Regulation 13.7.1 Approved Method

Application: Ships constructed 1 Jan 1990 to 31 Dec 1999
Marine diesel engine power output >5,000 kW
Per cylinder displacement 90 litres

If a method has been approved by Party according to chapter 7 of the NOx Technical Code 2008 then ship is required to fit the "approved method" to enable the engine to meet Tier I limits.

IMO to be notified of approved method

The approved method to be installed at first renewal survey 12 months or more after IMO notified the "method" is approved

Tier	n < 130 rpm	130 ≤ n < 2000 rpm	n ≥ 2000 rpm
I	17.0 g/kWh	$45.0*n^{(-0.2)}$ g/kWh	9.8 g/kWh

Johnson Matthey
Catalysts

Technology for meeting IMO III NOx limits

Mexico Sept 26th Sept

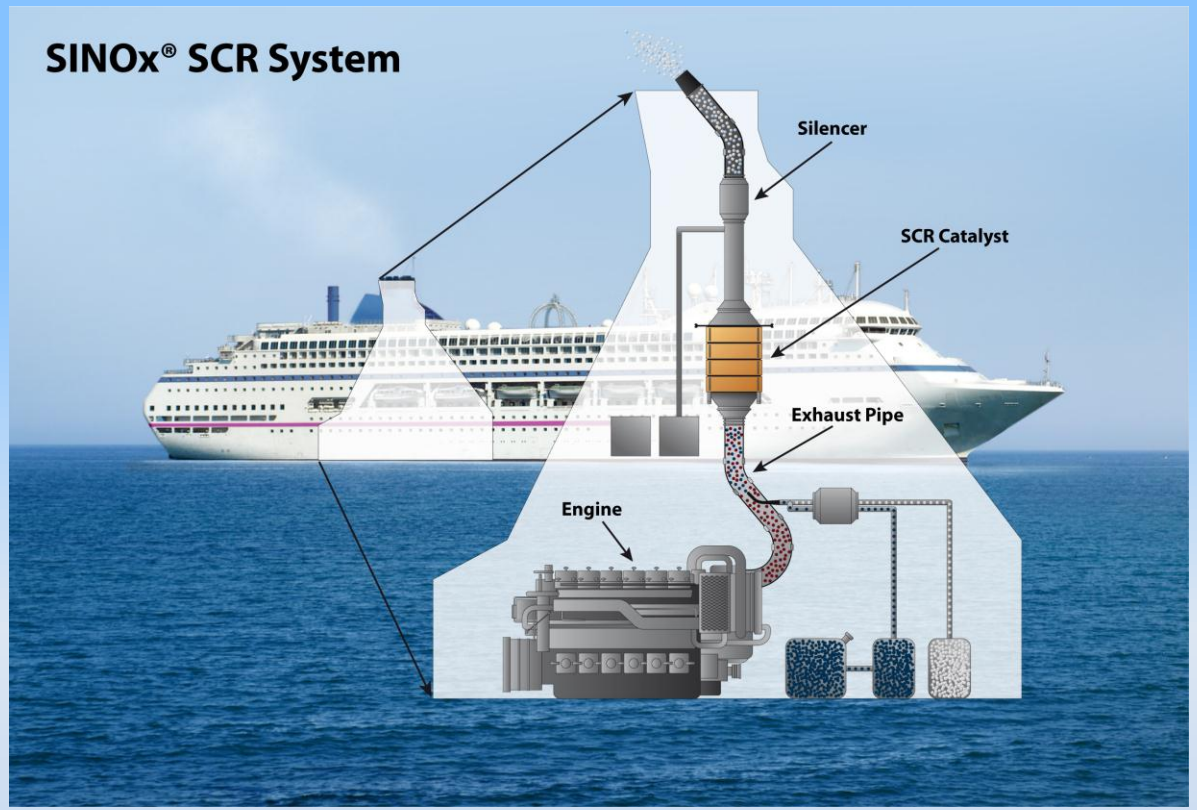
Joseph Mc Carney

Johnson Matthey

EMISSION CONTROL TECHNOLOGIES

IACCSEA

International
Association for
Catalytic
Control of
Ship
Emissions to
Air



EMISSION CONTROL TECHNOLOGIES

IACCSEA

International
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EMISSION CONTROL TECHNOLOGIES

