

Produkt / Product: Planar Wide Band Lambda Sensor

Typ / Type: LSU 4.2

Bestellnummer / Part Number: 0 258 007 ...

Angebotszeichnung / Offer Drawing: A 258 400 ...

Gültig ab / Valid from: 21.3.2001

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-	-	Erstausgabe / First Edition	26.5.97			
1.1	3	Trim resistance range added				
1.3	3	Iso. measurement conditions				
1.4	4	Heater supply spec. extended				
1.5	4	Heater supply frequency added				
2.7	6	Pumping current limits added				
4	8,9	Change of characteristic line and target $R_i=80\Omega$				
5.10	13	FV test for LSU4.2 added				
5.12	13	Gas leakage test pressure inc.				
5.13	13	Drop test added				
7.1	15	Assessment of field sensors				
8	17	Variation LSU4.2 added				
		Variation d2 added				
9.9	19	Sensor boss Spec. extended				
9.16	20	Note for water dripping added				
10.7	22	Note for interpret. AWS/CJ110	25.1.99			
2.3/4	5	Temperature spec. extended				
4	8-10	Characteristics extended				
7.1	16	Characteristics aged changed				
8	18	Variation "d4" prot. tube				
		Variation short PTFE tube				
		Variation "Inconel tube" deleted				
		Variation LSU4.7 deleted				
9.9	20	Sensor boss spec. extended	6.10.00			
5.12	15	Gas leak test reworked				
4.1	8	characteristics for "d4" variant	21.3.01	gez Hamann gez Meier	gez Neumann	

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Reference Specifications

Application guideline	KGS_LS (APP 108)
Handling instruction	Y 258 E00 000
Temperature measurement sensors	Y 258 E00 001
Test method: measurement temperature and thermoshock	Y 258 E00 003
Measurement in synthetic gas (PSG)	Y 258 E00 004
LSU test bench and test method	Y 258 E00 005

For design variations different values are marked.
 For explanation of variations see section 8.

General

The wide band lambda sensor LSU is a planar ZrO₂ dual cell limiting current sensor with an integrated heater. It is used to measure the oxygen contents and the λ -value of engine exhaust gases. Its monotonic output signal in the range of $\lambda=0.7$ to air makes the LSU capable of being used as an universal sensor for $\lambda=1$ measurement as well as for other λ ranges.

The connector module contains a trimming resistor, which defines the characteristics of the sensor and is necessary for the sensor function.

The wide band sensor LSU operates only in combination with a special control unit.

1. Characteristics

1.1 Electrical connection: 6 pole
 Range of trim resistor 30 ... 300 Ω

1.2 Heater supply

The heater supply voltage must be controlled, so that the temperature of the sensor is kept at a nominal temperature of approx. 750°C.

Nominal voltage, test voltage: 9 V

Nominal heater power at 9 V heater supply
 at thermal equilibrium (exhaust gas
 temperature 350°C, exhaust gas flow
 rate approx. 0.7 m/s): approx. 10 Watt

Nominal heater cold resistance at 20°C
 ambient temperature for new sensor,
 including cable and connector: 3.2 Ω

Minimum heater cold resistance at -40°C: 2.1 Ω

1.3 Isolation resistance

between housing and each heater- and
 sensor circuit connector pin under normal
 conditions (23°C/50% humidity) with heater off: $\geq 30 \text{ M}\Omega$

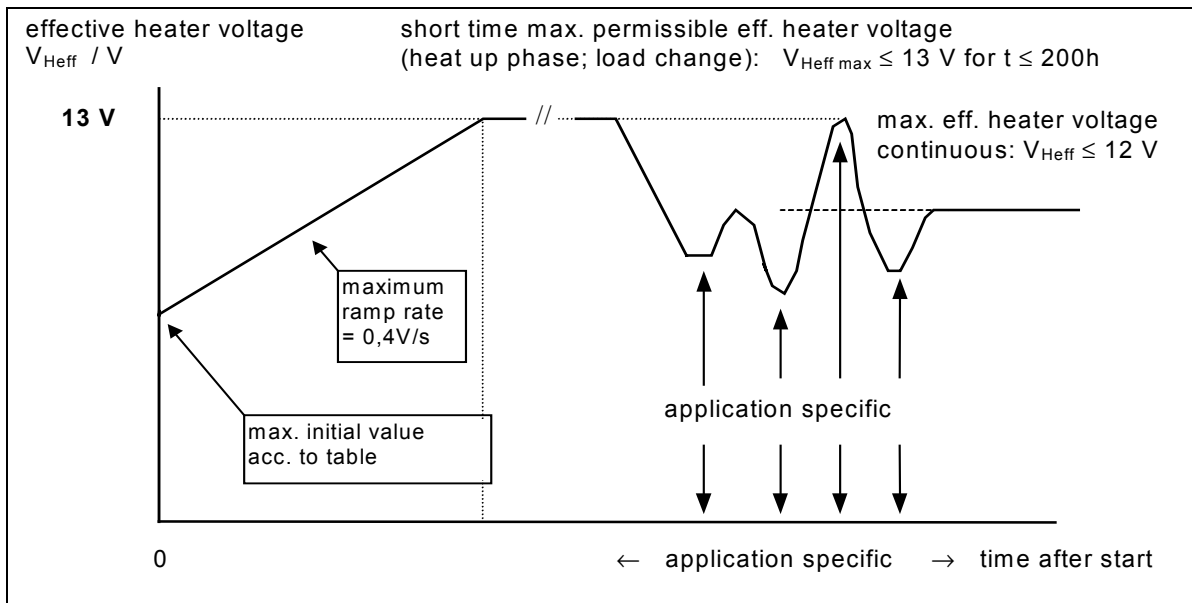
between sensor circuit and housing
 at 530°C hexagon temperature, new and
 after 500 h aging acc. to section 5.1: $\geq 100 \text{ k}\Omega$

1.4 When the heater is switched on, heater power must be limited as follows:

- the initial value of heater voltage during the heat-up phase is dependent on the temperature of the sensor at start.
For "fast light off" **all** conditions acc. to Y 258 E00 003 sec. 1.4.2 must be fulfilled, (e.g. sensor position close to engine, rapid heat up of exhaust gas).

