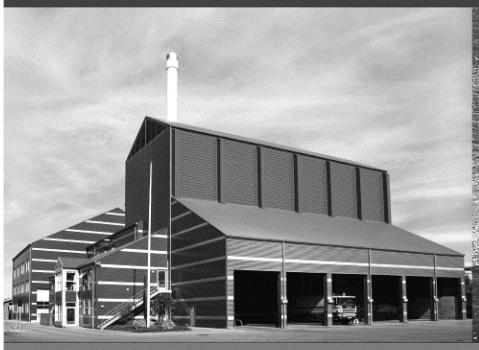
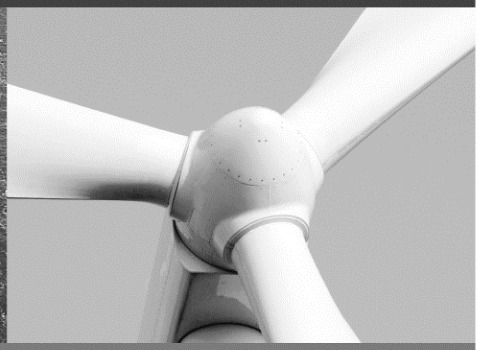
APPLICATION NOTES





DELOMATIC 400, DM-400 GAS

Emission control

- Lambda sensor
- p/T regulation
- Combustion chamber temperature regulation
- Emission control configuration
- Emission control curve

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1. About this document

General purpose

This document contains the application notes for DEIF's Delomatic 400, DM-400, used in gas applications.

For functional descriptions, the procedure for parameter setup, complete standard parameter lists, etc., please see the Installation Instructions.

The general purpose of the application notes is to offer the designer information about the two methods available for emission control.

Please make sure to read this handbook before working with the DM-400 controller and the genset to be controlled. Failure to do this could result in damage to the equipment or human injury.

Intended users

The document is mainly intended for the person responsible for designing DM-4 systems. In most cases, this would be a panel builder designer. Naturally, other users might also find useful information in this document.

Contents/overall structure

The document is divided into chapters, and in order to make the structure of the document simple and easy to use, each chapter will begin from the top of a new page.

2. Warnings and legal information

Legal information and responsibility

DEIF takes no responsibility for installation or operation of the generator set. If there is any doubt about how to install or operate the generator set controlled by the unit, the company responsible for the installation or the operation of the set must be contacted.

The DM-4 is not to be opened by unauthorised personnel. If opened anyway, the warranty will be lost.

Electrostatic discharge awareness

Sufficient care must be taken to protect the terminals against static discharges during the installation. Once the unit is installed and connected, these precautions are no longer necessary.

Safety issues

Installing the unit implies work with dangerous currents and voltages. Therefore, the installation should only be carried out by authorised personnel who understand the risks involved in working with live electrical equipment.

Be aware of the hazardous live currents and voltages. Do not touch any AC measurement inputs as this could lead to injury or death.

Definitions

Throughout this document, a number of notes and warnings will be presented. To ensure that these are noticed, they will be highlighted in order to separate them from the general text.

Notes

The notes provide general information which will be helpful for the reader to bear in mind.

Warnings

The warnings indicate a potentially dangerous situation which could result in death, personal injury or damaged equipment, if certain guidelines are not followed.

3. Abstract

This document is relevant for gas engines using a gas/air mixer placed in the air intake of the engine.

In order to protect the environment against excess hazardous and green house gasses, the combustion of the gas engine must be monitored, and adjustments of the air/gas mixture must be carried out.

The monitoring in DM-400 Gas can be done using either a lambda sensor, by gas mixture p/T (pressure over temperature) or by cylinder combustion chamber temperature control.

For lean burn operation, DEIF recommends the p/T or cylinder combustion chamber method which in this running mode offers a better precision than the lambda sensor.

4. Functional description

General

For exhaust emission control, the Delomatic DM-400 Gas provides an integrated emission controller.

Therefore we recommend mixers using a stepper motor with a stepper motor driver to be connected to the DM-400 Gas.

