University of California, Los Angeles

Aeration Systems Past, Present and Future. What to Expect from Aeration System Upgrades

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Outline

- Aeration system types
- Terminology
- Mechanical (surface) aerators and combined (jets and turbines)
- Diffused aeration
  - Coarse
  - Fine pore
- Current Performance Estimates
- Maintenance and Economics
- Conclusions

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 O_2/hr or kg O_2/hr
- SAE – lb O_2/hp-hr or kg O_2/kW-hr
- All above at standard conditions (e.g. 20^{o}C, clean water, etc.)
- OTE, OTR, AE – at process conditions

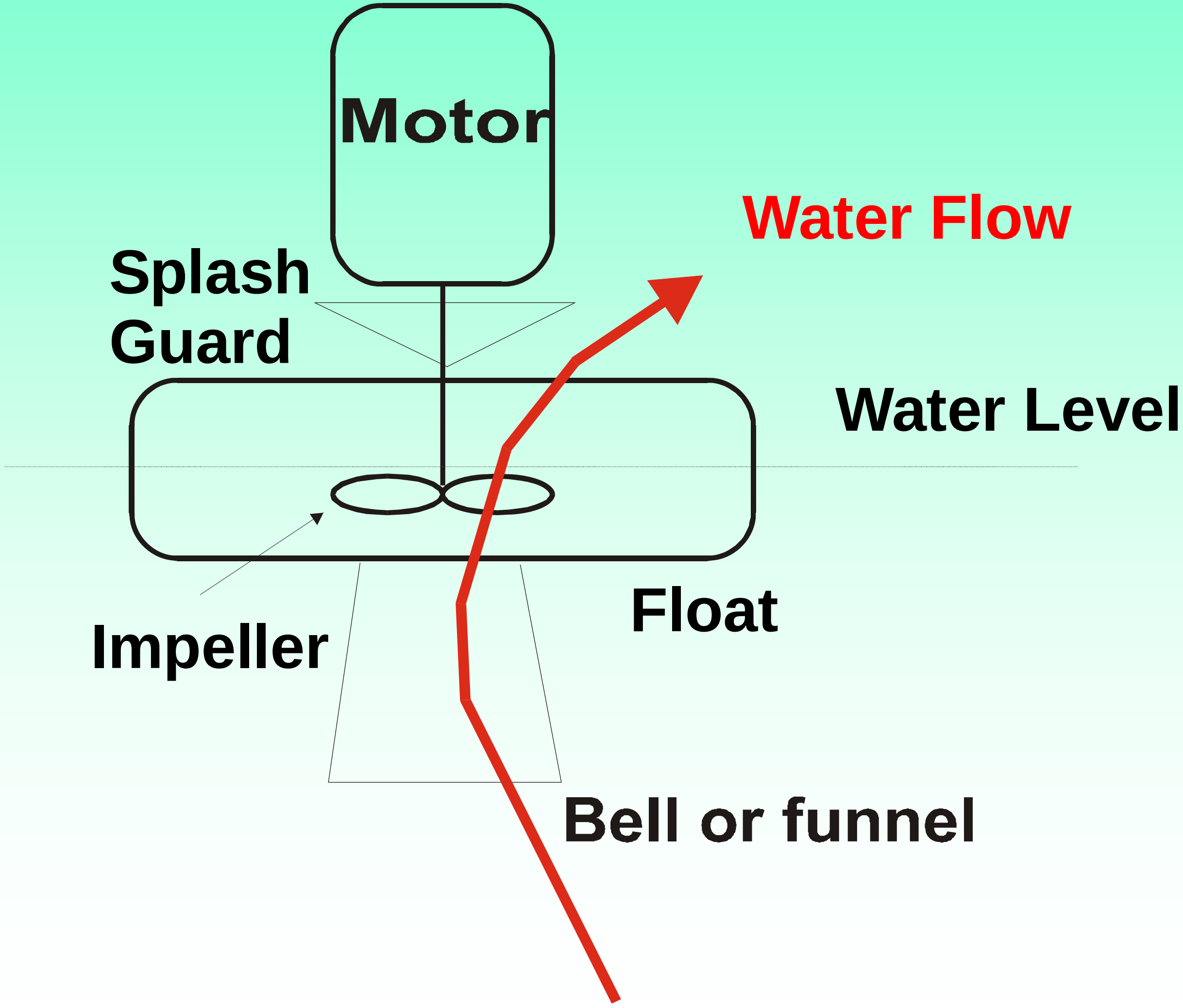
Standard and Process Conditions

- 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)



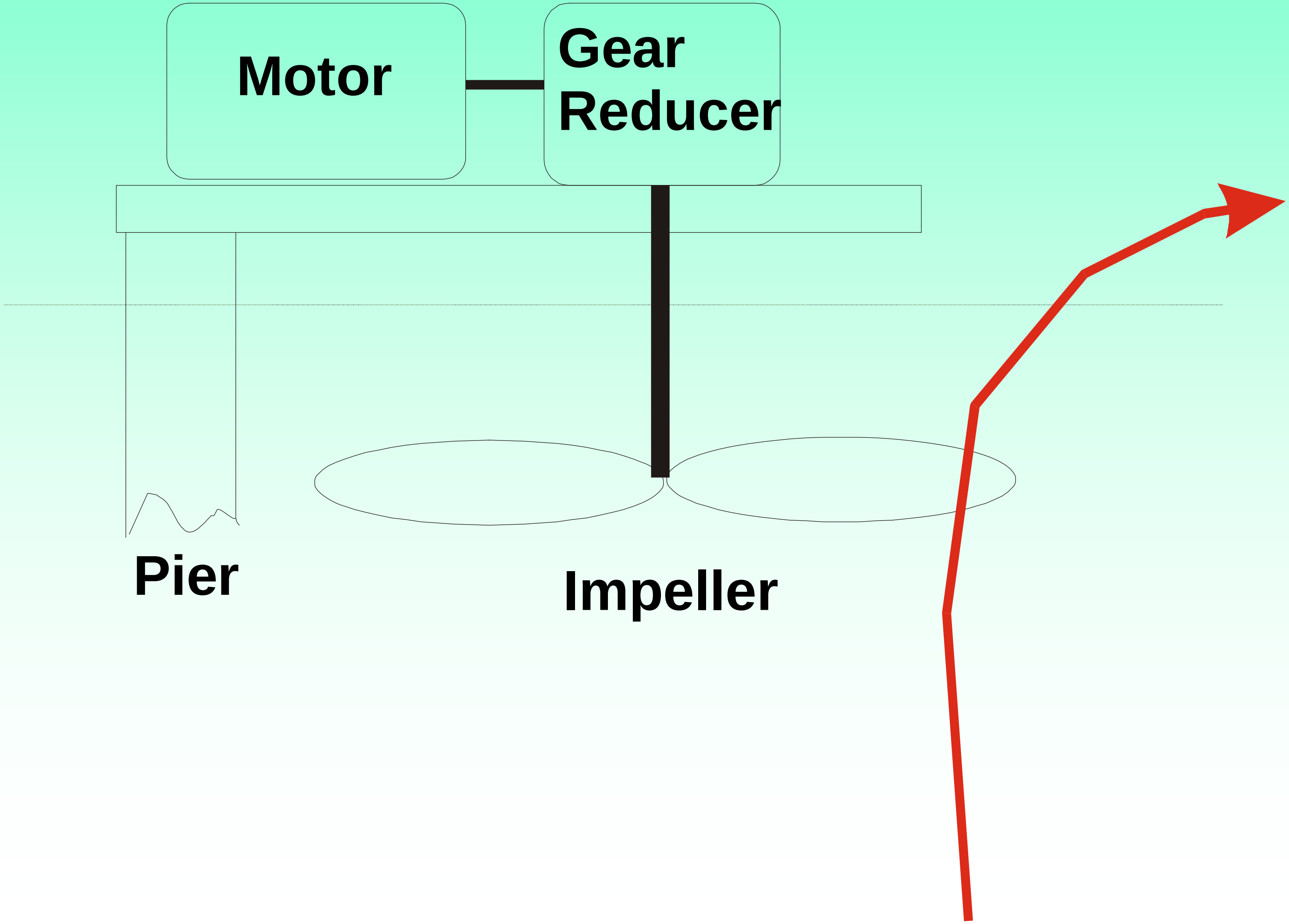
Specifications

- 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
- Quick installation, quick delivery
- 8 ft (2.5 m) depth without draft tubes

High Speed – Out of Service

For Sale !!!!

