



USE OF INNOVATIVE NDIR GAS ANALYSIS FOR MONITORING INDUSTRIAL GAS MIXING EQUIPMENT

Mixed gases are of great importance for many applications in the industrial and medical sectors. Gas mixers, which can adjust these gas concentrations precisely and as required, are generally used for this purpose. Gas mixers make it possible to use the process gas for a perfect protective atmosphere in food packaging or the optimum mixture for welding and cutting metals at any time. Special gas mixtures are also required in laboratories or in anesthesia. In some cases, gas mixers can also be transported to the place of use and thus enable economical and flexible utilisation of process gases.

Gas mixers are used in numerous industrial processes:

- Metalworking
- Medical technology
- Helium leak test
- Food industry
- Protective gas packaging
- Glass processing
- Laser technology
- Dipping technology

How a gas mixer works

Gases are usually mixed dynamically with different volume flows. By varying the respective volume flows ($\dot{V}_n$), the desired gas mixtures are created with a defined concentration c_n . At least 2 gases are required to generate a variable gas mixture. In technical applications, however, almost any gas components can be added. In practice, 3-gas mixers are probably the most frequently used mixing devices. As gases mix very quickly, no complex mixer M is required. In the simplest case, the gases mix in the downstream pipework or a downstream buffer volume.

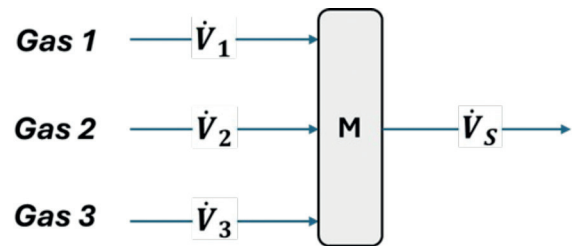


Fig. 1: Generation of technical gas mixtures

The concentrations c_x of the individual gases in the gas mixture result from the following relationship:

$$\dot{V}_S = \dot{V}_1 + \dot{V}_2 + \dot{V}_3$$

$$c_x = 100 \text{ vol. \%} \cdot \frac{\dot{V}_x}{\dot{V}_S}$$

In the simplest case, the different volume flows ($\dot{V}_n$) can be set using a proportional valve. These valves consist of a piston with a needle that is located in front of an orifice and, depending on its position, opens the gas path more or less. If the needle is completely in the orifice, the flow is blocked (=0%). If the needle is completely removed from the orifice, the flow rate is maximised (=100%). All other intermediate values result from the respective position of the needle. The valves are usually set using rotary knobs which, depending on the proportioning range or scale, allow a setting accuracy of $\pm 1\%$ abs. (scale 0-25%) or $\pm 2\%$ abs. (scale 0-100%). Models with electronic control via a display are also available on the market. However, the accuracy and reproducibility of this setting is limited, as the scaling of the rotary knob is only divided into 10% increments. It is also difficult to find the exact previous position after turning the knob. The setting accuracy is therefore specified as $\pm 2\%$. As a separate valve is required for each gas that is to be added, the accuracy of the gas mixture results from the square error propagation of the individual valves. With 3 valves, this would be:

$$\text{Error} = \sqrt{2^2 + 2^2 + 2^2} = \pm 3,47\%$$

The total error for an uncontrolled gas mixture can therefore be specified as $\pm 4\%$. Monitoring of the gas concentration is therefore recommended to obtain reproducible results in application technology.

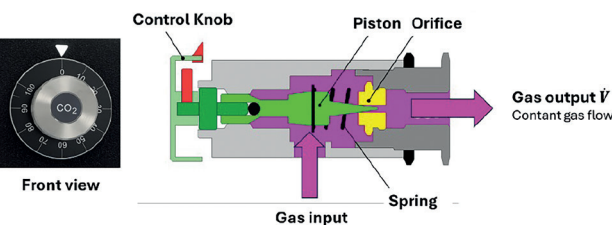


Fig.2: Cross-sectional view of a proportional valve for use in gas mixers

The overall schematic structure is shown in Fig. 3. The three control valves are connected in parallel so that the outputs are combined in one gas path. After a mixing phase in the supply line, the gas mixture enters the buffer volume. Depending on the application, the buffer volume is designed for a capacity of between 100 and 250 litres and different pressure ranges.

