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D5.2: Seaweed derived fuels from thermochemical conversion

MacroFuels – Project

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Danish Technological Institute

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Summary

This delivery report deals with engine testing of thermochemically derived furanics produced in WP3. The engine tests were conducted at the Danish Technological Institute's engine laboratory in Aarhus, Denmark.

In the tests, a 5% mixture of thermochemically derived furanics in a reference diesel is used. Reference diesel is either diesel without the addition of biodiesels which is used for engine bench testing or commonly available diesel that is used for the test car. In all the tests, the thermochemically derived furanics blends are benchmarked against measurement results obtained on 100% reference diesel.

DTI has analysed the lubricity, cetane number/cetane index, miscibility, and health and safety hazards. The corrosivity of the fuel mixture on the engine was assessed by visual inspection and no obvious corrosion was observed. The engine tests have been performed, partly on an engine mounted in a test bench and partly during driving with a real car on a chassis dynamometer and on during driving in real traffic situations.

The tests have been carried out to verify whether a modern car can be operated on a blend of diesel with furanics fuels produced by algae biomass via a thermochemical production process. The engine tests have been carried out on a compression-ignited engine and include NO_x and particulates formation. Additionally, cylinder pressure measurements have been used to reveal combustion characteristics such as ignition delay, rate of heat release and cylinder pressure oscillations related to diesel engine knocking.

With the engine in the test bench, it has been investigated whether thermochemically derived furanics affect the combustion properties. The engine has been operated in four load modes that are representative of the load that the engine will experience during real driving. Via the pressure sensors built into the engine's combustion chamber, the development of the combustion process is examined, and the associated flue gas emissions are measured.

In addition, the thermochemically derived furanics have been tested by real driving in a car, partly on the chassis dynamometer and partly in real driving situations representing city driving, rural road and highway driving. In these situations, the transient behaviour of the car is investigated, and the associated emissions are measured.

The results from the tests have been very successful. The combustion properties of the thermochemically derived furanics blends used have been trouble-free. No issues with cold or hot start of the engine and the combustion quality and transient characteristics have been fully in line with the operation on reference diesel. No significant challenges regarding the emissions are observed. We see minor variations of the emissions from the different test methods, but the emissions are regarded to be within the acceptable limits form a modern car engine.

Contents

1 INTRODUCTION

During this MacroFuels project three different fuels, i.e. ethanol, ABE and furanic fuels are produced. This report covers description of work including test procedures and results carried out by the Danish Technological Institute during engine testing of thermochemically derived furanics based fuel (FBF). Engine testing of ethanol and ABE is covered in a separate delivery report: D5.1.

This deliverable compares the seaweed derived fuel blends with commercial grade fuels as available for the consumer. The fuels were analysed for among others lubricity, cetane number/cetane index, miscibility, and health and safety hazards (Section 2), as well as initial corrosivity on the engine during operation.

FBF are considered to have a great potential to be used as an additive reducing the CO_2 emission from fossil diesel. Modern cars are designed to run on pure fossil diesel or diesel mixed with a lower percentage, normally 5 to 10% biodiesels. In the engine and car tests carried out in this project diesel are mixed with 5 weight% FBF and the fuel is tested in an engine dynamometer and in a real car tested on a chassis dynamometer and during real driving testing on different road types in real traffic.

The engine testing in the laboratory and on the road is done with the engine/car in standard configuration i.e. no modifications are done to engine ECU settings or emission system. The tests are carried out to identify any problems using FBF compared to a reference diesel fuel. The goal is to identity whether the produced FBF can be a future blending component in conventional fossil diesel and thereby reduce the fossil share of the huge fuel amounts used in our transport sector.

The tests include investigation on combustion quality as well as emission measurement during all load and driving situations. Precision instrumentation for transient emissions measurements (FTIR) have been used to examine the exhaust gas composition for both regulated and non-regulated emissions, including aldehydes, methane, ethanol and various other hydrocarbons.

2 MATERIAL AND METHODS

2.1 Fuels

One type of FBF fuels was delivered to DTI engine testing facility in Aarhus, Denmark.

Table 1: Fuels received for testing

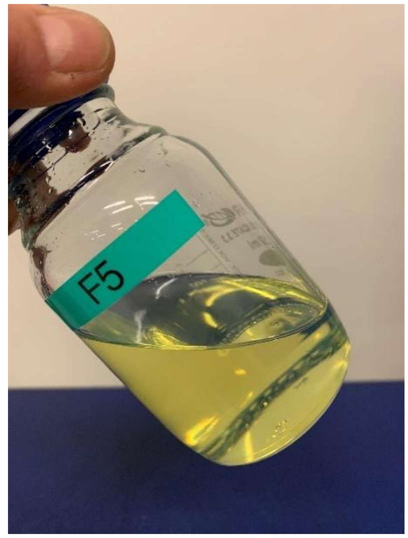
Fuel	Supplier [name]	Production process [Type]	Amount [Litre]	Water content [vol.%]
Thermochemically derived furanics based fuel (FBF).	DTI	Thermochemical	≈ 8	0
Reference diesel	OK Denmark	Standard diesel production	≈ 200	0

Commercially available diesel in Denmark contains 7% biodiesel. In relation to the engine testing carried out on the engine test bench we have chosen to use a reference diesel without the addition of biodiesel but including the ordinary additive package as found in the commercial grade diesel. The tests carried out in a real car on the chassis dynamometer and during real drive measurements we have used commercially available diesel that includes the biodiesel fraction. The reference diesels are supplied by the Danish oil company OK.

In all test situations we have used a mixture of 5 weight% FBF into 95weight% diesel. In the following we have used the abbreviation "F5" which covers the fuel mixture of FBF and diesel. A fuel mixture containing the 5% furanics additive is appropriate and it gives clear and measurable results about engine operation, combustion process and flue gas emissions.

2.1.1 Miscibility

Figure 1: Furanics as delivered and in the final fuel blend



The furanics fuel was received as a clear homogeneous liquid without any phase shifting. To test if the miscibility limits have been exceeded in the 5% mixture used, furanics and diesel mixing tests have been performed.

No miscibility issues were found. As shown on the right-hand picture, the F5 was fully and successfully mixed with diesel into a homogeneous fluid without any phase shifting.

2.1.2 Fuel analysis

Fuel analysis has been made by an external laboratory. Results are shown in the table below and copies of the analysis certificates are included in appendix to this report.

Table 2: Fuel analysis

Analysis	Unit	Ref. Diesel	F5	Remarks
Lubricity	µm	320	420	ISO 12156
Cetane number	-	53,8	50,8	EN15195
Cetane index	-	50,7	49,4	ENISO4264
Density @ 15°C	kg/m³	840,3	839,8	ISO 12185
Ignition Delay	ms	2,81	2,96	EN15195

The lubricity is slightly reduced in the F5 compared to the reference diesel. ISO 12156 has specified a lubricity of 460 µm as a maximum. F5 are fully within this limit.

The cetane number and cetane index is slightly reduced in F5 compared to the reference diesel. A modern high-speed diesel engine as found in our cars operate well with a cetane number from 48 to 50. Fuels with lower cetane number have longer ignition delays, requiring more time for the fuel combustion process to be completed. Hence, higher speed diesel engines operate more effectively with higher cetane number fuels. In Europe, diesel cetane numbers were set at a minimum of 40 in year 2000. The F5 are fully within the fuel standard figures.

The density and ignition delay are at the same level for the two fuels. The differences are minimal and of no importance for engine operation.

