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AIR POLLUTION PREVENTION

Study on developing on board sampling methods of fuel oil intended to be used or carried for use on board a ship

Submitted by the Netherlands

SUMMARY

Executive summary:	The Dutch Inspectorate sampled several bunker tanks to gain experience for inspections of the carriage ban. Sampling was done through the sounding pipe. The vacuum method works for tanks with less than 8 meters of empty pipe above the fuel. For deeper tanks, the flow through method is more suitable. It is possible to sample all kinds of tanks and fuels. The method is safe, feasible and affordable.
Strategic direction, if applicable:	1
Output:	1.17
Action to be taken:	Paragraph 6
Related documents:	MEPC.1/Circ.864/Rev.1 and MEPC.1/Circ.889

Introduction

1 The amendments to MARPOL Annex VI on the prohibition on the carriage of non-compliant fuel oil for combustion purposes for propulsion or operation on board a ship, also known as "the carriage ban", were adopted by MEPC 73 by resolution MEPC.305(73).

2 The carriage ban entered into force on 1 March 2020.

3 At PPR 7, the *Guidelines for on board sampling of fuel oil intended to be used or carried for use on board a ship* were discussed and finalized with a view to approval at MEPC 75, particularly, to support the enforcement of the carriage ban.

4 On 14 February 2020, the Working Group on Air Pollution Prevention, at PPR 7, noted a presentation by the delegation of the Netherlands. In this presentation, the Dutch Environment and Transport Inspectorate shared experiences with taking of onboard fuel oil samples from the bunker fuel oil tanks of ships calling at ports in the Netherlands, using the

sounding pipe. Following the presentation, the Group exchanged views, inter alia, on potential contamination of the fuel samples, the representativeness of the sulphur content of the fuel carried in the tank, the depth of the tank at which the sample should be taken, and possible safety implications when taking on board fuel samples.

5 The annex to this document contains the sampling study, including a further elaboration of the aspects of contamination, representativeness, sample depth and safety implications.

Action requested of the Committee

6 The Committee is invited to note the information contained in this document.

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ANNEX

1 Introduction

Being a SECA country, the Dutch Human Environment and Transport Inspectorate ("ILT") has done many inspections checking the sulphur content of in-use fuel. Because of the carriage ban, the ILT is also planning to inspect the sulphur content of fuel oil in bunker tanks. No standard method is yet available. In 2019, the ILT carried out 26 inspections of different tanks on different ships.

2 Materials and methods

Sampling point

There is a large variation in the location and numbers of fuel tanks on board ships. Wing tanks are situated at the top of the ship with relatively short pipes. In other cases, they are designed as double bottom tanks. Although the size of the ship can give an indication of the expected situation, this is not always the case. A large ship can have wing tanks and a small ship bottom tanks.

What would be the best sampling point? Sampling via the manhole is not a good option. It is impractical, because opening the manhole takes a lot of time. Moreover, it is dangerous to open the manhole.

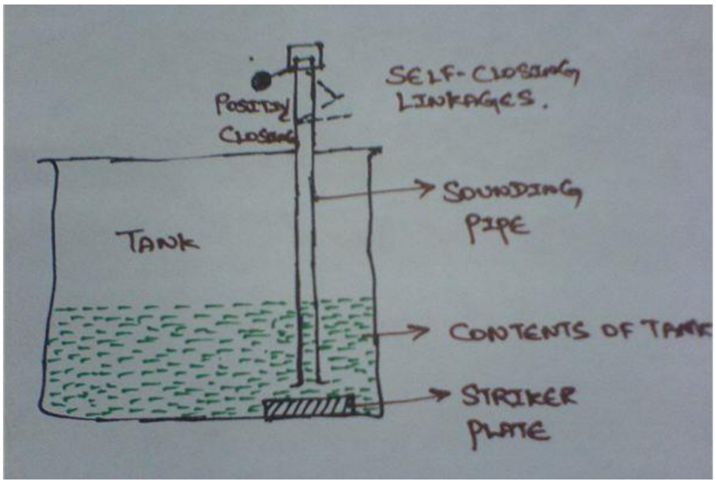
Sampling on transfer points is a good option for sampling the last tank in use, but it has limitations for sampling bunker tanks that are not in use:

.1 the chief engineer is not keen on circulating fuel from one tank to another because different batches may not be mixed;

.2 it is a time-consuming process to circulate the fuel, especially when the tanks must be heated; and

.3 it is necessary to pump the volume of the pipe, to be sure that the sample is representative. The best way to be sure is to sample directly from the tank.

