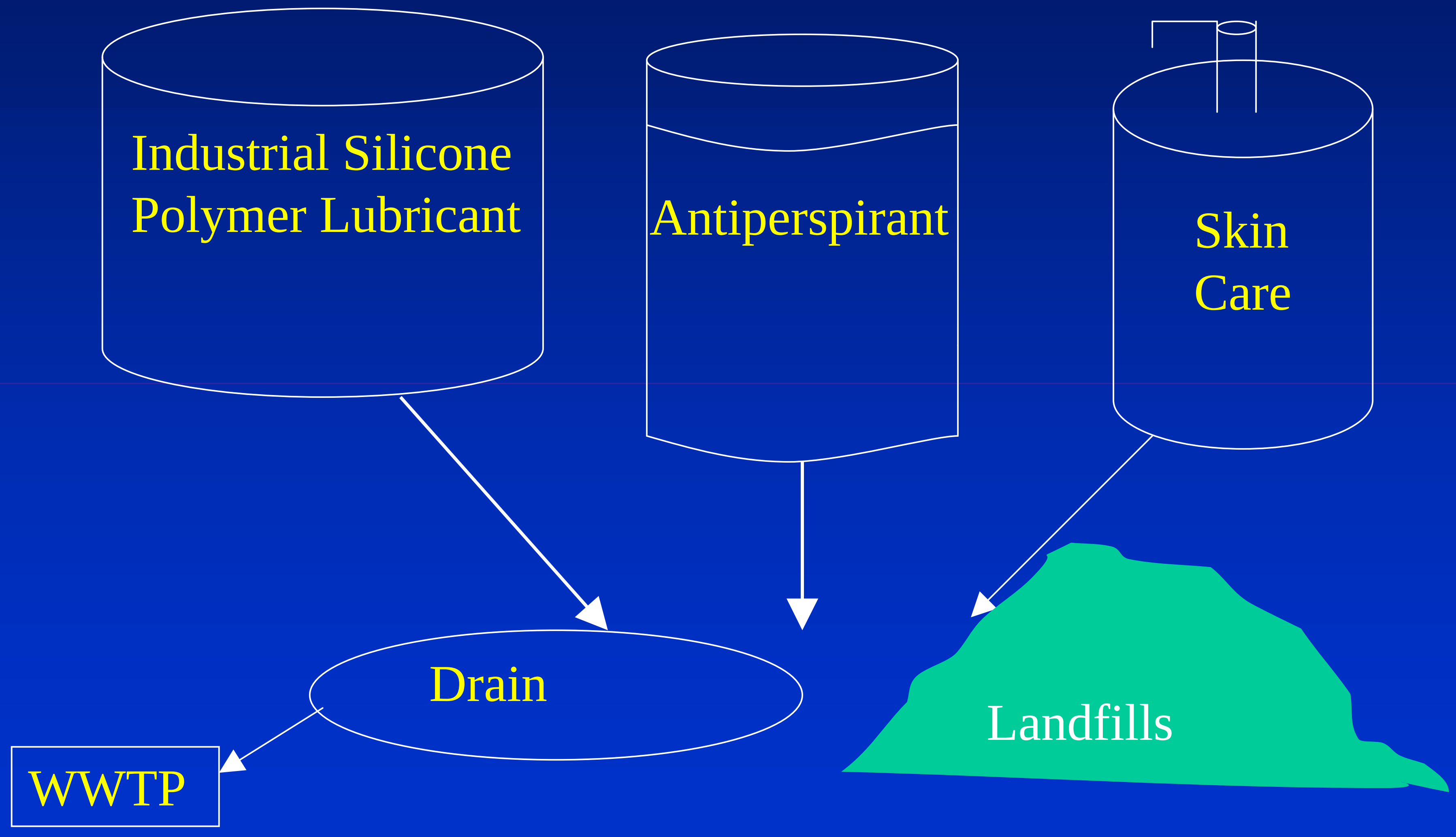
Research Project to Remove Siloxanes from Digester Gas

County Sanitation Districts of Los Angeles County

DEFINITION OF SILOXANES AND FATE OF SILOXANE BEARING PRODUCTS

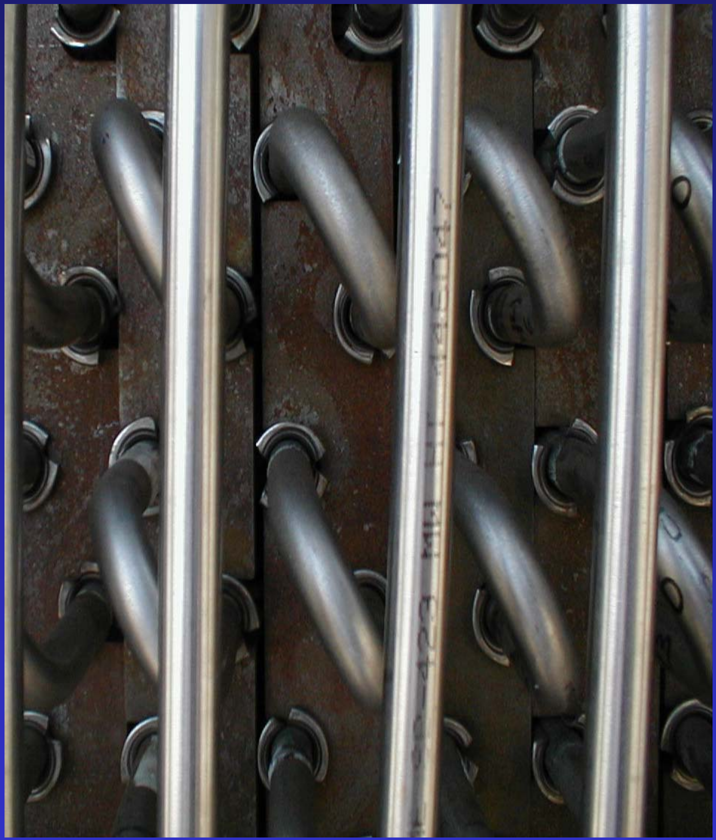


Why Treat Digester Gas For Siloxane Removal?

When combusted, siloxanes form silicon dioxide, which can coat equipment, cause damage to equipment and cause a loss of heat transfer efficiency.

