

Measurement of Gaseous Emissions from the Boiler Operating on a PanaMax Class Container Vessel

Final Report (April, 2009)

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California Air Resources Board
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Acknowledgements

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California Air Resources Board

- Ms. Peggy Taricco
- Ms. Bonnie Soriano
- Mr. Paul Milkey

1 Introduction

The auxiliary boilers on diesel driven ships are used for supplying steam and hot water for non-propulsion uses such as fuel heating, galley, cabin space heating, and to drive steam turbines on tankers that offload petroleum crude oil in port. Boilers are a significant source of gaseous emissions, mostly at dockside or close to shore, and can be comparable to the SO_x emissions from auxiliary engines, as shown in Table 1¹. There is a lack of existing in-use emissions data from the boilers on ocean going vessels. This study helps to address this by presenting the gaseous emissions from the boiler on a modern container vessel.

Table 1: Projected Emissions from Different Engines on an Ocean-going Vessel

2010 Uncontrolled Emissions (tons/day)		
Ship Emissions Source	NO _x	SO _x
Main Engines	130	76
Auxiliary Engines	55	35
Auxiliary Boilers	3.3	26

Source: ARB Emissions Inventory. Emissions within 24nm of coastline. Assumes all auxiliary boilers use heavy fuel oil at 2.5% sulfur and there are no boiler emissions during transiting.

2 Test Method

The boiler operation data is provided in Table 2. The boiler was SAACKE-ESV² type. The concentrations of gases in the raw exhaust were measured with a Horiba PG-250 portable multi-gas analyzer. The PG-250 can simultaneously measure up to five separate gas components using the measurement methods recommended by the EPA. The calibration sheets for the measurements are provided in Appendix A of this report.

Table 2: Boiler Operation Data

Steam p (Bar)	8.1
Steam T (°C)	181.2
Engine Room T (°C)	25.4
Outside T (°C)	17.5
Engine Room p (Mbar)	2
Fuel Consumption (l/hr)	160

3 Results

The emission factors of the boiler on the PanaMax Class container vessel are presented in Table 3. The NO_x and CO emission factors were calculated based on the measured concentrations of the pollutants. The sulfur dioxide emission factor was calculated from the sulfur content in the fuel and the fuel consumption. The fuel analysis sheet is attached

¹ <http://www.arb.ca.gov/ports/marinevess/presentations/092407/092407boilerpres.pdf>

² http://www.saacke.de/downloads/land/en/SKV-A_m105_engl.pdf

in Appendix B of this report. The PM measurements were not done due to time constraints.

Table 3: Emission Factors for the Boiler (kg/tonne)

	NO_x	Calculated SO₂	CO
Run-1	7.27	50.46	0.12
Run-2	7.22	51.36	0.12
Run-3	7.15	51.81	0.11
Average	7.21 ± 0.06	51.21 ± 0.68	0.12 ± 0.01

4 Comparison of the emissions from the container vessel's boiler and the boiler on a crude oil tanker

The emissions from the boilers depend heavily on the size of the boiler and the extent of their use. On the container vessels, boilers are usually used for auxiliary hotel loads while on crude oil lightering vessels the boilers are used for discharging the crude oil. In Table 4, the gaseous emissions from a tanker boiler in a past study³ are compared to the container vessel under consideration in this study. It is evident from Table 4 that the gaseous emissions from the boiler on a crude oil tanker are higher.

Table 4: Comparison of the Gaseous Emissions from a Crude Oil Tanker³ and the Container Vessel (kg/tonne)

	Crude Oil Tanker ³	Container Vessel
NO _x	9.24 ± 0.09	7.21 ± 0.06
Calculated SO ₂	55.72	51.21 ± 0.68
CO	0.51 ± 0.04	0.12 ± 0.01

³ Agrawal, H.; Welch W.A.; Miller J.W.; Cocker D.R.; Emission Measurement from a Crude Oil Tanker at Sea. Accepted for publication in Environmental Science and Technology (2008)

Appendix A: Gaseous Calibration



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CERTIFICATE OF ANALYSIS / EPA PROTOCOL GAS

