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PREVENTION OF AIR POLLUTION FROM SHIPS

New Solutions for Effective Reduction of VOC Emissions from Tankers – implications for regulation 15 to MARPOL Annex VI

Submitted by Norway

SUMMARY

Executive summary:	This document provides information on a new technology for VOC reduction, and relates these findings to a possible need to amend regulation 15 of MARPOL Annex VI.
Action to be taken:	Paragraph 10
Related documents:	

Background

1 In accordance with commitments in the Protocol concerning the control of emissions of volatile organic compounds to the UNECE LRTP-Convention, Norway has to reduce national VOC emissions. Shuttle tankers operating on the Norwegian continental shelf and entering Norwegian ports represent a large portion of Norway's national emissions, and such tankers are thus required to undertake emission reduction measures.

2 The Norwegian VOC regulations have triggered a need for finding solutions leading to large emission reductions. This document provides information concerning a new technology for VOC reduction, and relates these findings to regulation 15 of MARPOL Annex VI.

Challenges related to VOC emissions

3 VOC are the mixture of light end components (methane to octane) in crude oil, which are emitted from the oil and oil products during production, processing, loading, transport, unloading and storage. In addition, volatile inorganic compounds such as H2S, can be emitted together with VOC.

4 The lightest component (mainly methane) contributes to the greenhouse effect, whilst the heavier components (mainly propane and butane) contribute to ground level ozone, which is detrimental to human health and the vegetation. VOC can also be the direct cause of oil spill on the ship's deck, as high flow out of the cargo tanks/riser mast due to severe VOC generation can cause oil entrainment into the inert/VOC flow.

5 The implications of regulation 15 of MARPOL Annex VI are very uncertain. It is possible that the regulation will not lead to any reduction of the VOC emissions from tankers. In addition, regulation 15 only addresses "vapour collection systems" which do not encompass other solutions for the reduction of VOC emissions. Possibly, the reason for drafting regulation 15 in its present form was that, only a limited number of solutions were developed, and that a cost effective technology for reducing VOC emissions was not available when Annex VI was adopted.

A new and effective solution for the reduction of VOC emissions from tankers

6 Researching solutions, a Norwegian shipping company studied the basis for VOC formation on tankers. The assessment and measurements revealed that under pressure or vacuum in the loading system is the dominating reason for VOC emissions during the entire sea voyage for tankers. The solution to reducing VOC emissions is to redesign the loading system in order to prevent under pressure to occur and establish a positive pressure in the loading arrangement.

7 This new and effective system for the reduction of VOC emissions is installed on four ships. A design preventing under pressure or vacuum exposure during loading, has shown a reduction in the generation of VOC and H2S between 70% and 90%, depending on oil volatility and composition. The system is simple in operation, and there are in fact no operational changes compared to existing loading procedures on tankers. A more detailed description of the system is provided in the annex to this document.

8 Installation of the new technology on new built tankers will be less than 1% of the new built price since the new arrangement replaces other arrangements. A retrofit would require some additional cost depending on existing arrangement and interface.

Proposal

9 In Norway's view, there are now effective solutions to the reduction of VOC emissions from ships. Norway invites the Committee to investigate how regulation 15 of MARPOL Annex VI may be amended to better include the results presented above.

Action requested of the Committee

10 The Committee is invited to consider the above views and decide as appropriate.

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ANNEX

Introduction

1 Since 2001 a Norwegian shipping company has investigated the fundamental reasons to reduce VOC emission from tankers. The initial purpose for the investigation was to develop efficient and economical technology to meet the strict requirements to reduce Non Methane Volatile Organic Compounds (NMVOC) from shuttle tankers loading on the Norwegian Continental Shelf. The new approach adopted was to prevent emissions to occur instead of treating VOC already generated.

2 The basic principle adopted is to ensure that the loading systems on tankers is designed to prevent gas release as a result of crude oil to be exposed to low pressure or vacuum during loading. To verify the new approach, extensive fluid simulations and laboratory testing has been performed. This resulted in a full-scale installation of a new loading system on an oil tanker. Since then, three other tankers have been equipped with similar systems that include measuring device to be able to further document the reduction in VOC emissions.

3 Product losses resulting from VOC emissions are substantial on a world scale basis and the latest predictions performed indicate that as much as 9 million tonnes of VOC could be emitted annually due to crude oil transport with about 5 million tonnes emitting during transit. This corresponds to about 70 million barrels of light end hydrocarbons representing a value between 3.0 to 3.5 billion USD/year.

