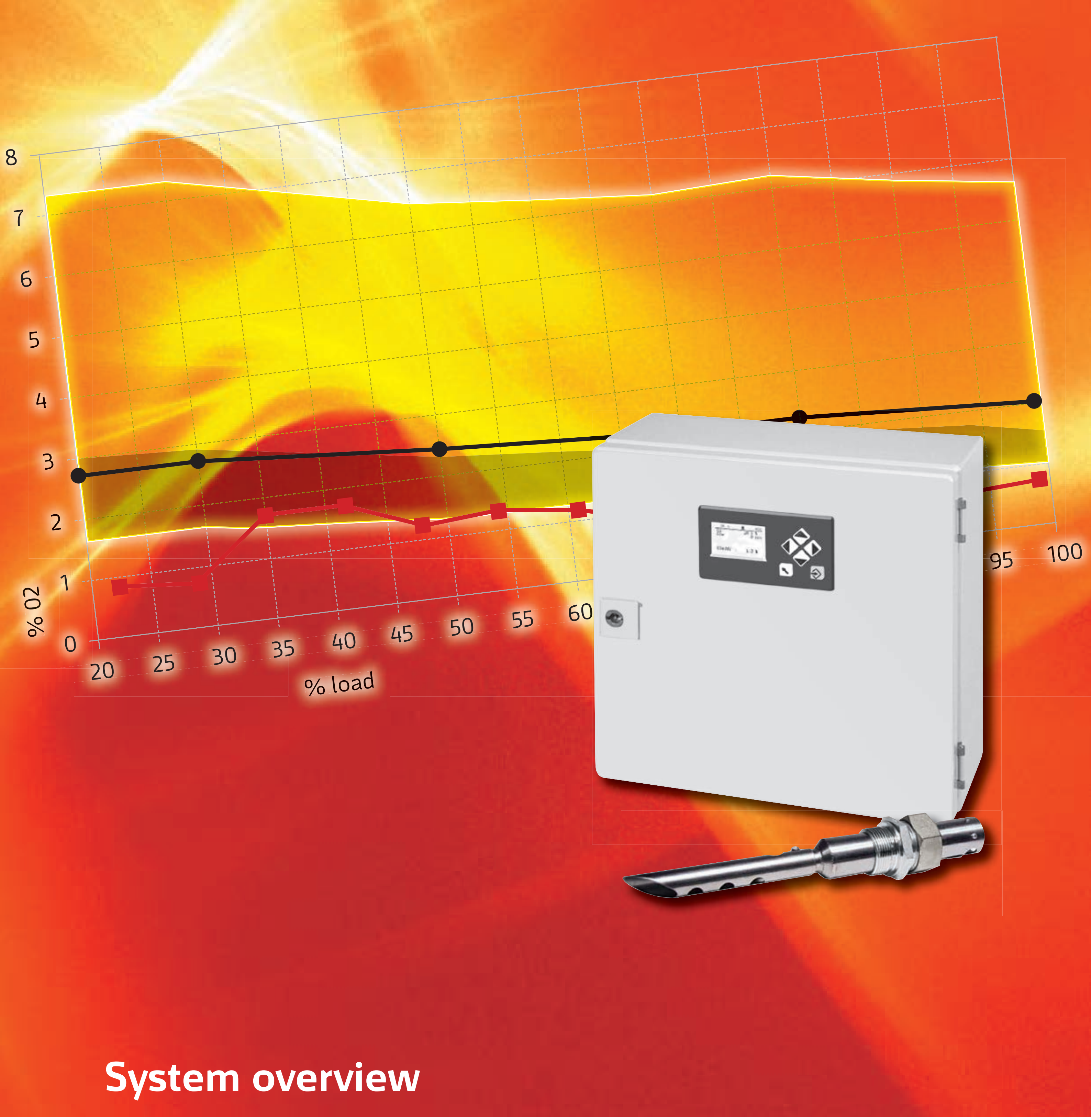


System overview

CO/O_2 control - SIL2
Lambda Transmitter LT3-F

LAMTEC

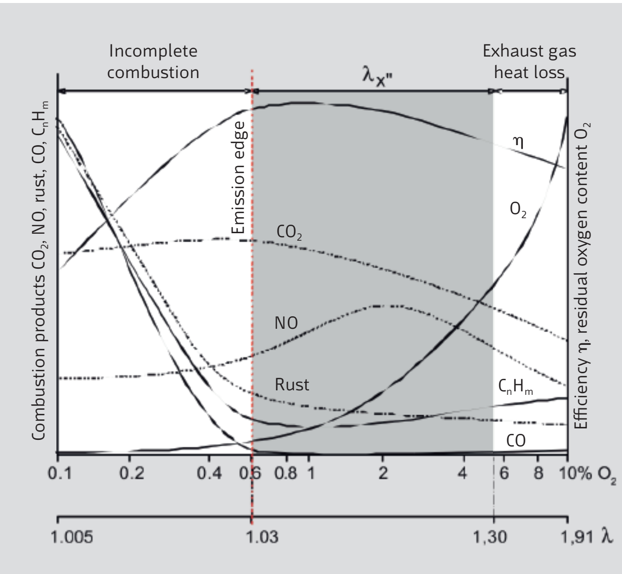
Sensors and systems for combustion engineering

www.lamtec.de

CO/O_2 control – the better alternative to O_2 control for gas combustion.