The stepper motor driver will be controlled by the signals “clock“ and “direction“ from the DM-400 Gas. Furthermore, a mechanical limit stop for the position “lean“ is required. If the limit stop lean is reached, there must be a low signal at the digital input of the Delomatic.

Alternatively, gas mixers using a 4-20 mA signal can be used, but mixers with stepper motors are recommended.

The regulation is done either by lambda control, by mixture pressure and mixture temperature control (p/T) or by cylinder combustion chamber temperature control.

Lambda control

For lambda control, the actual value (mV) given by a lambda sensor has to be converted (to 4…20 mA) and connected to the Delomatic.

The required value will be set by parameter (4…20 mA).

The lambda sensor control type is selected in the parameters under the “gas mixer control” section, accessible on the operator interface via the overview. Per default, the lambda sensor control is turned OFF.

Mixture pressure/temperature control

For p/T control, two signals are needed: pressure and temperature measured in the gas mixture just before the mixture enters the cylinders (intake manifold).

The pressure sensor must give a 4…20 mA signal and be connected to the Delomatic.

The temperature must be measured using a Pt100 connected to the Delomatic.

The pressure over temperature (p/T) control feature is based on the gas constant formula

$$\frac{p1 \times v1}{T1} = \frac{p2 \times v2}{T2}$$

and the relation between the p/T value and the generator output (kW).

For optimised (low) emission of NO_x gasses, this relation can be expressed by a curve. This curve can be adjusted via the easy-to-use emission configuration tool. The curve setting is made during commissioning, using a gas analyser connected to the exhaust pipe of the engine.

The gas analyser must be able to measure O_2, CO, NO_x and HC content in the exhaust gas:

Combustion chamber temperature control

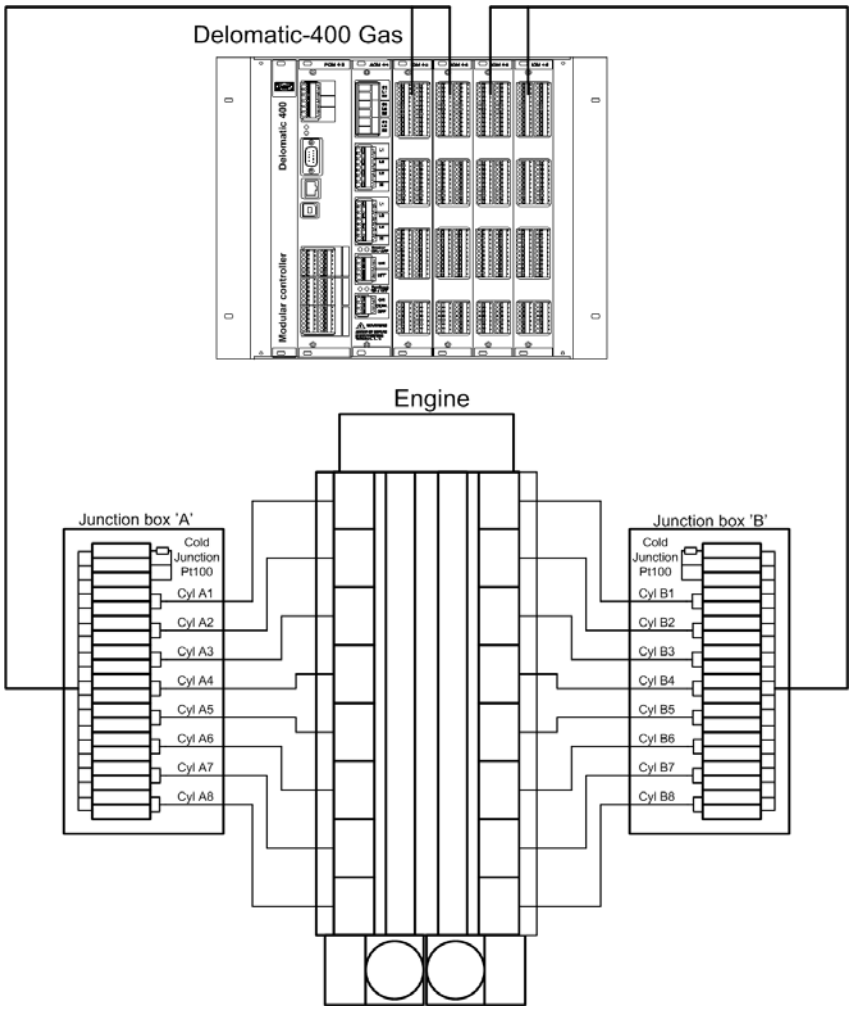
This method requires a temperature measurement of the cylinder combustion chamber, one for each cylinder.

