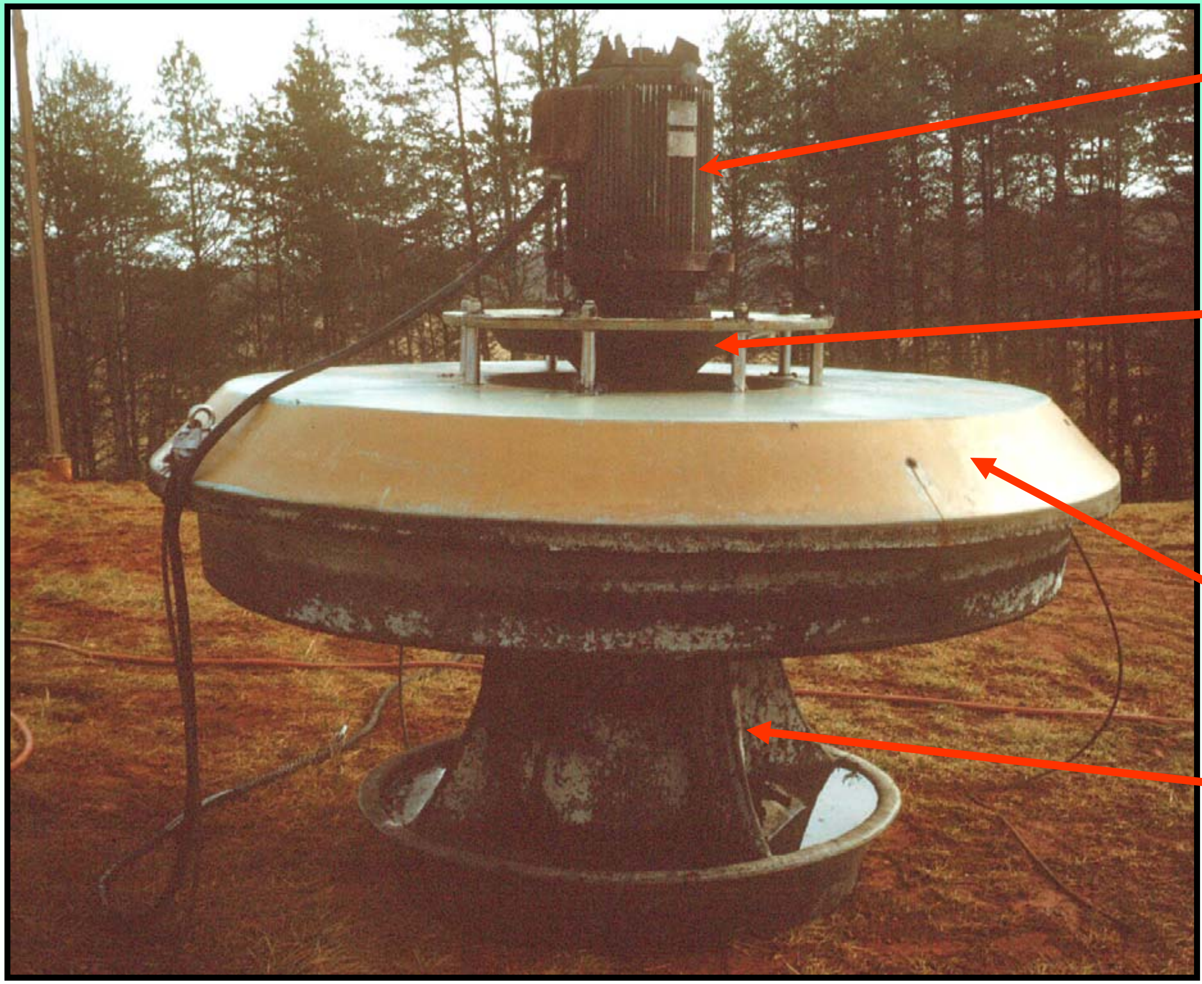
High Speed Surface Aerator (Axial Pumping)



Specifications

- 1 to 75 hp (1 to 56 kW)
- Up to 2.2 lb O2/hp-hr (1.3 kg O2/kW-hr)
- 900 to 1200 rpm motors, no gear box
- Floc shearing potential
- Misting and drift potential
- Quick installation, quick delivery
- 8 ft (2.5 m) depth without draft tubes

High Speed - Out of Service



Direct Connect Motor (1 – 75 hp)

Splash guard, directs water flow

Float

Bell, acts as a funnel.

High Speed – Out of Service

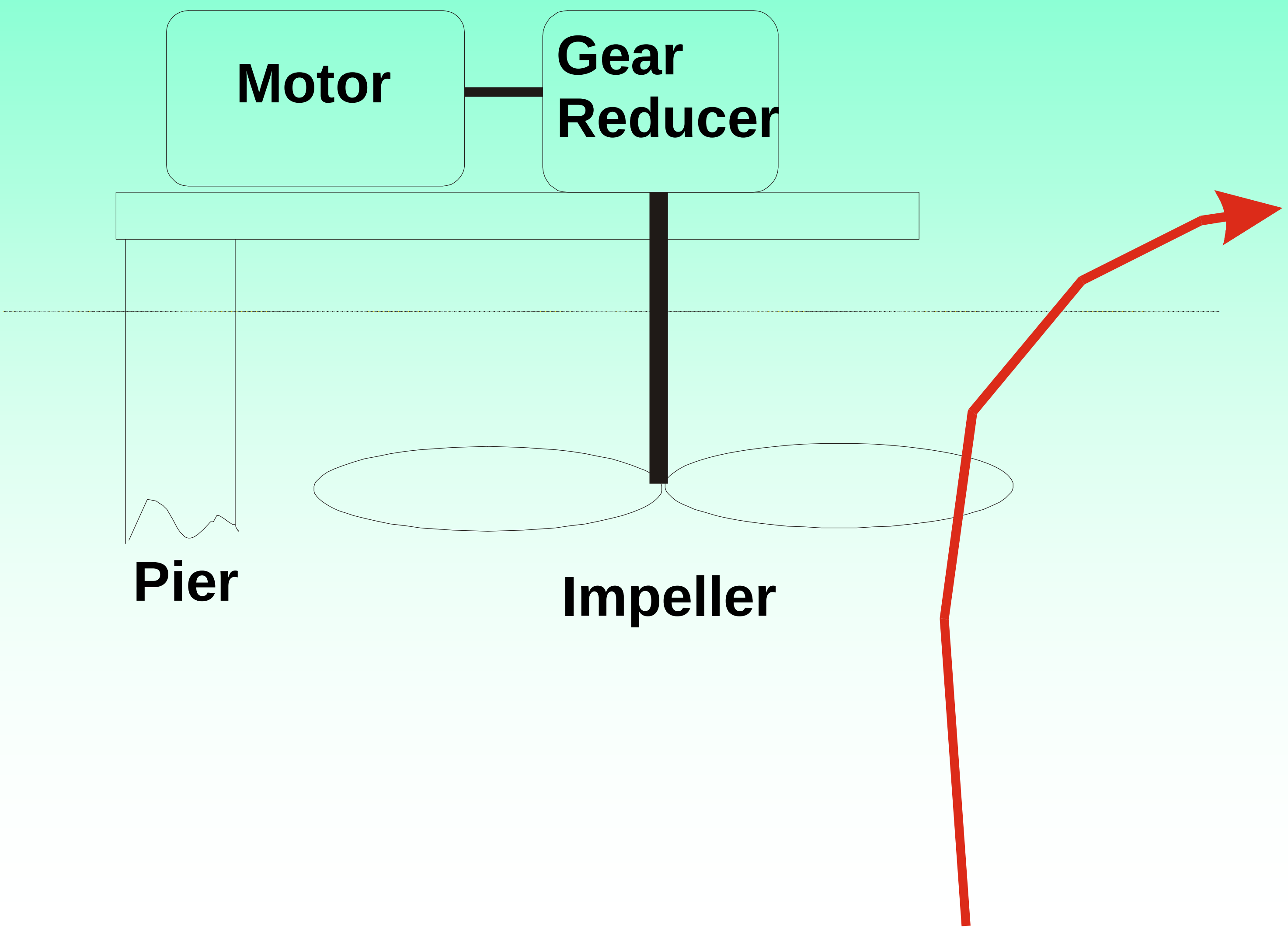
Splash Guard Detail

For Sale !!!!

In Service

Maintenance

Low Speed Vertical (Radial Pumping)

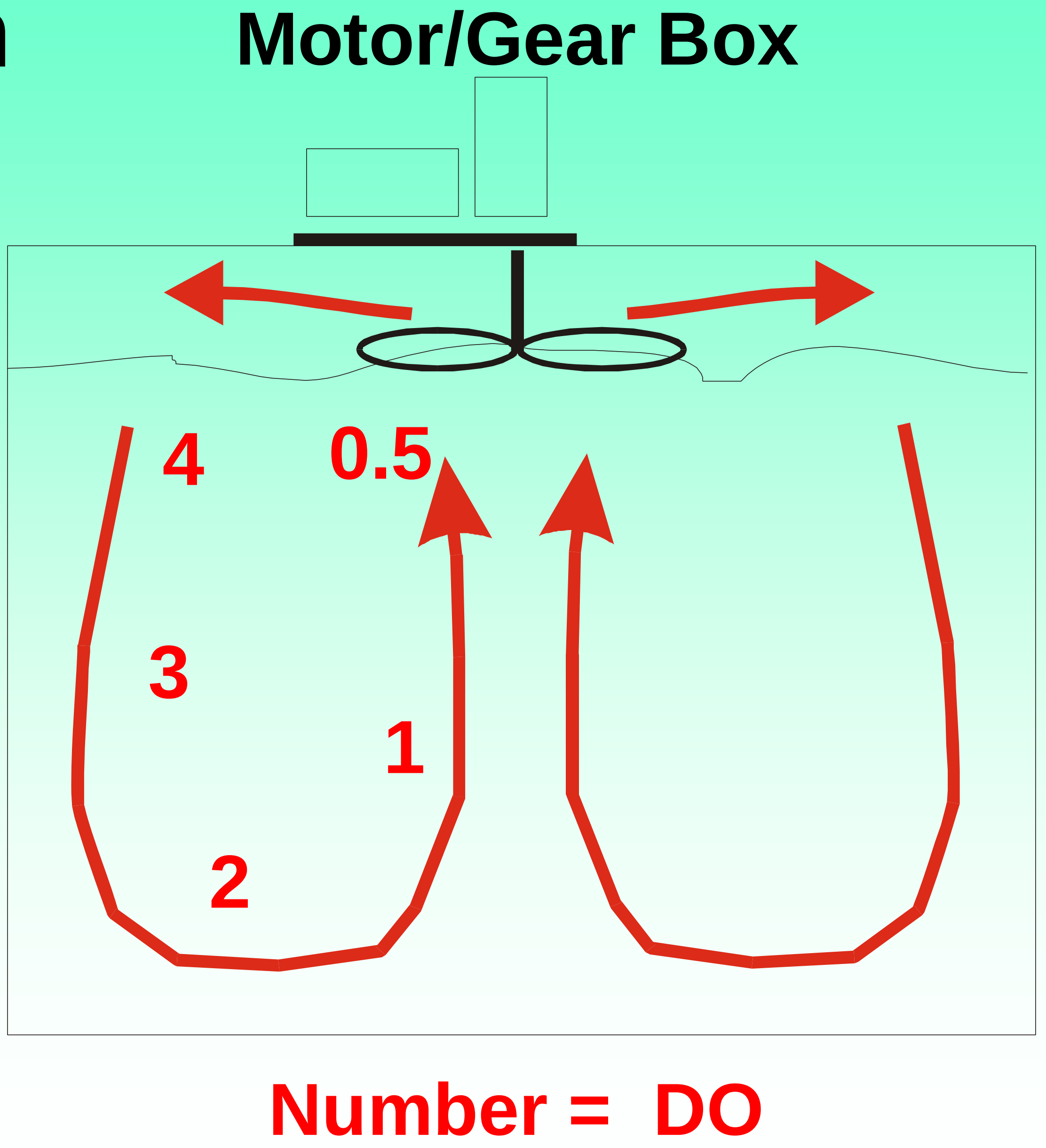


Specifications

- 5 to 150 hp (112 kW), rarely greater, but possible
- 3 to 3.5 lb O2/hp-hr (1.8-2.2 kg O2/kW-hr)
- ~40 to 80 RPM impellers
- Depths to 15 ft (3.5 m) without draft tubes or lower impellers
- Usually pier mounted, but occasionally mounted on floats
- Long lead time for purchase and installation
- Misting and drift potential
- Little potential for floc shear
- Lower impellers and draft tubes for operation at greater depth
- New impeller designs

Flow Pattern

Never uniform DO!



During Construction

Pitch bladed turbine with lower impeller

3 to 10% power used for lower impeller

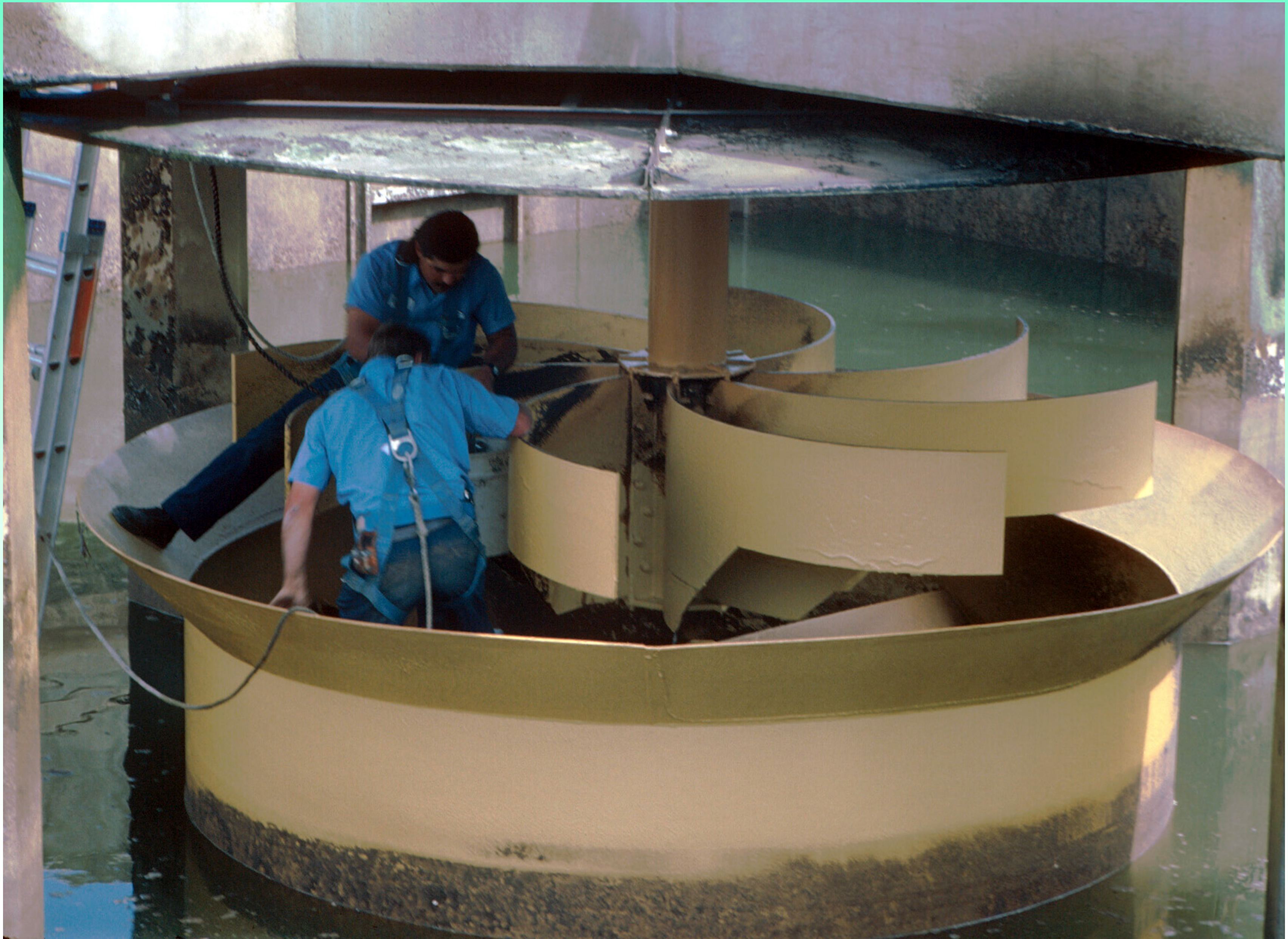
In Service

High speed

Low speed

In Service

Maintenance



Floating

HPO-AS Application

Experimental

Slow Speed Horizontal

- Used in oxidation ditches
- Much less frequently used in the US
- Used to impart a linear velocity as well as aerate
- Efficiencies similar to slow speed vertical aerators