Low Speed Vertical (Radial Pumping)

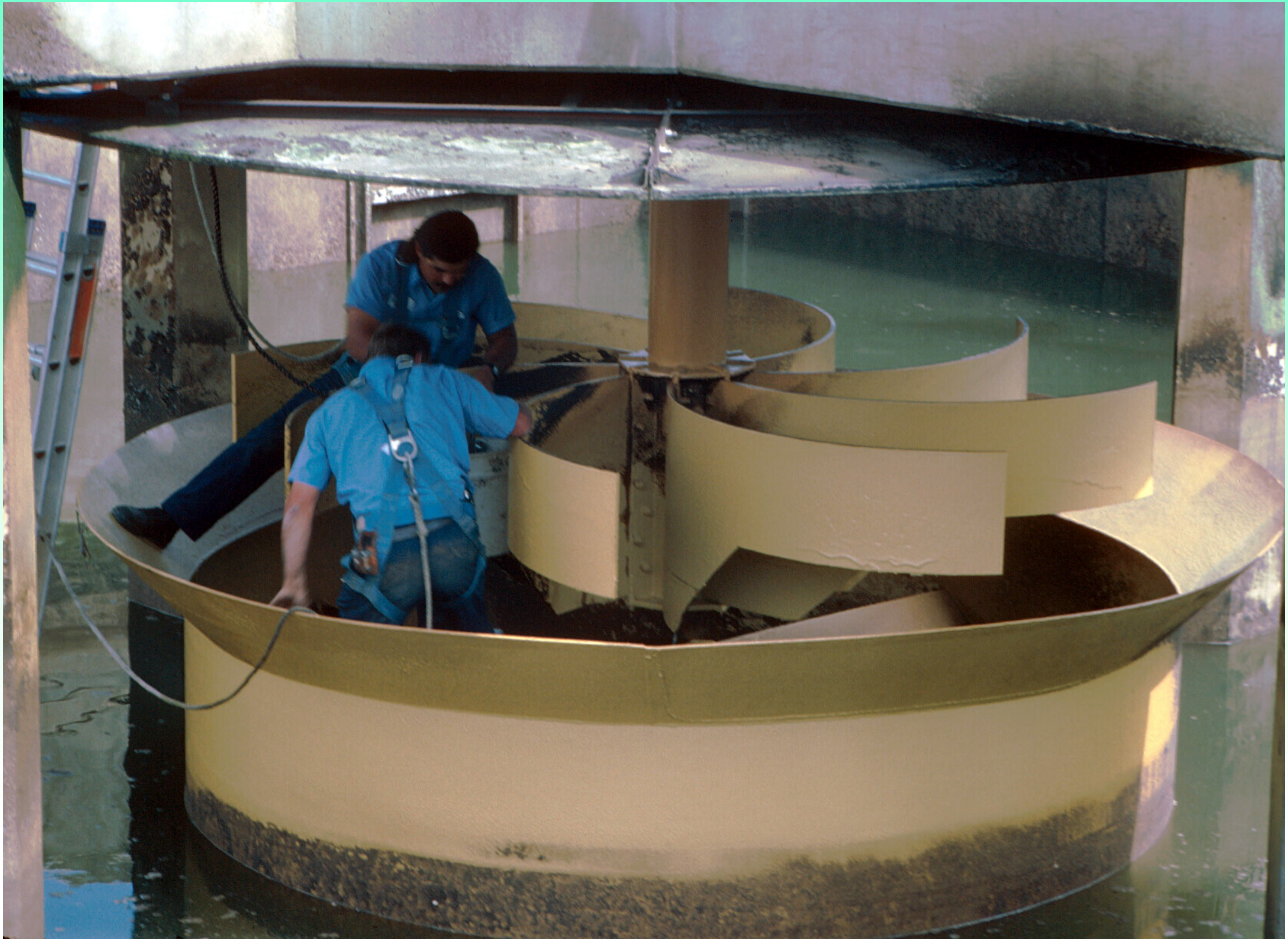


Specifications

- 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
- Less potential for floc shear
- Lower impellers and draft tubes for operation at greater depth
- New impeller designs

In Service

Maintenance



HPO-AS Application

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)