As it is practically impossible to have a temperature sensor inside the combustion chamber, a cylinder wall temperature sensor is used. The temperature measured here will not be the combustion chamber temperature, but a value that can be used to represent it.

The method is based on the fact that at a certain power output, the combustion chamber temperature will vary with the gas mix (richer = hotter, leaner = colder).

This can be used for creating a curve representing the lowest emission (~ combustion chamber temperature) over the power range (0-100%).

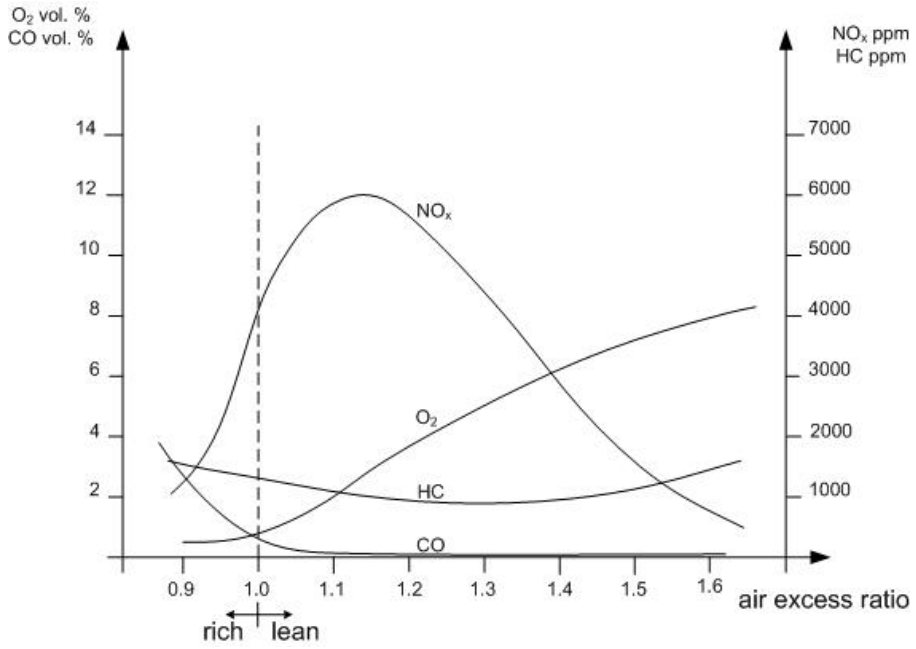
DM-4 Gas accepts signals from NiCrNi thermocouple sensors directly. In order to make the use of external terminal boxes possible, there are 1 or 2 cold junction compensations available for in-line or vee-engine configurations:



The above example shows a 16-cyl. engine.

Gas analysis

The gas analyser used for tuning the p/T and combustion chamber temperature control methods must be able to measure O_2, CO, NO_x and HC content in the exhaust gas:



The curves show that the NO_x value decreases with an increasing excess air ratio, so in theory the mix should be as lean as possible. On the other hand, the HC content increases when the air excess ratio exceeds approx. 1.35, so the resulting air excess ratio will be a compromise. Finally, if the air excess ratio gets too high, the mix gets so lean that misfiring will take place.

Choice between two different gas types

The system can switch between two different gas types (called A and B), so that e.g. the engine is started on natural gas, and when running and warmed up, the system can shift to the other type. The shift can be made automatically or based on a digital input.