Heat Recovery Steam Generators

Clean

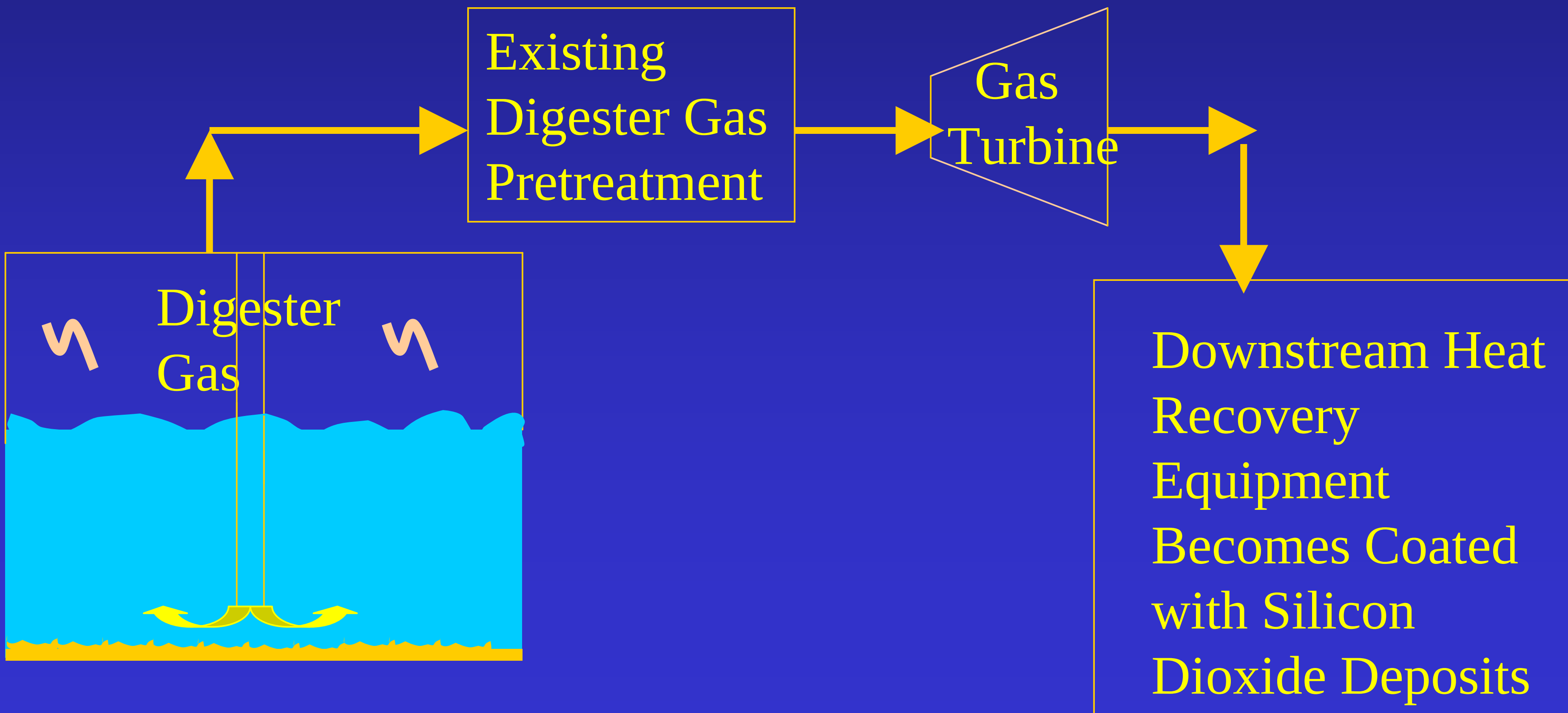


Treatment Costs
$200,000/year

W/ Silicon Dioxide Deposits
20% Loss of Heating Value

Loss of Heat Value and
Equipment Damage
$400,000/year

Digester Gas



Octamethylcyclotetrasiloxane (D_4)

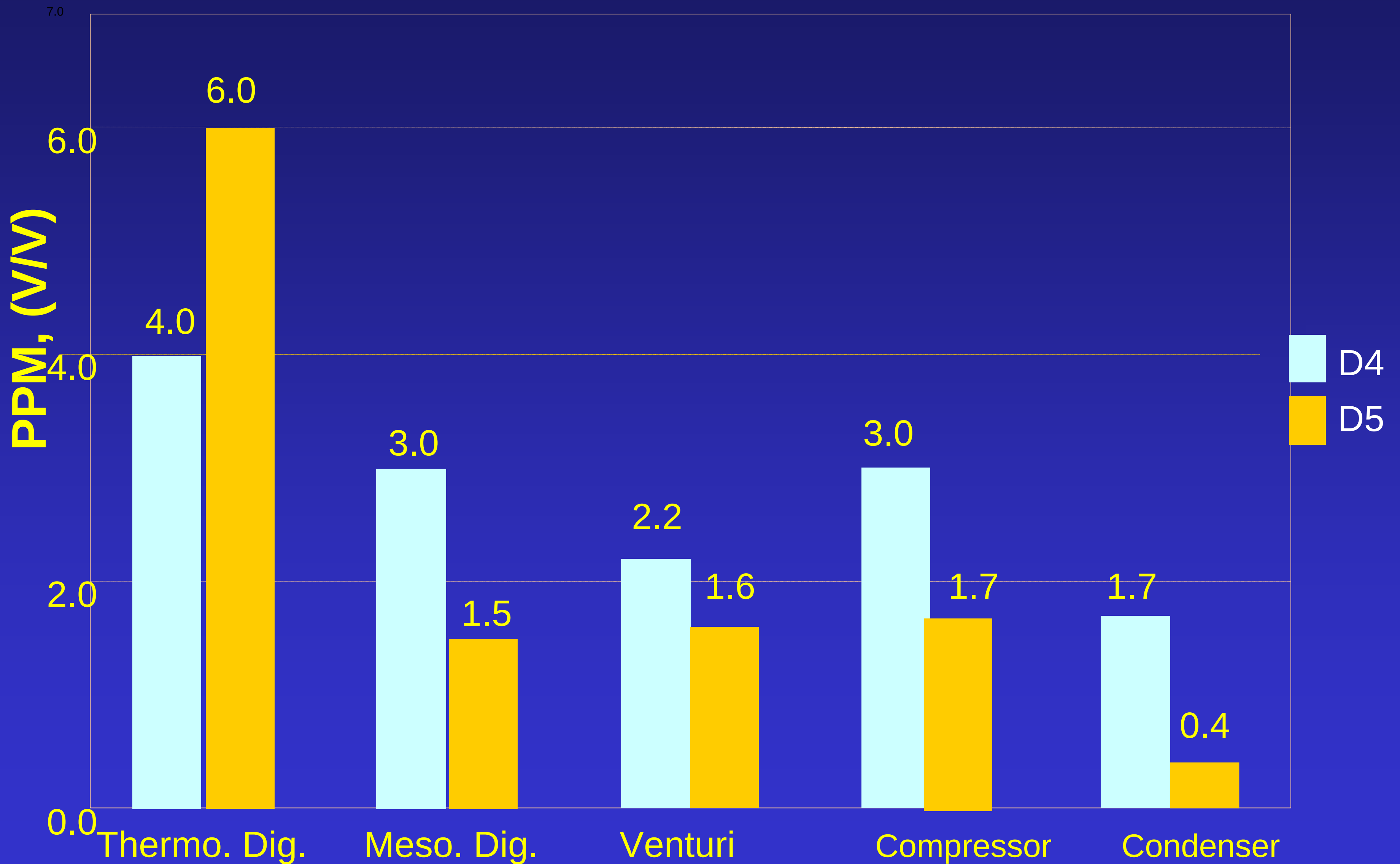
Physical Properties of D_4 Siloxane

Water Solubility	Low	74 micrograms/ L
Vapor Pressure	High	1.0 mm Hg at 25^{o}C
Henry's Law Constant	High	3 to > 17 (Benzene is 2.2)