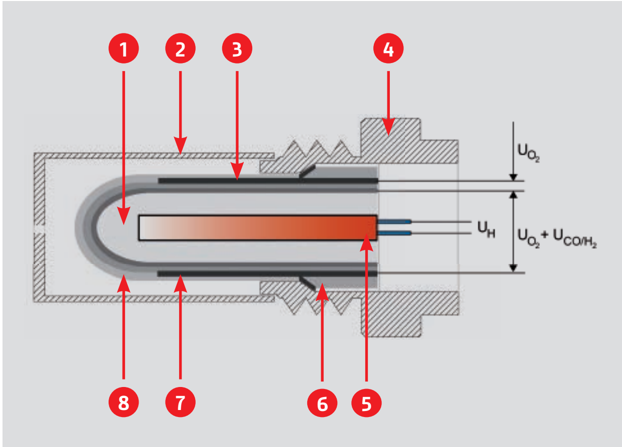
To provide an alternative to existing technology for O_2 trim, an innovative concept for binary burner regulation based on a modified zirconium dioxide probe has been developed using the by-products of the combustion process (CO/H_2) as indicators of the quality of the combustion process. The ultimate aim of this development was to create a dynamic and self-optimising regulation method which would further reduce exhaust gas losses in industrial combustion systems.

Combustion processes must be monitored and regulated in order to save energy and avoid damage to the environment, property and health. Simply measuring the oxygen content in exhaust gases does not indicate if combustion is complete. Therefore, it is particularly important to detect the amounts of unburned components in the exhaust gas and to reduce these. These unburned components include carbon monoxide (CO) and hydrogen (H_2). In the case of incomplete combustion, hydrogen and carbon monoxide emissions always occur together in the exhaust gas.



Efficiency and combustion products.

With the KS1D Combination Probe it is now possible for the first time to measure unburned components in exhaust gases of gaseous fuels in situ quickly and maintenance-free and subsequently regulate and optimise combustion. At the same time, the dual sensor measures and reports the O_2 content for safe limit value shut-down.



Design principle for the LAMTEC Combination Probe KS1D

1 Reference electrode **2** Cap with gas inlet **3** O_2 electrode **4** Housing **5** Heater **6** Functional ceramics **7** CO_e electrode **8** Protective coating

Measurement principle

Sensor technology principle for the O_2 electrode:

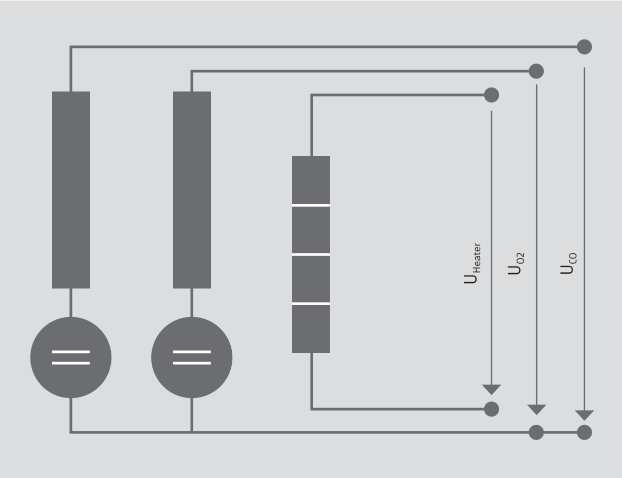
The LAMTEC KS1D Combination Probe is based on a heated electrochemical measuring cell made from zirconium dioxide ceramic (ZrO_2).