CUSTOMER UC RIVERSIDE

P.O NUMBER EZ149

REFERENCE STANDARD

COMPONENT	NIST SRM NO.	CYLINDER NO.	CONCENTRATION
NITRIC OXIDE GMS	vs. SRM#1685	CC 140559	249.6 ppm
CARBON MONOXIDE GMS	vs. SRM#1680	CC 95754	499 ppm
CARBON DIOXIDE GMS	vs. SRM#2745	HA 8215	9.99 %

ANALYZER READINGS

R=REFERENCE STANDARD

Z=ZERO GAS

C=GAS CANDIDATE

1. COMPONENT	NITRIC OXIDE GMS	ANALYZER MAKE-MODEL-S/N	Thermo Env. 42H S/N 42H-44979-273
ANALYTICAL PRINCIPLE Chemiluminescence		LAST CALIBRATION DATE 03/01/07	
FIRST ANALYSIS DATE 02/22/07		SECOND ANALYSIS DATE 03/01/07	
Z 0.0	R 246.3 C 143.0 CONC. 145	Z 0.0	R 243.4 C 144.4 CONC. 148
R 245.6	Z 0.0 C 143.3 CONC. 146	R 243.7	Z 0.0 C 143.7 CONC. 147
Z 0.0	C 144.4 R 246.8 CONC. 146	Z 0.0	C 143.1 R 243.9 CONC. 146
U/M ppm	MEAN TEST ASSAY 146	U/M ppm	MEAN TEST ASSAY 147
2. COMPONENT	CARBON MONOXIDE GMS	ANALYZER MAKE-MODEL-S/N	HORIBA, VIA-510, S/N 576876015
ANALYTICAL PRINCIPLE NDIR		LAST CALIBRATION DATE 03/01/07	
FIRST ANALYSIS DATE 02/22/07		SECOND ANALYSIS DATE 03/01/07	
Z 0.0	R 498.9 C 449.8 CONC. 450	Z 0.0	R 499.0 C 449.9 CONC. 450
R 499.0	Z 0.0 C 450.0 CONC. 450	R 499.1	Z 0.0 C 450.0 CONC. 450
Z 0.0	C 449.7 R 499.4 CONC. 449	Z 0.0	C 450.1 R 499.1 CONC. 450
U/M ppm	MEAN TEST ASSAY 450	U/M ppm	MEAN TEST ASSAY 450
3. COMPONENT	CARBON DIOXIDE GMS	ANALYZER MAKE-MODEL-S/N	Siemens Ultramat SE S/N A12-730
ANALYTICAL PRINCIPLE NDIR		LAST CALIBRATION DATE 02/02/07	
FIRST ANALYSIS DATE 02/22/07		SECOND ANALYSIS DATE	
Z 0.00	R 10.00 C 9.21 CONC. 9.20	Z	R C CONC.
R 10.00	Z 0.00 C 9.22 CONC. 9.21	R	Z C CONC.
Z 0.00	C 9.22 R 10.00 CONC. 9.21	Z	C R CONC.
U/M %	MEAN TEST ASSAY 9.21	U/M %	MEAN TEST ASSAY

THIS CYLINDER NO. CC 159747	CERTIFIED CONCENTRATION
HAS BEEN CERTIFIED ACCORDING TO SECTION EPA-600/R97/121	NITRIC OXIDE 146 ppm
OF TRACEABILITY PROTOCOL NO. REV. 9/97	CARBON MONOXIDE 450 ppm
PROCEDURE G1	CARBON DIOXIDE 9.21 %
CERTIFIED ACCURACY ± 1 % NIST TRACEABLE	NITROGEN BALANCE
CYLINDER PRESSURE 2000 PSIG	
CERTIFICATION DATE 03/01/07	ALL VALUES NOT VALID BELOW 150 PSIG.
EXPIRATION DATE 03/01/09 TERM 24 MONTHS	NOX VALUE FOR REFERENCE ONLY.

