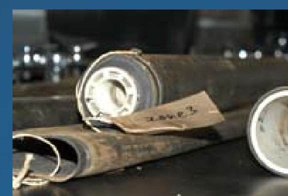
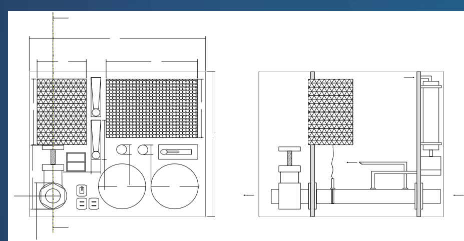
UNIVERSITY OF CALIFORNIA, LOS ANGELES

Real-Time Monitoring of Aeration Efficiency in Wastewater Treatment

Diego Rosso, Ph.D.
Michael K. Stenstrom, Ph.D.
UCLA – Civil Engineering



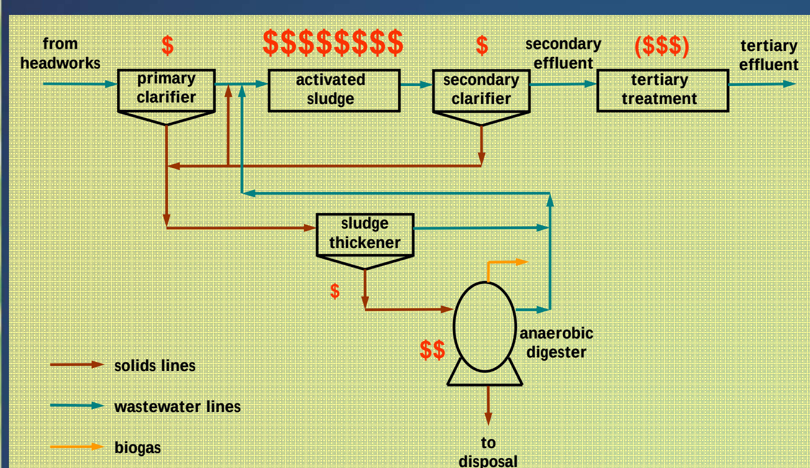


SUMMARY

- Aeration costs
- Off-gas testing and process control
- Aeration systems fouling
- Potential energy savings
- Impact on plant economics
- Summary and conclusions

I. AERATION PHENOMENA

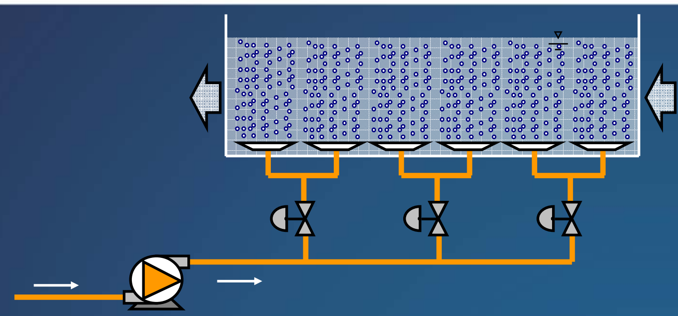
WHERE IS THIS ENERGY SPENT?



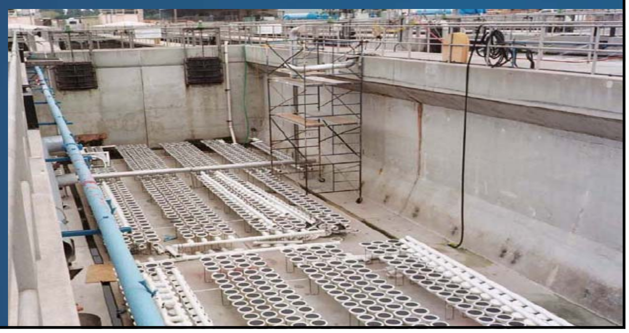
Aeration cost = 45-75% of plant energy cost

Rosso and Stenstrom (2005) *Wat. Res.* 39: **3773-3780**

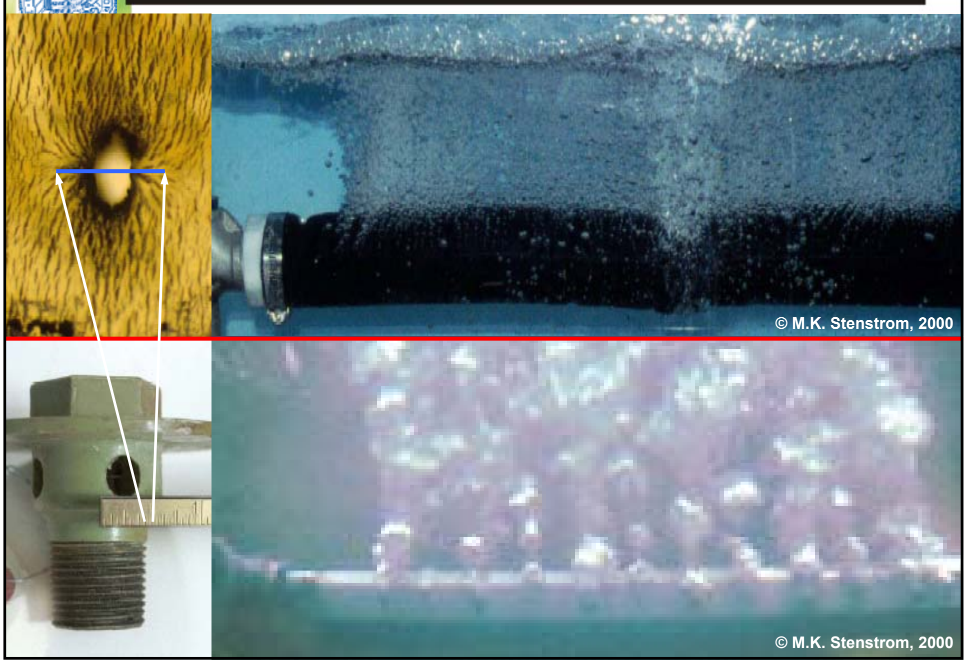
WHY IS SO MUCH ENERGY REQUIRED?