It has 3 electrodes:

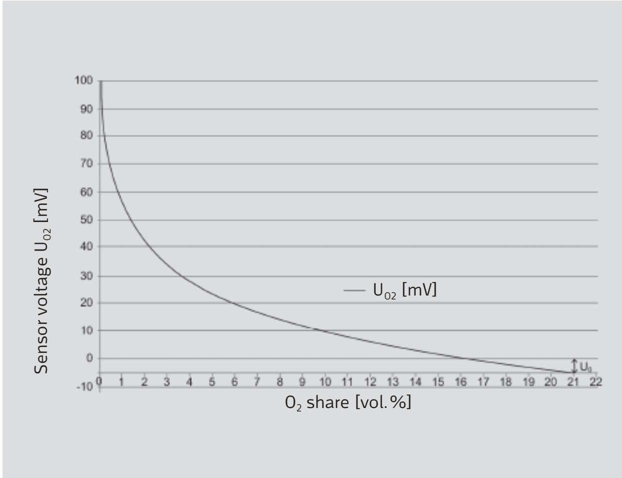
- O_2 electrode (platinum)
- CO_e electrode (platinum/noble metal)
- Reference electrode (platinum)

The probe is a zirconium dioxide ceramic tube that is sealed on one side. It protrudes into the combustion system's emissions channel and divides the reference gas compartment (surrounding area) from the measuring gas compartment (emissions channel) so that no gas can escape. The reference electrode is located on the inner side of the zirconium dioxide ceramic in the reference gas compartment. The two measuring electrodes for O_2 and CO/H_2 are located on the outer side of the ceramic in the measuring gas compartment. An integrated heater warms the probe to a temperature of around 650 °C and controls this temperature. At this temperature, the zirconium dioxide ceramic conducts oxygen ions and the two sensor signal voltages U_{O2} (between the reference and O_2 electrodes) and U_{COe} (between the reference and CO_e electrodes) are generated and can be measured.

The sensor voltage U_{O2} [mV] corresponds to the known Nernst voltage, which is dependent on the sensor temperature T [K] and on the logarithm for the O_2 partial pressure ratio between the reference and measuring



Simple equivalent circuit diagram for the KS1D.



Nernst sensor characteristic $U_s = f(O_2)$.

chambers, with the constants k = 0.21543 [mV/K] and the sensor-specific offset voltage U_0[mV]. as per the formula: $U_{O2} = U_0 + kTln(p_{O2,ref}/p_{O2,meas})$.

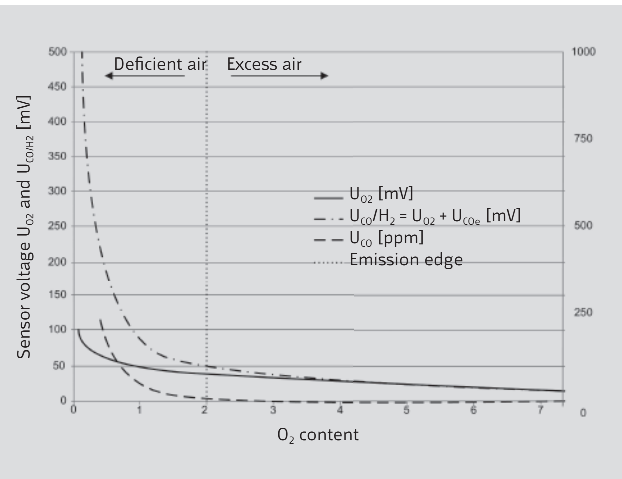
U_0 is determined by calibrating the probe with the ambient air: With $p_{O2,ref} = p_{O2,meas} = 0.21$, the last part of the equation becomes zero and the offset voltage is measured $U_0 = U_{O2}$ at 21 vol.% O_2. A typical Nernst O_2 characteristic (U_{O2}) at a typical sensor temperature T = 923° [K] with a typical offset voltage of U_0 = -5 [mV] is shown in "Nernst sensor characteristic Us = f (O_2)".

Sensor technology principle for the CO_e electrode:

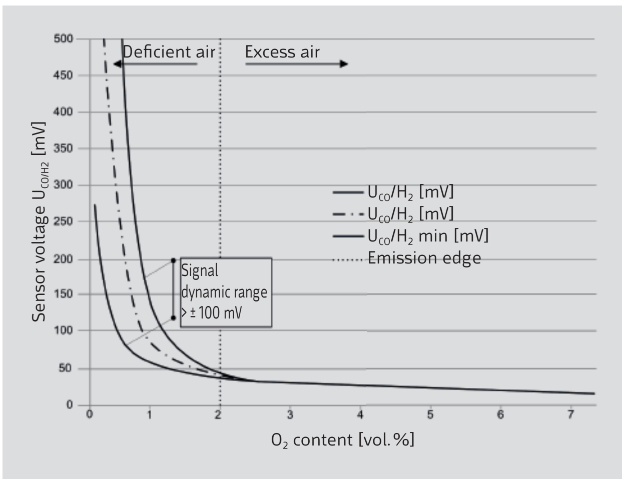
The CO_e electrode is identical to the O_2 electrode apart from the fact that the electro-chemical and catalytic properties in the signal materials are different, thus enabling combustible components such as CO, H_2, to be detected.