Trade Show

In Service (Off) – Oxidation Ditch

trom

In Service – Oxidation Ditch

In Service- Lagoon

Combined Types

- Turbines – using mechanical energy to make fine bubbles from a coarse orifice
  - Sparged
  - Down draft
- Jets – air and water flowing through a venturi creates fine bubbles without a small orifice
- Alpha factors similar to fine bubble diffusers, as opposed to mechanical aerators (0.3 to 0.6)

Turbines

- Energy efficiency to 3 lb/hp-hr (1.8 kg O_2/kW-hr)
- Very large power input possible (> 200 hp mixers (150 kW))
- Gear boxes (~ 100 to 400 RPM)
- Much less frequently used today
- Fewer in-tank maintenance problems

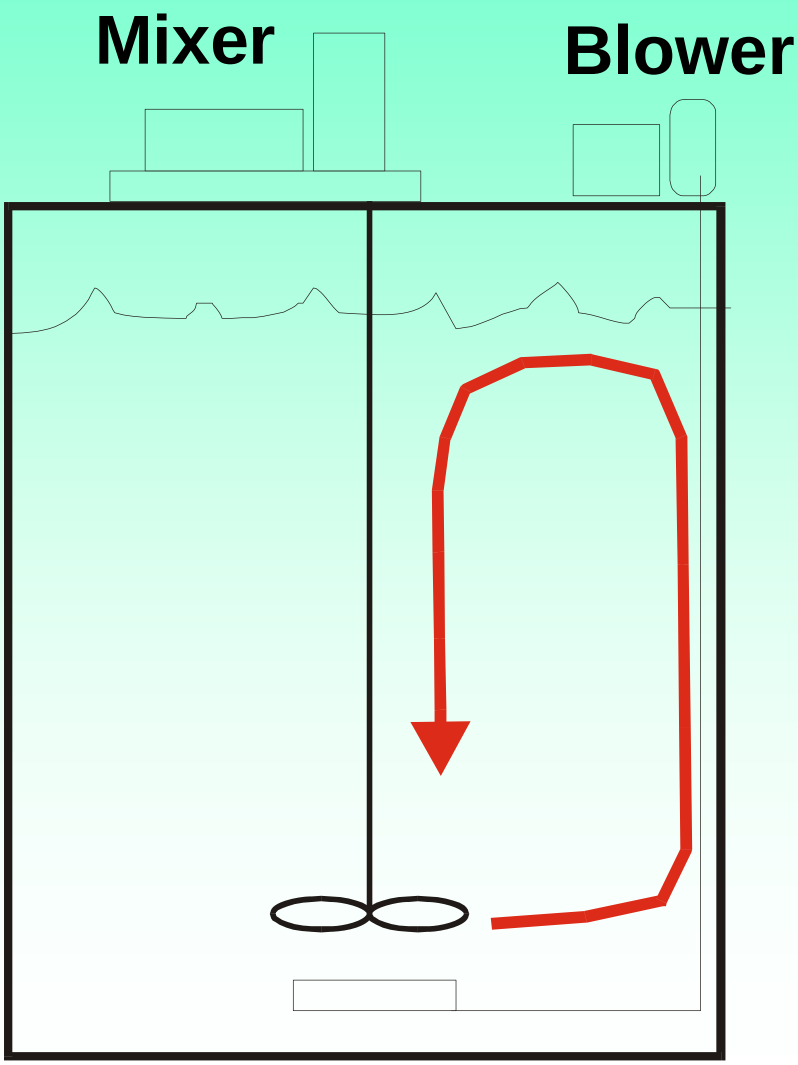
Sparged Turbine

Requires two “primer movers”

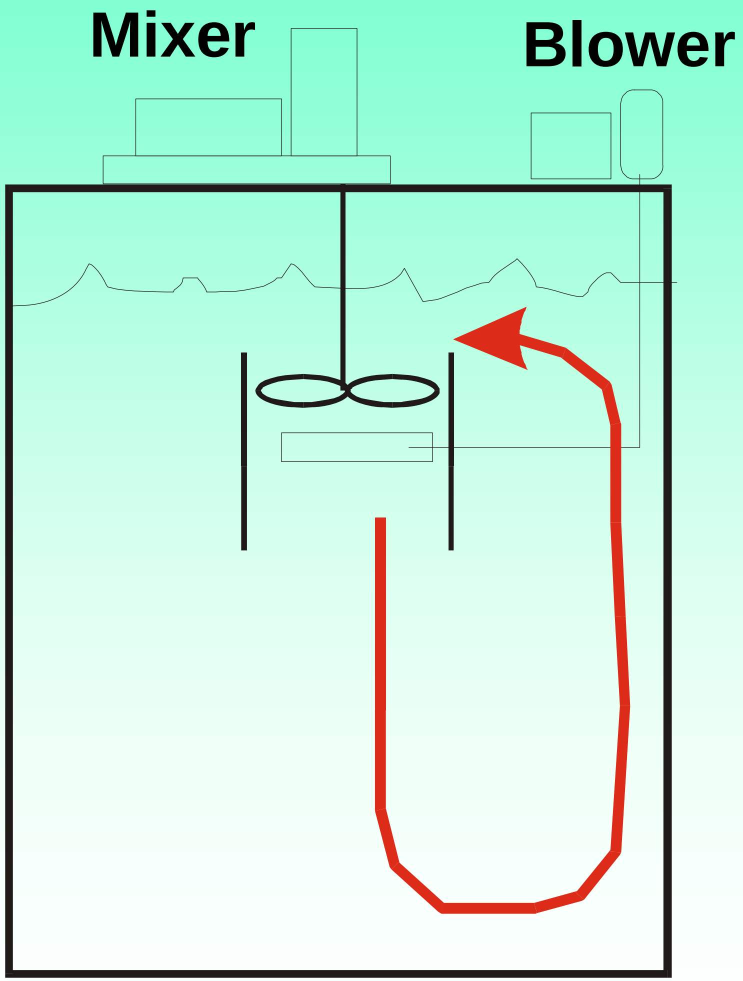
Depths to 10 m or more

Very large OTR can be obtained in a small volume

Used more in industry that for wastewater treatment



Down Draft Turbine



Requires two "primer movers"

