MAN Energy Solutions

US California WIF project

NOx Reduction Program US-California
MAN B&W Engine Type S90

Contents

Intro

In this document the test plan for emission measurement is laid out for the demonstrator project for voluntary NOx reduction on frequent calling OGV at the US California west-coast ports, mainly the port of Los Angeles and the port of Long Beach.

The demonstrator project is performed in close cooperation with vessel owner / vessel operator MSC, who have expressed their commitment to participate in the program with the 8800 TEU Container vessel MSC Anzu. The demonstrator project will enable the NOx reduction on coastal operation in an operation range of about 140 to 200 nautical miles from/to the ports. As a result of the demonstrator project an incentive scheme will be made available by the authorities for owners to benefit if they take actions to reduce NOx emissions while conducting inbound/ outbound operation to US California ports.

AQMD (South Coast Air Quality Management District), USA, California, hereafter called “AQMD”
MAN ES 2-stroke engine R&D and PrimeServ, DK Copenhagen (DK), hereafter called “MAN”
Vessel owner MSC, Cyprus (CY), hereafter called ”MSC”
Ports of Los Angeles and Long Beach, hereafter called “Ports of LA and LB”
ENH Engineering (Supplier for the WIF System), hereafter called “ENH”
Water in Fuel, hereafter called “WIF”
Marine Emission Technology (Responsible for PM measurement), hereafter called “ME-Tech”

Project description

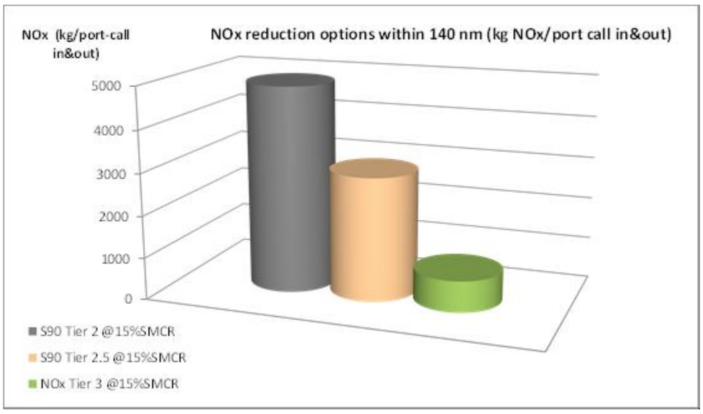
The demonstrator project has been performed in close cooperation with vessel owner / vessel operator MSC, whom provided the demonstration vessel MSC Anzu; a 8800 TEU Container vessel. The demonstrator project will support the NOx reduction on coastal operation in an operation range of about 140 to 200 nautical miles from/to the ports.

The expected emission reduction was evaluated in an internal report shared with MSC and AQMD in 2018 [1] and is the basis of below section.

The vessel is supposed to operate along the coastal approach in the VSR (vessel speed reduction) zone for total approximately 25 hours / per port call (inbound and outbound).

The vessel profile analysis based on data provided by MSC indicates a low-load engine operation during that approach with an engine load of approx.13 to 17% SMCR. The WIF system operation shall therefore be optimized in the range between 10% and 25% SMCR. The maximal WIF capacity will be however laid out for max. 50% SMCR of the main engine, as stated in 5 above.

In the figure below a typical S90ME Tier 2 engine NOx emission per port call/duration is illustrated and compared with the WIF retrofitted version (Unofficially named Tier 2.5) and Tier 3 level emission reduction technologies:



There are (at this point of time) about 46 container vessels identified that are frequently calling both the ports of LA and LB and equipped with S90 engine type similar to MSC Anzu. Subject to the incentive program launched after the demonstrator project, we forecast some retrofit potential for those identified vessels, potentially participating in the US California incentive program. At first wave, the S90 engine is the only one applicable.

Test Fuels

The vessel operation in US waters requires MDO fuel with max. 0.1% Sulphur content due to the existing ECA zone regulations. Therefore the WIF demonstration is also based on 0.1% Sulphur fuel. During emission measurement, fuel samples are taken for the different load points, drawn from the final filter drain of the engine, upstream of injector rail for analysis.

Test vessel / Engine

The tests have been performed on board an 8800 TEU vessel named MSC Anzu. The ship is 980 feet long and 157 feet wide.

The ship is driven by a 9cylinder engine with a bore of 900mm. The specific engine code is 9S90ME-C10.2 TII. This engine produces 47.430 kW.

