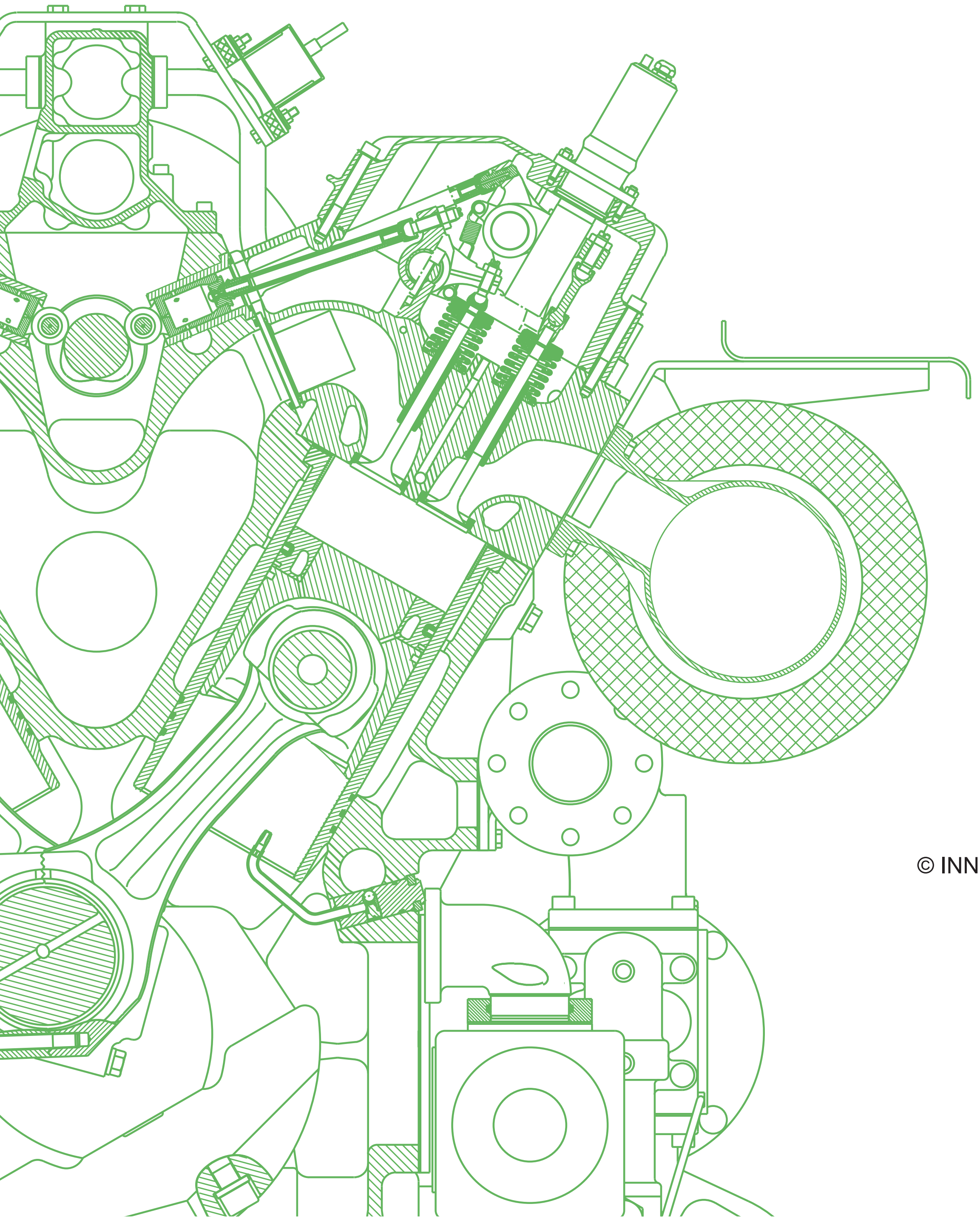
JENBACHER

TA 1400-0300

Technical Instruction

Instructions on NOx measurements and LEANOX settings



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TA 1400-0300 Instructions on NOx measurements and LEANOX settings

The target recipients of this document are:

Distribution Partners, Service Partners, Commissioning Partners, Subsidiaries/Branches, Jenbach location

1 Scope

This Technical Instruction (TA) applies to the following Jenbacher Gas Engines:

- Type 2 engines
- Type 3 engines
- Type 4 engines
- Type 6 engines
- Type 9 engines

2 Purpose

This Technical Instruction [TA] describes the procedure for complying with regulatory exhaust gas emissions in the design of the system and while the engine is running.