The default gas type for island operation in case of mains failure can be selected.

Mixer stepper motor control

The stepper motor control features two digital outputs (direction, step) to control the stepper motor, as well as configuration of the stepper motor (number of steps).

These outputs interface to a small stepper motor driver which can be supplied by DEIF if needed.

Mixer position feedback

By counting the step commands issued to the stepper motor, the DM-4 Gas control system always knows the exact position of the mixer with high accuracy. A fully automatic calibration run of the mixer makes sure that the accuracy is kept over time.

Fixed positions and regulation

The DM-400 Gas supports four fixed configurable mixer positions:

- Start position
- Idle position
- Parallel position
- Island position

The mixer moves directly to these positions, depending on the operation state. In mains parallel operation, the DM-4 Gas will switch to active regulation after reaching the release load.

Calibration and start

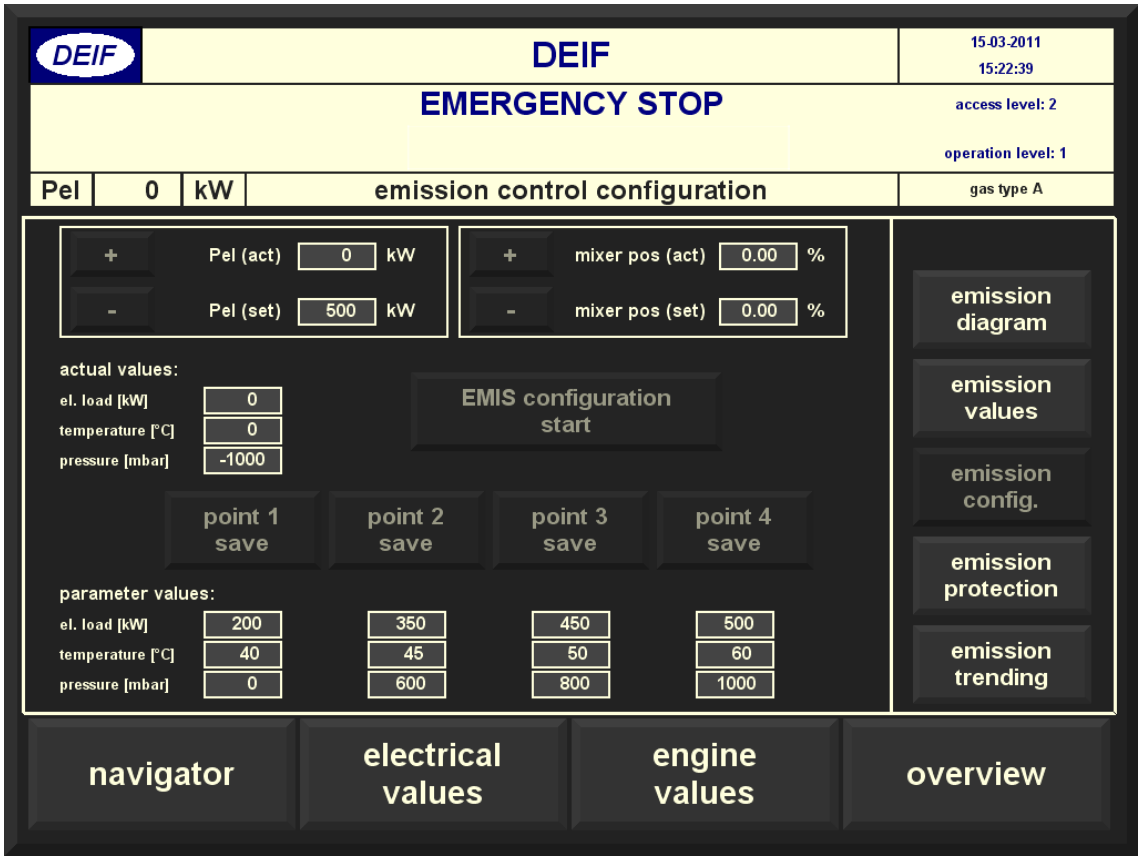
Before every start procedure, a calibration of the stepper motor drive will be initialised and the mechanical system will be checked (for loss of steps). If a calibration succeeded within the last 15 minutes, there will be no calibration before the start procedure.

