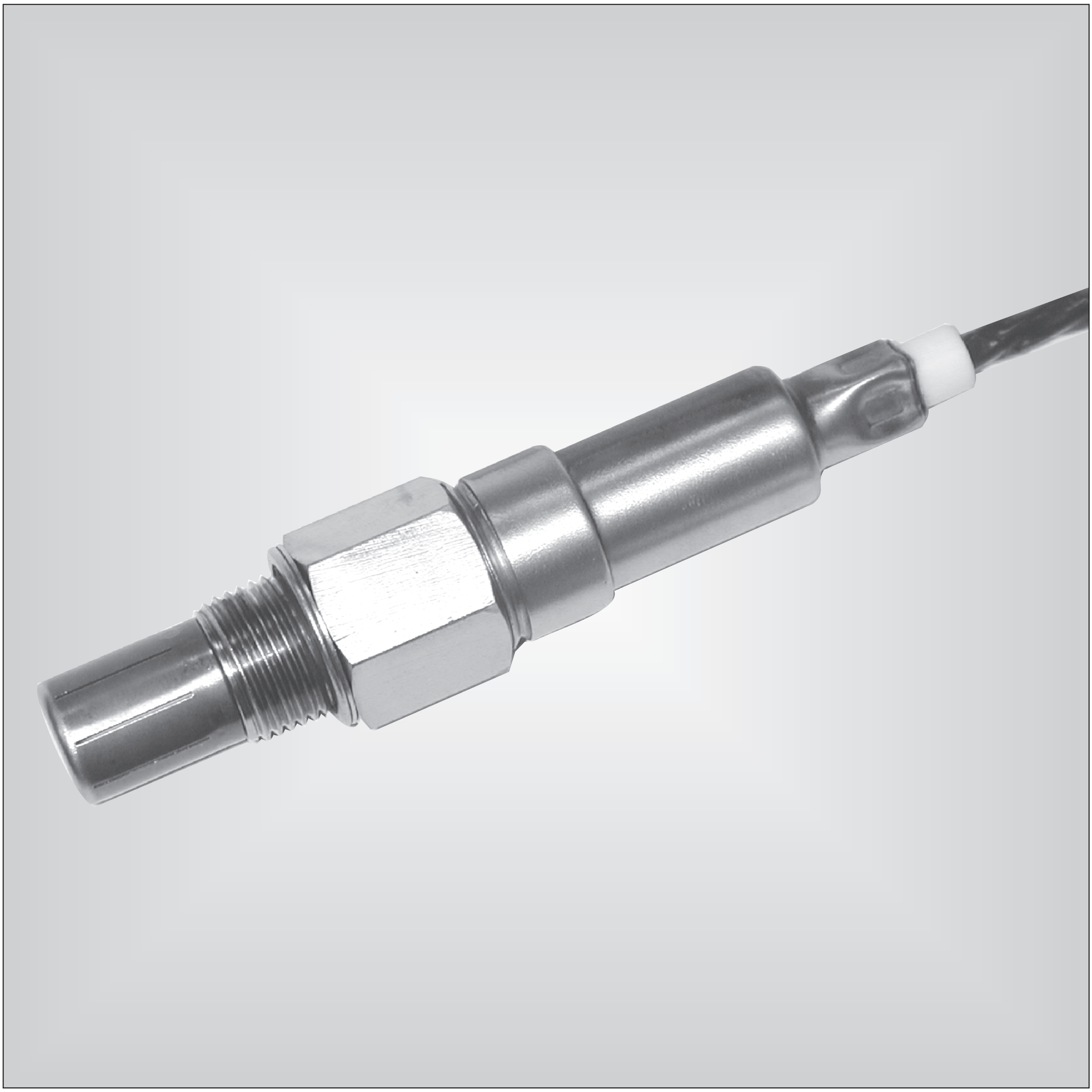
Application
Description of Function
Technical Data

Combination Probe KS 1

Zirconium dioxide measuring sensor for direct indication of unincinerated substances (CO/H_2) in furnace exhaust gases



Sensors and Systems for Furnace Technology

LAMTEC

Zirconium dioxide probe for monitoring and optimising incineration processes through the direct indication of unincinerated substances (CO/H_2) in furnace exhaust gases.

In complete incineration processes, the KS1 probe can be used as an O_2 measuring sensor.

Other applications are also possible, such as the measurement and monitoring of CO and H_2 concentrations in gases.