For "clean" combustion, the Nernst voltage U_{O2} also forms on the CO_e electrode and the characteristics of both electrodes follow an identical path. In the event of incomplete combustion and in the presence of combustible components, a non-Nernst voltage U_{COe} also forms on the CO_e electrode and the characteristics for both electrodes move apart (see "Typical signal characteristics for the two KS1D sensor voltages").

The total sensor signal $U_{CO/H2}$ on the CO_e electrode is made up of the total of these two voltages: $U_{CO/H2} = U_{O2} + U_{COe}$. If the oxygen content – measured by the O_2 electrode – is deducted from the total sensor signal, the result $U_{COe} = U_{CO/H2} - U_{O2}$ can be used to generate the concentration of combustible components CO_e in ppm. The "Typical signal characteristics" graph for the two KS1D sensor voltages shows the typical path for CO_e concentrations (dashed line) when O_2 content reduces gradually. When moving into the deficient air range, the CO_e concentration increases significantly at the so-called emission edge as a result of the poor/incomplete combustion caused by insufficient air for combustion. The resulting signal characteristics U_{O2} (continuous line) and $U_{CO/H2}$ (dotted dashed line) for the KS1D are also shown. In the excess air range with clean CO_e free combustion, the two sensor signals U_{O2} and $U_{CO/H2}$ are identical to one another and show the current oxygen content in the exhaust gas channel in accordance with the Nernst principle. Close to the emission edge, the sensor signal for the CO_e electrode $U_{CO/H2}$ increases at a disproportionate rate due to the additional non-Nernst CO_e signal.



Typical signal characteristics for the two KS1D sensor voltages.



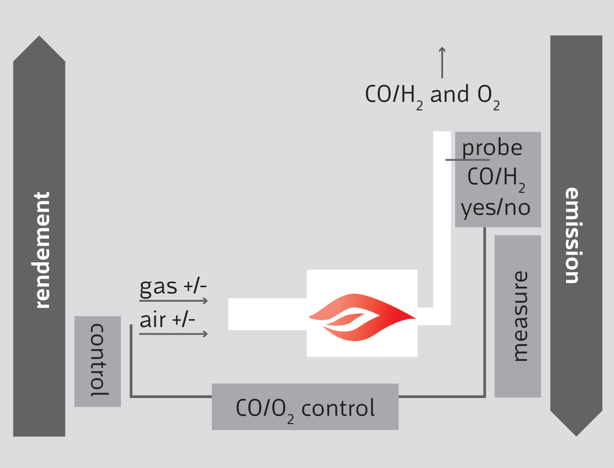
Dynamic range of the CO_eelectrode signal U_{CO}/H_2 in the deficient air range.

The typical signal characteristics for the two KS1D sensor voltages U_{O2} and $U_{CO/H2}$ in relation to the O_2 content in the emissions channel. The typical characteristic of combustible components CO_e is also shown.

In addition to the absolute sensor signals $U_{CO/H2}$ and U_{O2}, the relative change to the sensor signals after time dU_{O2}/dt and $dU_{CO/H2}/dt$ and, in particular, the signal dynamic range for the CO_e electrode can also be used to determine the emission edge (see “Dynamic range of the CO_e electrode signal $U_{CO/H2}$ in the incomplete combustion range”).

Control philosophy

Searching for the optimum working point of the combustion near the emission edge, adjusting this accordingly, maintaining it, optimising further, if necessary, and monitoring. This procedure is repeated cyclically so that the optimum working points are always maintained even for unfavourable weather and system-related conditions.



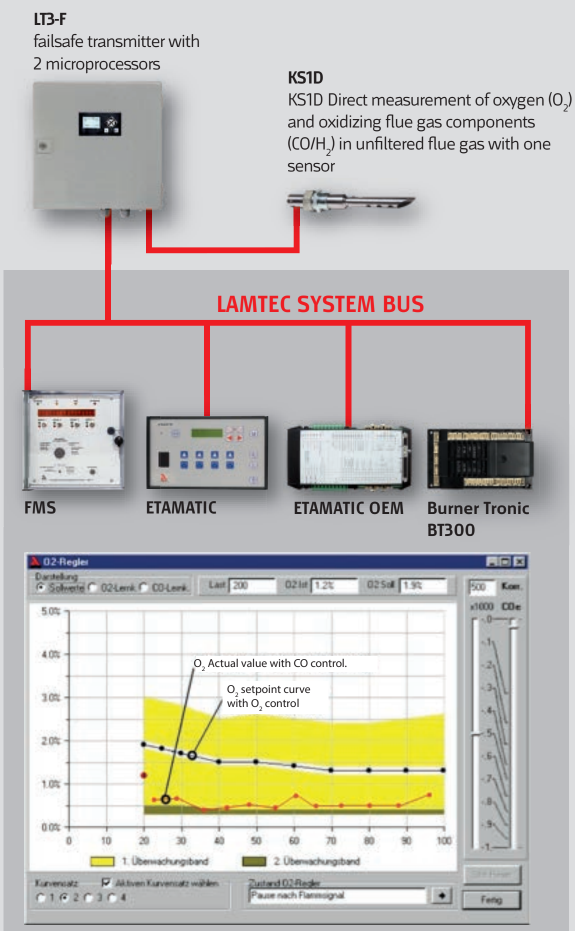
If the KS1D Combination Probe detects unburned CO/H_2, for example, due to changes in specific system ratios, the working point is immediately shifted in the direction of a greater lambda (more air, less fuel).