The gas is then analysed with the INFRA.sens® on the way to the buffer volume. A partial flow from the supply line is fed to the gas analyser, which is usually designed for low flow rates of <1 litre/minute. The current gas concentration c is shown on an integrated display (see Fig. 4) without any significant time delay (t_{90} time <3s). If deviations occur during the analysis, the respective volume flow can be readjusted so that the optimum concentration value is adjusted. The value set in this way remains constant for the rest of the process. The zero-point stability of the INFRA.sens® can be regularly checked with the nitrogen (N_2) already present in the process and readjusted if necessary. An end point check should be carried out once a year with an appropriate test gas.

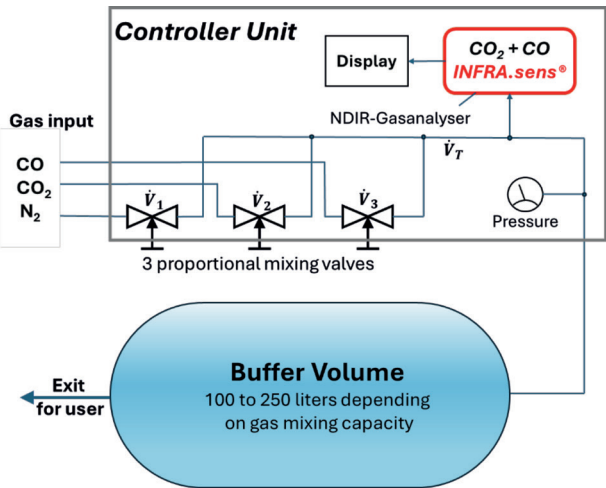


Fig.3 : Schematic diagram of a gas mixing system with controlled composition using an INFRA.sens® (NDIR gas analyser).

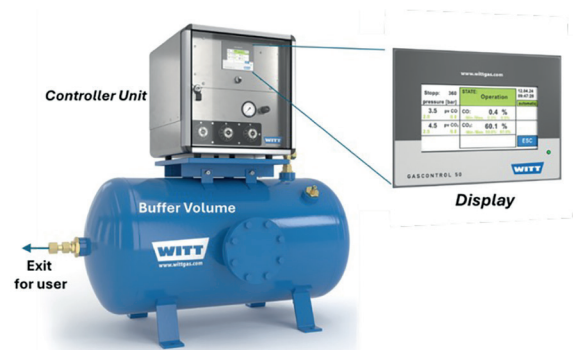


Fig. 4: Overall design of a typical gas mixing system for the food industry with integrated gas analysis (INFRA.sens®).

In order to monitor the accuracy of the gas mixture, continuous measurement of the set gas concentration cn with a highly accurate gas measurement system is required. For most industrial gases, NDIR gas measurement technology is best suited. The accuracy class of typical gas sensors is ±2%, so no significant improvements can be expected from their use. The requirements for high-precision gas analysis are ±1% and can only be realised by using complex evaluation algorithms. This requires complex calibration and compensation processes.

Gas analysis

The gas concentration to be monitored is measured using the tried-and-tested INFRA.sens® modules. With this sensor technology, almost all diatomic gases can be detected with high precision and a low detection limit. These are in particular the technical gases listed in Table 1:

Table 1: Gas measurement ranges with the INFRA.sens®

Gas Type	chem. Formula	Measuring Ranges (FS)
Methane	CH ₄	1000 ppm to 100 vol. %
Ethane	C ₂ H ₆	1000 ppm to 100 vol. %
Propane	C ₃ H ₈	1000 ppm to 100 vol. %
Butane	C ₄ H ₁₀	1000 ppm to 100 vol. %
Hydrocarbons	C _n H _m	1000 ppm to 100 vol. %
Nitrous oxide	N ₂ O	100 ppm to 100 vol. %
Carbon dioxide	CO ₂	50 ppm to 100 vol. %
Carbon monoxide	CO	500 ppm to 100 vol. %
Sulphur hexafluoride	SF ₆	50 ppm to 100 vol. %
Tetrafluoromethane	CF ₄	30 vol. % to 100 vol. %
Water vapour	H ₂ O	5000 ppm bis 5 vol. %

CO and CO₂ gas mixtures in N₂ are mainly used in the food industry (packaging). As the concentrations can reach values of over 50 % by volume, the respective measuring ranges must be designed for the range from 0 to 100 % by volume. Both gas concentrations c_x (CO₂) and c_y (CO) are determined using the NDIR method (Wiegleb 2023). This method is based on the selective absorption of infrared radiation by the different gas molecules. The CO₂ measurement therefore takes place in the infrared spectral range at 4.3µm and the CH₄ measurement at 3.4µm. Spectral overlaps are excluded using narrow-band interference filters, so that this type of gas measurement guarantees high selectivity (Wiegleb 2023). The INFRA.sens® uses a multi-channel detector for this purpose, with which both gases (CO and CO₂) can be detected simultaneously in one measuring cuvette. In total, up to 3 different gases can be detected with the INFRA.sens® in one set-up. This has the advantage that the different gas concentrations are measured simultaneously. If gas sensors were connected in series, there would inevitably be a time offset, which would cause a considerable error, especially at low gas flow rates.

The INFRA.sens® have a very high measuring accuracy of <1%. To achieve this characteristic, all measurement errors are compensated electronically. These are in particular

- Temperature compensation between 5°C and 45°C
- Air pressure compensation between 600hPa and 1200hPa
- Carrier gas dependency between cx (CO₂) and cy (CO)
- High long-term stability (=low drift rate) due to a spectral reference measurement

By using a gold-plated analyser cuvette (AK), changes in the reflection properties on the inner wall of the cuvette can also be effectively prevented, so that the long-term stability can be significantly improved.

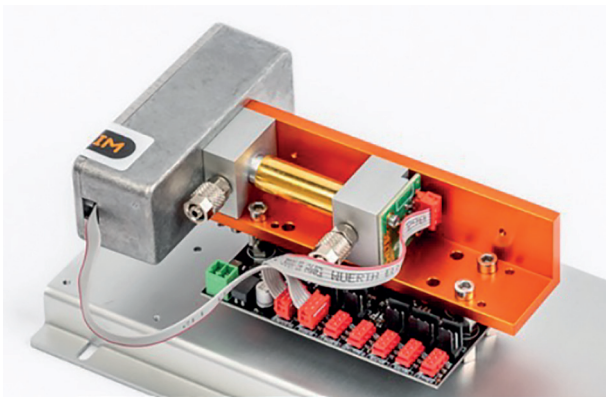


Fig. 5: INFRA.sens® gas measurement module for simultaneous analysis of carbon monoxide (CO) and carbon dioxide (CO₂) with a gold-plated analyser cell (AK50mm)

The measured temperature and pressure values required for compensation are recorded directly in the analyser cuvette using a microsensor. This provides the exact physical data of the gas to be measured and improves the quality of the electronic compensation.

Data communication takes place via an RS232 interface. A USB interface, a CAN interface and a Modbus protocol are also available. The module is supplied via a 24VDC connection, whereby the electrical power consumption is P<2Watt.

Fig. 6 shows a comparison of the set gas concentration with and without gas analysis. The formal linear relationship between the set gas concentration and the actual gas concentration can be improved by a factor of 3-4 with a gas analysis.

Example: Modified atmosphere packaging of red meat and minced meat

MAP packaging is basically used to extend the shelf life of the packaged food. For this purpose, the ambient air/oxygen is replaced by a mixture of CO₂ and N₂. Table 2 lists the optimum gas concentration for different foods (Bender 2023).

