



*Working Together for Clean Air*

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# Testing Cleaner Fuels at Washington State Ferries



**Presented By**

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# Did You Know That WSF....



- Owns 27 vessels
- Serves 10 routes with approximately 550 safe trips per day
- Moves 25 million people per year
- Uses more than 18 million gallons of diesel fuel annually

# Did You Know that in the Puget Sound Region.....



- **Washington State Ferries generate approximately 3 % of the PM and SOx emissions attributed to commercial marine vessels**
- **SO2 and fine particles contribute to regional haze production and reduce visibility**
- **Diesel emissions contain more than 40 substances listed as hazardous air pollutants**
- **Diesel particulate emissions are considered the primary air pollution health risk**

# What is Puget Sound Clean Air Doing About Diesel Emissions?



- **Implemented “Diesel Solutions” in collaboration with EPA’s Voluntary Retrofit Program**
  - Introduced ultra-low sulfur diesel fuel early
  - Promote low sulfur - cleaner fuels
  - Retrofit existing transit, school, and solid waste vehicles with emission control devices
- **Expanding the program to address non-road sources in the rail, marine, and construction sectors**

# So What are We Working on Together?



- **Evaluated cleaner fuel options for WSF fleet**
- **Conducted tests on a selected WSF vessel**
- **Evaluated the results of testing and working with decision makers on potential next voluntary steps**



- **Develop emission factors for tested fuels**
- **Compare fuel costs**
- **Determine compatibility with vessel equipment**
- **Give WSF personnel experience handling new fuels**

# M/V Rhododendron





- **High sulfur diesel (HSD)**
- **Low sulfur diesel (LSD)**
- **Ultra-low sulfur diesel (ULSD)**
- **Blend of low sulfur diesel with 20% biodiesel (B20 – LS)**

# Test Conditions



- **May – September 2003 during actual vessel operations**
- **Vessel received at least 4 batches of fuel prior to each stack test**

# Typical Operating Conditions for the M/V Rhododendron



OPERATION	TYPICAL % OF MAXIMUM RPM (Max 780 RPM)	TYPICAL DURATION OF OPERATION (in minutes)
Pushing against the dock to load vehicles	25%	7.5
Acceleration away from the dock	60%	0.5
Transit	100%	9-10
Slow down upon dock approach	50%	1 – 1.5
Docking maneuvering	Variable – from 10 to 100 % depending on maneuvering need	2
Pushing against the dock to unload vehicles	25%	7.5
<p><b>Note: Environmental conditions (tide, current, and wind, etc) greatly effect these assumptions, which are provided for illustration purposes only.</b></p>		

# M/V Rhododendron Docking



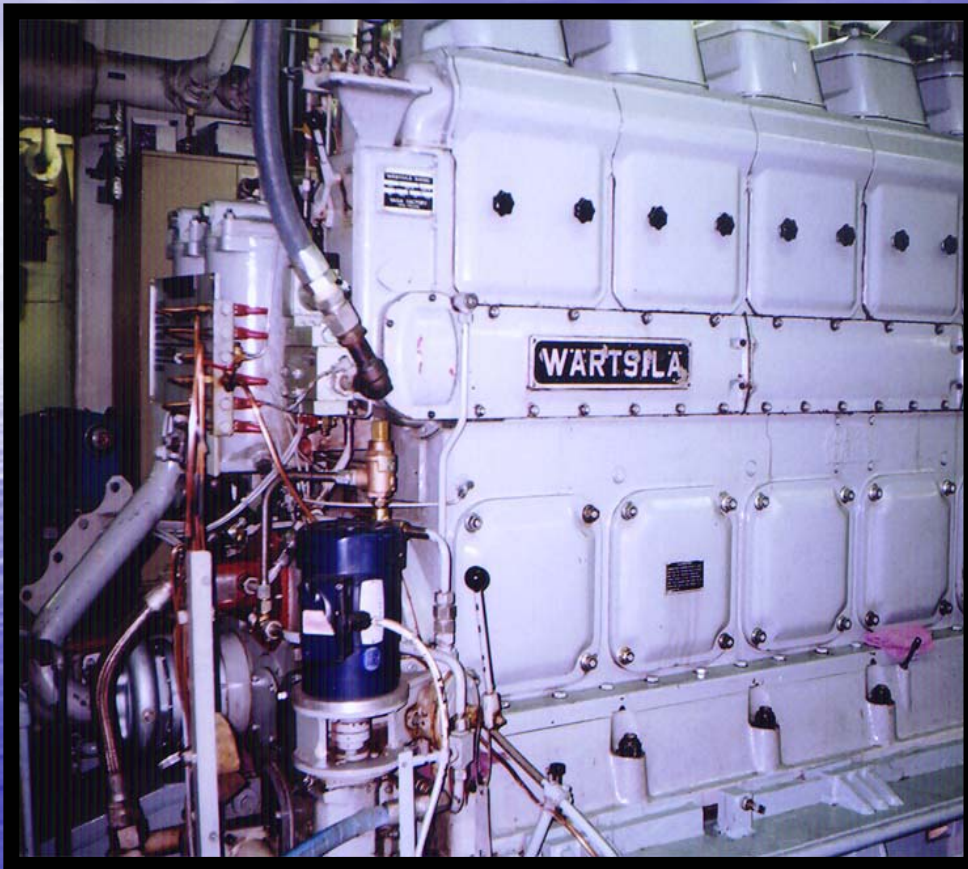
# Unloading Cars Around Source Test Equipment on Car Deck