System technology:

CO/O_2 control has been integrated into the proven BT300/ETAMATIC/VMS/FMS electronic fuel/air ratio control system control system as a software tool.

The simultaneously measured O_2 value is not required for CO/O_2 control itself. It is only required for monitoring and visualisation purposes. An important point here is that the O_2 measurement acts as a safety feature enabling CO control to be deactivated should the oxygen level fall below a predefined threshold. Also, consider failsafe requirements.

If it not possible, for combustion related reasons such as low flame velocity, to apply CO control over the whole firing range then it is possible to switch smoothly from CO control to O_2 trim at a defined firing point.



LAMTEC burner controls with integrated CO/O_2 control.

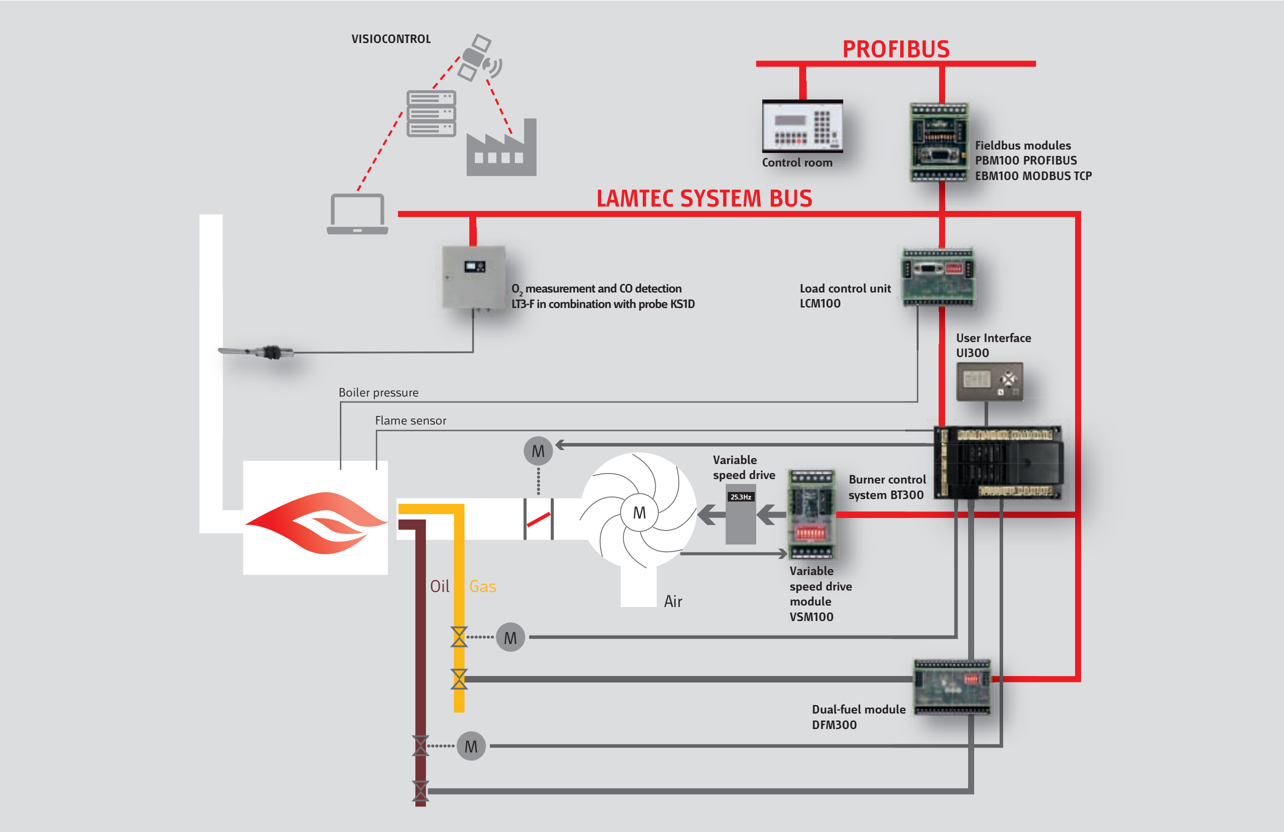
CO/O_2 control is fail-safe. It has been tested by TÜV Bavaria and certified for SIL2 to DIN EN 61508 for applications with natural gas and domestic fuel EL.