To overcome wastewater Hydrostatic head



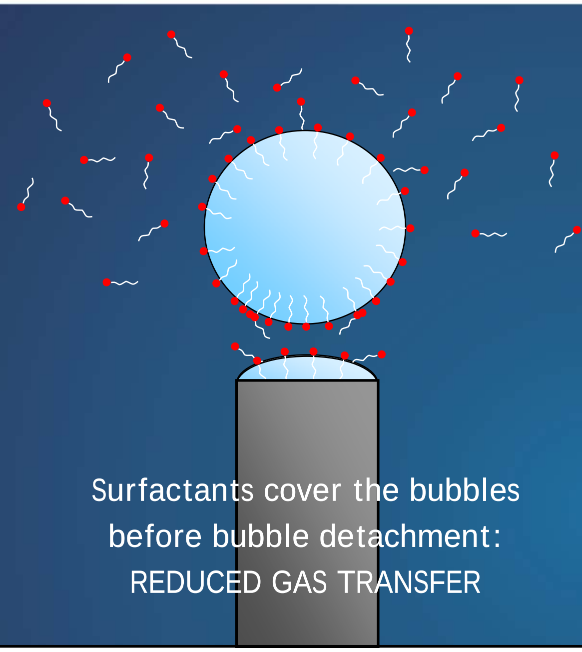
AERATION SYSTEMS



WHAT ARE THESE CONTAMINANTS?

CONTAINS:
15-25% anionic surfactants
0-15% non-ionic surfactants
0-15% soap
0-15% cationic surfactants
fillers to 100%

WHAT HAPPENS TO BUBBLES?



Surfactants cover the bubbles before bubble detachment:
REDUCED GAS TRANSFER

Terminology

OTE: Oxygen Transfer Efficiency (%)

OTR: Oxygen Transfer Rate (mass/unit time)

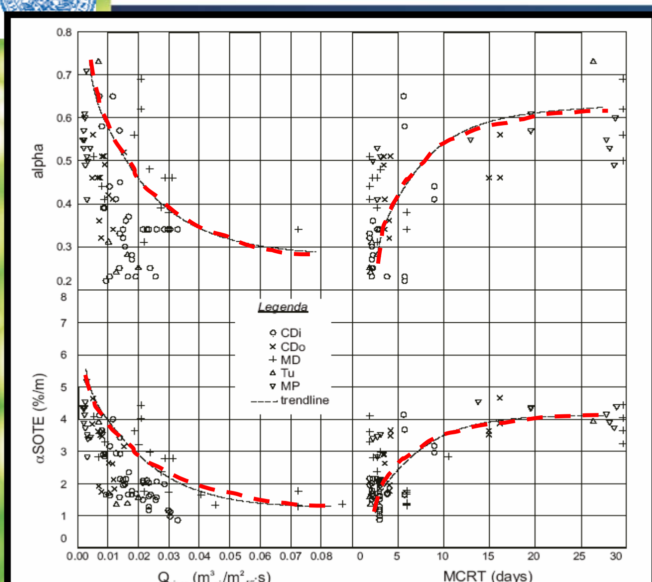
SOTE: Standardized OTE in clean water

αSOTE: Standardized OTE in process water

MCRT: Mean Cell Retention Time

α = αSOTE/SOTE (water quality estimate)