Design and Function

The probe operates using the potentiometric measurement principle, on the basis of a solid electrolyte of stabilised zirconium dioxide (Fig. 1).
This material, already proven in the Lambda Probe LS 1, enables measurements to be taken in-situ, directly in the exhaust gas from a furnace. The measurements taken with the probe have long-term stability.

The probe has been specially developed to produce a rapid and distinct reaction to the occurrence of CO or H_2 in the exhaust gas. CO and H_2 emissions are reliable indicators of an improperly functioning incineration process.

In complete incineration without combustible gaseous constituents, the function of the probe is identical to that of a potentiometric oxygen probe.

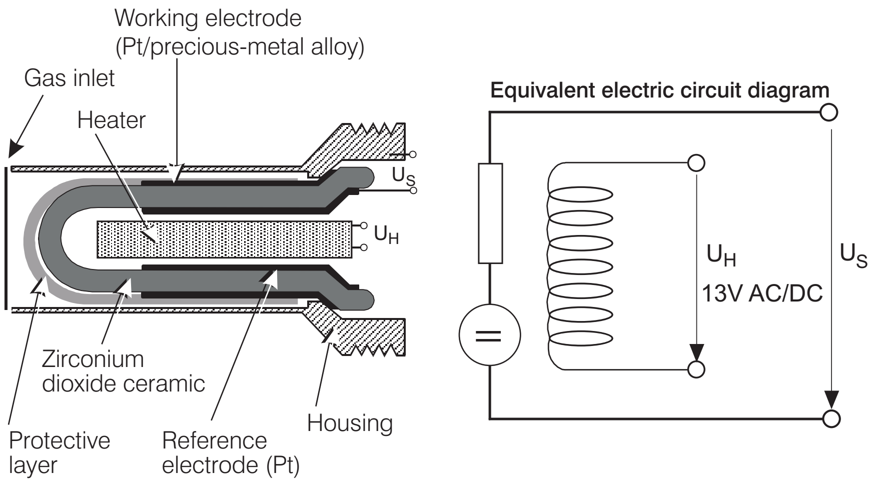


Fig. 1: Schematic showing the design principle of KS 1

Figure 1 shows the design principle of the LAMTEC Combination Probe KS 1 in schematic form.

The principal feature of the probe is a zirconium dioxide solid electrolyte tube, sealed at one end, with precious metal layers on the inner and outer surfaces as electrodes. The sensor is brought to an operating temperature of 600 °C to 700 °C by an electric heater inside the tube.

The gas which is to be measured (flue gas) reaches the working electrode through slits in the sensor cover. Air is used as a reference gas. This is supplied to the reference electrode (L) via the connection cable (Fig. 2a).

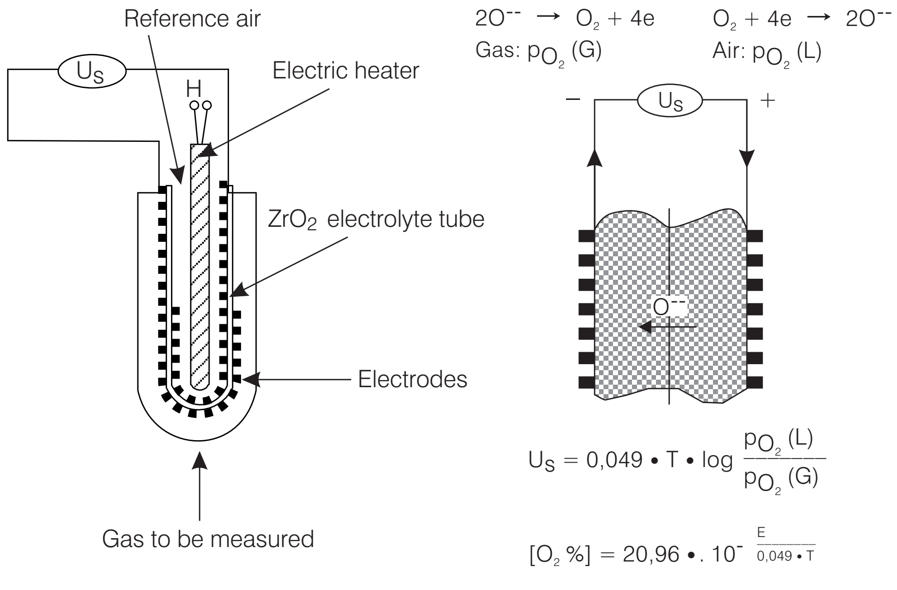


Fig. 2a: Potentiometric measurement principle Fig. 2b

The potential difference U_S that occurs between the working and reference electrodes is a function of partial pressure of the residual oxygen and of the oxidisable substances that remain in the flue gas in cases of faulty incineration mainly CO and H_2. The following mechanism forms the basis for a signal output:

"Complete incineration" without combustible gaseous constituents

The cell operates as an electrochemical concentration chain (Fig. 2) and generates a direct-current voltage which is dependent on the absolute temperature T and the logarithm of the O_2 concentration ratio, or O_2 partial pressure ratio pO_2 (L) / pO_2 (G), at the inner and outer electrodes.

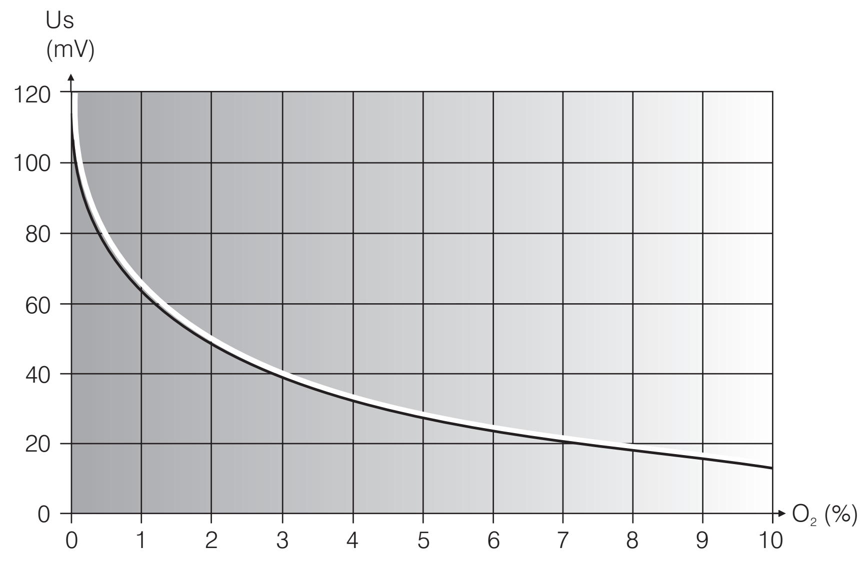


Fig. 3: Correlation between probe voltage and oxygen concentration in the Combination Probe KS 1

If the gas to be measured, with the unknown O_2 concentration pO_2 (G), or $[O_2]_G$ is supplied to the outer electrode and a reference gas with a known O_2 concentration, e.g. air, is supplied to the inner electrode with pO_2 (L) = 0.21, or $[O_2]_L$ = 20.96 %, at a constant temperature T, this results in the logarithmic correlation, shown in Figure 3, between the probe voltage U_S and the oxygen concentration of the gas to be measured.

"Incomplete incineration" with combustible gas constituents (CO/H_2)

Combustible constituents are adsorbed like oxygen molecules at the working electrode and diffused to the "three phase boundary" formed by test gas (gas to be measured), electrode and zirconium dioxide. As well as the Nernst voltage determined by the oxygen content, the combustible constituents present in the test gas generate an additional direct-current voltage across the sensor. The sensor voltage is the sum of the two voltages $U_S = U_{O_2} + U_{CO/H_2}$ (Fig. 4). Even at low concentrations of oxidisable gases such as H_2 or CO, the mixed potential is markedly higher than the signal of the pure O_2 probe. The mixed potential develops very rapidly, attaining t_{60} times under 2 seconds. Sensitivity to O_2 and combustible constituents is influenced by the sensor temperature. Lower sensor temperatures result in a higher sensitivity to CO/H_2 but in lower sensitivity to O_2 (Fig. 5).
The oxygen concentration also affects the sensor voltage U_{COe}.
A higher O_2 content results in a slight drop in the sensor voltage in the high CO range (Fig. 6).