Sampling via the sounding pipe offered the most practical and reliable solution. All inspections were done via the sounding pipe.



The samples were taken by two methods: the vacuum method and the flow method. They are elaborated below and in a movie: https://www.youtube.com/watch?v=EuvYLAnTAnk.

Vacuum method

The vacuum method is based on the principle of under pressure. A hose is lowered with a weight (stainless steel 316, 700 grams, antistatic). The weight has a sample feedthrough and is conical on both sides. Because of its shape, the sample opening will not make contact with any impurities present on the inside of the pipes. It has the same angle as is usual with the cones of the measuring tapes.

Once the weight is in the fuel, the sample is collected with a pump. This pump is manual, to enable inspections on all kind of ships (also ships with dangerous cargo). The fuel comes into the first bottle, the second bottle serves as a safety buffer to prevent contamination of the pump. It is equipped with a pressure gauge to record the pressure and a vent valve to release the vacuum. A bottle of compressed air is available to empty the hose with air after sampling. The hose and weight are replaced after each sampling. The weights are cleaned afterwards.

Due to pressure limitations, this method is only suitable for ships with less than 8 meters of empty pipe above the fuel.



Flow method

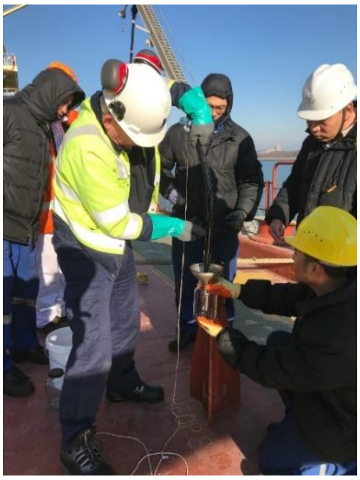
The flow method has been developed for deeper tanks (more than 8 meters of empty pipe above the fuel) and fuels with temperatures below 10 degrees Celsius (viscosity of 380 centistokes).

The method is based on the principle of the flow-through sample, which is used in the oil and petrochemical industry. The following standards are available for sampling liquid petroleum and chemical products: ASTM D4057 and NEN-EN-ISO 3170.

A flexible sample unit has been developed, which consists of a stainless steel 316 bottom and top (both conical). The intermediate piece is a silicone hose, to facilitate moving through bends in the monitoring pipes. The lower part is equipped with a ball that closes the opening. A restriction prevents the ball from floating too far upwards. When the unit drops in the fuel, the ball will float. This creates an opening through which the fuel will flow into the hose. As long as the unit drops, the fuel will flow through the opening in the top. Once the desired height has been reached, the unit is raised and the ball closes the bottom opening.

The sample size is 150 ml. This is sufficient for 15 sulphur measurements.





Costs

A full set of measuring equipment costs about 3000 EUR. The weight is specially designed (spark free material) and costs €300. The equipment can be used again after cleaning. All hoses are replaced after sampling.

3 Results

We performed 26 inspections on different types of ships: 11 tankers, 6 bulk carriers, 6 containerships and 3 general cargo ships. All bunker tanks could be sampled, without having difficulties with inaccessibility or depth of tanks. There was a positive atmosphere during the inspections. The chief engineers and other crew members were curious and cooperative. The use of the sounding pipe for sampling was fully accepted.

Inspections with the vacuum method are listed in table 1 (ship and tank specifics) and table 2 (sulphur content). Results of the flow method are listed in table 3 (ship and tanks specifics) and table 4 (sulphur content).

Ship and tank specifics

It is hard to determine the depth of a tank in advance. A large ship could have wing tanks, and a relatively small ship double bottom tanks. We experienced that most bulk carriers have wing tanks (3-5 meter depth). Containerships have deeper tanks (9-20 meter depth). Tankers and ships with general cargo are more unpredictable. Almost all ships have perforated sounding pipes.

There is no relation between ship type and fuel type, nor between depth of tank and fuel type. The maximum viscosity (or "thickness") of the fluid was 380 centistokes for HFO. But even those fuels could be sampled without any difficulties. Both methods are fit for fuels of 380 centistokes, but below 10 degrees Celsius, it gets hard to sample with the vacuum method. All bunker tanks with HFO were heated (from 2870 °C), except ship 18. The flow method was carried out successfully on this ship.