3 Safety information

⚠ WARNING

Personal injury

Failure to use personal protective equipment and comply with safety instructions or employee protection information may lead to personal injury.

- ➢ Wear the relevant personal protective equipment (PPE).
- ➢ Observe the safety instructions as per Technical Instruction 2300-0005.
- ➢ Observe the employee protection information as per Technical Instruction 2300-0001.

4 Additional information

In the development of its engines, Jenbacher Gas Engines, the gas engine division of INNIO Jenbacher GmbH & Co OG, takes close account of the German "TA Luft" (Technical Instruction on Air Quality Control of 24 July 2002), which imposes limits on CO, NOx and CH2O emissions. As an aid to operators of the engine or plant, please refer to two VDI (Association of German Engineers) Guidelines for guidance on how to plan and perform emission measurements:

- VDI 2448 Planning random-sample measurements of stationary source emissions
- VDA 4200 Performing measurements of stationary source emissions

A 1:1 application on engine-operated power plants is sometimes difficult, if not impossible. Nevertheless, these guidelines provide valuable information that lightens the tasks of acceptance and recurring emission measurements.

Relevant documents

E 8057 - Operational data sheet – NOx measurement

IW 0309 M0 - Spark plugs

IW 8057 M4 - NOx measurement

TA 1310-0011 - Standard tool catalogue

TA 1400-0200 - Engine optimisation - Type 4 engines

TA 1503-0041 - Engine adjustment instruction, extended Leanox control, type 2/3 engines gas mixer for DIA.NE XT

TA 1503-0042 - Engine adjustment instruction, extended Leanox control, type 2/3 engines TecJet for DIA.NE XT

TA 1503-0043 - Engine adjustment instruction, extended Leanox control, type 4 engines for DIA.NE XT

TA 1503-0045 - Engine adjustment instruction, extended Leanox control, type 6 engines (DIA.NE blue)

TA 1503-0046 - Engine adjustment instruction – type 6 engines (Diane XT)

TA 1503-0047 - Engine adjustment instruction - Type 6 (DIA.NE XT)

TA 1503-0050 - Oil consumption meter, online oil consumption measurement

TA 1510-0067 - Setting instructions for gas type 1-2

TA 1530-0181 - Humidity compensation for intake air

5 General

Combustion engines are generally subject to emission regulations. Emissions must be categorised either as raw engine emissions (measured downstream of the turbine in the turbocharger) or as plant emissions (at the chimney outlet after possible exhaust gas treatment). Usually, the regulatory authorities set the emission limits for the chimney, where the exhaust gas transfers from the plant to the environment. Every operator of a plant is legally required to ensure that it is operated properly, compliance with the legal emission limits is monitored and the plant is maintained correctly. The following harmful emissions are often subject to regulation. For current situation, see date in revision history:

- Carbon monoxide: CO
- Oxides of nitrogen: NOx (sum of NO and NO2)
- Formaldehyde: CH2O
- Other emissions may be regulated on a plant-by-plant basis. The limit values can be taken from the relevant plant permit.

5.1 INNIO solutions for complying with emission limits

Carbon monoxide (CO):

- Raw engine emissions are lower than the set limit - no exhaust gas treatment is required.
- Raw engine emissions exceed the set limit:
  - Use a CO oxidation catalyst to treat the exhaust gas.
  - Use a "regenerative thermal oxidiser" (Cl.Air® system).

Oxides of nitrogen (NOx):

- Use the principle of lean mixture burning to reduce the NOx emissions inside the engine: Recalibrate and adjust the engine by periodically measuring the NOx emissions at set intervals and use a controller (LEANOX controller) that controls the NOx emission values in the permissible part-load to full-load operation range.
- Use an SCR (Selective Catalytic Reduction) system to further reduce the NOx emissions.

Formaldehyde (CH2O):

- Raw engine emissions are lower than the set limit - no exhaust gas treatment is required.
- Raw engine emissions exceed the set limit:
  - Use a CO oxidation catalyst.
  - Use a "regenerative thermal oxidiser" (Cl.Air® system).