2.1.3 Health & Safety Hazards considerations of furanic fuel

The final furanic fuel mixture synthesised for engine tests had an approx. composition of 5-15% 2-furaldehyde dibutylacetal (CAS No. 1829-09-0), 5-10% 2-furaldehyde (CAS No. 98-01-01) and 70-90% 1-butanol (CAS No. 71-36-3). According to regulation EC No. 1907/2006 REACH and No. 1272/2008 CLP, this mixture is classified as a flammable liquid under category 3, to a corresponding estimated flash point between 23 and 60 °C. As a reference, gasoline 95 E10 is classified as a flammable liquid 1. Health hazards include:

- Acute oral toxicity (category 4, H302)
- Acute inhalation toxicity (category 2, H330)
- Skin corrosion/irritation (category 2, H315)
- Serious eye damage and irritation (category 1, H318)
- Carcinogenicity (category 2, H351)
- Organ toxicity (category 3 respiratory tract irritation and narcosis, H335, H336)

The classifications above are consistent to that of gasoline 95 E10, for which the same or more severe danger classifications are assigned in each category. Gasoline 95 E10 has a flashpoint <0° C, therefore no additional fire hazard is expected for the furanic fuel blend in butanol.

In terms of ecological toxicity, the components in the furanic fuel mixture are not currently classified as harmful to aquatic organisms nor to cause long-term adverse effects in the environment, unlike typical gasoline. However, direct studies on the possible effects of the actual or future fuel mixtures on the environment are needed to further confirm this. In general, the same health & safety hazards considerations for gasoline 95/98 E5 and E10 apply can apply for blends of gasoline 95/98 with up to 10% of the furanic fuel mixture. Nevertheless, complete safety assessment and REACH registration is lacking for 2-furaldehyde dibutylacetal.

In should be noted that considerations and classifications may change upon the change in the formulation of the furanic fuel blend when further compositional changes are implemented in the furanic fraction of the mixture, e.g. when including other furanic components such as methyl tetrahydrofuran, butyl tetrahydrofurfuryl ether or highly toxic 2-methyl furan.

2.2 Test Setup and Test Procedures

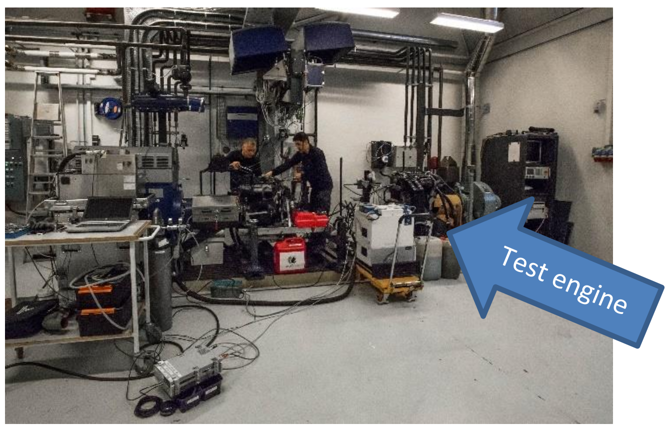
Combustion analysis and emission measurements under static and dynamic load situations has been carried out with the F5 fuel compared to the reference diesel. The F5 fuel were tested in a test engine and in a car on a chassis dynamometer and during real driving situations.

2.2.1 Engine Dynamometer Testing

The test engine used in this test, is a four-cylinder 1,6 litre diesel engine. The engine was set up in a Horiba Schenck eddy current dynamometer test bench. The engine has a common rail fuel system and an EGR system, both controlled by the engine's control unit (ECU).

During testing cylinder pressure and rate of heat release was continuously logged together with the corresponding engine load. Throughout the test, both regulated and unregulated emissions were measured.

Figure 2: The test engine located in the test bench at DTI.



2.2.2 Emission measurement equipment

Two types of emission measurement equipment were used during the tests.

Table 3: Equipment used for emission measurement.

Equipment	Make	Gas components	Equipment used for:
FTIR	Antaris IGS	Water, CO, CO_2, CH_4 (methane), NO (Nitric oxide), NO_2 (Nitrogen oxide), N_2O (Nitrous oxide), NH_3(Ammonia), SO_2 Sulphur dioxide, CH_2O (Formaldehyde), C_2H_6 (ethane), C_2H_4 (Ethene) C_2H_2 (Acetylene), C_3H_8 (Propane), C_3H_6 (Propene), C_2H_5O (Aldehyde)	- Dynamometer testing
PEMS*	AVL M.O.V.E	CO, CO_2, NO, NO_2, O_2	- Dynamometer testing - Chassis dynamometer

			- RDE* road testing

*PEMS is a commonly used abbreviation for “Portable Emission Measurement System”.

2.2.3 Test Engine

The test engine used, is a four-cylinder 1,6 litre diesel engine form Peugeot. It is a widely used engine found in many of the cars form the PSA Group and the engine is representative for the engines used in our cars today.

Table 4: Test engine key figures.

Manufacture	Peugeot
Displacement	1560 ccm^3
Engine type	DV6
Fuel	Diesel
Power	66 kW@4300 rpm.
Torque	215 Nm @ 1750 rpm.
Euro class	EURO 4

The test engine was kept in standard configuration and no modifications was made to the engine control unit or to the DPF aftertreatment system (Diesel Particulate Filter)

The only modification made to the engine was mounting of a pressure sensor in the combustion chamber of the no.1 cylinder.

2.2.4 Load Points

An important element of the engine tests is to determine operating points that are representative of a car's daily usage pattern. To determine the operating points, we analysed the operational data from the RDE tests and converted this data into a measurement plan that represents idle, city road driving, urban road driving and motorway driving.

Table 5: Four-mode test schedule for the test engine.

Test schedule for the Peugeot test engine					
Mode [No.]	**Torque [Nm]**	**RPM [min.$^{-1}$]**	**Power [kW]**	**Load [%]**	**Torque [%]**
1 (Idle)	0	800	0	0	0
2 (City)	30	1500	4,7	7	19
3 (Urban)	60	2000	12,6	20	38
4 (Motorway)	100	3000	31,4	50	63

2.2.5 RDE/PEMS Testing

The car used for the tests is a Mercedes Vito. We had this car available at our Institute. A test car from any other car producer could have been chosen, but it has been important for us to choose a car type that is widely used and representative for the cars driving on the European roads today.

The car was kept in standard configuration – no modifications made to engine or aftertreatment system.

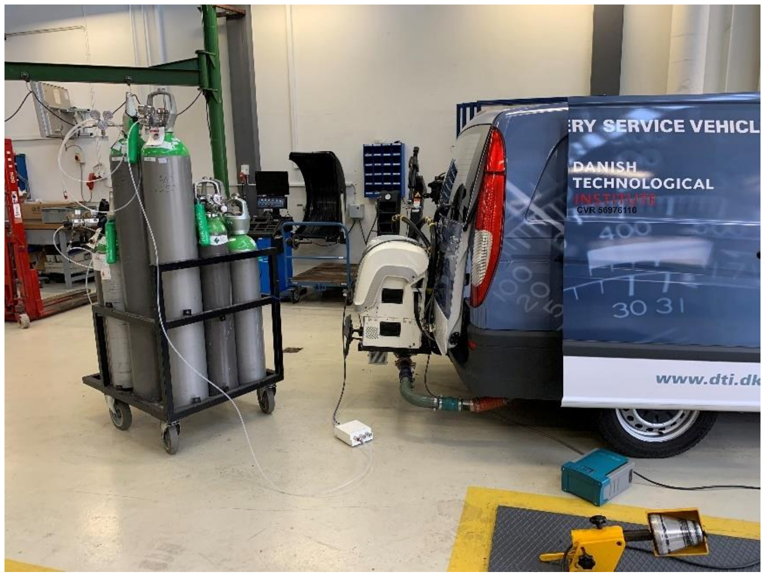


*Figure 3: Mercedes Vito test car being prepared for *RDE/PEMS testing. (RDE: Real Drive Emission)*

During testing, the car was equipped with the PEMS equipment. The PEMS equipment is mounted on the car and consists, of a gas analyser measuring CO, CO_2, NO_x, and O_2 content. Simultaneously the particulate emissions from the car is measured. The flue gas mass flow and temperature are measured by the flow tube unit seen connected to the car exhaust pipe.

