The mitigation measures for the regulation on SOx･PM, and Environmental Improvement led

－ IMO’s SOx･PM regulation stringent from 2020－

29th November 2016
ClassNK

Today's Contents

ClassNK

1. Introduction
2. Clarification on Regulation 14 of Annex VI as PM regulation
3. Correlation between Sulphur contents in fuel and PM emission
4. Improvements on Atmospheric Environmental expected in Japan
5. Overview on Mitigation Measures
6. Current and Future Contribution by NK

Introduction

ClassNK

In this presentation, ClassNK identifies the regulation up coming from 2020 (hereafter, the Global Cap) not as a mitigation measure on SOx, but as a mitigation measure on PM2.5.

The current situation of SOx(SO2) in Japan has been already improved significantly, and both the national environmental quality standards and criteria by WHO on SO2 have been attained.

→ Additional mitigation measures on SOx can be less prioritized.

On the other hands, higher concentrations of PM2.5 were repeatedly observed in the Main China from 2013. Even in western Japan, the higher concentration than the national environmental quality standards of PM2.5 were frequently observed.

→ Additional mitigation measures on PM2.5 can be highly prioritized in Japan and surrounded states.

Introduction

ClassNK

Comparison between the mitigation technology of diesel engines used on land and that used onboard.

Historically, the same mitigation technologies, applied to mobile diesel cars, have been used for the marine diesel engines. These technologies (including gas treatment technologies) were originally developed according to the regulation for diesel cars.

However, the mitigation for PM2.5 is fundamentally differed from that for PM from diesel cars, because the mechanism of pollution have been changed significantly from those era.

In 80's and 90's, when the PM emission from diesel cars were dominated,

the main mitigation measure were improved combustion in engines and attaching Diesel Particulate Filter, for the purpose of reduction on road at congested area.

In 00's and 10's, when concerns are moved to PM2.5 from PM.

It is necessary to reduce the secondary particle, photo-reacted from gas pollutants, so that a different approach would be needed.

1. Introduction
2. Clarification on Regulation 14 of Annex VI as PM regulation
3. Correlation between Sulphur contents in fuel and PM emission
4. Improvements on Atmospheric Environmental expected in Japan
5. Summary for Mitigation Measures
6. Current and Future Works by NK

The review of MARPOL 73/78 Annex VI (Air pollution from ships) started in April 2006, and adopted in April 2008.

During the review, there were two major discussion points;

1. The needs to strengthen the regulation on SOx、NOx
→2 tiers approach was adopted, the general standard is for global regulation and the strengthened standard applied only in Emission Control Area(ECA).

2. Particle Matter as an additional Pollutants
⟶ Particle Matter was added, but indirectly occurred by the sulfur contents in fuel.

The title of chapter 14 of Annex VI was revised as Sulphur Oxides (SOx) and Particulate Matter.

The global sulfur cap will be reduced from current 3.50% to 0.50%, effective from 1 January 2020
In ECAs sulfur cap will be reduced to 0.10%, effective from from 1 January 2015.

Therefore, the purpose of regulating the sulfur contents in fuel explicitly includes the reduction of PM.

How the reduction of sulfur contents will make PM reduction ?

