Feature Article

New Product Introduction: MU-2000 UV Analyzer for Process Applications

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HORIBA Gas Measurement R&D Department has developed a new ultra-violet (UV) analyzer MU-2000 for process applications. This product has been developed based on the increasing market demands in process UV analyzers, particularly, for the natural gas processing areas. The heart of the analyzer is a compact diode array, based spectrometer manufactured by HORIBA Jobin Yvon. In this article, with a brief analysis of natural gas demand the MU-2000 applications to this market are presented. The analyzer design features, including the spectrometer, are highlighted. A novel technique, called chemometrics that is used in this analyzer, is briefly introduced. Some other applications are also described.

Introduction

HORIBA Gas Measurement R&D Department has developed a new ultra-violet (UV) analyzer, MU-2000 (Figure 1). This new product was developed based on the increasing market demands in process UV analyzers, particularly, for the natural gas processing areas. The analyzer is designed for continuous monitoring of industrial process streams. The analyzer is composed of a compact diode array based spectrometer manufactured by HORIBA Jobin Yvon, a panel mount computer, I/O modules and sample cell. MU-2000 is totally controlled by using a PC. The spectrometer operating parameters, signal processing, sample system operation and signal output and input are all processed through the PC.

Figure 1 MU-2000 UV Analyzer for Process Applications

Natural Gas Market Trend and the Need for MU-2000 Analyzers

Global natural gas demand is steadily increasing as it is shown in annual consumption data, from 1980 to 2004, in Figure 2.

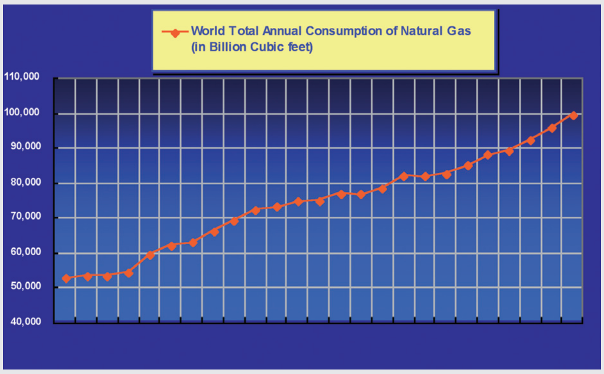

Figure 2 World Total Annual Consumption of Natural Gas (in Billion Cubic feet)*

*Energy Information Administration, US Department of Energy, "International Energy Annual 2004", available from < http://www.eia.doe.gov/pub/international/iealf/table13.xls >.

The consumption growths in the world's two most populated countries (China and India) are more significant comparing to the world total consumption, especially based on 1990 data as shown Figure 3.

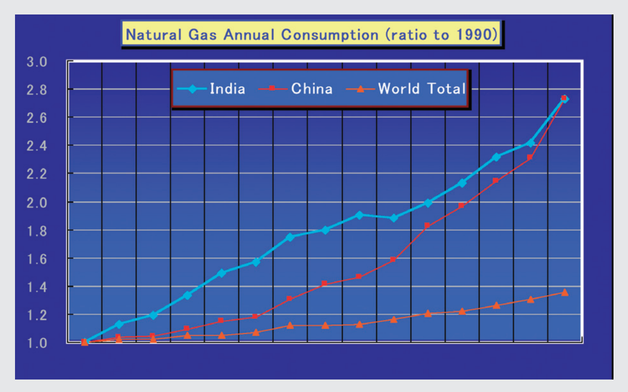

Figure 3 Natural Gas Annual Consumption (ratio to 1990)*

*Energy Information Administration, US Department of Energy, "International Energy Annual 2004", avaibale from < http://www.eia.doe.gov/pub/international/iealf/table13.xls >.

The exploration and production of natural gas are increasing over the years to meet the demand that also produce undesirable air pollution as a byproduct. Additionally, the ever increasing environmental protection pressure also forces the natural gas producers to reduce the existing pollution and to control the new source of air pollution by using process analyzers in the automatic process control.

The major pollution gases from the natural gas production process are the sulfur compounds, namely H_2S, SO_2 and others. These gases are strong UV absorbers and have been analyzed by using UV analyzers. As the natural gas production and consumption increases, especially in India and China, the market for the analyzers also increases. Additionally, a large number of the UV analyzers installed in the field for these analyses are aging and may not meet the new lower detection limit that has been imposed by the compliance agencies. These analyses have created a business opportunity for MU-2000 analyzers and other HORIBA environmental analyzers. The natural gas area is probably the largest market opportunity for MU-2000. There are many other applications in the UV area for MU-2000 analyzers. These will be described in the analyzer application section.