Table 1: Results vacuum method (ship and tanks specifics)

#	ship type	Fuel type	Temp	Viscosity	Tank height (incl sound. Pipes) (m)	Liquid height	Sampling	Sampling	perforated sounding Pipe
							height 1	height 2	
			°C	(15 °C)		(m)	(m)	(m)	
1	Tanker	MDO	12	4,19	6	3,96	2	3,5	yes
2	Bulk Carrier	MGO	14	0,965	3,77	1,15	3	3,5	yes
3	Tanker	MDO	15	4,2	3,28	1,39	2	3	unknown
4	Tanker	MDO	18	4,31	9,5	3,5	6,5	7,5	yes
5	Bulk Carrier	MDO	14	6	5,26	2,9	3	4	yes
6	Container	MDO	20	4,98	10,63	3,86	7,5	9	yes
7	Container	HFO	69	180	9,76	4,21	6	8,5	yes
8	General cargo	MGO	15	0,09	6,77	2,96	4,5	5,7	unknown
9	Tanker	MDO	13	4	9,5	2,89	7,5	8,5	unknown
10	Container	HFO	51	380	10	4,2			Yes
11	Bulk Carrier	MGO	13		3,77				Yes
12	Bulk Carrier	MGO	13		3				Yes
13	Tanker	MGO	15		3,28				Yes

Table 2: Results vacuum method (sulphur content)

#	ship type	BDN sulphur content	sulphur content	sulphur content	Average sulphur content	Difference sulphur content	Difference BDN and average
			height 1	height 2	h1 and h2	h2 - h1	
		(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)
1	Tanker	200	153	174	164	21	-37
2	Bulk Carrier	600	550	650	600	100	0
3	Tanker	300	300	350	325	50	25
4	Tanker	700	749	776	763	27	63
5	Bulk Carrier	900	842	848	845	6	-55
6	Container	890	853	821	837	-32	-53
7	Container	2000	2025	1871	1948	-154	-52
8	General cargo	700	778	815	797	37	97
9	Tanker	900	853	1013	933	160	33
10	Container	2500	2700	2700	2700	0	200
11	Bulk Carrier	600	550	600	575	50	-25
12	Bulk Carrier	400	300	350	325	50	-75
13	Tanker	800	800	780	790	-20	-10

Table 3: Results flow method (ship and tanks specifics)

#	ship type	Fuel type	Temp	Viscosity	Tank height (incl sound. Pipes) (m)	Liquid height	Sampling	Sampling	perforated sound. Pipe
							height 1	height 2	
			°C	(15 or 50 °C)		(m)	(m)	(m)	
14	Tanker	HFO	70	380	11,33	3,03	9	13	yes
15	Bulk Carrier	HFO	28	380	5,45	4,2	1,5	3	yes
16	Tanker	MGO	20	4,3	15,9	4,93	12	13,5	yes
17	Bulk Carrier	HFO	30	190	4,91	3,4	2,5	3,5	unknown
18	Tanker	HFO	10	79*	15,6	2,97	13,5	14,5	yes
19	General cargo	MDO	18	5,9	12,51	3,9	9,5	10,5	yes
20	Container	HFO	65	180	20,1	4,67	16,5	18	yes
21	Container	MGO	14	0,089	16,9	4,21	13,5	15,5	yes
22	Tanker	HFO	49	180	18,45	3,97	15,5	16,5	yes
23	Tanker	MDO	16	5,8	6	4,46	2,6	4	yes
24	Tanker	HFO	40	13,9*	14,32	4,39	10	13	yes
25	Container	HFO	55	180	9				yes
26	General cargo	HFO	35	180	20,5				yes

*Viscosity at 50 °C

Table 4: Results flow method (sulphur content)

#	ship type	BDN sulphur content	sulphur content	sulphur content	Average sulphur content	Difference sulphur content	Difference BDN and average
			height 1	height 2	h1 and h2	h2 - h1	
		(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)
14	Tanker	4900	4878	4954	4916	76	16
15	Bulk Carrier	5000	5841	5779	5810	-62	810
16	Tanker	590	542	504	523	-38	-67
17	Bulk Carrier	4900	4940	4924	4932	-16	32
18	Tanker	4500	4853	4975	4914	122	414
19	General cargo	820	886	864	875	-22	55
20	Container	4900	3180	4850	4015	1670	-885
21	Container	500	564	523	544	-41	44
22	Tanker	400	404	445	425	41	25
23	Tanker	850	1118	1060	1089	-58	239
24	Tanker	947	1007	890	949	-117	2
25	Container	2500	2500	2550	2525	50	25
26	General cargo	1000	1250	1230	1240	-20	240