Today's Contents

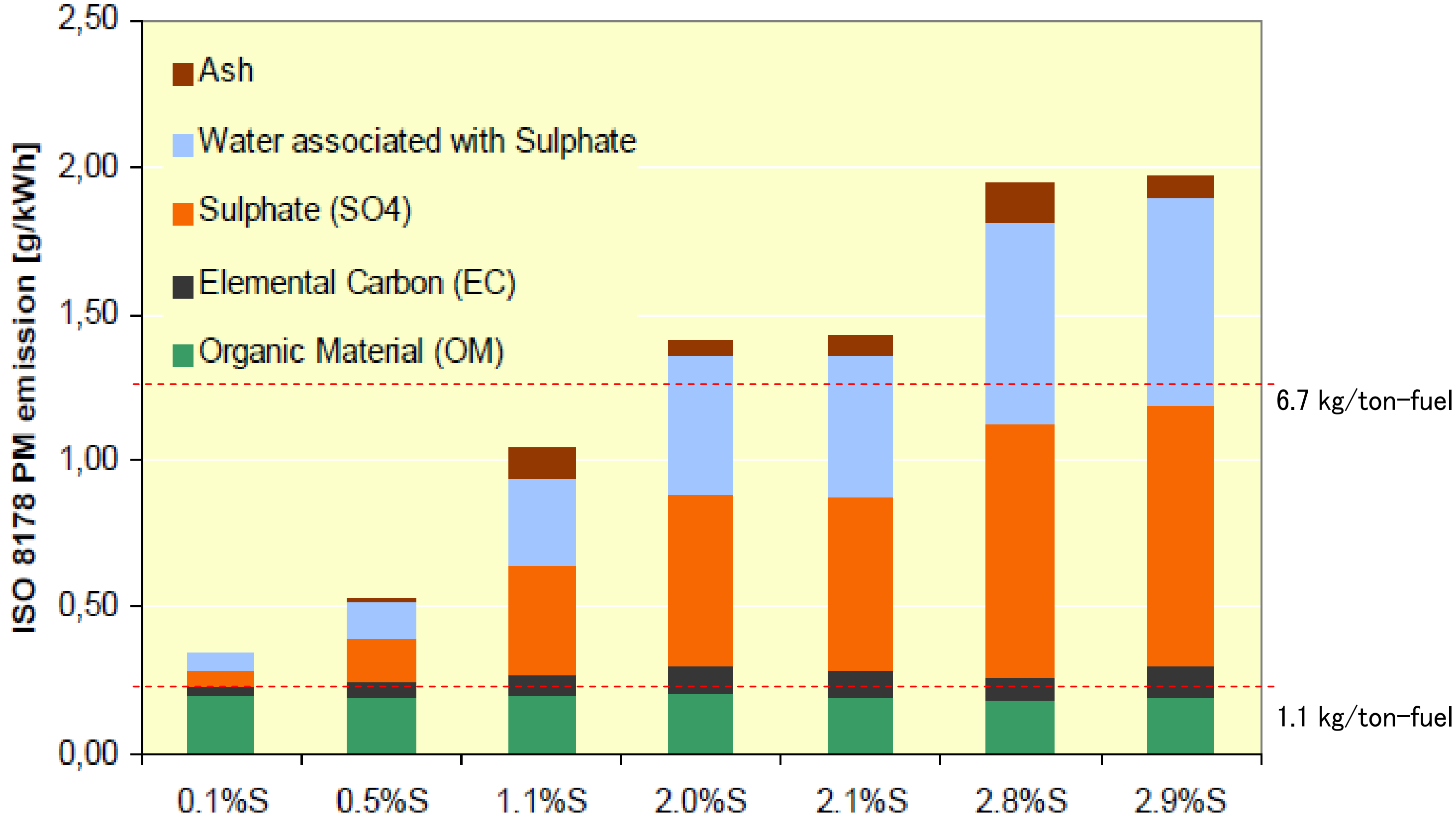
ClassNK

1. Introduction
2. Clarification on Regulation 14 of Annex VI as PM regulation
3. Correlation between Sulphur contents in fuel and PM emission
4. Improvements on Atmospheric Environmental expected in Japan
5. Overview on Mitigation Measures
6. Current and Future Contribution by NK

Correlation between Sulphur contents in fuel and PM emission

During the reviewing process, IMO documents and working papers noted that there is a clear and food correlation between Sulphur contents in fuel and PM emission.

For example, refer to the measurement data shown below, they noted that 80 % of total PM is contributed by the sulfate and associated water, only the rest is composed by the Diesel Particle).



