Measurement of corrosive process gases

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In many areas of process engineering, reactive gases are used as starting products in chemical processes. These gases often are corrosive, so that only certain materials can be used. In process measurement technology, these gases are usually detected with special photometers that are located locally outside the process. The process gas therefore comes in contact with all materials on its way from the process to the sample cell. Both the design of the gas paths and that of the sample cell must therefore be adapted to these requirements.

What is corrosion?

The term corrosion is mostly used to describe the natural transformation of metals into a more stable chemical form, such as oxide, hydroxide, or sulphide. Generally, this transformation leads to a significant deterioration of the material properties. Individual materials react in different ways during this transformation process. To assess this behaviour better, the term **resistance** was added, which can also be used to include non-metallic materials.

This term subsumes many properties of a substance to be able to determine its suitability for use. In process gas analysis, these are primarily the following influencing variables:

- gas type (reaction rate **r**)
- gas concentration (**c**)
- existing humidity (**RH**)
- temperature range (**T**)
- time duration/operating hours (**t**)

The resistance **B** can be described as an empirical function of these influencing variables:

$$B = f(r, c, RH, T, t)$$

In practice, the resistance of materials is determined based on practical tests or empirical values. These results are then given in a classification to be able to better assess their suitability for use:

+	**resistant** (little or no impairment of the material)
0	**partially resistant** (weak to moderate attack)
-	**unstable** (strong attack to complete destruction)

For the practical assessment of materials, there are resistance tables which are usually published by manufacturers (materials, fittings, hoses, etc.) [1]. DECHEMA provides a comprehensive work on this subject [2].

Influence of gas type

The corrosive effect of different gases is mainly due to the reactivity or reaction rate **r** with the respective substance. Chlorine (Cl_2), sulphur dioxide (SO_2), ozone (O_3) and hydrogen chloride (HCl) can be classified as very corrosive in this respect. In contrast, noble gases and other inert gases such as nitrogen (N_2) are very inert and therefore not corrosive. All other gases are in between regarding this assessment.

Gasconcentration c

In the resistance tables, 100% gases are usually assumed, so that the most critical case is always shown here. If, on the other hand, there are lower concentrations in the process gas, the resistance improves with decreasing concentration.

Example:
Stainless steel 1.4571 is only partially resistant to 100vol.% chlorine (dry). If the concentration is reduced to e.g. 100ppm, the resistance increases and thus also the time until the first damage to the material occurs.

Influence of humidity

Corrosive gases in the presence of increased humidity can lead to a deterioration in the resistance of different materials.

Example:
PEEK is resistant to dry chlorine gas, whereas moist chlorine gas leads to severe surface attack. This material is therefore only suitable for dry gas.

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Temperature range

Higher temperatures are generally an accelerating factor in chemical reactions. This means that the resistance decreases with higher temperature. On the other hand, a higher temperature prevents the condensation of moisture and the formation of aerosols, which in turn reduce resistance. A compromise is therefore necessary to define the optimal temperature range for the respective application.

Influence of time

The exposure time **t** naturally also has a considerable influence on the resistance of a material. Here, the concept of **Dose** can be used, which is linked to the concentration **c** and the time **t**.

$$Dose = c \cdot t$$

In practice, this means that the stability is given over a longer period at a low concentration but is correspondingly shortened at a higher concentration. The dose would then be the same in both cases. This time frame **t** is also called the service life, during which the material withstands the effects of corrosive gases. After this time, the material or the component may have to be renewed in order to maintain the specified properties. This time period is also mostly supported by practical experience.

Materials for corrosive gases

Suitable materials for use with corrosive gases include metals such as stainless steel (e.g. 1.4571), Monel, Hastelloy®, Tantalum or plastics such as Teflon™, PEEK, polyamide and ceramic materials (Al_2O_3). O-rings required for sealing are available in very different designs (Viton®, Kalrez®, FKM, Teflon™/PTFE etc.). For these materials, too, there are corresponding resistance tables from the various manufacturers.

Design of the process gas sample cell

The process gas sample cell developed by Wi.Tec consists of a sample cell block into which the gas connections (fittings) are screwed and sealed. The fittings are suitable for a hose connection or for piping. The windows are connected gas-tight to the sample cell body from the outside via a suitable O-ring. A flange is used for this purpose, which is attached to the sample cell body with several screws.

The flange also contains the beam guidance of the measuring radiation, which is irradiated through the cell. The different cell lengths, with L=25mm, L=70mm and L=220mm, are connected to the radiator or detector block of the photometer with corresponding holding.