Down Draft Turbine

Motor/Gear

Support Columns

Impeller

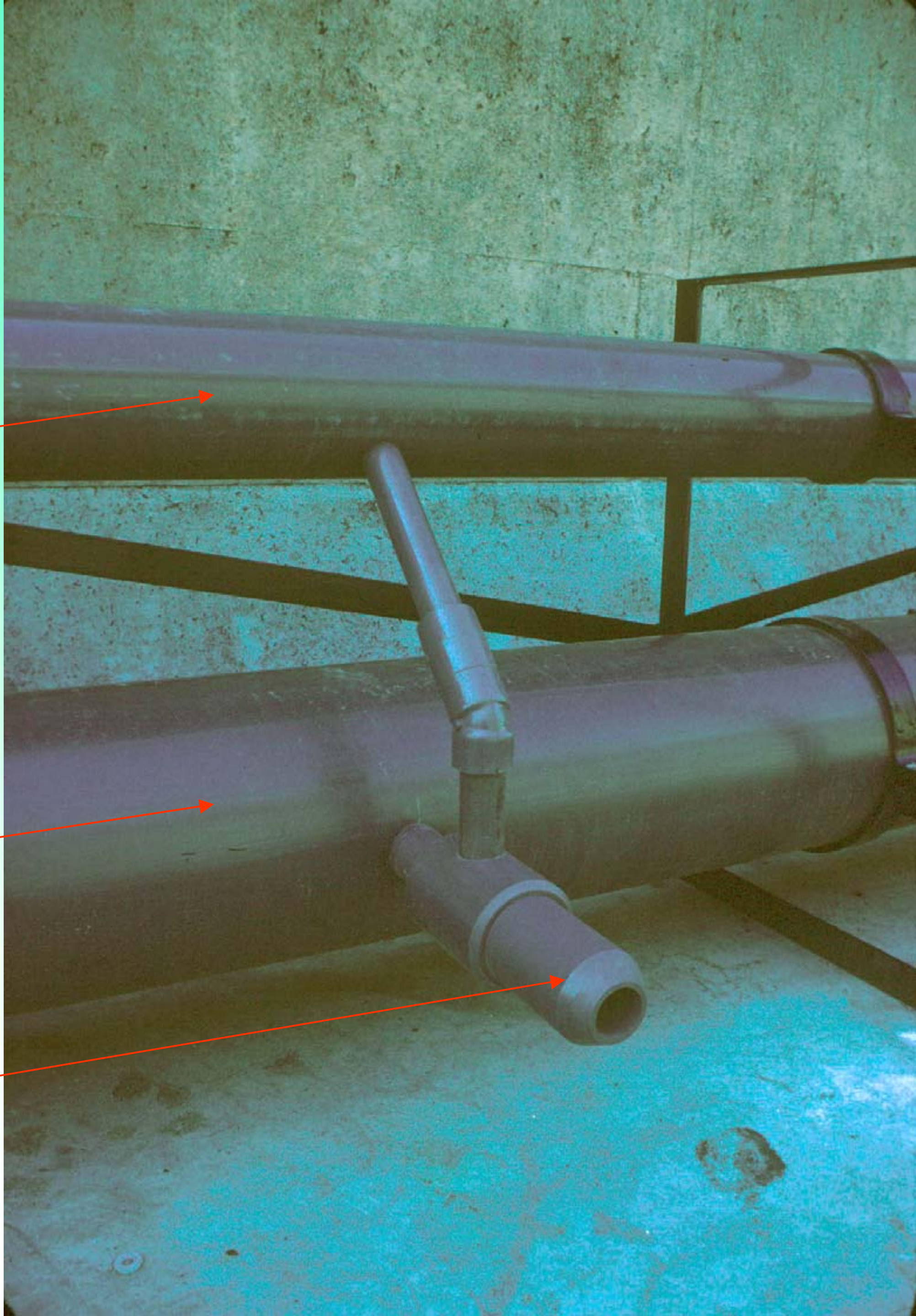
Draft Tube

Nozzle and Piping

Air Supply

Mixed Liquor Supply

Nozzle



Aspirating Mixer

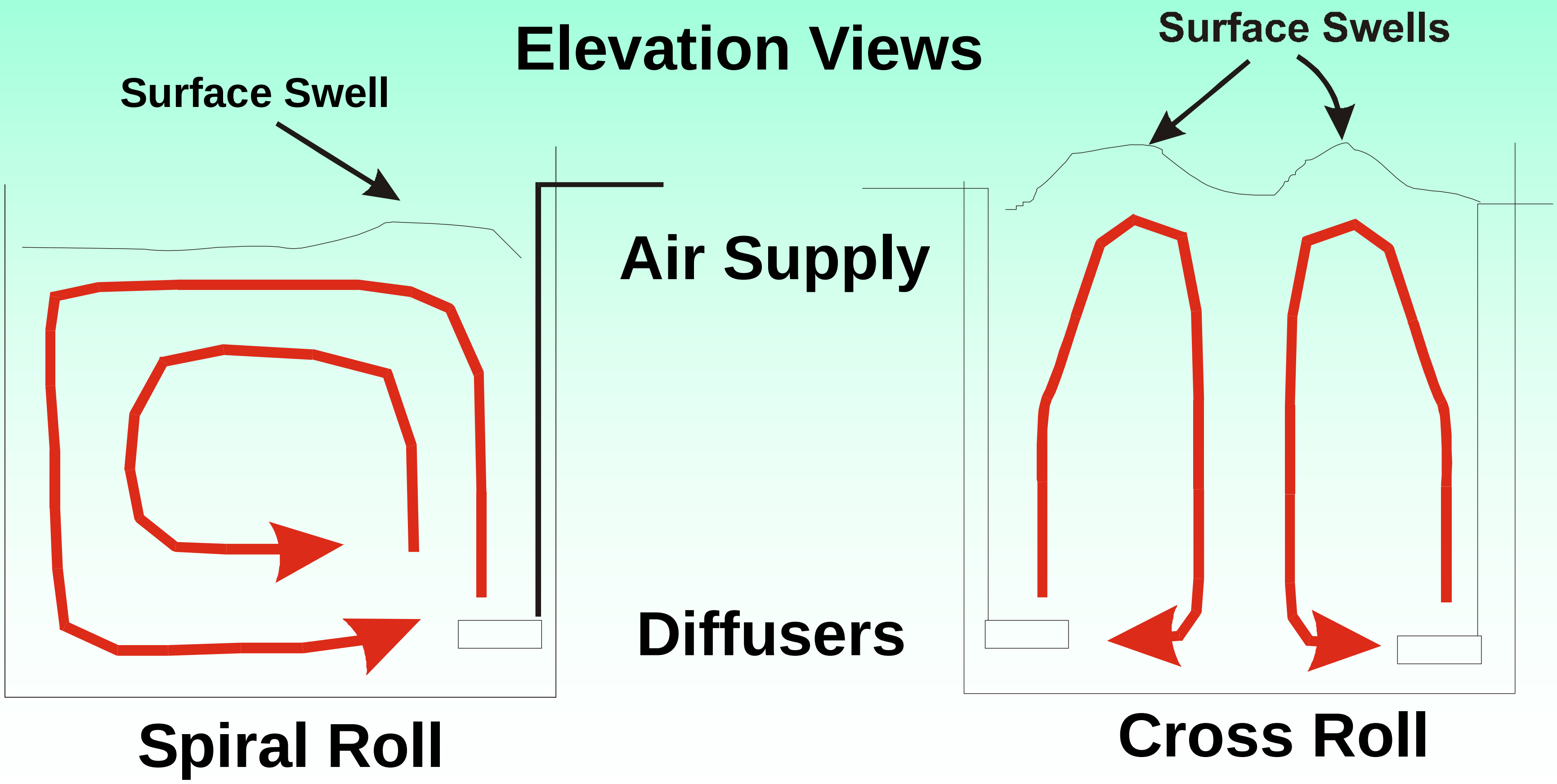
Diffused – Coarse Bubble

- Low maintenance, low efficiency
- 1 % /ft or (3%/m) SOTE
- 2.0-3.0 SAE (1.2 – 1.8 kg O_2/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