Depths to 5 m or more

Lower blower horsepower due to shallow diffuser depth

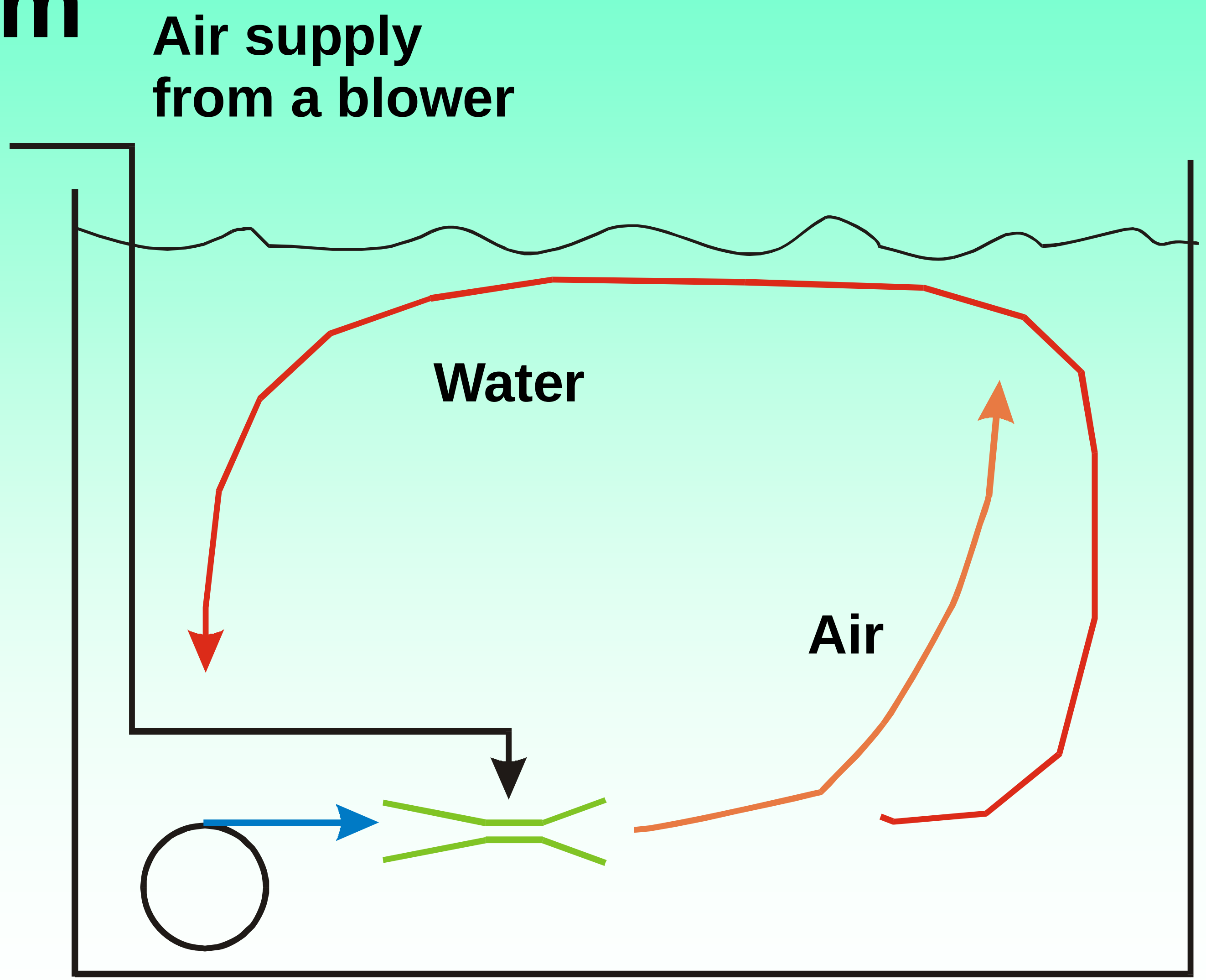
Turbine in Service

Down Draft Turbine

Impeller and sparge ring

Down Draft Turbine

Jets Flow Diagram



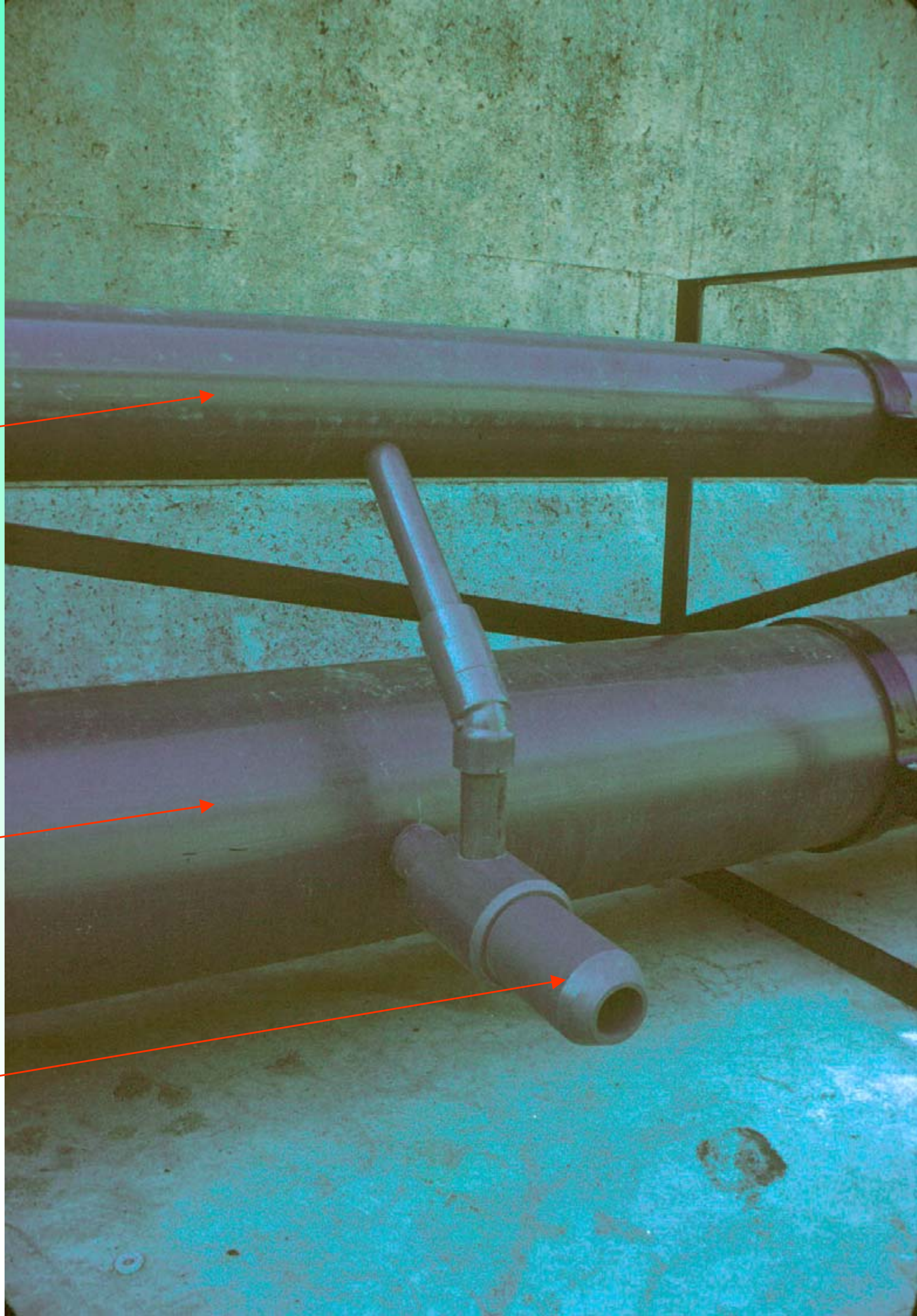
Mixed Liquor Pump

Nozzle and Piping

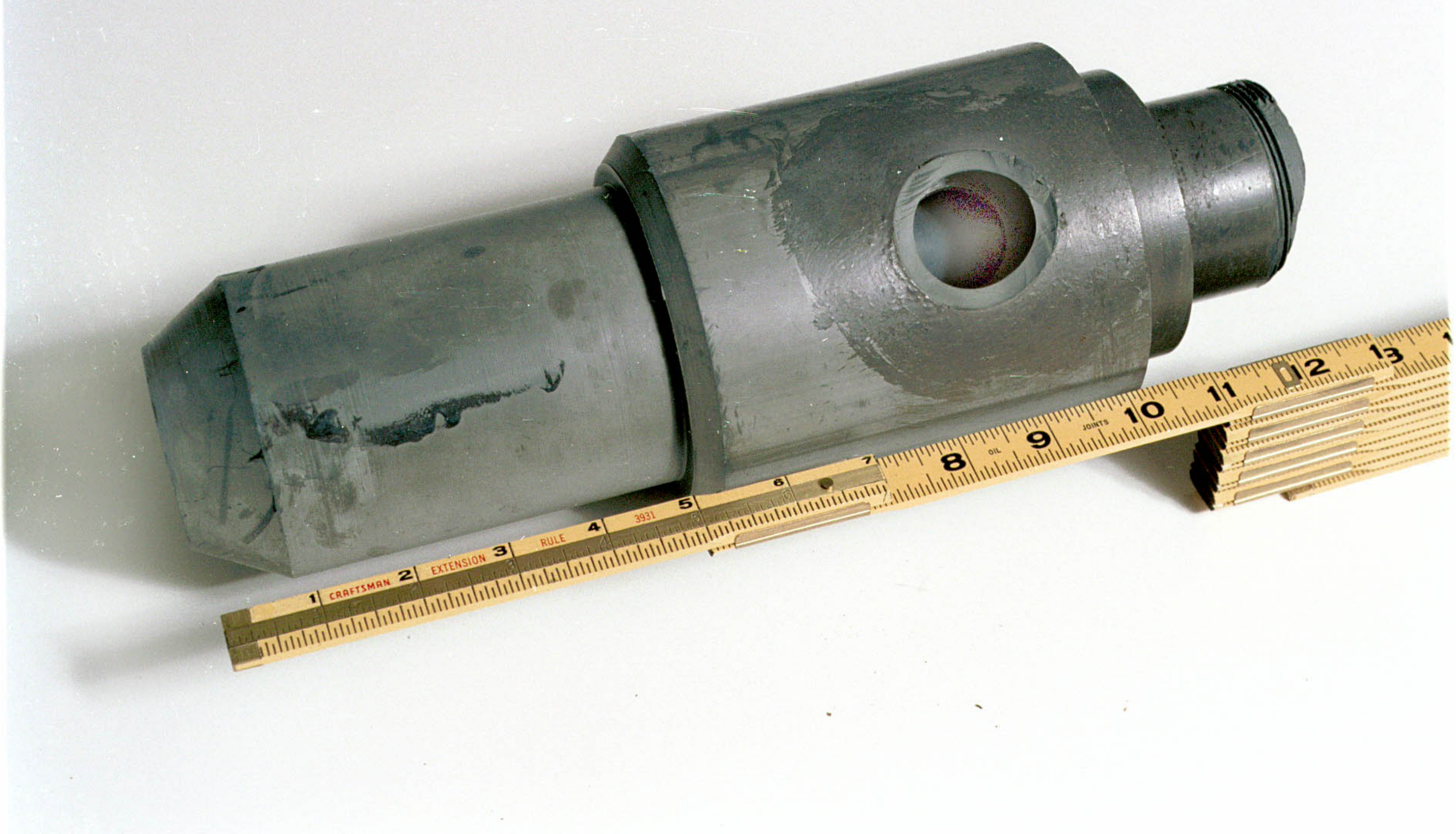
Air Supply

Mixed Liquor Supply

Nozzle



Jet Nozzle



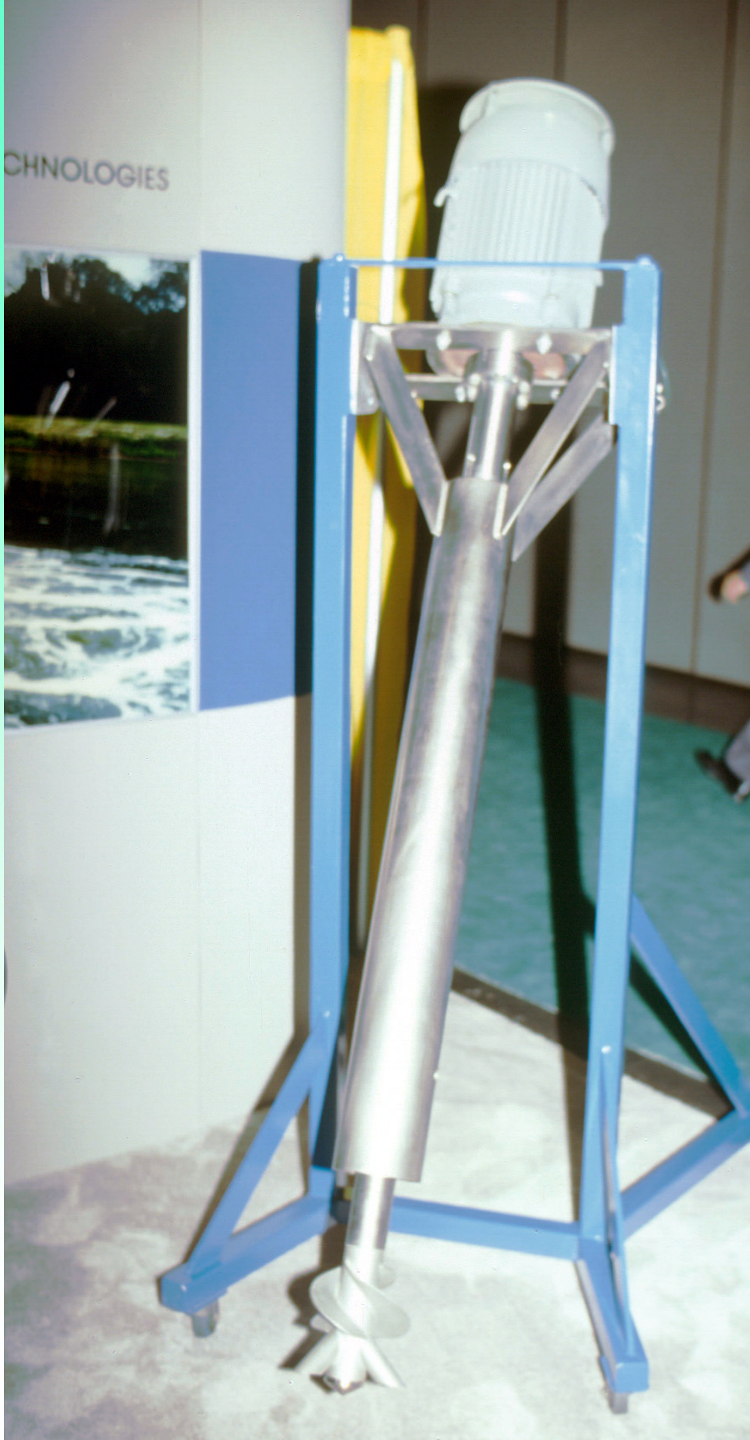
FiberGlas Jet

Air Supply

Nozzle

Mixed Liquor Supply

New, Novel Designs



Aspirating Mixer

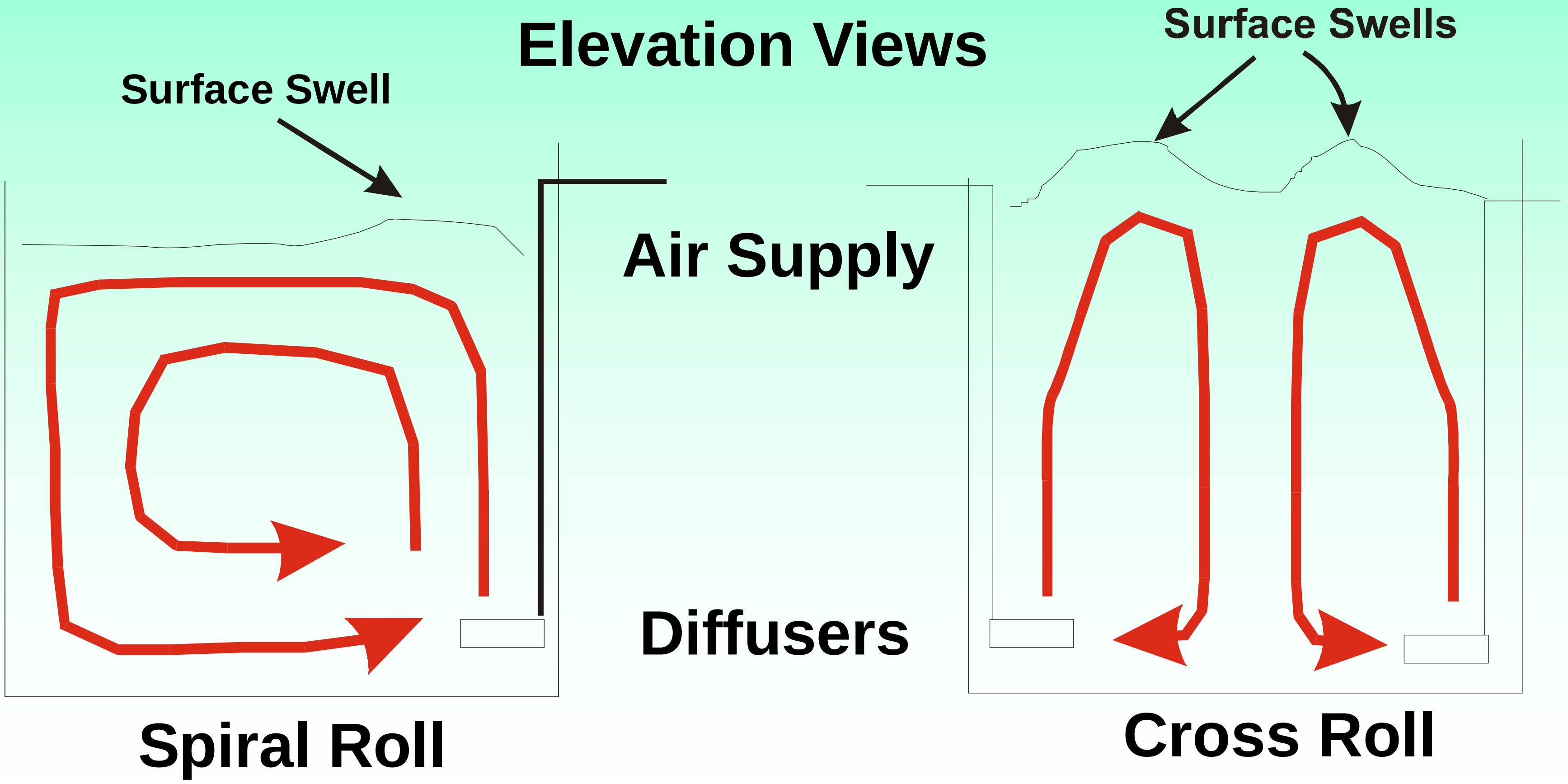
Diffused – Coarse Bubble

- Low maintenance, low efficiency
- 1 % /ft or (3%/m) SOTE
- 2.0-3.0 SAE (1.2 – 1.8 kg O2/kW-hr)
- Large orifices – 0.25 in (60 mm)
- Handles large air flow and high OTRs for many industrial applications
- Phased out in most municipal applications in favor of more efficient fine pore systems
- Alpha in the 0.6 to 0.8 range

Floor Coverage

- Spiral roll – least efficient but great mixing (0.3 to 0.5 % SOTE/ft)
- Cross roll and “ridge and furrow”
- Full floor coverage – most efficient
- Odd arrangements often work well
- Depth limited by blower restrictions

