Reduction of Emissions from a High Speed Ferry

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SCX Hydrofoil Ferry

Unique In-Use Marine Issues

- Environmental
  - Sea
  - Ambient
  - Hull Fouling
- Equipment
  - Engine Types
  - Wet Exhaust Installation
  - Fuel
  - Space
- Operational
  - Payload
  - Maneuvering
  - Modes
  - In-service
  - Personnel On Board
- Safety
  - Calibration gases
  - Limited ventilation

Objectives

- “Project 81, Governor’s Congestion Relief Program – High Speed Low-emissions Ferry Demonstration” granted to the Unified Port District of San Diego
- Examine Intake Fumigation (WIS) and Low Sulfur Fuel (LSD) to Achieve Emissions Reduction of Oxides of Nitrogen (NOx) and Total Particulate Matter (TPM)
- Measure Fuel Consumption (FC)
- Steady State Operating Points

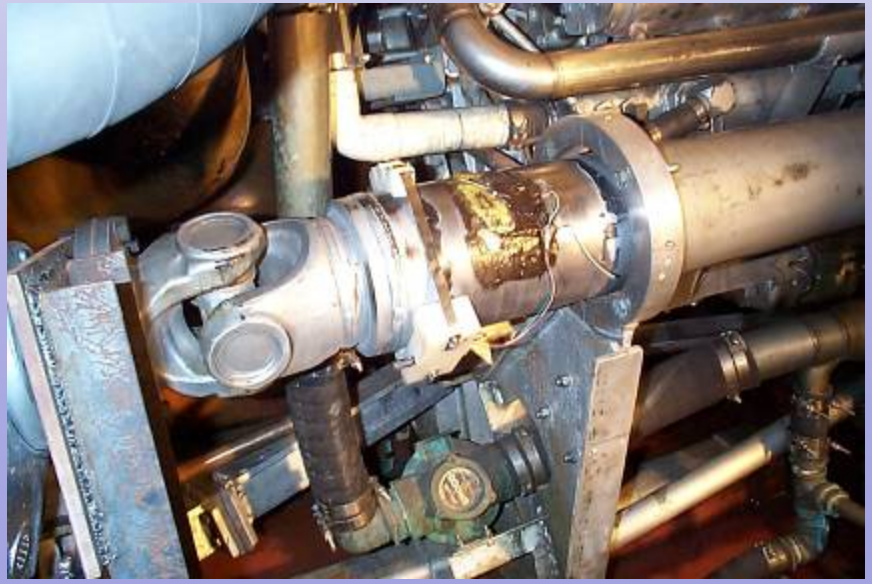
Waverider Propulsion System

- Four Engines (DDC 12V92), Two Port and Two Starboard
- Each Set Joined Via Gearbox
- Water Jet Propulsion

Measurement Approach

- Raw Gaseous
  - NDIR CO_2
  - Zirconium Oxide NOx
  - Wide Band O_2
  - Electrochemical Cells as QA/QC
- Dilute TPM
  - Mini Tunnel
  - MFC and CO_2 Dilution Ratio
- Fuel Flow
- Intake Flow
- Shaft Torque
- GPS