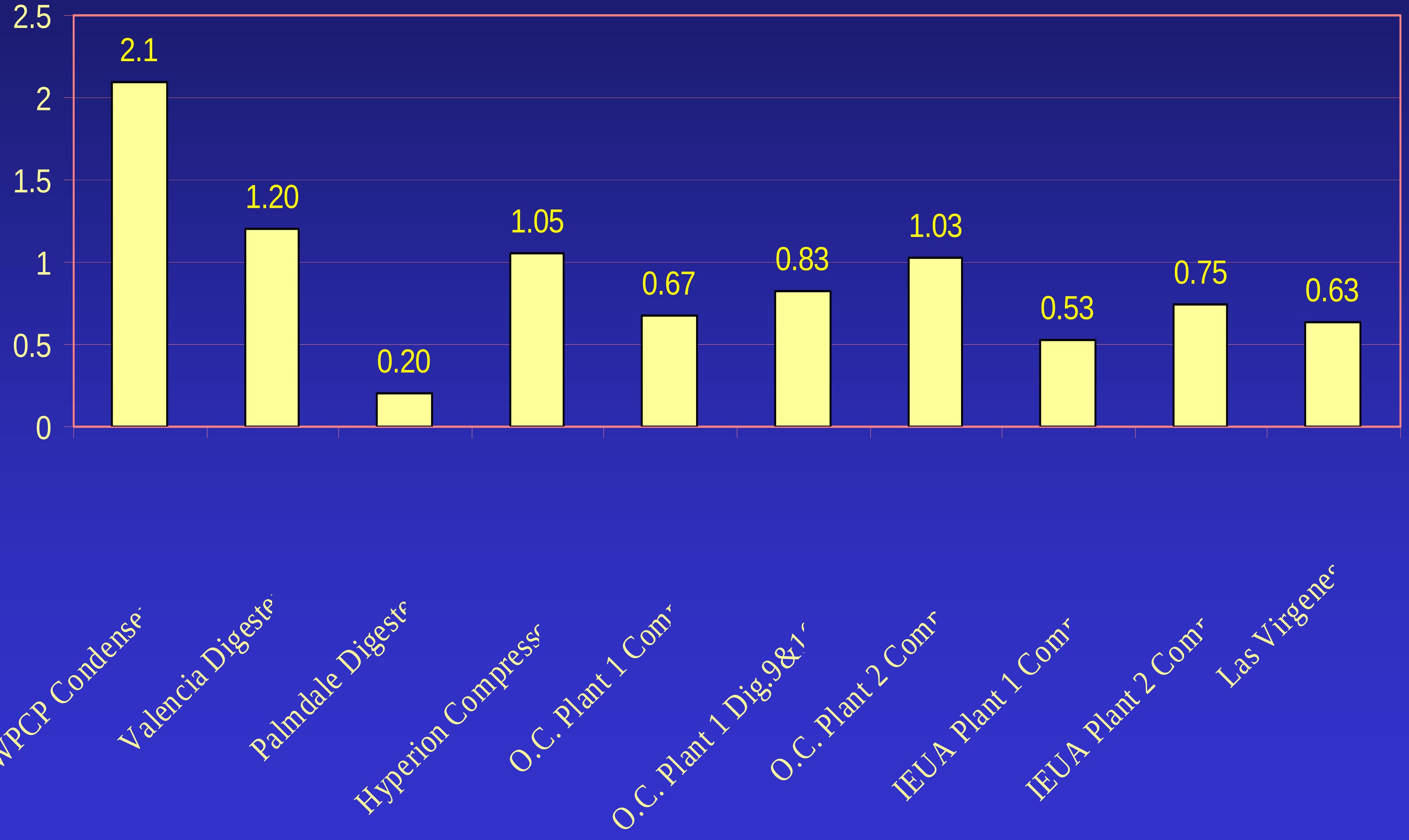
Existing JWPCP Gas Pretreatment System

- Venturi- Removes Dust
- Mist Separator
- Cooling Coil- 50^{o}F
- Compressor- 350 PSIG
- Condenser- 40 ^{o}F. Installed a few years after the original system to remove VOCs.

Siloxanes Concentrations at Various Digester Gas Pretreatment Locations



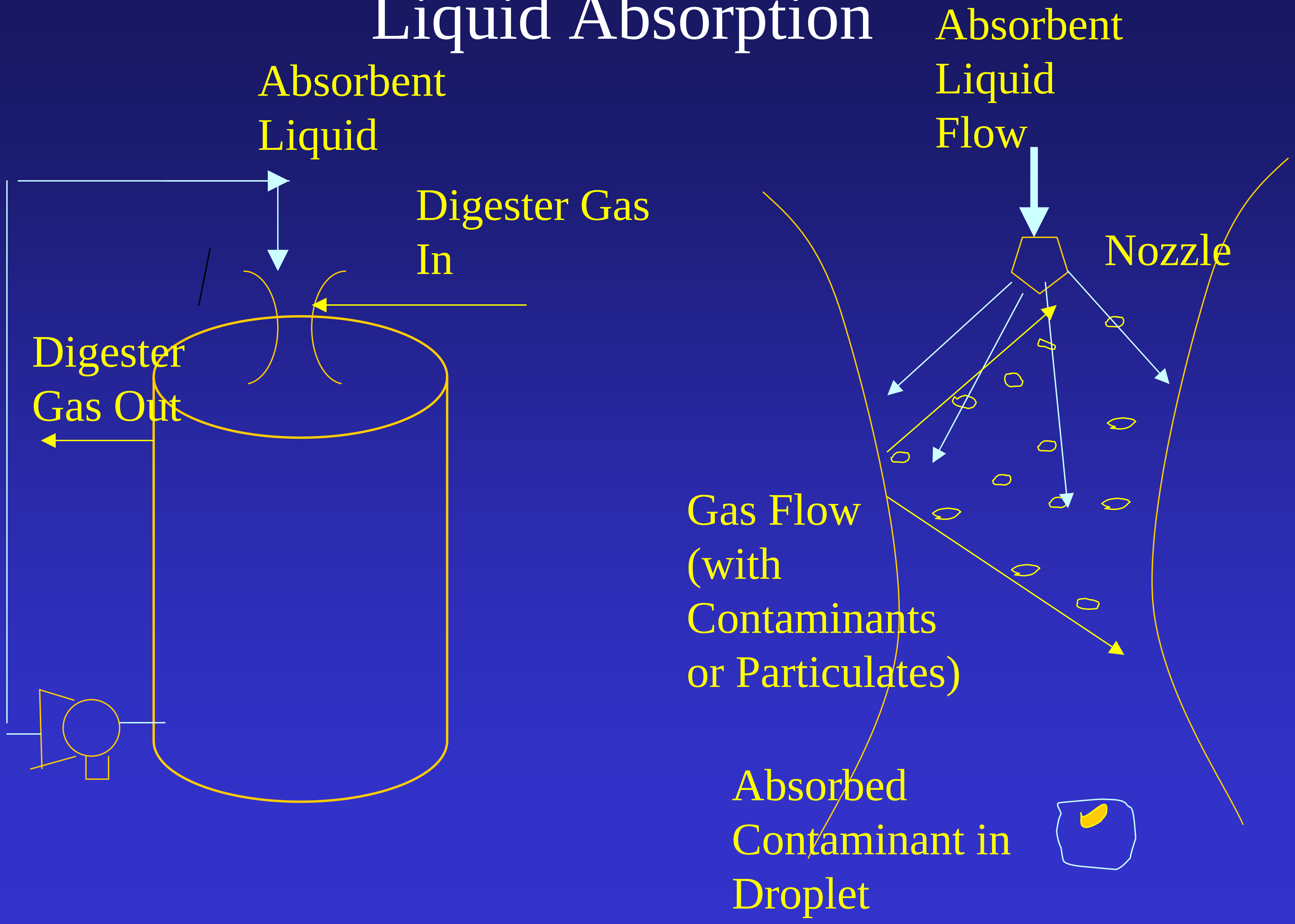
Combined D4 AND D5 AT JWPCP AND OTHER TREATMENT PLANTS