On the car roof a weather station is recording the climatic conditions during the test and a GPS sensor is logging the route driven. The system control computer is located inside the car and connected to a display giving feedback to the driver about route details.

The route we've driving is approx. 80 km. long, taking about 1 and a half hour to drive. The route is distributed between 1/3 city driving, 1/3 rural roads and 1/3 motorway.

The PEMS testing method is an EU recognised method used by the car manufacturers as an obliged element during type testing. DTI holds a full accreditation to perform the PEMS testing.

2.2.6 Chassis Dynamometer Testing

The car used for the RDE tests was also driven on a chassis dynamometer in order to further verify the transient behaviour of the car when driving on E10 and ABE10.

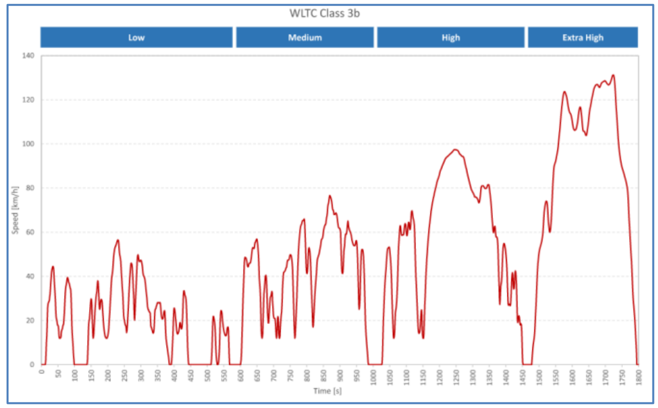


Figure 4 Test car on the chassis dynamometer and the WLTP test cycle used for transient testing.

The WLTP, World-wide harmonised Light vehicle Test Procedure, is a transient test procedure is developed using real-driving data, gathered from around the world. WLTP represents everyday driving profiles.

3 RESULTS AND DISCUSSION

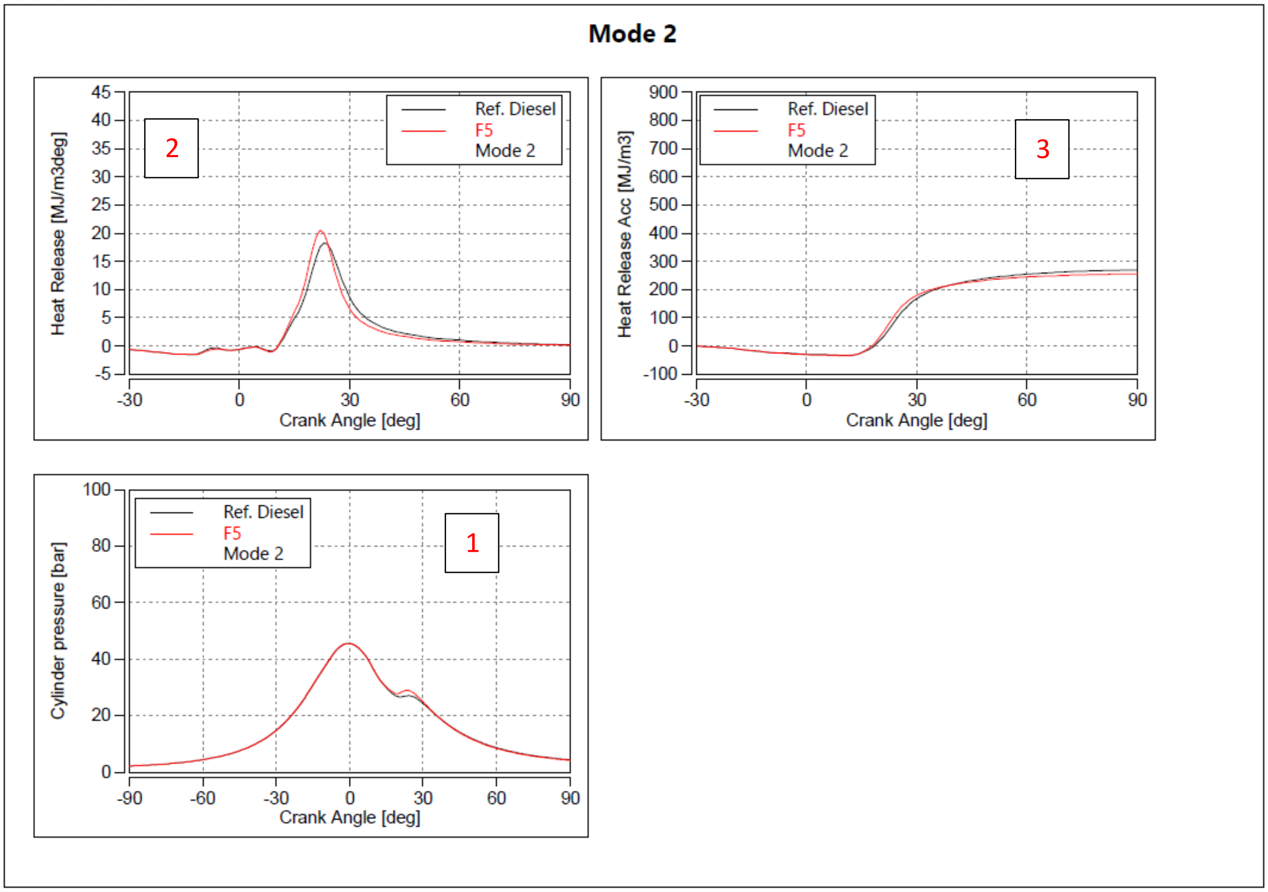
The results of the measurements from the engine test bench and from the real car driving are presented below. Four reporting charts, each covering one load mode are presenting the results from the engine testing where combustion characteristics have been investigated. The reporting below is a zoom-in on selected graphs. A complete set of graphs covering the engine testing results are attached to this report's appendix section. Corresponding emission figures to the load points driven on the testbench are enclosed in this section.

Results from the transient WLTP measurements on the chassis dyno and from real drive emission measurements are included in this section.

3.1 Cylinder Pressure Measurements

The aim is to investigate how the combustion process proceeds with the F5 fuel compared to the reference fuel. It is investigated whether unwanted pressure oscillations occur during the combustion cycle. Via the cylinder pressure measurements, the rate of heat release is calculated and reported.

Figure 5: Combustion quality reporting chart. Here the reporting chart for the no.2 test mode is shown. A zoom-in and explanations on the chart sections are given below.