A Major Player

Johnson Matthey Catalysts

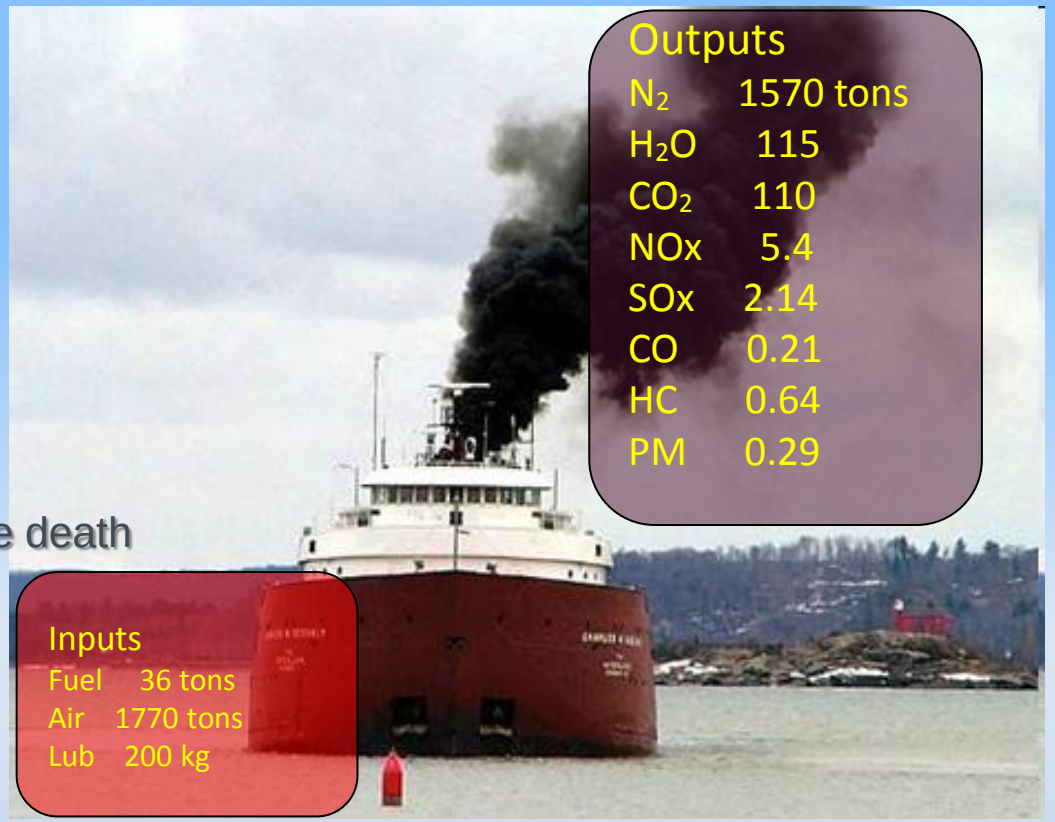
- Speciality chemicals –advanced materials
- 1817 1942 2002 2008 2012
- Core skills in Catalysis, PGMs & Process Tech.
- Invest in R&D and Manufacturing Technology
- Operate in over 30 countries, 10000 employees
- Focus on Growth Opportunities - environment
- Technology & Market Leadership
- 160 SCR systems on ships – large and small

EMISSION CONTROL TECHNOLOGIES

A Major Contribution NOx

Johnson Matthey Catalysts

- Formed in the heat of the engine
- SMOG & Particulates
- Acidifies the environment
- Lung and heart disease
- Economic costs
  - Medical care
  - Lost Productivity
  - Cost of pain / ill health / premature death