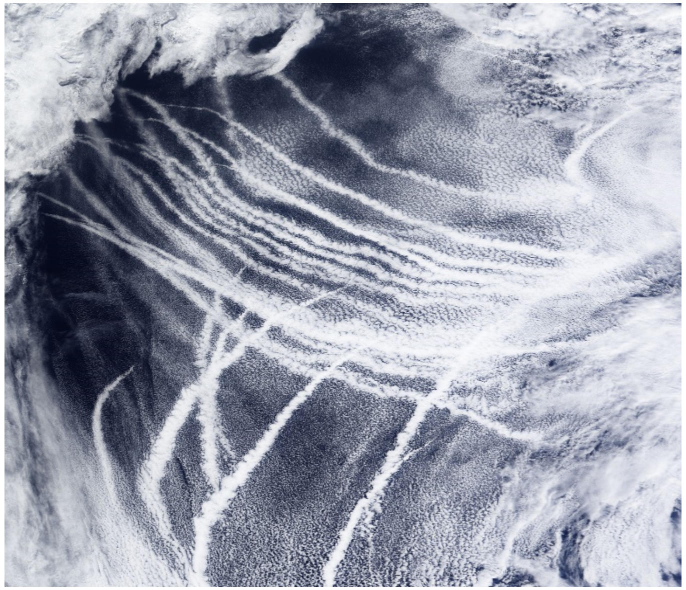
Correlation between Sulphur contents in fuel (w/w%) and PM emission (g/kWh)

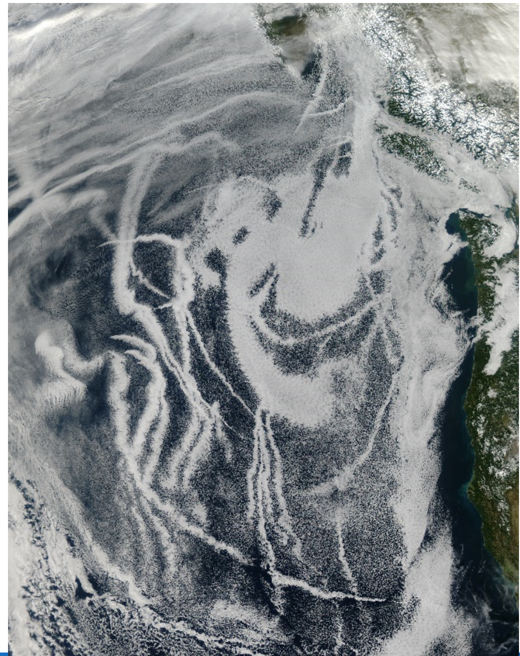
(IMO BLG-WGAP 2, Berlin, 2007)

One of the visual evidences that exhaust gas from ships contains amount of Sulphate and associated water is shown in below pictures from Satellites.

Sulphate and associated water in the exhaust gas has the optimized size as condensation nucleus of Clouds. Therefore, we can observe ship trace cloud at humid area on ocean, same as the vapor cloud by air plane.