Siloxane Removal Technologies

- Liquid Absorption
- Condensation
- Solid Phase Adsorption

Liquid Absorption

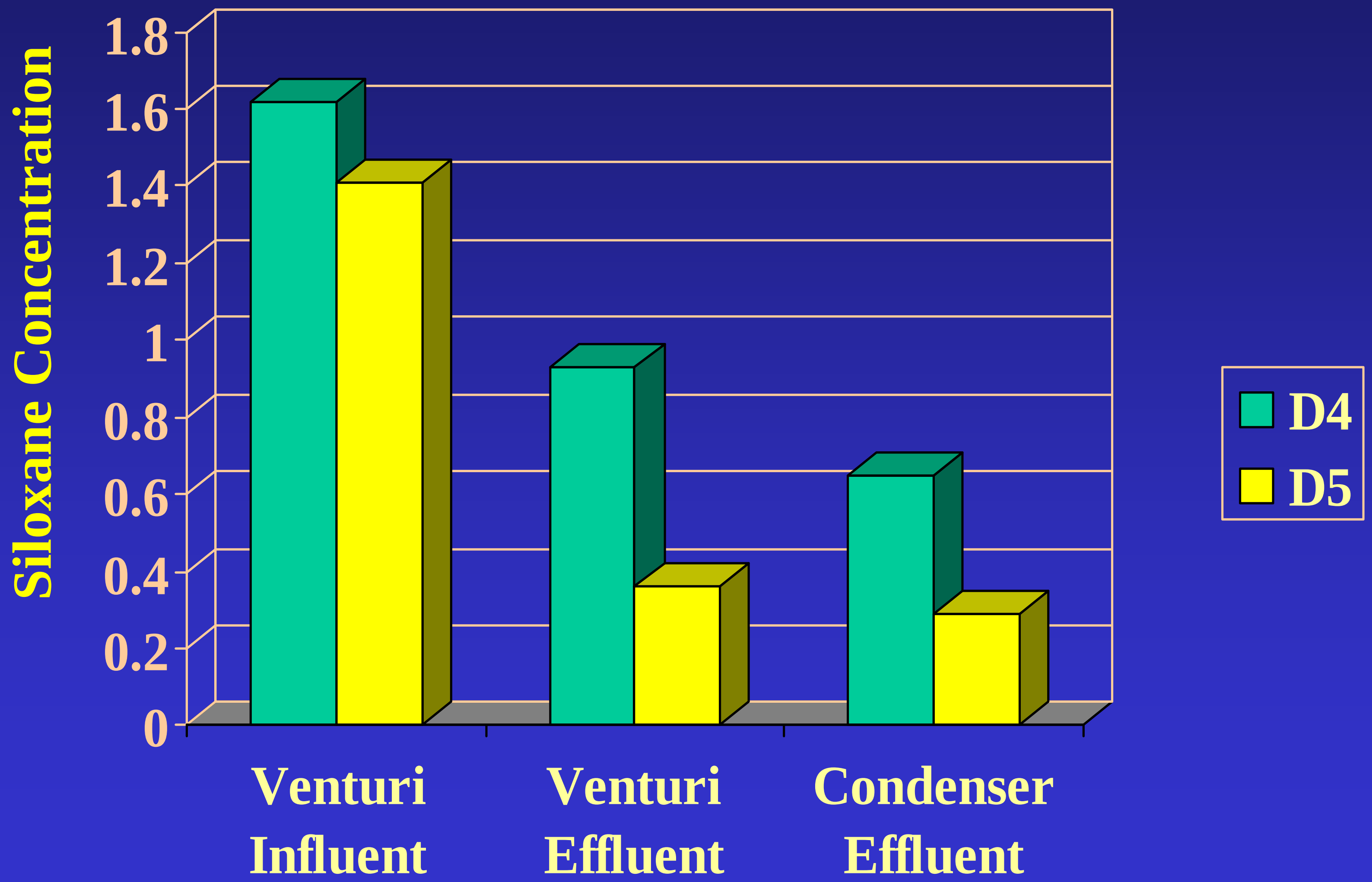


Scrubber Testing

- Water Not Effective
- Bench Scale Impingers Efficient When Digester Gas is Bubbled into Solution (Polypropylene Glycol, Methanol, Ethoxy-based Detergent)
- Pilot-Plant Testing at 50 scfm showed that much more scrubbing agent needed in both Venturi and Packed Tower