Description of MU-2000 Analyzer

The MU-2000 is designed for on-line applications with high reliability and long-term stability. It contains no moving parts and is of modular design, which means that components can be easily replaced, if necessary, with minimal down time. The analyzer is typically connected to a flow cell or an insertion probe with a pair of optical fiber cables (Figure 4). This way, the analyzer and the electronic components can be located in a safe and clean environment (up to 5 meters away) while the flow cell or probe can be near the process stream. This arrangement makes the installation economical, protects the analyzer from the harsh process conditions and shortens the analyzer response time to the process change. The length of the flow cell depends on the application. It can be from a few mm to one meter long. We also have a specially design insertion probe for natural gas desulphurization process (tail gas) application (see more detail later). Temperature and pressure are also measured for gaseous samples so that data will be temperature and pressure compensated.

Figure 4 Optical Fiber Cables

The analyzer is composed of an UV light source, a detector (spectrometer), I/O modules, a computer and the power supplies. In general, these components are assembled in an enclosure for weather protection and the enclosure can be purged, if necessary, to meet hazardous area classification requirements. The I/O modules are used to control the sample system operation and manage the input/output signals.

Depending on the application, either a flow cell or an insertion probe is used to allow the UV light to interact with the sample. The analysis is based on Beer Lambert's Law with the aid of chemometrics.

The spectrometer is a HORIBA Jobin Yvon linear array spectrometer (Figure 5). It is useful for the UV range at 190-620 nm. The spectrometer collects the entire spectrum of the wavelength absorbed by the components of interest, and uses a powerful mathematical technique (chemometrics) to convert the spectrum into useful concentration data. The chemometrics used in this analyzer is called P-Matrix, or Inverse Least Square (ILS). The chemometrics model (calibration) is fairly complex and is generated only at the factory based on the customer's specifications. See more description below.

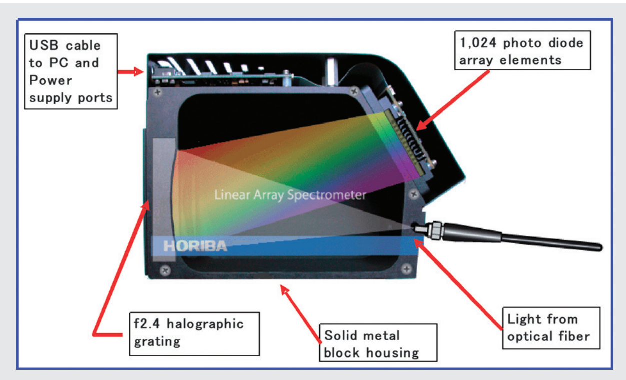

Figure 5 HORIBA Jobin Yvon Linear Array Spectrometer

The analyzer data are displayed on the analyzer computer screen and also sent to the distributed control system (DCS) in various output formats, such as 4-20 mA and Modbus communication protocol. The data can be displayed as bar graphs, trend charts, or digital concentrations. The data and spectra can be stored in the analyzer computer if desired. The spectra can be exported to Excel spreadsheet format for off-line analysis.

The analyzer output includes up to 10 isolated 4-20 mA analog outputs and a general alarm output. As an option, it can be equipped with additional I/O and relay modules, which can be configured at the factory for various special application needs. These include alarms, analog outputs, temperature and pressure inputs, and solenoid valve controls. Authorized users are permitted to change the I/O configurations as required (with password protection). The I/O can be programmed to automatically switch valves to clean the flow cell or probe, or to automatically adjust the baseline on a regular basis. The I/O configuration is very flexible and can be easily programmed.

The analyzer performance is maintained by regularly correcting the baseline (called blanking) with zero gas. The analyzer is typically configured in the factory to perform the automatic blanking. When blanking is initiated either manually or automatically, the proper valves will be closed/opened so that the zero gas will be introduced to the optical path where the baseline spectrum to be taken. Normal operation will resume when the blanking is completed.

The analyzer operating screen contains useful information such as analyzer status, concentration data, temperature and pressure of the process (if the indicators are installed) alarm(s) and the alarm/error message(s). The user can easily navigate through all menu screens to configure or display other information. A typical screen is shown Figure 6.