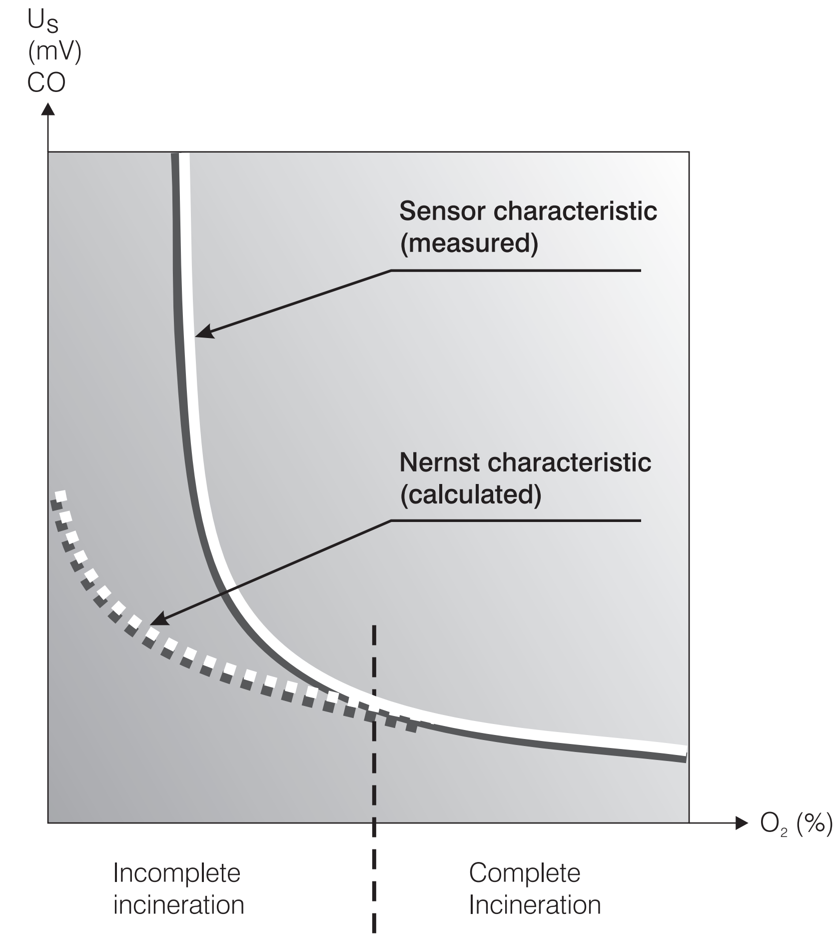


Fig. 4: Sensor characteristic at a gas burner

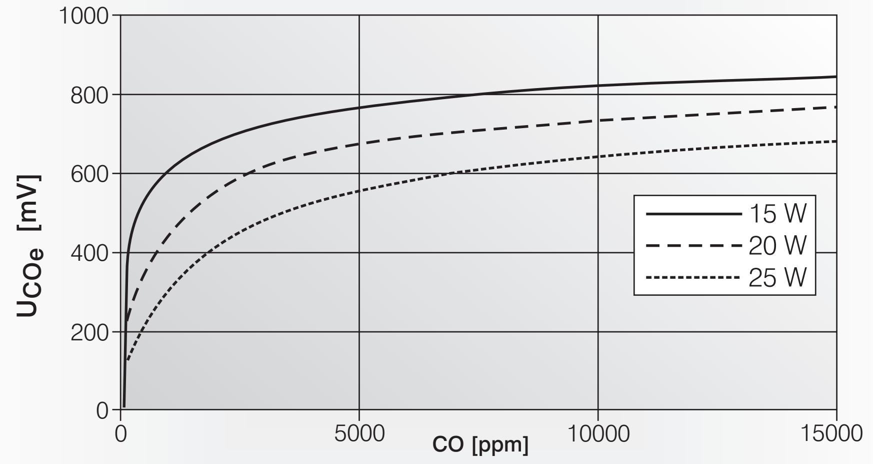


Fig. 5: Sensor voltage U_{COe} as a function of the sensor temperature (heat output)