Engine particulars	“Member”
Engine type	S90ME-C10.2
Number of cylinders	9
Engine serial number	AA5558
Engine manufacturer	HHI (Korea)
Date of engine build	apr-15
Cooling system	Central fresh water cooling system
Design spec (Original)	4207700-3
Design spec (WIF)	TO BE CREATED -
Rated power [kW]	47430
Power per cylinder [kW]	5270
Rated speed [rpm]	78
MEP [bar]	19,5
Compression shim thickness [mm]	37
Engine group	HYUNDAI-MAN B&W 9590ME-C-2014-09
Hull number	208806
Parent engine number	AA5553
Engine class	DNV GL
IMO number	9710426
Vessel name	MSC Anzu
Vessel type	Container Ship
Owner	China International Marine
Shipyard	Jingjiang
Flag	Panama

Installation of WIF unit

The WIF unit was installed during normal operation of MSC Anzu. The installation was carried out over 5 weeks and involved a team of 4 persons.

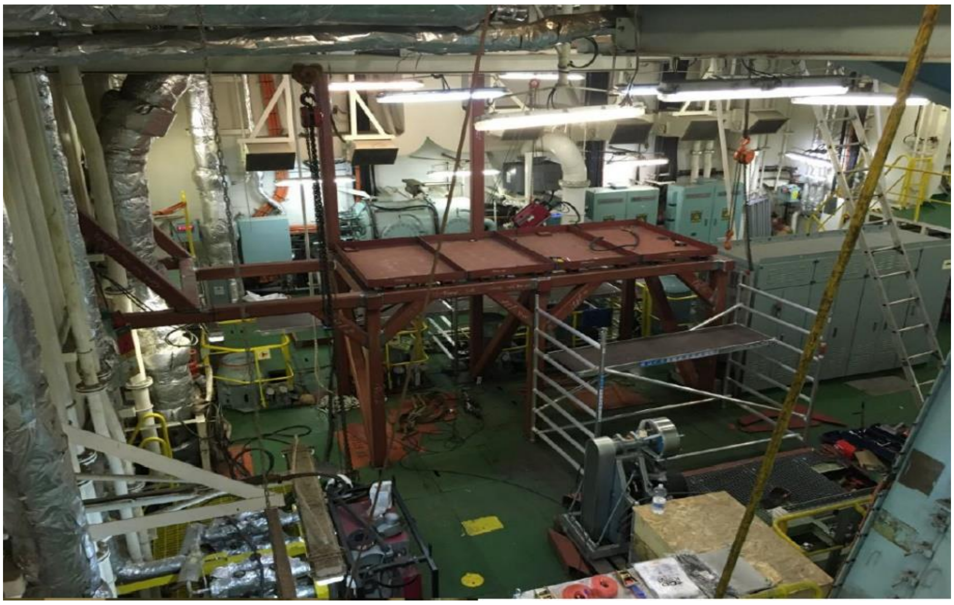