Floor Configurations

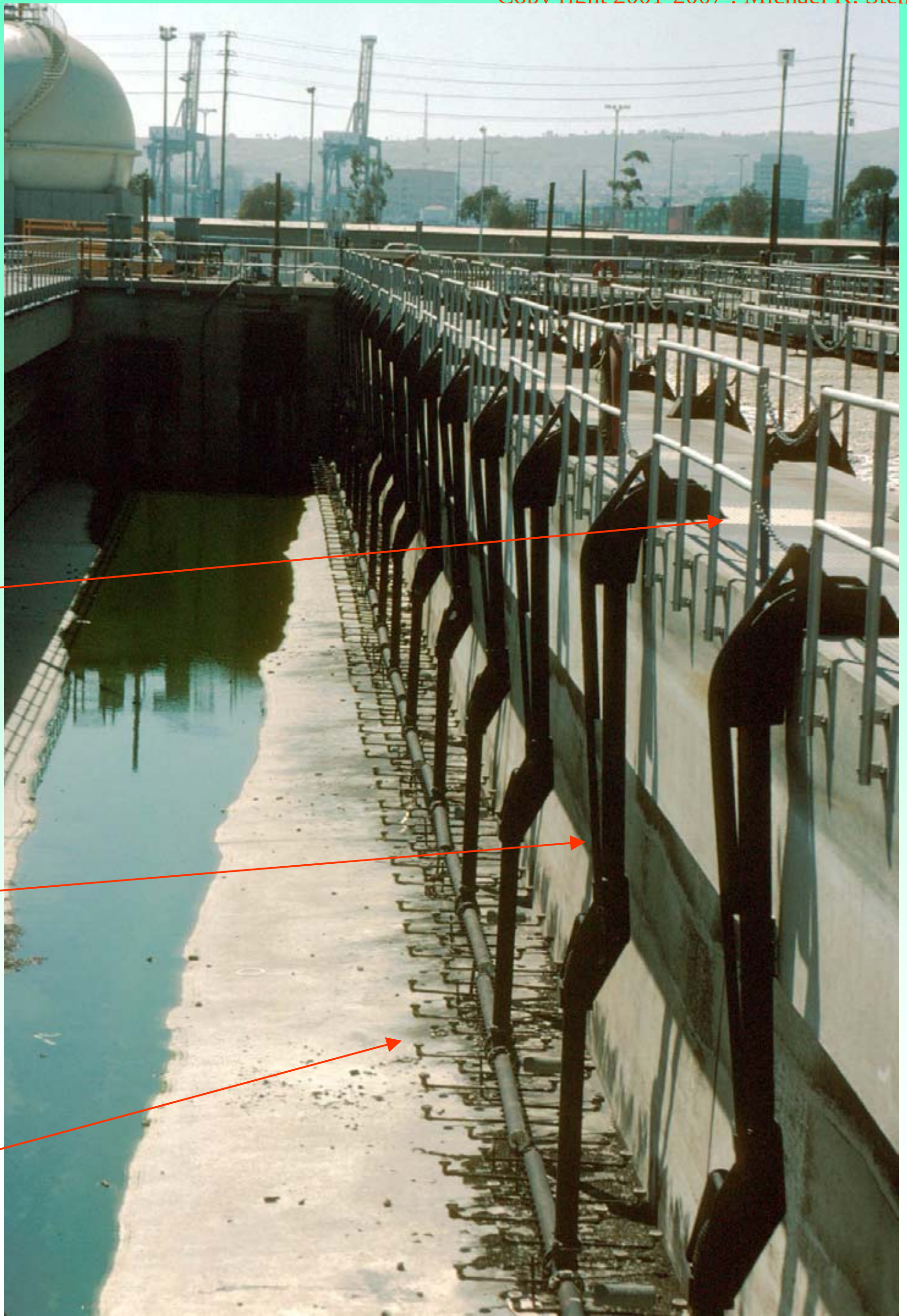


Spiral Roll – Empty Tank

Cut off valve under the deck for each arm

Swing Arms, with knee joint

Spargers



Retracted Swing Arm

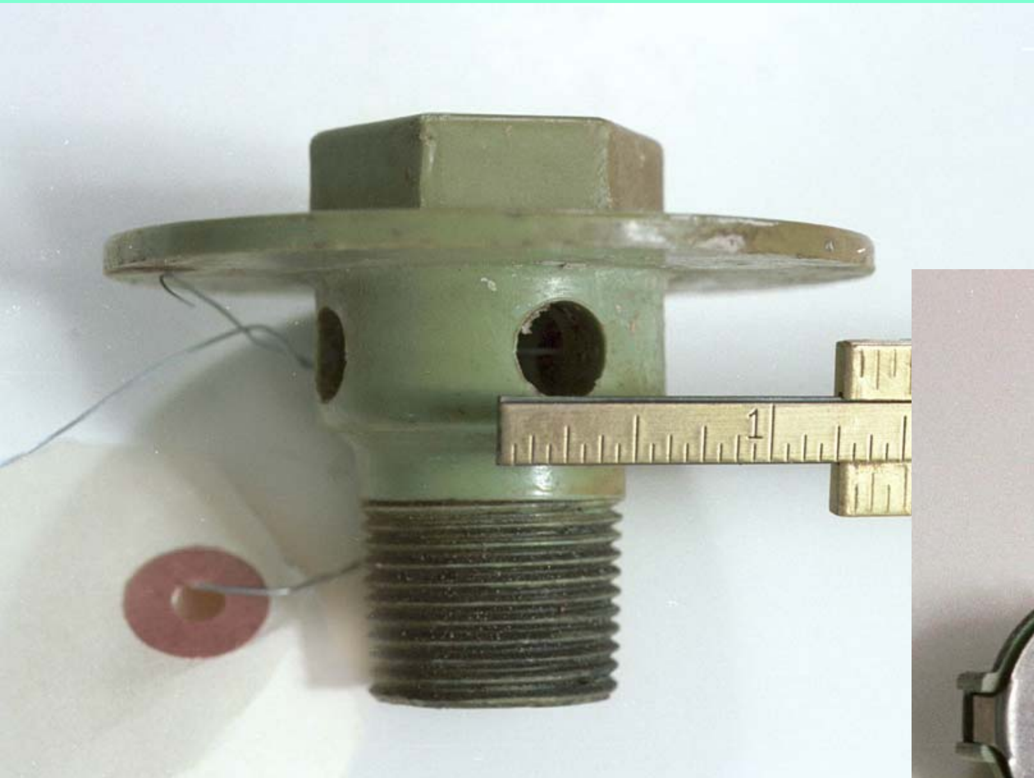
Knee Joint

Sparger

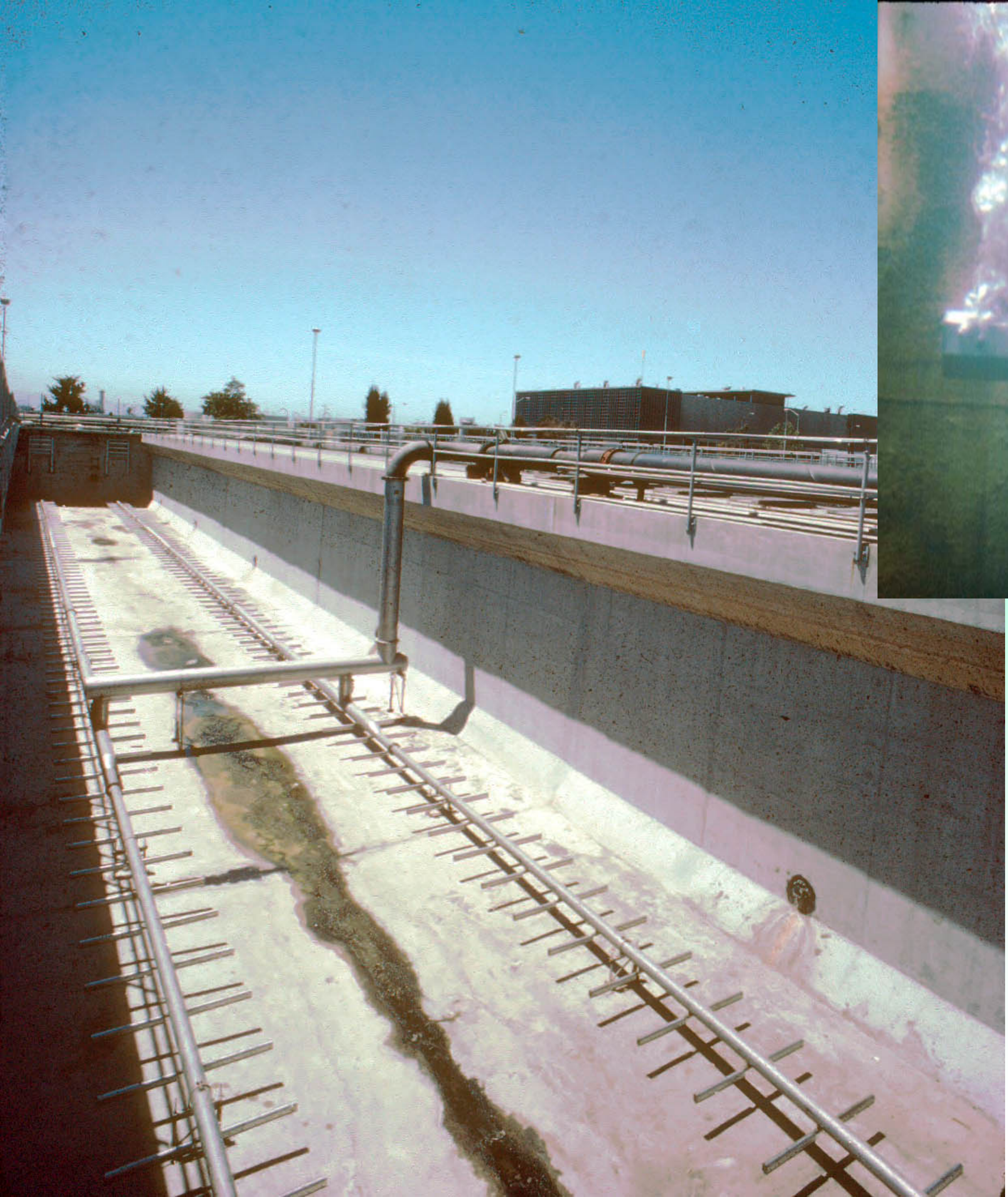
Cut off valve

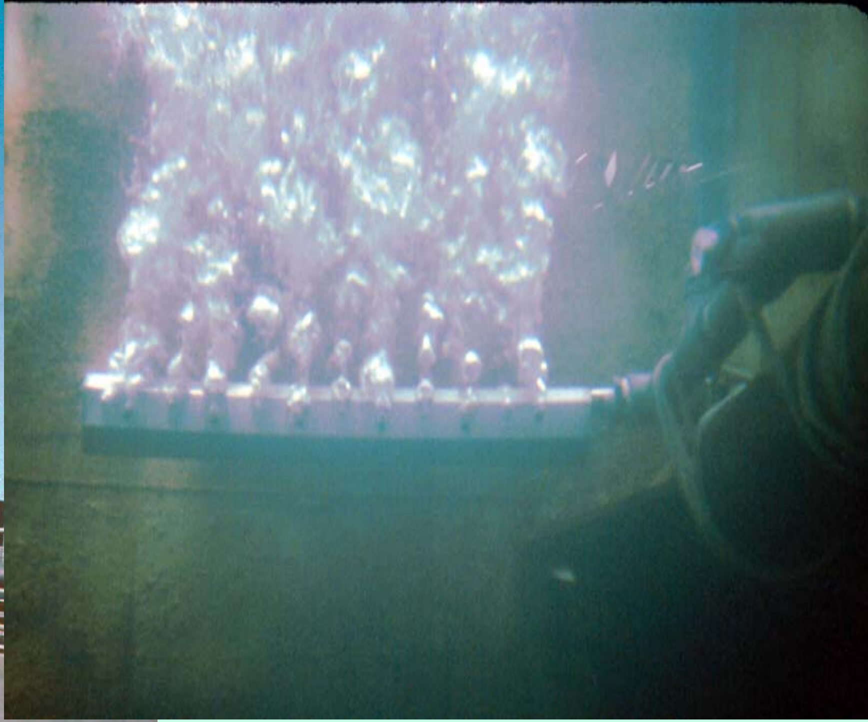
Swing Arm With Spargers

Spargers



Coarse Bubble – D24





Cross Roll System

Full Floor Coverage

Kenics static tube

Cells

Air Header

Fine Pore Diffusers

- Ceramic plates – original custom build systems
- Ceramic domes – imported from England, technology ruined in the US
- Ceramic discs – pioneered by Sanitaire
- Ceramic tubes – old and new versions
- Membrane discs – sometimes interchangeable with discs
- Membrane tubes – many manufacturers
- Plastic tubes and discs – some special uses
- Panels – proprietary geometry

Fine Pore Diffusers

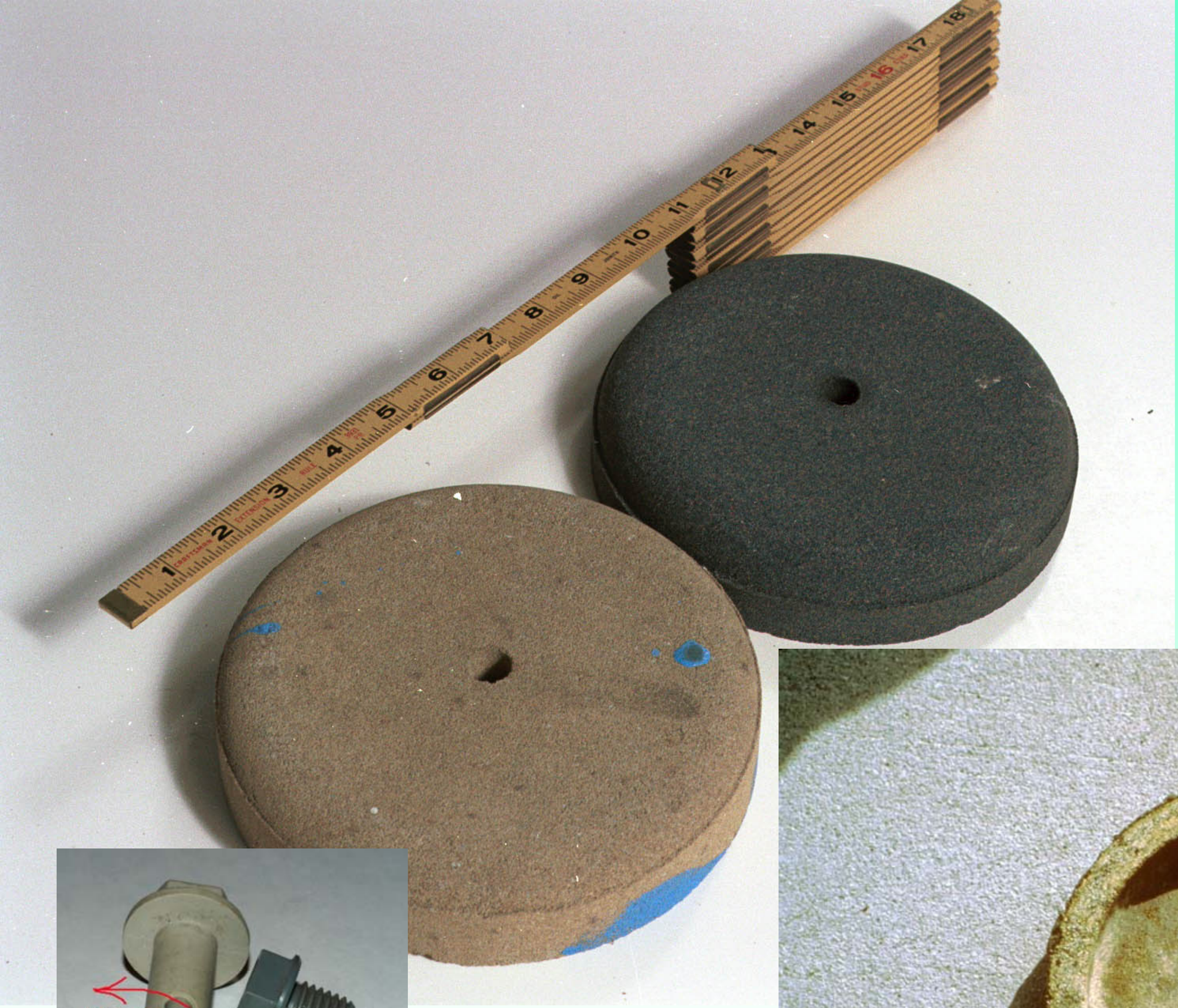
- **Usually implemented with full floor coverage**
- **Quiescent systems – low turbulence and low fluid velocities**
- **Suitable for low to medium rate systems**
- **Requires routine cleaning**
- **Highest efficiency of all the systems, *so far!* 8.0 SAE (4.8 kg O2/kW-hr)**
- **Best system to minimize VOC release**

Fine Pore Plates

Developed and used by many large US cities, in custom, site-specific designs.