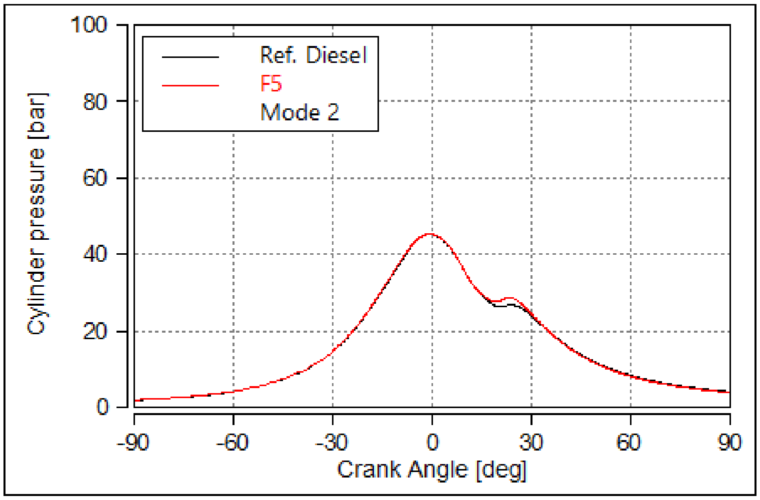
The combustion quality measurement consists of a reporting chart found for all load points in the appendix section with the following information:

1. Cylinder pressure
2. Rate of heat release
3. Accumulated rate of heat release

3.1.1 Cylinder pressure measurement and detection of oscillations

The cylinder pressure occurring during a single combustion stroke is measured and recorded with the pressure sensor located in the combustion chamber on the test engine.

Figure 6: Cylinder pressure measurement. Here the no.2 test mode pressures are shown.



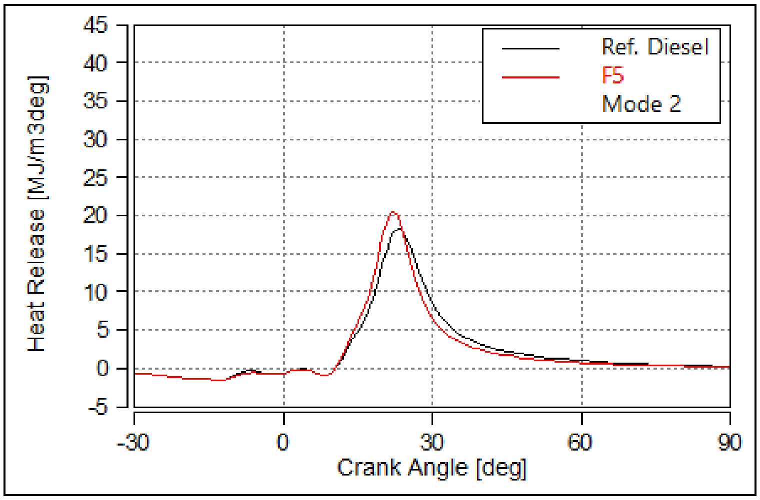
The interesting part of the pressure diagrams is to consider whether undesirable pressure gradients occur during the combustion stroke and further to consider if the combustion velocity is kept within appropriate limits. The above figure shows the combustion pressure in the combustion chamber (y-axis) as a function of the crank angle degrees (x-axis).

For all test modes, it can be seen and concluded that undesirable pressure gradients do not occur using the F5 furanics fuel. When comparing the combustion process from F5 with the reference fuel it is seen that the pressure curves within negligible limits has the same profile as the reference fuel. No pre-combustion (self-ignition) are seen.

3.1.2 Rate of Heat Release

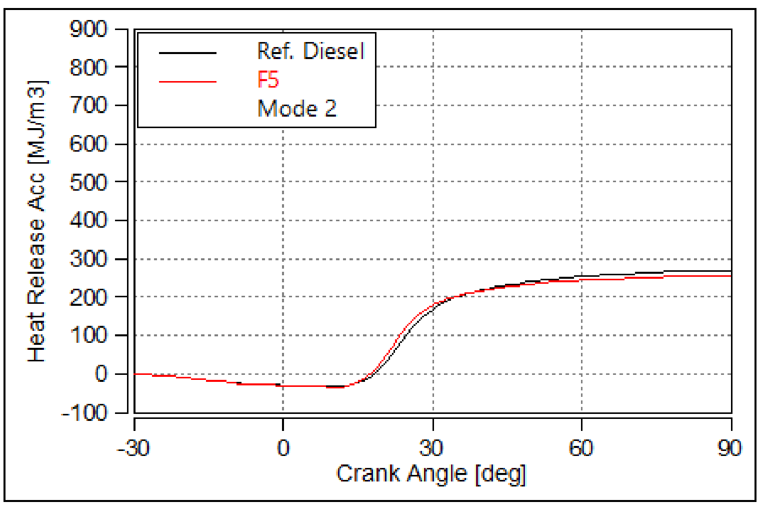
Based on the recorded cylinder pressure the heat release rates are calculated.

Figure 7: Rate of heat release. Figures from the no.2 test mode is shown.



The calculated heat release rates show a very fine progress during the combustion stroke that is fully in line with the reference fuel. The slight difference seen in the shape of the curve is due to small changes in engine load and is not an indication that F5 performs better or worse. The small differences are fully within the acceptable limits.

Figure 8: Accumulated rate of heat release. Figures from the no.2 test mode is shown.



The calculated heat release rates seen during all load modes show a smooth combustion progress without peaks or “ringing” due to engine knock.

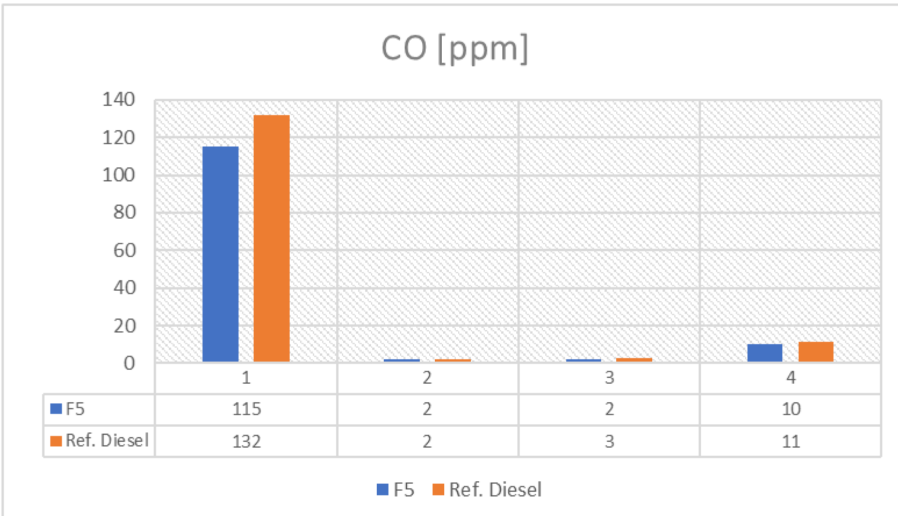
3.2 Emission Measurements at test bench

During engine testing the flue gas emissions from the F5 fuel are compared with the emissions from the reference diesel. Emissions are measured in each mode of operation and both regulated emissions and the so-called unregulated emissions, have been measured and recorded.

3.2.1 Exhaust gas composition – regulated emissions

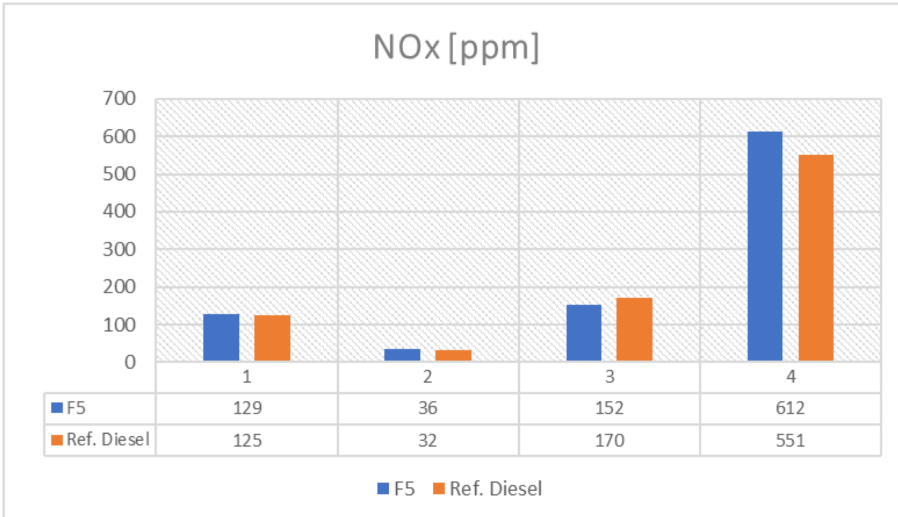
Regulated emissions are CO, NO_x (sum of NO and NO_2) and particulates.