Compared with O_2 trim, the O_2 content in the exhaust gas can be significantly reduced still further. This means an increase in combustion efficiency of approximately 0.5 to 2% and a corresponding reduction in fuel consumption.

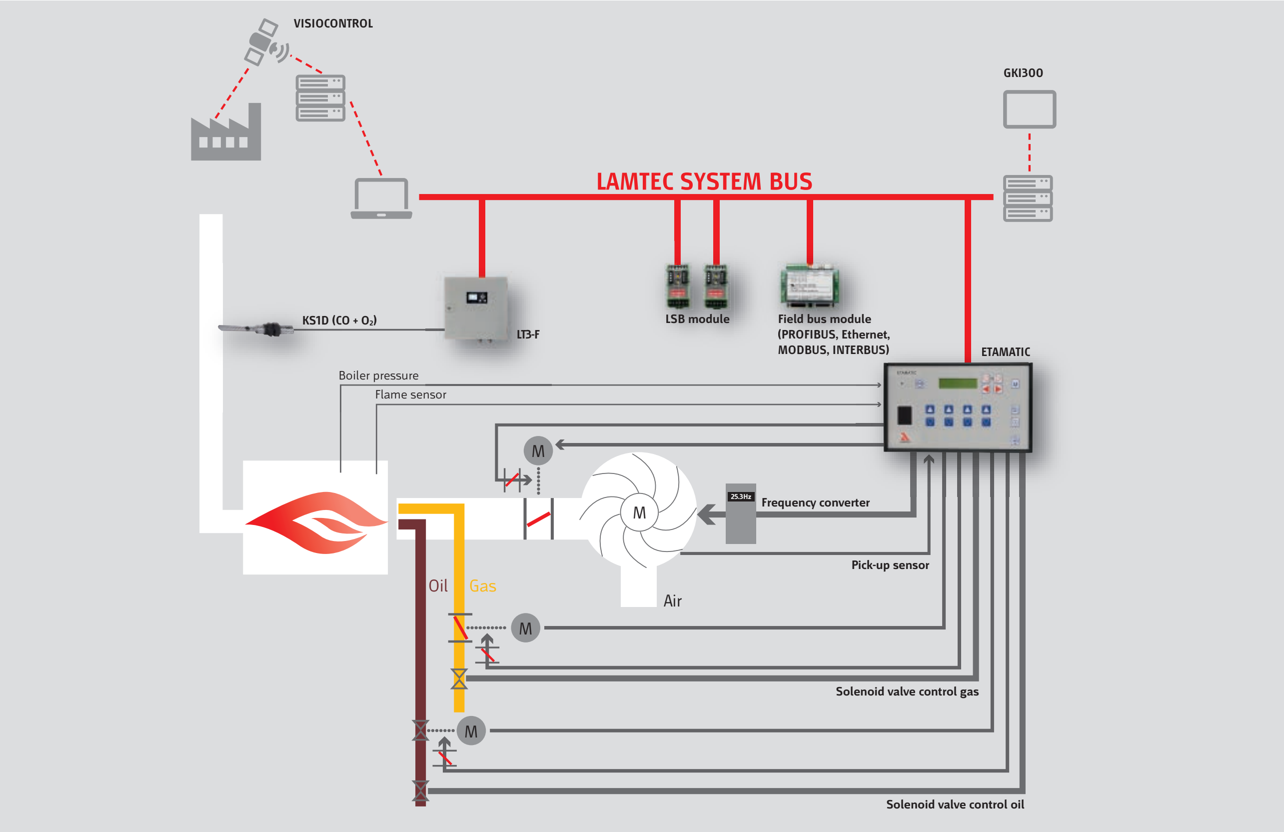
Advantages:

- Up to 2 % higher energy savings through continuous self-optimisation at every firing rate point
- Better control performance through significantly shorter set-up times
- Not affected by excess air
- Higher operating safety
- Robust
- Maintenance-free
- Fail-safe – SIL 2 to DIN EN 61508 – approved to DIN EN 16340 for applications with natural gas or domestic fuel EL

System overview.