$T_{\text{Sensor}} / ^\circ\text{C}$		-40	-10	20	50
$V_{\text{H,eff,max}} (t=0) / \text{V}$	(standard)	7.4	7.8	8.2	8.6
	(fast light off)	9.0	9.5	10.0	10.5

- ramp rate $\Delta V_{\text{H,eff}} / \Delta t \leq 0,4 \text{ V/s}$



Maximum permissible heat up rate with limited heater power to reduce the thermal stresses in the heat-up phase

1.5 Maximum permissible effective heater voltage $V_{\text{H,eff}}$ at $T_{\text{ceramic}} < 900^\circ\text{C}$

- short time $\leq 200\text{h}$: $\leq 13 \text{ V}$
- continuous: $\leq 12 \text{ V}$

Minimum frequency of heater voltage control

- at supply voltage V_{batt} (peak) $\leq 16\text{V}$: $\geq 2 \text{ Hz}$

Note: the use of the sensor with 24V power systems is not recommended.

Note: duty cycle = $(V_{\text{H,eff}} / V_{\text{batt}})^2$

2. Application conditions

For all temperature measurements refer to section 3: test methods.

2.1 Temperature range, passive: -40°C ... +100°C
(storage temperature)

2.2 Operating temperatures

Exhaust gas at sensor element: ≤ 930°C

Hexagon of the sensor housing: ≤ 570°C

Cable grommet (PTFE formed hose)
- sensor side: ≤ 250°C
- cable side (upperhose crimp): ≤ 200°C

Cable and protective sleeve: ≤ 250°C

Connector: ≤ 120°C

2.3 Maximum temperatures (max. 250 h accumulated over lifetime)

Exhaust gas at sensor element: ≤ 1030°C

Hexagon of the sensor housing: ≤ 630°C

2.4 Maximum temperatures (max. 40 h accumulated over lifetime)

Cable grommet (PTFE formed hose)
- sensor side: ≤ 280°C
- cable side (upperhose crimp): ≤ 230°C

Cable and protective sleeve: ≤ 280°C

Notes:

If the exhaust gas temperature of 850°C is exceeded, the heater power must be switched off. In this case the accuracy of the sensor signal is limited.

If the max. gas temperature exceeds 850°C or hexagon temperature exceeds 500°C, the use of a longer thread boss is recommended (see section 9.9).

If the operating temperature is exceeded (within the max. temperature limits) for more than 10 minutes without break, the sensor function might be affected during this time.

2.5 Temperature of sensor ceramic element with condensation water present at exhaust side: ≤ 350°C
Note: sensor is not ready to control at a sensor temperature of 350°C

2.6 Permissible vibrations
(measured at the sensor housing)

Stochastic vibrations:
(peak level) $\leq 1000 \text{ m/s}^2$

Sinusoidal vibrations
- vibration displacement: $\leq 0.3 \text{ mm}$
- vibration acceleration: $\leq 300 \text{ m/s}^2$

2.7 Max. current load of $\lambda=1$ Nernst-cell

Continuous DC: $\leq 10 \text{ }\mu\text{A}$
Continuous AC ($f = 1 \dots 4 \text{ kHz}$) $\leq 250 \text{ }\mu\text{A}$
for R_I measurement

Max. pumping current into pump cell
- for rich gas signal $\geq -9 \text{ mA}$
- for lean gas signal $\leq 18 \text{ mA}$

2.8 Permissible fuel additives
In accordance with DIN EN228 for commercially
available unleaded fuel.

For use of leaded fuel see section 7.2

2.9 Oil consumption and oil brand
Permissible figures and data must be determined by the
customer by the way of adequate large-scale tests.

Guide value: $\leq 0.7 \text{ l/1000 km}$

2.10 Silicon resistance ref. to test 5.11**2.11** Lifetime
The technical development of the sensor is aligned to a service life of
160.000 km and a maximum life time of 10 years. Failure criterion is the
non-compliance with the measurement data as mentioned under section 7.

The following conditions must be fulfilled in order to reach this service
life:

- Application conditions acc. to section 1 and 2.
- Installation conditions acc. to section 9.
- Checking of each application/installation location according to applica-
tion guideline KGS_LS
- Usage of a RB approved sensor connector with single chamber sealing and
gold plated sensor signal contacts.

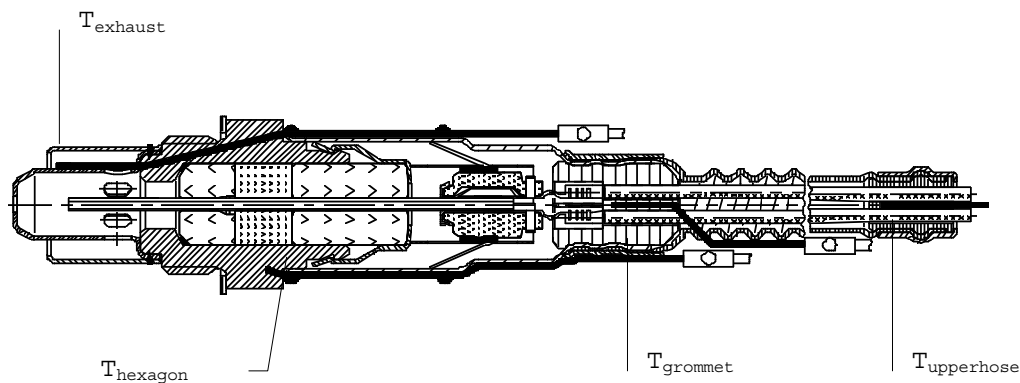
The commercial warranty and liability is regulated in the conditions of
delivery, independent of the above figures.

