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Feature Article
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Air Pollution Monitoring Systems, AP-360 Series

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Abstract

The environmental changes affecting the world have become a cause for serious concern. One result of this has been the increasingly important role that air pollution monitoring systems have come to play in environmental preservation. Foremost among these is Horiba's AP-360 series of air pollution monitoring systems, which are based on the cross-flow modulation method, developed by HORIBA engineers, and the extension of this principle, the multi-flow method. These systems are capable of stable and simultaneous measurement of carbon monoxide (CO), ozone (O_3), methane (CH_4), non-methane hydrocarbon (NMHC), total hydrocarbons (THC), nitrogen oxide (NO), nitrogen dioxide (NO_2), and nitrogen oxides (NO_x) in the air. This paper describes the principles and applications of cross-flow modulation.

1. Introduction

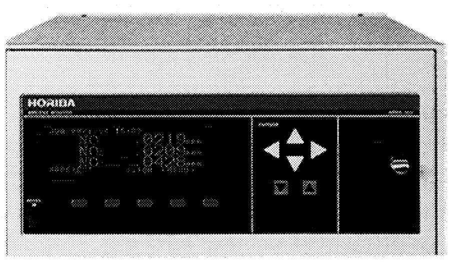

Figure 1 Analyzing Unit for AP-360 Series

Air pollution is no longer a problem affecting only industrialized countries, but an issue of global impact. To preserve the air environment, it is important to properly understand its state, which in turn requires an accurate and highly-reliable air pollution monitoring system.

Analyzers using the non-dispersive infrared (NDIR) analysis, ultraviolet absorption (UVA), chemiluminescence (CLD), and flame ionization detection (FID) have conventionally been used in the measurement of air pollution. However, more accurate and stable measurement systems are now required, as the monitoring of air pollution requires high stability over weeks, months, and years. Horiba has responded to this need with the AP-360 series of air pollution monitoring systems (**Figure 1**). All the systems in the series apply Horiba's unique cross-flow and multi-flow modulation methods.

2. Cross-flow Modulation Method

Cross-flow modulation is an analytical technique which uses the sample gas to be measured for certain components along with a zero gas, identical to the sample gas except that these components have been removed. These gases are alternately introduced into the same measurement cell, and the difference between them is output as an alternating signal. With this method, fluctuations in the optical device or detection system have virtually no effect, and any components that might interfere with the measurements have no effect at all, because they are present in both the sample and zero gas. These features ensure extremely accurate and stable measurements over a long period of time.

2.1 APMA-360 Carbon Monoxide Analyzer

Molecules composed of more than one elements, like CO, selectively absorb infrared light at a specific frequency. The APMA-360 CO analyzer uses this property to measure the CO concentration. The APMA-360 consists of a light source, a cell, a detector, an optical filter, and a flow modulator. In conventional NDIR, a rotating partition is used to alternately cut off and modulate the sample cell and reference cell in order to obtain a signal. By contrast, in an infrared analyzer using the cross-flow modulation method, fixed amounts of sample gas and zero gas are alternately introduced into the measurement cell, and an alternating current is produced as a signal as a result of the two gases' different absorption strengths. This method has the advantage of eliminating measurement error (ensuring zero drift) caused by soiling

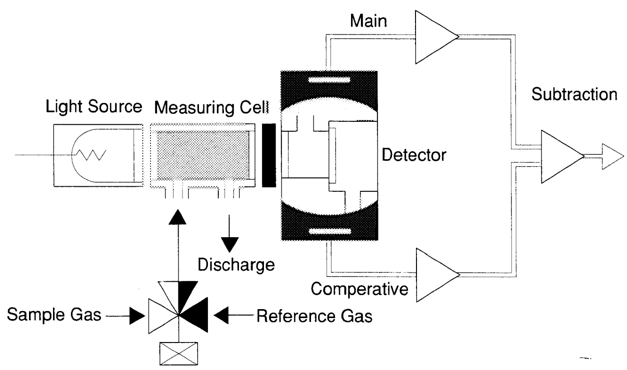

Figure 2 Measuring Principle of Cross-flow Modulation, Non-dispersive Infrared Absorption(NDIR) Technology

of the optical system in the analyzer, or deterioration of the optical system. The result is stable measurements over long periods.

In the APMA-360, oxidation catalysts remove only the carbon monoxide in the sample gas so that this gas can be used as the zero gas. Therefore, even if there are interfering components present in the sample gas, their influence can be ignored because they are present in the zero gas as well. This allows an accurate signal for only the desired component to be extracted. **Figure 2** shows the basic principles of non-dispersive infrared absorption analysis using the cross-flow modulation method.