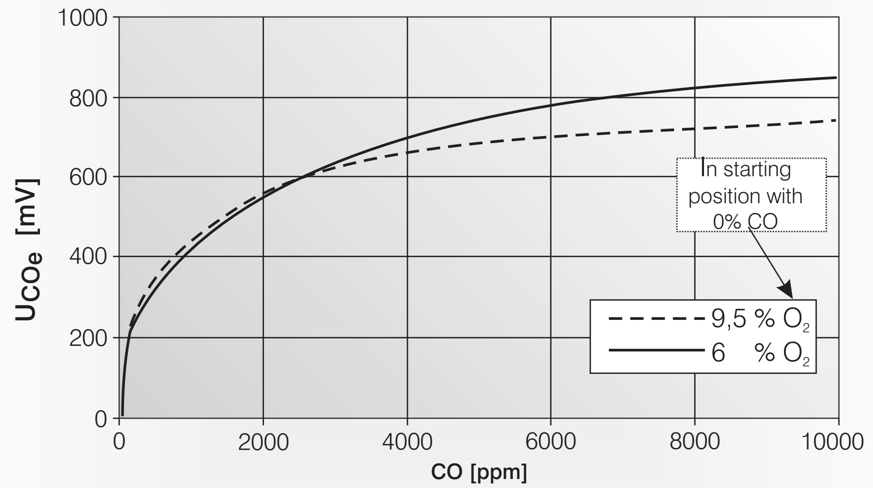


Fig. 6: Sensor voltage U_{COe} as a function of the O_2 content

A further indication of unincinerated CO/H_2 is provided by the dynamic response of the sensor signal (U_S). The dynamic response decreases as the proportion of unincinerated constituents increases. Fig. 7 shows the rise of the sensor signal over the O_2 value measured on a reference installation (12 MW SAACKE gas burner), on low load, using a Lambda Probe LS1.

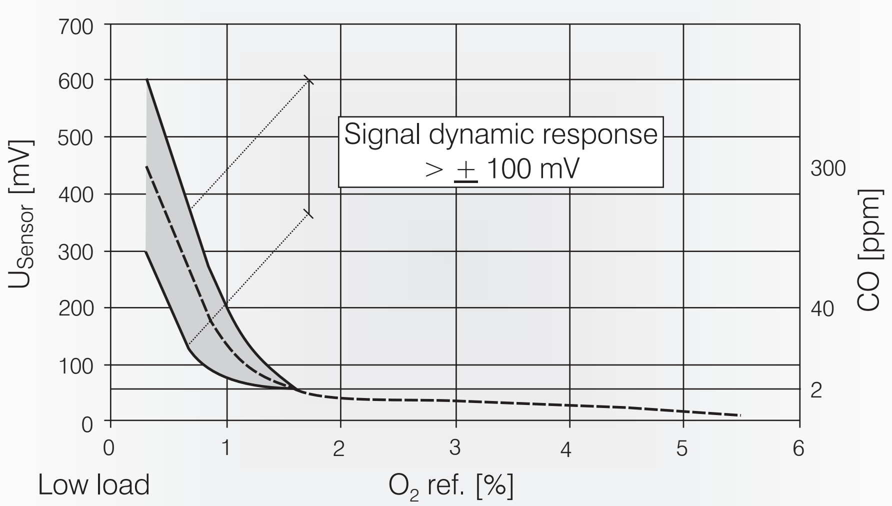


Fig. 7:

Application

Figure 8 shows two possible applications of the Combination Probe KS 1.

1. As a threshold-value pickup for monitoring incineration plants
2. For self-adapting burner regulation

Burner characteristic CO over O_2 content from 4 different incineration plants

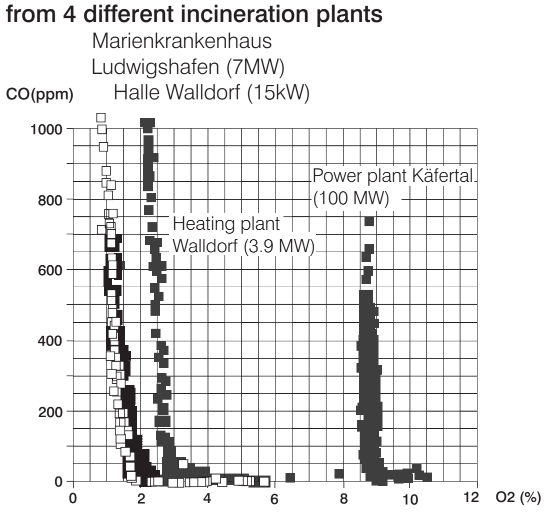


Fig. 8a

Characteristic U (CO) of a sensor over O_2 content at 4 different incineration plants