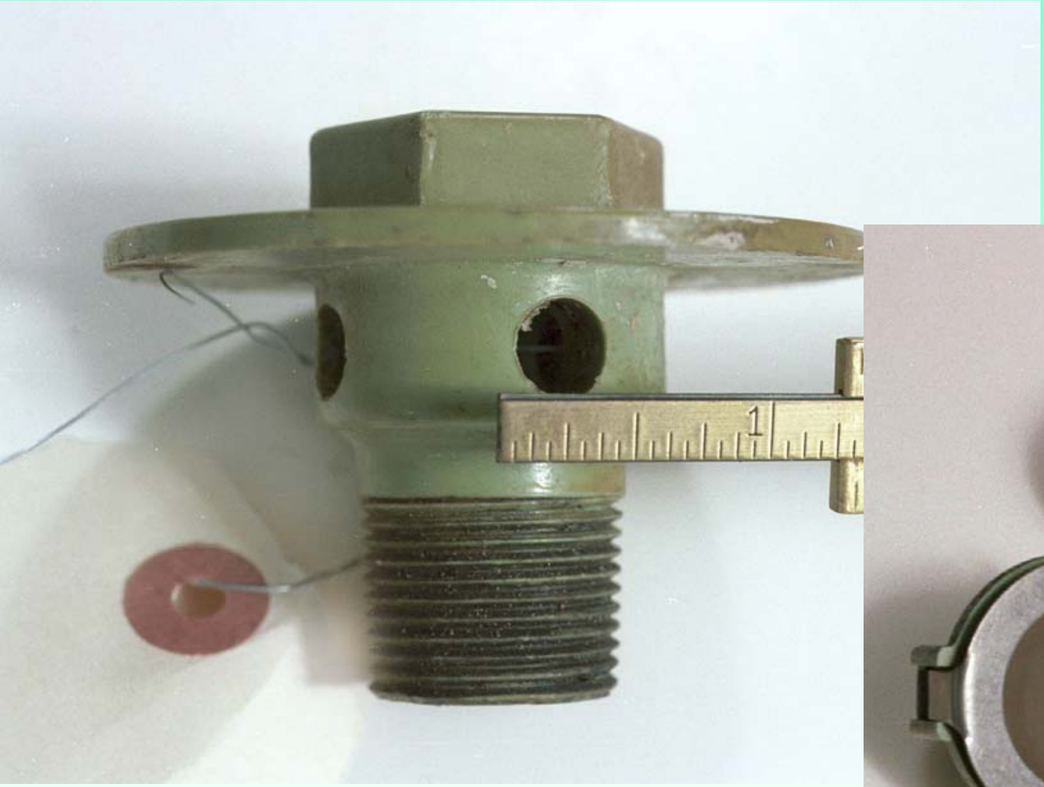
Floor Coverage

- 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



Spargers




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.