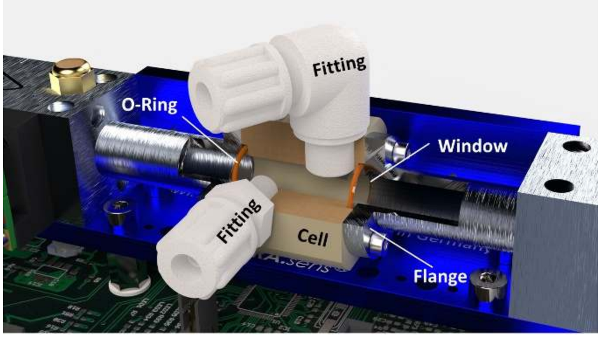

Figure 1: Sectional view of the AK25 process sample cell (L=25mm), with the positioning of the fittings for the connection of a 4/6 PTFE tube. The length of the flanges can be adapted to the respective cell length L

The choice of materials for the gas-contacting parts is optimally adapted to the application and customer requirements. Many different materials are available for this purpose.

The design of the process sample cell allows the complete assembly to be dismantled so that the individual components can be cleaned if necessary. This may be necessary, for example, if condensate or particles (dust or similar) get into the cell. In the case of maintenance, the seals and fittings can also be replaced if this should be necessary.

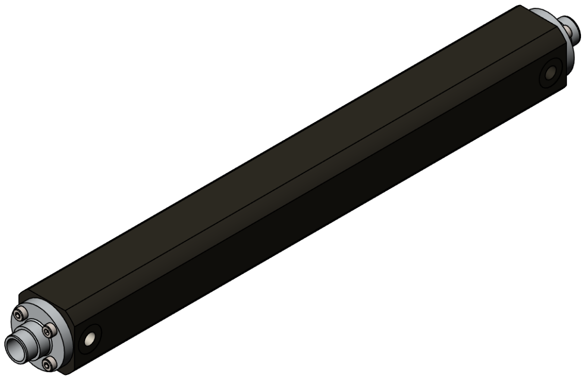

Figure 2: Process gas sample cell with an optical path length of 220mm (AK220) for small gas concentrations (ppm- range)

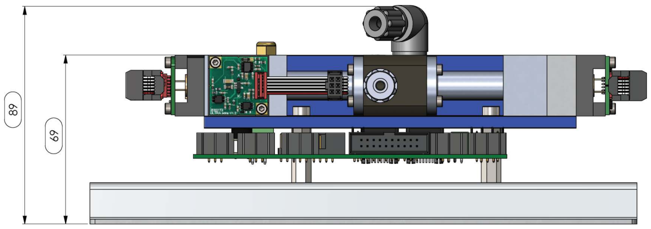

Figure 3: Side view of the photometer setup with a 25mm process gas sample cell (AK25)

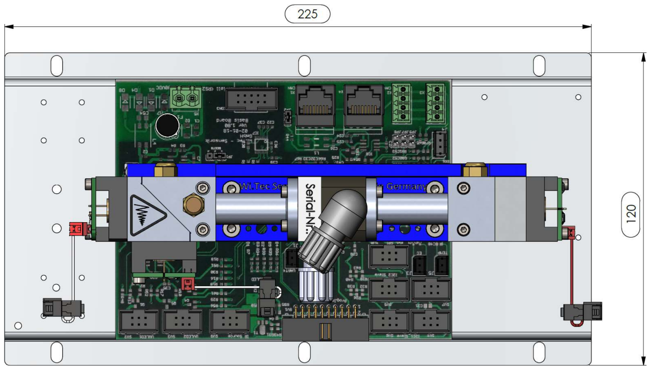

Figure 4: Top view of the entire photometer assembly with a 25mm process gas sample cell (AK25), with evaluation electronics and mounting plate for installation

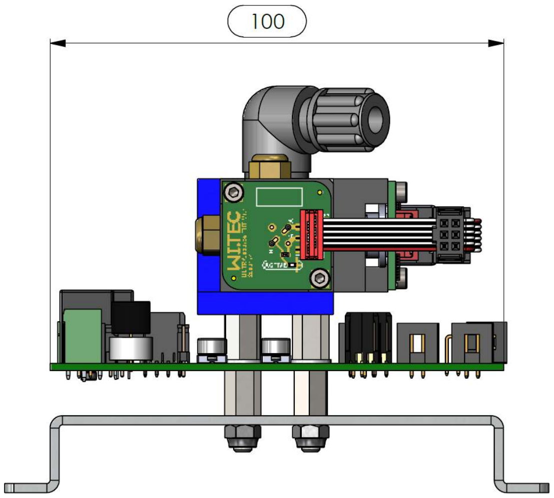

Figure 5: View of the entire photometer setup with a 25mm process gas sample cell (AK25)

Measurable gases

The process gas sample cell was initially developed for applications with the **ULTRA.*sens*®** design. However, due to its modular design, this sample cell can also be easily integrated into the **INFRA.*sens*®** setup. Other window materials may be required for this.