3. Test methods

3.1 Temperature measurement

Temperature measurements are performed with a special sensor equipped with NiCrNi thermoelements, see sketch. Sensor Type "MM" has measurement points at the upper side of the PTFE formed hose ($T_{\text{upperhose}}$), the cable grommet (T_{grommet}) and at the hexagon of the sensor housing (T_{hexagon}). The sensor type "MXT" has an additional measurement point for the exhaust gas temperature (T_{exhaust}).

For more information see description of temperature measurement sensors Y 258 E00 001 and description of measuring method Y 258 E00 003.



3.2 Test benches and test methods for measuring the functional values as in section 4:

Synthetic test gas test bench (PSG)
LSU test bench and test method

Y 258 E00 004
Y 258 E00 005

Special hints for carrying out test bench measurements:

Due to the limited measurement device capability of the gas test benches cpk calculations with the specified tolerances are not useful.



4. Functional values

The measurement is done with the sensor operated with a AWS control unit. The given tolerances are only for the lambda sensor LSU4. The heater power is closed-loop controlled while the measurement is done, so that a nominal sensor internal resistance of $R_{IN}=80\Omega$ (measured with 1...4 kHz) is reached, this corresponds to a sensor ceramic temperature of approx. 750°C in new state.

4.1 Measurement at $\lambda = 1$ in synthetic gas test bench at 350° gas temperature acc. to test method Y 258 E00 004:

Sensors with protection tube "d1", see sec. 8	New	After 500h test bench run see 5.1	After 2000h test bench run see 5.1
λ static (pump current $I_p=0$)	1.009 ± 0.006	1.009 ± 0.007	1.009 ± 0.008
λ dynamic	1.010 ± 0.006	1.010 ± 0.007	1.010 ± 0.008
Frequency [Hz]	2.8 ± 0.8	2.8 ± 1.0	2.6 ± 1.0

Sensors with protection tube "d2"	New	after 500h	after 2000h
λ static (pump current $I_p=0$)	1.009 ± 0.006	1.009 ± 0.007	1.009 ± 0.008
λ dynamic	1.010 ± 0.006	1.010 ± 0.007	1.010 ± 0.008
Frequency [Hz]	2.3 ± 0.8	2.3 ± 1.0	2.1 ± 1.0

Sensors with protection tube "d4"	New	after 500h	after 2000h
λ static (pump current $I_p=0$)	1.010 ± 0.006	1.010 ± 0.007	1,010 ± 0,008
λ dynamic	1.010 ± 0.006	1.010 ± 0.007	1,010 ± 0,008
Frequency [Hz]	2.8 ± 0.8	2.8 ± 1.0	2,6 ± 1,0



4.2 Measurement of rich and lean characteristic in LSU test bench at 20° gas temperature acc. to test method Y 258 E00 005:

	New	After 500h test bench run see 5.1	After 2000h test bench run see 5.1
Measurement gas for $\lambda=1.7$: 8.29% O ₂ in N ₂ at p=1013 hPa			
λ signal at $\lambda=1.7$: (*)	1,70 ± 0,05	1,70 ± 0,10	1,70 ± 0,15
Measurement gas for $\lambda=0.8$: 3.15% H ₂ , 3.15% CO ₂ , 4.05% CO in N ₂ at p=1013 hPa			
λ signal at $\lambda=0.8$:	0.80 ± 0.01	0.80 ± 0.02	0.80 ± 0.04

(*) For other λ values and operating conditions the λ tolerances can be calculated.

For the range of $\lambda > 1$: $\Delta\lambda = \lambda(\lambda-1)\Delta I_P/I_P$

For a H/C-ratio of H/C=2: $\lambda = (x_{O_2}/3 + 1) / (1-4.76*x_{O_2})$

4.3 Measurement of the light-off time of the sensor in synthetic gas test bench at 20° gas temperature acc. to test method Y 258 E00 004:

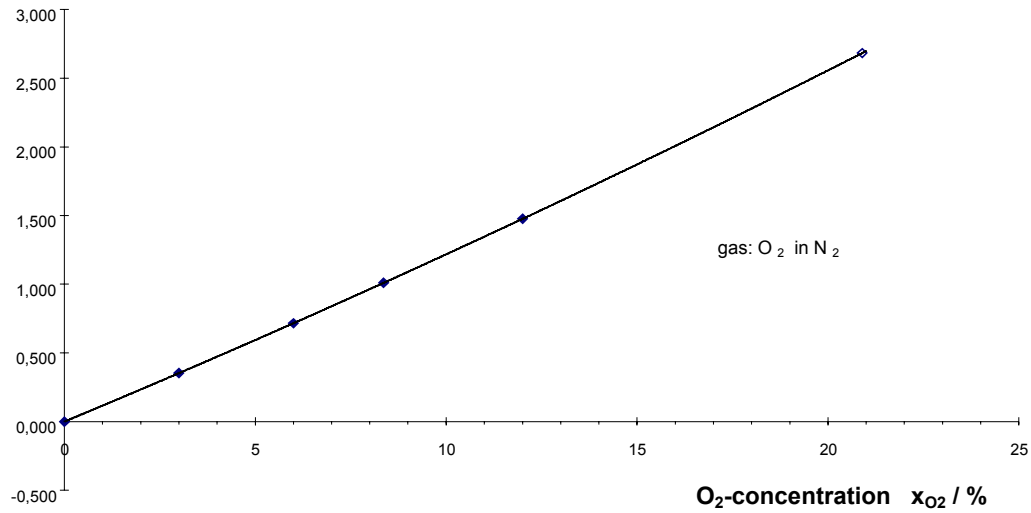
	New	After 500h test bench run see 5.1	After 2000h test bench run see 5.1
Light-off time [s]	≤ 20	≤ 20	≤ 20

Note: in the engine the light-off time might be shorter, depending on installation and gas temperature conditions.

