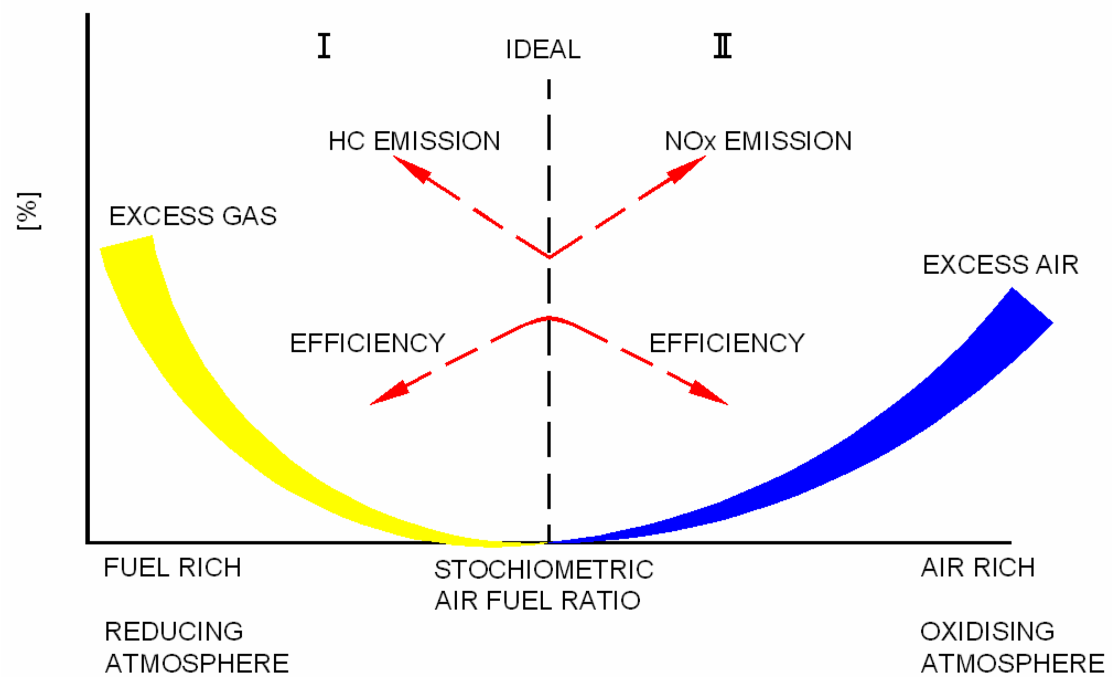
WIM 9900 Wobbe Index - and Calorimeters

Optimize your combustion efficiency using Wobbe Index and / or Combustion Air Requirement Index

In today's market, the gas you use or deliver has to meet certain specifications. In many refineries and petrochemical plants, furnaces, turbines and boilers can be exposed to frequent and sudden changes in the fuel gas composition. These changes will immediately affect the operating stability and efficiency of your combustion process and causes unwanted emissions.

Application:
Users are looking for a method to control the air/fuel ratio in such a way that disturbances are minimised and the combustion process occurs with maximum efficiency and minimum emissions.



The table above shows the efficiency vs the amount of air / gas introduced to the combustion process. The black dotted line indicates the stochiometric air fuel ratio (the exact amount of air required for the combustion of 1m3 of gas under normal conditions), and is the most efficient way to combust your product and have lowest possible NOx or HC emission.

Regime I (reducing atmosphere)
Adding less air then required for the complete combustion will result in unburned fuel gas (HC and or CO) emissions. By venting unburned fuel gas into the atmosphere energy is

spilled and will result in unnecessary air pollution like greenhouse gasses and smog. HC's combined with NOx and sunlight forms ozone which is a key component of smog.

Regime II (oxidizing atmosphere)
When combusting a gas with an excess amount of air the combustion efficiency is decreased by the energy required to heat up the excess air. As a result extra energy will be consumed. Another disadvantage is the formation of NO_x emission. NO_x emissions have to be monitored by law (air pollution legislation) and contribute acidification and the formation of ground-level ozone

CARI (Combustion Air Requirement Index):
The Cari is the required amount of dry air to burn 1Nm3 of fuel gas compensated for the specific gravity of the gas. In formula:

$$\text{CARI} = \frac{\text{Air demand}}{\sqrt{\text{Specific gravity}}}$$

Why using CARI in stead of Wobbe index for air fuel ratio control?

The Wobbe Index is a measure for the interchange ability of gas when fluctuations in gas composition are expected. Two gasses with different composition but with the same Wobbe Index, produce the same amount of energy when combusted.