Field observations on efficiency



$$Q_{air\ sp} = \frac{\text{Airflow Rate}}{(\# \cdot Z \cdot \text{area})}$$

↓ AFR ⇒ ↑ transfer

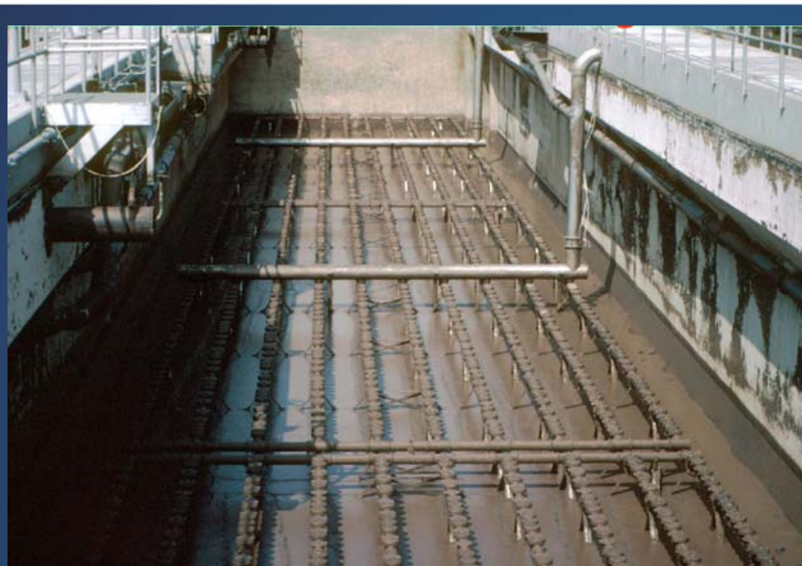
↑ Z ⇒ ↑ transfer

↑ area ⇒ ↑ transfer

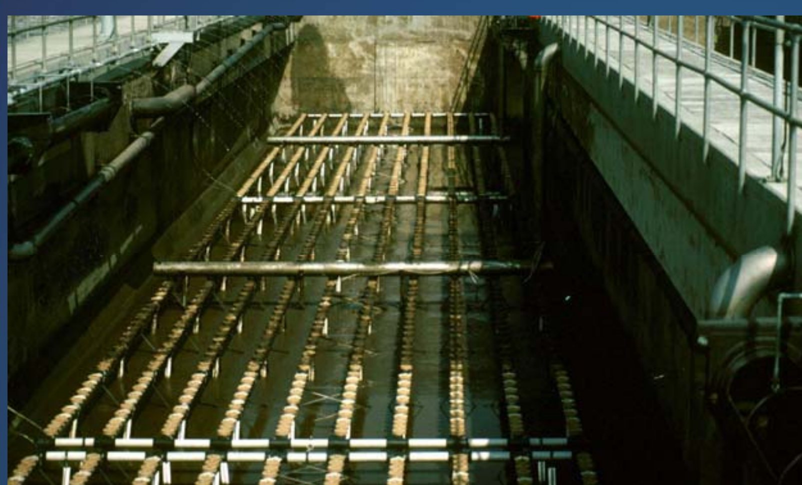
↑ MCRT ⇒ ↑ transfer

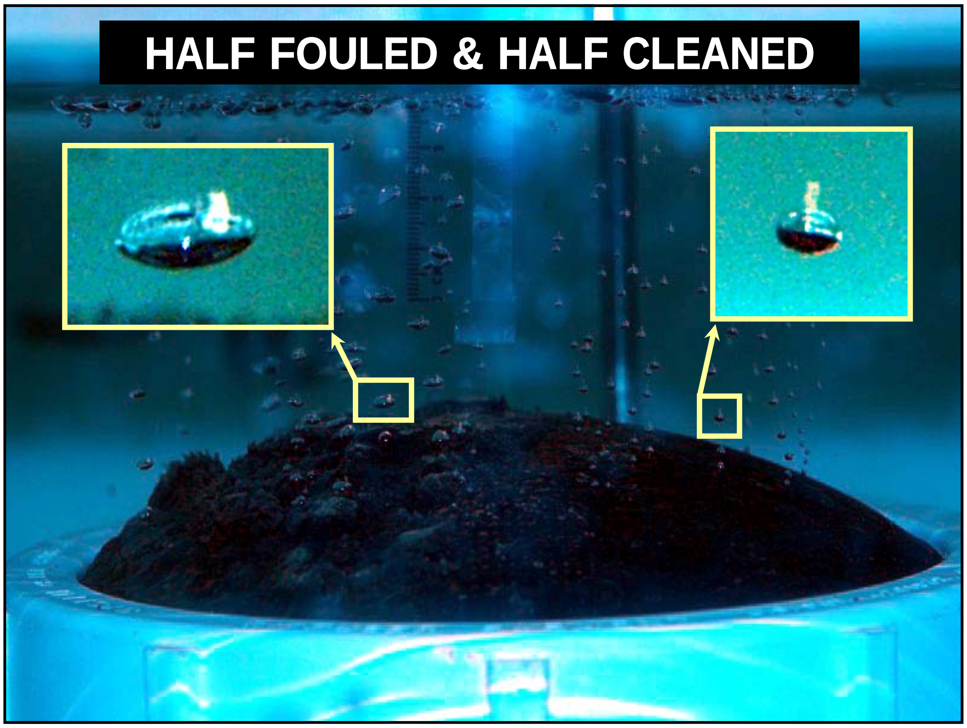
Rosso et al (2005) *Wat Env Res* **77 266-273**