4.4 Nominal characteristic line

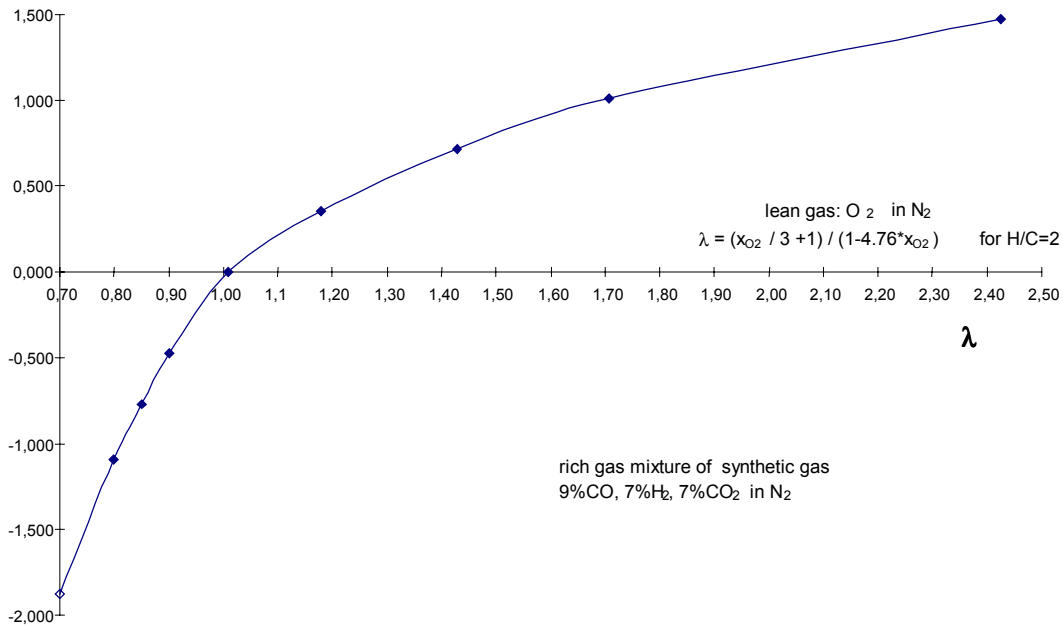
Characteristic current through measuring resistance 61.9Ω , $p_{gas}=1013hPa$, internal resistance of $\lambda=1$ Nernst cell $R_{IN} = 80\Omega$ (AC 1...4 kHz)

$I_{p, meas} / mA$



O ₂ -conc. x _{O2} /%	0,0	3,0	6,0	8,29	12,0	20,9
I _{p, meas} / mA	0,00	0,34	0,68	0,95	1,40	2,55

$I_{p, meas} / mA$



λ -value	0,70	0,80	0,85	0,90	1,009	1,18	1,43	1,70	2,42	207
I _{p, meas} /mA	-1,85	-1,08	-0,76	-0,47	0,00	0,34	0,68	0,95	1,40	2,55

Note: these characteristics are valid for the specified test gas only. They may be different for real engine exhaust gas and must be determined separately.

5. Environmental test specification

Each test must be carried out with new sensors. If not otherwise specified, after the tests the sensors must fulfill the functional values of new sensors as in section 4. The tests are carried out with an applied heater voltage of 9V, if not otherwise specified.

5.1 Engine endurance run

For measurements of functional values after endurance test the sensors have to be fitted into the exhaust system of a $\lambda=1$ controlled gasoline engine. The sensors are operated with a LSU control unit in this test (closed loop control of heater power).

Speed and load are changed in a 6-cycle program so that a temperature curve is reached in the sensor tip as per sketch.

- Fuel: according to DIN EN228 for commercially available unleaded fuel.

- Oil consumption $\leq 0,04$ l/h.

- Oil brand: multi-range oil viscosity 10W-40, API specification SF.

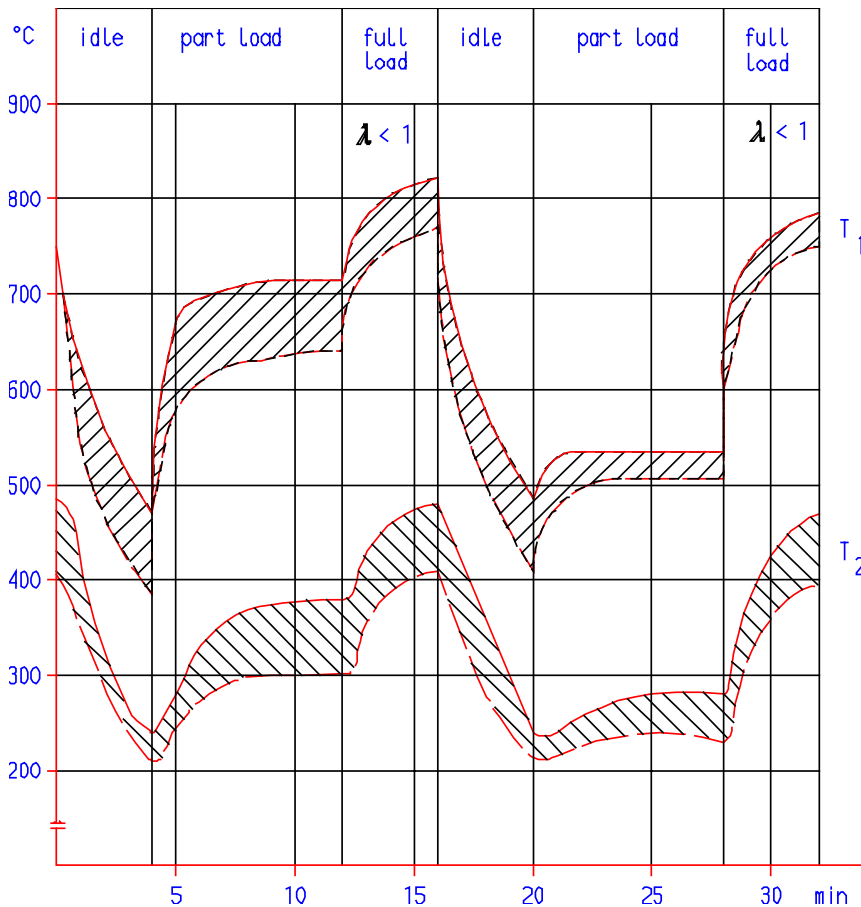
Compliance with the temperature limits as per section 2 must be ensured by adequate cooling. After the test the functional values for aged sensors in section 4 must be fulfilled.