Plastic Plates – An Old Idea With New Materials

Ceramic Domes



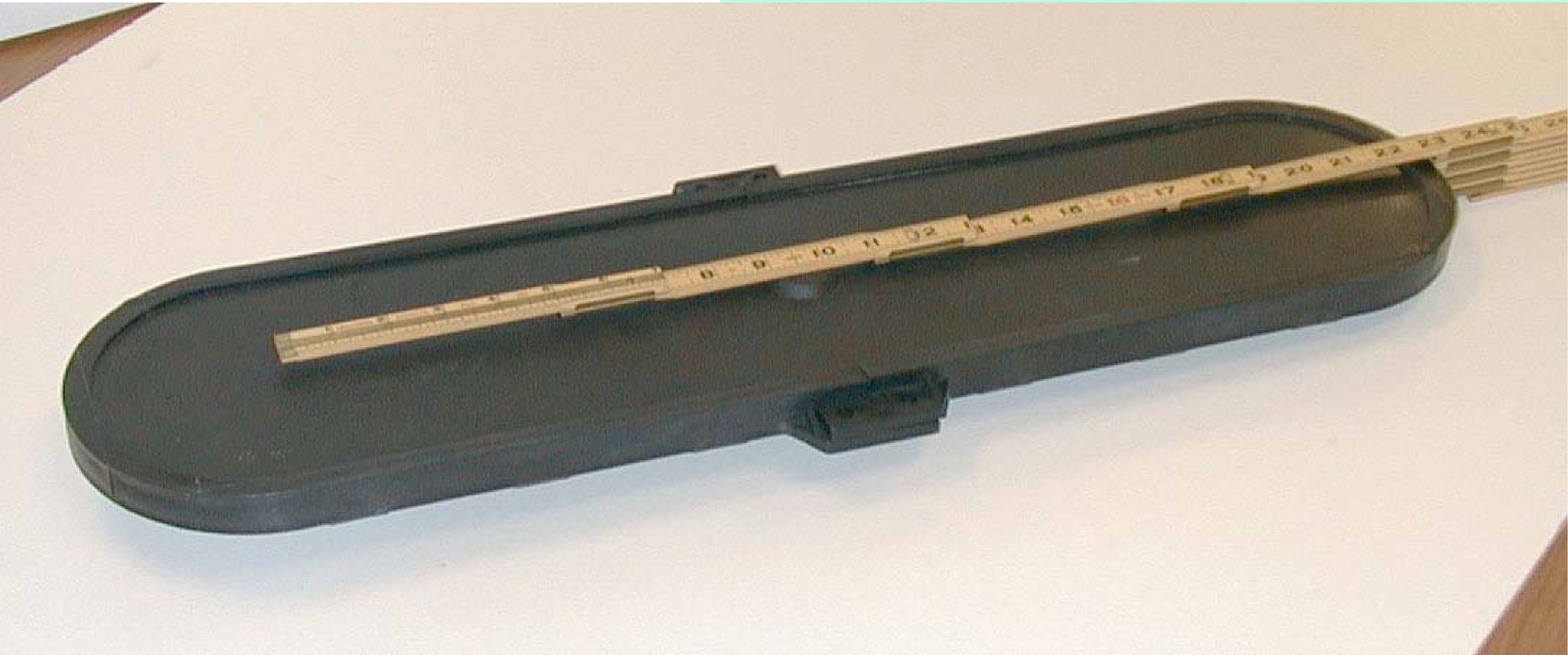
Domes On Air Headers

Ceramic Disc Diffusers

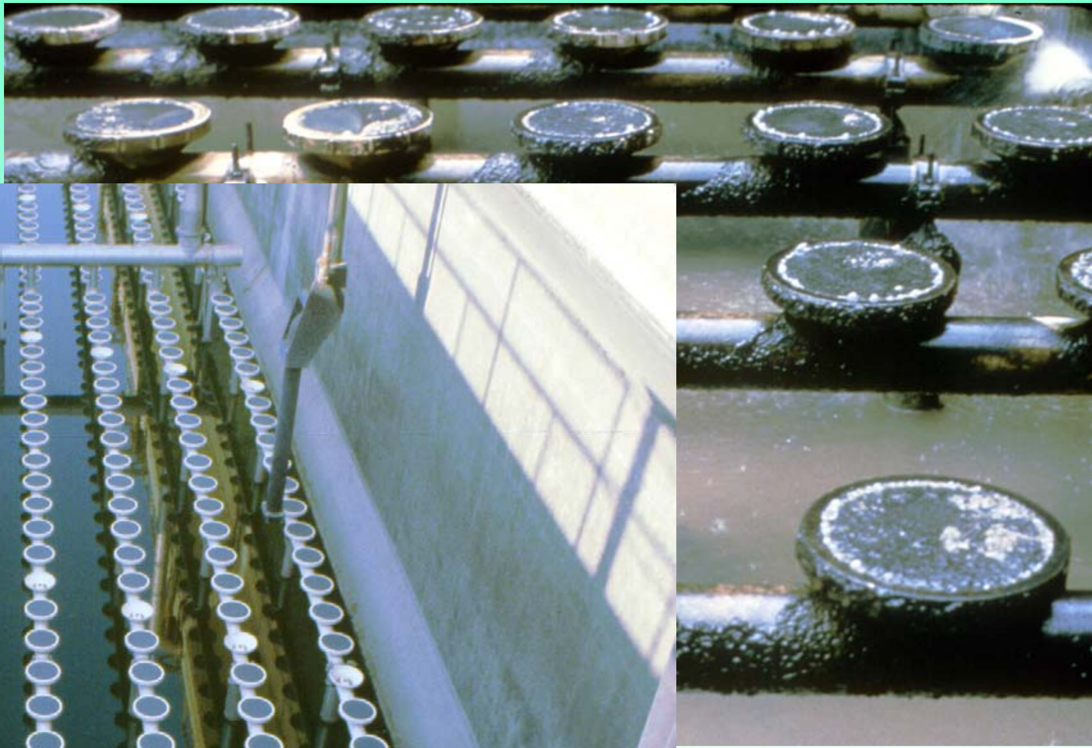
Membrane Discs

Other Discs

Mini Panel



Empty Tank With Discs



Saran Wrap Tubes

Five Different Tubes

EPDM

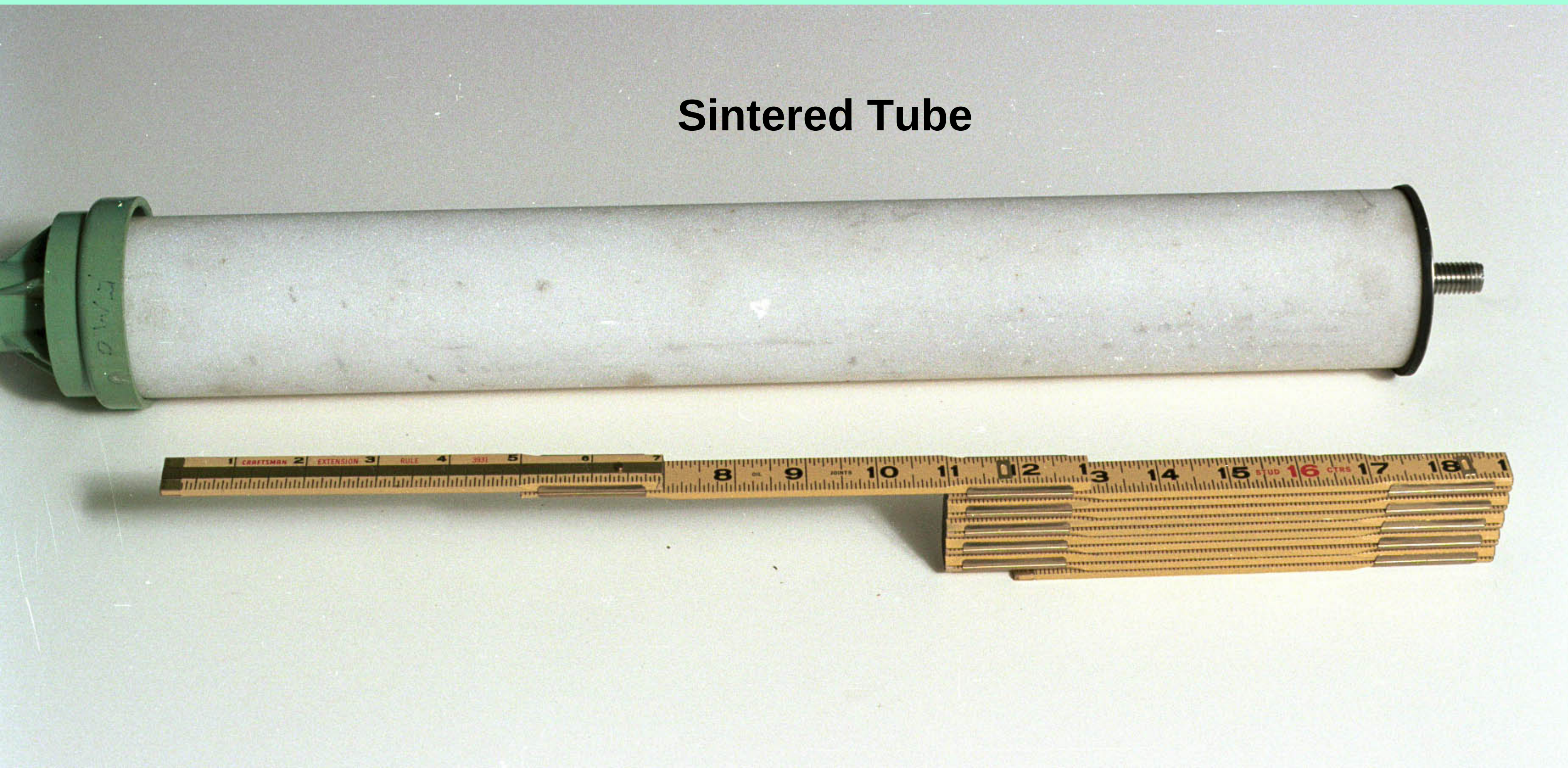
PVC

Ceramic

EPDM