- **Engine operating parameters**
- **Fuel properties and costs**
- **Stack emissions**

# Engine Specifications

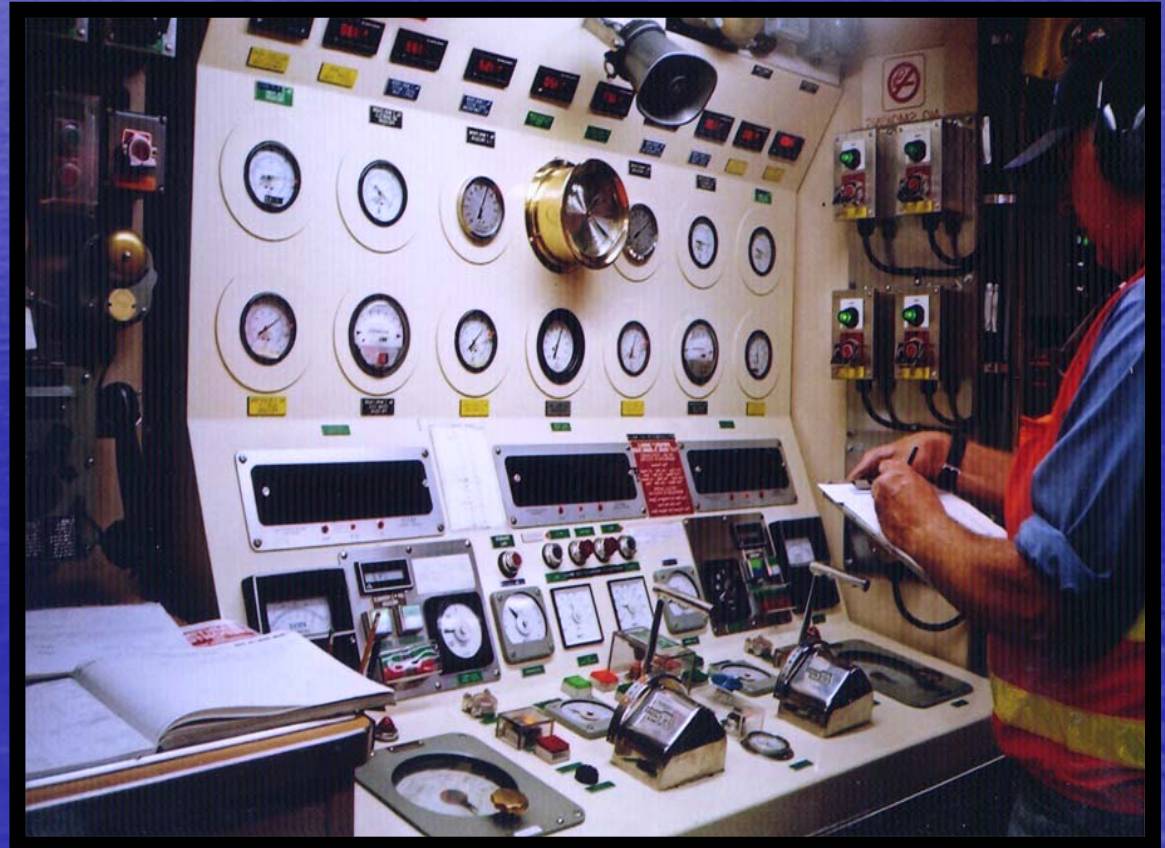


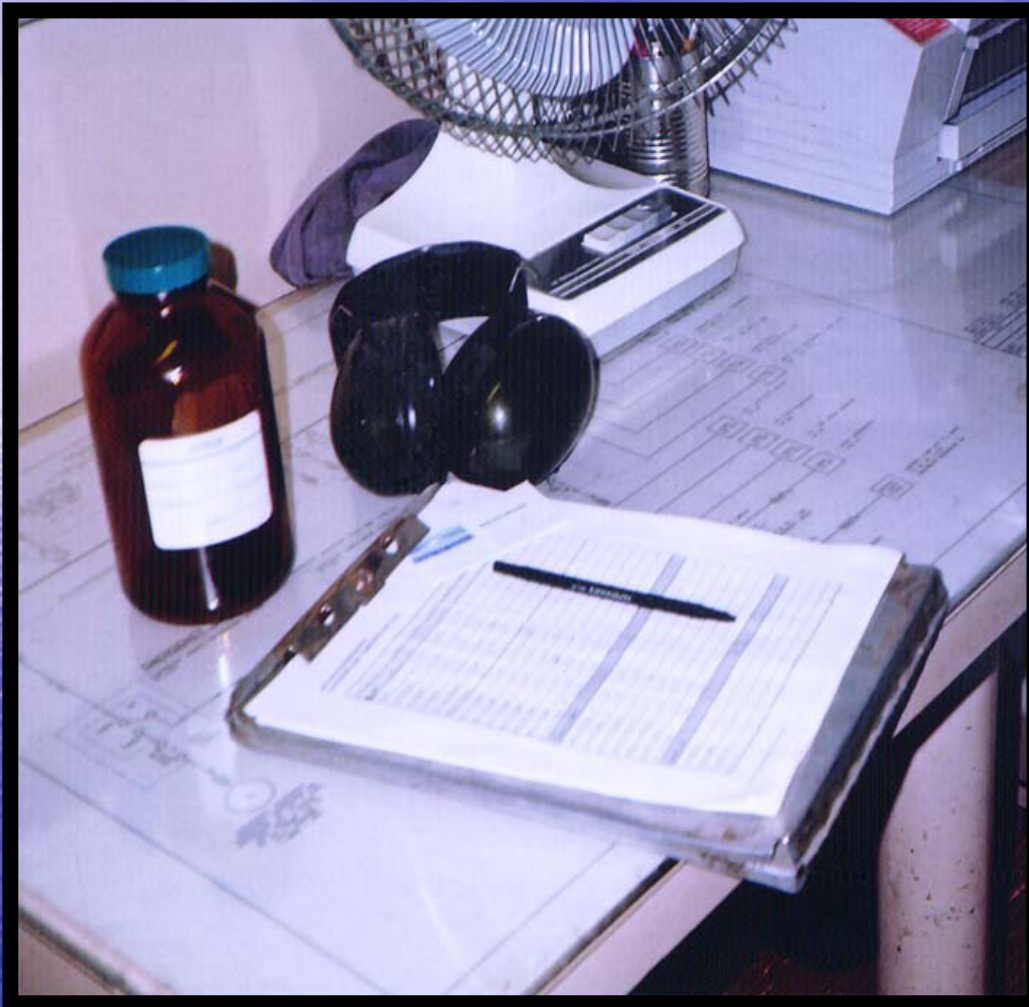
- 2 Wartsila Main Engines
- 800 - horsepower
- 4 - Stroke
- Turbocharged

# Engine Operating Parameters



- **Revolutions per minute (RPM)**
- **Cylinder temperatures**
- **Exhaust temperatures**
- **Lubricants – pressure and temperature**
- **Coolants – pressure and temperature**
- **Fuel consumption**





- Samples collected from vessel tank prior to each stack test
- Analyzed for API Gravity, aromatics, ash content, Cetane index, distillation 90% recovery, distillation end point, flash point, total nitrogen, total sulfur.
- Test performed by Conoco-Phillips refinery