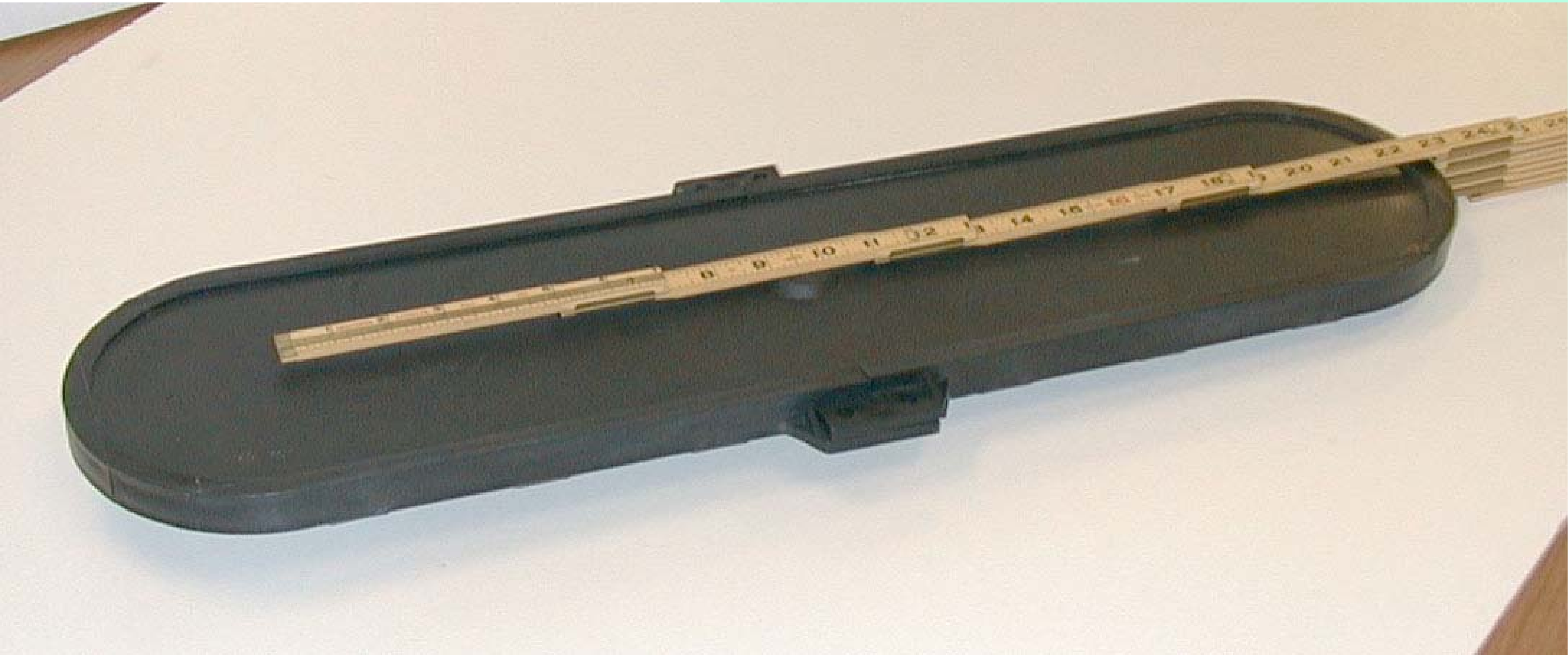
Domes On Air Headers

Ceramic Disc Diffusers

Membrane Discs

Other Discs

Mini Panel



Five Different Tubes

EPDM

PVC

Ceramic

EPDM

Plastic

Installed

Aerostrip

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

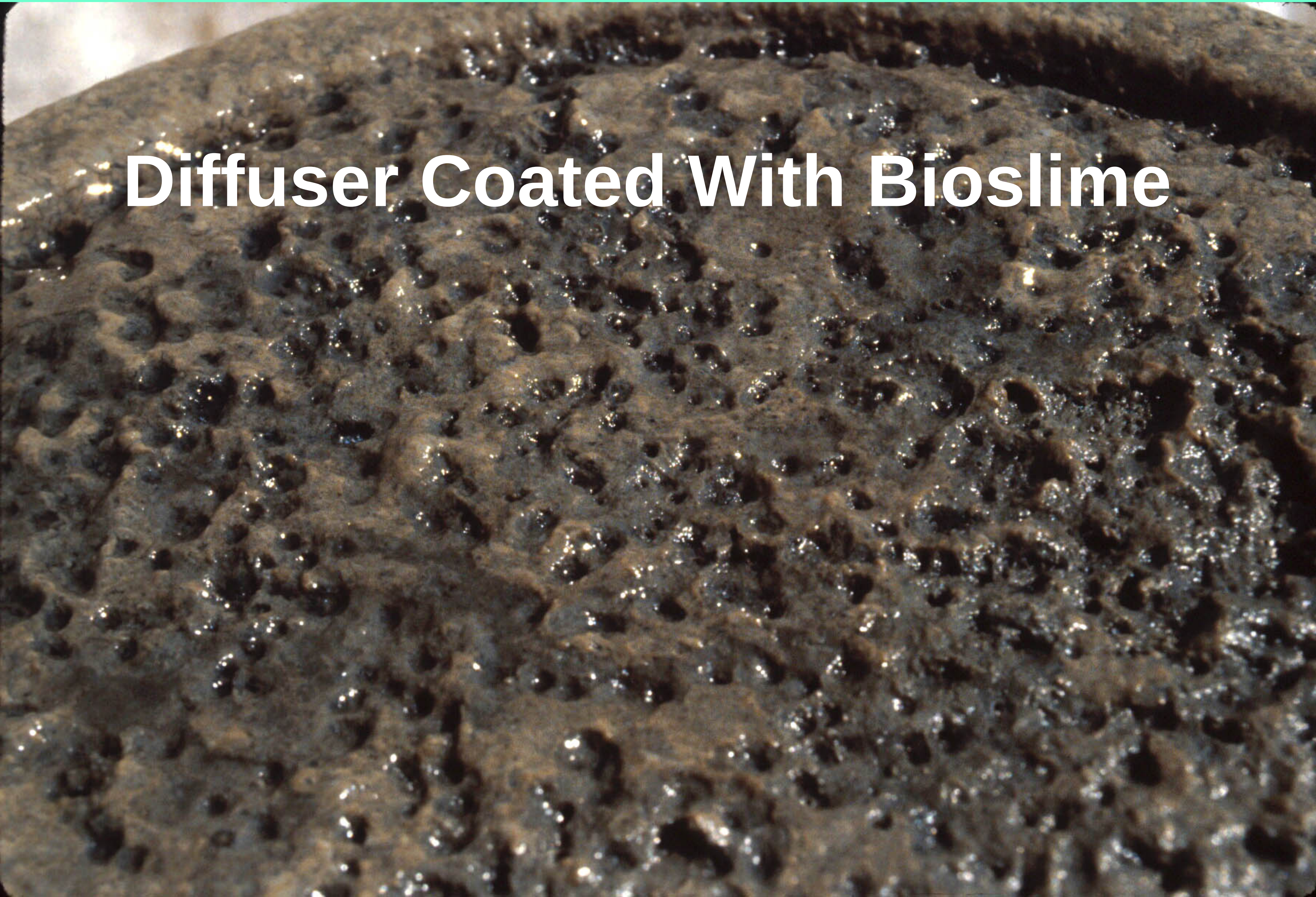