The exhaust gas temperature is set by varying engine speed and load.

The temperature at the hexagon is limited by additional air cooling.

T1 = exhaust gas

T2 = housing hexagon



5.2 Sinusoidal vibration test acc to IEC 68-2-6 test Fc

Test equipment: electrodynamic vibrator

Test between 50...150 Hz at constant amplitude $\pm 0,3$ mm and between
150...500 Hz at constant acceleration of ± 300 m/s².

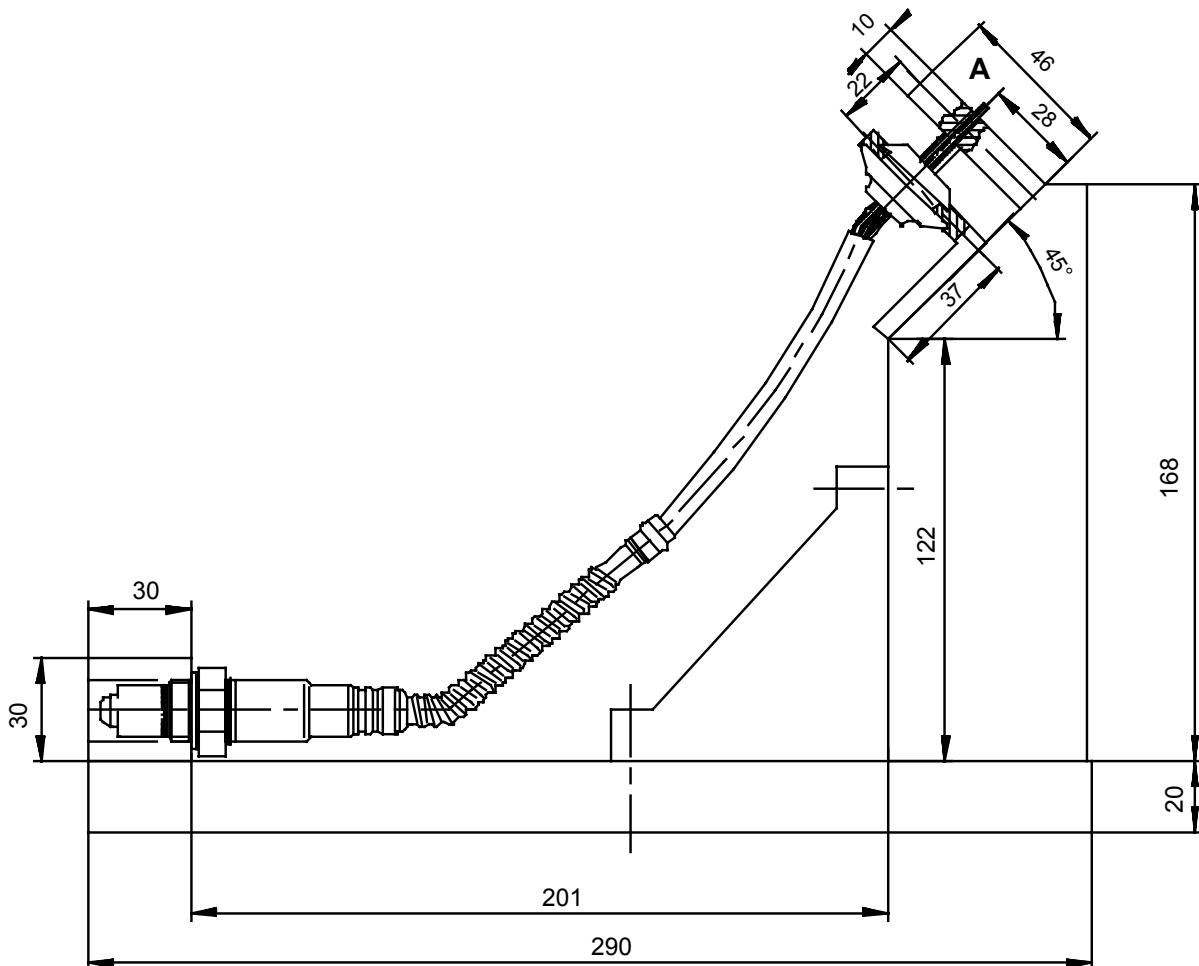
Frequency change velocity: 1 octave/min.

Test duration: 8 h to be performed in all 3 perpendicular planes.

Ambient temperature: 25 ± 3 °C.

Sensor mounting see sketch. In order to provide a defined wire sag, the cable end is at first pre-tensioned with 5 N and then moved 10 mm towards the sensor and fixed in position A.

Sensor mounting for vibration test



5.3 Random vibration test

Test equipment:	Random vibration test bench as per Bosch standard N42 AP 411.
Acceleration:	1000 m/s ² (peak level)
Test duration:	24 h
Sensor mounting:	same as 5.2
Ambient temperature:	25 ± 3°C

**5.4 Test with damp heat, cyclic (12+12-hour cycle)
acc. to IEC 68-2-30, test Db**

No. of cycles:	21
max. air temperature:	40°C

The heater has to be switched off during this test.