# Sulfur Content of Vessel Fuel

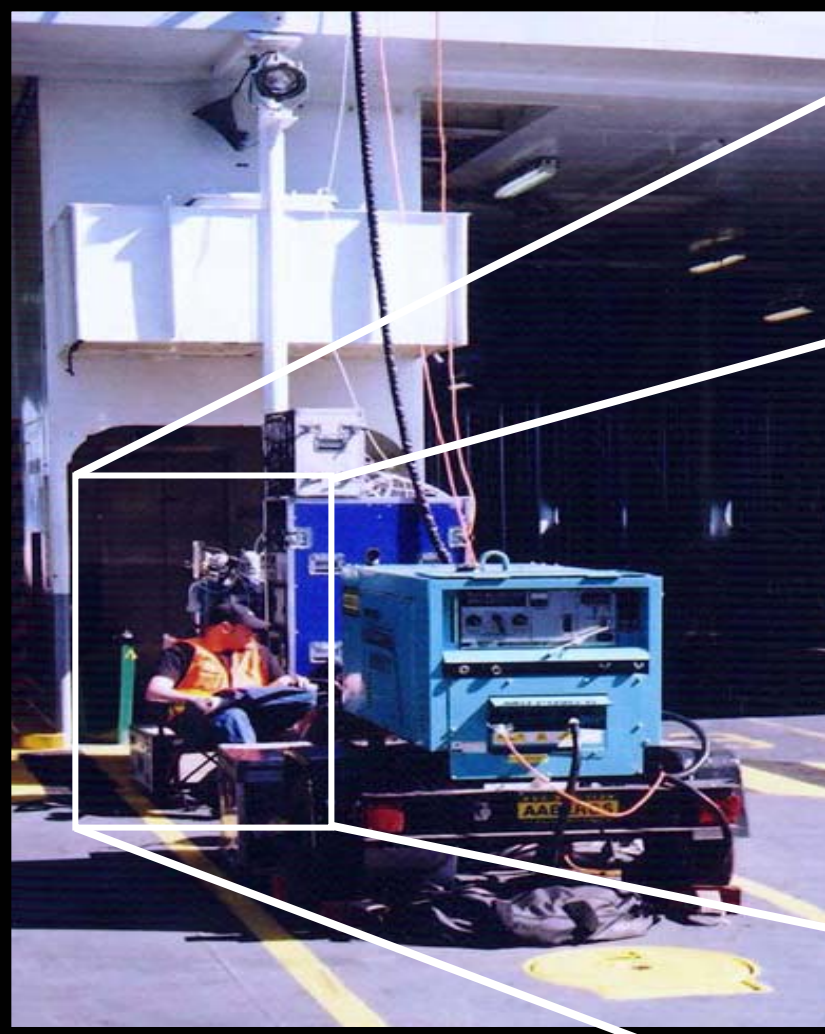


- HSD            3575 ppm
- LSD            420 ppm
- ULSD           52 ppm
- B20-LSD      335 ppm