ANALYZED BY

Henry Koung

CERTIFIED BY

IMPORTANT

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CERTIFICATE OF ANALYSIS / EPA PROTOCOL GAS

CUSTOMER UC RIVERSIDE/EZ149

P.O NUMBER

REFERENCE STANDARD

COMPONENT	NIST SRM NO.	CYLINDER NO.	CONCENTRATION
NITRIC OXIDE GMIS	vs. SRM#2630	CC 240946	1517 ppm

ANALYZER READINGS

R=REFERENCE STANDARD

Z=ZERO GAS

C=GAS CANDIDATE

1. COMPONENT	NITRIC OXIDE	GMIS	ANALYZER MAKE-MODEL-S/N	BECKMAN 951A	S/N#0101354		
ANALYTICAL PRINCIPLE		CHEMILUMINESCENCE		LAST CALIBRATION DATE	01/16/07		
FIRST ANALYSIS DATE		02/08/07		SECOND ANALYSIS DATE	02/15/07		
Z 0	R 526	C 832	CONC. 2400	Z 0	R 601	C 953	CONC. 2405
R 527	Z 0	C 834	CONC. 2401	R 601	Z 0	C 953	CONC. 2405
Z 0	C 836	R 528	CONC. 2402	Z 0	C 952	R 600	CONC. 2407
U/M mV		MEAN TEST ASSAY	2401	U/M mV		MEAN TEST ASSAY	2406

NOx value for reference only.
 All values not valid below 150 psig.

THIS CYLINDER NO. SA 11914	CERTIFIED CONCENTRATION
HAS BEEN CERTIFIED ACCORDING TO SECTION EPA-600/R97/121	NITRIC OXIDE 2404 ppm
OF TRACEABILITY PROTOCOL NO. Rev. 9/97	NITROGEN BALANCE
PROCEDURE G1	NOx 2423 ppm
CERTIFIED ACCURACY ± 1 % NIST TRACEABLE	
CYLINDER PRESSURE 2000 PSIG	
CERTIFICATION DATE 02/15/07	
EXPIRATION DATE 02/15/09 TERM 24 MONTHS	

ANALYZED BY

GEORGE WAHBA

CERTIFIED BY

VICTOR DOTAN

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Appendix B: Fuel Analysis



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 Telephone: (+45) 59 51 32 23
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 E-mail: opscbe.denmark@intertek.com
 CVR nr.: VAT reg. no: 19 85 99 08

MAN B&W DIESEL A/S
 TEGLHOLMSGADE 41
 DK-2450 KØBENHAVN SV

Att.: Jens Bierkvig

Deres ref. / Your ref. Vor ref. / Our ref. **LH** Dato / Date 28.11.2007

Sample received from: **Yourselves**
 Sample submitted as: **HFO2**
 Description on label: **Test 43**

Certificate of Quality
31989

Seal on sample: -

The above sample was examined with following result:

Ash (20 g)	0,035	% mass	Method: ASTM D 482
Asphaltenes	11,9	% mass	Method: IP 143
Cetane Index	*		Method: ASTM D 4737
Conr. Carbon, direct	19,6	% mass	Method: ASTM D 4530
Density at 15°C	1,0042	g/ml	Method: ASTM D 4052
Flash Point P.M., c.c.	94	°C	Method: ASTM D 93/B
Heat of Comb. Nett	39,66	MJ/kg	Method: ASTM D 4868
Equal to	9473	Kcal/kg	
Sulphur	2,98	% mass	Method: ASTM D 4294
Viscosity (50°C)	482,9	mm ² /s	Method: ASTM D 445
Water	0,3	% mass	Method: ASTM D 95
C-content	86,3	% mass	Method: ASTM D 5291
H-content	9,6	% mass	Method: ASTM D 5291
N-content	0,35% < 0,75 %	% mass	Method: ASTM D 5291
O-content	4,64	% mass	Method: E.A.
Al-content	5	mg/kg	Method: A.A.S.
Ca-content	11	mg/kg	Method: A.A.S.
Zn-content	2	mg/kg	Method: A.A.S.
P-content	< 1	mg/kg	Method: I.C.P.
Si-content	6	mg/kg	Method: A.A.S.
V-content	100	mg/kg	Method: A.A.S.

* Not possible to calculate

*Jatustet i perf database
 værdier er staleret
 / non*