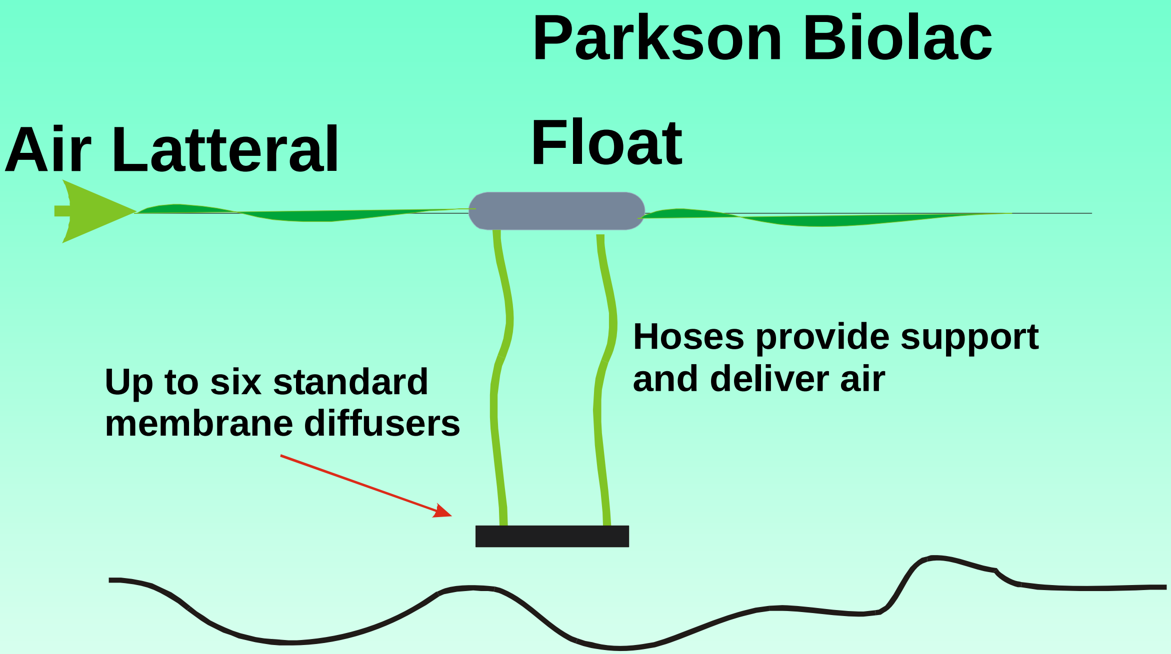
Plastic

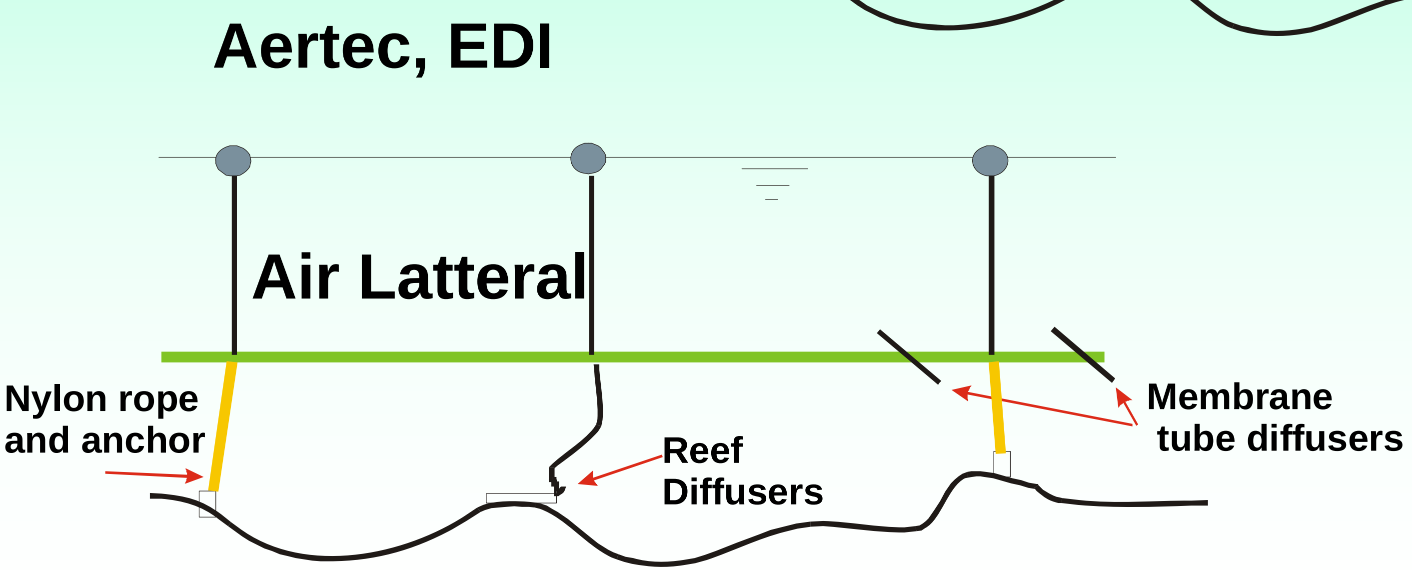
PearlComb Plastic

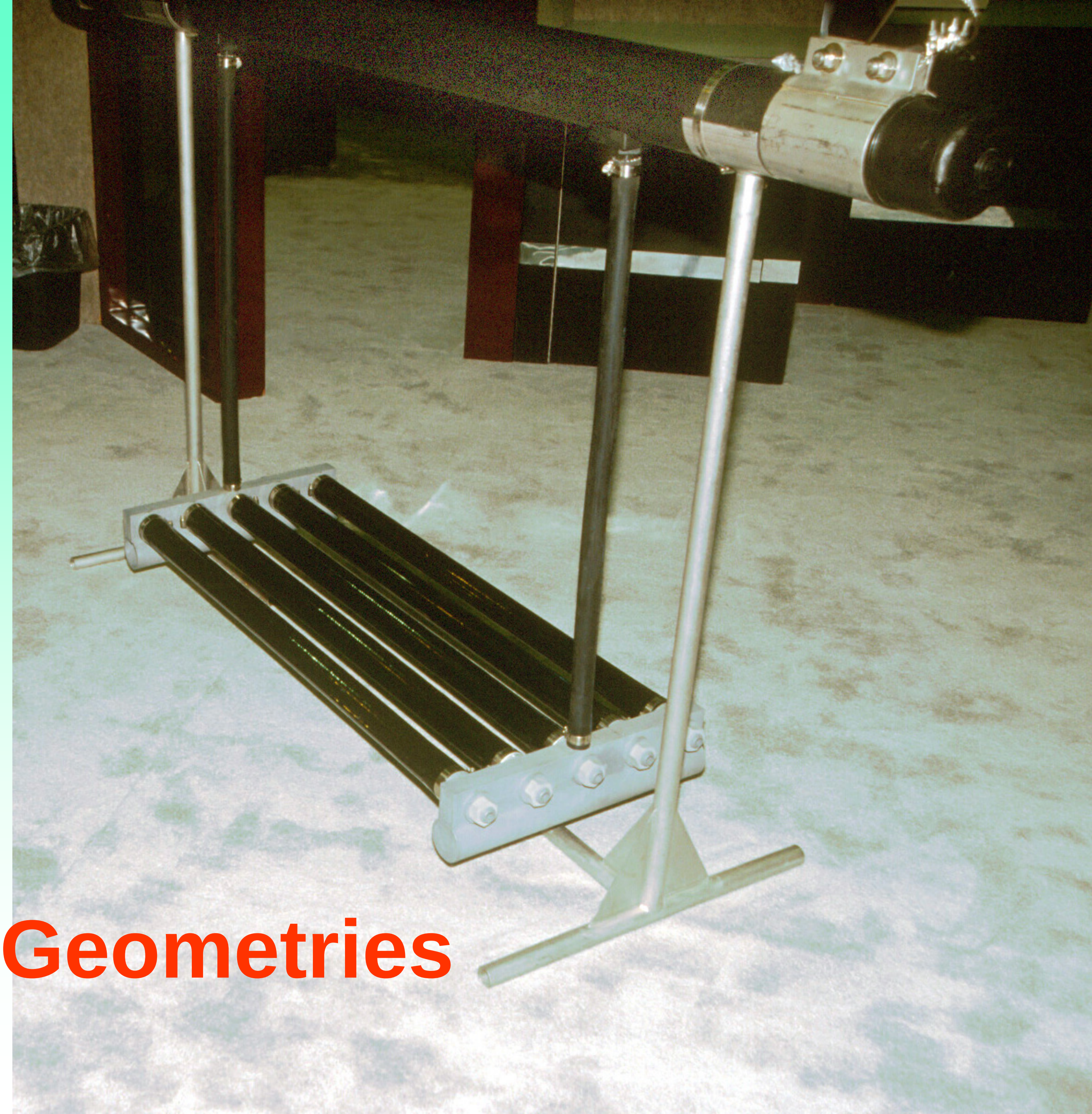


One Manufacturer's Offerings

Diffusers in Lagoons

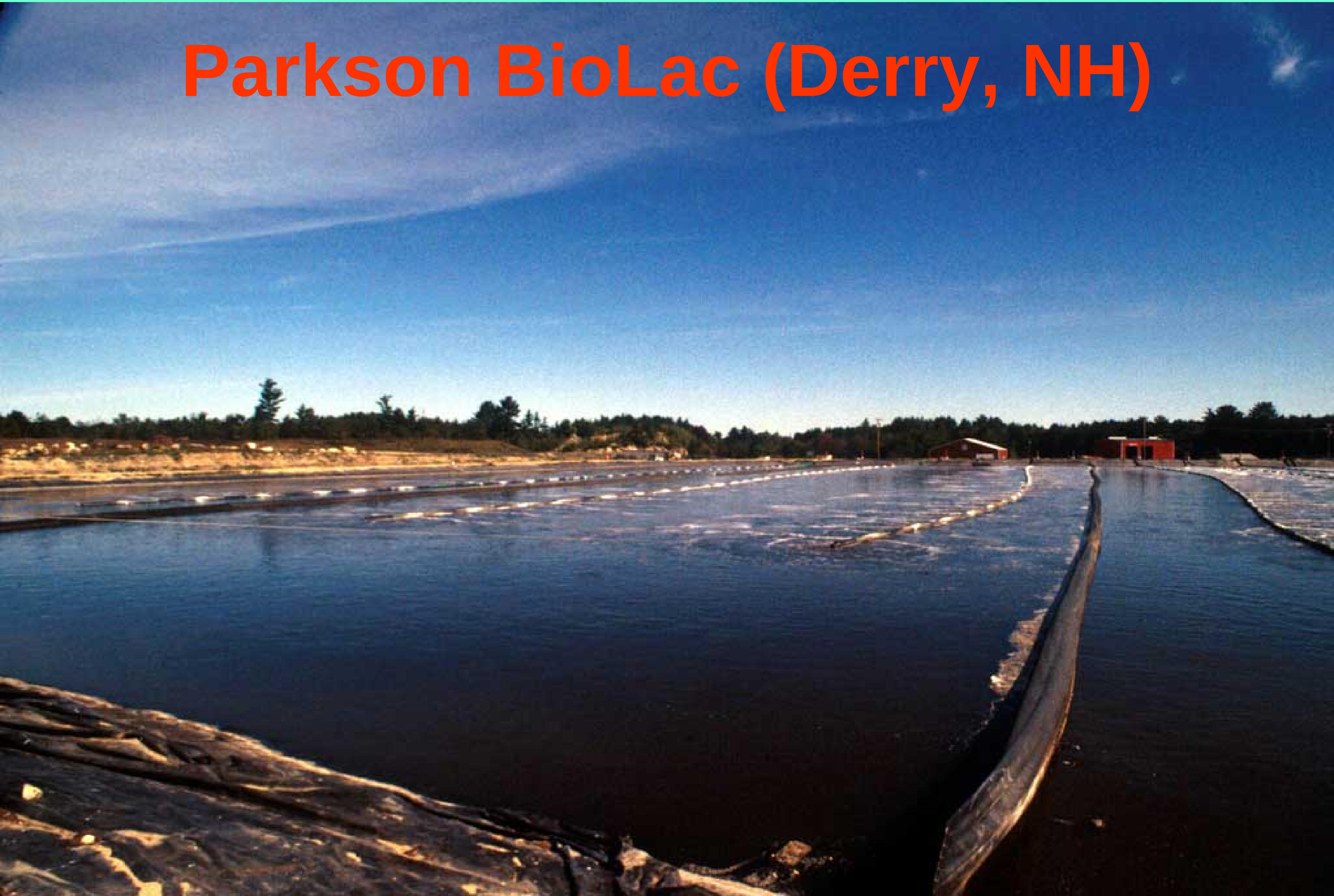


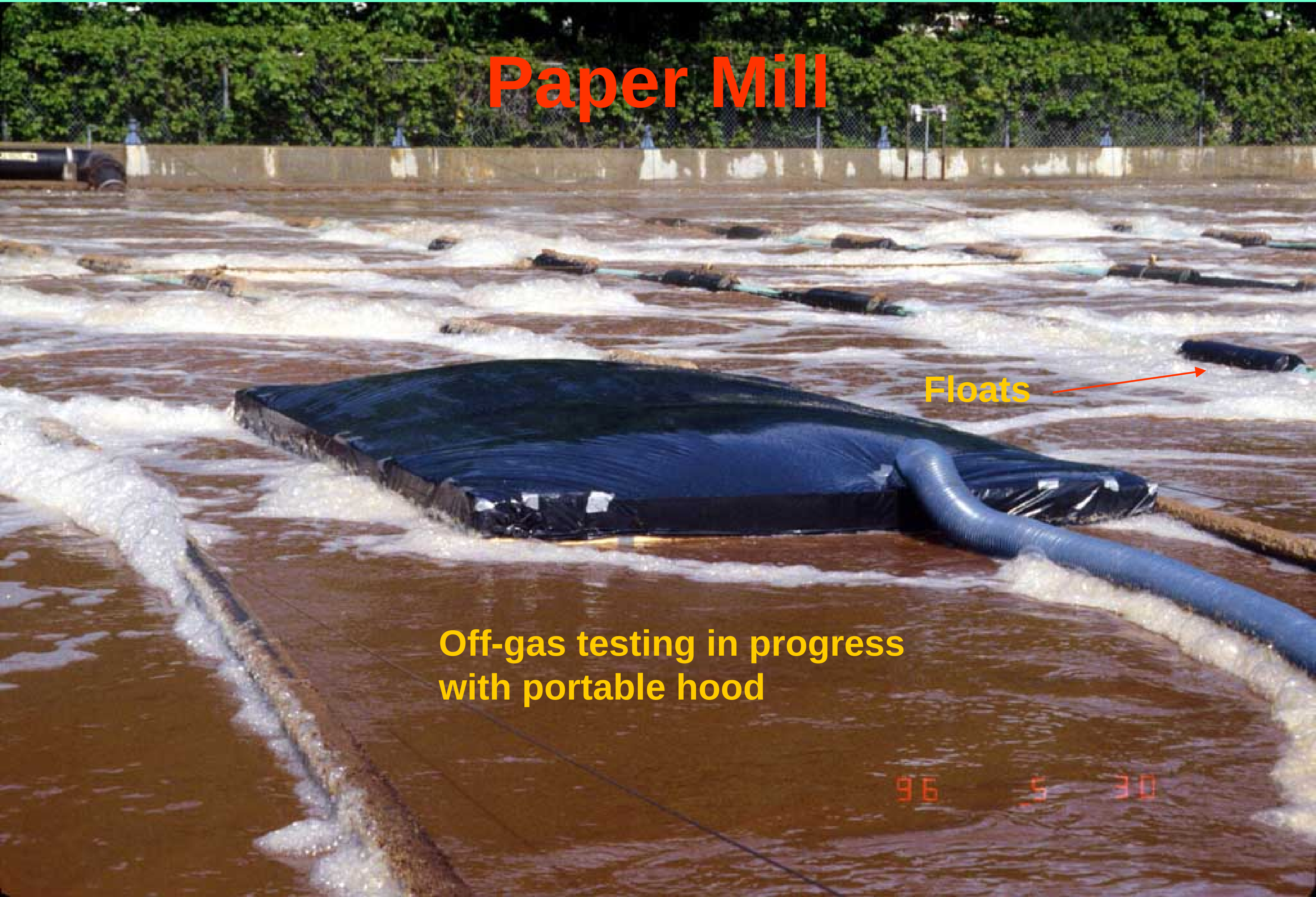




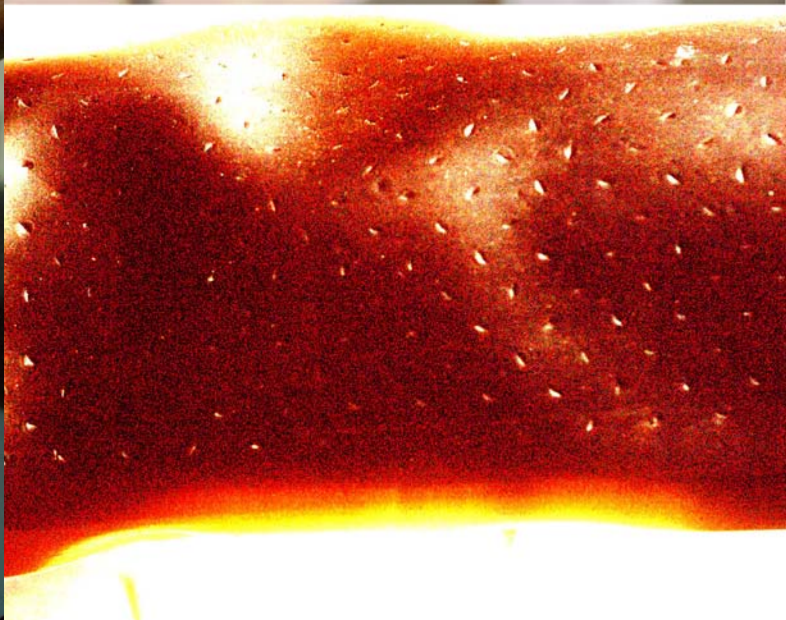
Special Geometries

Parkson BioLac (Derry, NH)