5.5 Salt mist test acc. to IEC 68-2-11, test Ka

Testing time:	288 h
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The sensor heating is switched on 5 minutes before and during testing. In order to prevent water from reaching the exhaust side sensor ceramic a stainless steel sleeve is screwed onto the sensor thread for proper sealing.

5.6 Change of temperature acc. to IEC 68-2-14, test Na

Minimum temperature:	-40 °C
Maximum temperature:	130 °C
Exposure duration at each temp.:	30 min.
No. of temperature cycles:	250

The heater has to be switched off during this test.

**5.7 Sulfur dioxide test with general condensation of moisture
acc. to DIN EN ISO 6988**

No. of cycles:	6 (24 h for each cycle)
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The heater has to be switched off during this test.
In order to protect the exhaust side sensor ceramic a stainless steel sleeve is screwed onto the sensor thread for proper sealing.

5.8 Submergence test acc. IEC 529, IPx7

Water level 150 mm above sensor cable outlet. Test duration is 30 min. The connection system must be out of the water during the test. The sensor is operated with a LSU control unit in this test, the sensor signal is monitored. In the test time the signal must be stable.

5.9 Wire pull test

The mounted sensor has to withstand an axial force of 100 N applied to the connector for 1 min.

5.10 Fuel vapor test

The exhaust gas side of the sensor is exposed to fuel vapor of 43°C in a test chamber. The soak time is 2 h. After this the sensor is removed and then heated with 9V. The $\lambda=1$ -cell signal of the sensor in ambient air is monitored for the time t_{meas} . A failure is defined as a decrease of the lean output voltage of the $\lambda=1$ cell below -100 mV.

t_{meas} : 120 min

5.11 Silicon resistance test

Engine test run with additional silicon content in fuel. The sensors are fitted in the exhaust pipe of a $\lambda=1$ controlled engine as in 5.1 (with LSU control unit), but operated under the following conditions:

exhaust gas temperature	: 400°C
test time	: 6 h
Silicon content in fuel	: 0.12cm ³ /l Oktamethylcyclotetrasiloxane
fuel consumption over the test time	: 18 l

Test evaluation: after the test λ_{static} (see section 4) must be within the range of 1.000 ... 1.022

5.12 Fine leak test

The gas leakage is measured from exhaust gas side with an air pressure of 4 bar. The leakage rate must be smaller than 0.1 ml/min.

5.13 Drop test acc. to IEC 68-2-32 test Ed proc. 1

The sensor is dropped to a concrete floor from a height of 1m for one time.

6. Production monitoring tests

For monitoring production quality the following tests are carried out on a regular basis:

500 h engine endurance run as in 5.1
(audit test)

Submergence test equivalent to 5.8
(audit test)

Wire pull test as in 5.9
(audit test)

Sensor characteristics as in section 4
(lot release test)

Sensor function test
- calibration of sensor characteristic in synthetic lean gas
- functional test in synthetic rich gas
(100% test)

Fine leak test as in 5.12
(audit test)

Isolation resistance between heater, sensor signal circuit and housing
under normal conditions acc. to 1.3
(100% test)

Isolation resistance between sensor signal circuit and housing under hot
conditions acc. to 1.3
(audit test)

**7. Assessment of aged sensors****7.1 Sensors from general endurance runs and from field operation**

The measurement is done with measurement conditions as in section 4.

Measurement of rich and lean characteristic in LSU test bench at 20° gas temperature acc. to test method Y 258 E00 005:

Measurement gas for $\lambda=1.7$: 8.29% O ₂ in N ₂ at p=1013 hPa	
λ signal at $\lambda=1.7$: (*)	1,70 ± 0,15
Measurement gas for $\lambda=0.8$: 3.15% H ₂ , 3.15% CO ₂ , 4.05% CO in N ₂ at p=1013 hPa	
λ signal at $\lambda=0.8$:	0.80 ± 0.04

If these figures are complied with, it can be expected that the sensor will be capable of closed loop control under normal operation conditions. However since a vehicle's exhaust gas emission values also depend to a great extent upon other components in the system (engine, catalytic converter, mounting position, closed-loop control circuit), these figures cannot be taken as a reliable indication of emissions behavior in an emission test.

7.2 Sensors Used with leaded fuel

Depending on the lead contents of the used fuel the expected service life time is: (preliminary data)

- for 0.6 g Pb/l: 20 000 km
- for 0.4 g Pb/l: 30 000 km
- for 0.15 g Pb/l: 60 000 km

In general, when using leaded fuel the sensor will be replaced, when functional problems occur, e.g. unstable idle speed, driveability problems.

The system diagnose functions should be rechecked for the reduced demands on the sensor and the increased response times when leaded fuel is used.

7.3 General function test

The following tests can be done as a rough check of the sensor function (operation with control unit):

Plausibility check in rich exhaust gas:

- sensor signal: rich

Plausibility check on air:

- sensor signal: air signal

Heater cold resistance at room temperature:

- resistance measurement with multimeter between grey and white cable, sensor not connected to control unit, connector pinout see offer drawing:

$$R_{H,cold} = 2,5 \dots < 10 \Omega$$

Visual inspection for mechanical damage

If a failure is seen in the above tests, the sensor should be installed in another test bench or vehicle and tested again. Goal: Exclude a failure of the wire harness or the control unit resp. the ECU.

8. Design variations

The following variations are available:

8.1 Protection tubes

Sensor with protection tube type "d1" with big holes.

Sensor with protection tube type "d2" with smaller holes.

Sensor with protection tube type "d4" with smaller holes.

Sensors with d2 and d4 tube can be applied in cases of high particulate concentration in the exhaust gas. The d2 protection tube gives also a partial improvement regarding the resistance against condensation water in the exhaust gas at engine start (thermoshock).

