



WIM COMPAS™ APPLICATION NOTE

Minimise Cost of SAGD Steam Generation

Save hundreds of thousands of dollars annually by optimizing fuel gas consumption in real time

The lower profit margins on production of heavy crudes than for light oils, because of

- the need for diluents
- higher costs of extraction and upgrading
- lower price

demand a particular focus on minimizing total cost of operation.

Energy Efficiency

Improvements in energy efficiency are particularly valuable for SAGD (Steam Assisted Gravity Drainage) plants as ~60-70% of total operating cost stems from steam boiler consumption of natural gas. Implementing technologies that facilitate optimum performance of the steam generators is thus essential.

The steam generators are fired with grid-quality natural gas in combination with off-gases from the process. The mixing ratio varies by location. Typically the ratio of off-gases blended in the natural gas is 30-50%. These off-gases have considerable methane content, but also contain 20-40% CO₂. CO₂ is relatively heavy, however, does not contribute to the calorific value of the gas. As the composition of both the natural gas and off-gas is not consistent, this mixture creates a challenge for burner management.

Both the air-fuel ratio as the gas and energy flow will fluctuate with the composition.

For a steam generator, the air-fuel ratio is often controlled by stack O₂ analyzers. Due to the slow response of these analyzers they only allow for small corrections. The typical set point is at 3-4% residual O₂, while the optimum combustion efficiency is typically reached at 1.5-2% residual oxygen (and low ppm CO). The additional safety bandwidth of 2% residual oxygen is incorporated to handle the fluctuations in the fuel gas composition. The excess air required to deliver this 2% oxygen cools down the process. To compensate for this loss of heat, the fuel gas flow has to be increased and combustion efficiency is lost.

On a SAGD process, optimizing the residual oxygen – reducing it from 4 to 1.5% (on average) saves hundreds of thousand dollars annually in fuel gas cost.

Representative example

- Furnace capacity: 70MW operating
- Flue gas temperature: 200°C
- Ambient temperature: 0°C
- Wobbe Index Fuel gas: 34 MJ/Nm² (60% natural gas, 40% off gas)
- Fuel gas price: 0,034 Euro/kWh (60% of natural gas price)
- Corresponding fuel gas flow: 2.06 Nm³/s
- Annual fuel gas cost: ~ €20m / \$24m

Reducing the residual oxygen in the stack from 4% to 1.5% saves €200k / \$240k per year in fuel gas cost.

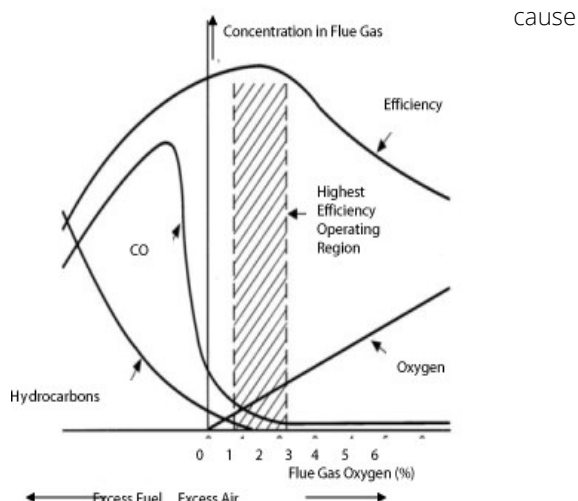
By installing a fast responding Hobré WIM Compas analyzer in the fuel gas supply line, the gas flow and/or air requirement can be controlled before the actual combustion takes place, with a feed forward signal from the analyzer. Disturbances are minimized

and the combustion process occurs with maximum efficiency and minimum emissions.

The remainder of this Application Note explains how.

Optimize Steam quality

Although the water used for steam generation is treated, considerable amounts of minerals are still present. When producing steam, these minerals will



additional (unplanned) maintenance due to scaling of the boiler tubes.

In order to optimize your combustion process, monitoring the input fuel for swings in BTU value into the steam generator is crucial, as it allows feed-forward control of your combustion process and therefore control of your steam quality.

Measuring and controlling the amount of energy introduced to the steam generator is the only practical way to optimize the process, as steam quality is extremely difficult to measure (mixed phase) and the feed-back signal does not allow compensation for rapid fuel gas fluctuations. Mixed fuel with a high CO_2 content has low heating value. Light petroleum solvent, such as butane in the mixed fuel, has a high heating value. The heating value of the fuel change rapidly throughout any given period of time.

Reduce maintenance by increasing the life of the boiler tubes

Being an expensive production process, unplanned downtime, drastically reduces the oil production and therefore the profitability.

Keeping your process up and running requires control of the combustion process.

1. Maintain target steam quality to prevent excess scaling of the boiler tubes.
2. Implement real time burner control to prevent hot spots on the boiler tubes.