Equipment



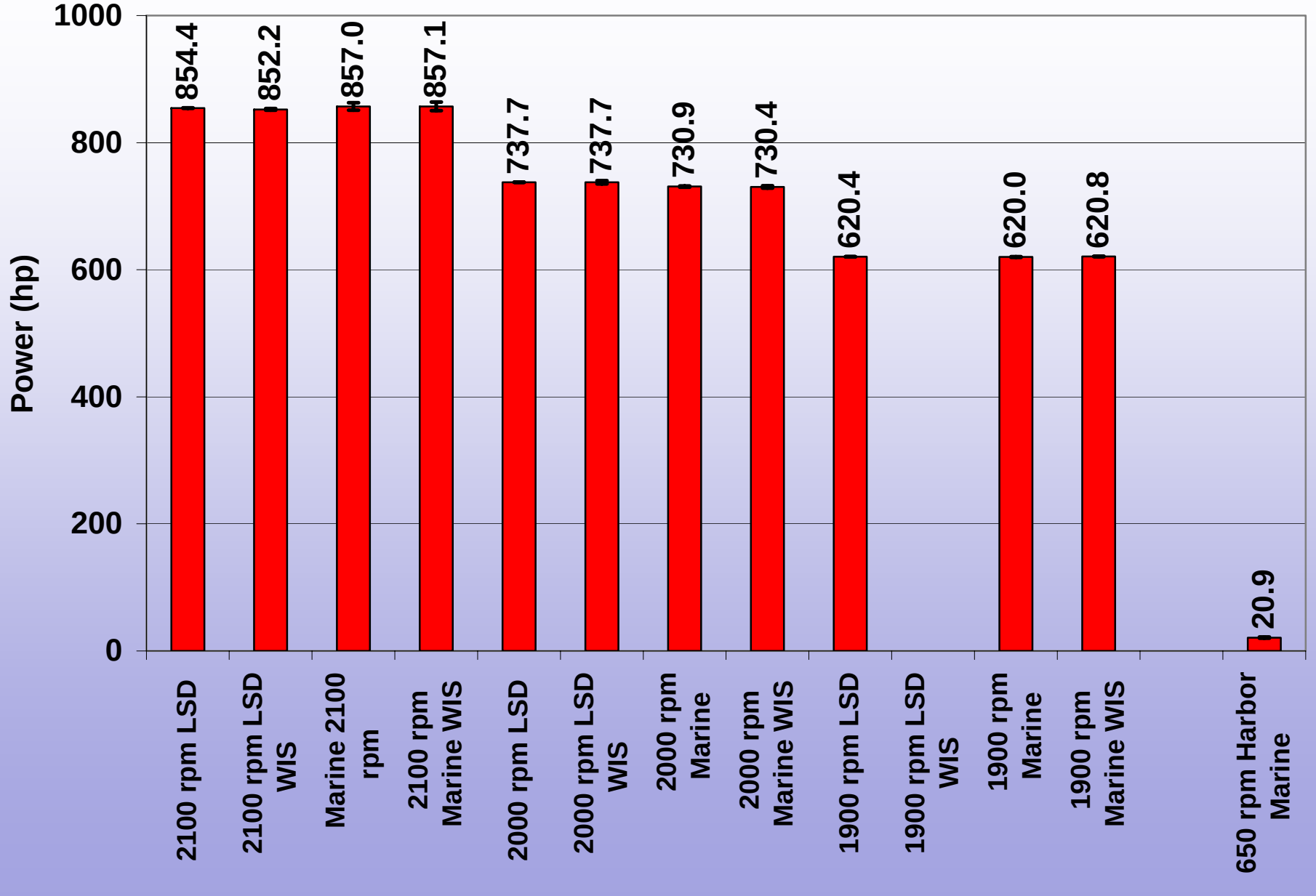
Test Fuels

Test	Units	Method	Fuel	
			LSD	Marine
API Gravity @ 60 Deg. F	deg.API	ASTM D-1298	39.2	34.7
Carbon	wt%	ASTM D-5291M	86.36	86.49
Cetane Index, Calculated	-	ASTM D-976	51.8	47
Cetane Number	-	ASTM D-613	53.1	46.1
Hydrogen Content	wt%	ASTM D-5291M	13.56	13.42
Kinematic Viscosity @ 40 deg. F	cSt	ASTM D-445	3.33	2.7
Specific Gravity	@ 60 deg.F	ASTM D-1298	0.8289	0.8514
Total Sulfur	wt%	ASTM D-4294	0.032	0.394
Distillation				
IBP	deg.F	ASTM D-86	365.6	347.9
5% Rec	deg.F		389.4	390.4
10% Rec	deg.F		401.2	413.4
20% Rec	deg.F		424.8	444.5
30% Rec	deg.F		447.3	469
40% Rec	deg.F		467.8	492
50% Rec	deg.F		492.1	514.1
60% Rec	deg.F		517.1	536.6
70% Rec	deg.F		542.8	559.7
80% Rec	deg.F		574.3	54.3
90% Rec	deg.F		612.5	623.3
95% Rec	deg.F		644.9	664.4
FBP	deg.F		667.2	676.4
Recovery	%		98.2	97.6
Residue	%		1.5	1.2
Loss	%		0.3	1.3
Flash Point, PMCC	deg.F	ASTM D-93(A)	140	136
Hydrocarbon Type - FIA		ASTM D-1319		
Aromatics	lv%		21.8	27
Olefins	lv%		0.8	0.7
Saturates	lv%		77.4	72.3