Figure 9: CO emission.



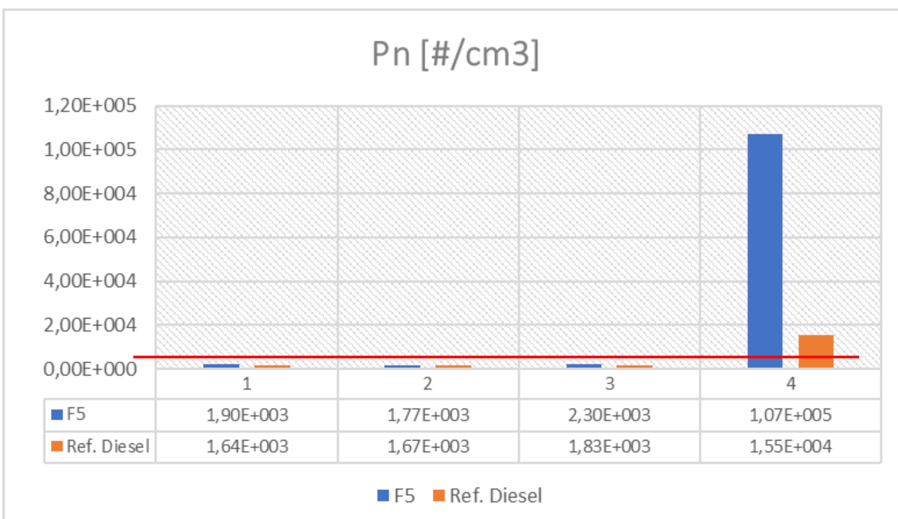
At all load points it is seen that the CO emission is at the same level. The high CO level in mode 1 is because the engine's after-treatment system cannot maintain an adequate temperature at idle. The phenomenon is well known. The higher load points show that the CO emission is brought to very low values and there is no difference between the F5 and the reference fuel.

Figure 10. The NO_x emisions.



The NO_x emissions (sum of NO and NO_2) are within small and acceptable margins at the same level during the four load points.

Figure 11 Particulate emission.

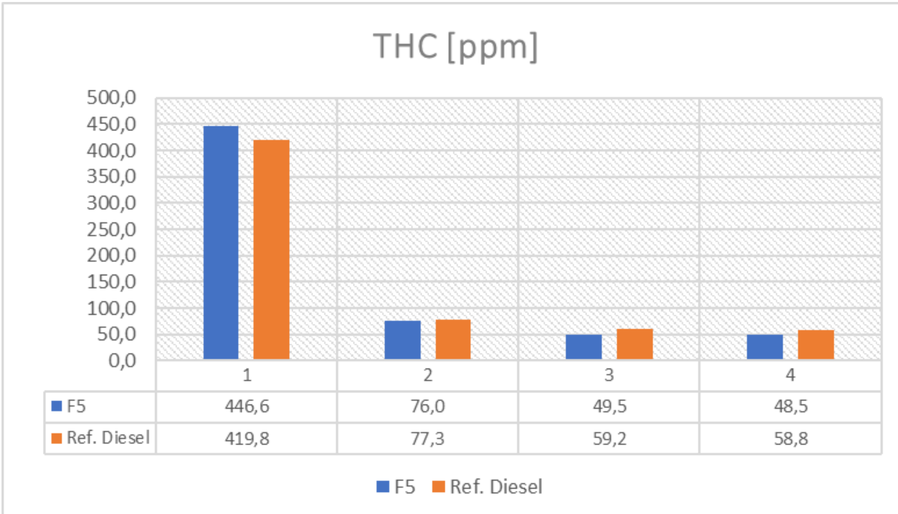


In general, a particulate emission below detection level is seen. The actual detection level of 2500 #/cm3 is marked with a red line in the figure 11 graph. At mode 5 a rather high particulate emission is seen on F5. But here it is important to mention, that the EURO 5 emission limit is approx. 6E+05 $\#/cm^3$ which is nearly 6 times higher than the figure measured on F5. The F5 emission figure is fully within the acceptable window with a good margin.

3.2.2 Exhaust Gas Composition – unregulated emissions

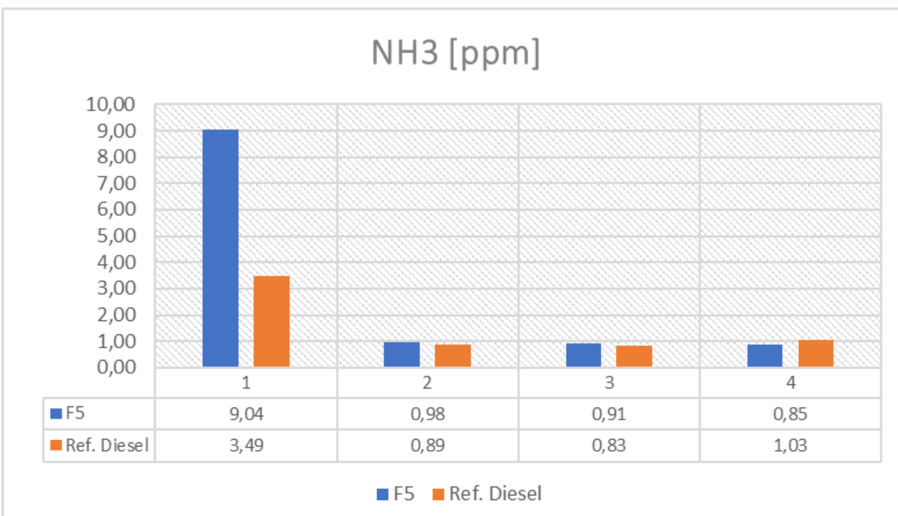
In all operating modes we have measured the concentration of the unregulated emissions with the FTIR equipment. We measured concentrations of the substances listed in table 3 which include aldehydes, methane, ethanol and other hydrocarbons. The only unregulated emissions we have been able to detect at measurable level are THC and NH_3.

Figure 12:The THC concentrations



The THC (Total Hydrocarbons) is at the same level during the four load modes. We see higher emission figures at mode 1. Again, this situation is due to the operation temperature in the after-treatment system.

Figure 13: The NH_3 concentration.



A higher NH3 concentration is seen on F5 in the no. 1 load mode. In the latest EURO 6 heavy duty standards, the emission limit for NH_3 is 10 ppm. Since F5 has an emission of less than 10 ppm, the value must be considered fully acceptable bearing in mind that the test is done on a EURO 4 engine.

3.3 Emission measurement transient testing

As described in Section 2, transient tests including emissions measurements have been performed with a car on the chassis dynamometer (WLTP test) and during real driving on the road (RDE/PEMS testing).

3.3.1 Chassis Dynamometer Testing

Figure 14:Emission figures from WLTP testing.

Gas component	Distance specific [g/km and #/km]	
	Ref. Diesel	F5
CO	0,02	0,00
CO2	167	163
NO	0,66	0,65
NO2	0,29	0,28
NOx	0,95	0,94
PN	1,5E+10	1,1E+10

At the chassis dyno we saw very low CO emissions on both fuels. The NO_x emission (sum of NO and NO_2) is at the same level. The particulate emission is slightly lower on F5, but the difference is not considered to be significant.