Gas type	smallest range	largest range
Chlorine Cl_2	100ppm	100Vol.%
Hydrogen sulphide H_2S	5000ppm	100Vol.%
Sulphur dioxide SO_2	100ppm	100Vol.%
Chlorine dioxide ClO_2	100ppm	10Vol.%
Ozone O_3	100ppm	10Vol.%

Table 1: Possible measuring gases and the corresponding measuring ranges that can be realised with the different cell lengths L

Literature:

[1] Chemische-Beständigkeitstabelle (2019), Bürkert Fluid Controll Systems, Ingelfingen, Deutschland

[2] DECHEMA Werkstofftabellen (Jahrgänge 1953-2021), DECHEMA e.V. Informationssysteme und Datenbanken, Frankfurt am Main, Deutschland

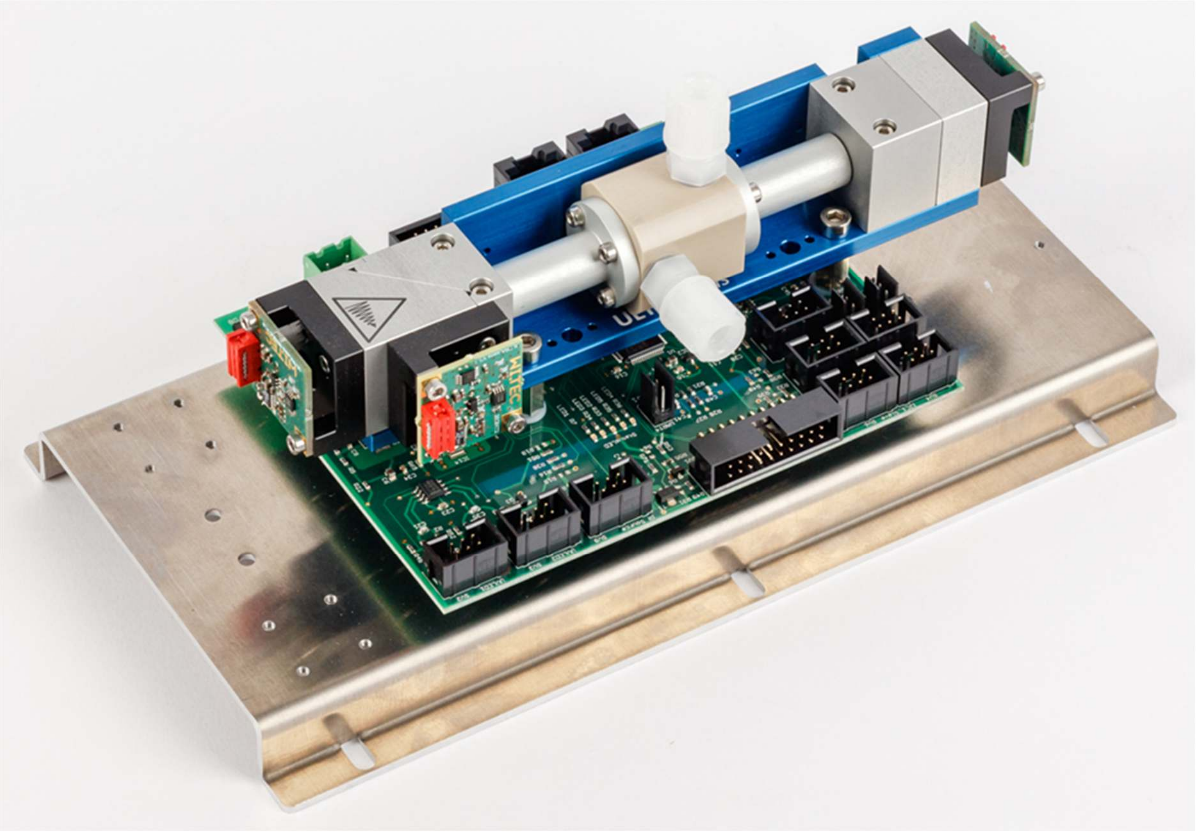

Figure 6: General view of the process gas sample cell (L=25mm) in an **ULTRA.*sens***® *set-up for chlorine gas analysis*

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