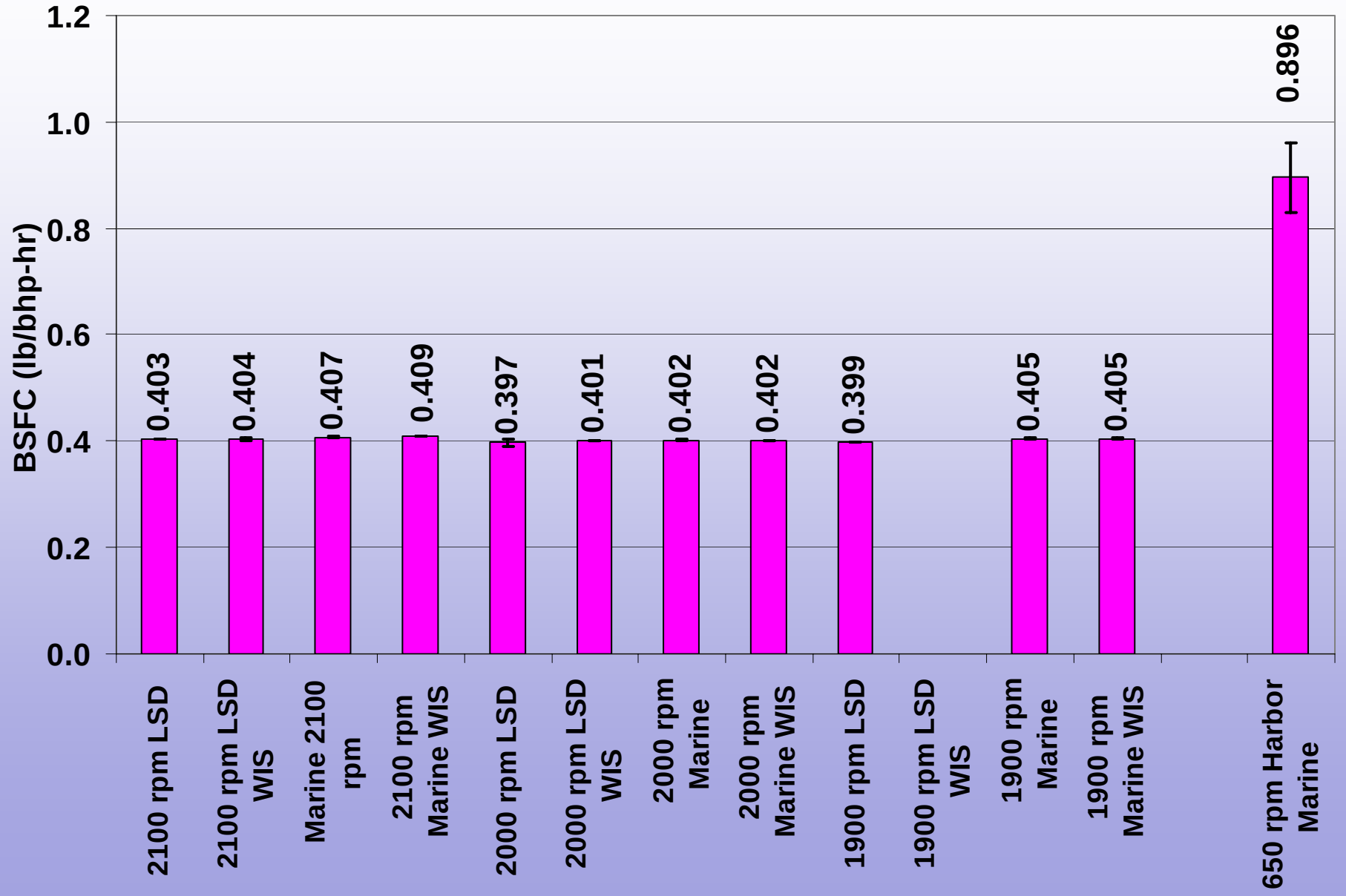
Test Matrix

Fuel	Engine Speed (rpm)	Water Injection	Comment
LSD	650 (Idle)	Off	
	1900	On	Failure of Torque Measurement
	2000	On / Off	
	2100	On / Off	
Marine	650 (Idle)	Off	
	650 (Marina)	Off	
	1900	On / Off	
	2000	On / Off	
	2100	On / Off	