Material Failures

- 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

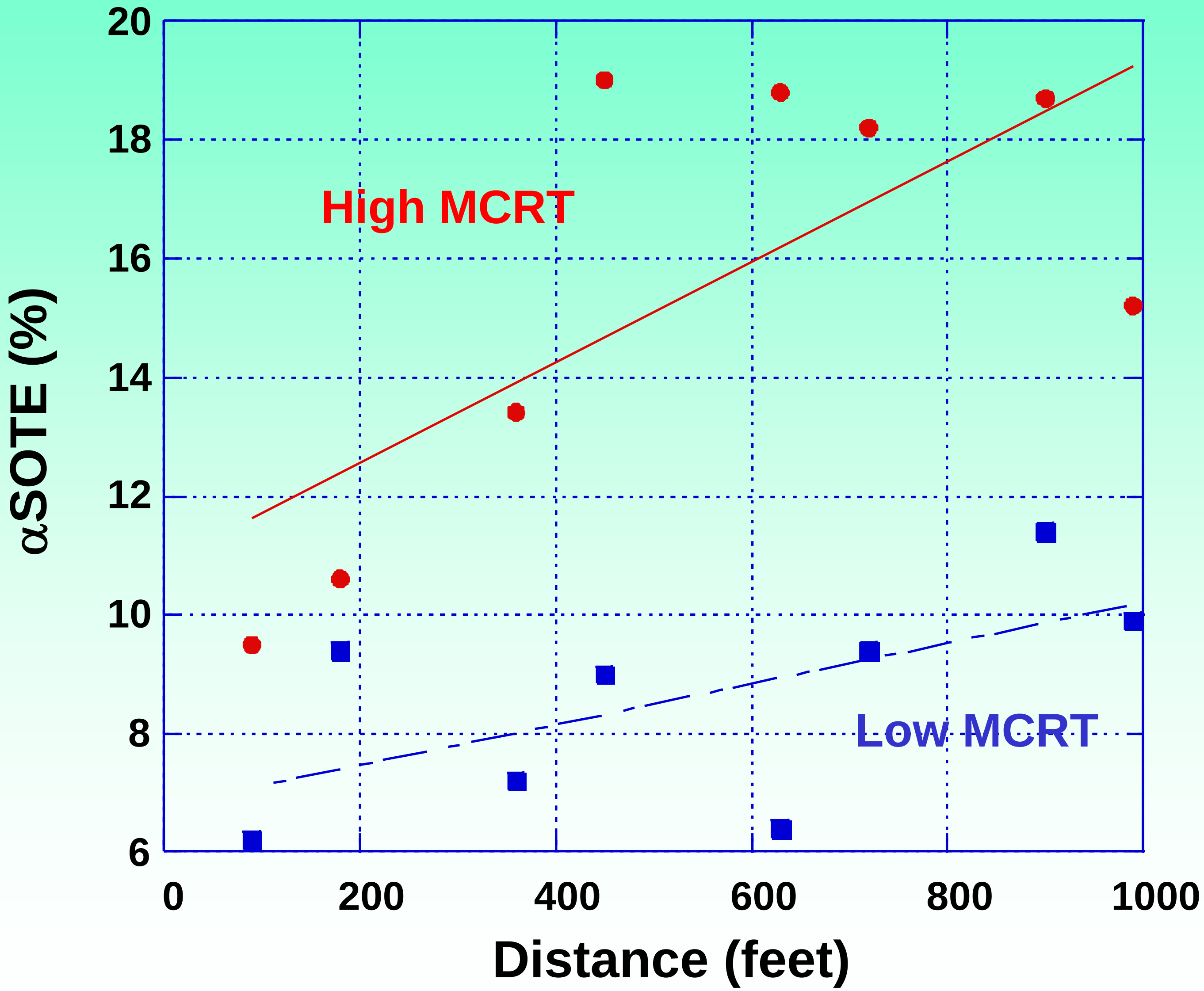
Tank With Partial Cleaning From Hosing


Diffuser Coated With Bioslime

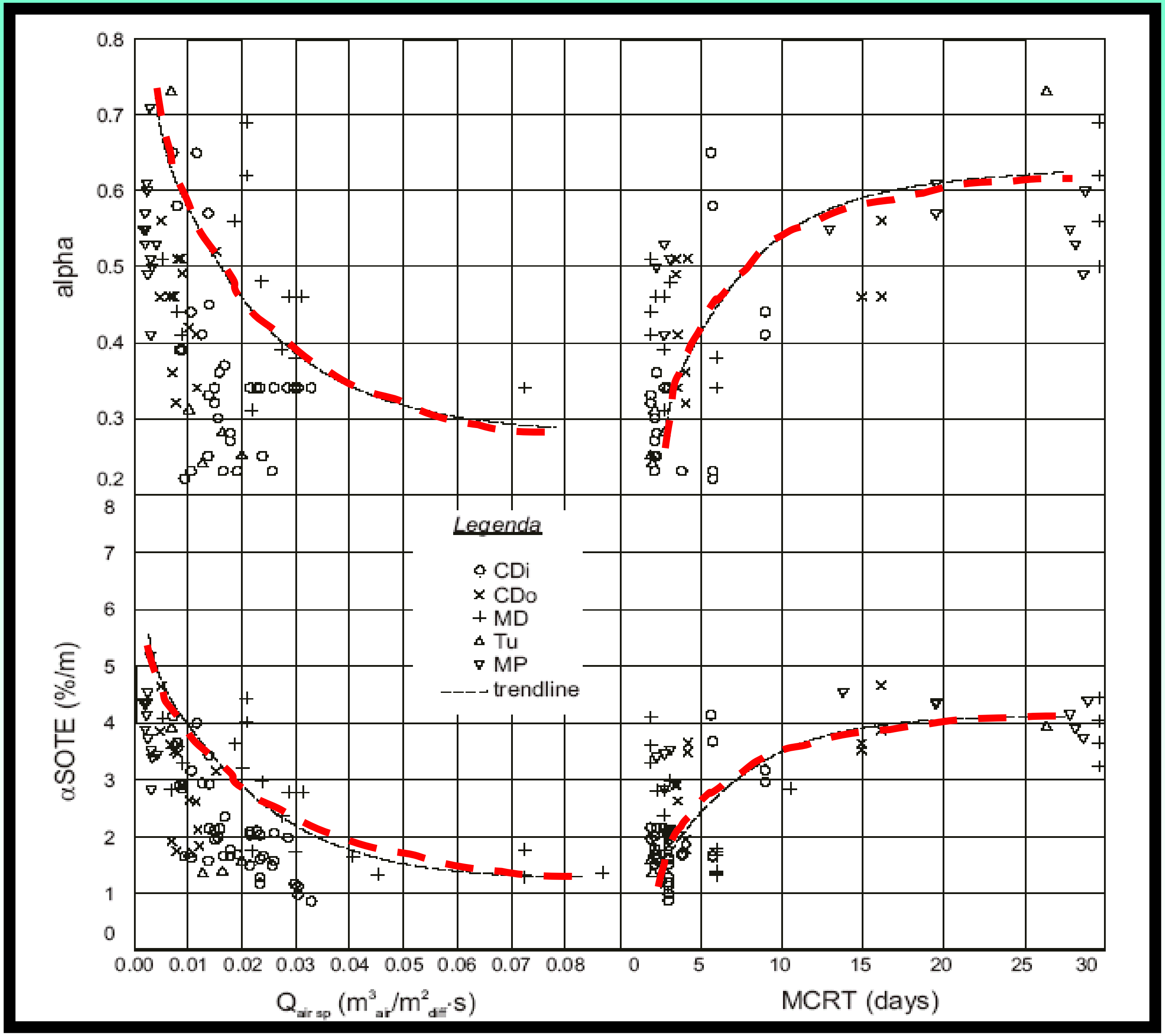
How Does this Affect Design, Operation and Economics?