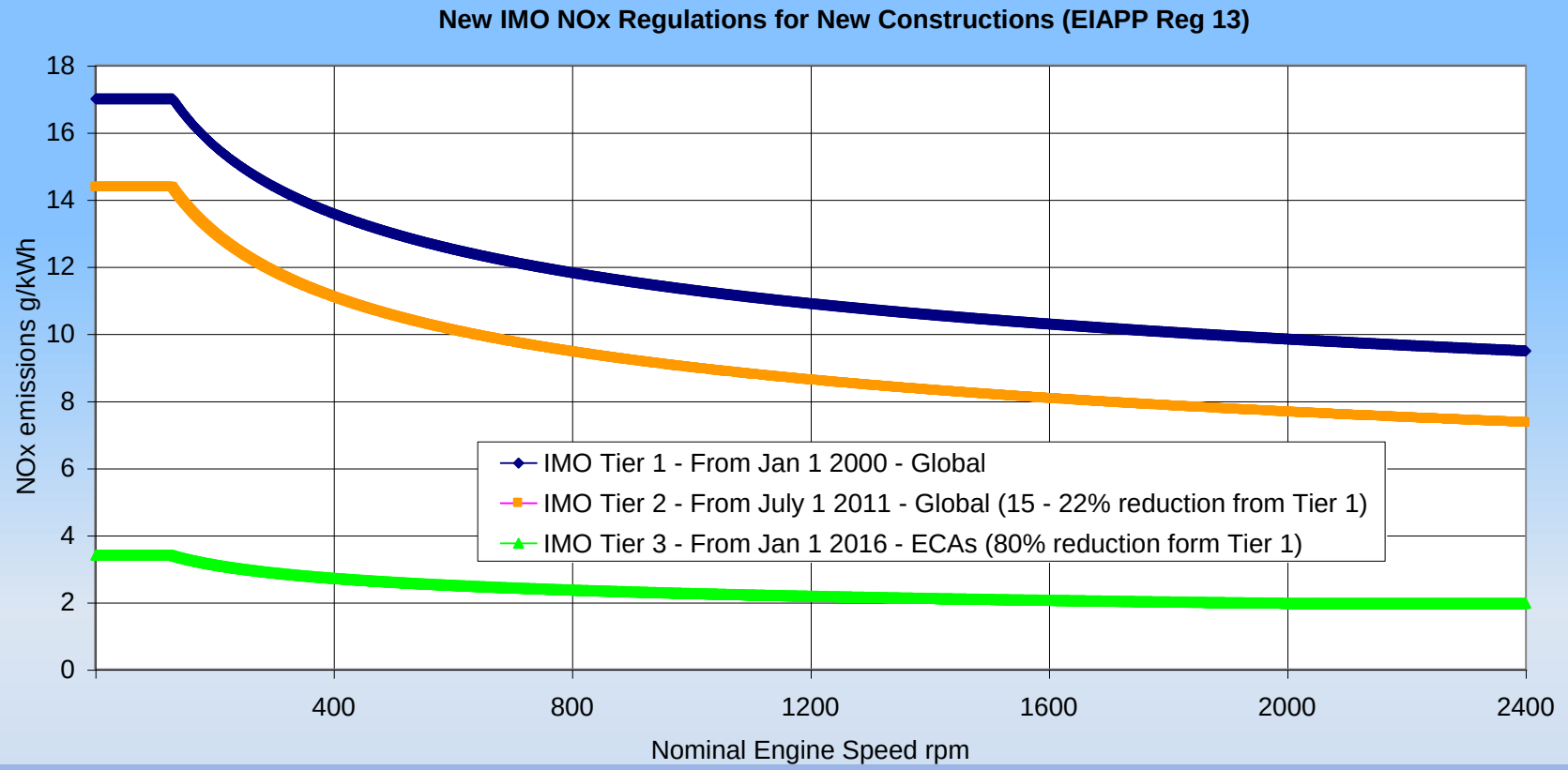
- US EPA – ECA application
  - 14000 lives saved p.a
  - 5m experience relief – respiratory symptoms

EMISSION CONTROL TECHNOLOGIES

A Major Requirement

Johnson Matthey Catalysts

"IMO Tier III scripted to force after-treatment in NOx ECAs"



"Beginning in 2012 and completed no later than 2013, the Organization shall review the status of the technological development s to implement the standards set forth in paragraph 5.1.1 of this regulation and shall, if proven necessary, adjust the time periods set forth in that subparagraph." Regulation 13.10 of Annex 13, Resolution MEPC 176 (58):

