

Development of a Large Vessel Emission Measurement Protocol

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U.S. Maritime Administration
Shipboard Energy Technologies
Workshop

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- ❖ MAN B&W

Overview

- ❖ Vessel Categories
- ❖ Large Vessel Emissions Standards
- ❖ Test Cycles
 - Certification
 - In-Use
- ❖ Testing Measurements
 - Exhaust Flow Rate
 - Work
 - Pollutant Concentrations

Vessel Categories

Category 1: > 37 kW and < 5 liter per cyl.

Category 2: 5 liter $<$ cyl. $<$ 30 liter

Category 3: 30 liter $<$ cyl.

Large Vessel Emission Standards

Tier 1
(from model
year 2004)

NOx:

17.0 g/kW-hr for max. speed < 130 rpm

45.0 X N^{-0.20} g/kW-hr where N = max. speed
for 130 rpm < max. speed < 2000 rpm

Tier 2

Will be finalized on or before April, 2007

Large Vessel Emission Standards

“Blue Sky
Series”
(voluntary)

NO_x:

4.8 g/kW-hr for max. speed < 130 rpm

$9.0 \times N^{-0.20}$ g/kW-hr where N = max. speed for
130 rpm < max. speed < 2000 rpm

HC: 0.4 g/kW-hr

CO: 3.0 g/kW-hr

Certification Cycles

International Standards Organization (ISO) Type E “Marine Applications”

- E1: diesel engines for craft less than 24 m in length
- E2: heavy-duty constant speed engines for ship propulsion
- E3: heavy-duty marine engines
- E4: pleasure craft spark-ignited engines for craft less than 24 in length
- E5: diesel engines for craft less than 24 m in length

Certification Cycles

ISO 8178 E3 Cycle "Heavy-Duty Marine Engines"

| Mode Number (cycle E3) | 1 | 2 | 3 | 4 |
|---------------------------|-----|-----|------|------|
| Speed, % | 100 | 91 | 80 | 63 |
| Power (%) | 100 | 75 | 50 | 25 |
| Weighting Factor | 0.2 | 0.5 | 0.15 | 0.15 |

“In-Use” Cycles

- ❖ Developed from ship’s logs and/or activity data logging
- ❖ Designed for evaluating emissions in operating modes that may affect air sheds
- ❖ Examples:
 - voluntary cargo ship speed reduction
 - port maneuvering
 - normal cruising speed

Practical Considerations

- ❖ Real world application of certification test cycles for large vessels is challenging
 - mode points
 - safe operation
 - navigation
 - fuel costs
 - time schedule
 - sea and wind conditions

- ❖ “In-use” test cycles provide very useful information; there are some limitations



Testing Measurements

- ❖ Exhaust Flow Rate
 - direct measurement (e.g. diff. pressure)
 - calculated (based on exhaust CO₂, fuel flow measurement)