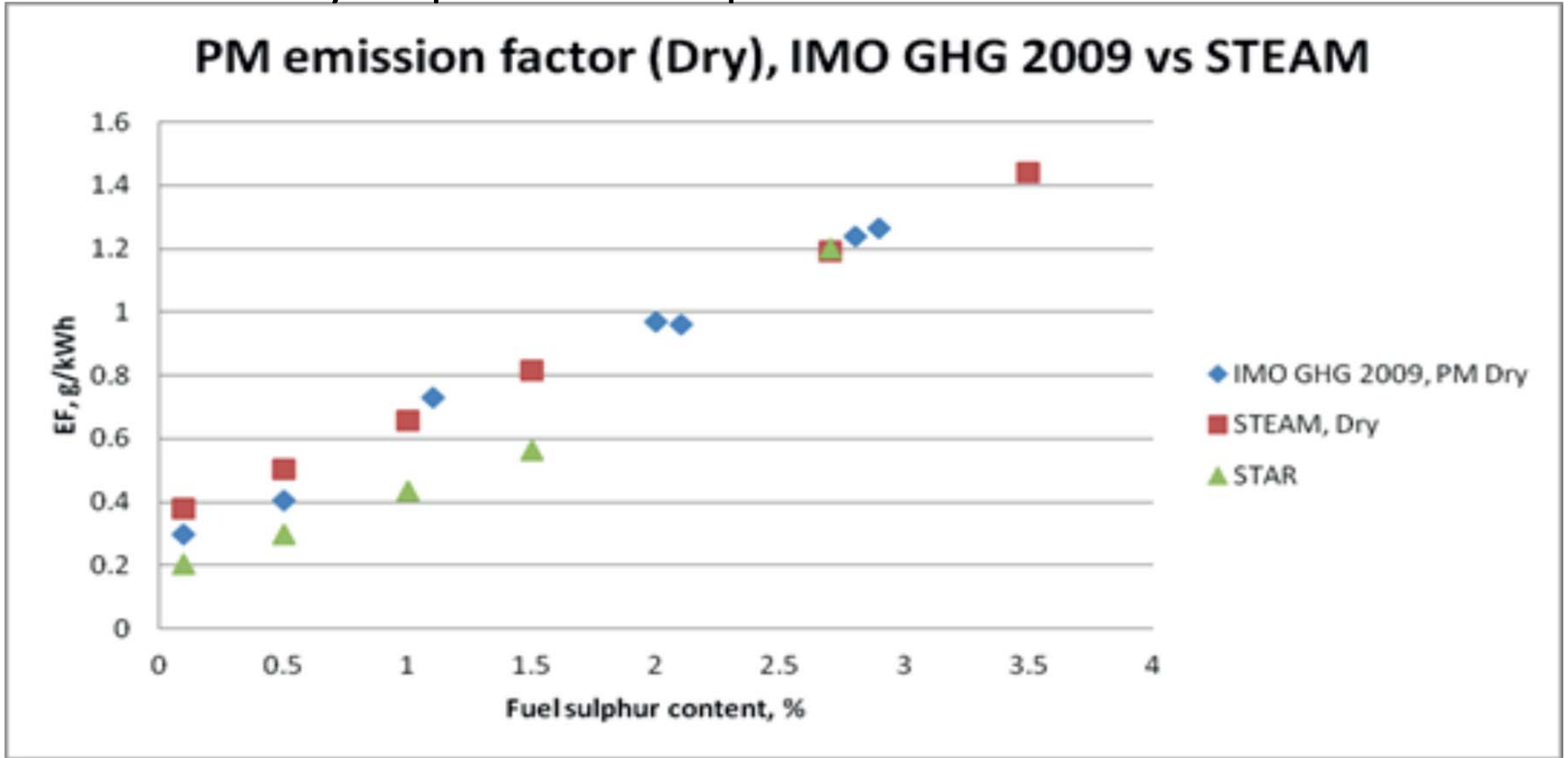
The actual image of ship trace cloud caught by the satellite of US NOAA, near US Aleutian Islands and US west coast.





It should be noted that even if the major contents of particle is water, tiny Particles < 50um can be harmful to the circulatory and respiratory systems, because of its physical/chemical irritation to lung.

In the report of the 3rd IMO GHG study 2014, the correlation shown in page 9 was evaluated with the other two measurement results. Three Dot's Groups are on the same line, therefore, it is confirmed that PM from marine diesel engines are dominated by Sulphate and depended on the sulfur contents in fuel.



Correlation between Sulphur contents in fuel (w/w%) and PM emission (g/kWh) (IMO、2015、3rd IMO GHG Study 2014)

(data measured in 2012▲and that in 2013年■ were expressed as PM without associated water, so that data in page 7 ◆ is also converted as dry basis in this figure.)

Today's Contents

ClassNK

1. Introduction
2. Clarification on Regulation 14 of Annex VI as PM regulation
3. Correlation between Sulphur contents in fuel and PM emission
4. Improvements on Atmospheric Environmental expected in Japan
5. Overview on Mitigation Measures
6. Current and Future Contribution by NK

How much reduction of PM emission from ships can be expected by the Global Switch? And on atmospheric concentration of PM2.5?

It is estimated that after Global Switch, PM emission factor will be reduced by nearly 70%, PM emission in Tokyo Bay from Ships will be reduced by nearly 60%.