Figure 1 - WIF unit installation in progress

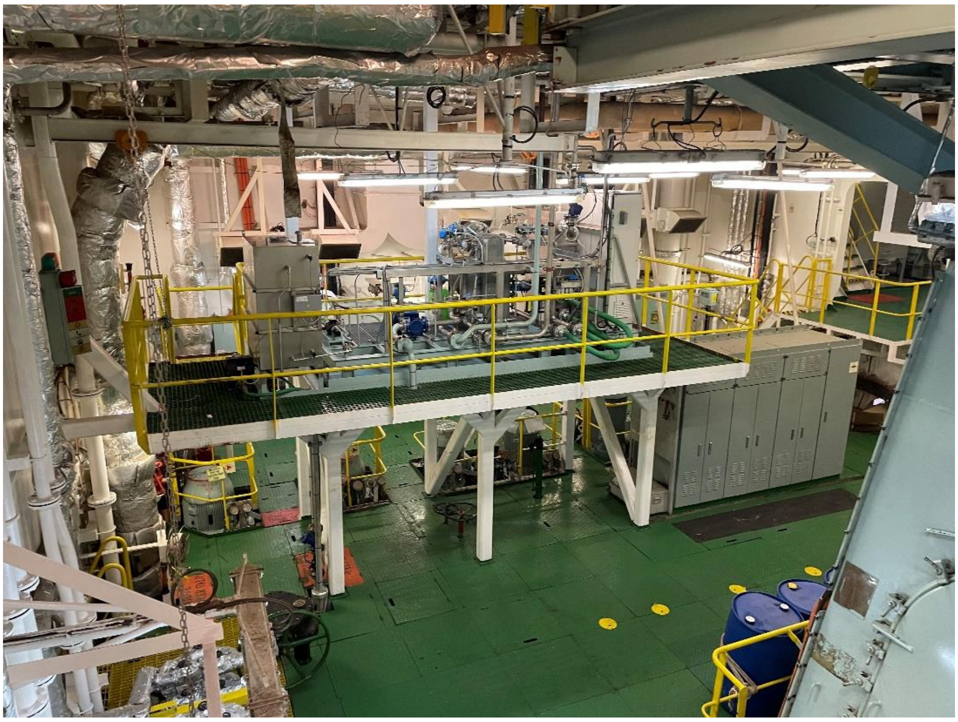


Figure 2 - WIF unit Installation completed

WIF unit

The WIF unit consists of two platforms, one mixer unit and one pump unit. The mixer unit is located in the engine room next to the MAN 2 stroke engine. The Pump unit is located in the purifier room next to the ship's fuel system.

The mixer unit is where the diesel, water & emulsifier is mixed together before it is pumped to the emulsified fuel tank on the pump unit.

The Pump unit function is to pump the emulsified fuel to the MAN 2 stroke engine.

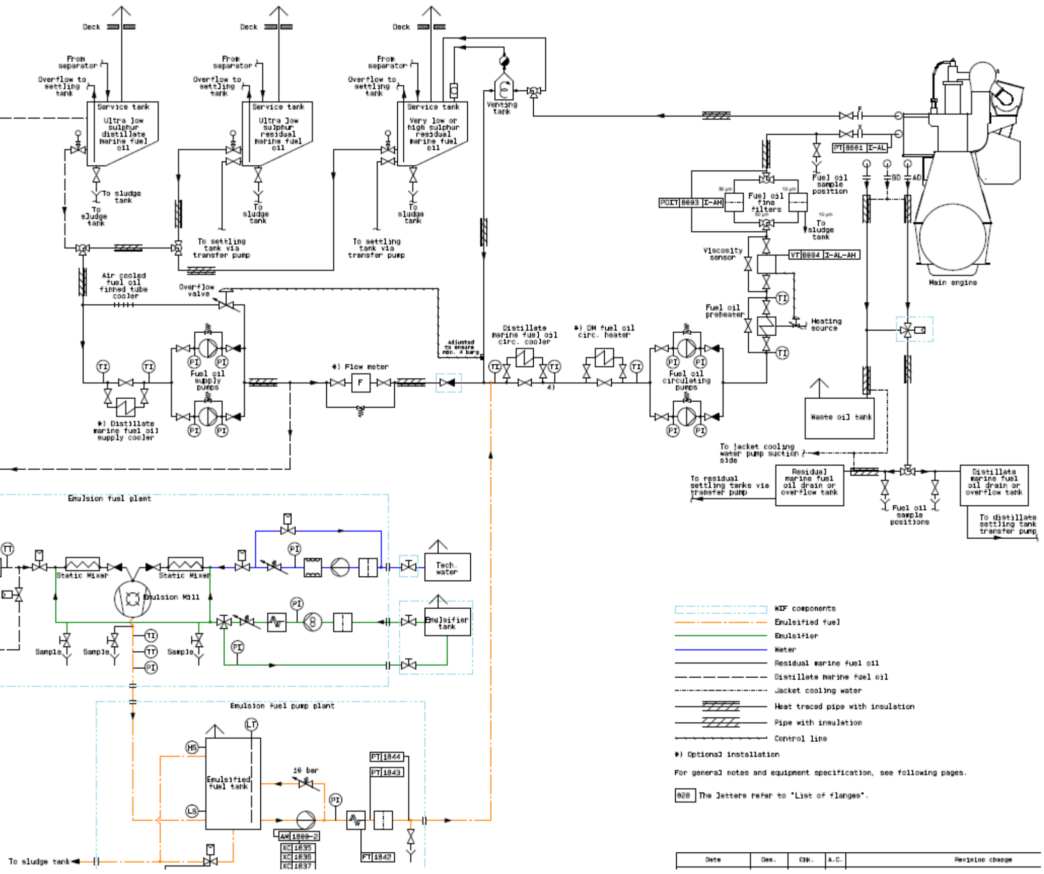


Figure 3 - PI&D diagram of ship fuel system with WIF unit

WIF Fuel Mixture

The WIF fuel mixture consists of 41% water and 0,5% emulsifier combined with diesel. In figure 4, correct mixtures of diesel, water & emulsifier are shown.