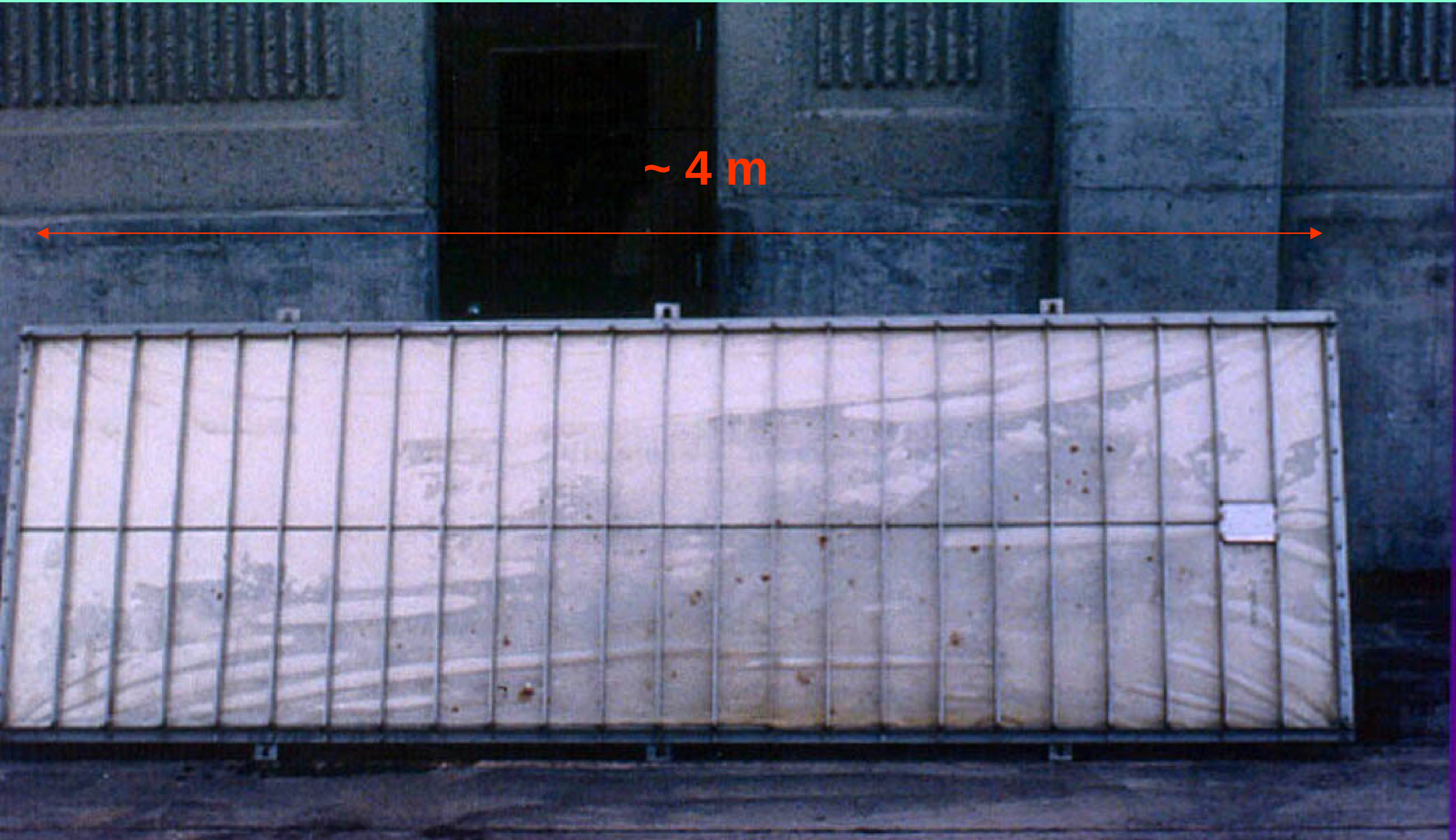



Paper Mill
Floats
Off-gas testing in progress
with portable hood
96 5 30

Diffuser Details

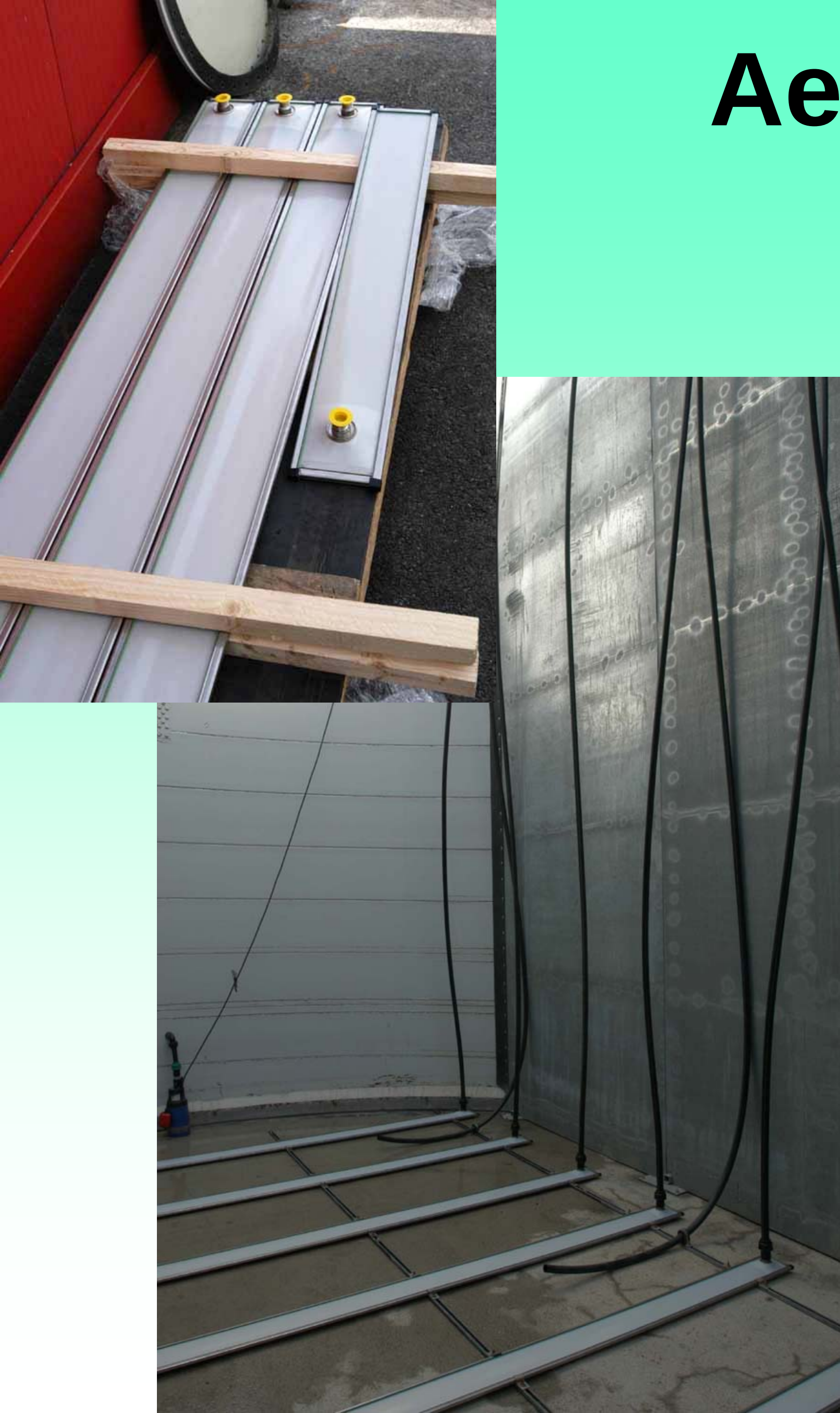


Panel Diffuser



Installed

Aerostrip

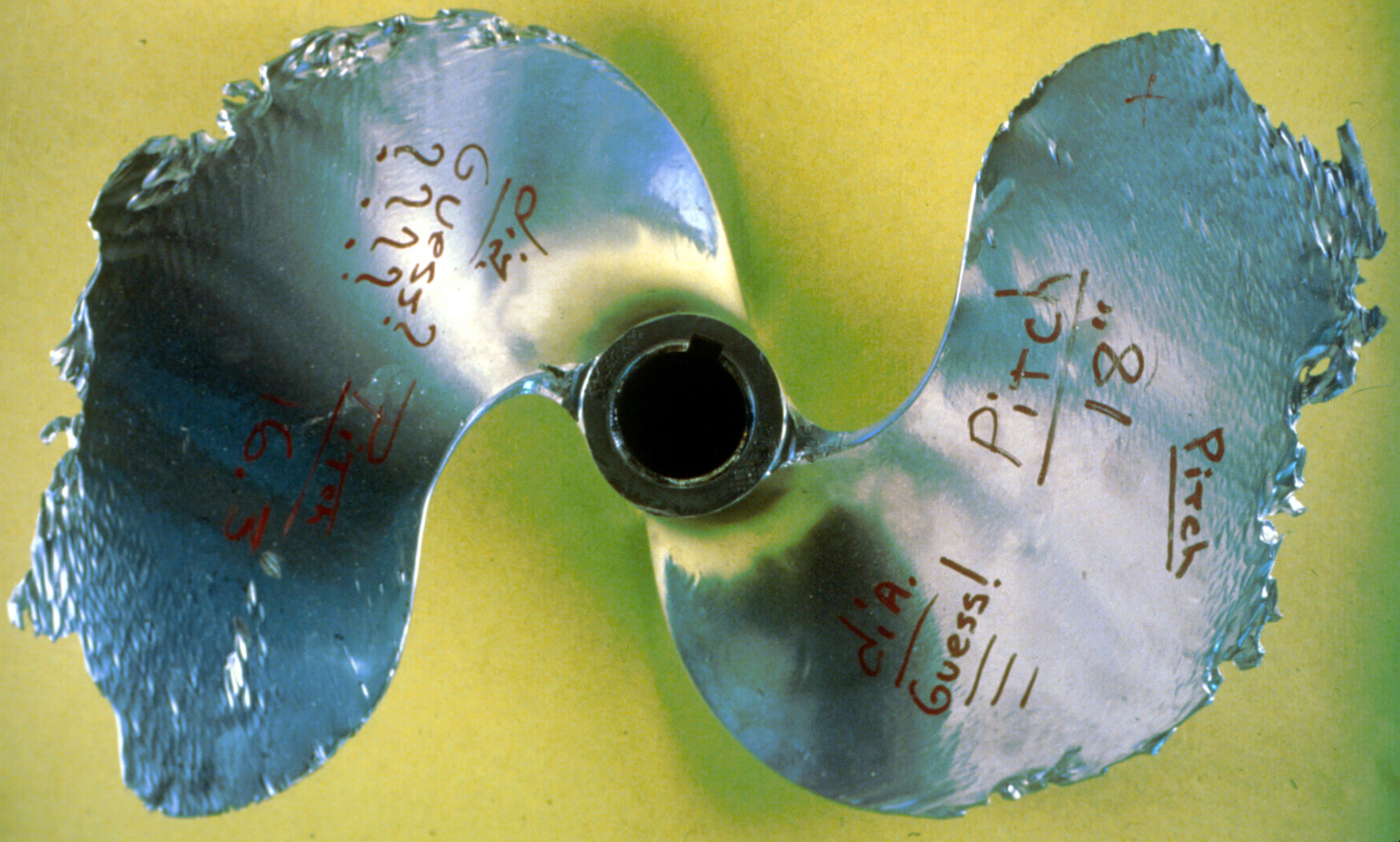


Mesner Panels

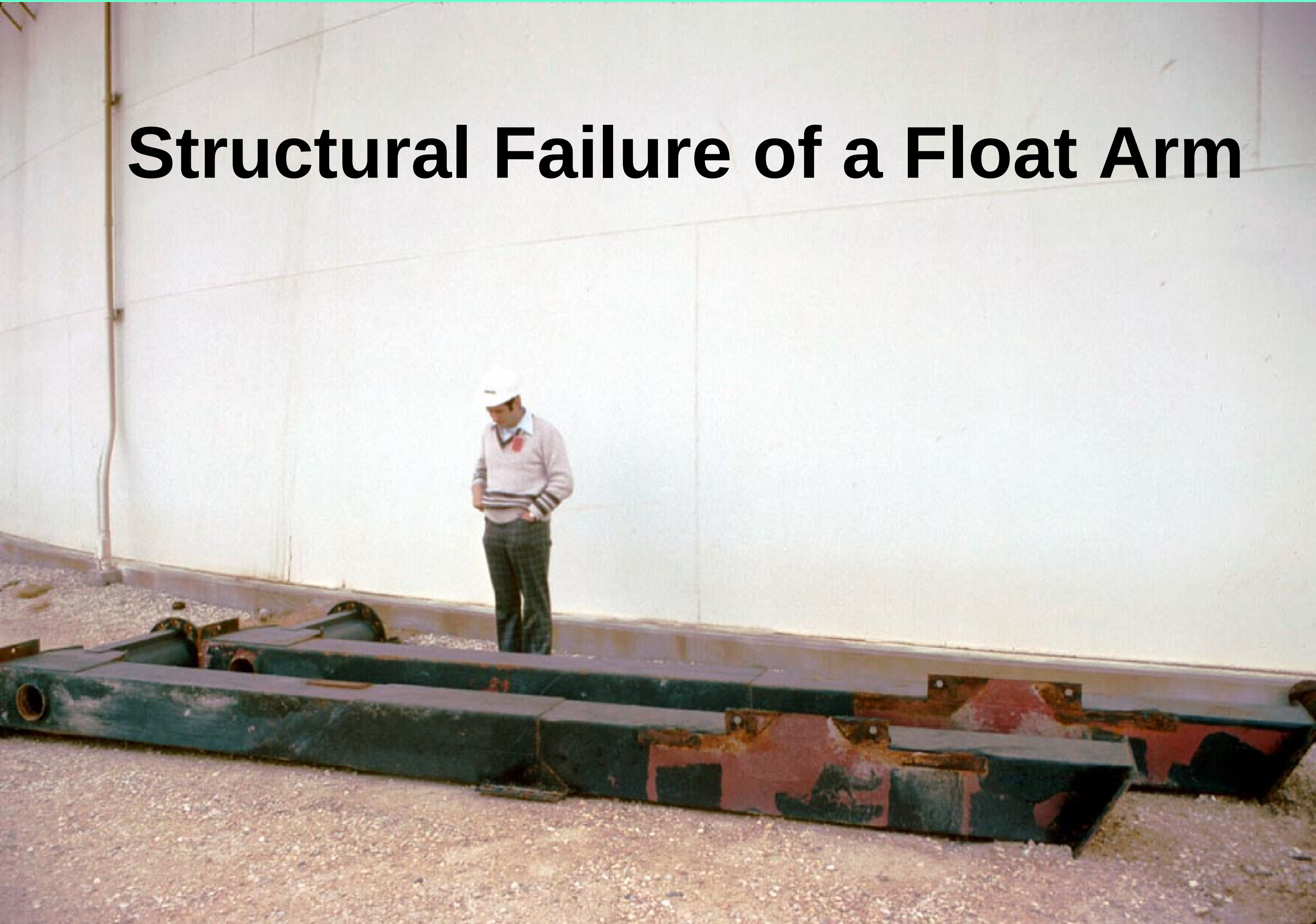
Surface Aerator Problems

- High speed
  - Freezing
  - Impeller wear
  - Bearing failure
- Low speed
  - Gear box failures
  - Structural failures
  - Surging, oscillation, unstable conditions
  - Impeller or hub failure

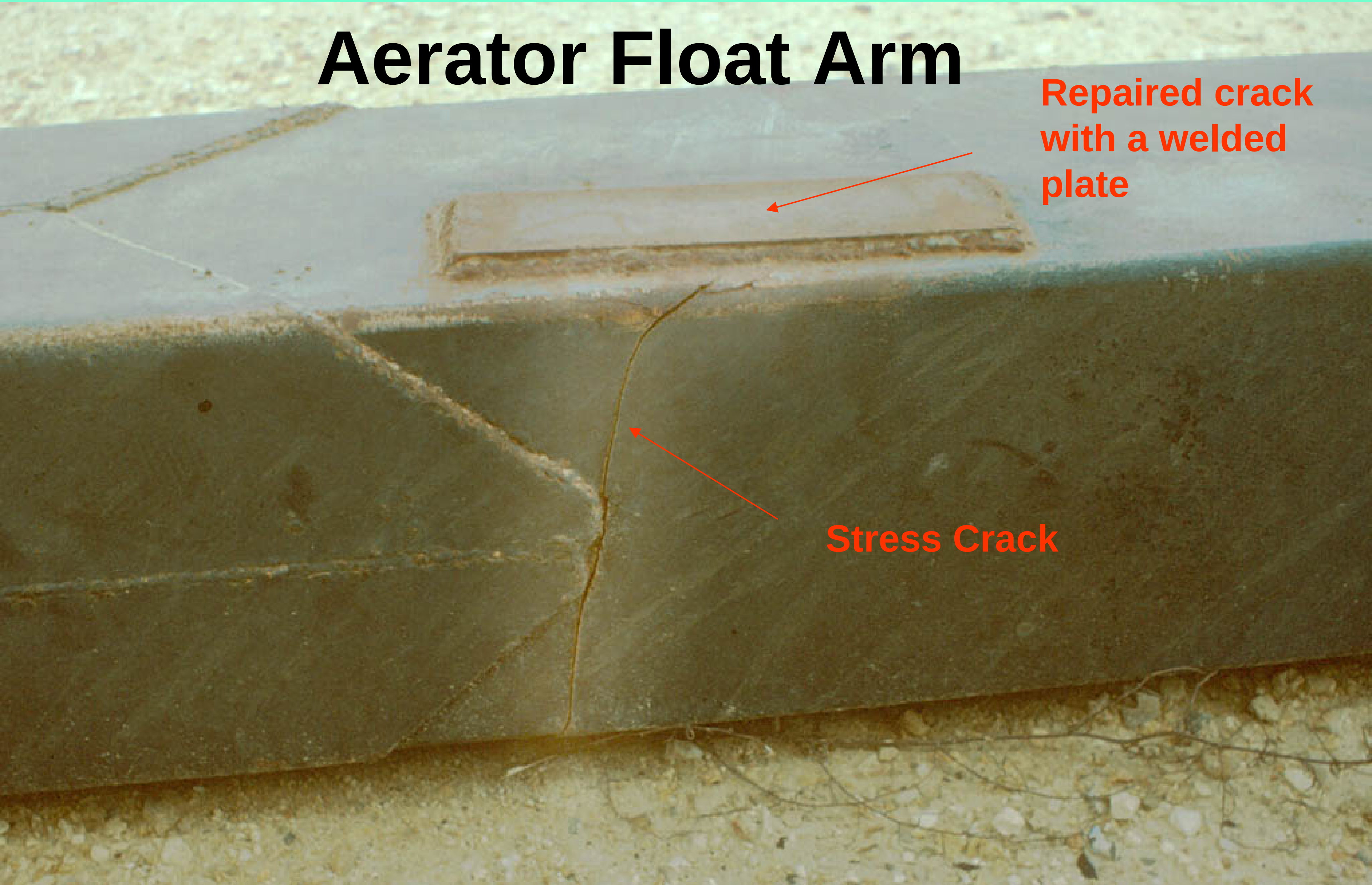
Impeller Damage



Structural Failure of a Float Arm



Structural Failure of an Aerator Float Arm



Diffused Aerator Problems

- Coarse bubble
  - Piping failure
  - Corrosion
  - Leaks
- Fine pore
  - Fouling (biological)
  - Scaling (chemical)
  - Leaks into the piping system that foul diffusers
  - Back pressure build up
  - Material failures (membrane problems)
  - Piping failures
  - Leaks