IMO Review-Terms of Reference

Johnson Matthey Catalysts

Exceptions & Exemptions

Range

NOx Review
Of Technology Solutions
To Meet IMO III

Applicability & Suitability

Status / Readiness
Technology Trajectory
Supply Chain Issues

EMISSION CONTROL TECHNOLOGIES

Contributors

Johnson Matthey Catalysts

Canada	Japan	BIMCO	ICOMIA
Denmark	Liberia	CLIA	ICS
Estonia	Netherlands	CSC	IMarEST
Finland	Norway	Euromot	INTERTANKO
France	Sweden	IACS	IPIECA
Germany	United Kingdom	IADC	OCIMF
Ireland	United States	IAPH	WSC
European Commission		Integer	IACCSEA

Disclaimer – The views set out in this document reflect the interpretation of the author – and do not necessarily concur with the interpretation of the IMO or other stakeholders

EMISSION CONTROL TECHNOLOGIES

Technology Options

Johnson Matthey Catalysts

LNG

Fuel Combustion – controlled to Low NOx

SCR

NH3 neutralises NOx on Catalyst

Other

Water Based / Valve Timing / TC Control combustion process in Diesel engine - Low NOx

EGR

Lower O2 content & lower Combustion Temperatures

Technology Options

Johnson Matthey Catalysts

Meeting IMO III NOx limits

LNG
Fuel Combustion – controlled to Low NOx

SCR
NH3 neutralises NOx on Catalyst

Other
Water Based / Valve Timing / TC Control combustion process in Diesel engine - Low NOx

EGR
Lower O2 content & lower Combustion Temperatures

Technology Options - SCR

Johnson Matthey Catalysts

State of Technology Readiness
SCR

Issue / Concern	Response
Operating Conditions e.g. Temperature Catalyst Fouling – ABS Low Load Performance	Flexibility - SCR reactor placement Charge Air, Timing, Burner Below 25% Load – SCR off
SCR System - design Catalyst Lifetime Ammonia Slip Small Vessels	Experience- >16000 hours / 2 years Mobile, Stationary, Ships – 500 Compact SCR – Design Phase
Supply Chain Concerns Urea	Competitive Global Supply Chain AUS 40 Standard US Supply Chain - by 2014

Technology Options - EGR

Johnson Matthey Catalysts

State of Technology Readiness
EGR

Issue / Concern	Response
Technology Readiness Combined with other technology? Not available for most engines	Capability Demonstrated High NOx reduction – IMO III Development Focus Engine OEMs Low operating costs Mg(OH)2
H2SO4 / PM Reagent / wash water	Scrubber Developing Experience

Technology Options - LNG

Johnson Matthey Catalysts

State of Technology Readiness
LNG

Issue / Concern	Response
Low emissions – dependent on Engine size / duty cycle / pilot fuel Energy Density	Experience 100's Gas engines – low emissions 20 Vessels Meets IMO III Lower Fuel Costs

Technology Options - Other

Johnson Matthey Catalysts

State of Technology Readiness – Other
VVT, 2Stage TC… Water Based...

Issue / Concern	Response
Not Tier III Compliant 30% - 50% - 65% DWI – HAM – FE	Can be used in combination
Miller Timing Decreased Power	Loss over come with 2-stage TC

EMISSION CONTROL TECHNOLOGIES

Technology Options - summary

Johnson Matthey Catalysts

LNG

Fuel Combustion – controlled to Low NOx

Practical

SCR

NH3 neutralises NOx on Catalyst

Panacea

Other

Water Based / Valve Timing / TC Control combustion process in Diesel engine - Low NOx

Partial

EGR

Lower O2 content & lower Combustion Temperatures

Potential

Conclusion / Insight

Johnson Matthey Catalysts

Technology to meet IMO III limits is available
There are a number of options / combinations

Greater collaboration between Engine OEMs and other technology providers will deliver efficient, economical, environmental solutions, for cleaner shipping

IACCSEA

Greater collaboration between technology providers and regulators will maximise the gain to society at an “efficient” cost