Figure 4 – Correct mixture of fuel and water

We have tested different mixture levels with different diesel, water & emulsifier ratios to ensure the WIF fuel mixture does not separate.

Figure 5 show what happens if the emulsifier is not able to hold the mixture stable before it reaches the engine. The outcome is three separated liquids with water at the bottom, emulsion in the middle and diesel on the top. The two glasses farthest to the right illustrate good, stable emulsion mixtures.

Figure 5 – Unstable emulsions vs stable

Sea Trials

During the demonstrator project there have been 3 sea trials all of which have been done in European waters.

First Sea Trial

The first sea trial was done during voyage from London (UK) to Hamburg (Germany) and further on to Rotterdam (Netherlands) in the period of March 29th to April 6th, 2022. During this sea trial, commissioning & performance test was done on diesel with the WIF unit from London to Hamburg. From Hamburg to Rotterdam it was planned to run in WIF mode, but due to an planning error the test had to aborted.

During the Sea Trial MAN was represented with 4 Engineers and ENH was represented with 2 technicians on board MSC Anzu.

Figure 6 – First sea trial

Second Sea Trial

The second sea trial was done from Antwerp (Belgium) to London (UK) and further on to Sines (Portugal). During this sea trial in the period of June 11th to June 18th, 2022 commissioning and initial test were done in WIF mode.

During the Sea Trial, MAN was represented with 2 Engineers, ENH was represented with 1 technician & ME-TECH was represented with 1 Engineer on board MSC Anzu.

Figure 7 – Second sea trial

Third Sea Trial

The third sea trial was done from Antwerp (Belgium) to Sines (Portugal) in the period of August 20th to August 25th, 2022. During the sea trial initial test and final test were completed.

During the Sea Trial MAN was represented with 4 Engineers, ENH was represented with 1 technician & ME-TECH was represented with 1 Engineer on board MSC Anzu.

Figure 8 – Third sea trial

Test results

MAN made engine performance and emissions measurements during the sea trials. All of these specific measurements are described in the CARB test plan. Please see appendix A.

During the third sea trial we were able to run at 5% load with the WIF unit and perform start and stop sequence. This is important when performing manoeuvres in ports.

The emission measurements were conducted during the sea trials to measure NOx, CO_2, PM, as well as the specific fuel oil consumption (SFOC).

Oxides of Nitrogen (NOx) results

The NOx results illustrate (figures 9 and 10) an average reduction of approx.15%. At 10% load we can see the biggest reduction of NOx of up to 20,9% - see figure 2. This illustrates that the WIF system is able to reduce NOx in the entire 10 – 50 % engine load range.