5.2 Factors affecting emissions

Jenbacher Gas Engines do not have ongoing emission measurement and are regulated indirectly on the basis of NOx emissions. Because of influencing parameters, e.g. combustion chamber deposits (and others, as described below), the operator must check the emissions at set intervals, if necessary adjust the engine for NOx emissions (recalibration of LEANOX controller) and if possible maintain the exhaust gas treatment system (unregulated oxidation catalysts for CO or CH2O and regulated SCR DeNOx systems). Due to physical conditions, emissions will drift in each plant, irrespective of engine type or size. The following points influence the raw engine emissions and must be taken into account during plant design, initial engine commissioning and engine operation (servicing). The table below provides an overview of influencing factors as well as a matrix showing when to look out for the influencing factors.

Factors influencing raw engine emissions	Plant design	Engine commissioning	Engine operation (servicing)
Fluctuation in gas quality	X	X	X
Fluctuation in moisture in the gas/air mixture	X	X	X

Factors influencing raw engine emissions	Plant design	Engine commissioning	Engine operation (servicing)
Fluctuation in temperature of engine cooling water	X		
Fluctuation in temperature of low-temperature cooling circuit	X	X	
Knock control system			X
Deposits in the combustion chamber			X

5.2.1 Gas quality

Raw emissions can also change due to changes in the gas quality, i.e. the calorific value of the fuel gas. In the case of natural gas operation, the gas supplier will ensure that the calorific value of the fuel gas is kept constant within certain limits. If the engine is operated with non-natural gases, e.g. biogas (gas quality not monitored by gas supplier), fluctuations in fuel gas components CO2 and N2 in particular can have a substantial impact on raw engine NOx emissions. To compensate for fluctuations in the calorific value of fuel gas as far as possible, Jenbacher engine control systems for plants running on bio-gas or other methane-containing fuel gases are fitted with a "dual-gas operation" LEANOX controller. For dual-gas operation, the CH4 content of the fuel gas must be measured and communicated to the engine control system.

Recommendations in the event of gas quality fluctuations:

- Natural gas operation with slight fluctuations in calorific value (ΔHu[kWh/Nm^3]<5%): NOx fluctuations can be ignored.
- Operation on methane-containing gases / biogas (fluctuating gas components N2 and CO2 >5%Vol. and ΔHu[kWh/Nm^3]>5%): Use dual-gas operation with the CH4 signal provided (see TA 1510-0067 - Setting instructions for gas type 1-2)

5.2.2 Moisture in the gas/air mixture

Raw engine NOx emissions are affected by process- or weather-related water vapour in the intake air and fuel gas in the engine system and above all by its daily and seasonal fluctuations. INNIO Jenbacher GmbH & Co OG supplies a "moisture package" which can be integrated into the engine's air filter (sensor) and into the engine control system (not fitted as standard). It can prevent possible water vapour condensation forming in the engine in certain conditions through control technology and minimise the effect of fluctuating air moisture content, especially on the NOx emissions via the LEANOX controller. At the same time, the recalibrated LEANOX control lines are moved and thus compensated by control technology. As the moisture content of the air is the key factor (the fuel gas/air mixture consists of approx. 95% by volume of air and only approx. 5% by volume of fuel gas), there is no need to measure the moisture in the fuel gas.

Recommendations in the event of wildly fluctuating moisture content of the intake air:

- If the engine is operating with major fluctuations in air humidity (fluctuating air humidity >5 gH2O/kg of air), you are recommended to use the humidity compensation option by means of the sensor element in the intake air (see TA 1530-0181 - Humidity compensation for intake air).
- As an alternative to the "moisture package", the NOx values should be set when the intake air humidity is at a minimum. This represents the "least favourable" condition. Any increase in the air humidity will cause a reduction of NOx emissions.

5.2.3 Fluctuations in the engine cooling water temperature

Fluctuations in the engine cooling water temperature (high-temperature cooling circuit) or the oil temperature due to the integrated oil heat exchanger cause differences in NOx formation as a result of changes in the cooling of the combustion chamber. The plant should be designed to ensure that the engine cooling water temperature remains constant.