8.2 PTFE formed hose

Longer PTFE hose at cable grommet for installation with critical temperature conditions in the sensor area.

Shortened PTFE hose at cable grommet.

Note: the temperature resistance is the same for both types at the defined measuring points.

9. Installation instructions

In general, the sensor installation point must be tested sufficiently by the customer for function and durability in the respective application.

- 9.1** Installation in the exhaust system must be at a point guaranteeing representative exhaust gas composition whilst also satisfying the specified temperature limits.
- 9.2** The heater power must always be switched on power controlled (e.g. duty cycled heater power), starting with a maximum ramp-up duty cycle as shown in the diagram in section 1.4. This is necessary to reduce thermal stress of the sensor element at cold start due to high peak power in the first seconds.
- 9.3** The active sensor ceramic element is heated up quickly when the heater power is switched on. This means that the sensor installation location must be selected to minimize exhaust side stressing of the sensor ceramic element with condensation water in order to prevent ceramic element cracking.

Design measures:

- Locate sensor as close to the engine as possible, respecting max. allowed temperature range
- Attempt to achieve rapid heating-up of the exhaust pipes in the area in front of the sensor.
- The exhaust pipe in front of the sensor should not contain any pockets, projections, protrusions, edges, flex-tubes etc. to avoid accumulation of condensation water. A downwards slope of the pipe is recommended.
- Make sure, that the front hole of the double protection tube does not point against exhaust gas stream.

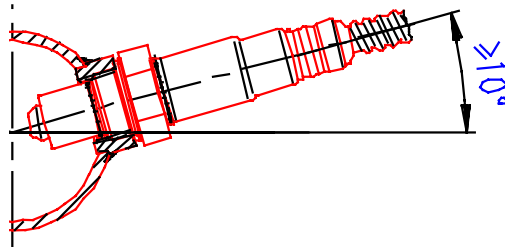
System measures:

- Never switch on sensor heating resp. control unit before engine start.
- Delay of sensor heater start or power control of the sensor heater (see diagram in 1.4) as a function of engine and ambient temperature.

For more information see test method Y 258 E00 003.

- 9.4 Installation angle should be inclined at least 10° towards horizontal (electrical connection upwards). Thus preventing the collection of liquids between sensor housing and sensor element during the cold start phase.

Other installation angles must be inspected and tested individually.



- 9.5 Avoid excessive heating up of sensor cable grommet, particularly when the engine has been switched off after running under max. load conditions.

- 9.6 The use of cleaning/greasing fluids or evaporating solids at the sensor plug connection is not permitted.

- 9.7 Assembly with special high temperature resistant grease on the screw-in thread (e.g. Bosch-No. 5 964 080 112 for the 120g tin).

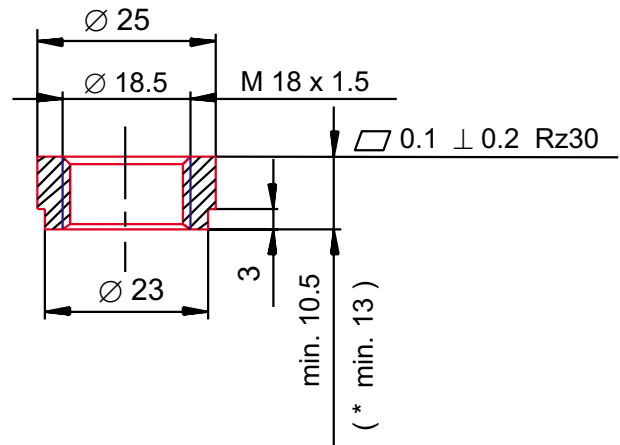
- 9.8 Tightening torque: 40-60 Nm, material characteristics and strength of the thread must be appropriate.

- 9.9 Recommended material for the thread boss in the exhaust pipe:

Temperature resistant stainless steel, e. g.
X 5 CrNi 18 10, DIN 17440 1.4301 or 1.4303 or SAE 30304 or SAE 30305 (US standard)
Thread boss dimensions should be as in sketch, note that sensor thread must be covered completely.

Note (*): For hot applications ($T_{\text{Hexagon}} > 500^{\circ}\text{C}$) the thread boss should be min. 13mm or longer to avoid overheating of the protec-

tion tube welding and to cool down the sensor hexagon.



- 9.10 The sensor must be covered when underbody sealant (wax, tar etc.) or spray oil is applied to the vehicle.

- 9.11 The influence of contamination which enters the exhaust gas through the intake air or as a result of fuel, oil, sealing materials etc., and thus reaches the λ -sensor, is application specific and must be determined by customer tests.

- 9.12** The sensor must not be exposed to strong mechanical shocks (e.g. while the sensor is installed). Otherwise the sensor element may crack without visible damage to the sensor housing.
- 9.13** For physical reasons the sensor needs ambient air at its reference gas side. Replacement of the air volume inside the sensor must be guaranteed by a sufficient air permeability of the wires and the connectors between sensor and ECU. The breathability should be higher than 1 ml/minute at a test pressure of 100mbar.
The current Bosch LSU connector is available with an integrated pressure compensation hole with a permeable membrane, which guarantees a sufficient air supply. This hole must be saved from deterioration as wax, oil etc.
- 9.14** Underfloor installation of the sensor at a distance from the engine requires an additional check of the following points:
- positioning of the sensor with respect to stone impact hazard
 - positioning and fixing of cable and connector with respect to mechanical damage, cable bending stress and thermal stress.
- 9.15** The PTFE formed hose is part of the reference air volume of the sensor and must be kept sealed and undamaged. For installation, the minimum bending radius of the hose must be 20mm (for long PTFE hose) resp. 12mm (for short hose). Keep the PTFE formed hose away from sharp edges and avoid contact/friction with frame/engine assembly.
The first fixing point for the cable to the car body should be 200mm to 400mm after the end of the PTFE formed hose, depending on movement of the exhaust system.
- 9.16** The sensor should not be exposed to continuous, one-sided dripping of water, e.g. by the air conditioning condensation water outlet. The thermal stress could lead to mechanical damage of the sensor.