The calibration run includes moving to limit stop lean, moving to position rich and then moving to start position. The effective position may vary, depending on cooling water temperature inlet and CH_4 value.

5. Emission control

Settings for emission optimisation, p/T method

Using the p/T method, the emissions can be optimised. The setting of the parameters for p/T is easily made with the “Emission configuration” tool, which is included in the HMI graphics presentation:



The generator must be parallel with mains when entering this page.

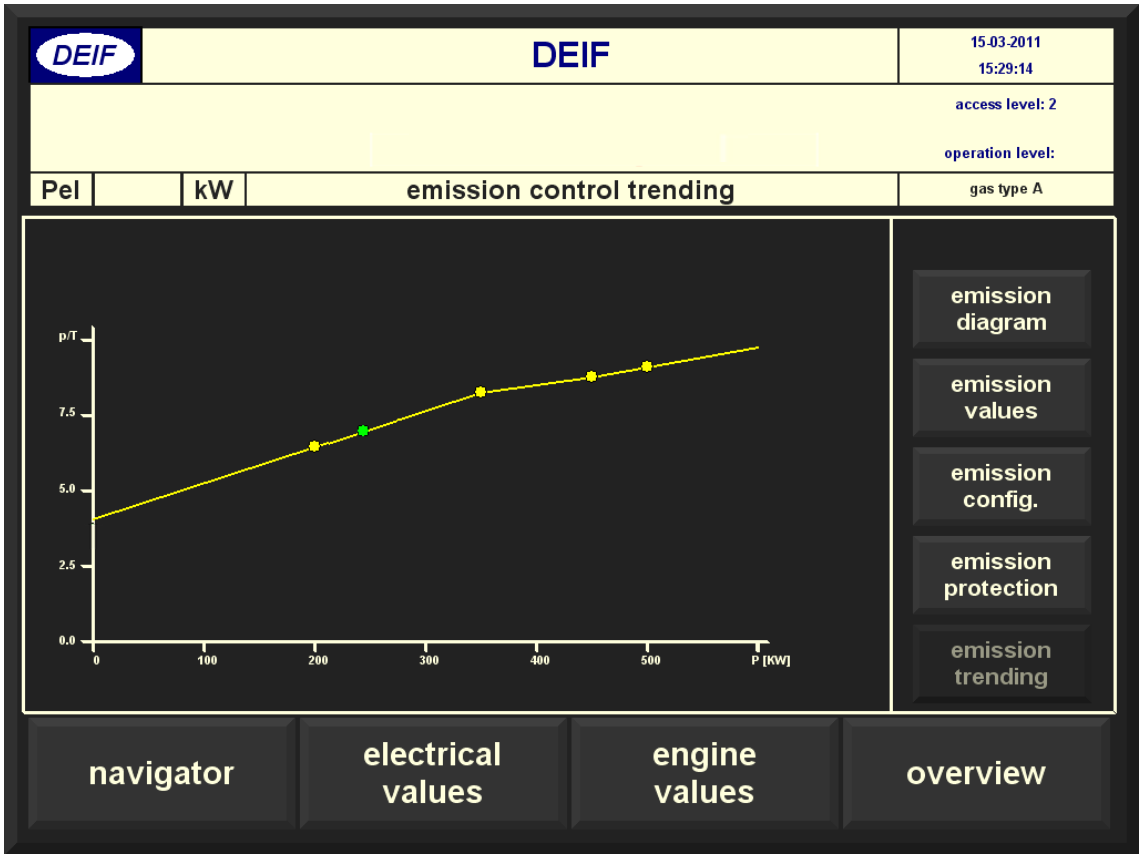
Click the “EMIS configuration start” button to enable the buttons for Pel + and - as well as mixer pos + and -. Using these buttons, the generator power as well as the mixer position and thus the emissions can be controlled manually. The actual emission value must be monitored with a gas analyser.