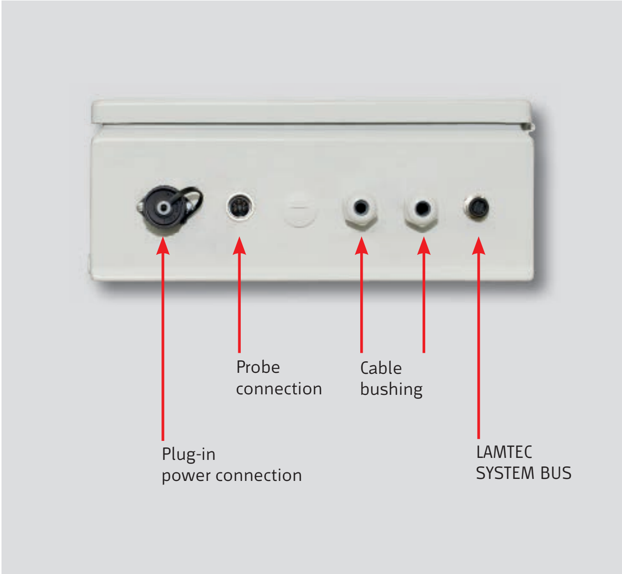
Overview of functions for BT340/341.



Functional overview of ETAMATIC/ETAMATIC S.

SIL2 - approved measuring system LT3-F (electronics) and KS1D (sensor) as a system component of CO/O_2 control.

Lambda Transmitter LT3-F.



LT3 connections on the underside.

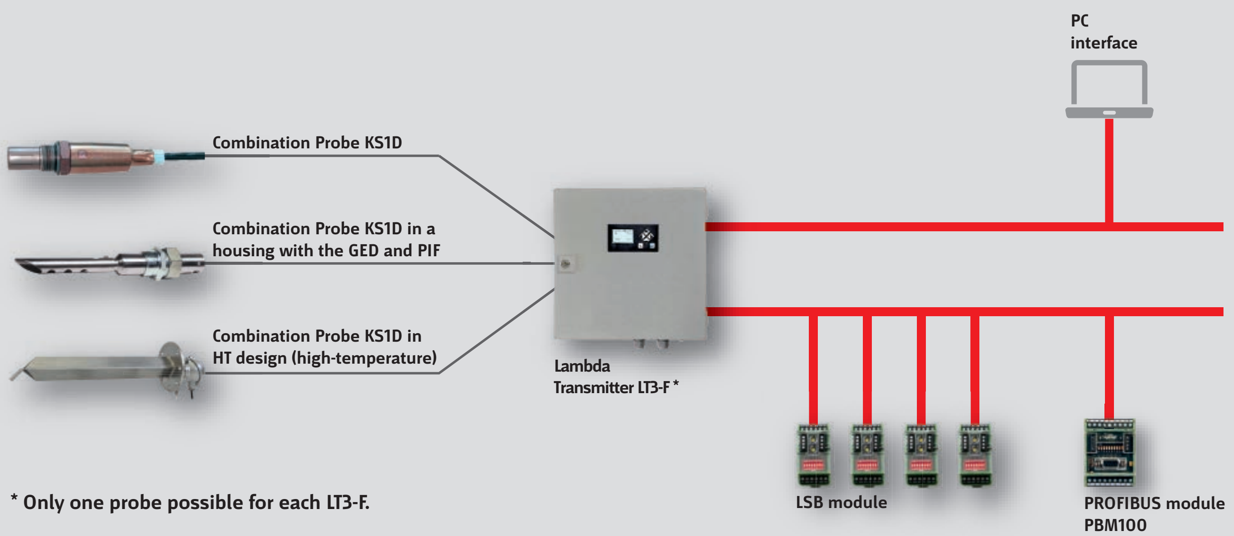
The LT3-F LAMTEC Lambda Transmitter is available exclusively with user interface. The user interface (UI) is attached to the front door and is equipped with the following functions:

- Display of O_2 and CO measured values
- Calibration of measurements
- Information about the operating state of the probe/measurement, the software version, CRC and serial number
- Password entry
- Settings, filter time, analogue output, probe replacement, display, maintenance mode

The following connections are located on the underside of the device:

- Mains connection
- KS1D probe connection (probe signal/probe heater)
- External LSB connection for the PC (use of LSB remote software)
- Cable bushing for connecting the LAMTEC SYSTEM BUS to the LSB modules
- Cable bushing for analogue and digital inputs/outputs

Various probe designs.



* Only one probe possible for each LT3-F.

Functions in the LT3-F with KS1D.

LAMTEC Combination Probe KS1D

The LAMTEC KS1D Combination Probe is available in a number of designs and can be combined with the LT3-F Lambda Transmitter to suit any requirement.

Combination Probe KS1D

Properties:

- Measurement directly in the moist flue gas up to 300 °C
- Protection rating IP42, the probe must be protected against water, snow, etc., if installed outside.

Applications:

- Natural gas, domestic fuel EL.

Combination Probe KS1D in a housing with the GED and PIF

Properties:

- Measurement directly in the moist flue gas up to 300 °C
- Protection rating IP42, the probe must be protected against water, snow, etc., if installed outside.