Recommendations:

- To ensure that the effect of the engine cooling water on the NOx emissions is minimised and can therefore be ignored, the deviation should not exceed ±1°C.
- If a plant is being operated at wildly fluctuating temperature levels, a control valve can be fitted to keep the engine cooling water temperature constant.

5.2.4 Temperature fluctuation in the low-temperature circuit

Jenbacher Gas Engines are usually operated with a second low-temperature cooling circuit to further reduce the mixture temperature (t2‘). Fluctuations in temperature and/or flow rates in the low-temperature cooling water circuit have a direct impact on the mixture temperature and therefore influence NOx formation.

Recommendation:

- The effect on NOX formation due to fluctuations in mixture temperature (t2‘) can be ignored, provided that the fluctuation does not exceed ±1.0°C. This can be taken into account by the customer or regulated by the engine control system.
- If it is not possible for the customer to stabilise the mixture temperature (t2‘), the Jenbacher engine control system has a compensation system in the LEANOX controller. You must make sure that this compensation system has been activated and correctly parametrised. See:
  - TA 1503-0041 - Engine adjustment instruction, extended Leanox control, type 2/3 engines gas mixer for DIA.NE XT
  - TA 1503-0042 - Engine adjustment instruction, extended Leanox control, type 2/3 engines TecJet for DIA.NE XT
  - TA 1503-0043 - Engine adjustment instruction, extended Leanox control, type 4 engines for DIA.NE XT
  - TA 1503-0045 - Engine adjustment instruction, extended Leanox control, type 6 engines (DIA.NE blue)
  - TA 1503-0046 - Engine adjustment instruction – type 6 engines (Diane XT)
  - TA 1503-0047 - Engine adjustment instruction - Type 6 (DIA.NE XT)

5.2.5 Knock control system

In order to protect combustion chamber components in the event of knocking during engine operation, the ignition point is retarded as a quick countermeasure by the knock controller in the engine control system. Any change in the ignition point has the effect of changing the peak firing pressure and NOx formation. The knock controller only retards the ignition point. This causes a reduction in peak pressure and, consequently, NOx emissions and is therefore not critical.

Recommendations:

- In the event of a change in the **average** engine ignition point of ΔIP<0.5°KW, the effect on NOx values can be ignored.

- If the knock controller reduces the average IP >0.5°KW, it is possible to compensate for this with a function contained in the engine control system. You must make sure that this compensation system has been activated and correctly parametrised. See
  - TA 1503-0041 - Engine adjustment instruction, extended Leanox control, type 2/3 engines gas mixer for DIA.NE XT
  - TA 1503-0042 - Engine adjustment instruction, extended Leanox control, type 2/3 engines TecJet for DIA.NE XT
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  - TA 1503-0045 - Engine adjustment instruction, extended Leanox control, type 6 engines (DIA.NE blue)
  - TA 1503-0046 - Engine adjustment instruction – type 6 engines (Diane XT)
  - TA 1503-0047 - Engine adjustment instruction - Type 6 (DIA.NE XT)

5.2.6 Ageing of the combustion chamber (deposits)

Raw engine emissions originate in the combustion chamber. Gas engines are designed to have a very long service life (60,000 - 80,000 Oh until the first general overhaul). The prolonged operation of the engine ages the combustion chamber and the adjacent components.

The following aspects should be borne in mind:

The wear on the spark plugs and the valve/valve seat pairing do not have a significant effect on emissions. The build-up of deposits in the combustion chamber (combustion plate of the cylinder head and on the piston crown. This is determined by contaminated fuel gas (e.g. silicates, etc.) and by oil consumption (e.g. oil type, additives, maintenance of the oil mist separator, the way the engine is operated, e.g. number of starts and load profile, etc.). Pronounced combustion chamber deposits increase NOx, CO and THC emissions.