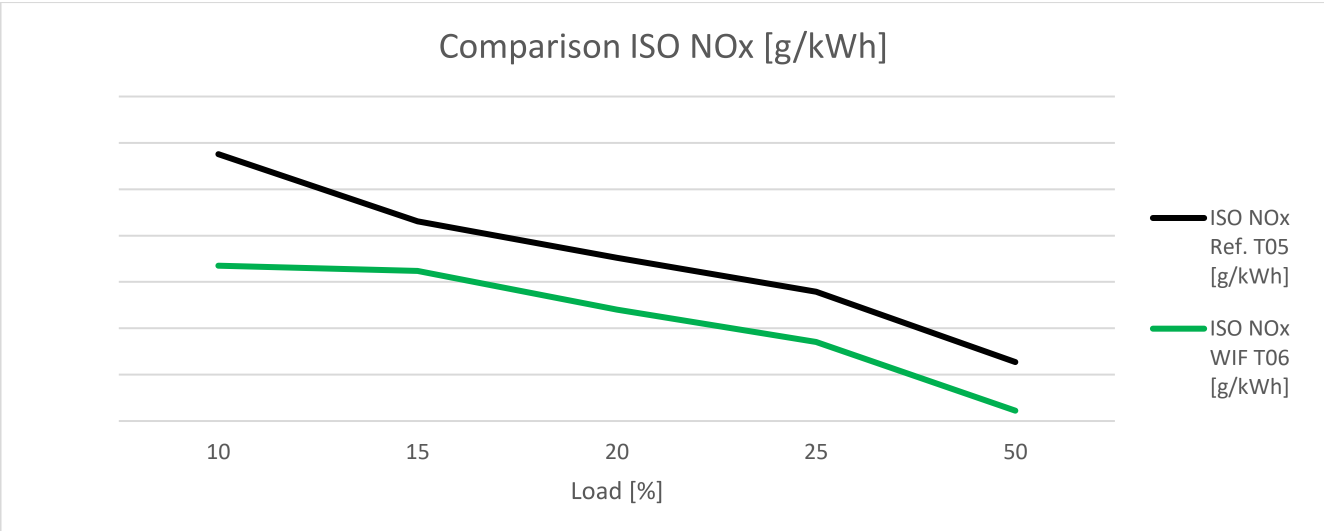


Figure 9 – NOx emission in the different loads

Load [%]	Deviation [%]
10	-22,4
15	-11,4
20	-13,1
25	-13,9
50	-16,7

Figure 10 – NOx reduction

*ISO: International Organization for Standardization

Carbon Dioxide (CO_2) Results

The WIF CO_2 level remained close to the reference level during our test, except at 10% engine load, where there is a slight reduction in CO_2 in the WIF test which is believed to be due to measuring uncertainty. Overall CO_2 level in the WIF tests was found close to the reference tests and we therefore believe that WIF has no significant impact on CO_2 emissions.

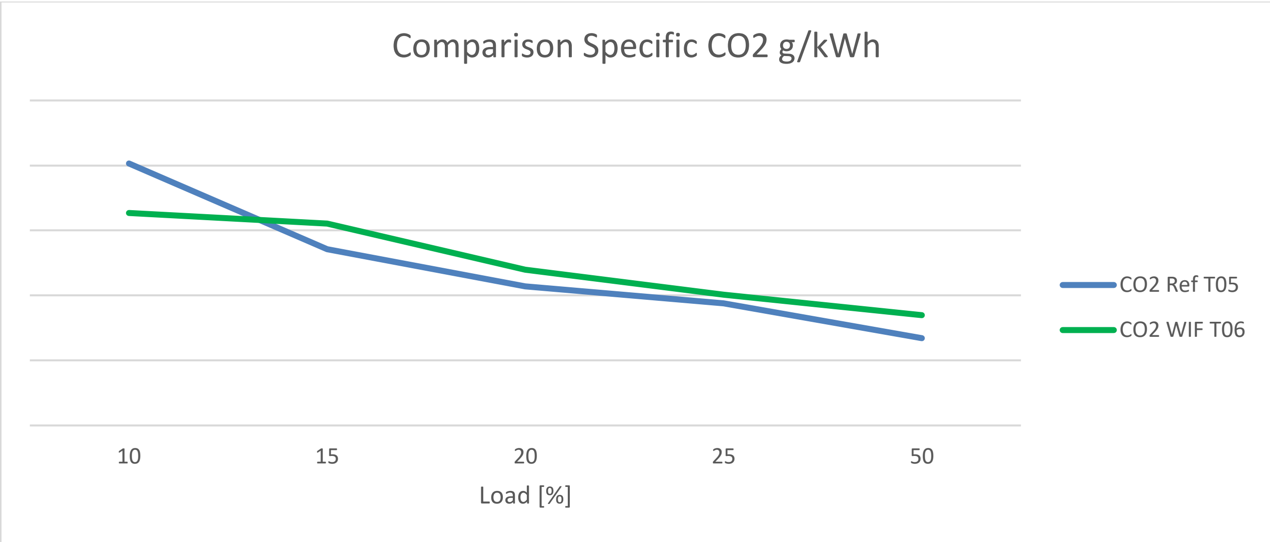


Figure 11 – Comparison of CO_2 for Ref. (T05) and WIF (T06) test series

Load [%]	Deviation [%]
10	-5,4
15	3,1
20	2,1
25	1,1
50	3,1

Figure 12 – ISO Corrected CO_2

Specific Fuel Oil Consumption (SFOC) results

The SFOC results in figures 13 and 14 show a fuel saving at 10% load when we have ISO correct our data. This data has been compared to what the flowmeters have recorded during our test in figure 15. Here we see little deviation in the fuel consumption. Our general conclusion of this data is that no particular fuel savings should be expected when using the WIF unit. This is in alignment with the previously show CO2 results.

