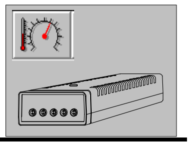


AUK Environmental Sensor

Environmental influences can be compensated in two ways:

1. "Manual" input of the current data for air temperature, humidity and pressure and the material temperature of the testpiece via the PC keyboard.
   This requires regular reading of separate instruments and regular updating of the data entered. In a measuring room, this should be done at least once every day, and in production environments several times a day, in order to obtain a measuring accuracy of **2 µm/m.**

2. Use of the AUK 500 Automatic Environment Detector (*269302-4053.226)* with sensors for air temperature, air pressure and humidity, and facilities for connecting up to five material temperature sensors. The data are automatically updated at an inquiry rate of < 1 Hz. Unless coarse mistakes are made when setting up the Laser Interferometer configuration, (if, e.g., Abbe's comparator principle is maintained), a measuring accuracy of **0.9 µm/m** can be achieved.

Determining the refractive index of the air

In order to reliably and constantly ensure the high measuring accuracy of the ZLM 500 Dual-Frequency Laser Interferometer in non-vacuum operation, it is necessary to continuously record the refractive index of the ambient air and to correct the laser wavelength accordingly. Basically, this can be achieved by three methods:

1. Reading the air temperature, air pressure and humidity off classical analogue instruments, and entering these data via the PC keyboard. The intervals at which readings must be taken depend on the rate at which the air parameters change. This method is the simplest one and will be sufficient in many applications.

   Uncertainty of measurement: 2 µm/m

2. Use of high-resolution sensors (*Parameter method*). In connection with a PC, the sensors automatically sense the temperature, pressure and humidity of the ambient air with a high precision, so that these parameters are constantly updated. As a rule, it is also possible to connect special material temperature sensors for automatically monitoring the temperature of the testpiece or of the entire measurement setup.

   Uncertainty of measurement: 0.6 µm/m

3. Installation of a refractometer (r*eference method*). This is the most expensive method. There is a wide variety of versions to suit the specific application, ranging from "simple" wavelength tracking refractometers to complex multi-chamber vacuum refractometers. They all have in common that refractive index is always measured against an external reference distance and that an extra interferometer channel is needed.

   Uncertainty of measurement: 0.3 µm/m

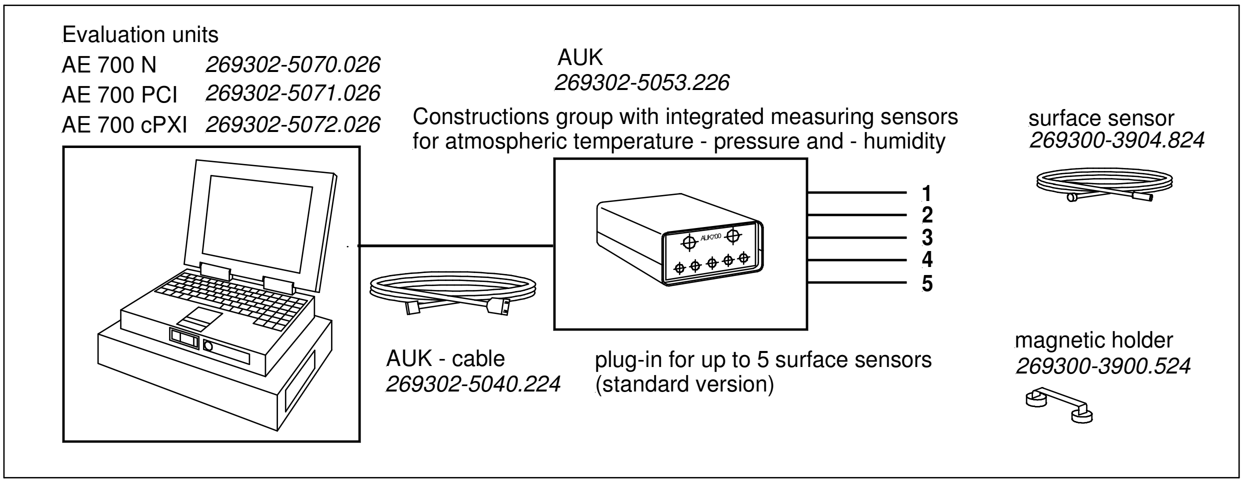
Once the refractive index of air has been identified by one of the three methods, the laser wavelength in air is computed via the equation

$$\lambda = \lambda_o / n$$

where λ : wavelength of laser light in air
λ_o : wavelength of laser light in a vacuum
n : refractive index of air

Design and Mode of Operation

The AUK Environment Sensor operates by the parameter method. The sensors integrated in the unit continuously measure air temperature, air pressure and humidity with high precision and transmit the measured data to the PC. Via the ***Edlen formula*** /1/ the PC determines the refractive index of the ambient air, and from this the current wavelength of the laser radiation.



Edlen's formula applies to humid "standard air" (containing, in addition to nitrogen and oxygen, a content of 300 ppm of carbon dioxide):

$$n = 1 + (2.8793 \cdot 10^{-7} \cdot P) : (1 + 0.003671 \cdot T) - (3.6 \cdot 10^{-8} \cdot P_w)$$

B: *Refractive index of „standard air“*
P: *Atmospheric pressure in hPa*
T: *Air temperature in °C*
P_w: *Water vapour partial pressure in hPa*
100% rel. air humidity at 20°C: 23hPa)

Given the following conditions, which are **typical for a measuring room**,

T = 20°C ± 1K
P = 1013 hPa ± 10hPa
F = 50% ± 20%

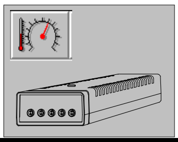
the Edlen formula yields a mean refractive index for the measurement room air of

$$n = 1.0002712 \pm 4 \cdot 10^{-6}$$

The necessity to constantly correct the refractive index is obvious from the amount of variation in refractive index.

