Rapid Determination of Air Demand, Wobbe Index, and Calorific Value in Industrial Off-Gases

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Off-gases, left over at chemical or petrochemical industrial processes as well as in the heavy industry are increasingly in use as a source of energy due to environmental reasons [1] and as a cost-saving alternative for natural gas. These off-gases used to be partially drawn off via a flare; however, nowadays they are used for the extraction of electrical energy and process heat. Yet, the composition of these off-gases varies strongly. On the other hand, a constant and controlled energy supply is an economical necessity minimising the emissions and costs desirably at the same time. Therefore, a reliable, rapid, and continuous measuring of the Air Demand and the Wobbe Index of the gas is required for adjusting the combustion process to varying gas qualities and operation conditions.

	CH4	C2H4	C3H6	C3H8	C4+	CO2	H2	N2	C5+
Min [Vol%]	1	0,9	2	0,2	0,1	4,6	2	3	0,1
Max [Vol%]	30	73	46	2,2	14,2	6,6	51,5	66	1,5

Table: Example of varying concentrations of the main components of a firebrand gas

Today, the efficient and cost-saving alternatives of expensive energy such as natural gas or electric current has become very important in the operation of industrial processes. In addition, governmental constraints imposing the avoidance of noxious substances or soot particles play an important role. The possible applications are manifold; the most important application possibilities are described below:

- Making use of off-gases from chemical plants, refineries, and bio gas plants [2,3]
- Using the off-gases from industrial furnaces, converters, and coking plants
- Facilities for the production of mix gases with a specific quality
- Processes in which the gas composition influences the gas flame and the product quality [4]

A specific problem is that in many measurements extremely varying gas compositions occur in a time frame of only a few seconds ranging from a few MJ/m³ to values over 100 MJ/m³. This corresponds to the variation from low calorific gas to Propane.

The caloric quality of such gases can be excellently determined through the instruments of the RHADOX™ series. These are a series of instruments that can determine the caloric parameters of broad gas compositions within an extraordinary short response time making them the state of the art instrument to determine the following caloric parameters:

- Stoichiometric Air Demand
- Wobbe-Index
- Specific Density and
- Calorific Value (LCV)

The measuring principle is based on the oxidation of the off-gas with air in surplus and measuring the residual Oxygen via a ZrO_2-probe. Each instrument delivered is designed, customised and tested according to the specific plant conditions.

The measuring sequence within the Rhadox™-System is the following:

- defined mixture of gas and air
- (catalytic) combustion resp. oxidation
- determining the residual Oxygen content
- calculating the Air Demand and Wobbe Index
- calculating the Caloric Value via the built-in Specific Gravity measurement

The key role of the Rhadox™ plays the mixing chamber for the gas and the air supplied in surplus. Specifically designed nozzles produce a laminar and homogenous flow of the mixture; this makes the gas mixture independent from viscosity variations of the gases [5]. The gas flow only depends on the density of the gas supplied, comparable to the burner's properties. A heat exchanger for the gas and the air controls the temperature difference between the gas and the air within some milli Kelvin. A control valve for the measuring gas and a differential pressure transmitter equalise the pressures to an accuracy of $<$ 0,05 mbar. It is critical for the correct determination of the parameters to keep the gas and the air at the same pressure and temperature – the absolute values of these parameters are of minor importance.

The sample gas is completely burned in the Rhadox™-system. The mixture of the gas and the combustion air has to remain constant and reproducible. The residual Oxygen is a reliable parameter to measure the Air Demand of the gas in the combustion process. Assuming a proper calibration of the Rhadox™ has been carried out, the Wobbe Index of the off-gas can be determined. The oxidation is carried out in a catalytic reactor if a gas does not burn constantly due to its composition [6].

The residual Oxygen content is determined via a ZrO_2-probe, i.e. our well-proven Lambda-probe. This probe has an operation temperature of appx. 600°C. Operating the Lambda-probe requires clean and dry instrument air, which is free of Hydrogen, Carbon monoxide, and Hydrocarbons.

The immediate measuring value is the corrected stoichiometric Air Demand of the combustion gas. Within reasonable concentration ranges, a linear relationship exists between the (corrected) stoichiometric Air Demand and the Wobbe Index for each group of gases. By using a computer simulation for the oxidation process, proper calibration gases can be determined.

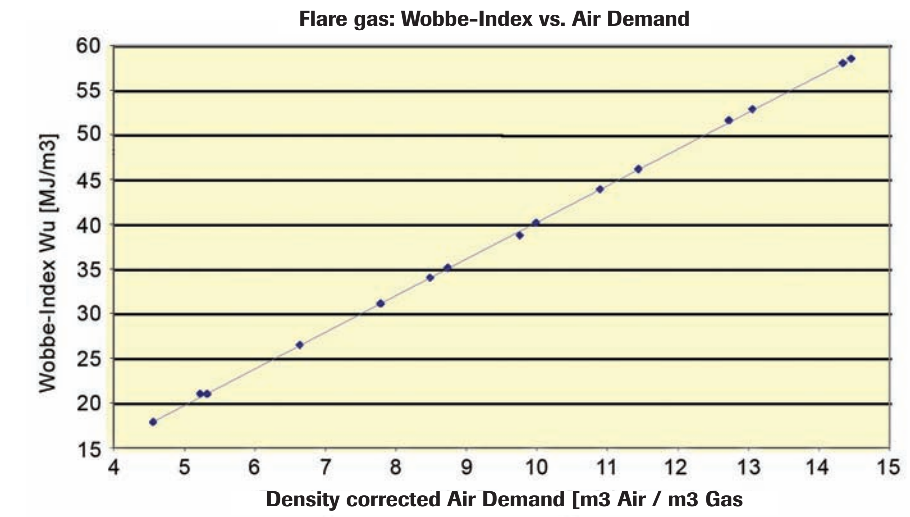

Diagram: Wobbe-Index as a function of the stoichiometric Air Demand

The Calorific Value H_u and the (lower) Wobbe-Index W_u are referred to the Specific Density d_{rel} of a gas as

$$H_U = W_U * \sqrt{d_{rel}}$$

Legend :

H_U	Calorific Value
W_U	(lower) Wobbe Index
d_{rel}	Specific Gravity (density of the gas related to air)

Via a built-in density measurement the Rhadox™ computer calculates the Calorific Value, taking into account the well-known method of the Bernoulli's Law. This method is based on the fact that the flow of a gas through a restriction depends on the gas's density [7,8].

Summary of the major features of the Rhadox™ measuring system:

- no extra calorimeter room is needed since the ambient temperature influence can almost be neglected
- very short response time of appx. 3 sec. // T90 10-20 sec. depending on the probe
- repeatability better than 0,15% of the actual value
- semi-automatic calibration with automatic control of plausibility, drift, and repeatability
- O_2-correction for pre-conditioned gases
- certified for EEx-Zone 2 (ATEX II 3 G // EEx nC IIB+H2 T3), including the danger of internal explosion of flammable probe gases

RHADOX™-system for the determination of calorific values in the flare gases of a chemical plant

Operation Experience:
The Rhadox™-measuring systems for the rapid determination of the stoichiometric Air Demand and the Wobbe Index in off-gases are in use in several refineries and chemical plant sites in Germany, Norway, Spain, Kuwait, South Africa, and in China. Not only are the swiftness of the measurements, but also the low maintenance requirements and the long-term stability of the instruments highly appreciated by customers worldwide.

Literature:

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[6] DE-GM 297 15 633.0.
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