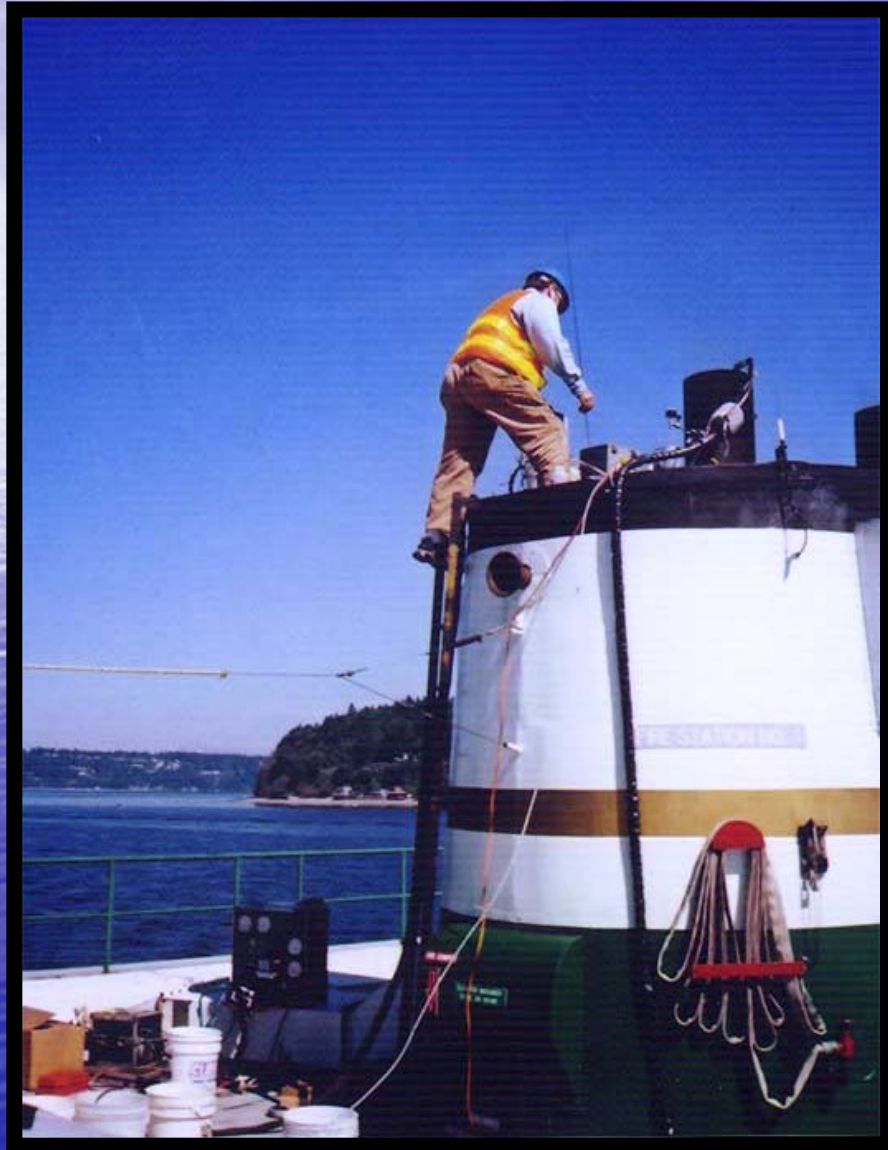


- **Continuous methods: SO<sub>2</sub>, NO<sub>x</sub>, HC and CO**
  - Data every 15 seconds
  - Tracked with engine operation modes
- **Grab methods: Particulate matter**