Besides measuring energy flow and air-fuel ratio control, close attention should be paid to the actual combustion process in order to prevent oxygen lean and rich areas in the steam generator. Oxygen lean locations cause incomplete combustion of hydrocarbons and formation of CO. The CO will eventually combust in other areas in the steam generator (for instance on the surface of the boiler tubes), resulting in reduced efficiency, hot spots and increased maintenance to the boiler tubes.

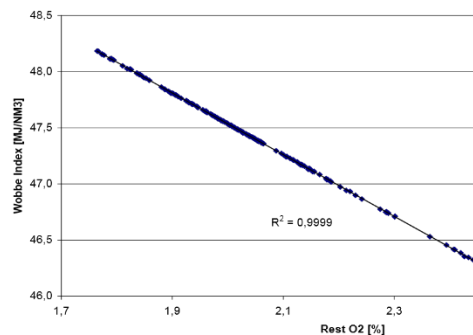
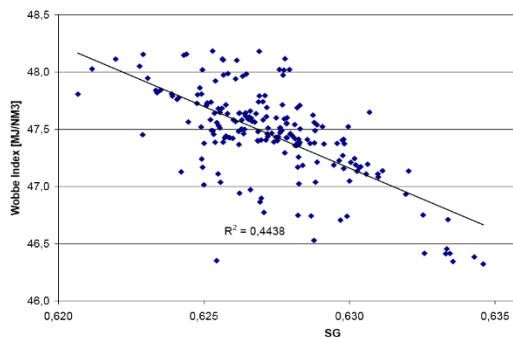
Using dedicated Wobbe/Heating value measurement devices is strongly recommended.

The use of algorithms in combination with Density / Specific Gravity to correlate to Heating Value / Wobbe Index or CARI / Air Demand will not bring you the desired result to optimize your combustion process. Both natural gas and off-gas contain fluctuating amounts of CO_2 and/or N_2 . The presence of CO_2 and N_2 results in large inaccuracies in the correlation as both are relative heavy but do not contribute to the combustion process.

The correlation between Specific Gravity and Wobbe index based on 200 natural gas samples with limited fluctuation is given in the graph below (left graph). The graph on the right gives the correlation used in a dedicated analyzer based on residual oxygen principle (WIM COMPAS™).

The inaccuracy in the correlation between SG and Wobbe (left graph) is caused by the minor CO_2 and N_2 fluctuations. When introducing off-gases with 20-40% CO_2 fluctuations, the correlation between SG and Wobbe Index will even be worse.

The correlation between SG and Air demand gives similar results. Due to the introduced measuring error, optimization of the combustion efficiency based on such a poor correlation will not result in optimization. With the possible savings in mind, the cost difference between a density meter and a dedicated analyzer cannot be difficult to justify.



CO2	1,15%	1,66%
N2	0,92%	3,58%
C2H4	0,00%	0,00%
C2H6	4,52%	5,58%
C3H6	0,00%	0,00%
C3H8	1,09%	1,50%
C4H10	0,38%	0,56%
C5H12	0,11%	0,18%
C6H14	0,07%	0,10%
CH4	87,78%	90,74%

Instrument installation and selection

When it has been decided to install an analyzer for feed-forward fuel and air/fuel ratio control, the following requirements should be fulfilled to gain optimum result.

1. Do not compromise on response time (analyzer response time $T_{90} < 5$ seconds)

It makes no sense to install an analyzer with a 30 seconds response time if changes occur within seconds. The WIM COMPAS™ has a response time of less than 5 seconds for a 90% response to a step change in sample composition - lag or "dead" time included.

Ideally the fuel gas Heat Value / Wobbe Index and Air Demand / CARI signals should be available before the fuel gas leaves the burner tip. This means that the travelling time of the fuel gas from sample tap point to the burner should be longer than the travelling time from sample tap point to the analyzer **plus** the analyzer response time.

2. Signal noise (<0.1%)

High signal noise levels will require smoothing of the signal, typically by averaging. As a consequence the response from the control system to a step change will be slower. The WIM COMPAS™ has a repeatability of 0.05% F.S.

3. Feed forward air/fuel ratio control can help to optimize combustion efficiency and reduce emissions

The Heating Value and/or Wobbe Index can be poor indicators for the air/fuel ratio in fuel gas applications containing large swings in Olefins, Carbon monoxide, Hydrogen and Oxygen. The WIM COMPAS™ is based on the residual oxygen

content principle and stores separate calibration lines for Wobbe Index/Heating Value and CARI/Air Demand.

4. Range ability of the analyzer should match all possible cases

Typically the analyzer should be able to handle large fluctuations in the fuel gas composition. The WIM COMPAS™ F can analyze fuel gases of all possible compositions in the 0-120 MJ/Nm3 (0-3000 BTU/SCF) range without the risk for flame-out or overheating.

5. Thorough application and site installation review

Each application is different and proper review is essential.

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