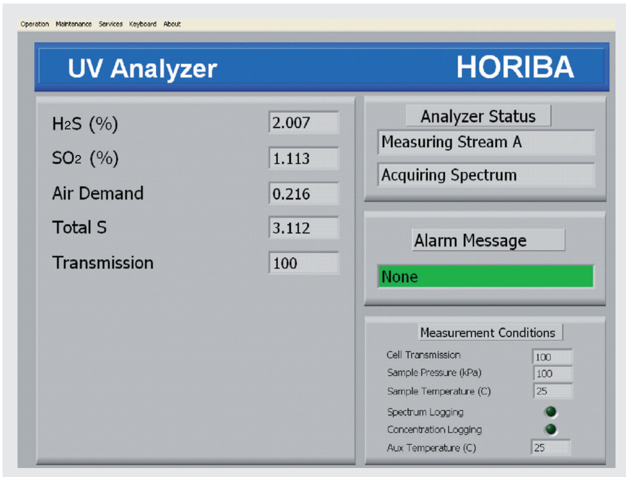

Figure 6 Typical Screen

Chemometrics

It is very common in a process stream that many components absorb light at similar wavelengths that cause spectral interference. It is almost impossible to measure absorbance at only two wavelengths and apply Beer's law to analyze mixtures with good results. In such case, the conventional non-dispersive analyzers usually require some front end separation, such as using a chromatograph column, for the analysis.

One particular feature that makes this new MU-2000 analyzer standout is the application of the chemometrics which overcomes the spectral interference problem. Chemometrics is a science of combining spectroscopy and statistics, using matrix algebra, to compute and extract information from a spectrum of complex mixtures without the separation process (e.g. gas chromatograph). The chemometrics "model" is a mathematical operation that is "trained" to recognize the spectra of the components of interest and to quantify them in the on-line analysis.

There are many different mathematical algorithms to do the chemometrics. Some chemometrics model (e.g., K-Matrix, classical least square) requires the full knowledge of every component in the sample mixture in order to do the analyses. We selected a technique for MU-2000 that is called P-Matrix, or Inverse Least Square (ILS) method. The advantage of this technique is that only the standard spectra of the components of interest are needed to build the model. This is particularly useful for the complex mixtures that customer is only interested in one or two components and does not know the complete compositions of the process sample. When building the model in the factory, the absorbance data at several carefully selected regions of the standard spectra are used in creating the model for the analysis. The model is created (trained) in the factory using many spectra of known concentrations by skillful technicians.

Sample System Control

One outstanding feature of the new MU-2000 analyzer is the flexibility of the software to control the sample system. Up to 8 solenoid valves can be connected to the I/O modules for the software to control. This enables MU-2000 to do multiple stream analyses with one analyzer. It also enables the operation of automatic sample system cleaning with steam or cleaning fluid at programmable frequency.

Summaries of the Analyzer Features

- Accurate multiple stream and multiple component monitoring
- Wide wavelength range for a variety of applications
- Concentration from low ppm to 100%
- Modular design with no moving parts - reliable and easy to maintain
- Temperature and pressure compensation - standard
- Industrial grade computer with touch screen display for user interface
- Turn key system for specific applications
- Modbus and 4-20 mA communication

Applications of MU-2000

Since the analyzer uses ultraviolet (UV) light for analysis, any compound that absorbs UV light is a candidate for analysis. However, each potential application needs to be thoroughly evaluated for the concentration range, accuracy, process conditions and other requirements.
Some notable applications that MU-2000 can be used are:

- Natural gas sulfur removal and recovery processes: to monitor H_2S, SO_2 and other minor sulfur compounds during the natural gas production.
- Pulp and paper processing: in chemical pulping process to monitor the concentration of H_2S and mercaptans and to monitor H_2S in the exhaust stack.
- Sulfuric acid production process: to monitor SO_2 at percent to ppm level for process control and environmental monitoring.

- Phosgene production process: to monitor phosgene from ppm to 100% level, and HCl and Cl_2 in ppm level for process and emission control. Also monitoring phosgene for personnel safety.

The following is an example of natural gas processing application for MU-2000. The picture below show a process called "Claus Process (Figure 7)".