Theory

4 The reasons for VOC generation and resulting emissions when crude oils are being moved from one tank to another must be understood in order to be able to prevent VOC emissions from tankers. Analysis of the loading process has revealed new information that has made it possible to initiate technology development that prevents most of the emissions. In the past, boiling and diffusion from the oil surface in the cargo tanks has been considered the main reason for VOC emissions. If this is correct, recovery technology that handles the flowing mixture of hydrocarbon and inert gas out from cargo tanks during loading and transit would be the only correct approach to reduce VOC emissions. However, thorough investigation of the loading process and the actual physical loading arrangements onboard tankers has revealed that under pressure in the loading system occurs. Such under pressure or vacuum exposure of crude oils with drop line pressures as low as 0.15 bar have been documented to have a crucial effect to the crude oil properties. When exposed to the low pressure, the crude oil will flash resulting in VOC emissions during loading. The vacuum exposure will also influence the emissions throughout the entire sea voyage for tankers.

5 Underpressure or vacuum occur due to the vertical down-flow in the loading system and in particular in the “drop” pipe. The drop pipe from the tanker deck to the oil distribution system below the oil tanks may be 20 metres or more on board Suezmax tankers while the VLCCs may have up to 30 metres drop pipe. The conclusion after assessment of the existing loading systems on various tankers revealed that almost all the existing loading arrangements today have a design that maximize the VOC generation from tankers.

6 The flashing of oil and other volatile products due to the loading system design in combination with flow and high share forces, will in most cases also accelerate the release of gas. This will again reduce the oils ability to reabsorb the gas back into the oil. Gas released will remain in the flow and follow the two-phase flow as tiny gas bubbles. Due to share forces created

in the vertical down flow, the speed of gas release and absorption will be very different. According to experts, the release of gas process could be more than 100 to 1,000 times faster than the re-absorption process.

7 This corresponds very well with the observations made during crude oil loading from different terminals and offshore loading systems. It also proves that if the flashing and prevention of share forces in the loading system can be prevented, a fundamental reason for VOC emission will be eliminated. It also gives a very good explanation of why VOC emissions for some crude oils are very sensitive to weather. If rolling occurs during a loading process, the migration of the gas bubbles to the tank surface will be accelerated. It also explains why some crude oils also emit large volumes of VOC during transit and why transit loss for some crude oils is weather sensitive.

8 Crude oil exposure to under pressure also affects the solubility of components such as asphaltenes and wax. Asphaltenes and wax may initiate creation of colloids and more rigid components when exposed to under pressure. This process is more or less irreversible and may require that the crude must be heated to the reservoir condition in order to bring the crude oil back to its original behaviour. Therefore, prevention of under pressure should also be avoided for various other reasons than reducing VOC or H2S emissions.

9 Based on the above in combination with calculations and theoretical assessments of oil properties and behaviour in general, it can be stated the exposing crude oil to extreme low pressure as will happen in almost every loading systems of today, will change the crude oil properties and increase emissions not only during loading, but through the entire sea voyage for tankers.

10 As the transfer system during loading also increases the VOC content in the inert gas atmosphere in the cargo tanks, the VOC released during purging or during the next loading will increase due to the release of inert with high VOC content. At many terminals, purging of the cargo tanks is requested prior to start loading to minimize VOC and especially H2S content mainly caused by loading of previous cargo with an unfavourable loading arrangement and oil composition.

11 The VOC emission volumes depend on many factors such as RVP, oil composition, temperatures, weather conditions and physical layout of the transfer systems. Therefore, the actual emissions differ from cargo to cargo. However, it has been a tendency that the crude oils have become more volatile with higher content of light end hydrocarbon components in the crude.

12 The most common way to reduce VOC emissions during loading is to install vapour return system and VOC recovery processing systems, and then return the recovered VOC back to the crude oil. The processes reduce VOC emissions from the tanker during loading, but the changes made to the crude due to re-injection of light end hydrocarbons, processing and mixing, VOC emissions could in many cases be considerably increased during transit voyages, discharging and oil transfer to other storage systems. Hence, the VOC emissions throughout the entire value chain should be addressed and documented before recovery technology is implemented.

Solution

13 Based on the theory outlined above, it was concluded that by prevention of under pressure exposure of the crude oil and subsequent changes in properties, a significant reduction in VOC emissions would be obtained during the complete vessel round trip.