10. Operating instructions

10.1 Conditions for connection and electrical operation of the sensor

It must be assured, that when the sensor is operated, the connection to the control unit is save and not disconnected during operation, or that the control unit diagnosis recognizes a failing connection.

It is also not allowed, to disconnect or to connect the sensor to the control unit or ECU while the sensor or control unit is being operated.

Background: if the signal of the $\lambda=1$ cell is missing (e.g. connection failure), the internal control circuit can not operate correctly, so that

a) an excessive pumping voltage with wrong polarization can destroy the pumping cell of the sensor

b) the sensor element can be destroyed by overheating, when the closed loop heater control is not able to measure the ceramic temperature

The control unit may only be switched on after the sensor is connected completely.

The sensor cables may never be connected in the wrong way or wrong polarity, otherwise the sensor might be destroyed.

10.2 Use without control unit

The sensor might stay in the exhaust gas stream for a short time also if the control unit is not connected. Connect and disconnect only, when the control unit is switched off.

10.3 Use of LSU outside of the exhaust gas system

The sensor can also be used outside an exhaust gas system, e.g. on air.

When used in a stoichiometric or rich gas ($\lambda \leq 1$), e.g. measurement gas in the test bench, it must be assured, that enough O₂ donators are available in the gas to allow the pumping cell to work. Otherwise the ZrO₂ ceramic of the sensor can be reduced and the sensor destroyed.

The O₂ donator may be free oxygen (non-equilibrium measurement gas), H₂O or CO₂.

Guide values:

H ₂ O:	≥ 2 vol %
CO ₂ :	≥ 2 vol %

10.4 Electrical heating of the sensor

The sensor heater may never be connected directly to battery voltage, it must always be controlled by the LSU control unit or the vehicle ECU. Heating the sensor before the engine is started is not allowed, see also section 9.3.

10.5 Sensor characteristic at low or high exhaust gas temperatures

Cold exhaust gas in addition to high gas velocity can lead to a reduced sensor ceramic temperature, when the heater control is not able to keep the constant ceramic temperature. This leads to a deviation of the sensor output signal.

Hot exhaust gas with a temperature above the operation temperature of the ceramic also leads to a deviation of the ceramic temperature and the sensor output signal.

Guide value: a temperature change of the sensor ceramic gives a deviation of the sensor output signal $\Delta I_p / I_p$ of approx. 6%..7% / 100K.

10.6 Pressure dependency of the sensor signal

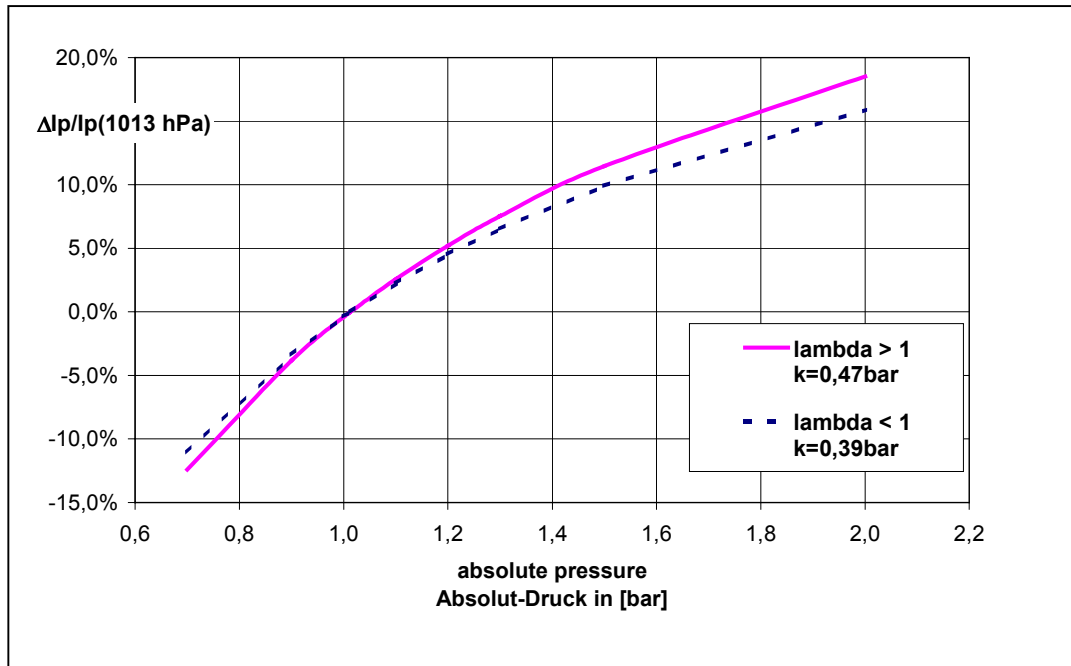
A pressure change of the measured gas gives a deviation of the sensor output signal of:

$$I_p(p) = I_p(p_0) * p / (k+p) * (k+p_0) / p_0$$

The factor k is depending on operation conditions "rich" or "lean" and is for the measuring gas from LSU test bench in section 4.2:

$$k_{lean\ gas} = 0.47\ bar$$

$$k_{rich\ gas} = 0.39\ bar$$



10.7 Note for calculation of the sensor signal I_p when using a control unit AWS or CJ110:

Output voltage AWS : $V_{AWS} [V] = 2.5 + 1.648 * I_{p, meas} [mA]$

Output voltage CJ110 : $V_{CJ110} [V] = 1.5 + 1.053 * I_{p, meas} [mA]$