Sulphur content

The sampling is done at two heights. The actual height depends on the tank height and the sounding height/ullage (a top and bottom sample). In most cases, it is about 1.5 and 3 meter depth in the fuel oil. The sulphur content of both heights is listed in table 2 and 4. The differences between the two heights are for all ships except a ship 20 less than 200 PPM (parts per million). This is 0.02 % sulphur. This equals the measurement uncertainty in laboratories. The height of the sample does not influence the sulphur content. We found no indications for stratification. The ship 20 was different. Each sample is analyzed in duplo with the XRF device. The duplos of ship 20 had a remarkable difference in sulphur content.

The BDN (bunker delivery note) shows the sulphur content according to the supplier. Table 5 shows the comparison of the BDN and the measured sulphur content. Most ships have a measured sulphur content slightly higher or lower than the BDN. But all these differences fall into the measure uncertainty. Four ships have substantively higher sulphur measurements. An explanation could be that the bunker tanks had not been cleaned yet. We have no information about bunker tank cleaning. Almost all ships have perforated sounding pipes, which makes exchange with the whole tank more easily.

All ships carried compliant fuel oil. A bulk carrier (ship 15) had a sulphur content in the bunker tank of 5810 PPM. This is 0.58 % sulphur. The inspection took place before 1 March 2020, so the carriage ban had not yet entered into force. If the ship had been inspected after that date, further investigation would have been carried out.

Table 5: Difference between BDN and measured sulphur content

#	ship type	BDN sulphur content	sulphur content	sulphur content	Average sulphur content	Difference sulphur content	Difference BDN and average
			height 1	height 2	h1 and h2	h2 - h1	
		(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)
20	Container	4900	3180	4850	4015	1670	-885
12	Bulk Carrier	400	300	350	325	50	-75
16	Tanker	590	542	504	523	-38	-67
5	Bulk Carrier	900	842	848	845	6	-55
6	Container	890	853	821	837	-32	-53
7	Container	2000	2025	1871	1948	-154	-52
1	Tanker	200	153	174	164	21	-37
11	Bulk Carrier	600	550	600	575	50	-25
13	Tanker	800	800	780	790	-20	-10
2	Bulk Carrier	600	550	650	600	100	0
24	Tanker	947	1007	890	949	-117	2
14	Tanker	4900	4878	4954	4916	76	16
22	Tanker	400	404	445	425	41	25
3	Tanker	300	300	350	325	50	25
25	Container	2500	2500	2550	2525	50	25
17	Bulk Carrier	4900	4940	4924	4932	-16	32
9	Tanker	900	853	1013	933	160	33
21	Container	500	564	523	544	-41	44
19	General cargo	820	886	864	875	-22	55
4	Tanker	700	749	776	763	27	63
8	General	700	778	815	797	37	97
10	Container	2500	2700	2700	2700	0	200
23	Tanker	850	1118	1060	1089	-58	239
26	General cargo	1000	1250	1230	1240	-20	240
18	Tanker	4500	4853	4975	4914	122	414
15	Bulk Carrier	5000	5841	5779	5810	-62	810