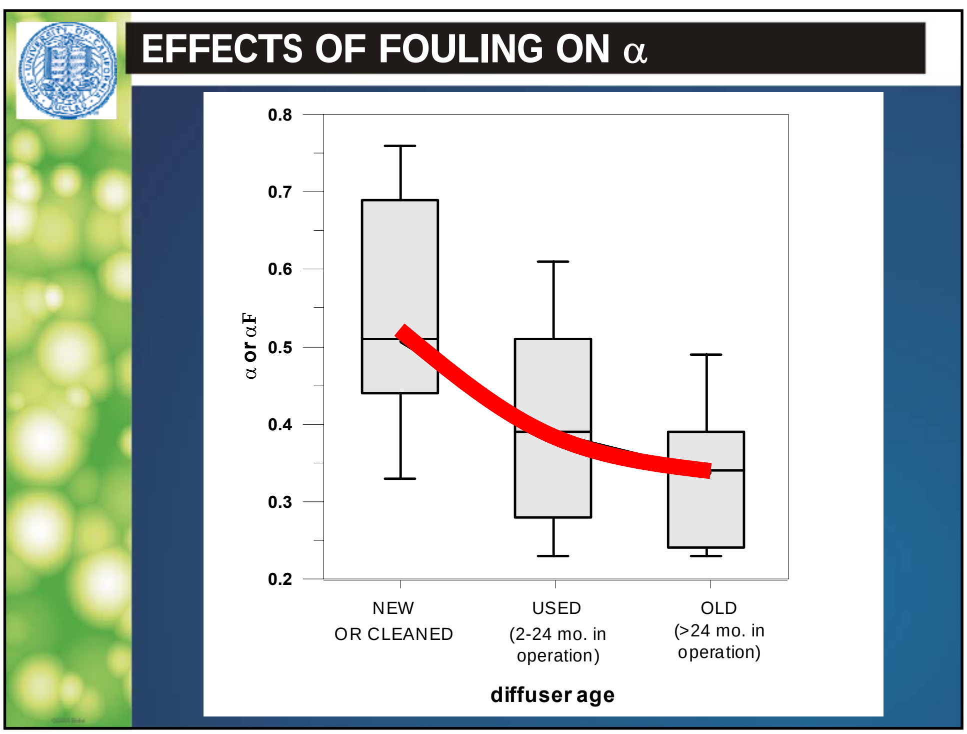
Pre-cleaning



Post-cleaning

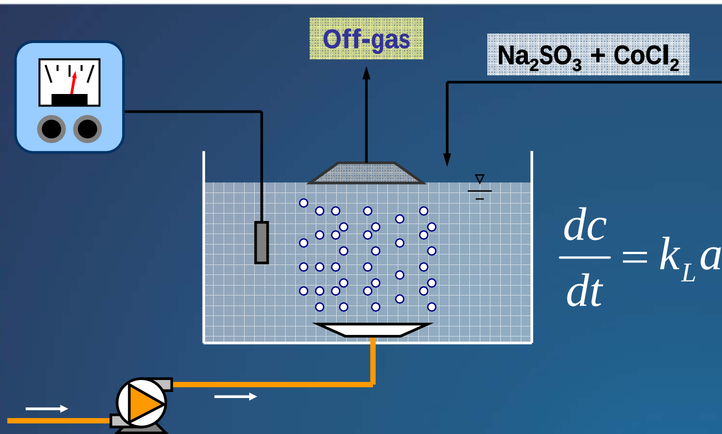



HALF FOULED & HALF CLEANED


EFFECTS OF FOULING ON α
0.8
0.7
0.6
0.5
0.4
0.3
0.2
α or αF
NEW
OR CLEANED
USED
(2-24 mo. in
operation)
OLD
(>24 mo. in
operation)
diffuser age