Recommendations:

- If the NOx emissions are too high, recalibrate the LEANOX controller to reduce the raw NOx emissions again.
  - TA 1503-0041 - Engine adjustment instruction, extended Leanox control, type 2/3 engines gas mixer for DIA.NE XT
  - TA 1503-0042 - Engine adjustment instruction, extended Leanox control, type 2/3 engines TecJet for DIA.NE XT
  - TA 1503-0043 - Engine adjustment instruction, extended Leanox control, type 4 engines for DIA.NE XT
  - TA 1503-0045 - Engine adjustment instruction, extended Leanox control, type 6 engines (DIA.NE blue)
  - TA 1503-0046 - Engine adjustment instruction – type 6 engines (Diane XT)
  - TA 1503-0047 - Engine adjustment instruction - Type 6 (DIA.NE XT)
- NOx emissions are a function of the cylinder pressure the operating point in question. If the engine has pronounced combustion chamber deposits or wide variations from cylinder to cylinder, individual cylinders produce disproportionately more NOx. Cylinder-specific NOx emissions can be evened out by measuring and adjusting the cylinder-specific ignition point and therefore reduced. This process is described for type 4 engines in the technical instruction below, but it can also be applied to type 3 engines.
  - TA 1400-0200 - Engine optimisation - Type 4 engines

- Low oil temperatures in the range 70 °C to 75 °C extend the oil service life. The ingress of oil into the combustion chamber (caused by lower viscosity at low oil temperatures) can also be reduced, thereby lowering the rate at which oil ash deposits form in the combustion chamber. A reduction in the oil temperature can be achieved by using bigger oil heat exchangers.
- Use IW 0309 M0 to prevent misfiring.
- The functioning of the oil mist separator (blow-by separator) must be guaranteed.
- If the raw CO, NOx and HC emissions are too high, the combustion chamber must be cleaned, as the increased surface area of the combustion chamber absorbs unburnt or incompletely burnt gas components and emits them. Contact the Excellence Center for details of the correct way to clean the combustion chamber. The Product Training Center deals with the subject of cleaning combustion chambers (piston, cylinder head and scraper ring) when disassembled as part of the maintenance training course.

The effect of fuel gas contamination and the combustion residues of the lubricating oil on deposits in the combustion chamber and therefore on emissions is specific to the engine or plant concerned and must be determined while the engine is operating.

6 Measuring equipment and performing emission measurements

Using an exhaust gas test kit to determine NOx emissions is a cost-effective solution compared with alternative measuring methods. Suitable exhaust gas test kits should contain measuring cells for at least NO, NO2, O2 and also CO. The measured values should be displayed and converted in units typically used in the country concerned, making them easy to compare with the requirements.

Example:

Output in mg/Nm³@5%O2-dry (milligrams per standard cubic metre at 5% residual oxygen in dry exhaust gas), with regulatory standard to DIN 1343 (273.15 K; 1013.25 hPa) and conversion to 5% reference oxygen content.

The measuring accuracy of standard measuring instruments is typically stated under laboratory conditions, with a newly calibrated measuring instrument (with test gas, immediately before the measurement) and without cross-influences from other components of the exhaust gas at ±5% NO, NO2 and CO and ±0.2% O2. In the case of NOx emissions in mg/Nm³ relative to a reference oxygen content, an accuracy of ±25 mg/Nm³@5%O2-dry can be achieved in the best-case scenario. Larger measuring tolerances must be expected as cross sensitivities to other exhaust gas components exist and no test gas is usually supplied for calibration on site.

Tolerances are added or deducted, depending on local emission regulations. If you don't know the exact regulations, you should always add the measuring tolerance to the measured value for safety's sake, i.e. keep the measuring tolerance and parametrise the LEANOX controller so that the sum of the two values remains below the setpoint value.

To comply with the required accuracy of emission measurement, use the exhaust gas analysers listed by INNIO in its standard tool catalogue or measuring instruments with the same or better measuring accuracy specification. The exhaust gas analysers are specified in TA 1310-0011.

6.1 Calibrating the test kit with test gas

If possible, use test gas (NO and NO2) to calibrate the emission-measurement equipment directly before the measurement and on site to compensate for the effect of pressure and temperature on the measuring cell. If this is not possible, keep a wider measuring tolerance, as contained in Section ⇨ Settings for NOx, when recalibrating the LEANOX controller.