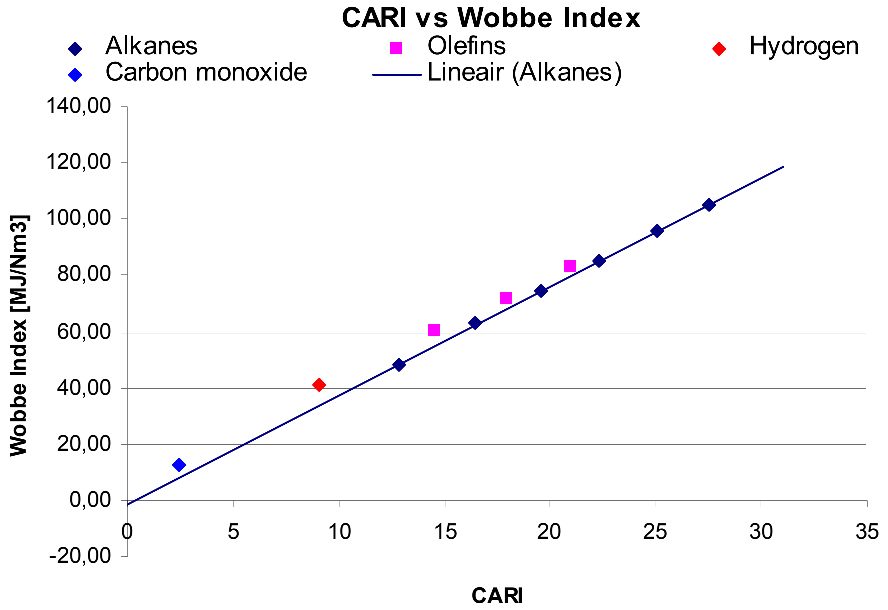
When using the Wobbe Index for air fuel ratio control, you have to take the following into consideration:
All flame type and all residual oxygen type Wobbe analysers (except for the Hobre WIM9900) are measuring Wobbe Index. The CARI, for air fuel ratio control, is correlated from the Wobbe signal.

This correlation can be done easily for gas composition based on Alkanes and Olefins because there is an almost linear correlation between the Wobbe index and CARI.

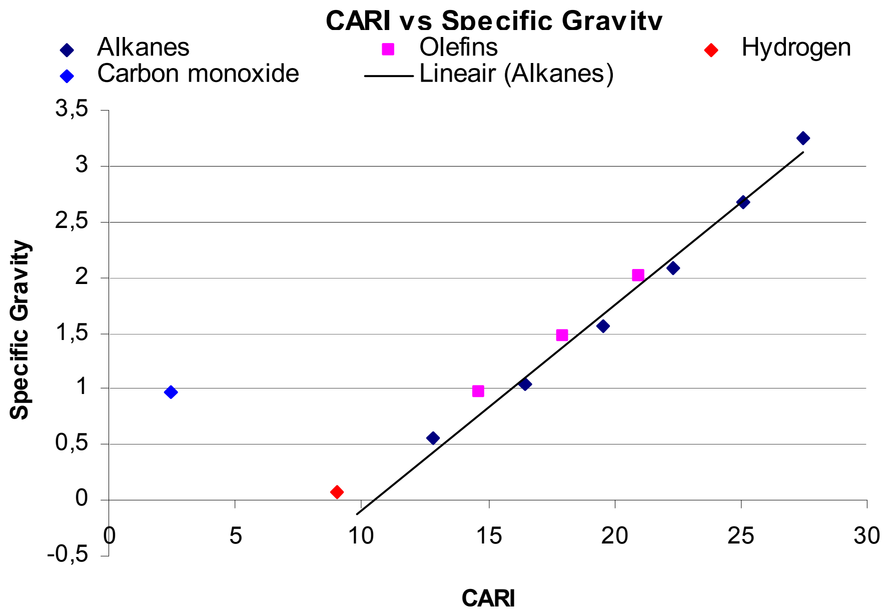
Correlating Wobbe Index and Cari for air / fuel ratio control for gas mixtures containing fluctuating CO and H2 concentrations error's are inevitable due to non linearity! (As indicated in the table below).

	Wobbe Index	Air demand	SG	Cari	Wobbe / Cari
CH4	48,17 MJ/Nm3	9,56 m3/m3	0,55	12,84	3,75
C4H10	85,43 MJ/Nm3	32,30 m3/m3	2,09	22,35	3,82
H2	40,89 MJ/Nm3	2,38 m3/m3	0,07	9,04	4,52
CO	12,85 MJ/Nm3	2,39 m3/m3	0,97	2,43	5,29

Indicated in the graph below is the relation between the Cari and the Wobbe index. The trend line indicates the error occured in case the Cari is derived from the Wobbe index, assuming the gas contains alkanes only.