- Alpha factors – the mother of all fudge factors!
- Efficiency decline over time by fouling/scaling
- Economics of cleaning and replacement
- Monitoring – New instruments coming

A tale of two tanks



20 years of field Results



$$Q_{air\ sp} = \frac{\text{Airflow Rate}}{(\text{No. * area * Z})}$$

↓ AFR ⇒ ↑ transfer

↑ Z ⇒ ↑ transfer

↑ area ⇒ ↑ transfer

↑ MCRT ⇒ ↑ transfer

What we learned?

- Fine pore diffuser performance is a function of the MCRT (sludge age or SRT)
- Higher MCRT means higher transfer efficiency!

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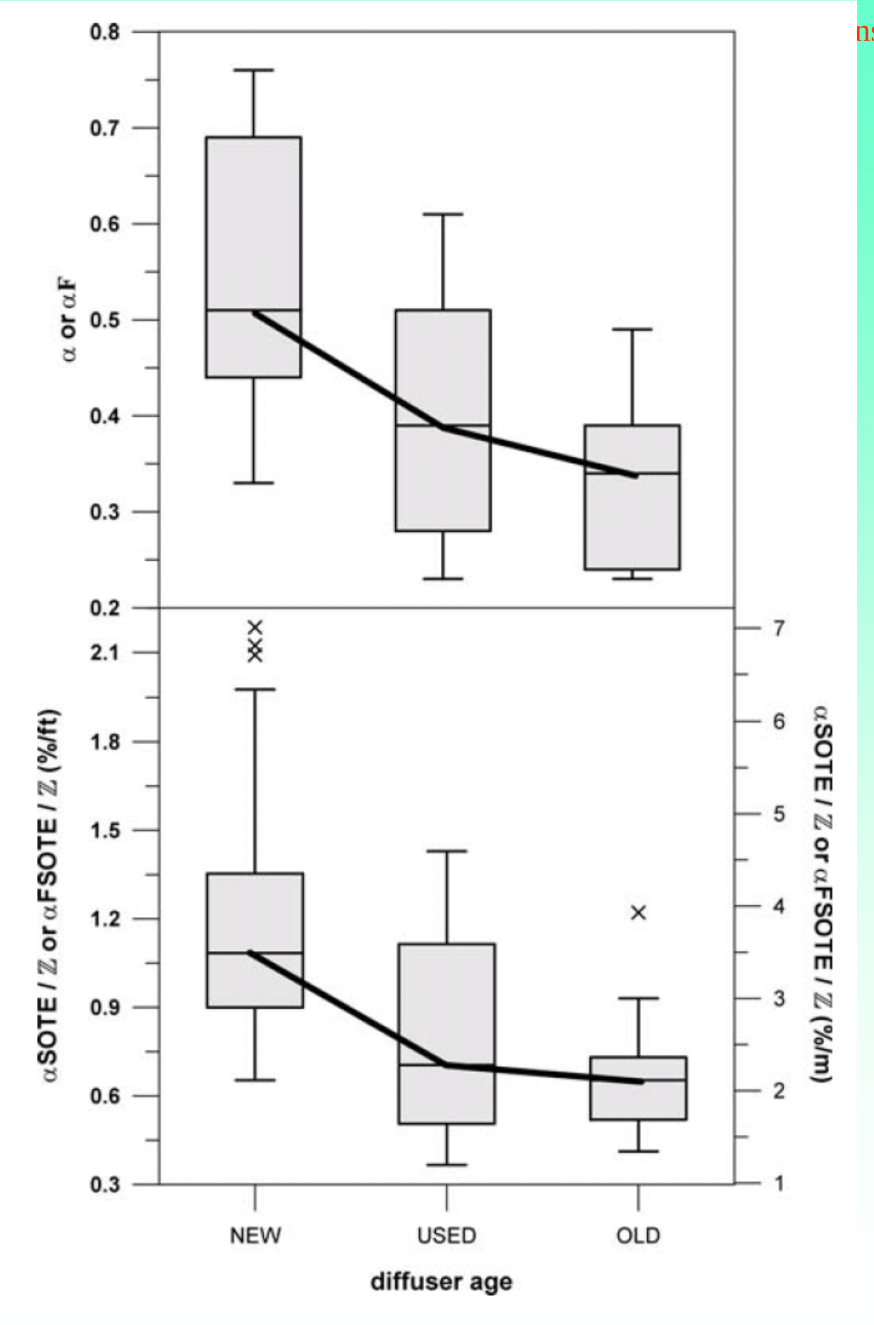
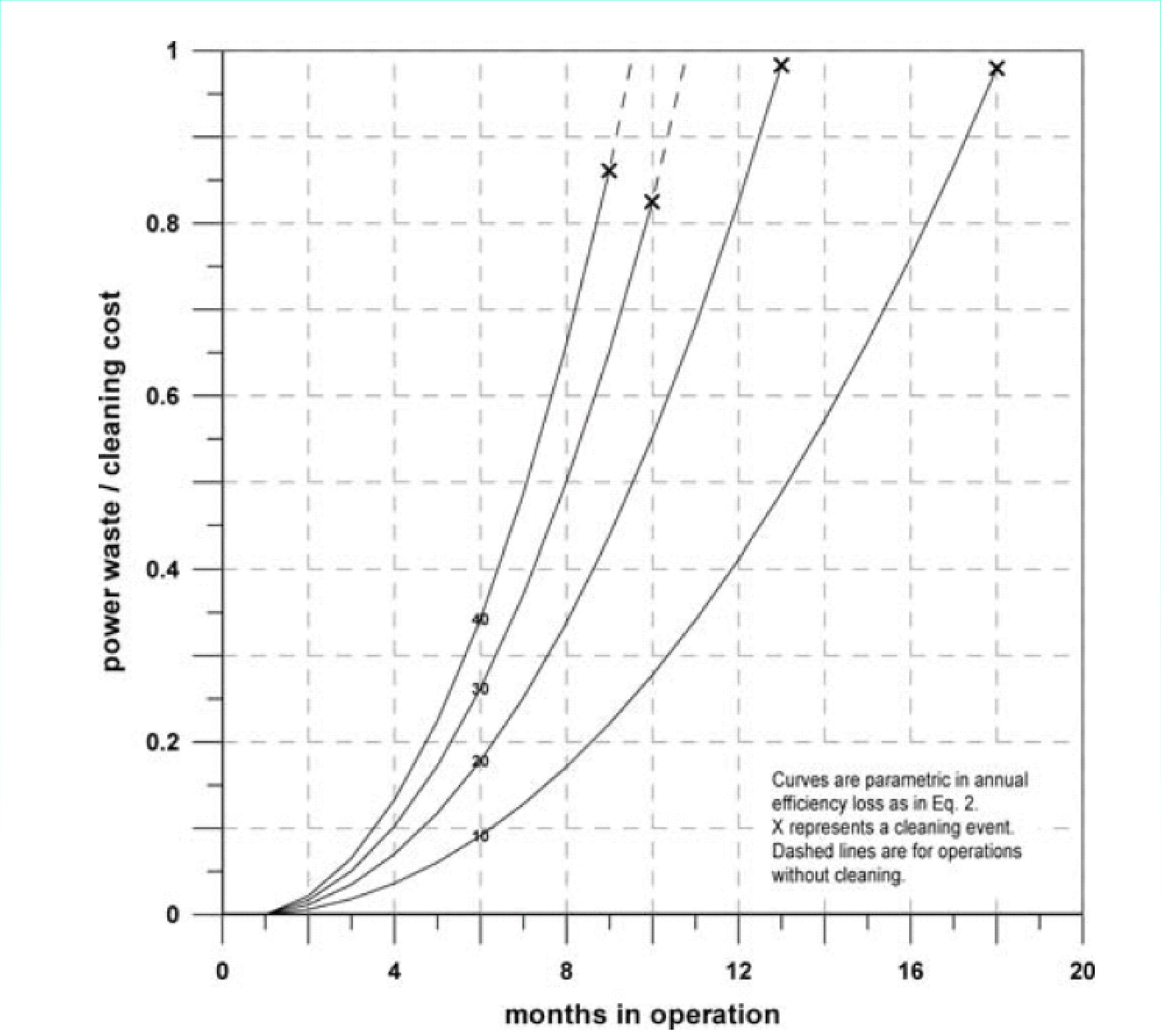
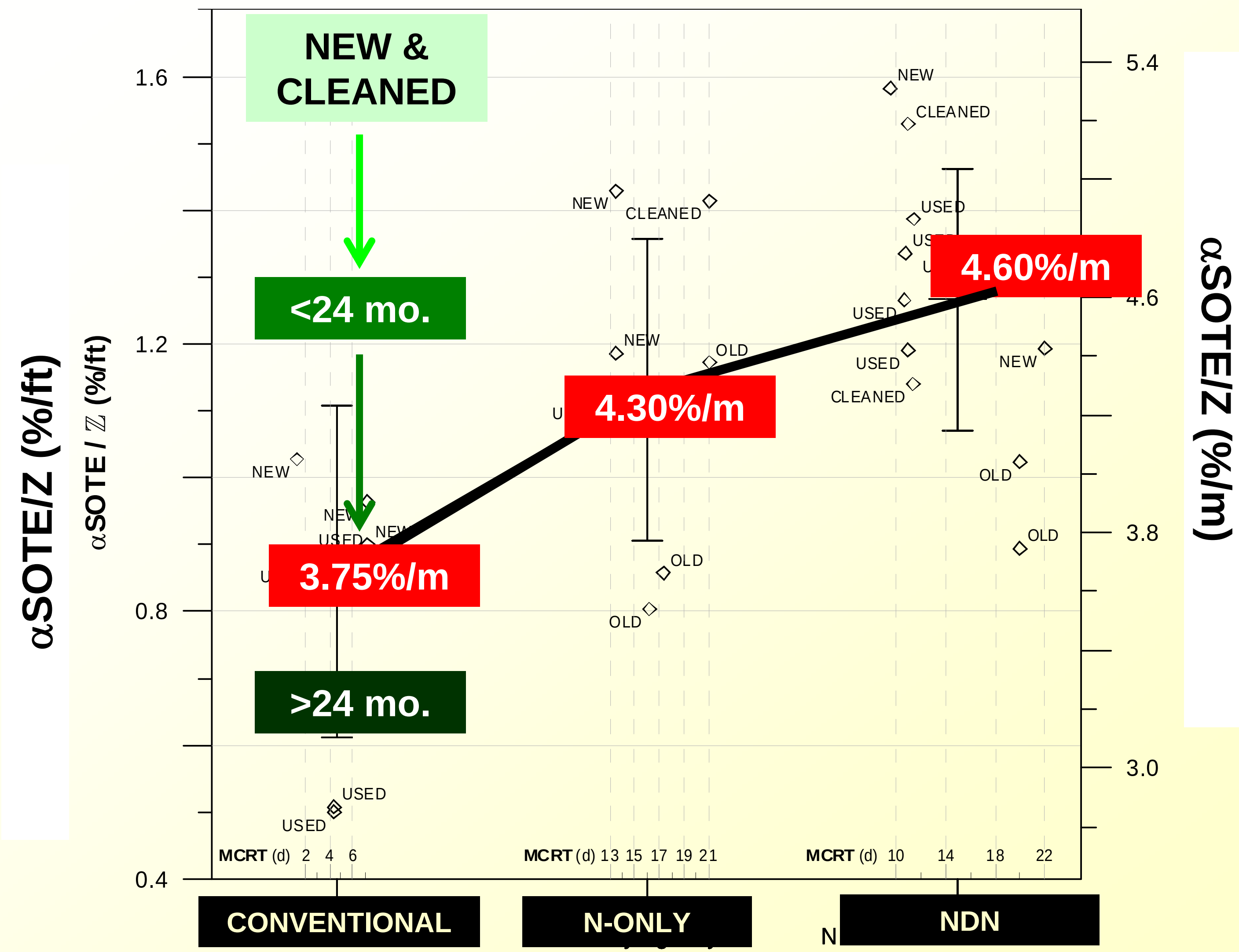
Performance as a Function of Diffuser Age