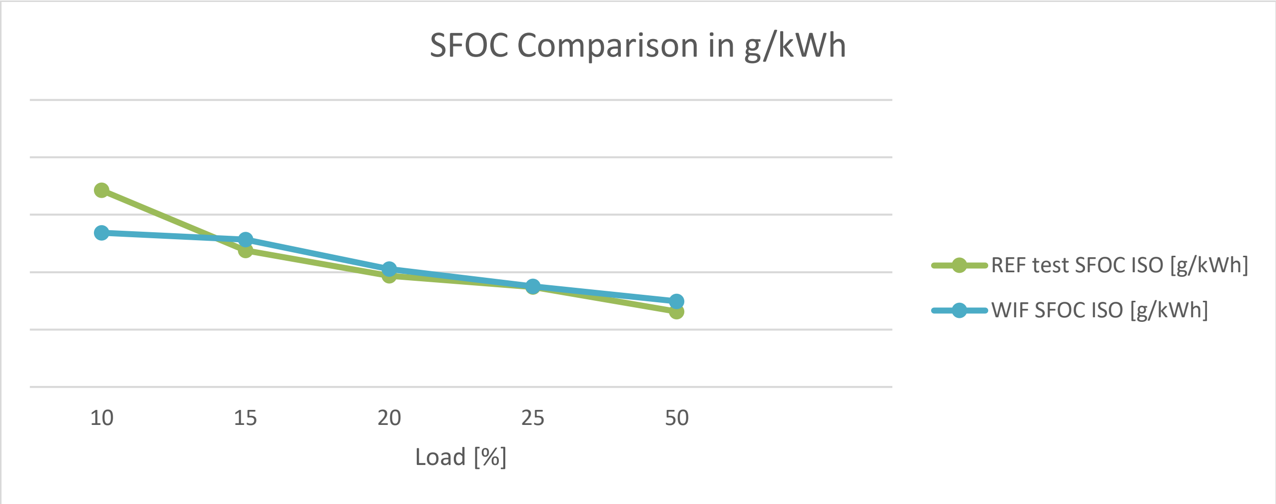


Figure 13 – Comparison of SFOC [g/kWh]

Load [%]	Deviation [%]
10	-6,8
15	1,9
20	1,2
25	0,1
50	2,0

Figure 14 – Comparison of SFOC [g/kWh]

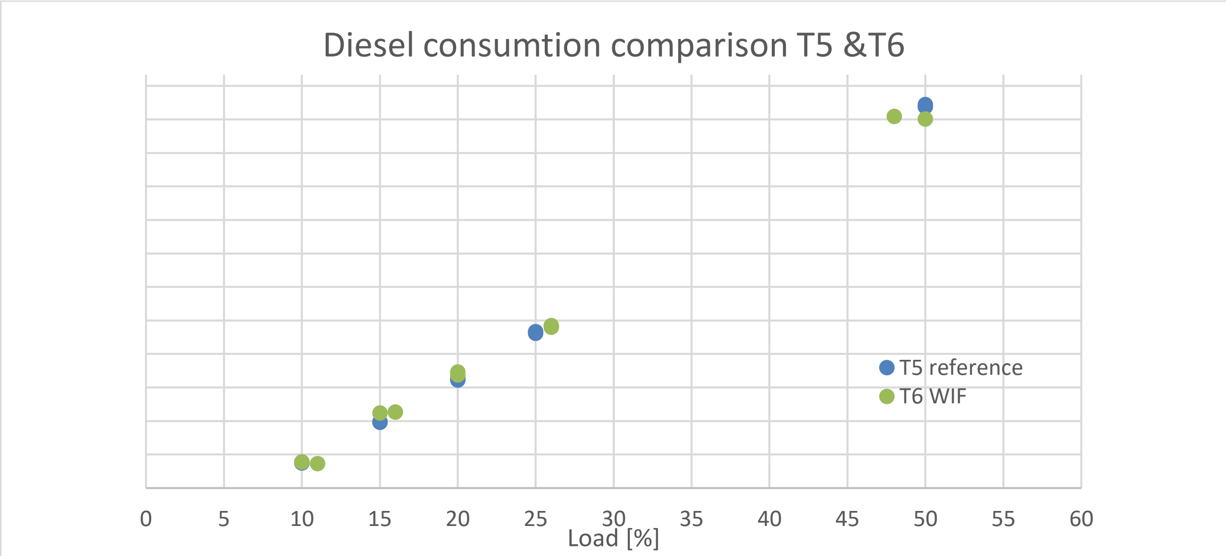


Figure 15 – Comparison of SFOC [kg/h]

Particular Matter (PM) Results

We can see that the PM level increases in figure 16 when the WIF system is active except for the 10% load. For more information about this topic please see appendix B.