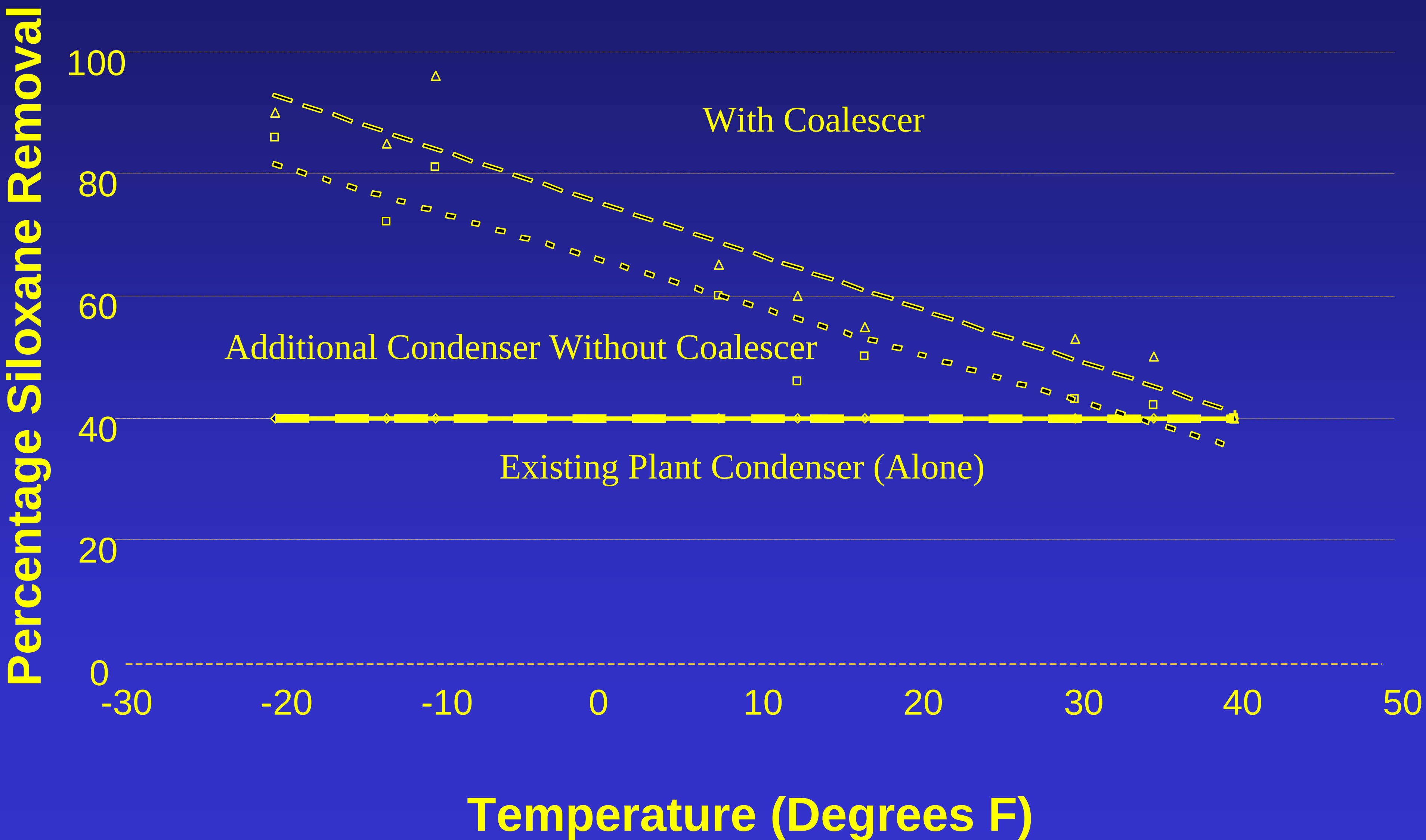
Venturi-Condenser Pilot-Plant

Venturi /40°F Condenser Pilot-Plant Results

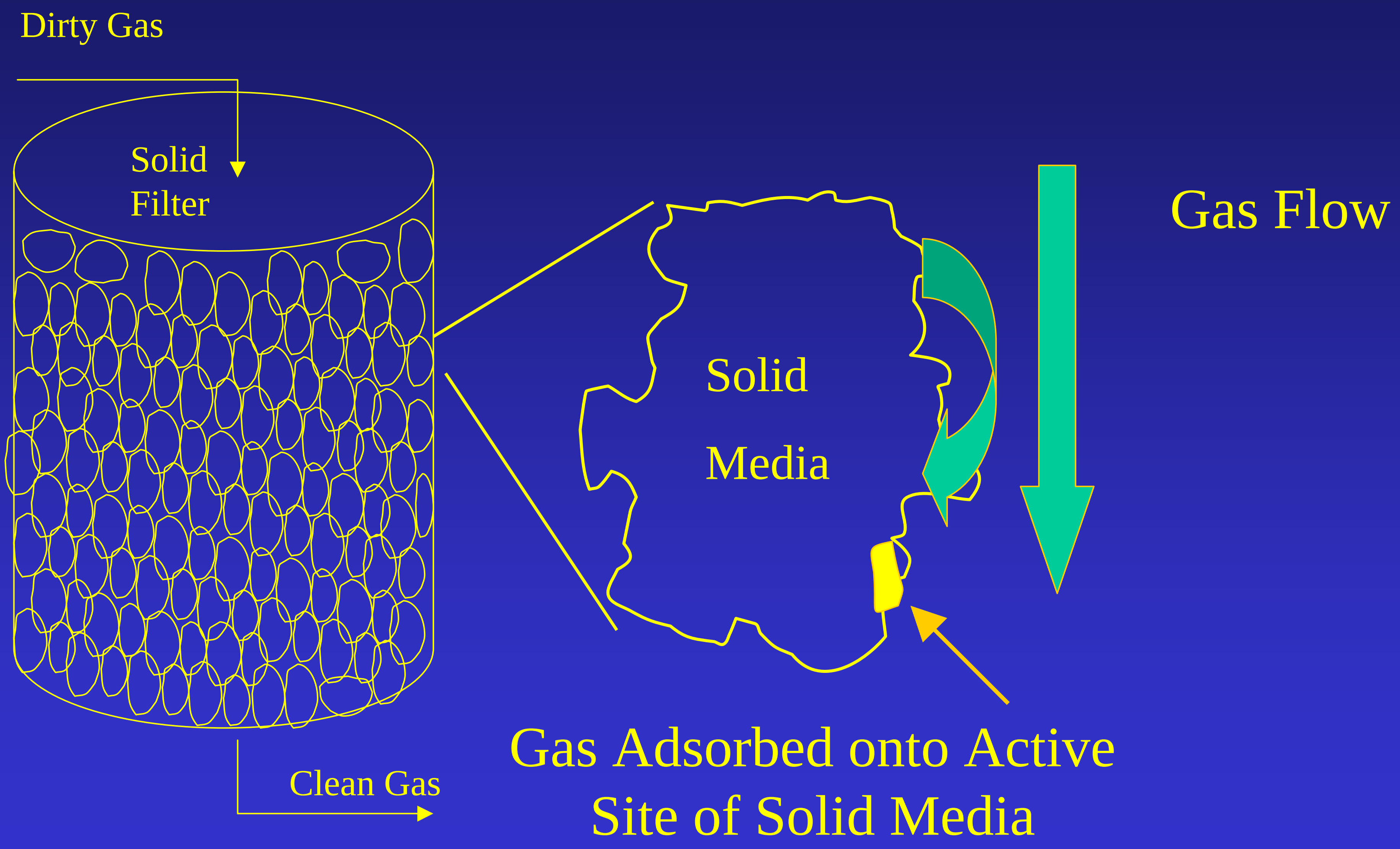


Test Condenser

Percentage Siloxane Removal as Function of Condenser Temperature

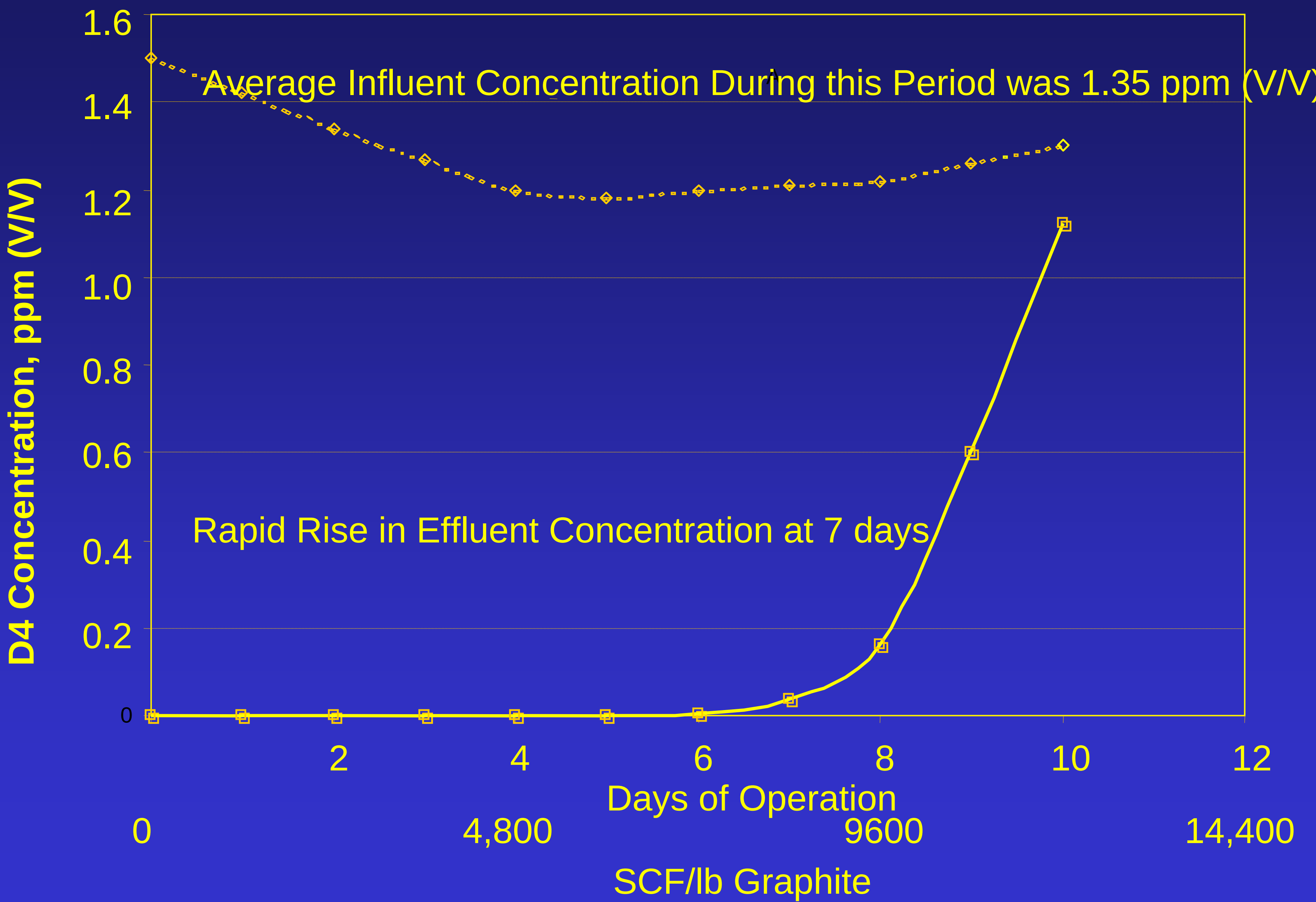


Gas Adsorption with Solid Media



High Pressure ASME Rated Test Filter Vessels

Typical Siloxane Filter Breakthrough Curve



Types of Solid Adsorbents

- Polymeric Synthetic Proprietary Resin
- Zeolite (Crystalline Aluminosilicates)
- Silica Gel
- Activated Carbon Graphite (with Various Adsorption Capacity Ratings)
- Activated Coconut Shell Based Carbon