Power Wasted Compared to Cleaning Cost



Efficiency per process type



Clea

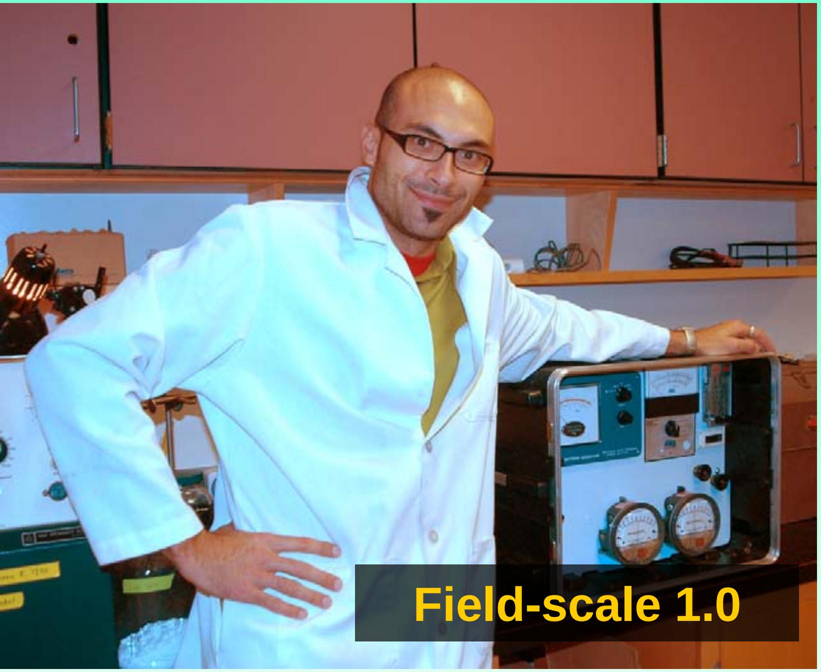
- Aeration cost
- Diffuser clea

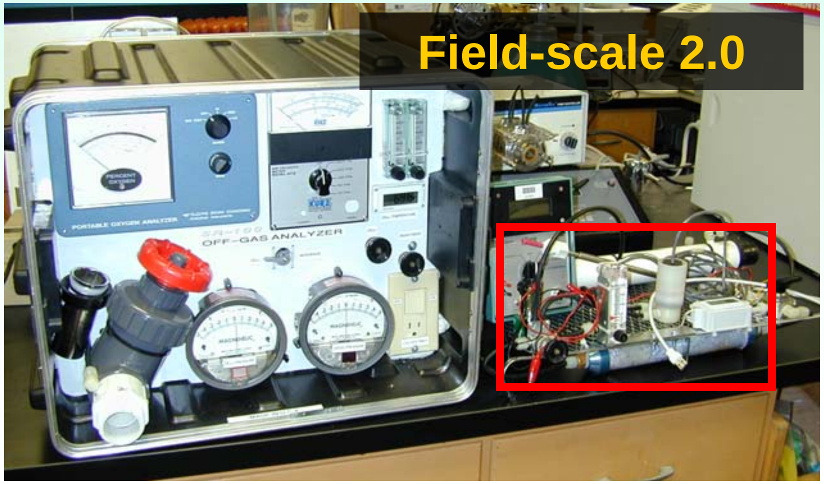
Ben Leu, 2005, Fine-pore Diffuser from Orange County

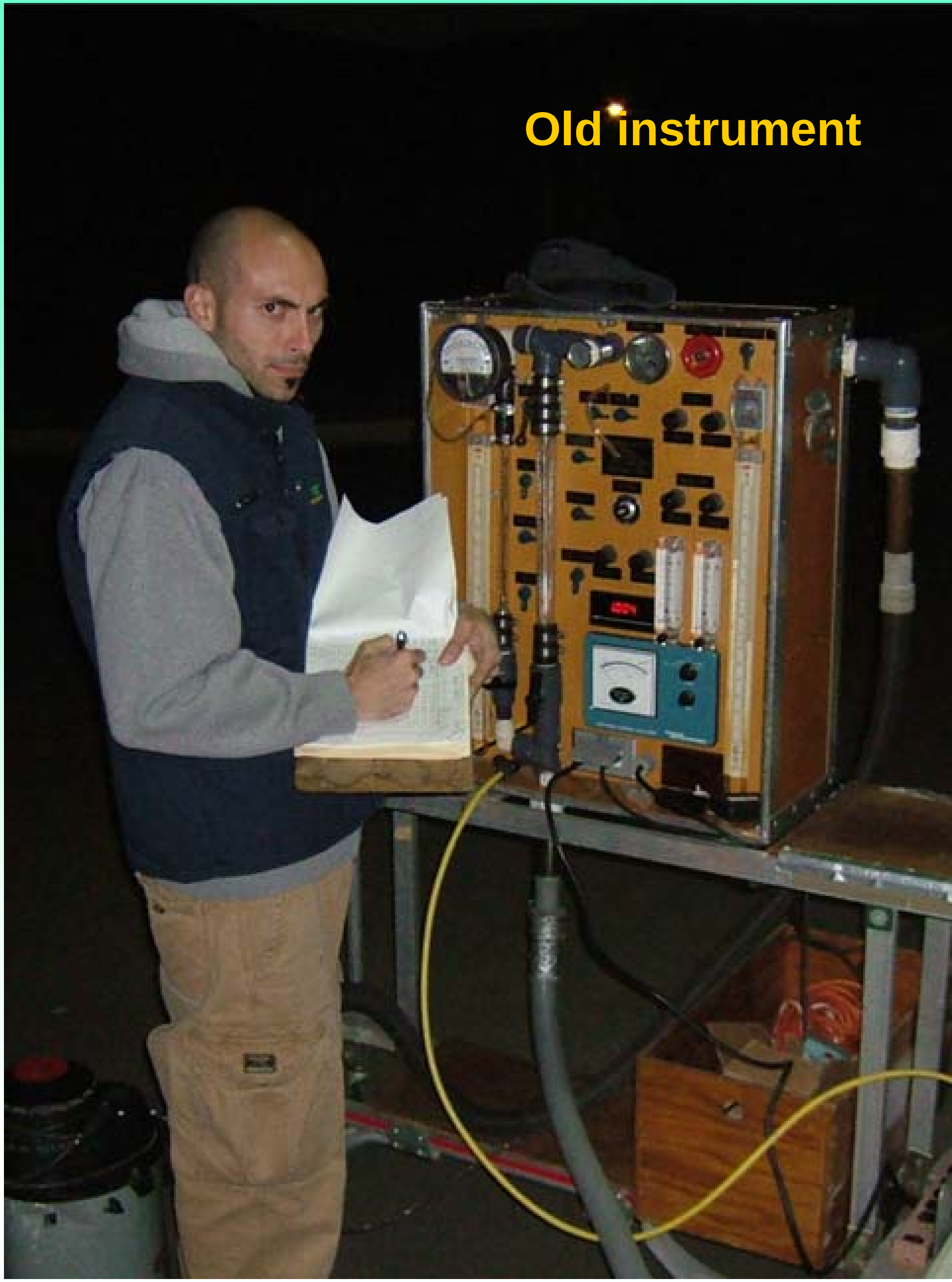
New Generation of Monitoring Equipment

- **Most of the results you see where collected through off-gas testing**
- **Requires an expert operator, 8 to 24 hours of time**
- **Cost amounts to several thousand dollars per test**
- **New Generation of equipment-**
  - **Automatic**
  - **Digital**
  - **Inexpensive**
  - ***Smaller!***

Instrument sizes







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

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

Diffuser Cleaning

- Depending on fouling rates, diffuser cleaning will pay for itself in 9 to 24 months, depending on fouling tendency
- High MCRT systems foul more slowly
- Low MCRT systems foul more quickly

To BNR or Not?

- Our work shows that
  - LOW MCRT Systems have the lowest OTE
  - High MCRT Systems have much higher OTE
  - BNR systems like the MLE process have the highest OTE
- The improved OTE and the denitrification credit compensate for the additional oxygen requirements of High MCRT operation
- BNR systems, because of the selector effect of the denitrification zone, resist bulking and are inherently more stable.
- Why build new low SRT systems ????