  - Three samples per fuel
  - Each sample covered two crossings (a mix of all operating modes)

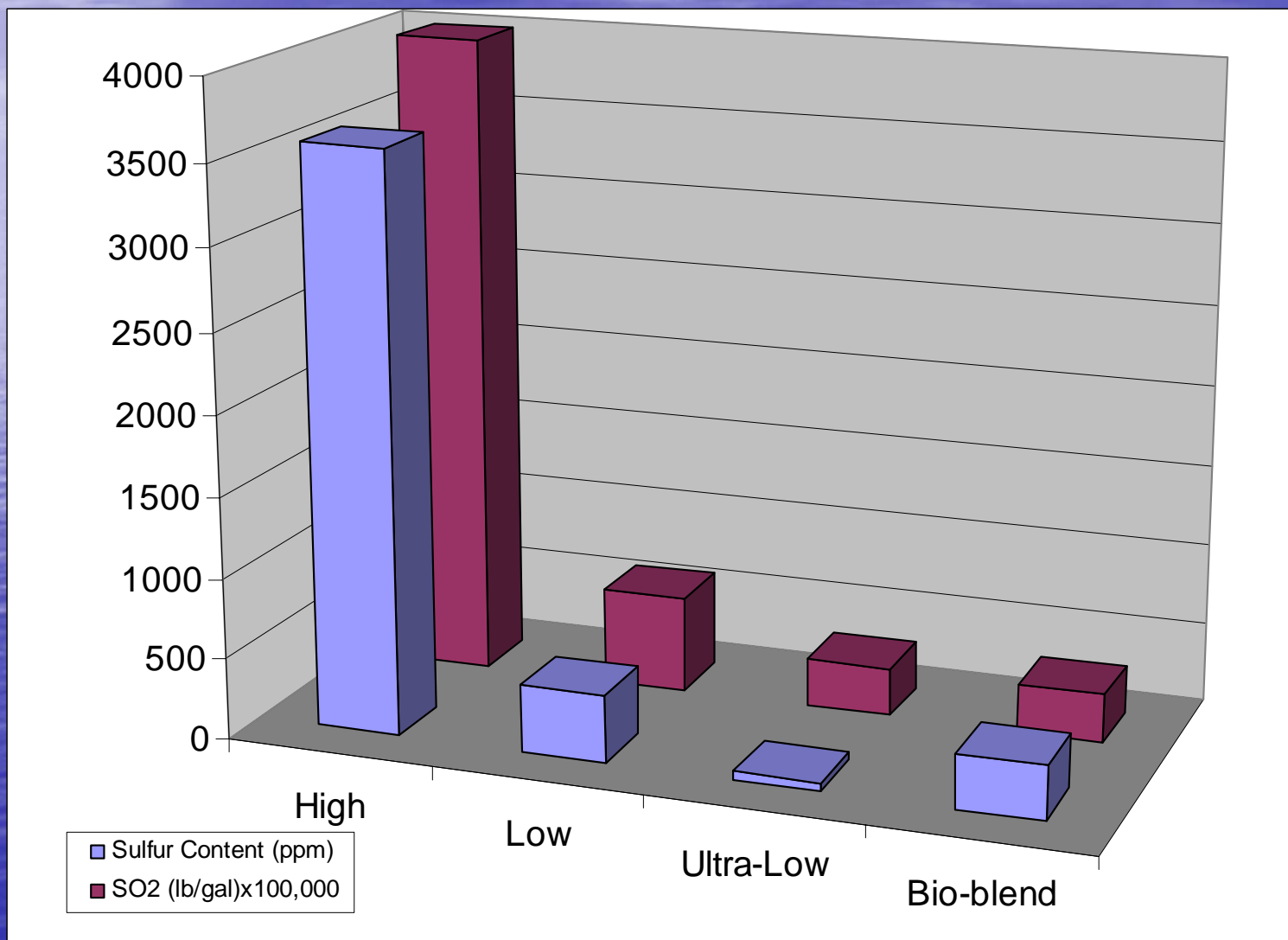
# Continuous Emission Monitoring Equipment