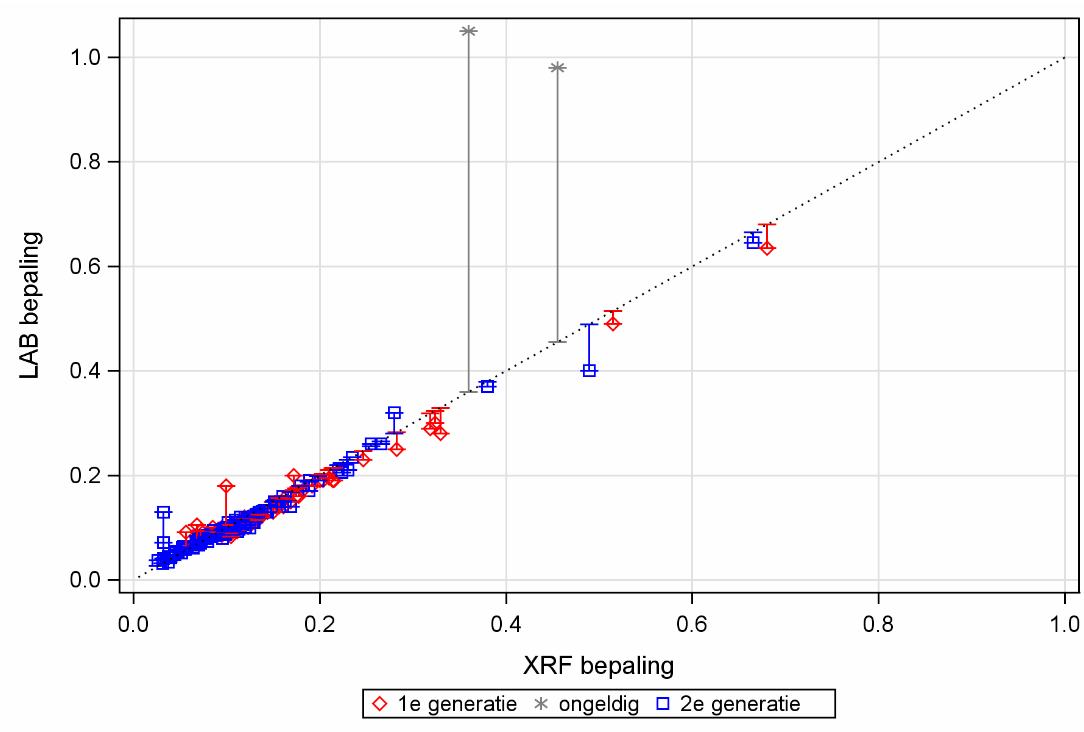
4 Validation

Reliability of XRF equipment

The ILT uses XRF, a handheld device that allows rapid analysis of the sample taken on board within half an hour. The XRF is taken in the car with which the inspector drives to the port site.

The reliability of the XRF equipment is equal to a laboratory sulphur measurement (see below). In case of sanctioning a second analysis takes place at a certified laboratory.

From January 2016 to October 2018, 234 sulfur determinations were made by both the ILT (with the XRF device) and the laboratory (LAB). There are 110 measurements taken with an old XRF device: the 1st generation model and 124 measurements with a new device: the second generation model. The scatterplot below shows the connection between the measurement results of the XRF and the LAB.



On the x-axis the results of the XRF determination and on the y-axis the results of the LAB determination. There are two outliers (in grey). These outliers were performed with a first generation XRF device on 8 February 2017. The laboratory results are deviating in such a way that they are declared invalid. Of the remaining 232 measurements, the provisions with the first generation XRF device are shown in red and the provisions with the second generation XRF device in blue.

A distinction can be made between the precision of the first and second generation XRF provisions. In 95% of the measurements with a first generation XRF determination, the difference lies with a LAB determination between -0.020 and 0.038. In 95% of the measurements with a second generation XRF determination, the difference lies with a LAB determination between -0.028 and 0.034. In comparison: the measurement uncertainty in a laboratory is 0.020. So it is in the same order size.

5 Discussion

Contamination

Direct contamination from the pipe will not occur. The sample opening will not make contact with any impurities present on the inside of the pipes because of its shape. All equipment is designed in a conical shape.

Materials are replaced after sampling. Each sample requires a cleaned weight and new silicon hoses.

Representativeness

Does the sample represent the whole bunker tank or the location from which it was drawn? The following aspects are relevant:

- .1 Current and previous batches;
- .2 Clingage;
- .3 Tank cleaning; and
- .4 Stratification.

It is important that the sample represents the **current batch**, and not a previous batch. In most cases, a fuel tank is completely "emptied" before bunkering new fuel. The chief engineer is not keen on mixing batches, in case of unexpected damage and/or disagreement about the quality of the product.

Some container feeders do not completely empty their tank, they normally bunker with the same supplier. In practice, the sulphur content of the same supplier will not differ much, therefore it is not likely that a previous batch would have much influence on the fuel quality.

It is not likely that fuel of the previous batch stays in the sounding pipe. The bottom of the sounding pipe is often perforated, so the fuel inside the pipe is the same as the fuel inside the tank.