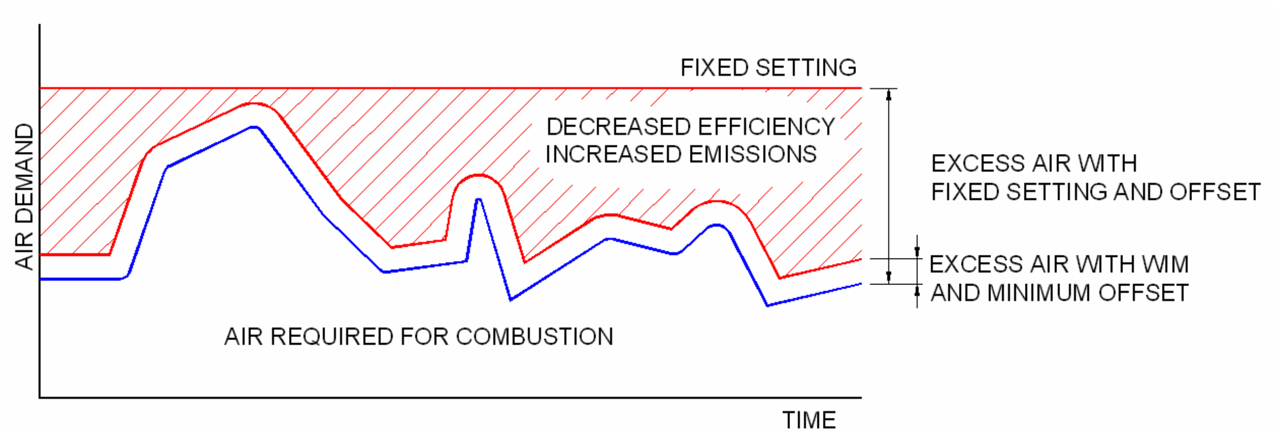
In some cases, end users correlate the air required for combustion to the specific gravity. Again this is not problematic for gases containing alkanes and olefins, but can decrease the efficiency and cause NOx emissions due to the presence of other inert elements.



Result: More air than required is added for the combustion of gas. Therefore the risk of unburned HC gas emissions is minimal but, the combustion efficiency is reduced and NOx emissions are increased.

Third possibility is the use of a fixed setting for the amount of air added to the combustion process. In these situations the amount of air is based on a worse case situation + safety margin. Besides the increased emissions also the efficiency of the combustion process is decreased due to the energy required for heating up air. Depending on the size of the furnace weather an online measurement can be justified. Cost reductions can achieved by:

- Reduction of air required for combustion
- Reduction of fuel gas (increased efficiency, less energy required)
- Possibility to sell emission rights



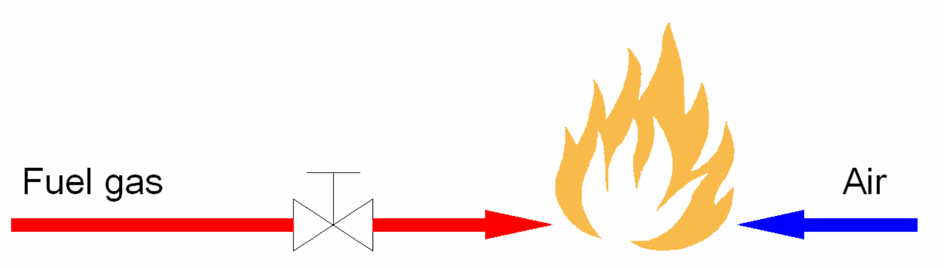
The Hobre WIM9900 measures both Wobbe Index and Cari separately!. Since the Cari measurement is related to the residual oxygen after complete combustion of the sample gas, the Cari is directly measured and an accuracy of +/- 0,4% MV is guaranteed, also in case of large fluctuations in H2 and/or CO occur.

Relation between Heating value and Wobbe Index

The heating value (or calorific value) of a gas is the amount of heat produced by the complete combustion of a certain volume of gas. The dimension of Heating value is MJ/Nm3 (or a derived dimension like BTU/SCF, Kcal/Nm3 etc).

The amount of energy produced during combustion depends on the amount of gas burned. By opening the valve, more gas is burned resulting in higher flames and more produced energy (similar to your stove at home).