The table below shows, for specified measurement lengths and any variations of the air parameters, the amount of apparent length change measured with the laser interferometer as a function of the changing air parameters.

Parameter	**Deviation from measured value**	
Air temperature	- 0.92µm/m/K	$(dn/dT \approx -0.92 \cdot 10^{-6} K^{-1})$
Atmospheric pressure	0.27µm/m/hPa	$(dn/dP \approx +0.27 \cdot 10^{-6} hPa^{-1}$
Air humidity	0.01µm/m/% rel. humidity	$(dn/dP_w \approx -3.6 \cdot 10^{-8} hPa^{-1})$



The Influence of Air Pollutants

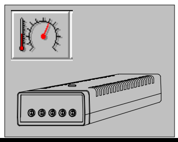
The parameter method assumes a standard composition of air. In industrial use, however, the ambient air may contain considerable admixtures of other gases, which are not allowed for by the AUK Environmental Sensor. In order to compute the change in refractive index in such cases, the following table specifies, for the most important gases, the concentration in air that will change its refractive index by $1 \cdot 10^{-7}$:·

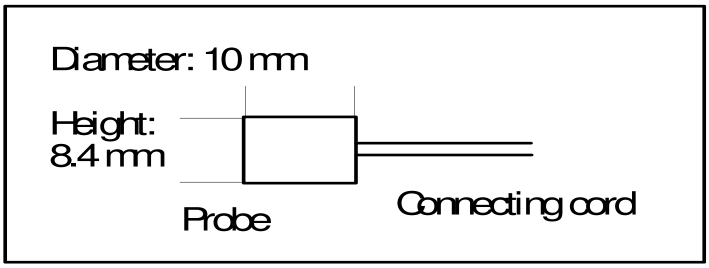
	Specific refractive index n - 1 $(\cdot 10^{-4})$	Concentration in air required for $dn = 1 \cdot 10^{-7}$ in ppm
Air	2.72	-
Carbon monoxide	3.2	2100
Carbon dioxide	4.2	680
Sulphur dioxide	6.3	280
Hydrogen cyanide	4.0	780
Ammonia	3.5	1300
Propane	10.3	130
Butane	12.9	98
Octane	23.0	50
Benzene	15.8	77
Ethanol	8.1	190
Acetone	10.2	130
Ethyl acetate	13.0	97
Tetrachlorethylene	18.7	63
Freons F22	7.3	220
F12	10.3	130
F1281	12.0	110

The values specified apply to an air temperature of 20 °C and an atmospheric pressure of 1013 hPa.

Surface Temperature Sensors

In practice, the limit of the uncertainty of measurement is not only determined by the uncertainty of refractive index measurement.
In order to avoid faulty measurements, it is also necessary to exactly know the temperature of the testpiece, or the temperature distribution throughout the measurement setup (thermal expansion coefficient of the materials!). Therefore, the AUK Environmental Sensor also has connection facilities for up to five material temperature sensors (surface temperature sensors). They precisely measure the temperatures on smooth, plane contact surfaces of technical components with a specific thermal conductivity of better than 10 $Wm^{-1}K^{-1}$.





The sensors are delivered in series with cable lengths of 5 m. Other lengths will be supplied on request. The sensors are hermetically sealed and will therefore withstand rough conditions in production environments.
The sensors are offers with screw-on, magnetic or adhesive holders for fixation to the testpiece.

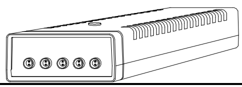
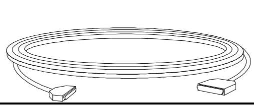
Dynamic behaviour

The dynamic behaviour depends on the specific conditions of the measurement. The time percentages specified are guideline figures only and refer to a testpiece of steel with a thermal conductivity of 50 $Wm^{1}K^{-1}$.

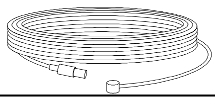
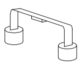
time percentages	T/50	T/90	T/95	T/98
(in sec)	3,2	7,8	12,4	30

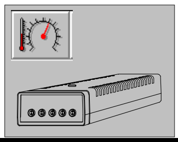
On request, the sensors can be supplied with a manufacturer's certificate or with a certificate of the German Calibration Service (DKD) or PTB. The measurement error specified does not include any user-specific error influences (thermal conductivity of the testpiece, heat transmission conditions at the point of contact between sensor and testpiece).

Scope of Equipment Supplied, Order Numbers

AUK Environmental Sensor 269302-5053.226	
AUK Connection cable 269302-5040.224	

Supplement to AUK: Material temperature sensor
(Material compensation)

Surface sensor 2 269300-3904.824	
Magnetic holder 2 269300-3900.524	



Technical specification

AUK Environmental Sensor

Measuring range

Air temperature	10 °C...40 °C
Atmospheric pressure	800 hPa...1200 hPa
Air humidity	10 %....90 % rel.humidity

Sensor reading cycle	1 s

Measurement uncertainty of individual components

Air temperature	100 mK
Atmospheric pressure	0.4 % of the measuring range
Air humidity	5.0 % rel.humidity

Measuring inaccuracy referred to the measuring distance	1.5 µm/m

Surface temperature sensor

Measuring range

Type OF 040050	-20 °C...+ 40 °C
Type OF 060050	0 °C...+ 60 °C

Sensor reading cycle	1 s
Measuring inaccuracy	100 mK

Literature

/1/ Edlen,B.: The Refractive Index of Air.
Metrologia 2 (1966), 71 - 80