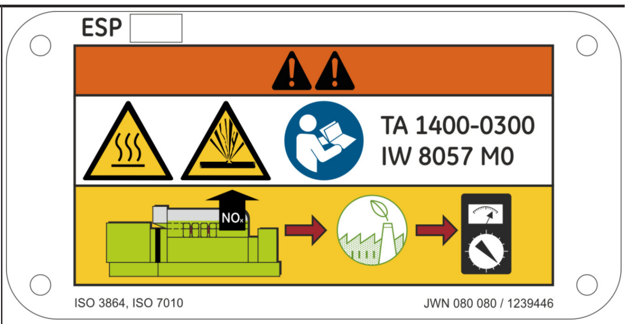
The measuring instrument must be tested, serviced and calibrated at least once a year in accordance with manufacturer's instructions. The manufacturer's calibration and maintenance record sheets must be retained and readily available.

6.2 Calibrating the test kit with ambient air

The exhaust gas test kit must be flushed and calibrated with ambient air before each measurement. You must make sure that the ambient air is not contaminated so as to avoid incorrect calibration. The calibration must take place at temperatures from >5°C up to a maximum of 40°C in well-ventilated premises or in the open air.

6.3 Emission sample point

A sample point must be provided to carry out the emission measurement. The dimension should be half an inch (not less) with a screw plug. The point must be freely accessible. The clearance required is 1 m x 1 m. A pipe wrench must be used to open the screw plug, i.e. the insulation must be designed to allow the pipe wrench to fit on to the screw plug. The **E**mission **S**ample **P**oints are entered on the technical diagram (ESP1.0, ESP2.0, etc.) and must be denoted on the plant with an appropriate sign.

Label, Part No. 1239446	

The emission sample points for the exhaust gas test kit vary according to INNIO Jenbacher GmbH & Co OG scope of supply and the local plant construction industry.

The plant operator is required to adhere to the emission values at the chimney outlet, so usually a suitable sample point on the chimney should be used to recalibrate the LEANOX controller.

Exceptions and additional measurements may arise in applications involving exhaust gas treatment units.

Examples of LEANOX recalibration:

- When oxidation catalysts are used -> LEANOX is recalibrated at the chimney, downstream of the chimney
- When Cl.Air systems are used -> LEANOX is recalibrated at the chimney downstream of the Cl.Air unit and the engine emissions are checked upstream of the Cl.Air unit NOx deviations of over 10% between the two values can indicate malfunctions and must be resolved.
- When SCR DeNOx or SCR Oxi-systems are used -> LEANOX is recalibrated downstream of the engine but **upstream** of where the reduction agent is added for the SCR; subsequently LEANOX shall be set to the contractually specified emission value (without taking account of the measuring tolerances) and the emission values checked at the chimney, once the SCR has reached a stable operating point.
- In the case of special gas plants with exhaust gas treatment, the emission values must also be determined downstream of the engine and documented, in addition to the measurement at the chimney. The recalibration of the LEANOX takes place at the chimney when the exhaust gas treatment unit is in INNIO scope of supply, or otherwise downstream of the engine.

Basically, the measuring probe should be positioned as centrally as possible in the pipe in the exhaust gas flow to be measured, but at least 100 mm from the internal wall towards the centre of the pipe, as far downstream as possible from the exhaust gas treatment systems. Striping in the exhaust gas system immediately downstream of the exhaust gas treatment system can lead to faulty measurements, but the exhaust gas is generally sufficiently mixed by the time it reaches the chimney, making it possible to obtain reproducible results at the chimney.

The sample points on the engine, e.g. in type 4 engines, are openings in the exhaust manifold downstream of the turbocharger and, in type 6 engines, the 90° bends downstream of the-turbochargers (measure both sides and, if necessary, adjust the engine so that the average value of both banks conforms to the specification). When insulating the plant, ensure that sample points remain freely accessible and cut-outs are provided in accordance with EHS.

All emission values in the exhaust gas measurement kit and its units must be entered in E 8057 - Operational data sheet – NOx measurement.

6.4 Background conditions for emission measurement

The engine must be at a stable operating point 10 minutes before the measurement and during the measurement. One indicator is the rated electric power, which may deviate from the power setpoint by a maximum of ±1.5 %. In addition, neither the engine cooling water temperature nor the mixture temperature should fluctuate by more than ±1°C. No serious misfiring should occur. This can be determined on the engine control system. The misfire integrator should be showing 0% and Idyn<3.0% over an observation period of one minute. You should also ensure that the average ignition point is stable (deviation <0.2 KW).