Proprietary Resin

- Copolymer of Styrene/ Divinylbenzene
- Hydrophobic
- Low Affinity for Methane
- Micropores 100-200 Angstroms

Crystalline Aluminosilicates Clinoptilolite Zeolite

- Inexpensive
- High Sorptive Capacity
- Pore Size 11 Angstroms
- Adsorbs Large Molecules
- Typical Use of Zeolites is Adsorption of water in presence of non-polar solvents

Graphite Based Activated Carbon

- Carbon composed of polymorphous graphite
- Pore size 10-100 Angstroms
- Different Adsorbant Grades

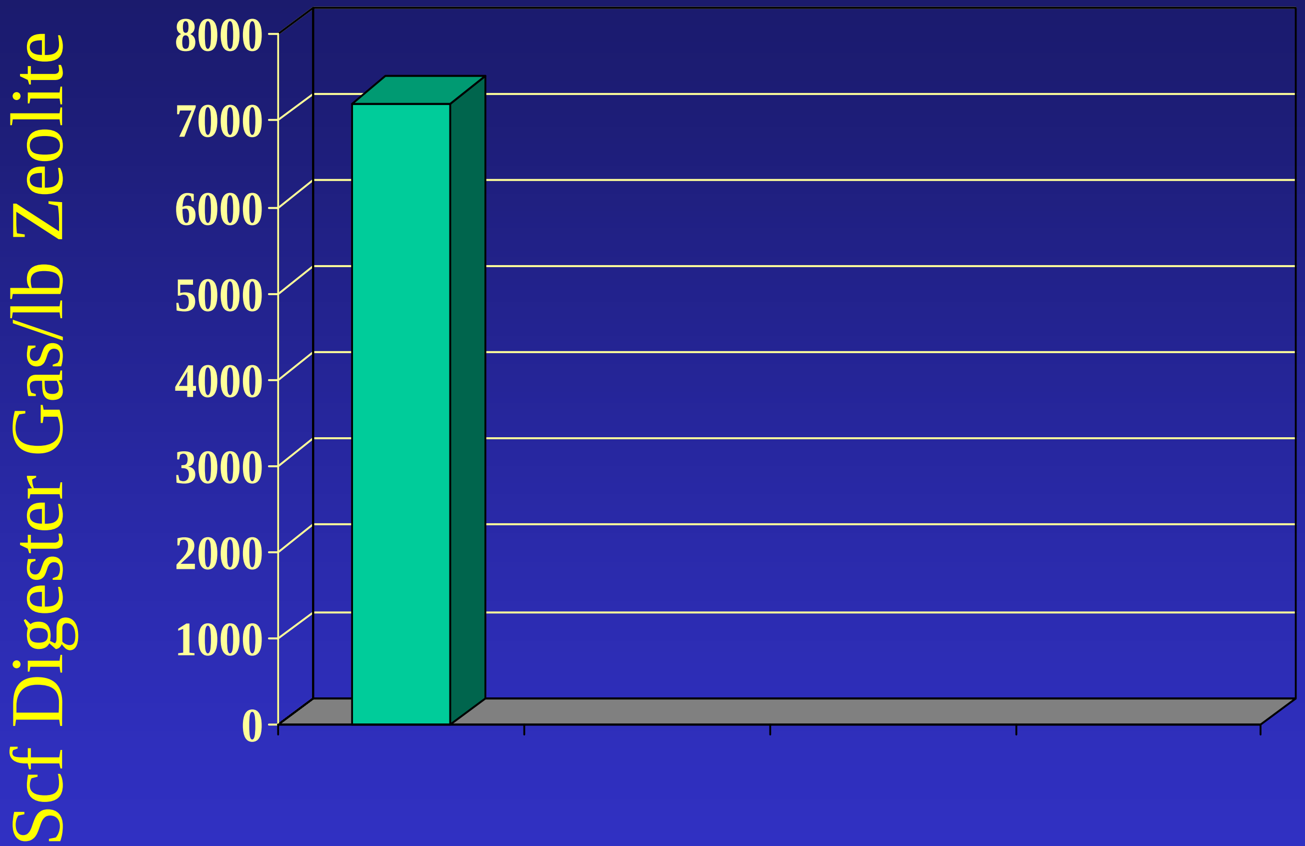
Coconut Shell Based Carbon

- Inexpensive
- Good Experience with Coconut Shell Activated Carbon for Air Pollution Control
- Average Pore Size 20 Angstroms