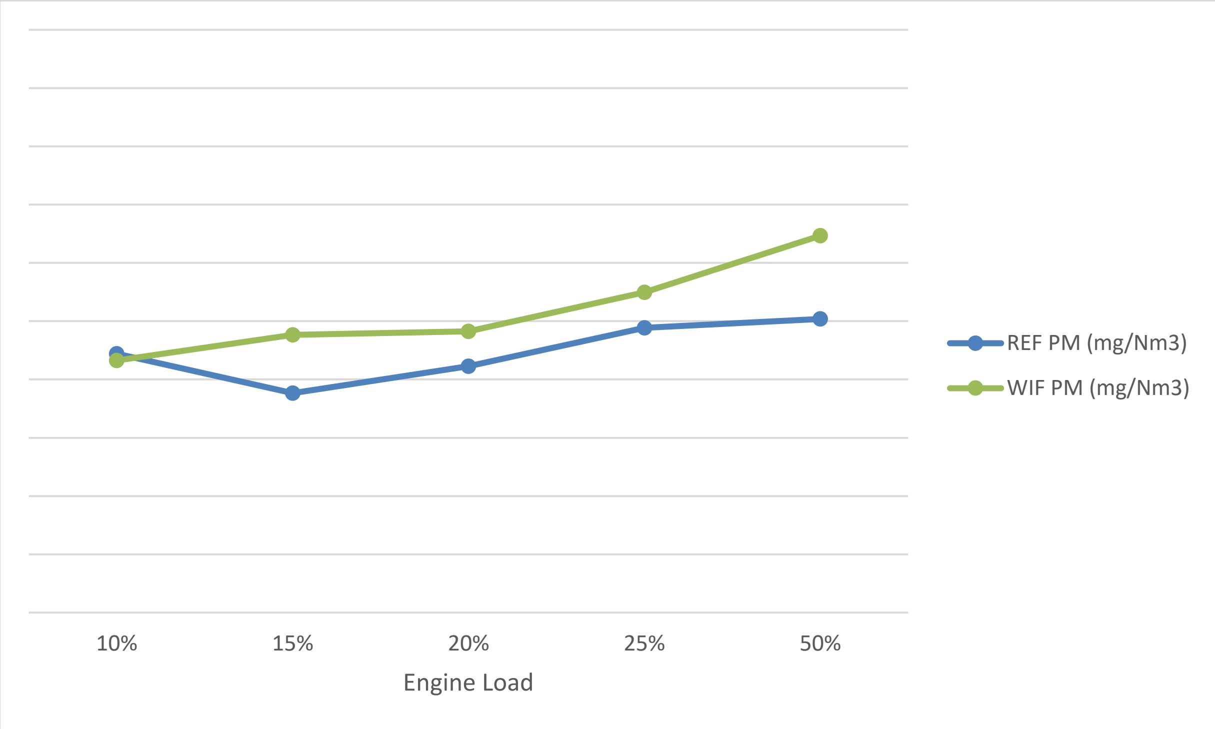


Figure 16 – Comparison of PM

Load	% Dev.
10%	- 3%
15%	+ 27%
20%	+ 14%
25%	+ 13%
50%	+ 28%

Figure 17 – Comparison of PM

Test with emulsifier content in WIF fuel

In order to figure out what has caused the raise of the PM we decided to make a test where we would increase the amount of Emulsifier added to the fuel. The test was performed at the same engine load and the same water–fuel ratio. As the results shown below an increase in emulsifier into the fuel have a slight impact on the level of PM. Based on this result, it is important that we ensure the lowest level of emulsifier to keep the PM level at a minimum and at the same time lower the operation cost for the owner.

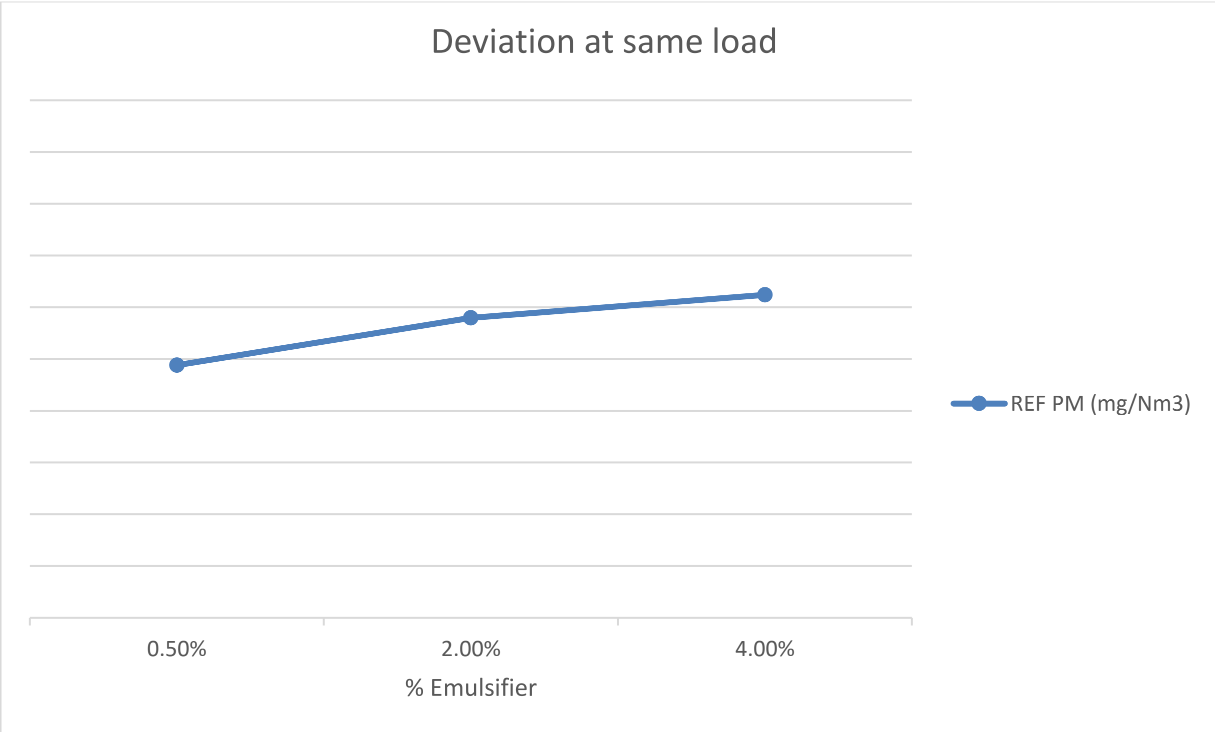


Figure 18 – Different percentage of emulsifier for the same load.

Conclusion

Emission and Performance measurements have been conducted as basis for the establishment of Water In Fuel (WIF) retrofit for S90ME-C10.2. The final measurements have been performed by MAN ES, ME-Tech and the ship's crew onboard MSC Anzu from the August 20th to August 25th 2022.

The emission measurements indicate a stable engine both for the reference test and the WIF test. The test reveals that the NOx emission is reduced when engine running on WIF mode in each load, especially in the lower load points. (See Figure 10 above.)

The WIF is most beneficial at very low load, especially at 10% engine load, where the highest amount of NOx reduction is achieved.

If MSC Anzu were approaching Port of Long Beach or Port of Los Angeles and used below red route inbound and outbound to Los Angeles, which is approximately 290nm, the NOx reduction would be estimated to be 700 kg / 1543 lb. per port call based on test results and using an average vessel speed and engine load of 10knts and 10% MCR, respectively.

Generally speaking, NOx emission reduction for ships in service is not a priority for ship owners as it is a costly endeavour and not mandated. An incentive or penalty program would play a crucial role in getting ship owners' attention about this topic. That would help to gain real traction for WIF(Water in Fuel) product development and go-to-market planning; consequently installing the system on more ships and multiplying the success we've had in MSC Anzu. Total cost of the project was $ 3 million which was within the original budget.

Covid-19 pandemic had a big impact on shipping lines and containership schedules. This made it challenging to plan the vessel attendances which was also the main reason for extending the contract and change the emission testing to Europe due to the travel restriction. In the end, all the attendances were successfully performed, and the project successfully concluded.

Next Step for the Technology:

The estimated price for a WIF system installed on board a large container vessel is approximately $650,000, including components, installation, and commissioning. The operational expenses, including emulsifier, fuel consumption, and maintenance, are $1,200 USD per round trip within 140-200 NM from the ports. There is potential fuel saving when the vessel is operated at or below 10% load however, additional testing is needed to qualify this savings, and it is unclear if the return on investment from any fuel savings will be significant enough to make the system attractive based on commercial interests alone. It is hoped that through the collaboration between European, Asian, and US ports, a program could be established to provide incentives to install the WIF system and offset a portion of operational and installation costs, making the system more attractive to vessel operators.