The transient behaviour of the car during testing was excellent and no differences between the two fuels was detected.

3.3.2 RDE/PEMS testing

Figure 15:Emission figures from RDE/PEMS testing.

RDE Ref.	Distance specific [g/km and #/km]			
	Urban roads	Rural roads	Motor -way	Trip
CO	0,03	0,00	0,01	0,01
CO2	246	168	203	203
NO	0,90	0,70	0,83	0,83
NO2	0,40	0,40	0,41	0,41
NOx	1,30	1,10	1,24	1,24
PN	3,0E+10	1,2E+10	2,0E+10	2,0E+10

RDE F5	Distance specific [g/km and #/km]			
	Urban roads	Rural roads	Motor -way	Trip
CO	0,01	0,03	0,03	0,02
CO2	233	182	199	204
NO	0,80	0,75	1,19	0,90
NO2	0,44	0,49	0,66	0,53
NOx	1,24	1,24	1,85	1,43
PN	2,4E+10	3,7E+10	5,1E+10	3,7E+10

At the RDE/PEMS testing we see a CO emission on the very same level. A slightly increase in NO_x emissions (sum of NO and NO_2) are seen on F5 but not significant. The particulate emission is slightly higher with F5 but again the differences are not considered to be significant.

4 CONCLUSIONS

The results from the tests have been very successful. As we saw from the miscibility tests there was no blending issues with the diesel/FBF. Visual inspection of the fuel system on the test engine after testing show no indication on corrosion.

The combustion test has been successfully completed and we see no challenges in using the 5% FBF mixture as used in these studies. We see no problems with cold- or hot start of the engine and engine operation at the various load points was carried out without detection of any unwanted pressure peaks, engine-knocking or other issues related to poor or inappropriate combustion.

When conducting the emission tests, we see differences in the gaseous and particulate emissions in the different test situations. It should be mentioned here that the engine we have used on the test bench is a Euro 4 engine and the engine in the test car is a Euro 5 engine. The aftertreatment system on the EURO 5 engine in the test car is more efficient giving lower emission in general.

The emission figures are therefore not directly comparable. The main results of the test bench are results relating to combustion quality. Here we achieve good results that will apply to all euro classes and we conclude that the combustion quality is excellent when using thermochemically derived furanics in a 5% blending with reference diesel.

The main results from the test car on the chassis dynamometer (WLTP) and when driving on the road (RDE/PEMS) are related to emissions. The newest cars in the EURO 6 segment are equipped with even more efficient after treatment systems and, if the tests were carried out on these vehicles, would give even lower emission figures.

The emission figures from the thermochemically derived furanics are fully within acceptable Euro limits and we see great potential for the further development of this algae biofuel, which in large-scale use can contribute to a significant reduction in greenhouse gases from our transport sector.

5 ACKNOWLEDGEMENT

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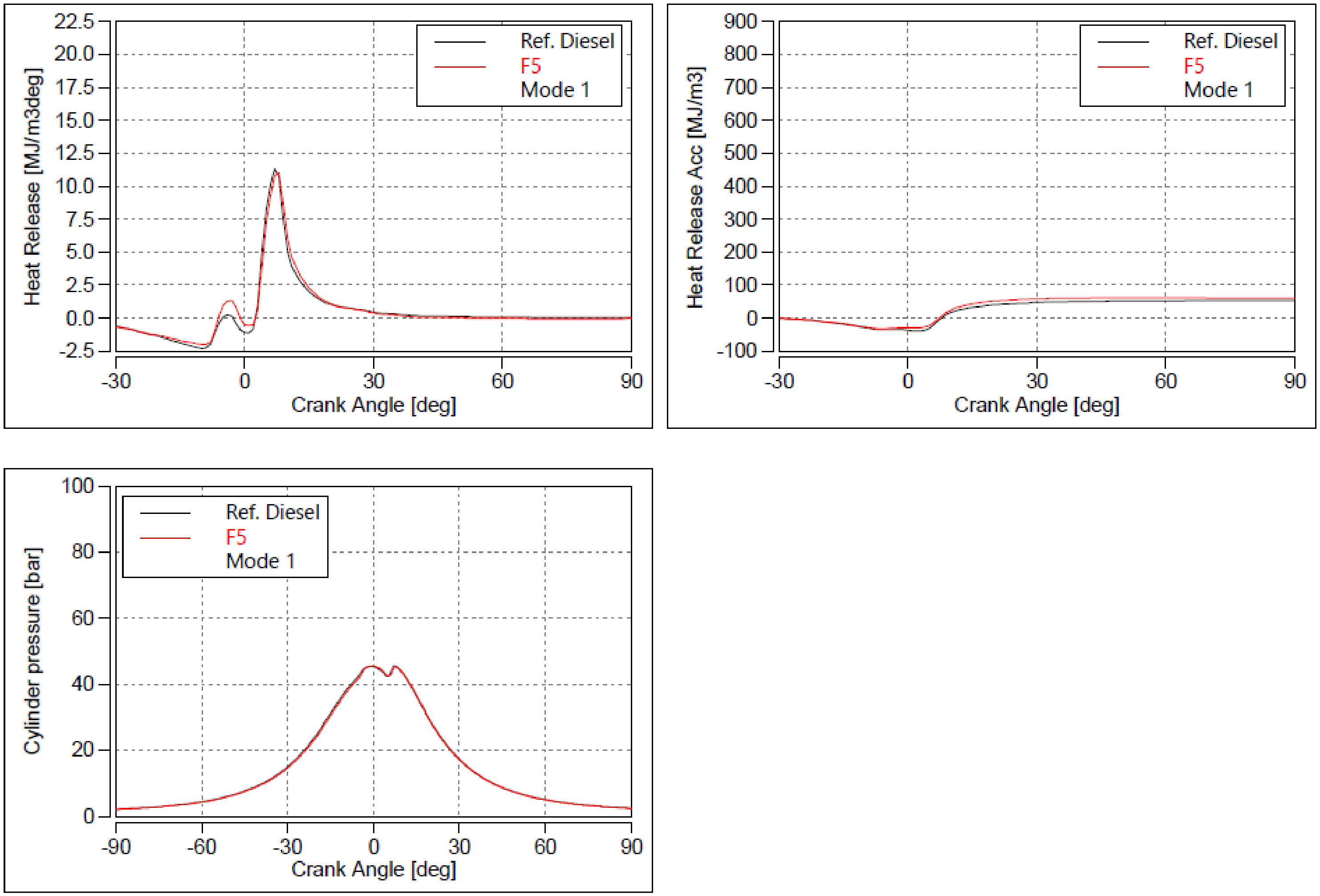
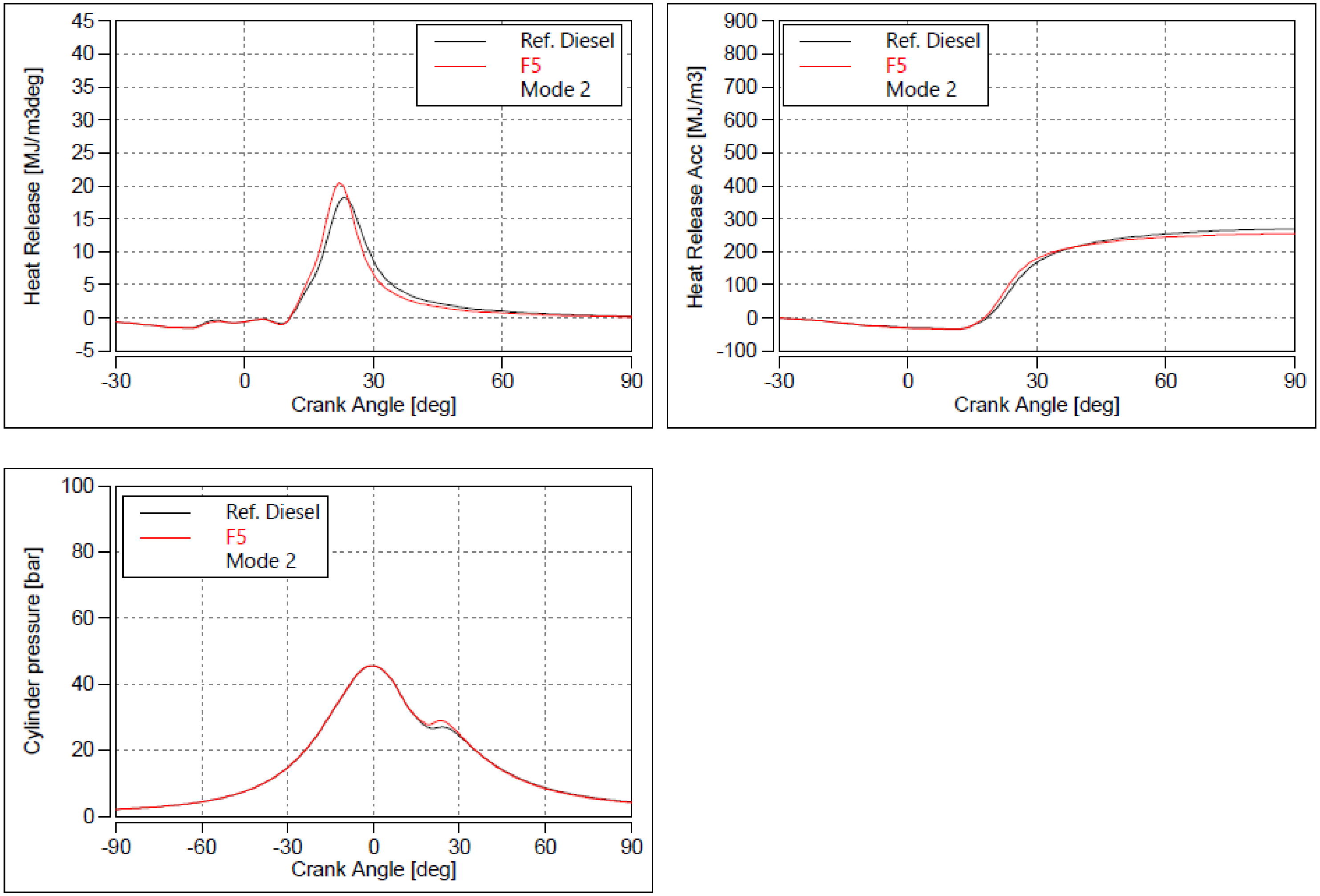
6 APPENDIX