14 The solution developed prevents under pressure during loading. The new arrangement is already installed on several shuttle tankers. All systems have proved that besides preventing a significant VOC and H2S reduction during loading, the solution also removes most of the emissions during transit voyages and reduce the VOC and H2S content in the inert gas after discharging. Reduced emissions will then be obtained during any purging operation and during the next loading operation as the VOC and H2S content in the inert gas is reduced.

15 To further improve the efficiency due to boiling and diffusion, a new pressure control valve has been installed on the inert gas system that maintains a constant inert pressure in the tanks.

16 The new loading system developed consist of a much larger drop line that maintain a constant back pressure in the transfer system independent of loading rate and loading arrangement. Thus under pressure (vacuum) is more or less eliminated.

17 A prototype installation of the new system for reduction of VOC emissions was installed on M/T Ragnhild Knutsen in April 2002. The results were very promising and flow-measuring device was installed in the inert riser to measure vapour growth during loading and transit. To make such equipment to operate accurately was challenging and required extensive follow up. Similar instrumentation was installed on a similar tanker operating without the VOC emission reduction system.

18 Several loadings were performed showing an average reduction of the VOC generated during loading to be between 70 and 90%. Besides reduction of VOC, H2S reduction during loading in some cases was measured to be about 90%. This is strong evidence that VOC reduction is significant as H2S gas is released due to the same phenomena as VOC.

19 To further demonstrate the efficiency, a mass balance method has been applied for REBCO oils loaded on M/T Ragnhild Knutsen with and without the new system for a total of 20 cargos. There were a total of 9 cargos with, and 11 cargos without new in operation during loading.

20 The results showed that new system for reduction of VOC emissions had a significant and positive effect and proves beyond reasonable doubt that it reduces the formation of VOC and that the effect is significant for the 20 data points analysed.

21 The new system for reduction of VOC emissions onboard M/T Ragnhild Knutsen was modified in December 2003 by installation of an ultrasonic flow meter in the riser mast, and a valve control to keep a constant and high pressure in the cargo tanks during loading and sea transit voyages.

22 The new measuring device has made it possible to establish vapour growth figures for many different cargos with different temperatures, crude oil properties, etc., Vapour Growth (VG) can be defined as a measure of the volume of gas flowing out of the tanks compared to the

volume of oil loading into the tanks. If the VG is equal to 1, little or no VOC has been generated. VG greater than 1 indicate that additional vapour has been generated and the more the VG increases, the more VOC has been generated. The VG clearly gives an indication whether elimination of under pressure would reduce VOC emissions or not.

23 The results confirm the earlier results, and the new system for reduction of VOC emissions reduces the vapour growth significantly. In most of the cases, the VG was close to 1 while at some fields known as having significant content of light end hydrocarbons showed a VG of about 1.2 to 1.3. Very few such measurements have been performed worldwide. However, the estimates prepared by the Oil companies operating on the Norwegian Continental Shelf have earlier indicated an average emission corresponding to about 0.1 to 0.2 wt %. If transferred to VG figures, this corresponds to VG of 1.4 to 1.8 respectively. For the most volatile fields, a VG of 2.2 has been indicated.

24 Measurements also indicate that new system for reduction of VOC emissions prevents most of the VOC emissions during transit even for high TVP crude oils. This proves that low pressure exposure occurring during conventional loading also has a significant effect on the transit losses. By preventing this effect, transit loss could be minimised. It also proves that emissions due to rough weather are reduced due to the same reasons as mentioned above.

25 When the results from using the flow-metering device and tank pressure control valve are compared to earlier measurements and the statistical mass balance method, the results are very consistent and prove a significant effect of new system for reduction of VOC emissions.

Conclusion

26 Underpressure appearing due to an unfavourable loading system design is the main reason for VOC and H2S emissions from cargo tanks during the entire sea voyage. A design preventing underpressure or vacuum exposure when loading, has shown a reduction in generation of VOC and H2S between 70% and 90% depending on oil volatility and composition.

27 Design that prevents under pressure to appear will also have a major reduction capability for all other volatile cargoes such as products, chemicals, LPG and LNG.

28 Recovery by extracting and re-injection of extracted products could make VOC and H2S emissions worse when the entire transport chain is analysed, as long as almost all loading arrangements still are designed to generate underpressure or vacuum. Before costly, energy consuming and large VOC recovery systems are being installed, prevention by pressure balancing on board ships should first be applied.