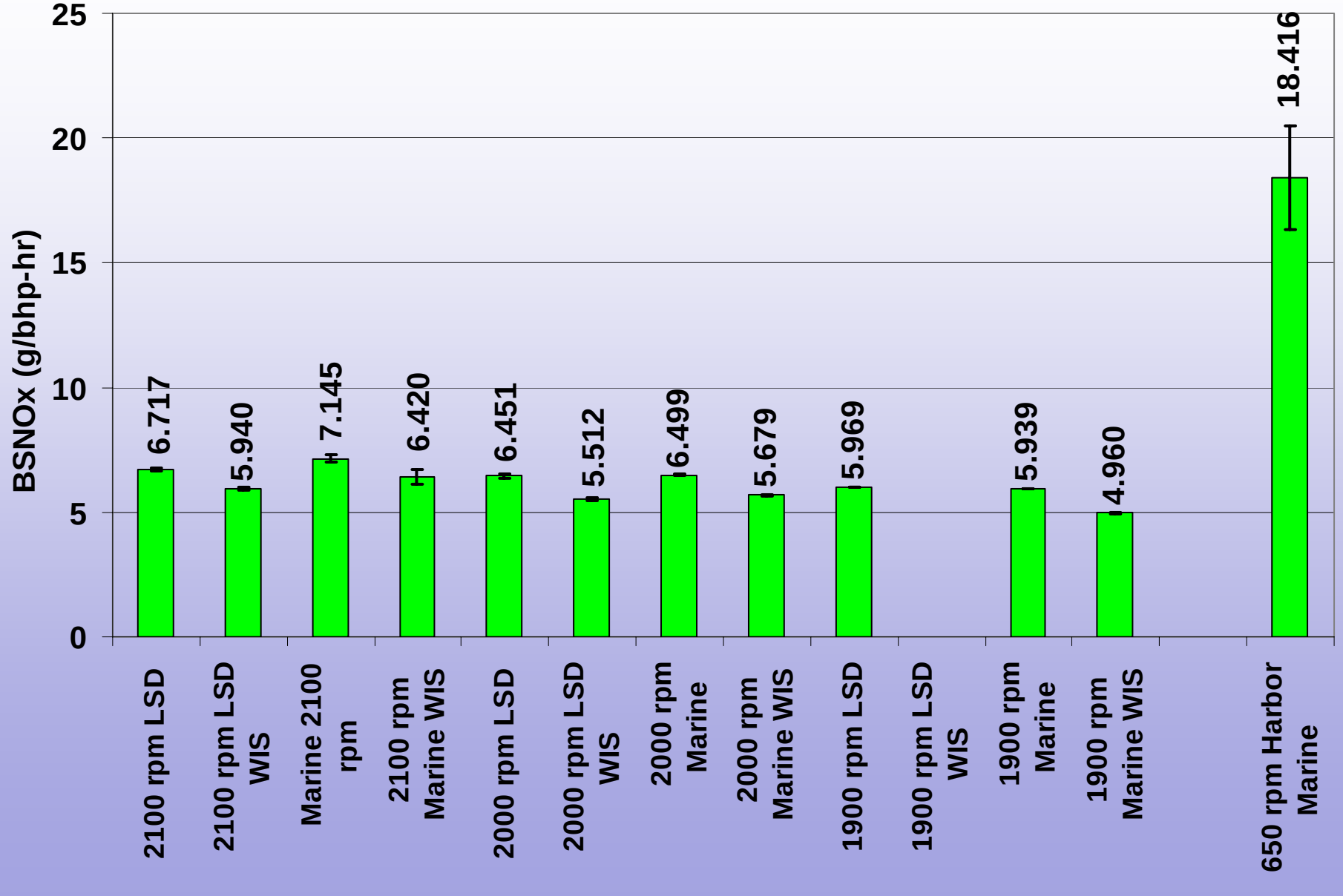
Results - Power



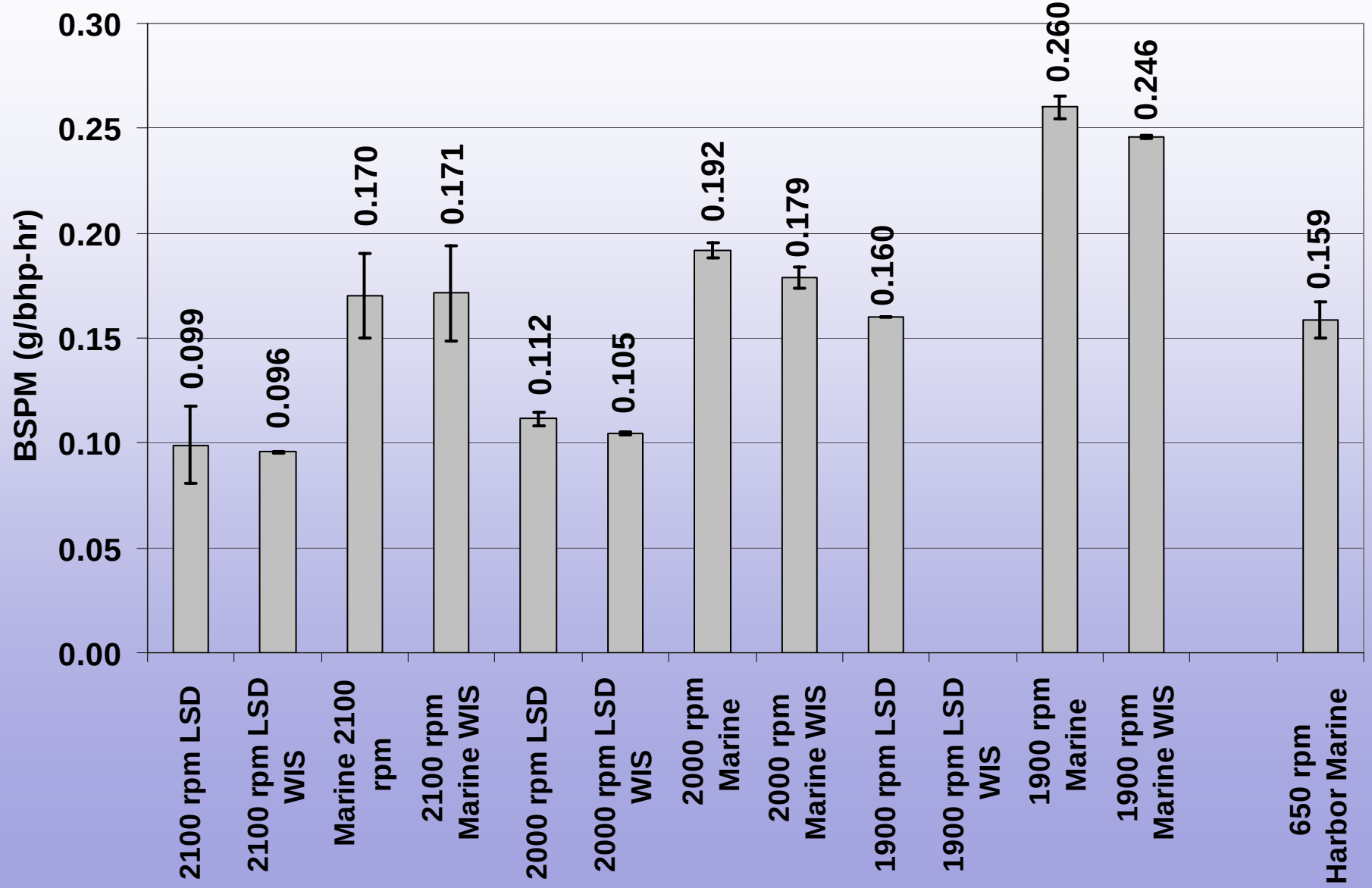
Results – Fuel Consumption



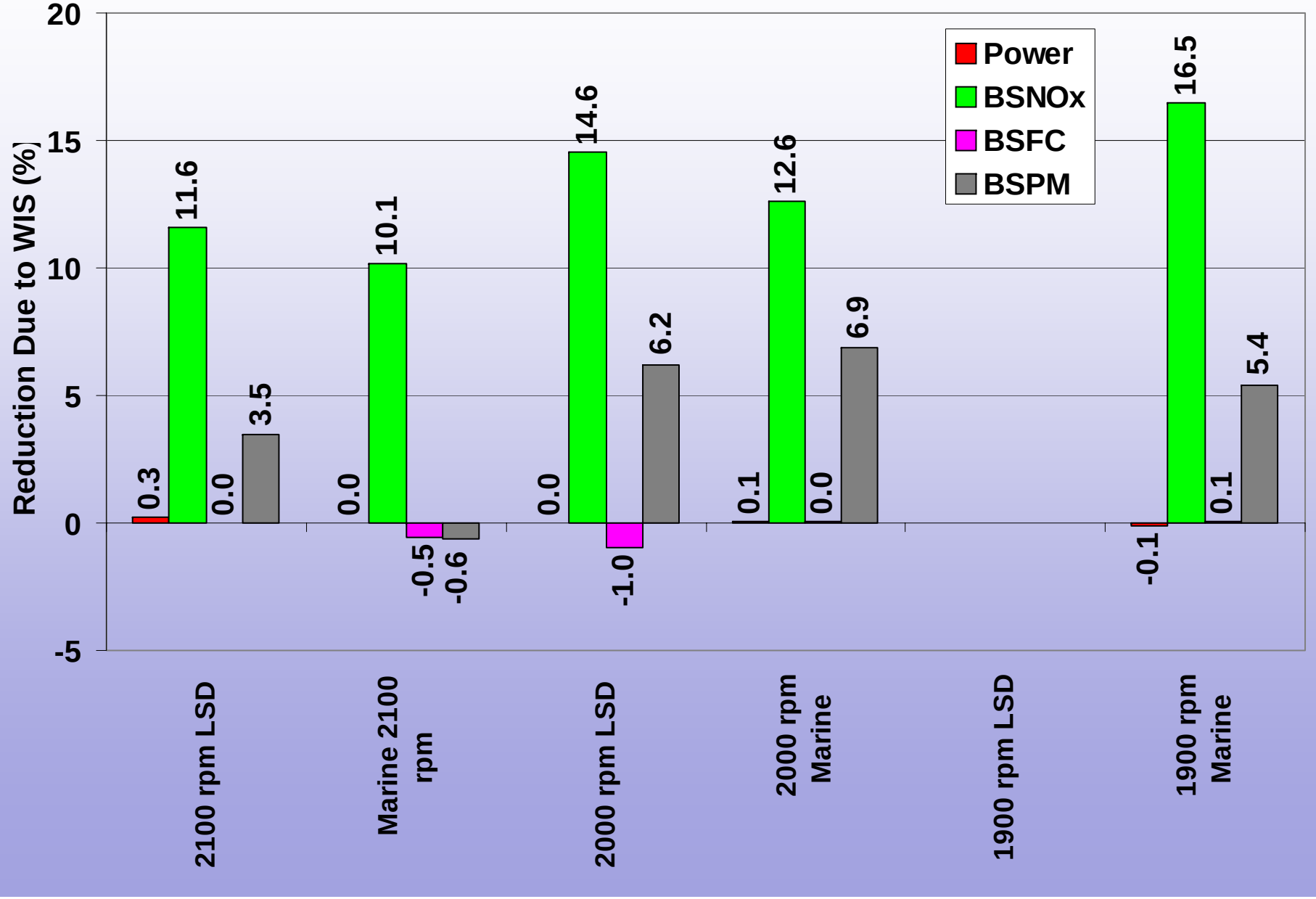
Results - NOx


BSNOx (g/bhp-hr)
25
20
15
10
5
0
6.717
5.940
7.145
6.420
6.451
5.512
6.499
5.679
5.969
5.939
4.960
18.416
2100 rpm LSD
2100 rpm LSD WIS
Marine 2100 rpm
2100 rpm Marine WIS
2000 rpm LSD
2000 rpm LSD WIS
2000 rpm Marine
2000 rpm Marine WIS
1900 rpm LSD
1900 rpm LSD WIS
1900 rpm Marine
1900 rpm Marine WIS
650 rpm Harbor Marine