For red meat, there is an additional function. Here, the modified atmosphere should also preserve the red colouring of the product as much as possible. Consumers favour this appearance, as it is often associated with a higher quality (fresher's) product. For this purpose, a small proportion of CO is added to the gas mixture. Typical composition is 60-70% CO₂, 0.4% CO, balance N₂. In the EU, CO is not authorised for this purpose. However, in the USA/Canada, Australia/New Zealand and in South American countries, for example, this process is widespread. The mixer generates a mixture with three mechanical mixing valves and feeds this into the buffer container. From there, the packaging machine removes the gas mixture in cycles and feeds it into the packaging before it is sealed. The integrated gas analysis with CO/CO₂ sensors permanently monitors the correct composition of the mixture in the container. An alarm is triggered if the limit values are

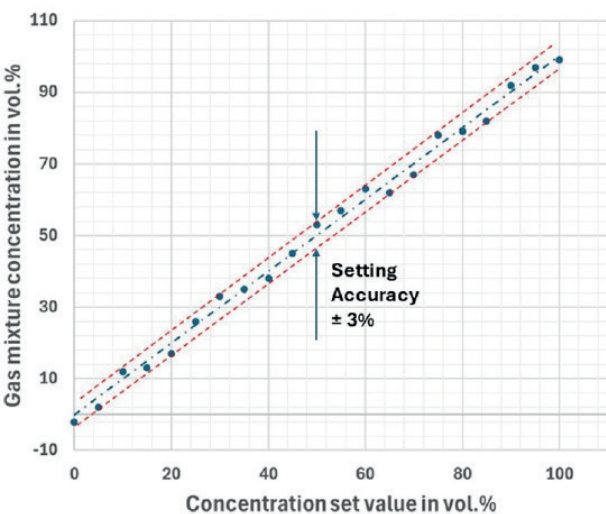


Fig. 6: Accuracy of the gas mixture with uncontrolled and controlled adjustment using NDIR gas analysis (INFRA.sens®).

Table 2: Examples from the EU for optimal gas mixtures in vol. %

Product	O ₂	CO ₂	N ₂
Raw red meat	70	20-30	0-10
Raw offal	80	20	0
Raw poultry with skin	0	30	70
Raw poultry without skin	70	20-30	0-10
Cooked meat and sausages	0	20-30	70-80
Hard cheese	0	30-100	0-70
Soft cheese	0	10-40	60-90
Cheese, sliced	0	30-40	60-70
Cream cheese	0	100	0
Yoghurt	0	0-30	70-100
Milk powder	0	0-20	80-100
Raw low-fat fish	20-30	40-60	20-40
Raw fatty fish	0	40	60
Shellfish and crustaceans	30	40	30
Cooked/smoked fish	0	30-60	40-70
Baked bread/bread rolls	0	50-100	0-50
Cakes, pastries	0	50	50
Fruit	3-10	3-10	80-90
Vegetables	0	30	70
Prepared dishes	0	30-60	40-70
Pasta/pizza	0	30-60	40-70
Sandwiches	0	30	70

¹ Modified Atmosphere Packaging

violated. This ensures high process reliability and consistently high quality of the MAP packaging. For high-quality and flawless food.

Summary

Even though modern gas mixing systems generally produce reliable gas mixtures, the use of NDIR gas analysis (INFRA.sens®) can increase the reliability of the system and thus the safety of the downstream process. The use of this sensor technology is therefore recommended for monitoring gas mixing plants. The costs for this effort are justifiable, but can significantly improve quality control. In particular, the flexible use of INFRA.sens® technology for different gases opens new applications that could not be realised with previous sensor technology.

References

- Bender, M.: Gas Measurement in Food Packaging, Chap.17.3 in Gas Measurement Technology in Theory and Practice Springer Nature 2023
- Wiegleb, G.: Gas Measurement Technology in Theory and Practice Springer Nature 2023



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