Polymeric Resin Results

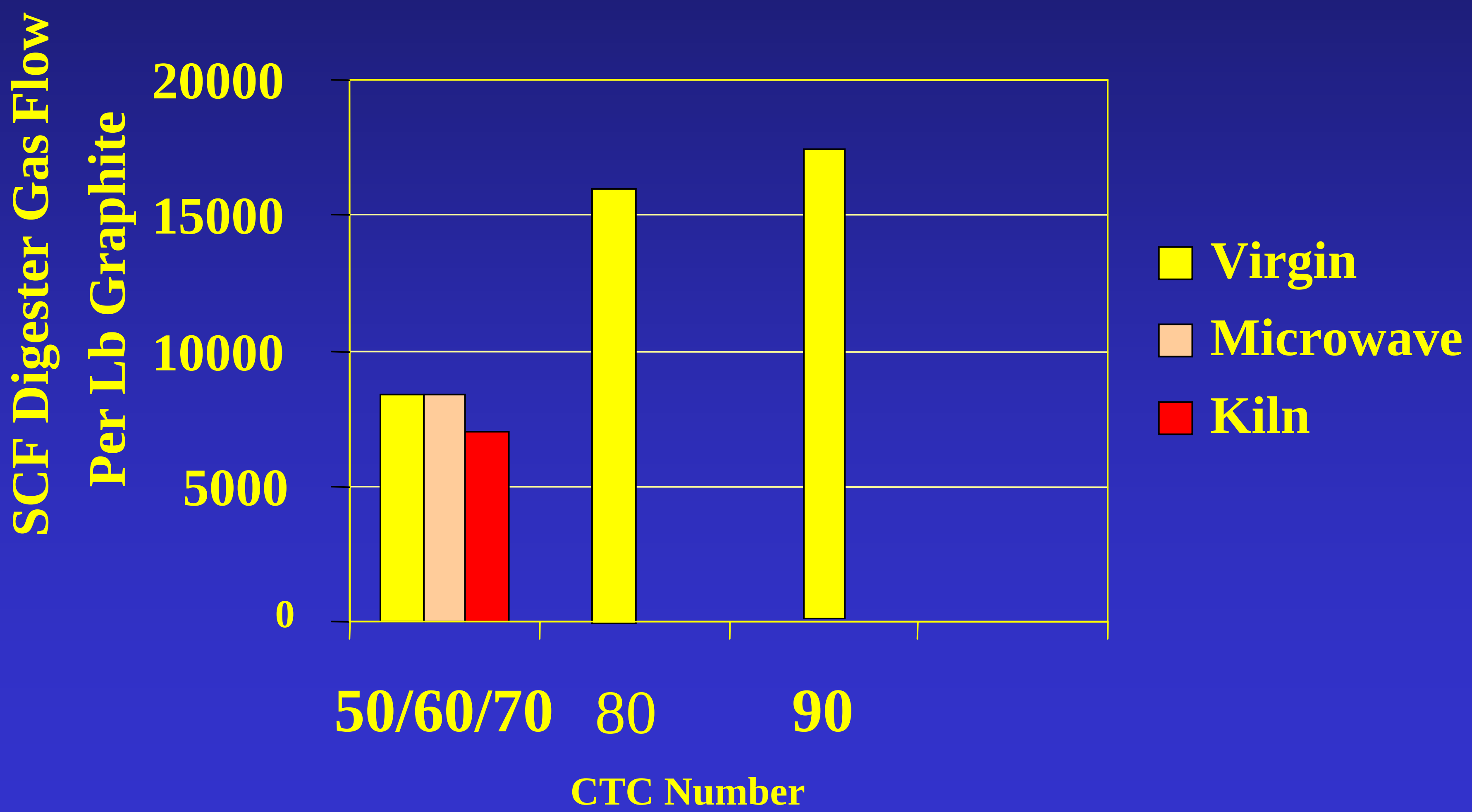
- Polymeric resin had high adsorptive capacity (20,000 scf gas/lb resin) on initial run but could not be regenerated with high efficiency.
- Along with siloxanes, other high molecular weight organics were adsorbed onto active sites in the resin.
- Overall rejection of the polymeric resin for this application. Resin good for low molecular weight contaminant such as methyl ethyl ketone (MEK)