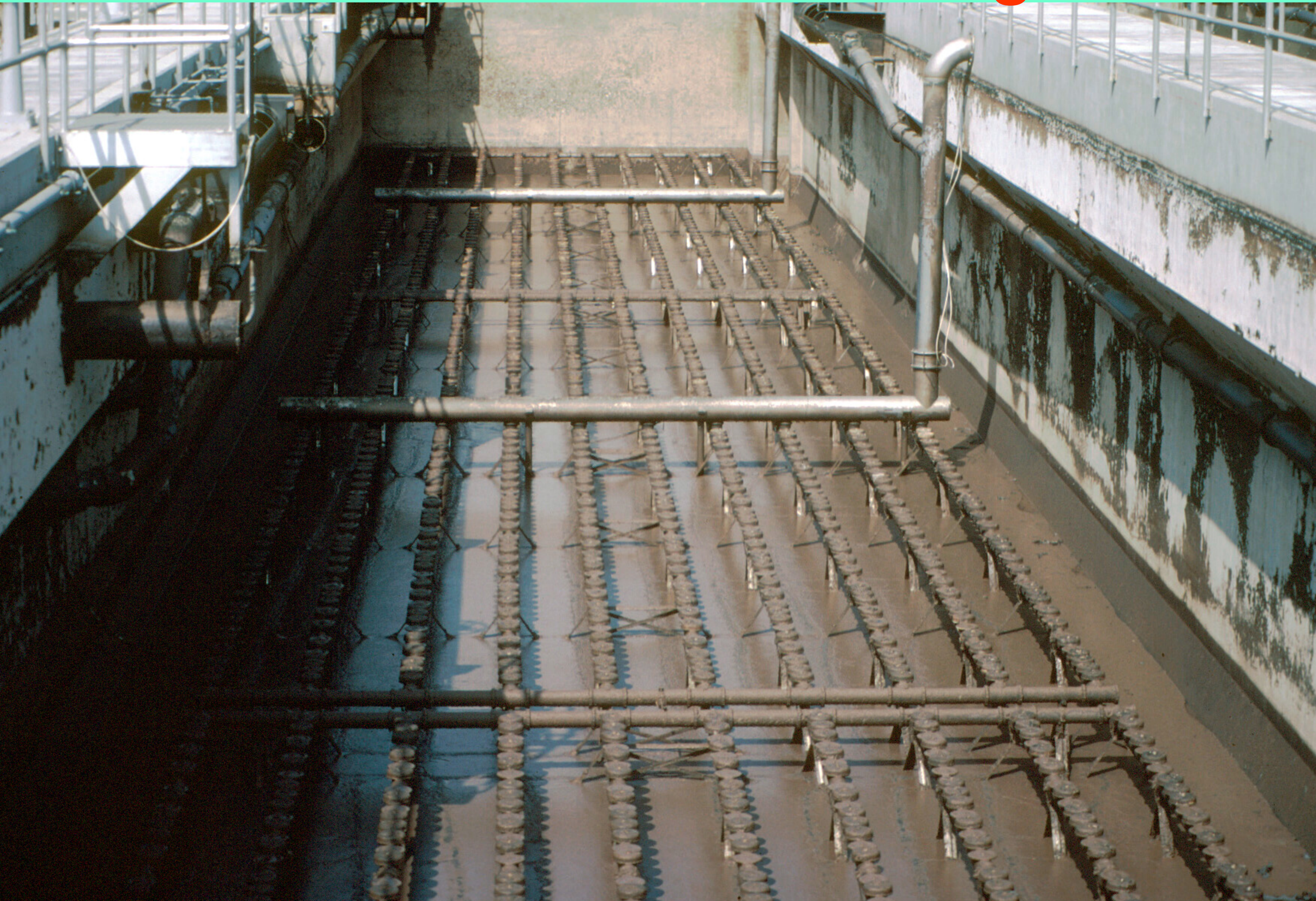
Material Failures

- Hardening of the membrane from leaching of membrane components, resulting in increased pressure drop and reduced efficiency
- Softening of the membrane due to absorption of wastewater constituents, resulting in membrane expansion, increased pressure drop and reduced efficiency
- Change in pore size due to aging

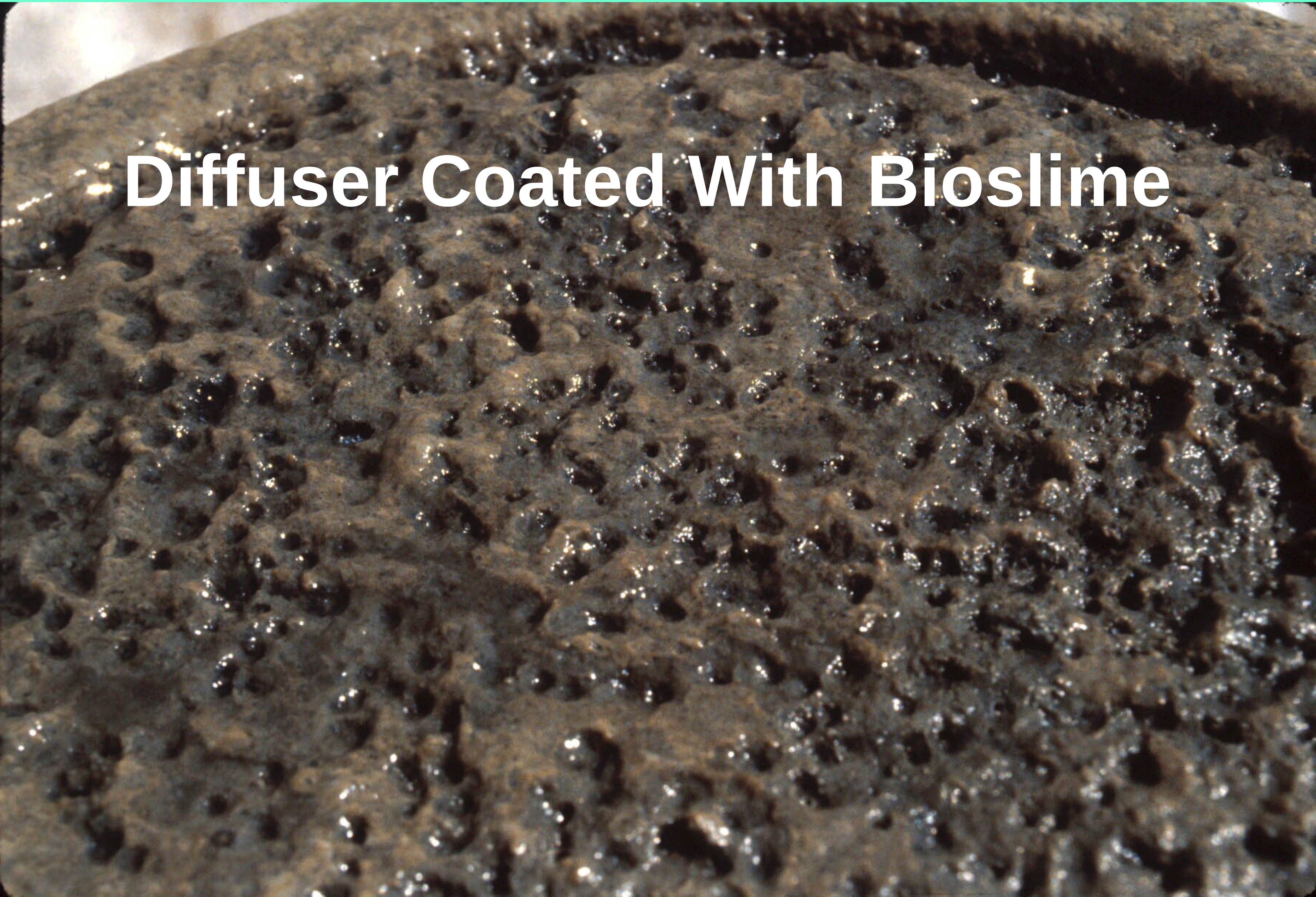
Fouling and Scaling

- Fouling – biological growth on diffuser surfaces, coalescing bubbles, increasing pressure drop
- Scaling – precipitation of minerals (calcium carbonate, silica)
- Fouling from the inside due leaks into the piping system

Tank Before Cleaning



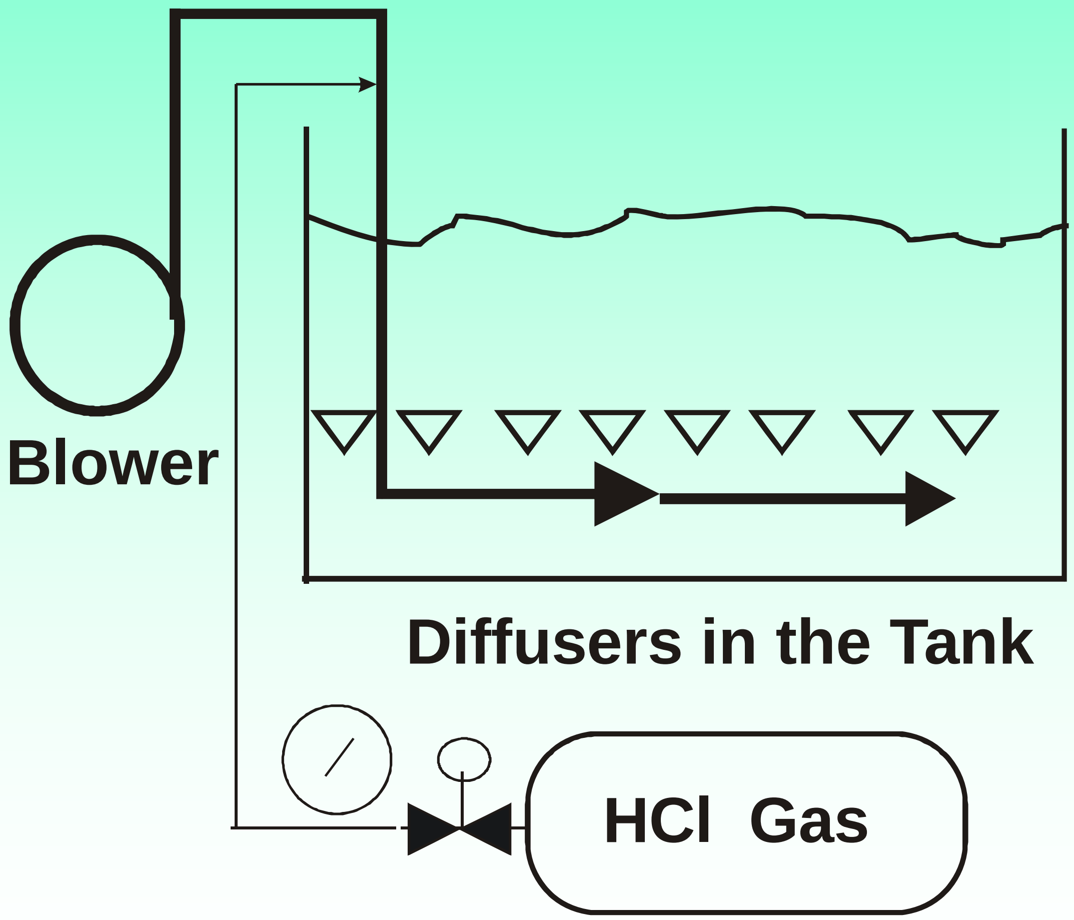
Tank With Partial Cleaning From Hosing


Diffuser Coated With Bioslime


Liquid Acid Cleaning
ACID

HCl Gas Cleaning

HCl Gas is introduced into the air headers and flows through the diffusers, dissolving salts



Experimental Setup

Some Energy Approximations*

Aerator Type	SAE lbO2/hp-h (kgO2/kW-h)	Low SRT AE at 2 mg/L DO	High SRT AE At 2 mg/L DO
High Speed	1.5–2.2 (0.9–1.3)	0.7–1.4 (0.4-0.8)	
Low Speed	2.5–3.5 (1.5–2.1)	1.2-2.5 (0.7–1.5)	
Turbine	2-3 (1.2-1.8)	0.6-0.9 (0.4-0.6)	0.9-1.4 (0.6-0.8)
Coarse Bubble	1-2.5 (0.6 –1.5)	0.5 – 1.2 (0.3-0.7)	0.6–1.6 (0.4-0.9)
Fine Pore	6–8 (3.6–4.8)	1.2-1.6 (0.7–1.0)	3.3-4.4 (2–2.6)

*Use at your own peril!

Final Thoughts

- Engineers have a wide range of options for aeration
- Mechanical aerators
  - High speed – simple quick solution, usually not best on any specific parameter
  - Low speed - expensive but can be relatively efficient, good mixing
  - Both have high cooling rates and high VOC stripping rates. Not recommended for cold applications
  - Good for lagoons

Final Thoughts

- Coarse bubble diffusers
  - Low maintenance
  - Low efficiency
  - Never a good energy conserving solution but often the maintenance free solution
- Fine pore (bubble)
  - Best energy conservation
  - High maintenance
  - Commit to clean or do not purchase
- Design standards exist to assist manufacturers, designers and owners