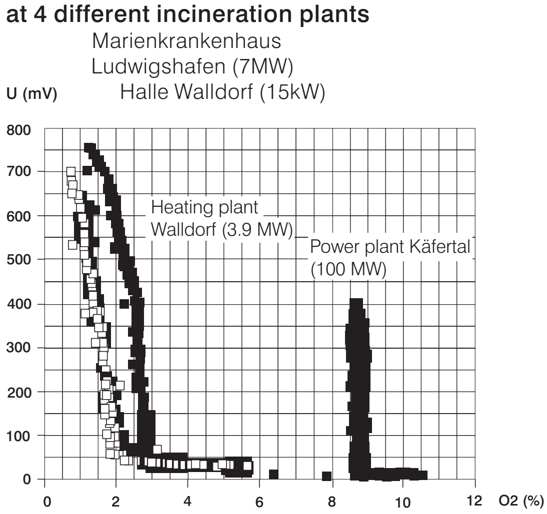


Fig. 8b

Threshold-value pickup

Figs. 8a and 8b show that exceeding of a CO limit can be reliably detected, above 50 ppm, in the flue gas of all 4 plants using a threshold voltage.
The threshold-value pickup offers a simple, continuous monitoring option for incineration plants and gives an alarm signal if the burner characteristic threatens to move into a range of unacceptably high CO emission, e.g. due to incorrect adjustment or dirt accumulation.

Self-adapting burner control

Fig. 8b shows how a burner can be controlled.

The operating point of the burner controller is no longer fixed or determined by a set of pre-programmed characteristics: instead, it is continuously determined and adjusted in interactive mode during operation.

This is achieved by varying the fuel/air mixture towards a lesser lambda value (less air, more fuel) until a sharp signal rise of the Combination Probe KS 1 and its dynamic response indicate the onset of incomplete incineration. From this point onwards, the fuel/air mixture is again varied slightly, but towards a greater lambda value (more air, less fuel), until the optimum operating point is found. This process is repeated cyclically, so that the optimum operating points are always maintained, even in unfavourable weather and plant conditions (see Fig. 9).
If there is a shift in the burner characteristic during operation, causing the Combination Probe KS 1 to detect unincinerated constituents (CO/H_2), the operating point is immediately shifted towards a higher lambda value (more air, less fuel).
The operating point can be periodically redetermined, using this method, to track slow changes in the burner characteristic.

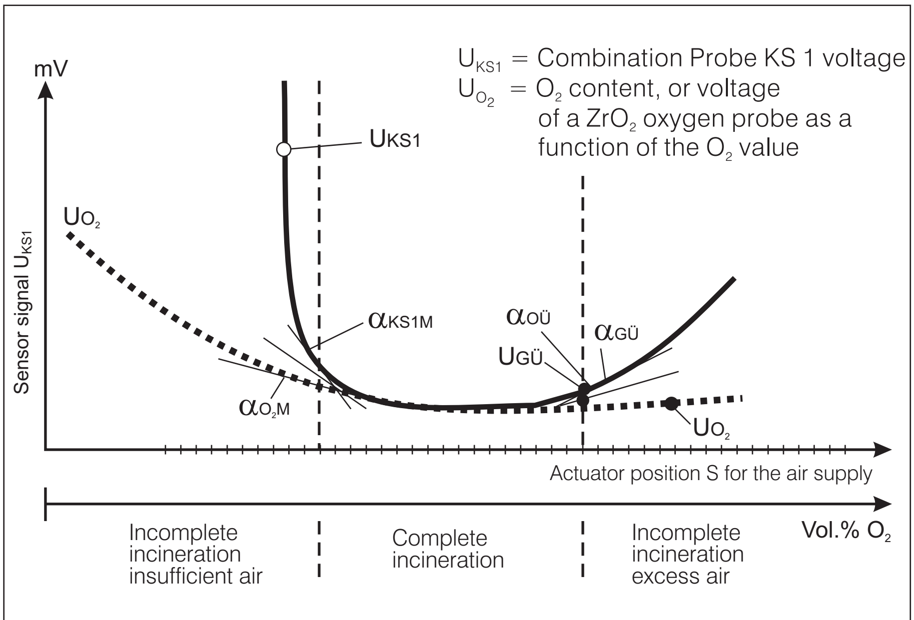


Fig. 9: U_{KS1} as a function of excess air

Advantages of CO control over O_2 control

- Up to 0.5 % greater energy saving through continuous self-optimisation in each load point; see Fig. 10
- Improved control behaviour due to substantially reduced response lag
- Independent of secondary air
- Fail-safe
- Highly dependable
- Robust
- Maintenance-free