Change on EF of PM, led by Global Switch (from the current level to 0.5%)

Sulfur (%)	emission factor (g/kWh)	Reduction rate by Global Switch
2.46	1.72	-
0.50	0.57	33%

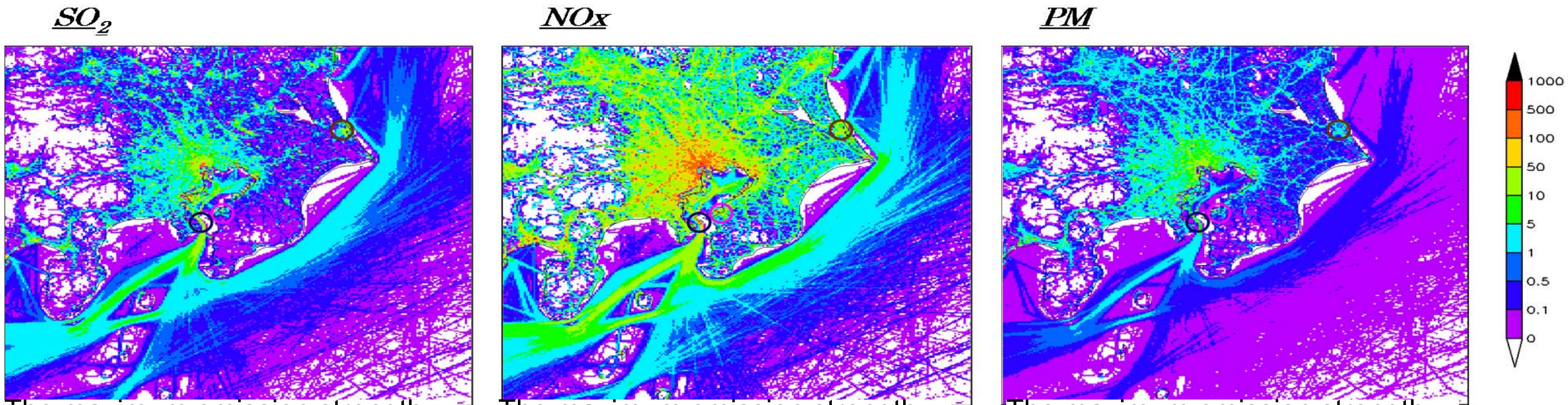
Change on PM emission in Tokyo Bay at 2020, led by Global Switch (from the current level to 0.5%)

scenario	PM emission (ton/year)	Reduction by Global Switch (Δton/year)
NO changes HFO 2.46% MGO 0.61%	2,588	-
Global Switch 0.5% for both	1,069 (41.3%)	1,519

Using CMAQ (Community Multiscale Air Quality) developed by US EPA, the improvement of PM2.5 in 2020 led by Global Switch was simulated.

The model includes the process not only the physical dilution process from emission sources but also including process of photo-chemical reaction among the pollutants, transformation from gas phase to particle, dry deposition onto ground/sea and washout by rain.

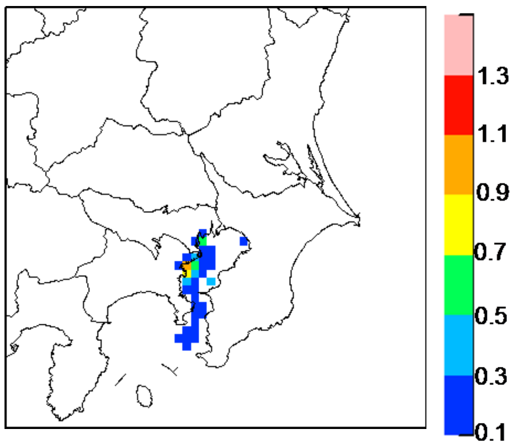
Also, the model was calibrated and evaluated with the actual measurement in 2004, and was considered as sufficiently accurate to reproduce the daily/seasonally concentrations both of primary pollutants and secondary particle (e.g. Sulphate, Nitrate and VOCs)



The maximum emission strength (ton/year/grid)	SO_2	NOx	PM
Ships Navigating:	64	142	12
Ships at harbor:	506	576	79
On-land sources:	7,681	8,707	437

Improvements on Atmospheric Environmental can be calculated to make a map of differential concentration between the annual average of PM2.5 in the Scenario A without Global switch and Scenario B with Global switch (but only in Tokyo Bay) .