Applications:

- Natural gas, domestic fuel EL, emission gases with a low ash content

Combination Probe KS1D in HT design (high-temperature)

Properties:

- Measurement directly in the moist flue gas up to 1,200 °C
- Option for semi-automatic calibration during operation with test gas
- IP65 protection rating.

Applications:

- Natural gas, domestic fuel EL, coal, biomass, particle-laden fuel emissions (available with optional compressed air purge).
- With de-dusting clean: emissions containing ash such as biomass, heavy fuel oil, lignite, etc.

Optional components.

LSB modules

The LSB modules are universally compatible input and output modules that can be controlled via the LAMTEC SYSTEM BUS. For this to occur, the module is triggered by an adjustable address. The relay outputs are activated manually using switches.

Analogue outputs:

There are two different modules for analogue outputs:

- Power module with 4 analogue outputs 0/4 to 20 mA
- Voltage module with 4 analogue outputs 0/2 to 10 VDC

Digital outputs:

The digital LSB module is equipped with 4 outputs.

Digital inputs:

The digital LSB module is equipped with 4 inputs. Use of a strapping plug means that two modules can be wired quickly and increases the number of inputs to 8.

LSB module for calculating combustion efficiency:

The efficiency module has the following properties:

- Two Pt100 temperature inputs to record the flue gas temperature and ambient temperature
- Two analogue outputs 0/4 to 20 mA to emit the flue gas temperature and its efficiency
- Power supply 24 VDC / 50 mA

Communication via PROFIBUS:

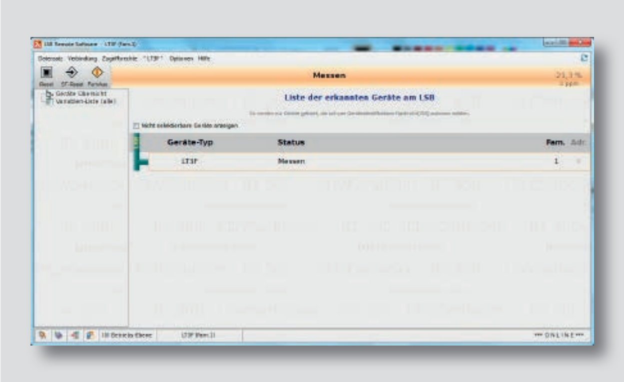
The fieldbus modules are connected via the LSB. With regard to integration into a parent process and building management system, PROFIBUS communication offers many advantages.

- Either installed straight onto the LT3-F or externally, e.g. in the control cabinet
- Fast and precise transmission of processor values
- Direct reading of inputs and outputs
- Remote diagnosis through a readout of the fault history

PROFIBUS PBM100.

LSB Remote Software

The LSB USB module PC interface makes working with the LT3-F Lambda Transmitter even easier: the device can be operated remotely using a laptop. Device configuration and parameter data can be saved and used as a back-up. Using this back-up, system data can be restored in the event of an emergency allowing equipment to be made ready for operation in just a few minutes. Using the LSB Remote Software enables users to retrieve and monitor data from the LAMTEC Lambda Transmitter from their office without needing to be on site.



Inputs.

Outputs.

LSB module Analogue outputs

- 1 O_2 measured value
- 2 CO_e measured value
- 3 Not assigned
- 4 Not assigned

LSB module Digital inputs 1

- 1 Resolve offset calibration
- 2 Reset fault
- 3 Changeover to CO_e curve fuel 1
- 4 Deactivation of limit value 1 to 4

LSB module Digital outputs

- 1 Fault
- 2 Warning
- 3 Limit value 1
- 4 Limit value 1

LSB module Digital inputs 2

- 5 Reset limit value 1 to 4
- 6 Changeover to CO_e curve fuel 3
- 7 Changeover to CO_e curve fuel 4
- 8 Deactivation for calibration

LSB module for calculating combustion efficiency:

Inputs:
- 1 Detection of flue gas temperature via Pt100
- 2 Detection of ambient temperature via Pt100

Outputs:
- 3 Flue gas temperature
- 4 Efficiency

Communication via PROFIBUS

Inputs:
- 1, 2 Fault/ warning reset
- 3 ID of the digital module 1 to 16
- 4 Coding for setting digital outputs

Outputs:
- 1, 2 CO_e actual value
- 3, 4 CO_e actual value status
- 5, 6 O_2 actual value
- 7, 8 CO sensor voltage rough
- 9, 10 O_2 sensor voltage rough
- 11, 12 Probe voltage U_{CO_e}
- 13, 14 LT3 status
- 15, 16 Warning value 1
- 17, 18 Warning value 2
- 19, 20 Fault value 1
- 21, 22 Fault value 2

Lambda Transmitter LT3-F

Input:
- Power supply 230 V

Notes.

Notes.

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