6.5 Performing the emission measurement

To be able to recalibrate and parametrise the LEANOX controller, you need at least password level 15 for enhanced access rights to DIA.NE XT controls. To have level 15 access enabled for you, you will have to complete various training courses, which are provided by the Jenbacher Product Training Center.

Read the operating instructions to familiarise yourself with the measuring instrument before starting the emission measurement. The measuring cells in the instrument must become acclimatised to the sample point (ambient pressure and ambient temperature). It is advisable to switch off the measuring instrument and leave it to acclimatise to the sample point for 1-2 hours. Only operate the measuring instrument in the temperature range >5°C up to a maximum of 40°C (see operating instructions).

6.6 Measuring time

It should take about two minutes to measure the emissions at each sample point. Average out the measured value over one minute and record it. As the measured value will fluctuate, record the maximum value and minimum value as well. If the fluctuation range is much bigger than ±5%, please contact the Service department.

6.7 Documentation

Record the measured values after the LEANOX adjustment. Record the following components in the appropriate unit and file them in the operational logbook as well as the service technician's report:

- NO in [ppm]
- NO2 in [ppm]
- O2 in [%]
- CO in [ppm] (optional, if available)
- NOx in [mg/Nm³@5%O2-dry]
- Actual electrical power output: Pel (not the parameter value)
- Actual charge air temperature: t2‘ (not the parameter value)
- Actual boost pressure: p2‘ (not the parameter value)

Formula for calculating NOx when using commercially available exhaust gas test kits (measuring the dry, condensed exhaust gas):

$$NO_x\left[\frac{mg}{Nm^3}@5\%O_{2trocken}\right] = \frac{NO_x\,[ppm] * \rho_{NO2}\left[\frac{kg}{m^3}\right] * (21 - O_{2Bezug}[\%])}{21 - O_2[\%]}$$

NOx	[ppm]	Sum of measured values for NO [ppm] and NO2 [ppm]
ρNO2	[kg/m³]	The density of NO2 is 2.05 kg/m³
O2referen ce	[%]	Reference oxygen, in this case O2reference is 5% (TA-Luft 2002)
O2	[%]	Measured value for oxygen in the exhaust gas in [vol. %]

Registering operational data: See E 8057 - Operational data sheet – NOx measurement

7 Settings for NOx

In accordance with and in implementation of the recommendations on the factors described in Section ⇨ Factors affecting emissions that influence NOx drift as well as the measurement tolerances in the exhaust gas test kit as described in Section ⇨ Measuring equipment and performing emission measurements, the NOx emission values for type 2/3/4 direct ignition engines must be set (using the LEANOX controller) to 80% up to a maximum of 85% of the NOx value specified by INNIO; for type 6/9 pre-combustion engines they must be set to 85% up to a maximum of 88%. The table below shows the absolute values to be set, taking as an example TA-Luft and TA-Luft-Halbe (figures in mg/Nm³ at 5%O2-dry):

Example:

Limit value	**500**	**250**	
Note	TA-Luft	TA-Luft-Halbe	
Unit	mg/Nm³@5%O2-dry		
Series	Average set value		
2/3	400…425	200…215	Direct ignition method
4	400…425	200…215	
6	425…440	210…220	Pre-chamber combustion method
9	425…440	-	

Remark:

A new engine or an engine with new combustion chamber components (pistons with piston rings combined with cylinder liner) must be run in during the first few hours of operation. This will increase the ingress of oil into the combustion chamber, which will affect NOx emissions. You can evaluate the exact situation by measuring the oil consumption. An aid to determining oil consumption is provided in TA 1503-0050. Oil consumption increases during the first 2,000 – 6,000 Oh and then stabilises at a constant lower value. During this initial time span, measure and set the NOx emissions at short intervals as specified in the maintenance plan. If you notice that there is substantial NOx drift and the limit value is being exceeded, carry out the maintenance work "LEANOX recalibration" at half intervals as specified in the maintenance plan.

8 Revision code

Revision history

Index	**Date**	**Description / Revision summary**	**Expert** *Auditor*

Revision history

2	30.04.2019	GE durch INNIO ersetzt / GE replaced by INNIO	**Stojiljkovic T.** *Pichler R.*
1	15.05.2017	Erstausgabe / First issue	**Fuchs J.** *Boewing R.*