It is confirmed that in the conatal area in Tokyo bay, annual concentration of PM2.5(μg m^{-3}) will be reduced. Also, the number of date with higher concentration > 50 μg m^{-3} can be reduced.



Reduction of annual concentration of PM2.5 caused by Global switch in Tokyo Bay (Δμg m-3)

Using the Code (BenMAP) by US EPA for the application of their ECA proposal to IMO, with the reduction on PM2.5 shown in the figure can reduce 281 premature death per year.

Today's Contents

ClassNK

Overview on Mitigation Measures

ClassNK

Mitigation Measures for the Global Switch

Regulation allows several Mitigation Measures rather than use of compliance fuel

1. use of compliant heavy fuel (HFO)
2. use of compliant light fuel (MGO)
3. use of alternative fuel
   (Methanol, Biofuel, LPG and DME)
4. Post treatment by EGCS(SOx Scrubber)

All 4 Mitigation Measures are matured for the emission sources on-land, however, re-evaluation will be needed whne they aare applied to onboard

Overview on Mitigation Measures

ClassNK

To select an appropriate Mitigation measure, cost analysis is necessary, however, the future fuel cost at 2020 is uncertain at this moment (even though the price of crude oil can be fixed). Therefore, it is premature to perform a quantitative cost analysis on OPEX.

According to IMO's fuel availability study, future fuel prices are estimated as follows. It should be noted that differential costs among the fuel type is maintained from the current situation.

Also, OPEX may be influenced by the local situation at ports, where the targeted ship will visit.

Product `	prices USD/ton
MGO Sulfur 0.10%	616
HFO Sulfur 0.50%	595
HFO Sulfur 1%	569
HFO Sulfur 3%	466
Brent crude (USD/bbl)	77

According to IMO's fuel availability study, this mitigation measure will be widely used in 2020.

The study estimates the major properties as follows;

viscosity 10-180 cSt	
Intensity	908-934 kg/m^3
CCAI	821-858
Flash point	94-118℃

As no significant changes are expected in those properties, the study concluded that there is no needs to adjust/modify engines and auxiliary equipment.

ClassNK

However, potential troubles caused by the new HFO may be occurred in 2020 such as ;

1. Because of low viscosity of the new HFO, the leakage from the seal on fuel pump can be increased, therefore, the actual volume of fuel provided to Cylinders may be insufficient compared to the designed value.
2. Because of low lubricity of the new HFO, abnormal abrasion on Plunger and Barrel in fuel pump may be occurred.
3. Because of higher volatility of the new HFO, fuel may be volatilized at fuel piping near/inside engines, so that vaper lock can be occurred.
4. Because of lower flashpoint of the new HFO, flash back may be occurred when fuel is leaked into boiler furnace.
5. Because of lower sulfur of the new HFO, the production sulfate will be reduced, therefore several alkali contents in the lubricant oil may be deposited to cylinder liners.

use of compliant light fuel (MGO)

ClassNK

According to the IMO study, the use of Compliant light fuel is only excepted in the existing ECA, but not for Global Switch. It is uncertain that fuel distributer can provided sufficient volume of both MGO with 0.5 % and that with 0.1%.

However, it may be beneficial to use MGO of 0.5% instead of HFO of 0.5%. Because in former case, lower OPEX coming from less maintenance costs on fuel preparation, bilge management and lubricant management is expected.

For new build ships, simplified purifier may make smaller engine rooms, then totally OPEX may be reduced?

Post treatment by EGCS(SOx Scrubber)

ClassNK

Regulation allows to use post treatment instead of the use of compliant fuel, in this case, compliance can be evaluated by the actual measurement of ration between SO_2 and CO_2 concentration monitored in exhaust gas.

If a ship will operated mainly in ECA, then the use of EGCS has a clear financial benefits rather use of MDO with 0.1 %. According to the IMO study, at the end of 2019, it is estimated that 3,800 ships will be installed with EGCS, and will consume 36 million ton of HFO/ year.
On the other hands, for the purpose of the Global Switch, the study estimated no ships with EGCS.