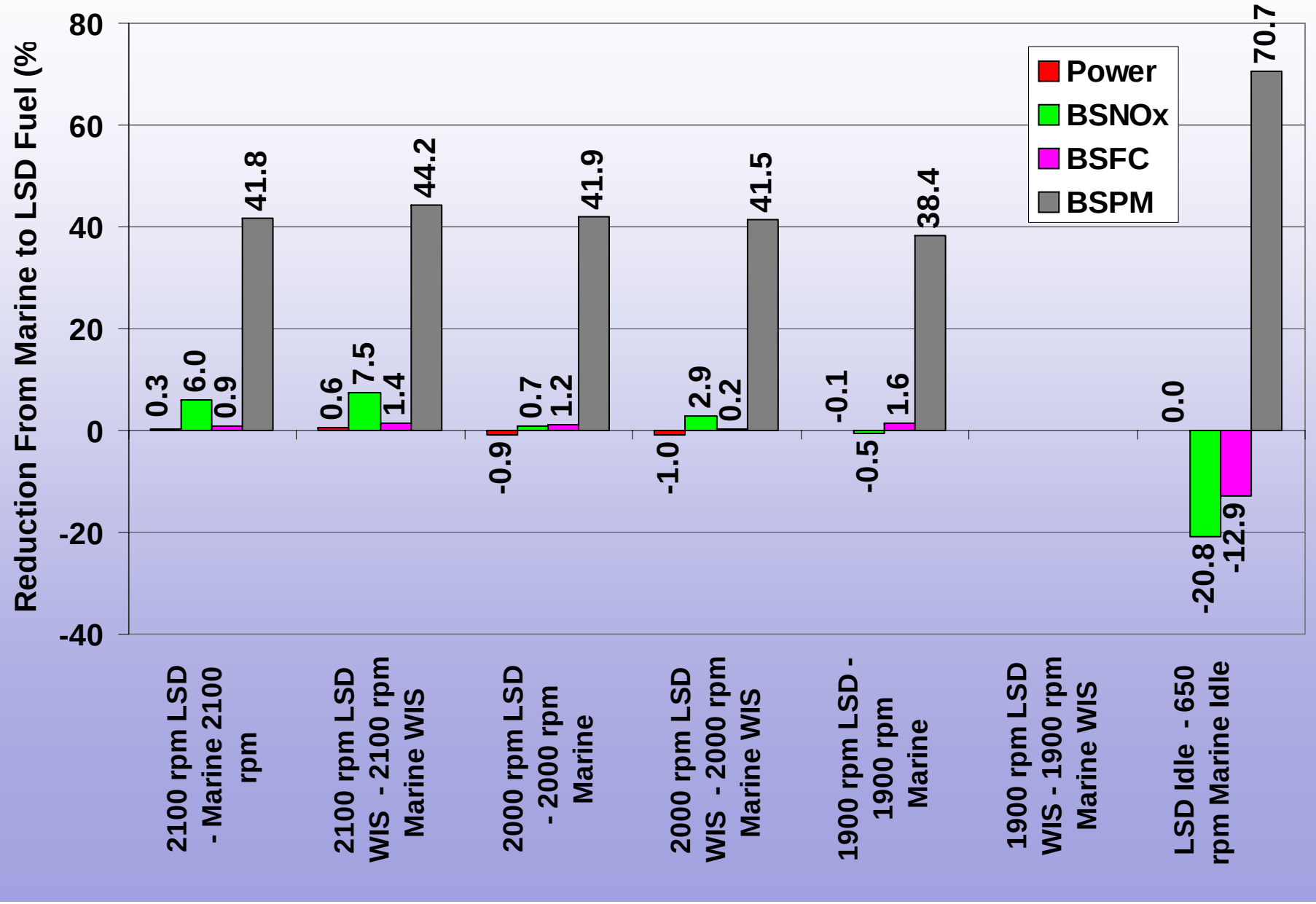
Results - PM


BSPM (g/bhp-hr)
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.099
0.096
0.170
0.171
0.112
0.105
0.192
0.179
0.160
0.260
0.246
0.159
2100 rpm LSD
2100 rpm LSD WIS
Marine 2100 rpm
2100 rpm Marine WIS
2000 rpm LSD
2000 rpm LSD WIS
2000 rpm Marine
2000 rpm Marine WIS
1900 rpm LSD
1900 rpm LSD WIS
1900 rpm Marine
1900 rpm Marine WIS
650 rpm Harbor Marine

Results – Reduction from WIS



Results – Reduction from LSD Fuel



Conclusions

- In-Use Emissions of a High Speed Ferry
- Brake-Specific Mass Emissions of NOx and PM
- Brake-Specific Fuel Consumption
- WIS - NOx Reduced up to 16.5%
- LSD - PM Reduced by 40%
- No Fuel Consumption Penalty
- Uncertainty in the LSD Fuel Composition
- WIS Control Improvements Could Result in Greater Reductions

Lessons Learned

- In-Use Measurements are “Doable”
- Need Standards (SAE, ISO, SNAME, etc.) That Are Acceptable for Most In-use Emissions Applications
- Standards Must Address Steady State and **Transient** Operation
- Large Vessels/Equipment Lend to In-use Testing: Construction Equipment, Marine, Locomotive
- Measurement Systems Must be Verified in a Laboratory Against Known Standards
- Transient PM …

Sponsors and Supporters

- US Department of Energy: Stephen Gogan
- NREL: Chris Tennant
- BP: Ken Kimura
- Maritime Administration: Bob Behr and Danny Gore
- SCX, Inc.: Michael Winn and Lou Adamo
- M.A. Turbo/Engines: Anatoly Mezheritsky
- Marine Services Express crew: Phillip Winter, captain Jim Saffer, mate Matt Hallisey, engineer Matt Rowley, and deckhand John Vierling

Questions?