In formula: $Energy\ \ produced = gas\ \ flow \times heating\ \ value$



The gas flow through the valve can be effected by:

- Opening / closing the valve (changing the internal diameter of the valve)
- Temperature fluctuations
- Change in differential pressure over the valve, a higher differential pressure creates a larger flow
- Change in relative density (specific gravity) of the fuel gas

The gas flow of a gas through a restriction (like a control valve) is dependent on the specific gravity of the fuel gas as per the following equation:

$$Gas\ flow = k \times \frac{\sqrt{pressure}}{\sqrt{Specific\,Gravity}} \qquad Specific\ gravity = \frac{density\ \ fuel\ gas}{density\ \ air}$$

At a given differential pressure, the gas flow of hydrogen (very light) through an orifice will be much higher than for instance propane (rather heavy).

Therefore a sudden change of gas composition, will influence both the heating value and the gas flow! This will have it's outcome in the amount of energy produced and the amount of combustion air required!

The formulas for the energy produced and the gas flow on the previous page can be combined into the following equation:

$$Energy\ \ produced = k \times \frac{\sqrt{pressure}}{\sqrt{Specific\,Gravity}} \times Heating\,value$$

As heating value relates to Wobbe index by:

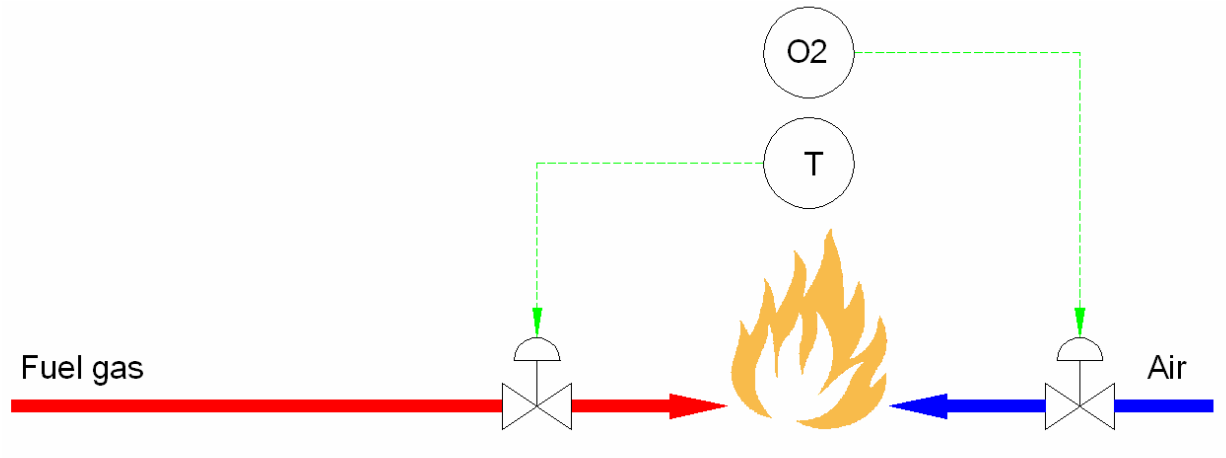
$$Wobbe\ Index = \frac{Heating\ Value}{\sqrt{Specific\ Gravity}}$$

The energy produced can be defined as:

$$Energy\ \ produced = k \times \sqrt{pressure} \times Wobbe\ Index$$

The Wobbe Index (WI) is the main indicator of the interchangeability of fuel gases and is frequently defined in the specifications of gas supply and transport utilities. Wobbe Index is used to compare the combustion energy output with different composition of fuel gases. If two fuels with identical Wobbe Indices are burned, then for given pressure and valve settings the energy output will also be identical. The Wobbe Index is a critical factor to minimize the impact of fluctuations in your fuel gas supply and can therefore be used to increase the efficiency of your burner or gas turbine applications.

Common combustion control



- Common combustion control is based on a flow control to regulate the fuel gas flow based on temperature (feed back control).
- Assuming a constant heating value or wobbe index, the gas flow determines the energy input to the burner. More gas results in higher energy.
- The required air for the complete combustion of gas is defined using an oxygen and combustible analyser installed in the stack based on feed back control.