ClassNK has investigated R&D projects from 2009 on EGCS, including future use of EGCS after 2020 to comply with the Global Switch on the existing ships, also for a new build PCC and bulk carrier.

Typing of SOx Scrubber

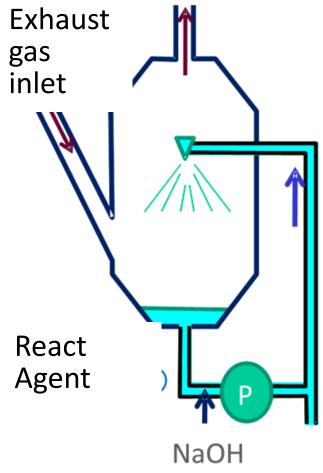
ClassNK

SOx Scrubber

- ✓ SOx scrubber consists Wet and Dry scrubber, the former uses solution media and the latter uses power media as a reacting agent.

Wet Scrubber

Use a (chemical) liquid or slurry media for Desulfurization



- Open Looped EGCS using seawater
- Closed looped EGCS using chemical solution
- Hybrid

Dry Scrubber

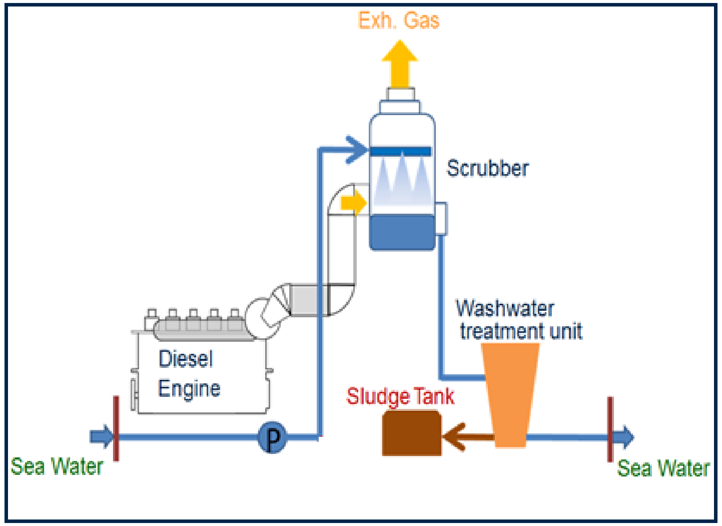
Use a (chemical) powder media for Desulfurization

- ✓ 98% of Desulfurization can be achieved (with 80% PM reduction)
- ✓ In general, Wet Scrubber is mainly used both on-land and onboard

Two types of Wet SOx Scrubber

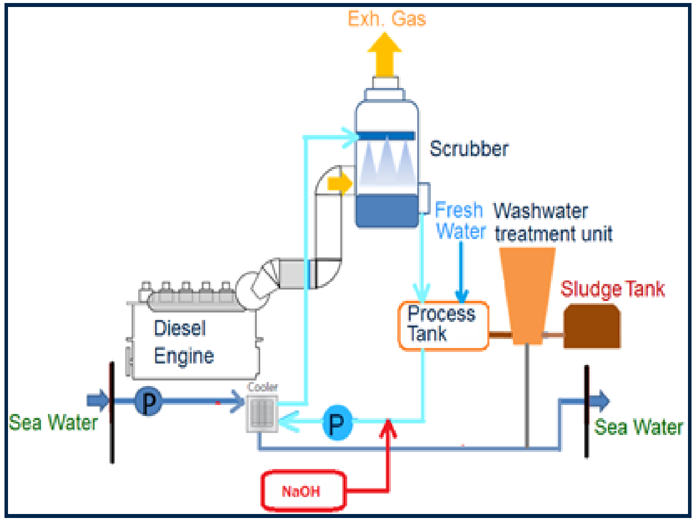
ClassNK

Open Looped EGCS using seawater



- Using seawater as wash water
- One through use of seawater

Closed looped EGCS using chemical solution



- Using Sodium hydroxide solution with recirculation ➡ NO needs for water discharge overboard