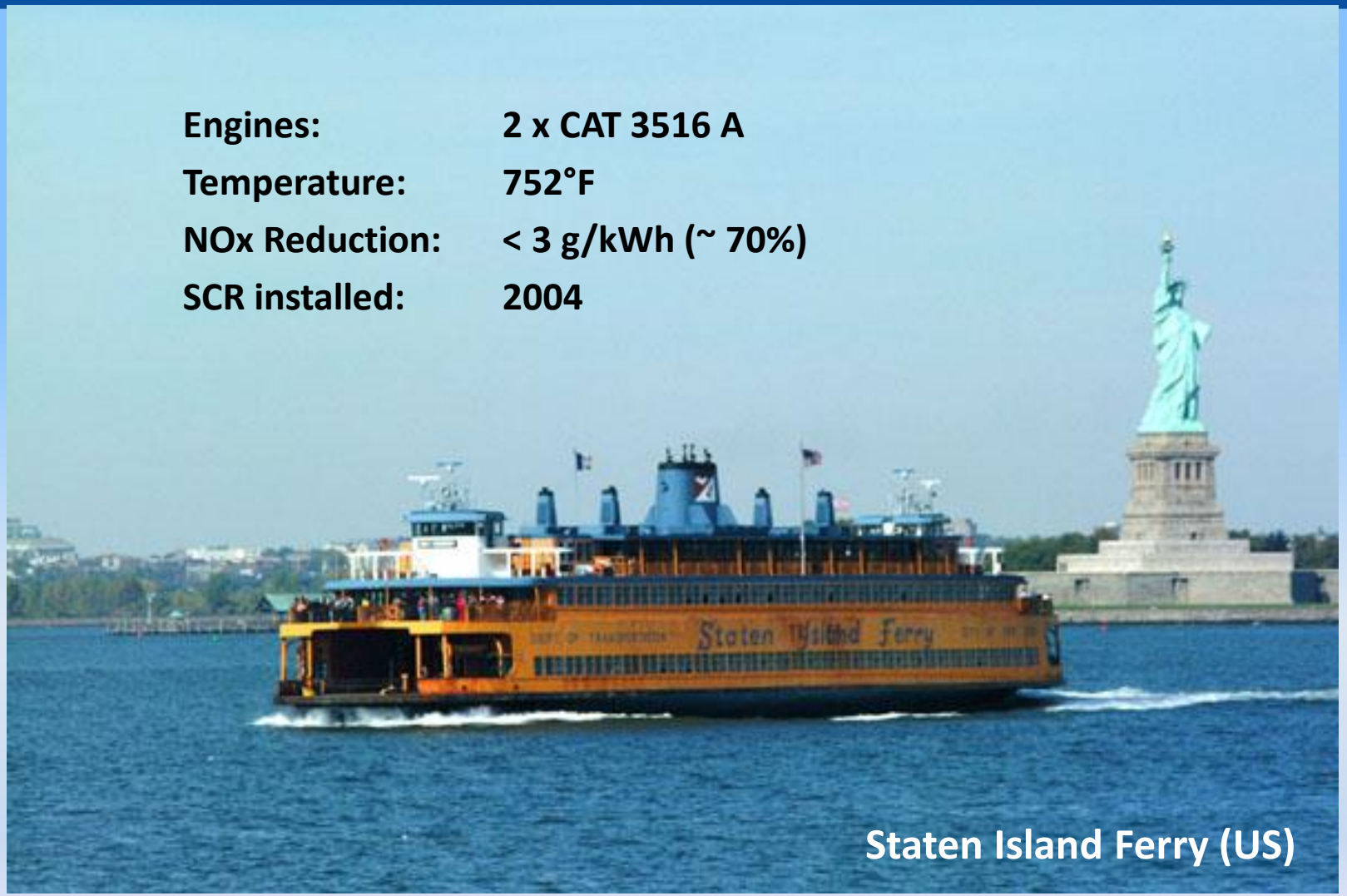
IACCSEA

EMISSION CONTROL TECHNOLOGIES

SCR installation – Alice Austen

Johnson Matthey Catalysts

Engines:	**2 x CAT 3516 A**
Temperature:	**752°F**
NOx Reduction:	**< 3 g/kWh (~ 70%)**
SCR installed:	**2004**



Staten Island Ferry (US)

EMISSION CONTROL TECHNOLOGIES

SCR installation – MS Timbus

Johnson Matthey Catalysts

SINOx® Installed:	**1999**
Type	**MaK 8M32 (Main)/ MAN 6L16/24 (Aux.)**
Power	**3,840kW / 540 kW (Aux.)**
Exhaust Gas Flow	**21,000 / 3,000 Nm^3/h**
Fuel	**HFO / MDO**
Temperature	**320 / 336° C**
Urea Consumption :	**97 / 8 l/h (@40%)**