Clinoptiolite Zeolite

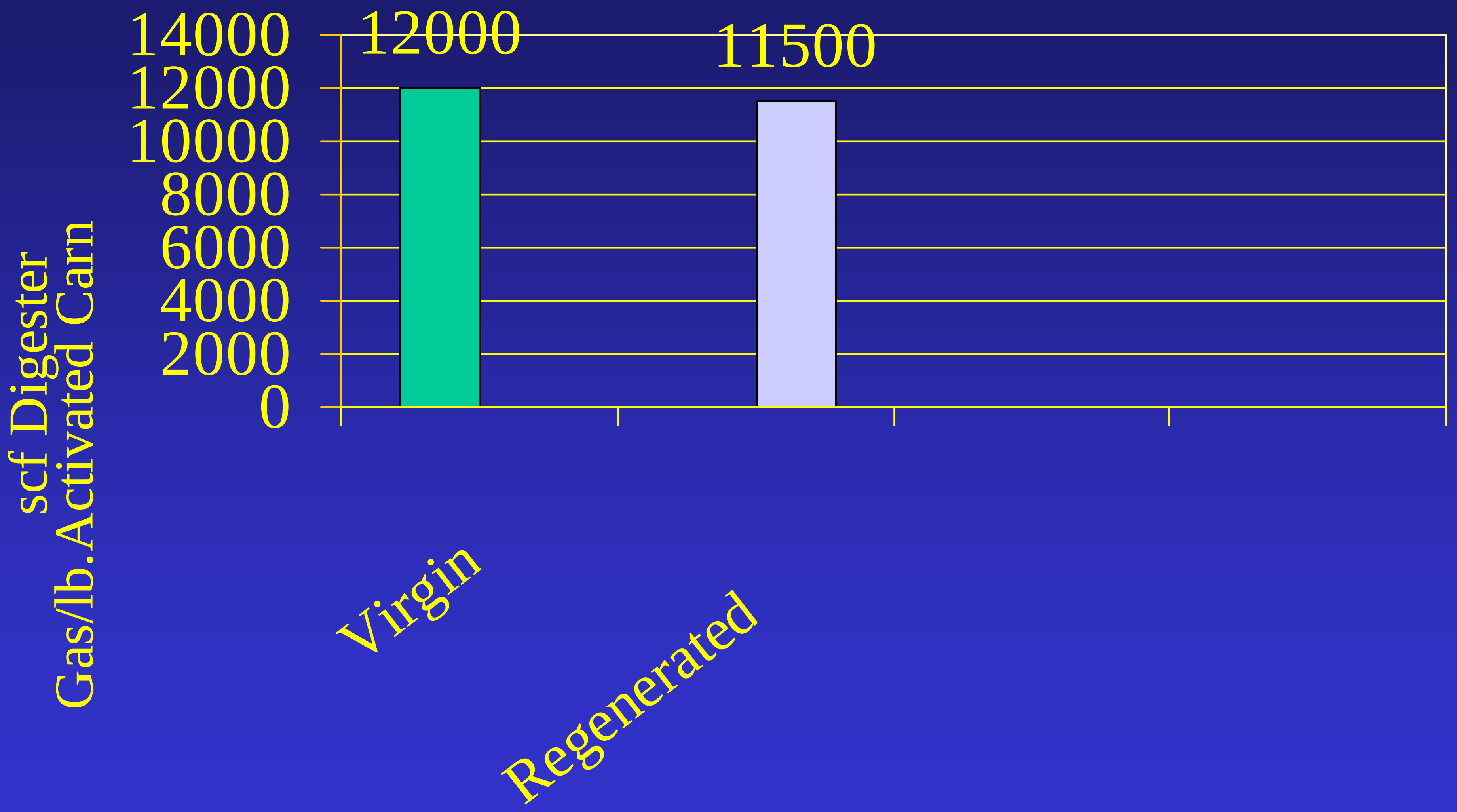


Silica Gel Had Same Performance of Zeolite

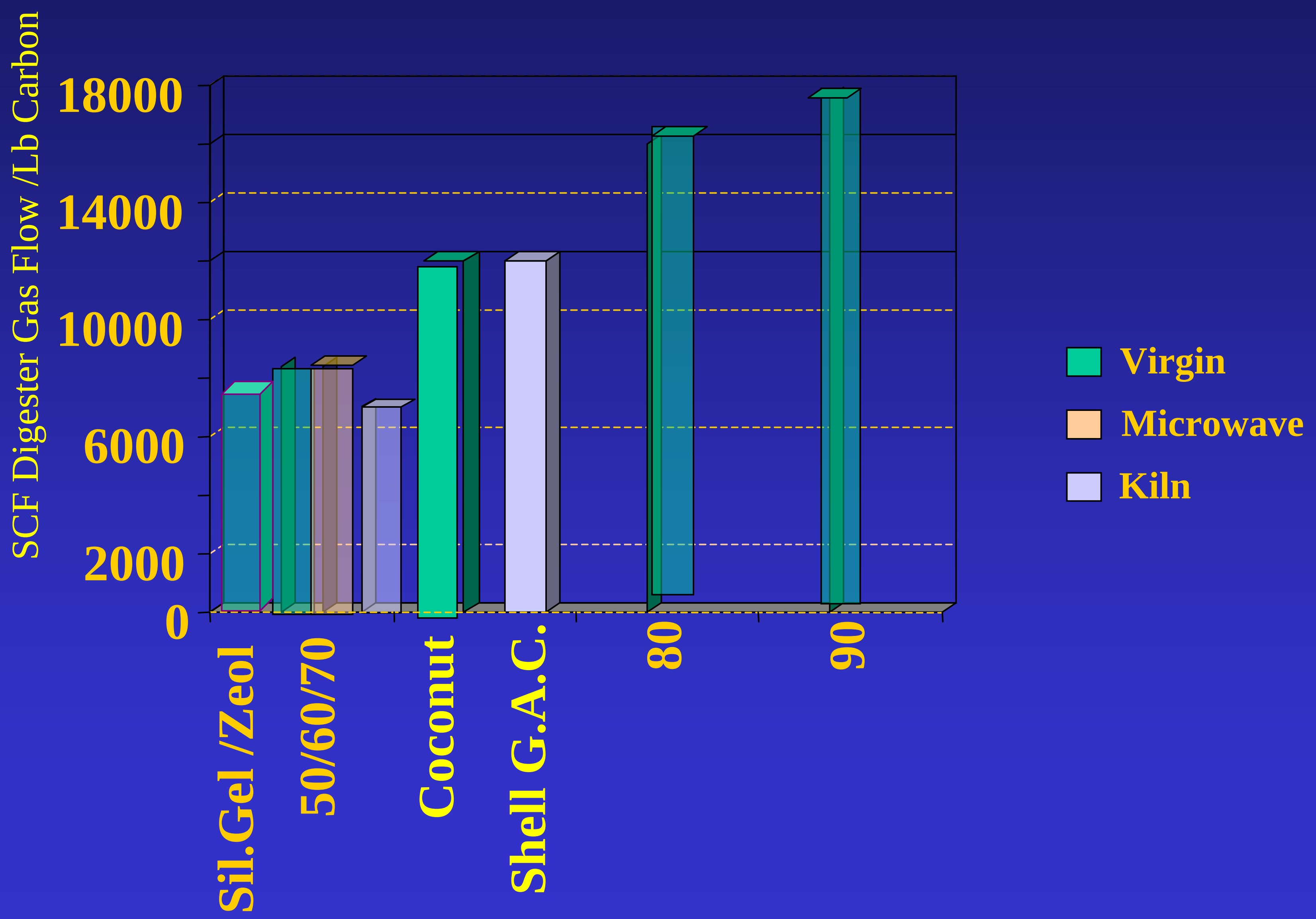
Graphite Carbon Results



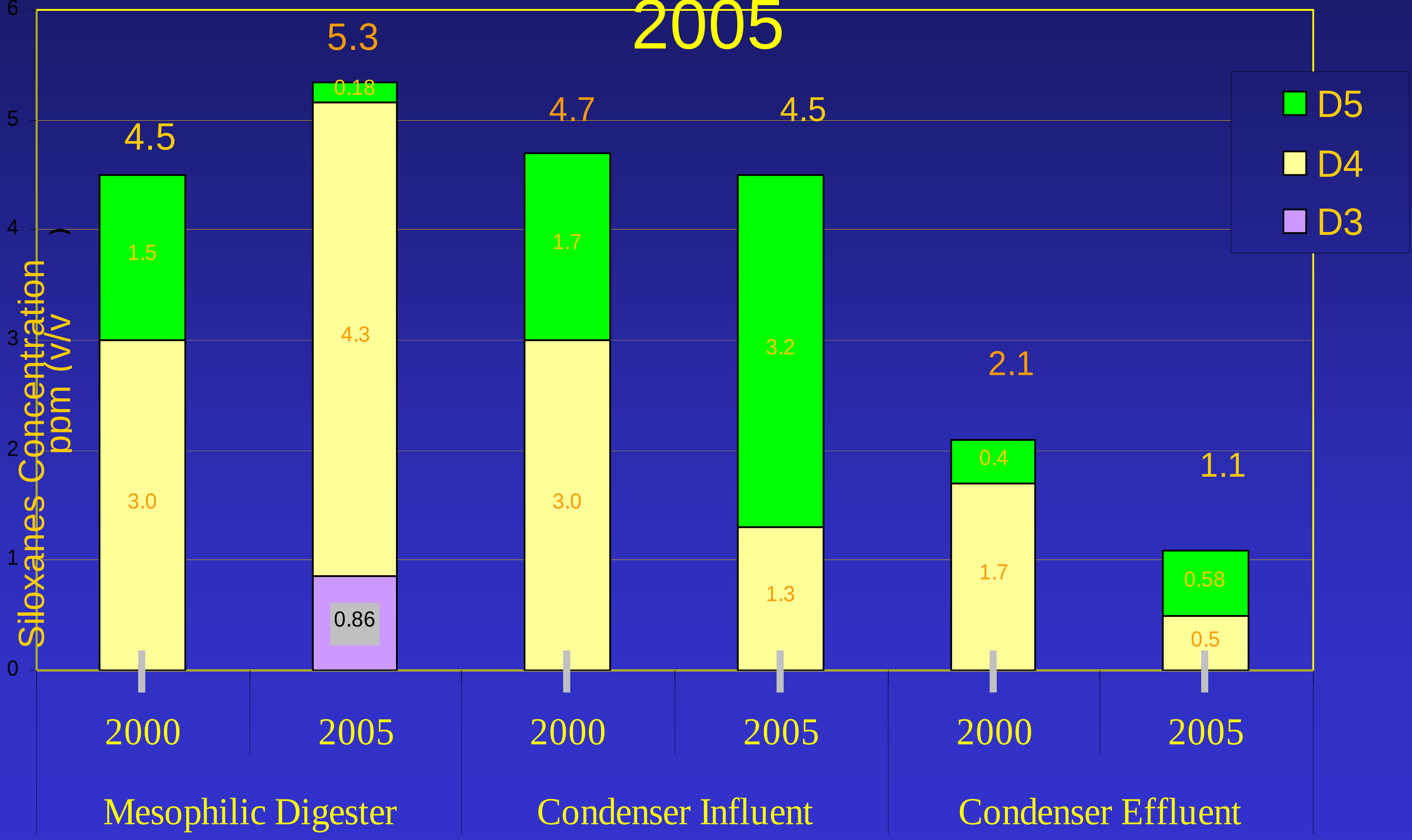
Activated Carbon Results



Coconut Shell Solid Media Performance



Siloxanes at JWPCP 2000 and 2005



Potential Full Scale Design

- 3- Filters; 2 on-line & 1 Stand By
- Each 30,000 lbs Graphite or Coconut Shell Carbon
- Each 10 ft. Diam. X 14 ft. Ht.

Estimated Capital & Operating Costs of 9,000 scfm Adsorption Filter System

System	Graphite-Based	Coconut Shell	New Additional Condenser*
Capital Costs	$360,000	$360,000	$750,000
Annual Operations/ Mainten-ance Costs	$160,000	$160,000	$85,000

*JWPCP already chills digester gas from 80^{o}F to 40^{o}F at capital cost of $500,000 and annual O/M of $64,000

Final Conclusions and Future Studies

- Removal of siloxanes can be done with adsorption and/or condensation

- Condensation/Adsorption costs $160,000 per year over 10 year period. Not treating costs $400,000/year

2006 Survey of Treatment Used

- LACSD: Carbon at Lancaster WRF Fuel Cell;Carbon and Silica Gel at Calabasas Landfill; Chiller at Palmdale Microturbine
- City of Los Angeles: Activated Carbon at Scattergood Electrical Station (Hyperion WWTP)
- Activated Carbon, Graphite and Chillers Used Elsewhere—"Second Generation" Low Temperature Chillers