Once the first value set (represented by electrical load in kW, intake manifold temperature in deg. C and intake manifold pressure in mbar) is optimised, press the “point 1 save” button, and so on with 2-4.

When “point 4 save” is clicked, the configuration is done and the engine runs emission-optimised.

p/T emission control trending

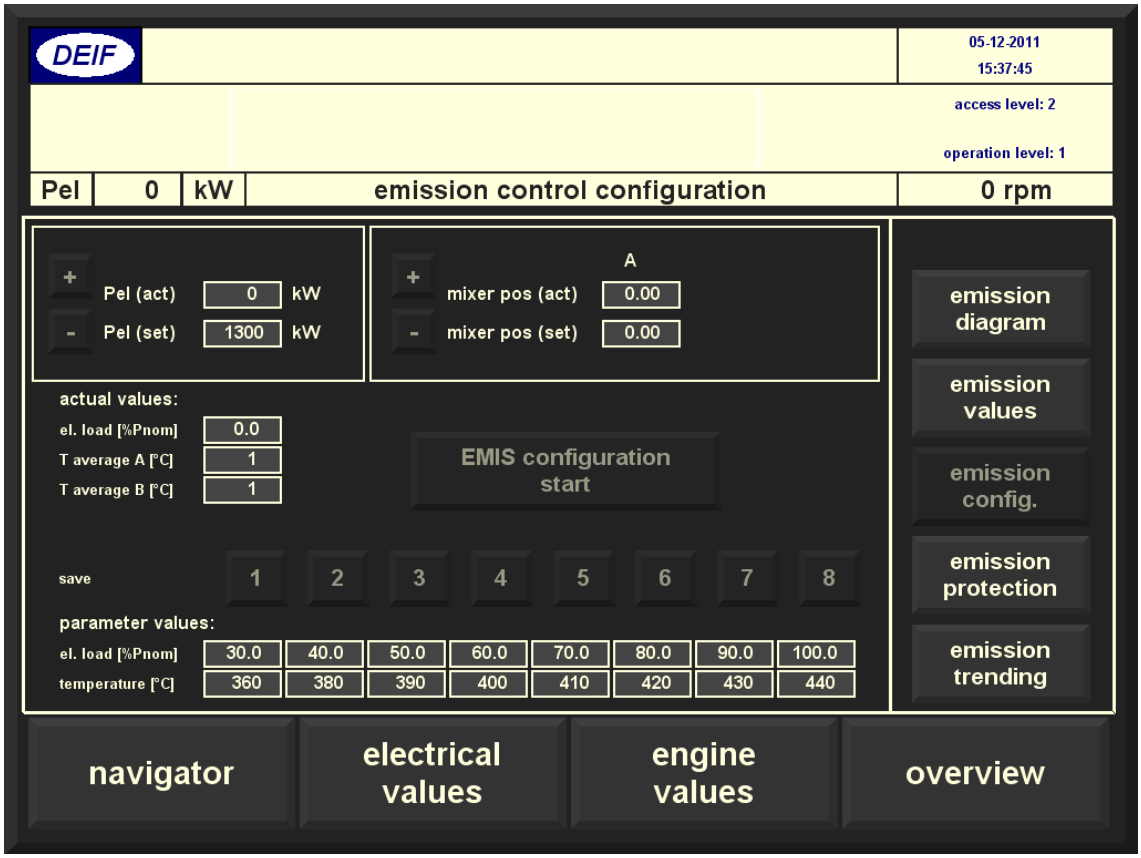
The resulting curve of the emission configuration can be monitored:



The green dot represents the actual value, and, by running engine, this must follow the curve.

The curve represents the optimal running of the engine for minimum emissions and maximum economy.

Settings for emission optimisation, combustion chamber temp. method



The generator must be parallel with mains or connected to a load bank when entering this page.