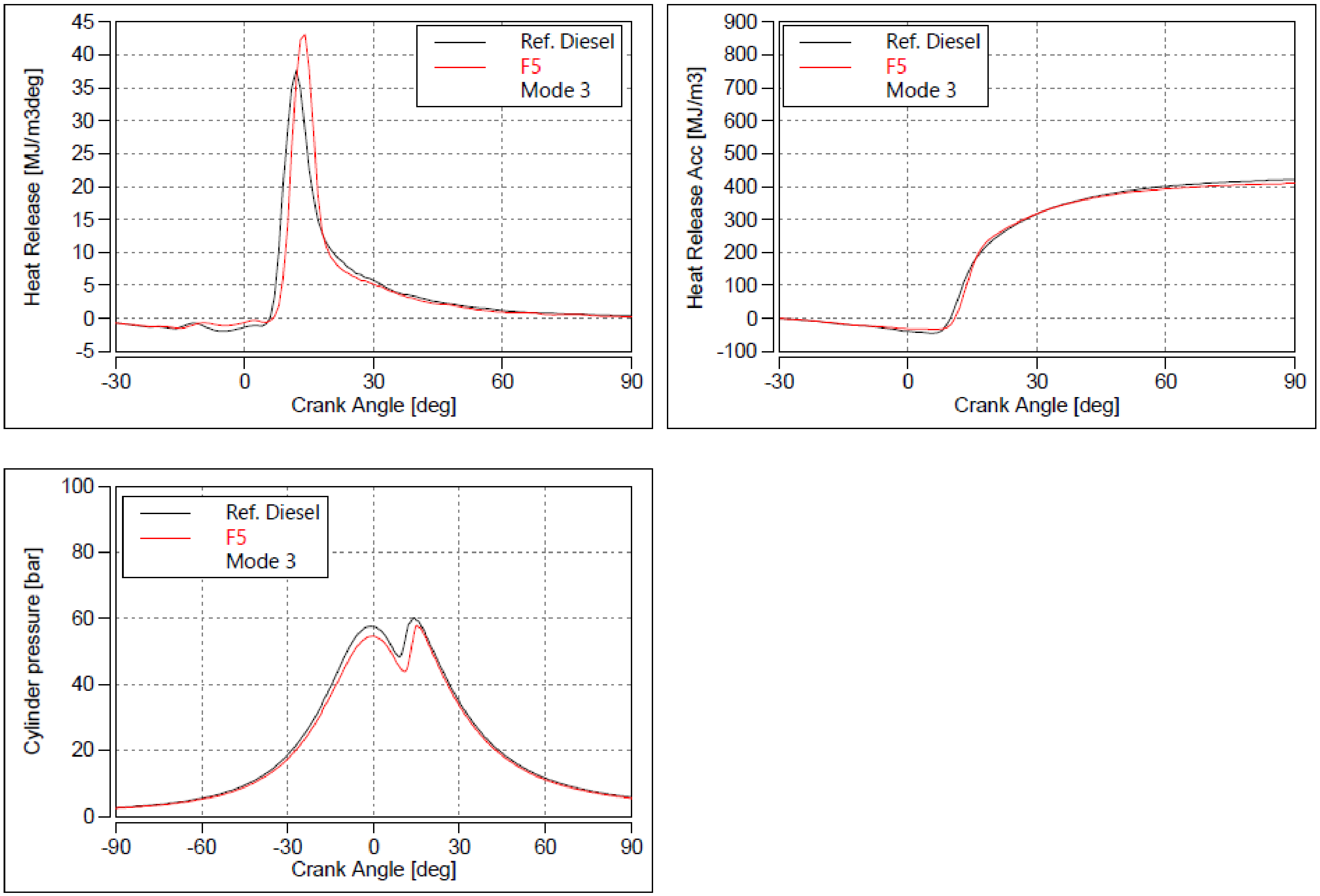
Mode 1


Heat Release [MJ/m3deg]
Crank Angle [deg]
Ref. Diesel
F5
Mode 1
Heat Release Acc [MJ/m3]
Crank Angle [deg]
Ref. Diesel
F5
Mode 1
Cylinder pressure [bar]
Crank Angle [deg]
Ref. Diesel
F5
Mode 1