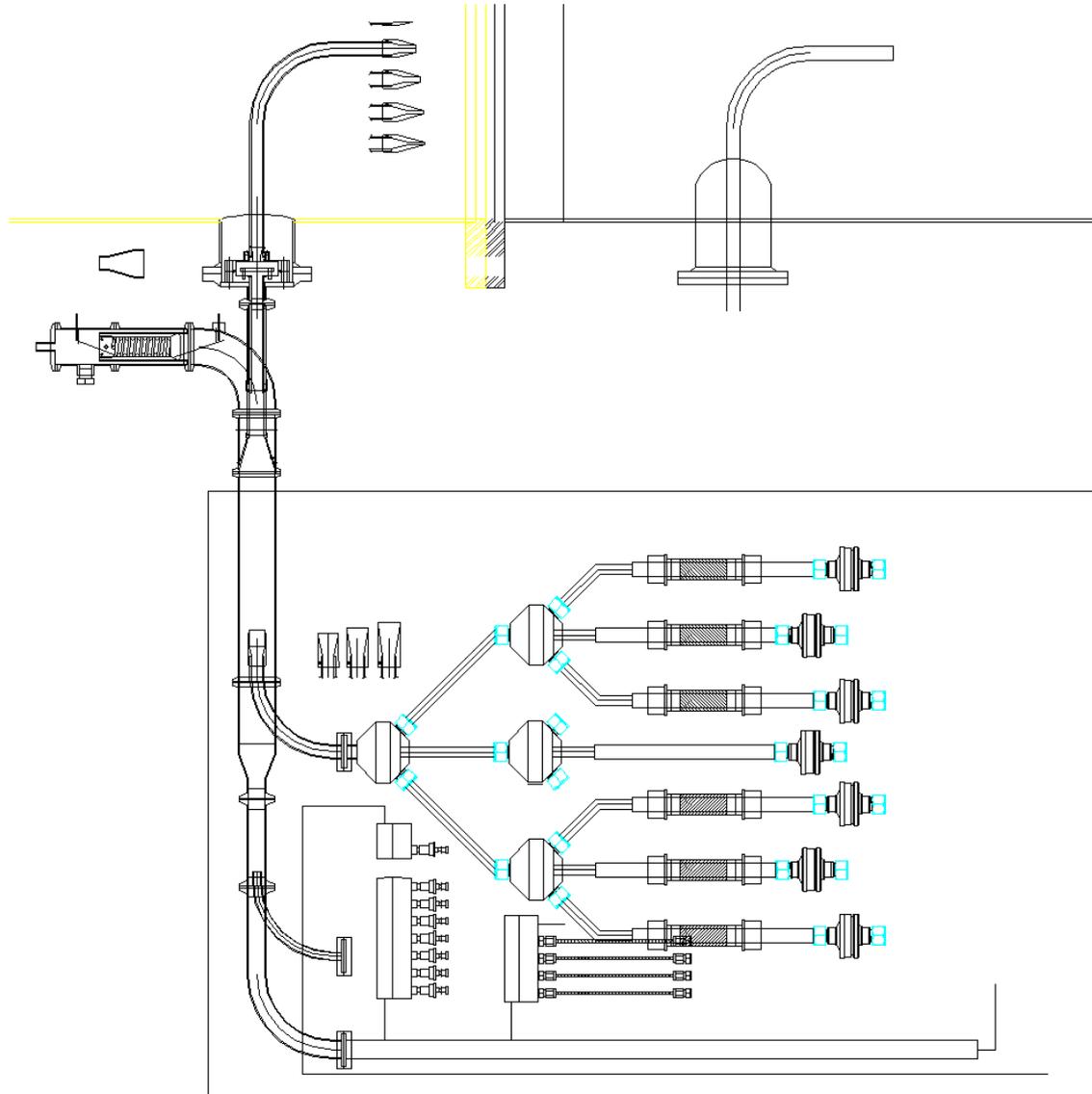
- ❖ Work
 - direct measurement (torque sensor)

- ❖ Pollutant Concentrations
 - particulate matter
 - gaseous emissions

Gaseous Emissions Measurement

- ❖ NO, NO₂ – Chemiluminescence
- ❖ CO/CO₂ – Non-Dispersive Infrared
- ❖ NMHC – Flame Ionization
- ❖ O₂ – Paramagnetic Pressure

Partial Dilution Sampling



PM Measurement Issues

- ❖ Sampling Location
- ❖ Sulfates
- ❖ Temperature Control
- ❖ Sampling Media
- ❖ Sample Flow/Pressure Drop

Additional Sampling/Analysis

- ❖ Fuel and lubricating oil

- ❖ PM characterization
 - EC/OC
 - SVOCs - PAHs
 - inorganic species
 - size distribution

- ❖ Gaseous characterization
 - speciated VOCs
 - speciated SVOCs

Preliminary Recommendations

- ❖ Stakeholders need to be involved in protocol development
- ❖ In-use testing should follow accepted reference methods to the extent possible
- ❖ Ship owners and engine manufacturers need to be involved in test program
- ❖ Your feedback is welcomed