II. EFFICIENCY MONITORING

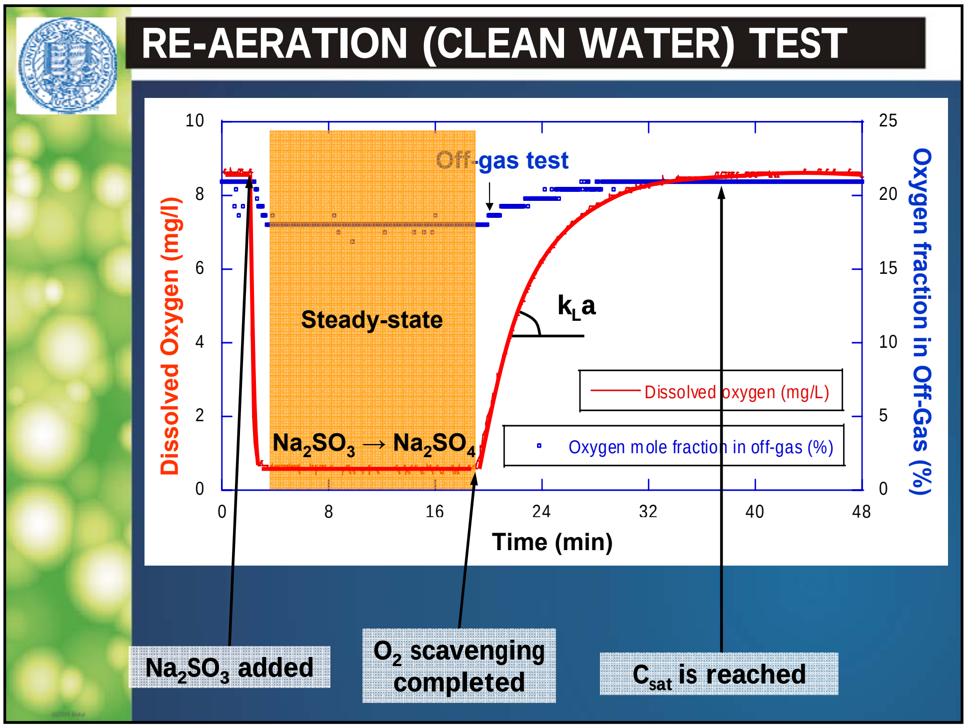
AERATION EFFICIENCY & ALPHA

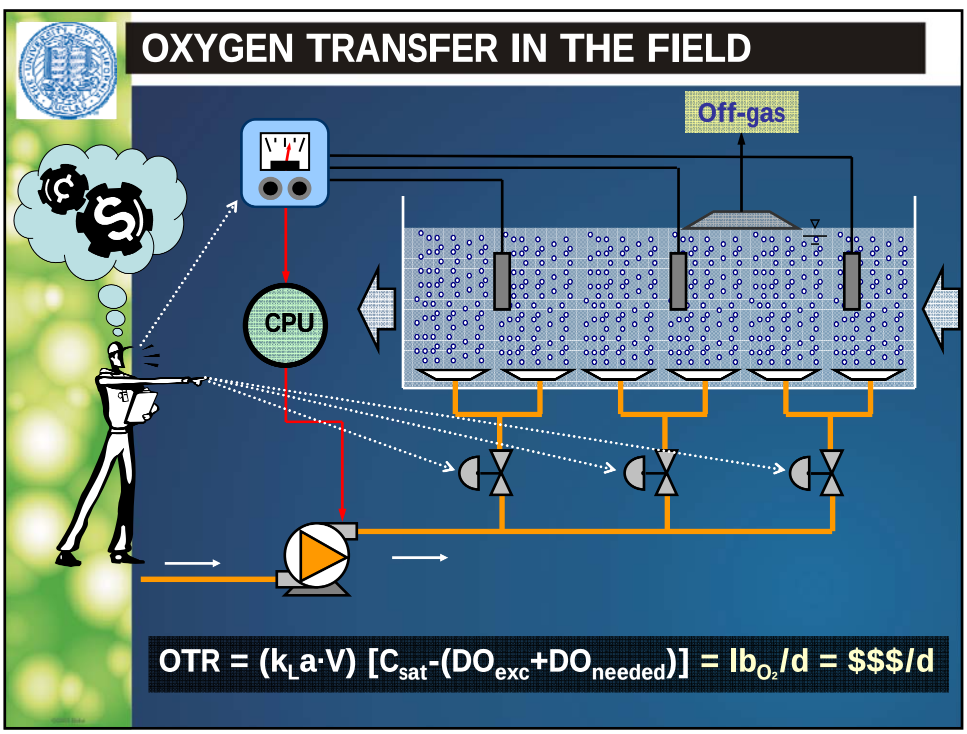


$$\frac{dc}{dt} = k_L a \cdot \Delta c$$

$$Na_2SO_3 + O_2 \xrightarrow{CoCl_2} Na_2SO_4$$

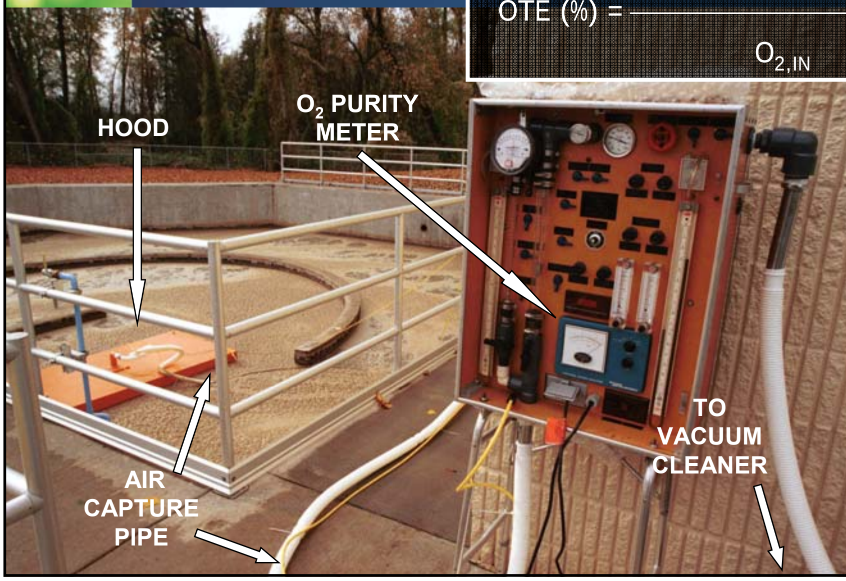
$$\alpha = \frac{(k_L a)_{\text{process water}}}{(k_L a)_{\text{clean water}}}$$


RE-AERATION (CLEAN WATER) TEST
Off-gas test
Steady-state
k_La
$Na_2SO_3 \rightarrow Na_2SO_4$
Dissolved oxygen (mg/L)
Oxygen mole fraction in off-gas (%)
Dissolved Oxygen (mg/l)
Oxygen fraction in Off-Gas (%)
Time (min)
0
8
16
24
32
40
48
10
6
4
2
25
20
15
5
Na_2SO_3 added
O_2 scavenging completed
C_{sat} is reached