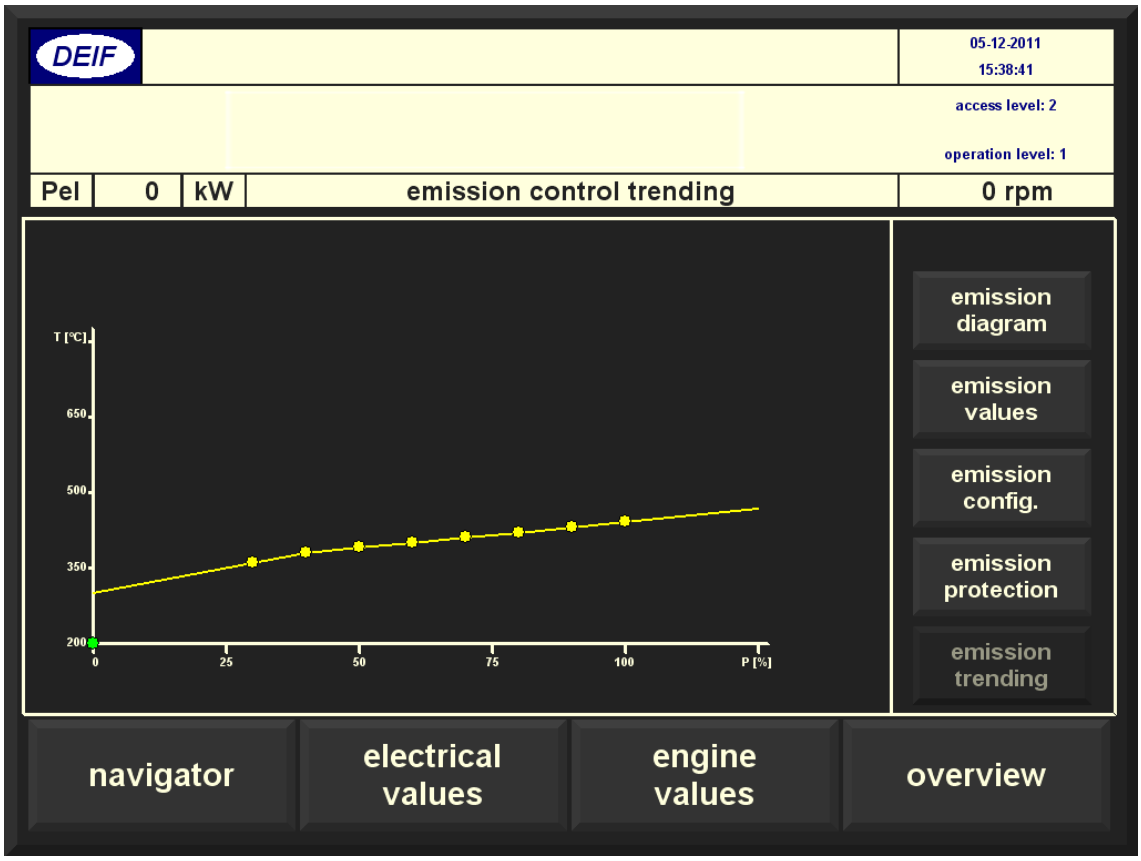
Click the “EMIS configuration start” button to enable the buttons for Pel + and - as well as mixer pos + and -. Using these buttons, the generator power as well as the mixer position and thus the emissions can be controlled manually. The actual emission value must be monitored with a gas analyser.

Once the first value pairs (represented by electrical load in % of nominal power and average combustion chamber temperature in deg. C.) is optimised, press the “save 1” button, and so on with 2-8. The temperatures indicated represent the average temperature of all combustion chambers. For V-engine, the T average for A and B banks can be read.

When “point 8 save” is clicked, the configuration is done and the engine runs emission-optimised.

Combustion chamber temperature emission control trending

The resulting curve of the emission configuration can be monitored:



The green dot represents the actual value, and, by running engine, this must follow the curve.

The curve represents the optimal running of the engine for minimum emissions and maximum economy.

Cylinder diagnostics

Monitoring of single cylinder combustion chamber temperatures: