

CONTEXT DESCRIPTION

The **Brittany Ferries** company wished to assess the Xbee biotechnology.

The *Mont St-Michel* ferry was selected to be the company's laboratory ship, with several goals:

- ✓ Demonstrate a reduction of the gases emissions; and
- ✓ Demonstrate the capacity of this biotechnology to clean up the engines.

Description of the work conducted on the *Mont St Michel* ferry

1) The *Mont St-Michel* ferry connects Ouistreham (France) to Portsmouth (United Kingdom), at a rate of twenty rotations per week.



2) The experiment was processed from October 2006 to December 2007.

3) Ship characteristics (IMO n°9238337)

- ✓ The ferry is 174 metres long, built in 2002, with a capacity of 2120 passengers
- ✓ Propulsion
 - ✕ 4 engines with a power of 5400 kW each, rotation speed 500 rpm
 - ✕ 6 turbo-charged in-line cylinders, brand: **MAK**
 - ✕ IFO 380 fuel
 - ✕ 2 shaft lines rotating at 150 rpm with variable pitch propeller
- ✓ Electricity production
 - ✕ 3 diesel oil generators of 1600 kW each
 - ✕ 9 in-line cylinders, brand: **Wärtsilä**
 - ✕ 2 coupled 1600 kW generators



[SUMMARY]

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DEMONSTRATE A REDUCTION OF THE TOXIC GASES EMISSIONS

During this campaign, a series of emissions were measured, with particular emphasis on sulphur dioxide. In the context of the SO₂ emission reduction goals determined by the IMO, it would be interesting to assess the ability of the Xbee biotechnology to exert a positive effect on these emission levels.

Method used

- ✓ The **Ascal** laboratory (www.ascal.fr), accredited by **COFRAC** and agreed the French Ministry of Ecology and Sustainable Development, was selected to perform the emission measurements.
- ✓ Measurement schedule:
 - First measurement on 8 October 2006, prior to using the Xbee biotechnology. From 13 October, during each bunkering operation, the bio-additive was added at a rate of 4,000:1 (1 liter of Xbee for 4,000 liters of fuel).
 - Second measurement on 8 November 2006, after one month of Xbee addition to the bunkers.
 - Third measurement on 13 December 2006, after two months of using Xbee fuel.
 - Fourth measurement on 29 March 2007, after almost six months of using Xbee fuel.
 - Fifth measurement to close the one-year long program, on 18 October 2007.

NB: Since the beginning of 2007, changes on the main engine number 4 and different quality of fuel alterate the results. Fourth and fifth measurements were witnessed by two engineers of the National Agency of the Marine Affaires.

Finally, one year of work with fuel additized with Xbee biotechnology are observed via five measurement campaigns, each one representing fifteen samplings of thirty minutes each.

- ✓ Measurements were made on the stack of the MaK main engine number 4, at a rate of three thirty-minute sequences, spread over a two-hour period during which the engine was maintained at a constant speed.
- ✓ From the onset of measurements, during bunkering, fifty liters of Xbee were added for two hundred tons of IFO 380, at a rate of two bunkering operations per week.
- ✓ During these campaigns, the following parameters were measured:
 - Exhaust gas temperatures;
 - Humidity (NF EN 14790);
 - Exhaust gas flow (ISO 10780);
 - Particulate concentration or weight (NF EN 13284-1 and NF X44-052);
 - VOC (Volatile Organix Compounds - NF X 43-301); and
 - The following gases:
 - ✕ SO₂ Sulphur Dioxide (NF ISO 11-632)
 - ✕ O₂ Oxygen (NF X 43-300 and FD X 20-377)
 - ✕ CO Carbon Monoxide (NF X 43-300 and NF X 43-012)
 - ✕ CO₂ Carbon Dioxide
 - ✕ CH₄ Methane
 - ✕ NO Nitrogen Oxide (NF X 43-300 and NF X 43-018)
 - ✕ NO_x Nitrogen Dioxide (NF X 43-300 and NF X 43-018)

Summary of the M/F Mont St Michel ferry measurement results

Measured parameters		IFO 380 11-oct-06	IFO 380 - Xbee - 08-nov-06	IFO 380 - Xbee - 13-déc-06	Change 3 over 1	IFO 380 - Xbee - 29-mars-07	IFO 380 - Xbee - 18-oct-07	Average 4 over 1
O2	% on dry gas	12,6	14,0	14,7	+ 16,7%	12,6	13 ,3	+ 8,33%
CO2	% on dry gas	6,1	5,6	4,7	- 22,9%	5,8	5,6	- 11,07%
CO	mg/Nm3 on dry gas	98,4	69,7	56,2	- 42,9%	66,9	57,7	- 36,36%
CH4	ppmv on wet gas	< 9	<9	<9	stable	<9	<9	stable
COV	ppmv on wet gas	76,9	71,3	45,6	-40,7%	64,9	59,3	-21,62%
SO2*	mg/Nm3 on dry gas	1222	1050	1002	-18,00%	1385	NA	-6,25%
	g/kWh	6,49	5,11	5,37	-17.26%	5,31	(2.07)**	- 18,97%
NO	ppmv on dry gas	1094	1073	826	- 24,5%	1149	1111	- 4,96%
Nox	ppmv on dry gas	1125	1120	851	- 24,3%	1174	1127	- 5,07%
Particulates	mg/Nm3 on dry gas	99,3	61,6	59,65	- 39,92%	60,2	53,0	- 40,97%
	g/kWh	0,53	0,33	0,33	-37,73%	0,30	0,27	- 42,43%
Fume temperature		306°C	300°C	267°C	-12,70%	303°C	280°C	-6,05%
Gas flow Nm3/h on dry gas		22536	21997	22521		21076	23111	
Power delivered on ME3 & 4 (kWh meter) ***		8427	8268	8140		8549	9128	
RPM		499	500	498		498	499	
Exhaust Gaz before TC		515	505	504		502	502	
Pitch		94.20%	92.40%	90.70%		90.70%	95.80%	
Torque kNm		496	493	486		511	545	
Speed RPM		154	154	154		154	154	
PMax medium - bar		151,3	150,3	150,3		156,5	156,3	

* based on a fuel containing 1.5% of sulphur max.

** those digits (2.07 g/kWh) represent the standardized measurements done by the laboratory Ascal during the three thirty-minute sequences. Complete check-up of the process and equipment has been done: nothing occurs that could have invalidate the results! The sulphur content of the fuel used at this very moment was about 1.43% and can not explain the evolution.

*** after +4% change to take the loss before meter into account.

Comments

The results bring roughly the same comments, either one consider the short period of time of the two first months of work with Xbee – during which the technical parameters were quite the equivalent – or later, considering parameters more and more different than the same on 11 October 2006.

O₂ – A considerable increase of the Oxygen, +16.7% and +8.33% respectively, demonstrate a dramatic improvement of the combustion.

CO₂ – The evolution of the CO₂ (Carbon Dioxide) exhausts is always in accordance with the evolution of the consumption. The reductions by -22.9% and -11.07% do not imply the same reductions of the fuel consumption, but is an indisputable proof of a real and eventual consumption decrease. Although it is quite difficult to measure, taking into account the several parameters. We recall that Xbee cost is around 1.5% only!

CO – The evolution of the CO (Carbon Monoxide) exhausts is always in accordance with the evolution of the consumption. Either at -42.9% or -36.36%, the combustion is clearly improved. And the reduction of the Particulates by -40% confirms the tense once again.

VOC – Reductions by -40.7% and -21.62%. The improvement of the quality of the combustion reduces dramatically the quantity of unburnt particles that are one of the main components of the VOC (Volatile Organic Compounds).

SO₂ – Consistent with the CO₂ emissions, we measured a significant drop in sulphur emissions: -18%.

Concerning sulphur emissions, theory states that total sulphur release remains identical for identical fuel consumption, the enzymes contained in this bio-additive transforming sulphur molecules to new sulphite and sulphate molecules. The reduction in SO₂ emissions is real, but it must be correlated with the increase in sulphur-containing particles in the emission signature.

The replacement of highly reactive SO₂ with a more stable compound limits environmental impact and is consistent with the goals defined in MARPOL Annex VI.

Refer to the comment ** of the table in page 4 concerning the last measurement of Sulphur. effectuée.

NO and NO_x – As for CO₂, the drop in gas flow consequently decreases by -24% and -5% the NO (Nitrogen Oxide) and NO_x (Nitrogen Dioxide), thus confirming that Xbee is capable of reducing CO₂ without altering NO_x values.

Particulates – The 40% reduction in mass collected from exhaust gases confirms the improved combustion observed via the other parameters. This dramatic reduction is certainly one of the most significative results. It is actually a necessary goal for Public Health and vessels working in urban harbors have a great interest on a short term to reduce the amount of their emissions.

DEMONSTRATE THE CAPACITY OF XBEE TO CLEAN UP THE ENGINES

Around the end of December 2007, after fourteen months of permanent work, Xbee addition is stopped and the vessel integrates the **Remontowa** shipyards on 8 January 2008 in Gdansk, Poland. This is for its first 30,000-hour maintenance period.





These observations are the visual translation of the results measured previously: dramatic increase of the Oxygen and great reduction by -42.9% and -36.36% of the Carbon Monoxide, sign of a change in the combustion. All this being confirmed one more time by another measure: the reduction by -40% of the Particulates emissions.

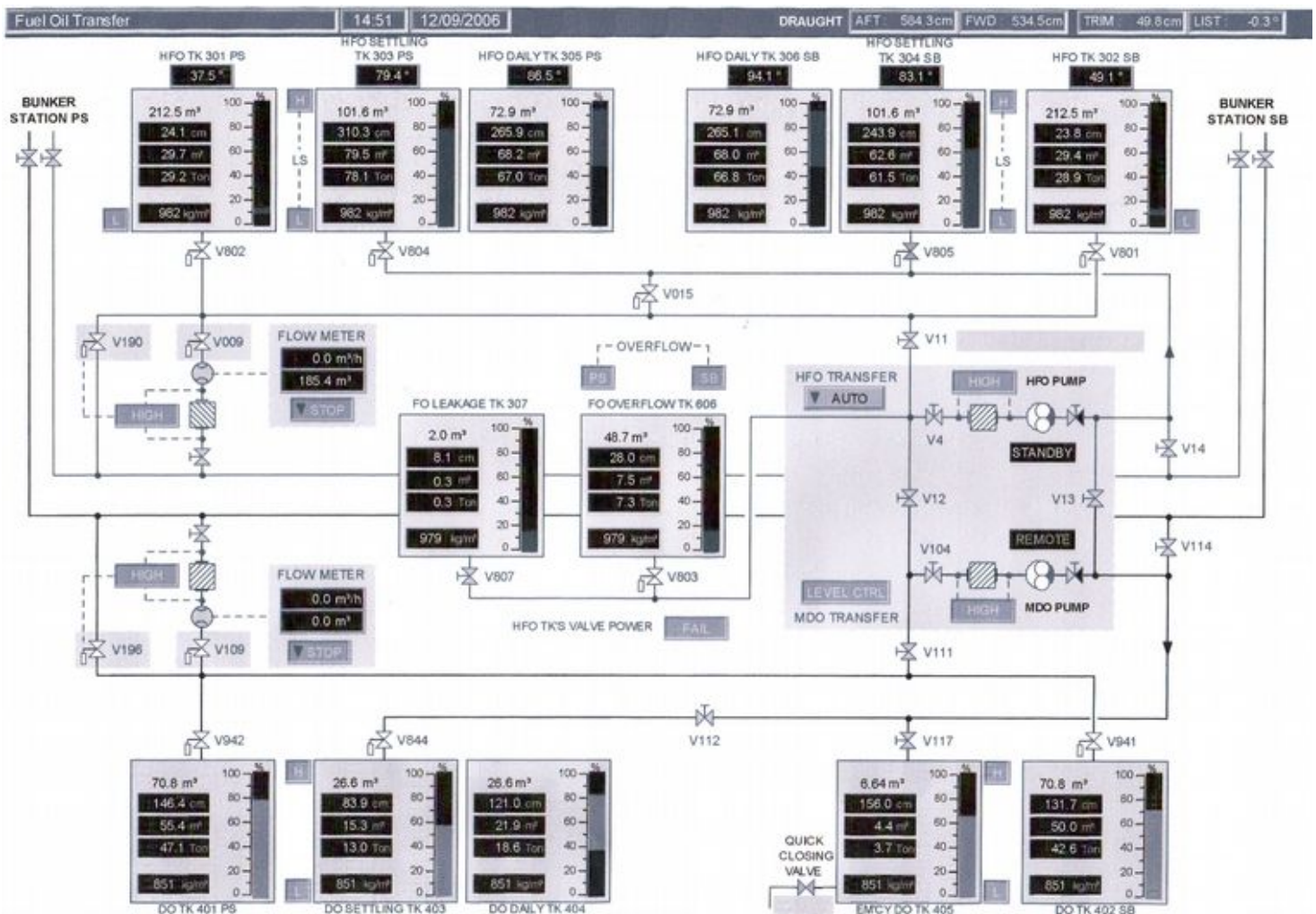
Such evolutions can only be the consequence of very clean engines. Such clean engines after 30,000 hours of work obviously reduce their toxic gases emissions and their fuel consumption.

ANNEXES

Annex 1 – Fuel circuit

Characteristics of the fuel circuit

- Two (2) 212.5 m³ bunkers
- Two (2) 101.6 m³ settling tanks
- Two (2) 72.9 m³ daily tanks



Annex 2 – Addition method illustration

The Xbee bio-additive is added to the fuel during spray bunkering.



Annex 3 – Sample collection illustrations



Continuous measurement probe and sample collection probe, placed in the ME4 flue.



Analyzers



**Sulfur sampling
and particulate
sampling filter**