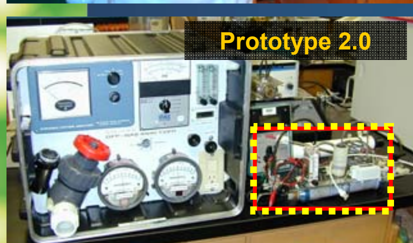

OXYGEN TRANSFER IN THE FIELD
Off-gas
CPU
$OTR = (k_La \cdot V)\,[C_{sat}-(DO_{exc}+DO_{needed})] = lb_{O_2}/d = \$\$\$/d$

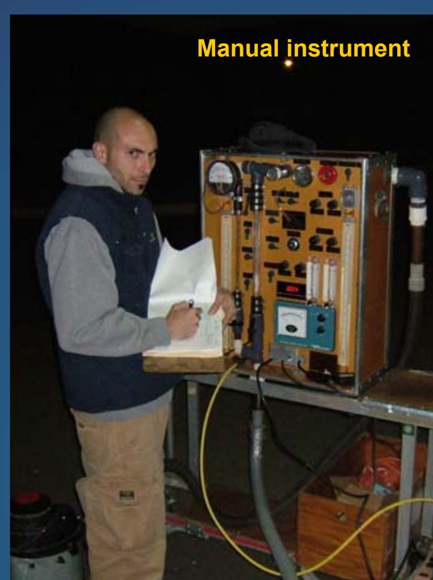
OFF-GAS TESTING SETUP

$$OTE\ (\%) = \frac{O_{2,IN} - O_{2,OUT}}{O_{2,IN}}$$

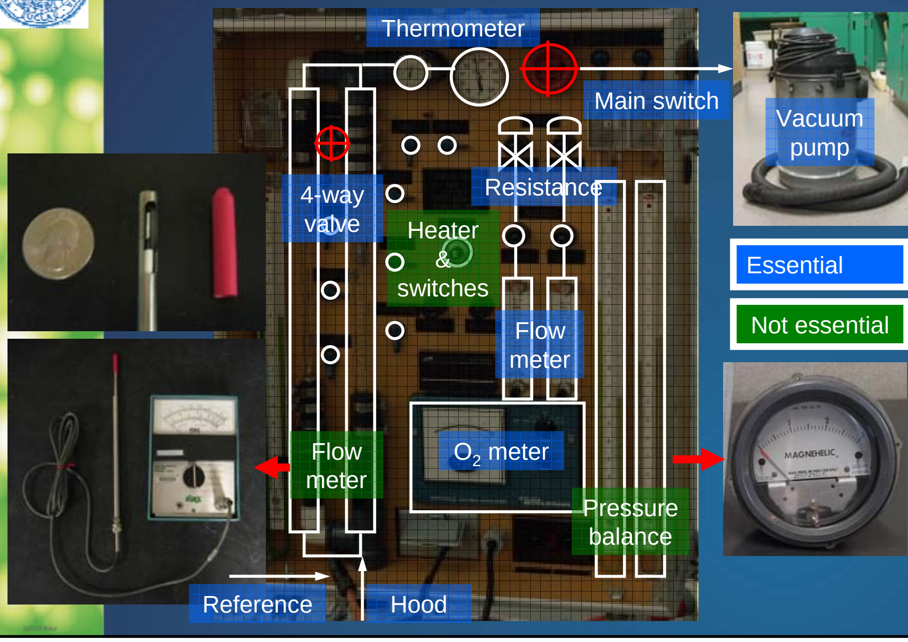


EVOLUTION OF INSTRUMENT SIZES



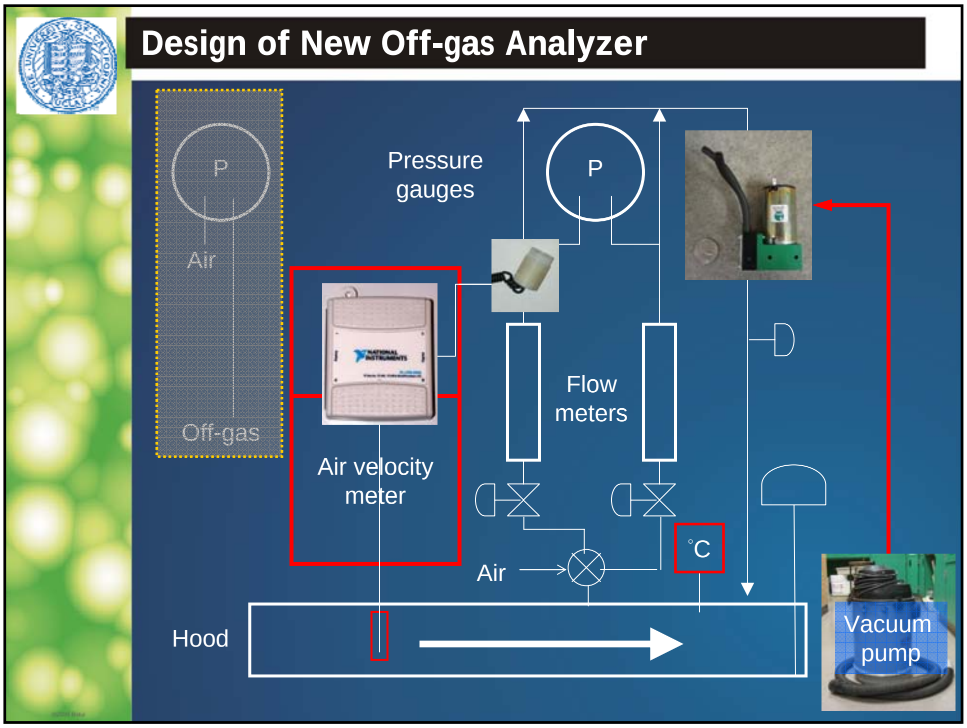


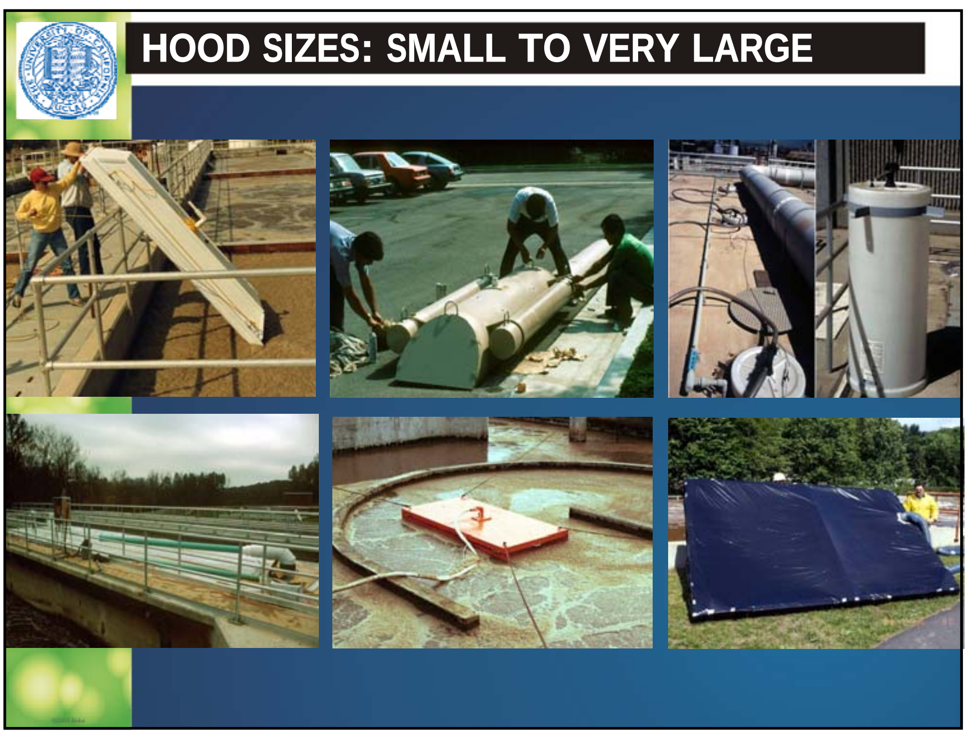
How did we reduce the instrument size?



Newer instrument

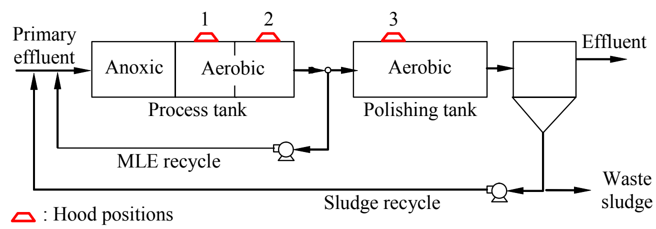
- Fuel cells produce analog ΔV output recorded by data logger
- Self-calibrating
- **Cost ~ 2000 USD**


Design of New Off-gas Analyzer
P
Air
Off-gas
Pressure gauges
P
Flow meters
Air velocity meter
Air
°C
Hood
Vacuum pump