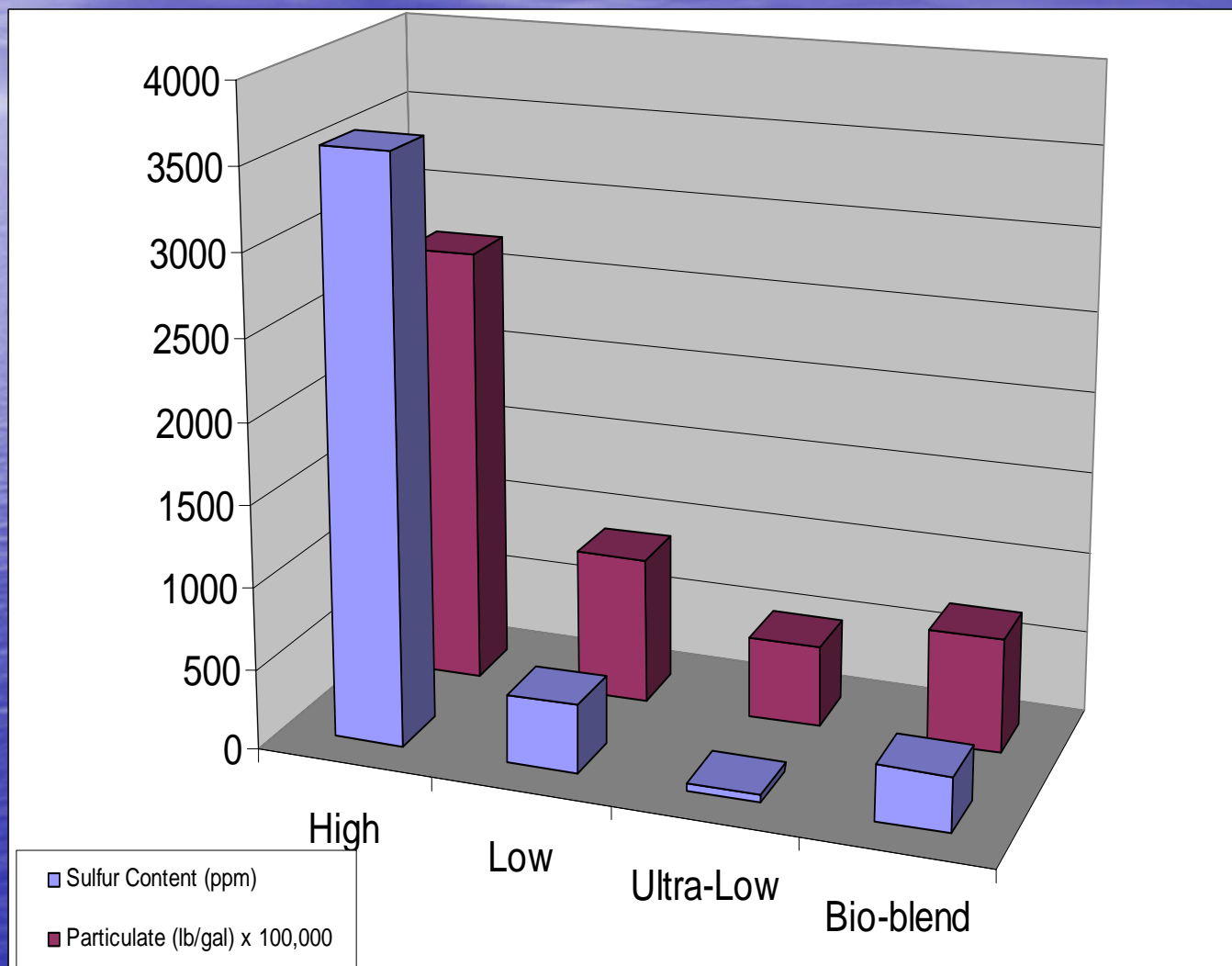
# AmTest Employee Checking Sampling Equipment

