Reliable explosion protection in an oil tanker vapor recycle plant

In-situ gas analyzer monitor oxygen in real-time

Project
The world-class transshipment and storage facility Kiire, Japan, contains 46 million barrels of crude oil in 57 storage tanks, an amount equal to Japan’s two week demand. Continuous loading and unloading of oil tankers generates odorous gases and additionally results in losses of volatile hydrocarbons into the surrounding environment. Recently, the terminal operator decided to implement a new Tanker Vapor Recycle (TVR) plant that treats the malodorous vapors exhausted from the hold of a carrier during loading and unloading. The plant improves the facility’s environmental profile by ensuring the reliable elimination of malodorous vapors, collecting previously lost volatile hydrocarbons, and helping to retrieve the equivalent of 17 million liters of crude oil per year.

Application
In the Tanker Vapor Recycle plant, a gaseous mixture containing combustible components as well as oxygen in varying concentrations is processed. Gas mixtures consisting of combustible, oxidizing, and inert gases in principle are flammable under certain conditions such as gas composition, temperature and pressure. To protect the plant from the danger of explosion, the oxygen concentration must be monitored continuously. The measured concentration values are used to immediately start preventive measures at the occurrence of a critical gas composition.

The in-situ laser gas analyzer was selected to perform this $O_2$ monitoring application.
Challenge

The gas analyzer main requirements have been:

- To deliver the measuring values in real-time for immediate reaction in case of sensing an explosive gas mixture
- To provide correct O\textsubscript{2} concentration values even under strongly varying gas composition, because with different types of crude oil, the HC concentrations in the vapor varies also.
- To withstand the harsh environmental conditions at the measuring location
- To be approved for installation in hazardous areas by the Japanese Institution of Industrial Safety (TIIS), an authority for test and certification of electrical apparatus
- Transmission of the measured data directly to the control system of the plant

Following an extensive evaluation and test phase, it became obvious that only an in-situ measuring principle based analyzer could meet the demands. And with the TIIS approval as mandatory requirement in mind, the in-situ laser gas analyzer was considered to be by far the best choice to solve this application.

Solution

Laser spectrometer

The rugged, reliable, and flexible laser diode spectrometer offers an ideal solution to monitor critical oxygen concentration levels. The in-situ laser gas analyzer is suitable for rapid, non-contact measurements of gas concentrations in process gases. The measurement principle is based on the specific light absorption of different gas components, where the laser enables single-line spectroscopy free of cross-interferences.

Key facts of success

The successful solution of the actual application is based on the following key facts:

- In-situ laser gas analyzer response time is about a factor of 15 to 20 shorter compared to an extractive system
- The intrinsically safe sensors of the in-situ laser gas analyzer can be installed up to EEx zone 0,
- Inherent self-monitoring of calibration and functionality of the analyzer ensures highest reliability
- Various and changing hydrocarbon mixtures do not influence the measurement, since the curve fit algorithm used for the in-situ laser gas analyzer showed that no cross-interferences take place
- Long-term stability resulting from a built-in maintenance-free reference gas cell and no need for field calibration.

Off-shore and on-shore installation

A total of 12 in-situ laser gas analyzers were installed at 6 locations off-shore and onshore, i.e. close to the piers and in front of the TVR plant (fig. 2). For redundancy reasons, the analyzer setup was generally done in pairs arranged either in parallel (fig. 1, left) or at a right angle to each other (fig. 1, right). The corresponding central units (fig. 3) were placed in measuring racks at a distance of 50 to 150 m away from the sensors and connected via fiber optic cables.
Project realization

Expert team demonstrates suitability
An expert team was founded between the local partner Nohken and Siemens, including analyzer specialists from both Siemens Germany and Siemens Laser Analytic in Sweden. The team set up a test assembly to demonstrate that the LDS 6 is not affected by the varying hydrocarbon concentrations. The installation passed successfully the commissioning procedure during a jointly performed laboratory and field acceptance test.

TIIS certification obtained
The application required an explosion certificate for the devices, issued by the Technology Institution of Industrial Safety (TIIS). TIIS is a test/certification body, whose function is to attest the compliance of explosion protection with a specific product. TIIS issues certificates of conformity according to the local requirements. The team of Nohken and Siemens obtained the required documents for the LDS 6 within an excellent collaboration.

Successful operation
Siemens and Nohken supplied the transshipment terminal with a total of 13 analyzers. The TVR facility operates reliably and safely, making the Kiire terminal more environmentally friendly and more economical at the same time.

Explosion protection concept
Safety measures to protect the plant against the threat of explosion, are directly initiated and controlled by the O₂ reading of the analyzers stepwise:
• at 6 % oxygen reading, a nitrogen supply into the process gas stream is initiated to dilute the gas
• at 7 % oxygen reading, an alarm signal is additionally actuated
• at 8 % oxygen reading, an emergency shut down of the process is initiated
• at 0 % oxygen, i.e. no tank ship is loading or unloading, the measurement is nevertheless stable due to the internal reference cell of the in-situ laser gas analyzer.

The in-situ laser gas analyzer is an integrated part of the plant`s safety system. Therefore, highest measuring accuracy and operating reliability of the analyzer are essential.

In-situ laser gas analyzer
In-situ laser gas analyzer is a diode laser-based in situ gas analyzer for measuring specific gas components directly in a process gas stream.

In-situ laser gas analyzer consists of a central unit and up to three pairs of cross duct sensors in a transmitter/receiver configuration. The central unit is separated from the sensors by using fiber optics. Regardless how hostile the environment is, the analyzer can always be placed outside any hazardous areas. Measurements are carried out free of spectral interferences and in real-time enabling pro-active control of dynamic processes.

Key features include:
• In situ principle, no gas sampling
• Three measuring points simultaneously
• Temperature up to 1200 °C
• Ex-version available (option)

Measuring components include:
O₂/Temp., NH₃/H₂O, HF/H₂O,
HCl/H₂O, CO/CO₂, low ppm H₂O, ...
**Benefits**

**Expectations fulfilled**
The analyzer entirely met the user’s expectations and contributes indirectly to the reduction of emissions and economic recycling of hydrocarbons.

The design of an in-situ laser gas analyzer makes it an ideal analytical tool for monitoring the O₂ concentration during the tanker vapor recycling process.

**Analysis performance, reliability**
- Real-time measurement allows fast process control safety reactions
- No cross interferences due to highly specific single line absorption measurement
- No influence by varying gas matrix
- No loose of line-lock due to internal reference cell

**Reasonable invest**
- Multi-channel capability: Three measuring channels can be handled simultaneously with one single central unit
- Reliable and long-time operation: Corrosive gases and sensors do not come into contact
- The sensors are designed to withstand very rough industrial environments. Low cost of ownership

**Conditions for O₂ measurement in a tanker vapor recycle plant**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas to be measured</td>
<td>O₂</td>
</tr>
<tr>
<td>Gas temperature</td>
<td>&lt; 50 °C</td>
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<tr>
<td>Optical path length</td>
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<tr>
<td>Pressure</td>
<td>&lt; 2 bar</td>
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<tr>
<td>Dust concentration</td>
<td>&lt; 100 mg/m³</td>
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<td>Required response time</td>
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<td>Purging media</td>
<td>Nitrogen</td>
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<td>MLFB gas code</td>
<td>A</td>
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<tr>
<td>MLFB application code</td>
<td>P</td>
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</tbody>
</table>

**Fig. 5: In-situ laser gas analyzer measuring conditions**

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