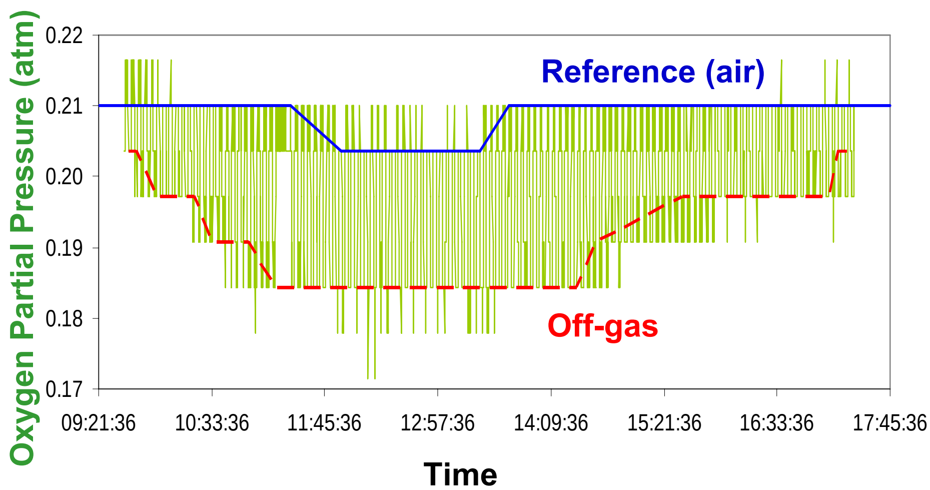

HOOD SIZES: SMALL TO VERY LARGE

III. FIELD-SCALE RESULTS

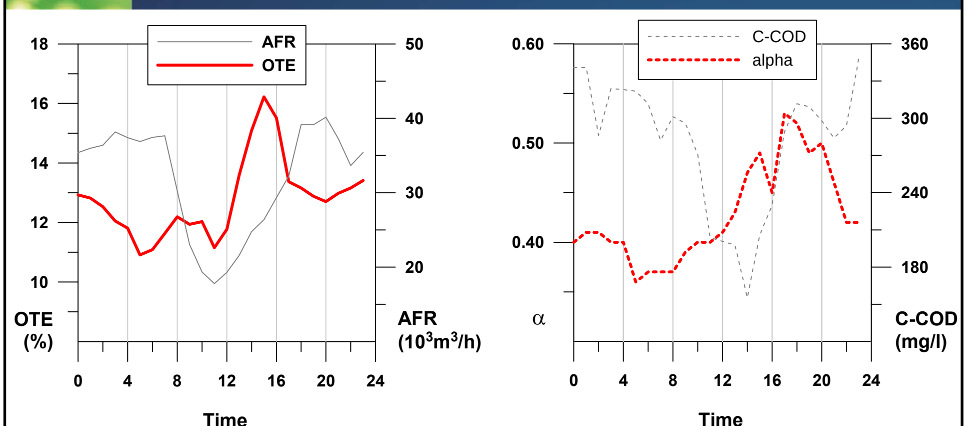
TESTING POSITIONS



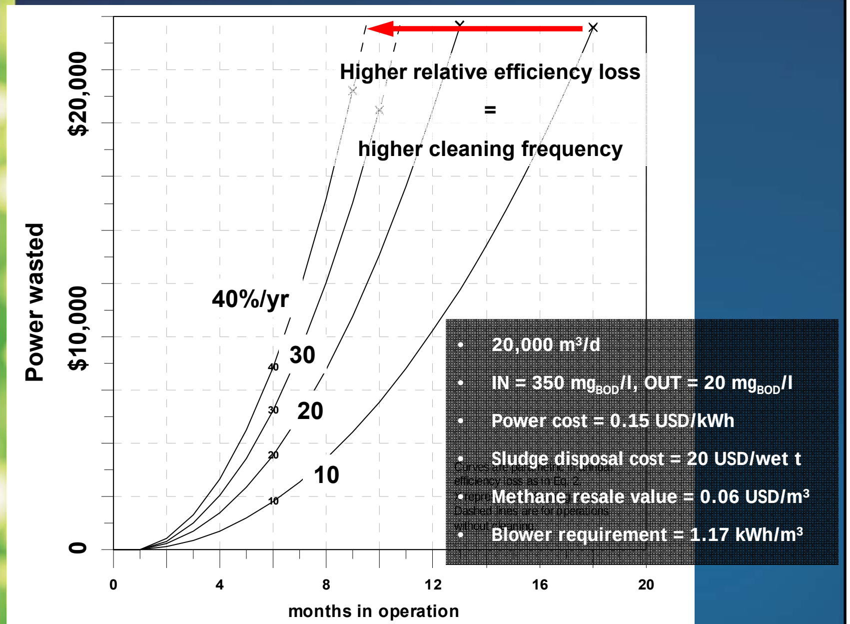
OFF-GAS TESTING RESULTS



EFFICIENCY, AIR FLOW, ALPHA, AND LOAD



EXAMPLE POWER WASTAGE CURVES



CONCLUSIONS

- Aeration costs have the highest impact on plant operating economics and energy consumption
- Transfer efficiency monitoring is essential for minimizing energy expenditure
- Real-time off-gas analyses can obtain time-varying information previously not obtainable
- The new instrument will make off-gas testing available as a routine procedure

REFERENCES ON AERATION

1. Rosso, D., Iranpour, R., Stenstrom, M.K. (2005) Fifteen Years of Offgas Transfer Efficiency Measurements on Fine-Pore Aerators: Key Role of Sludge Age and Normalized Air Flux, *WER* **77** 266-273
2. Rosso, D., Stenstrom, M.K. (2005) Comparative Economic Analysis of the Impacts of Mean Cell Retention Time and Denitrification on Aeration Systems, WR **39** 3773-3780
3. Rosso, D., Stenstrom, M.K. (2006) Surfactant Effects on α-factors in aeration systems, WR 40 1397-1404
4. Rosso, D., Stenstrom, M.K. (2006) Economic Implications of Fine Pore Diffuser Aging, *WER* 78 810-815
5. Rosso, D., Huo, D.L., Stenstrom, M.K. (2006) Effects of interfacial surfactant contamination on bubble gas transfer, CES 61, 5500-5514