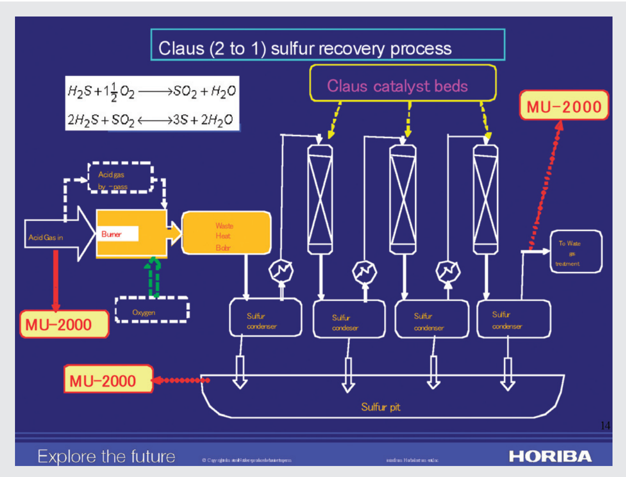

Figure 7 "Claus Process"

The process before this, Amine Sweetening Process, is to remove sulfur compounds in natural gas using amine solutions. The sulfur compounds absorbed by amine solutions are released (boiled off) in the amine regeneration process area. The exit gas from the amine sweetening process is called acid gas.

The acid gas, contains concentrated H_2S, is sent to the Claus sulfur recovery process. There are some chemical reactions taking place in this process that need to be pointed out. Ideally, in the burner (furnace), one third of the total H_2S is reacted with oxygen (burn) to become SO_2. The SO_2 is reacted with the remaining 2/3 of the H_2S in the Claus catalytic reactors. In the reactors, H_2S and SO_2 combine to become sulfur (in vapor and liquid forms). Sulfur vapor is condensed into liquid at the condenser and collected in the sulfur pit as solid. As shown in the picture, there are options to bypass some acid gas around the burner or add oxygen to the burner to optimize the process.

The net of the two reactions are for H_2S to react with oxygen to make sulfur and water. These three reaction equations are shown in the picture.

It is important to have the right ratio of the chemicals in the reaction for the reactants to be completely converted to products. The second reaction equation shows that the ratio of H_2S to SO_2 is 2 to 1. It is important to maintain such ratio for the H_2S to effectively convert to sulfur. Thus the measurement at the tail gas will help to maintain such ratio. This is where the MU-2000 is used for this purpose.

When the analyzer data show excess SO_2 ($H_2S/SO_2 < 2$), it is due to too much H_2S is converted to SO_2 in the burner. The air flow to the burner needs to be reduced. Conversely, when the H_2S/SO_2 is > 2, there is not enough SO_2 produced in the burner to react with H_2S in the catalytic reactors to convert H_2S into sulfur. The air flow needs to be increased. By maintaining the H_2S to SO_2 ratio at 2 to 1, the burner operation can be optimized. Therefore, MU-2000 is important to control the process.

The concentrations of H_2S and SO_2 in the tail gas can be a good indicator of the catalytic reactor performance. When the catalyst is new and the reactors and the burner are optimized, the ratio of H_2S to SO_2 should be at 2 and both the concentrations should be low. When the catalyst is aged and or the temperature and flow rate are not optimized, the H_2S and SO_2 concentrations will be high even though they may be in good 2 to 1 ratio. The flow rate to the reactors and the reactor temperature will affect the H_2S conversion.

In summary, the MU-2000 is used to optimize the burner performance (using the 2 to 1 ratio of H_2S to SO_2) and monitor and optimize the catalytic reactor performance (using both H_2S and SO_2 concentrations).

The concentration of H_2S in the acid gas, measured by using MU-2000 can help to control the air flow to the burner. Because the H_2S concentration in the acid gas can change rapidly from the sour gas and from the amine sweetening process, it is important to monitor the H_2S concentration in the acid gas to do feed forward control of the burner.

For personnel safety and environmental monitoring, the air above the sulfur pit can be monitored by using MU-2000 to monitor H_2S in the air.

Conclusion

The rapid advancement of sciences has helped to provide better living for human being than ever before. The conveniences we enjoy and take for granted is accompanied by the pollutions these conveniences bring along. It is our responsibility to protect the environments we live - we should control and minimize the pollution we create for the generations to come. HORIBA, for years, has committed to providing state of the arts analytical instruments to help preserve the environment. It is my personal hope that this new product, MU-2000, will be used in such a way.

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