Catalyst Type	**SW 30 Honeycomb**
Catalyst Volume	**3 m^3/engine (Main)**
	0.4 m^3/engine (Aux.)
Exhaust NOx:	**2g/kWh**

EMISSION CONTROL TECHNOLOGIES

SCR installation – Kleven

Johnson Matthey Catalysts

Project:	**Supply Vessel/Work ship Kleven**
Exhaust gas flow:	**8.790 m³/h**
Engine type:	**2 x MAN 6L 32/40, 2 x MAN 8L 21/31**
Fuel:	**MGO**
Temperature:	**335° C**
SINOx® Installed:	**2007**

Catalyst type:	**SW 40**
Catalyst volume:	**3.8 m³**
NOx Reduction:	**86%**

VIK-SANDVIK

DCF

KLEVEN MARITIME

EMISSION CONTROL TECHNOLOGIES

SCR installation – LNG Carriers

Johnson Matthey Catalysts

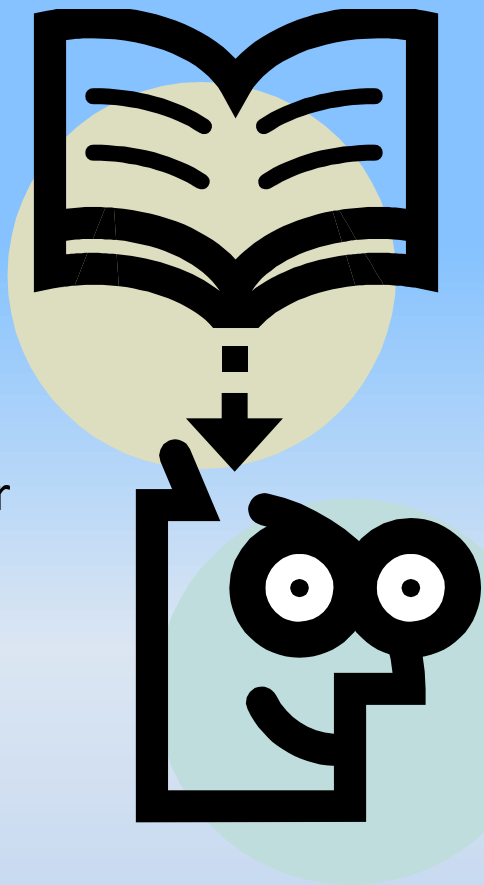
Project:	**2 x LNG Carrier, Exmar Excellence/Excelerate**
SINOx® Installed:	**2007**
Exhaust Gas Flow:	**2 x 70.100 Nm³/h**
Application:	**2 x 70t/h Regas Boiler**
Fuel:	**HFO/MDO**
Temperature:	**380°C**

Catalyst Type:	**SW 30 Honeycomb**
Catalyst Volume:	**10,62 m³**
Exhaust NOx :	**30 mg/Nm³**
Reduction Rate:	**93%**

EMISSION CONTROL TECHNOLOGIES

De-NOx - Selective Catalytic Reduction

- 1. Combustion →pollution inc. the acidic pollutants - NOx &SOx
- 2. NOx is dangerous, & increasingly its emission is regulated.
- 3. NOx can be controlled in the engine or neutralised in the tailpipe – via catalytic after treatment such as SCR
- 4. SCR is a proven technology (power-plants ,HDD and auto)
- 5. The SCR process produces Nitrogen as its end product
- 6. Marine SCR – >500 Case studies – yachts to container ships
- 7 SCR needs a reducing agent – Urea / Ammonia
- 8 The catalyst is robust but requires the correct conditions for optimum operation
- 9. Sulphur is not a poison to Marine SCR Catalysts – but its effects need to be considered – e.g. limiting temperature.
- 10. After-treatment can allow an increase in efficiency (fuel
- 11. SCR on its own can meet IMO III or as a top up technology



Johnson Matthey
Catalysts

Technology for IMO III

Mexico Sept 26th Sept

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EMISSION CONTROL TECHNOLOGIES