Mode 2

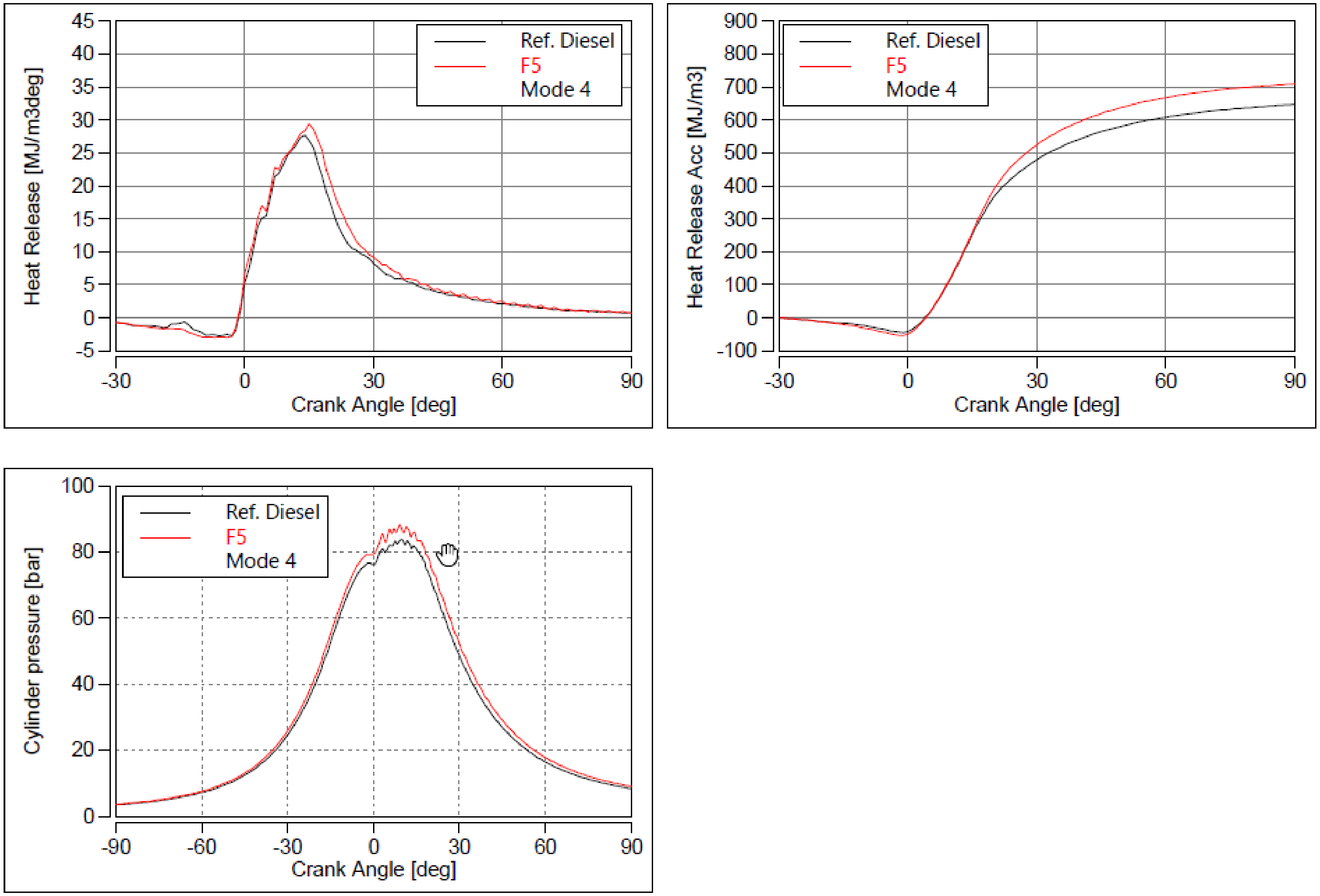

Heat Release [MJ/m3deg]
45
40
35
30
25
20
15
10
5
0
-5
-30
0
30
60
90
Crank Angle [deg]
Ref. Diesel
F5
Mode 2
Heat Release Acc [MJ/m3]
900
800
700
600
500
400
300
200
100
0
-100
-30
0
30
60
90
Crank Angle [deg]
Ref. Diesel
F5
Mode 2
Cylinder pressure [bar]
100
80
60
40
20
0
-90
-60
-30
0
30
60
90
Crank Angle [deg]
Ref. Diesel
F5
Mode 2

Mode 3



Heat Release [MJ/m3deg]
Crank Angle [deg]
Ref. Diesel
F5
Mode 3
Heat Release Acc [MJ/m3]
Cylinder pressure [bar]

Mode 4


Heat Release [MJ/m3deg]
Ref. Diesel
F5
Mode 4
Crank Angle [deg]
Heat Release Acc [MJ/m3]
Ref. Diesel
F5
Mode 4
Crank Angle [deg]
Cylinder pressure [bar]
Ref. Diesel
F5
Mode 4
Crank Angle [deg]

intertek
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Certificate of Analysis

TEKNOLOGISK INSTITUT
Kongsvang Allé 29
DK-8000 Aarhus C
Danmark

Laboratory Report ID : 20-000508-0-DNK-004-00
Our Reference Number : -

Sample ID	: 3598051 / 20-000508-0-DNK-004-00	**Date Taken**	: 09-Jan-2020
Product	: Reference Diesel	**Drawn by**	: Client
Client Reference	: Sten Frandsen	**Date Submitted**	: 09-Jan-2020
Submitted sample	: Brændstofanalyser	**Date Tested**	: 23-Jan-2020
Representing	: Reference Diesel		

Method	Test	Spec Limit	Result	Units
ISO 12156	Used Procedure		A	
	Lubricity (HFRR @ 60°C)		320	µm
ENISO4264	Cetane Index, Calculation		50.7	
ENISO3405	Initial Boiling Point		169.9	°C
	65% Recovery		292.6	°C
	95% Recovery		353.3	°C
ISO 12185	density @ 15° C		840.3	kg/m³
EN15195	Ignition Delay (ID)		2.81	ms
	Derived Cetane Number (DCN)		53.8	
	Average Charge Air Temperature		607.2	°C
	Performed by:		Intertek Antwerp	

Sampling location : -
Sample container : Plastic (> 250 ml)
Sampling Procedure : Standard

This certificate has been authorised by: Susanne Kristensen on Thursday, January 23, 2020

Susanne Kristensen
Laboratory Supervisor
Intertek Denmark A/S

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MACROFUELS

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caleb brett

Certificate of Analysis

TEKNOLOGISK INSTITUT
Kongsvang Allé 29
DK-8000 Aarhus C
Danmark

Laboratory Report ID : 20-000508-0-DNK-005-00
Our Reference Number : -

Sample ID	: 3598052 / 20-000508-0-DNK-005-00	**Date Taken**	: 09-Jan-2020
Product	: Diesel F5	**Drawn by**	: Client
Client Reference	: Sten Frandsen	**Date Submitted**	: 09-Jan-2020
Submitted sample	: Brændstofanalyser	**Date Tested**	: 23-Jan-2020
Representing	: Diesel F5		

Method	Test	Spec Limit	Result	Units
ISO 12156	Used Procedure		A	
	Lubricity (HFRR @ 60°C)		420	µm
ENISO4264	Cetane Index, Calculation		49.4	
ENISO3405	Initial Boiling Point		116.6	°C
	65% Recovery		290	°C
	95% Recovery		353.1	°C
ISO 12185	density @ 15° C		839.8	kg/m³
EN15195	Ignition Delay (ID)		2.96	ms
	Derived Cetane Number (DCN)		50.8	
	Average Charge Air Temperature		607.3	°C
	Performed by:		Intertek Antwerp	

Sampling location : -
Sample container : Plastic (> 250 ml)
Sampling Procedure : Standard

This certificate has been authorised by: Susanne Kristensen on Thursday, January 23, 2020

This report has been reviewed for accuracy, completeness, and comparison against specifications when available. The reported results are only representative of the samples submitted for testing and are subject to confirmation upon completion of the final report, which may contain warnings, exceptions and terms and conditions which are pertinent to the data supplied herein. It is the position of Intertek that the final report is the prevailing document, and that the use of interim documents by the client is at their own risk. This report shall not be reproduced except in full without written approval of the laboratory.

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