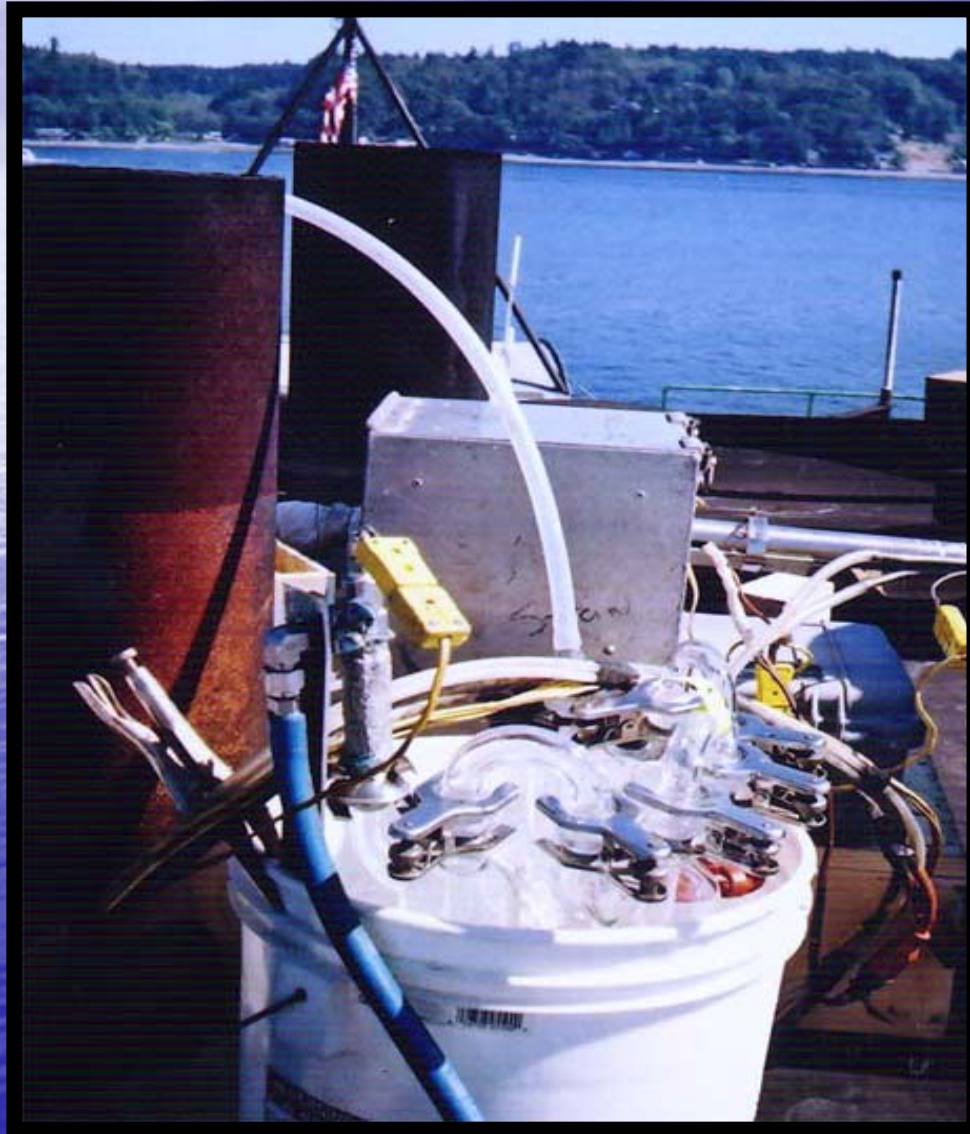


# Comparison of Sulfur Dioxide to Fuel Sulfur Content



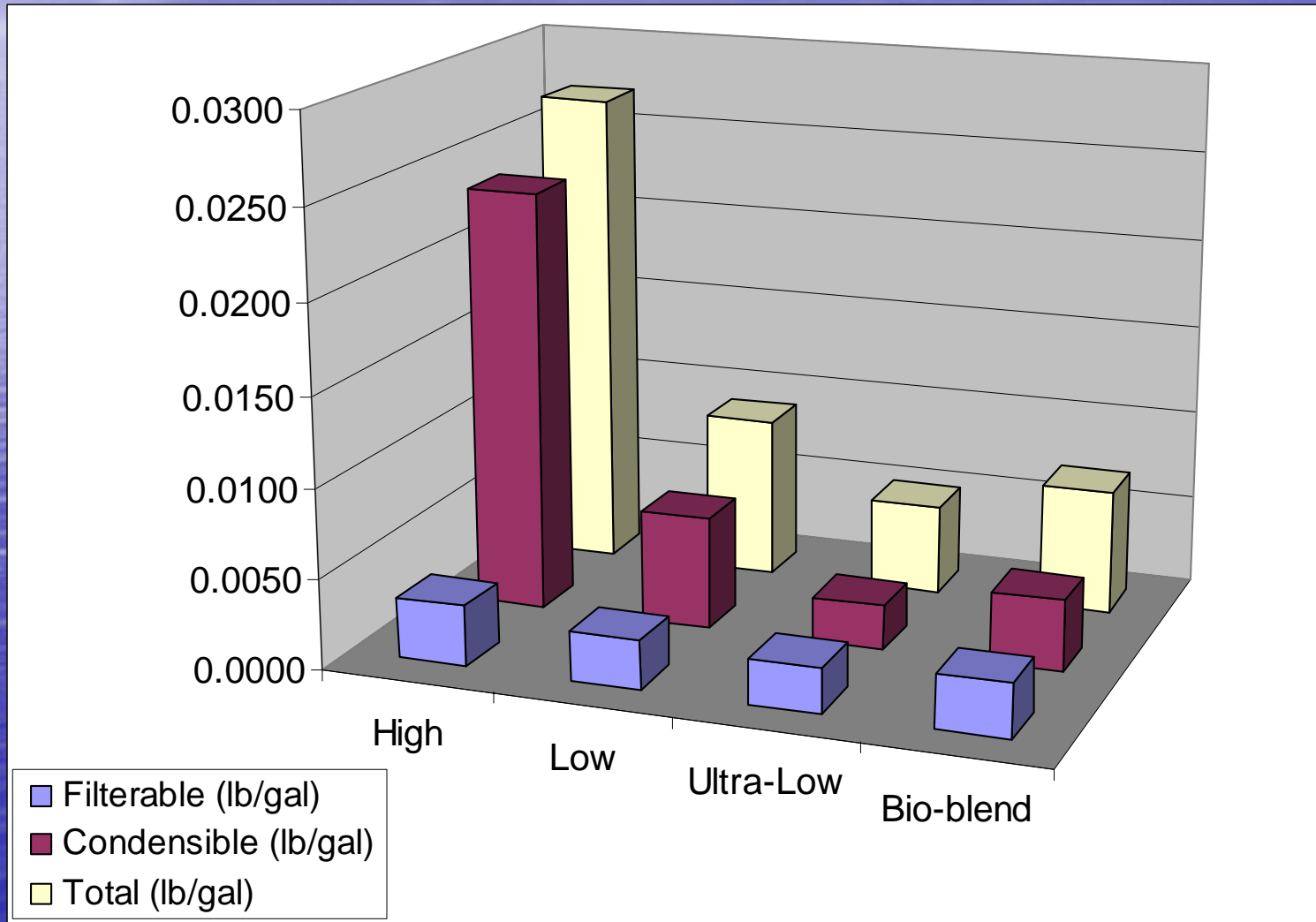
# Comparison of Particulate Emissions to Fuel Sulfur Content





- **Filterable (PM 10)=**  
Solids collected on the filter
- **Condensable (PM 2.5)=**  
Organic materials passing through the filter and condensing.  
Condensable particulates consist of:
  - unburned fuel
  - oils
  - incomplete combustion products

# Comparison of Particulate Matter Fractions





- **Averaged results for all fuels (lb/gallon) +/- standard deviation**

- **NOx = 0.439 +/- 0.018**
- **CO = 0.032 +/- 0.003**
- **HC = 0.013 +/- 0.002**

# Fuel Costs – Incremental Differences



- **HSD**            **baseline**
- **LSD**            **1 cent/gallon**
- **ULSD**        **3 cents/gallon**
- **B20-LSD**    **25 cents/gallon**



- **SO<sub>2</sub> and particulate emissions were proportional with fuel sulfur content:**
  - **SO<sub>2</sub> emissions were reduced by 85% with use of LSD and by 92% with use of ULSD and B20-LSD**
  - **Particulate emissions were reduced by 55% with use of LSD, 65% with use of B20-LSD and 75% with use of ULSD**
- **Particulate emissions consisted mostly of condensable materials (PM 2.5)**

# Significant Outcomes (cont'd)



- **NO<sub>x</sub>, CO and hydrocarbon emissions remained relatively unchanged regardless of fuel type**
- **No operational difficulties were encountered with short-term use of this fuel**
- **Greatest reductions in SO<sub>2</sub> (55%) and particulate emissions (85%) can be achieved by switching from HSD to LSD for a approximately \$.01 per gallon**
- **Switching to ULSD reduces particulates by an additional 20% and SO<sub>2</sub> by an additional 7% for approximately \$.03 per gallons**



## OUR THANKS TO:

- **U.S. Environmental Protection Agency**
- **World Energy – Pacific Functional Fluids – Southern Counties Oil – Pettit Oil**
- **Conoco-Phillips Refinery**
- **AMTEST**
- **Crew of the M/V Rhododendron**