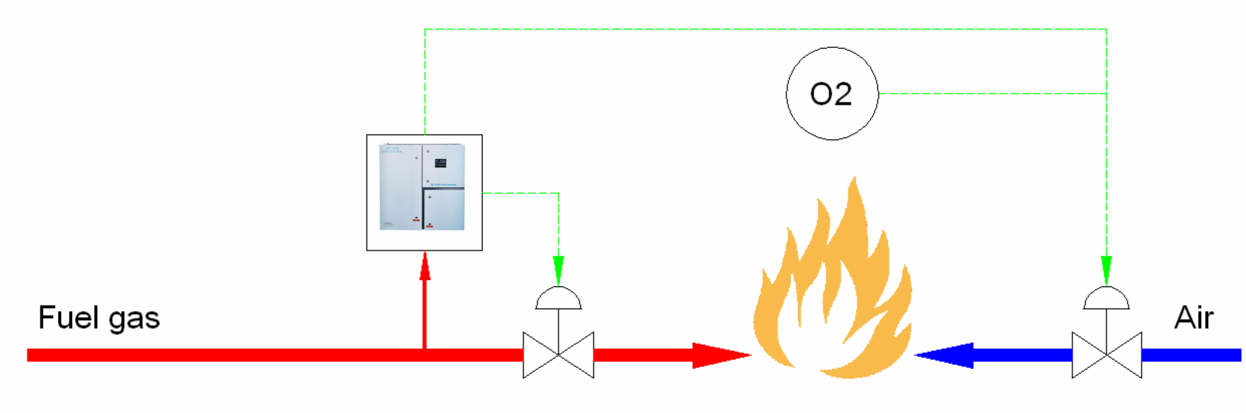
Sudden change in heating value of the fuel gas may result in:

- Change of flow due a change in specific gravity
- Loss of efficiency due to venting of unburned fuel gas or heating up of combustion air
- NOx or HC / CO emission into the atmosphere (environmental issues)
- Unstable furnace control (decreasing product quality)
- Even damage can occur due to hot spots when the HV suddenly increases

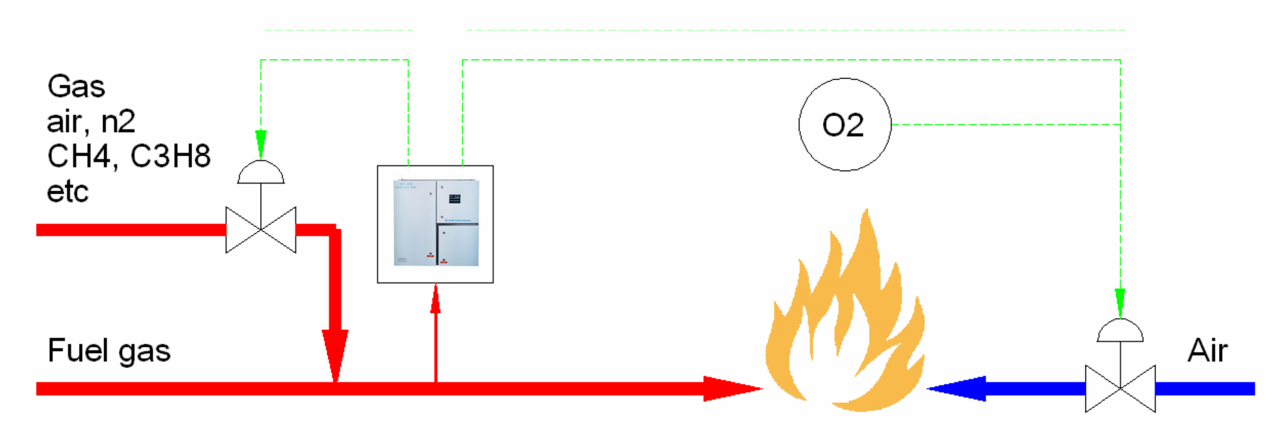
To prevent for unnecessary emissions and loss of efficiency, it is most important to control the air fuel ratio immediately when changes occur. Since changes in the combustion process happen in fractions of seconds a fast responding feed forward signal is mandatory for optimization of your combustion process. A feed back control based on a slow responding stack analyzer will act after the damage is done.

Combustion control based on fast responding feed forward control

By installing a fast responding analyser in the fuel gas supply line, the gas flow and/or air requirement can be controlled before the actual combustion takes place (feed forward signal).



In case large fluctuations in the fuel gas are expected. The wobbe index of the gas flow can be stabilized using the fast responding Wobbe Index signal.



In General:

- Use CARI (Combustion Air Requirement Index) for air fuel ratio control
- Use Wobbe Index for monitoring / controlling the fuel gas flow and or gas quality

Points of attention:

- Never compromise on response time, take the best you can get. A requirement for a fast responding feed forward signal to optimize your fuel gas management is the reason for installing this measurement.
- Always consider Wobbe (or heating value) and CARI output for H2 and CO containing fuels.
- As this measurement is used in control applications, availability, reliability, installation convenience and cost and low maintenance cost are important. This measurement is installed to improve efficiency and not to cause extra maintenance. Do not compromise on quality.
- Make sure you know how the flow is measured; In case the specific gravity is available in the flow meter you most likely do not need the integrated SG meter to convert to heating value.
- Look at the response time of the total system (where to be installed)