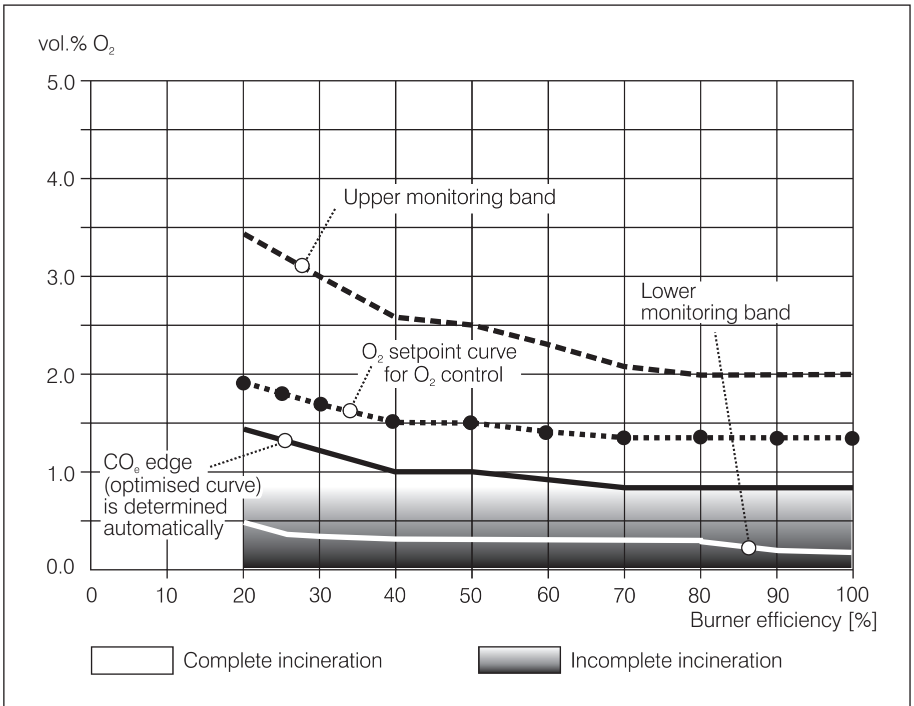
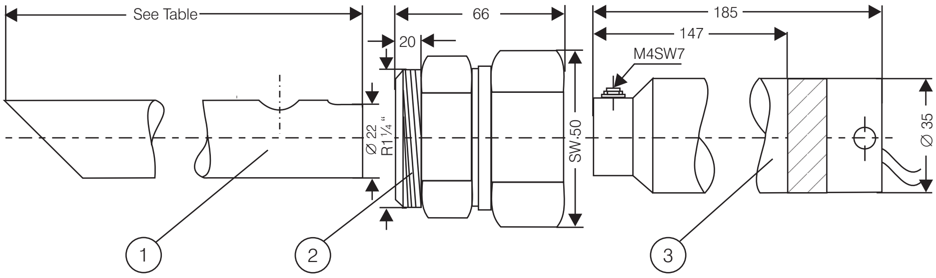


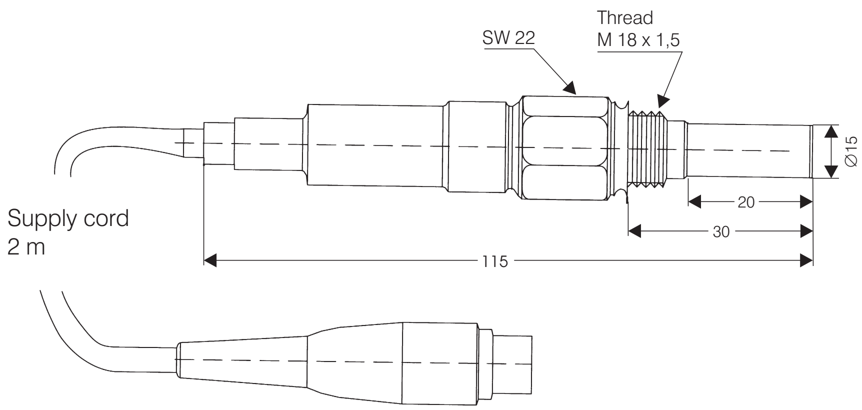
Fig. 10: Plant characteristic, natural gas combustion