	Open Looped EGCS using seawater	Closed looped EGCS using Fresh water
Additional Facility onboard	Wastewater Treatment system (in case) Wastewater monitoring system Sludge tank	Wastewater Treatment system Wastewater monitoring system Sludge tank ➡ Higher OPEX Storage tank for Sodium hydroxide Reaction tank with cooler

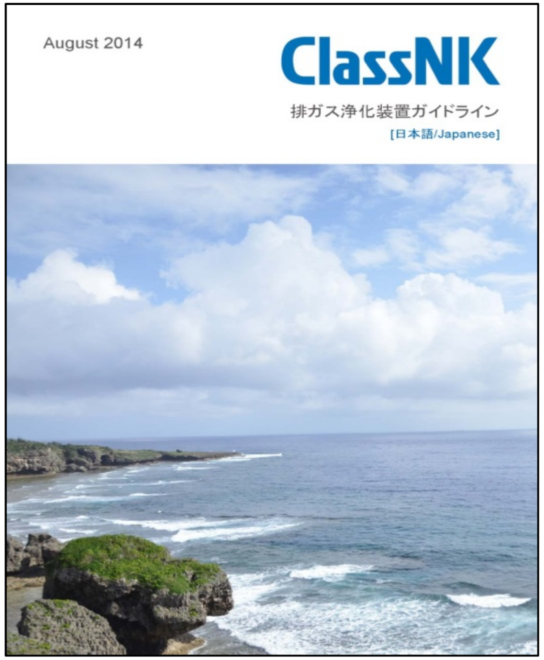
The use of EGCS (with fuel of > 0.5% Sulphur)

ClassNK issued "Guideline for Exhaust Gas Cleaning System" in 2014, which contains;

.1 Overlook on SOx scrubber,

.2 Commentary explanation on the Requirements in 2009 EGCS Guideline (MEPC.184(59)) by IMO, and

.3 Requirements on ship class for installation of EGCS.



The us of alternative fuel, such as LNG

ClassNK

- When using LNG as gas fuel, SOx emission could be completely eliminated, also PM emission could be reduced to negligible level.
- In IMO study, total 170 ships may be operated using LNG as fuel at 2020, which includes dry bulk carriers, container ships and tankers, who will be operated in ECA and short voyages.
- Even after 2020, if the cost estimation is not changed, then the Global switch does not lead wider use of LNG, for the purpose of SOx compliance.

- The use of the other alternative fuel, such as Methanol, Biofuel, LPG and DME, are also under development. The Global switch does not lead wider use of these alternative fuel.

Conclusion from Overview on Mitigation Measures

ClassNK

- To select an appropriate Mitigation measure, cost analysis is necessary, however, the future fuel cost at 2020 is uncertain at this moment (even though the price of crude oil can be fixed). Therefore, it is premature to perform a quantitative cost analysis on OPEX.
- Including PPR4 held in February 2017, unified implementation, compliance measures and a standard for new HFO may be discussed.
- With these further information, accurate cost analysis can be performed using a practical scenario.

Today's Contents

ClassNK

1. Introduction
2. Clarification of the PM reduction in Regulation 14 of Annex VI
3. Correlation between Sulphur contents in fuel and PM emission
4. Improvements on Atmospheric Environmental expected in Japan
5. Overview on Mitigation Measures
6. Current and Future Contribution by NK

Current and Future Contribution by NK ClassNK

NK considers that;

→The implementation of the Regulation 14 will cause huge impacts both on International and Internal ships.

→Also, it will lead significant evolution on every components of the propulsion system both in new-built and existing ships

The Maritime Cluster in Japan has already performed R&D on the elemental technologies, needed for this evolution. By 2020, it is crucial that managing those elements as a mitigation system, in which the each elements should be appropriately selected according to ship type and ship size, harmonizing with the local regulation and circumstances.

Current and Future Contribution by NK ClassNK

ClassNK will continuously tackle on the related technical concerns, taking into account of the voices by the stakeholders, and will evaluate the mitigation technologies from the view point of practicability and applicability.

Thank you for your kind attention!

Acknowledgment
The authors wish to acknowledge Profes sor Takasaki of Kyusyu University and A ssociate Professor Sakurai of Meisei Uni versity, who both provided useful suggest ion for making this presentation.