Clingage is oil remaining on pipe walls or on the internal surfaces of tanks after the bulk of the oil has been removed. Resolution MEPC.18(22) *Adoption of the Standards for Procedures and Arrangements for the Discharge of Noxious Liquid Substances* (adopted on 5 December 1985) makes it possible to calculate the clingage residues using the following formula:

Q_{RES} (surf) = 1.1×10^{-4} Ad + 1.5×10^{-5} Aw + 4.5×10^{-4} $L^{1/2}$ Ab

- .1 Ab = Area of tank bottom and horizontal components of tank structural members facing upwards (m^2)
- .2 Ad = Area underdecks and horizontal components of tank structural members facing downwards (m^2)
- .3 Aw = Surface area of tank walls and vertical components of tank structural members (m^2)
- .4 L = Length of tank (m)
- .5 Q_{RES} (surf) = amount of clingage residue on tank surfaces (m^3)

An average bunker tank is 750 m^3, (height 10 m, length 15 m and width 5 meters). The amount of clingage is 0.019% of the bunker tank volume (0.144963 of 750 m^3) and therefore negligible. Note that the structural members are not included in these calculations. They can double or triple the surface area, but the total amount will still be negligible. Also note that this clingage formula is valid for fluids with low viscosity, like MDO and MGO. It will be a few times higher for HFO, but still be of little influence.

Tank cleaning might influence the bunker sulphur content. A few ships still had to carry out tank cleaning. Some had had a cleaning carried out. A smaller part emptied the tanks and refilled them with low sulphur fuel.

There has been a lot of discussion about possible **stratification**. In land tanks, stratification is a common occurrence, especially with crude oil. It sometimes occurs, that the sulphur content is higher in the heavier layers of the tank. But there are big differences between land tanks and bunker tanks. Land tanks are larger than bunker tanks. Note that the maximum fuel height in bunker tanks in our inspections is only 4.9 meters. The storage time of fuel oil in land tanks is much longer than in bunker tanks. Our inspectors do not expect stratification in bunker tanks, and also, the results do not indicate any signs of stratification.

Sample depth

We found no significant differences in sulfur content in the samples taken at different heights in the tanks. This indicates that a sample can be taken into the tank at any height and can be considered sufficiently representative.

To avoid discussions about possible stratification and insufficient representativeness, sampling at two heights is recommended, in case of a possible non-compliant fuel oil. With two samples and in duplo analysis, we have a strong case for further investigation.

Safety

Safety aspects are crucial for both inspectors and crew. The sampling can be carried out safely with due observance of the standard safety regulations that apply during inspections on board ships. The samples are taken from the sounding pipe. This pipe is part of the safe zone of the ship. No extra risk analysis is needed.

The equipment is suitable for all kind of ships, including tankers. All parts are made of antistatic, spark-proof material. The pump is manually operated to avoid sparks.

It is important to pay attention to cleanliness during sampling. One must also be aware of fuel oil with high temperatures, this takes proper preparation. It is advisable to have this type of sampling only carried out by skilled samplers who know how to work cleanly.

Conclusion

It is possible to sample bunker tanks, using the sounding pipe. Not only technically, but also regarding acceptance by the ship's crew. Sampling from the fuel oil transfer system is less suitable in our view, because of the risk of mixing different batches and discussions between inspectors and crew about the representativeness of the sample. We prefer to sample directly from the bunker tank.

The method is safe, feasible and affordable:

.1 The sampling can be carried out safely, because of the spark free equipment and experience of the inspectors.

.2 All bunker tanks were accessible. The vacuum method works for tanks with a depth of 8 meters of empty pipe above the fuel. This method is preferred, because it is the easiest way. For deeper tanks, the flow through method is more suitable.

.3 Contamination is limited because of the conic shape of the equipment. The representativeness of the sample for the bunker tank is high. It is likely that the sample represents the current batch, also because most pipes are perforated. Clingage is negligible. We found no indications for stratification.

.4 In 22 cases, the differences between sulphur content and BDN were smaller than the measure uncertainty. In 4 out of 26 cases, the sulphur content was significantly higher than the bunker delivery note. A possible explanation might be the lack of tank cleaning. In case of doubt about the correctness of the BDN, any ships analysis of the fuel can be helpful.

.5 A full set of measuring equipment costs about €3000. This set is reusable for many years.

On 10 December, the international web conference "Sulphur enforcement IMO 2020" was held. The Inspectorate demonstrated onboard sampling to other countries. The outcome is included in the EMSA Sulphur Inspection Guidance.

From June to December 2020, the ILT inspected another 20 ships (bunker tank sampling). All bunker tanks contained compliant fuel.

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