Combination Probe KS 1
No. 656 R 0000 / R 0001



Part No.	Order Ref.	
1	655 R 1001	Test-gas extraction device (MEV) for LS 2, KS 1 150 mm long
	655 R 1002	ditto, 300 mm long
	655 R 1003	ditto, 450 mm long
	655 R 1004	ditto, 1000 mm long
2	655 R 1010	Probe installation fitting (SEA) for LS 2, KS 1 screw-in connection, R 1 1/4 "
3	656 R 0000T	Combination Probe KS 1 for exhaust gas temperature up to 300 °C
	656 R 0001T	Combination Probe KS 1 for exhaust gas temperature up to 400 °C

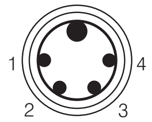
Combination Probe KS 1
No. 656 R 0010T / R 0011T



Electrical connection:

No. 656 R 0000T/R 0010T → Teflon line (4-core) , with 4-pole diode plug with lock, length 2 m

Pin assignment



1 = plus signal
2 = minus signal
3 = heating
4 = heating

Typ 656 R 0001T/R 0011T → glass-fibre insulated nickel line, length 2 m with connector sleeves

Measurement principle:
Zirconium dioxide cell
Potentiometric (voltage probe)

Probe voltage (U_S):
- 25 ... + 1000 mV (Air: - 25 ... + 25 mV)

Operating temperature of the measuring cell (sensor) with heating voltage of 13 V, in air (20 °C):
ca. 650 °C

Heat-up time:
10 mins. to operational readiness
120 mins. to electrical stability

Guide value for control readiness of the probe following switch-on of the burner and heating-up at 24 V from standby operation (7 V):
40 s

Response time after measured-value step change at heating voltage of 13 volts and T_{Gas} = 150 °C:

t_{60}	t_{90}
CO/H_2 < 2 s	< 5 s

Measurement range:
CO: 10 ... 10 000 ppm

Measuring accuracy:
For flue gas from natural gas firing after previous calibration under operating plant conditions with a CO-Reference Measurement

CO/H_2: $\pm$ 25 % of the measured value with output as CO-equivalent (CO_e)
not better than $\pm$ 10 ppm
After correction of the influence of the O_2-value
(by supplied O_2-value)
in the range of 0...100 ppm CO_e,
max. $\pm$ 10 ppm CO_e.

Error influences:
Temperature, other unincinerated hydrocarbons

Cross-sensitivity:
to SO_2, NH_3, NO, propane, aromatic hydrocarbons

Probe internal resistance R_i in air 20 °C and heating voltage of 13 V, measured at f = 100 kHz:
< 30 Ω (in new condition)

Heating power:
for T_{gas} = 150 °C in continuous operation
at U_H = 13 V → 20 W

for T_{gas} = 25 °C in standby mode
at U_H = 7 V → 8 W

for T_{gas} = 25 °C with rapid heating (only briefly, for heating-up, continuous operation not permissible)

at U_H = 24 V → 40 W

Heating current at U_H = 13 V:
Continuous 1,6 A
Short-time, for heating-up 3,4 A

Heating current at U_H =24 V:
Short-time, for heating-up 5,5 A

Insulation resistance between Heating and probe connection:
> 13 MΩ

Operating conditions:

KS 1 - Type (Order No.)	656 R 0000T	656 R 0001T	656 R 0010T	656 R 0011T
Permissible continuous temperature of exhaust gas:	< 200 °C	< 400 °C	< 300 °C	< 500 °C
Electrical connection:	Teflon line (4-core) with 4-pole diode plug with lock, length 2 m	Glass-filament-insulated 4-core cable with connector sleeve Length 2 m	Teflon line (4-core) with 4-pole diode plug with lock, length 2 m	Glass-filament-insulated 4-core cable with connector sleeve, length 2 m
Weight:	520 g	580 g	270 g	330 g
Mounting position:	Horizontal via vertical to horizontal			
Enclosure protection type:	IP42 **To be used only in a grounded power line network!**			
Auxiliary power:	12...14 VDC / AC 1,6 A continuous short-time: 3,4 A (heat-up phase)			
Permissible ambient temperature:				
In operation:	- 25 °C ... + 120 °C	- 25°C ... + 250°C	- 25 °C ... + 120 °C	- 25 °C ... + 250 °C
Transport and storage	- 25 °C ... + 60 °C			

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