2.2 APOA-360 Ozone Analyzer

Ozone molecules absorb only specific wavelengths of ultraviolet light, much as different molecules respond to different frequencies of infrared light. This property is used by the APOA-360 ozone analyzer, which also applies the cross-flow modulation method described above. Like the APMA-360, the APOA-360 is capable of stable, highly accurate measurements over a long period of time. **Figure 3** shows the basic principles for ultraviolet absorption analysis using the cross-flow modulation method.

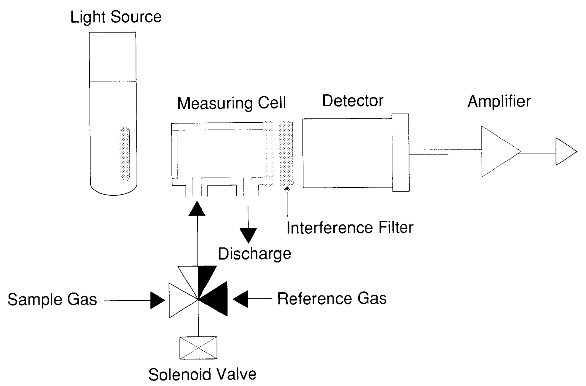

Figure 3 Measuring Principle of Cross-flow Modulation, Ultra-violet Absorption (NDUV) Technology

3. Multi-flow Modulation Method

Multi-flow modulation is an analytical technique based on cross-flow modulation. This method allows simultaneous and separate measurement of a wide range of components. The AP-360 series uses this method to measure nitrogen oxides and hydrocarbons in the air.

3.1 APNA-360 Nitrogen Oxide Analyzer

When nitrogen oxide comes into contact with O_3, NO_2 is produced through a chemical reaction. A portion of the generated NO_2 molecules are in an excited state, and these excited molecules generate chemiluminescence (CLD) in the 600 to 3000 nm wavelength region as they return to the ground state. Based on the strength of this light, which is detected by a semiconductor photo-sensor, the concentration of nitrogen oxide can be measured.

This concentration of NO_2 and other nitrogen oxides in the air is converted to NO using a pre-processing device (NOx converter), and then measured using the CLD method.

NO is detected as it reacts through direct exposure to the ozone; after the gas has passed through the converter, NOx can be detected as it in turn reacts. Finally, NO_2 is measured by subtracting NO from NOx.

Figure 4 shows the basic principles of the nitrogen oxide

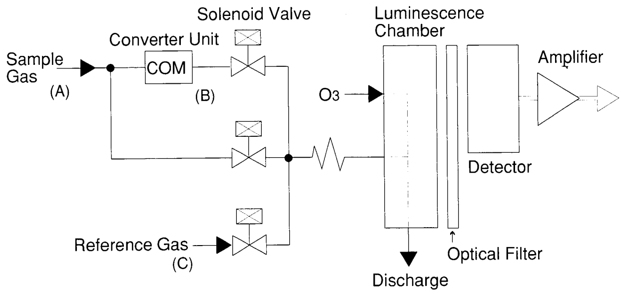

Figure 4 Measuring Principle of Multi-flow Modulation, Reduced PressureChemiluminescence (CLD) Technology

analyzer using the multi-flow modulation method. In this example, the sample gas is designated as A, the sample gas processed by the NOx converter as B, and the zero gas as C. When these gases are introduced into the sample cell in a fixed cycle, signals are generated from the detector in the order A, B, C. In the NO signal processing system, however, the A component is not read, and in the NOx system, B is ignored. Like the cross-flow modulation method, the multi-flow modulation method has no zero drift. In addition, this system uses a single detector for the continuous measurement of NO, NO_2, and NOx concentrations.

3.2 APHA-360 Hydrocarbon Analyzer

The APHA-360 uses selective combustion and flame ionization detection (FID) for measuring the CH_4 and NMHC concentrations in the air. Selective combustion is a technique making use of the varying combustion temperatures for different species of hydrocarbons. Since CH_4 has a higher combustion temperature than other hydrocarbons, heating the combustion catalysts under controlled conditions results in the combustion of all hydrocarbons in the sample gas except for CH_4. FID works differently in that it produces a reaction in all hydrocarbons.

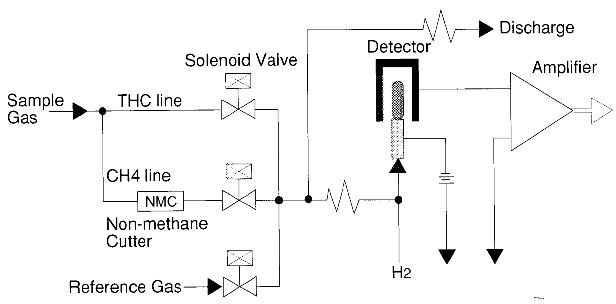

Figure 5 Measuring Principle of Multi-flow Modulation, Flame Ionization Detection Method (FID) with Selective Combustion Technology

As with the APNA-360, the introduction in set cycles to the FID device of the sample gas, the sample gas which has passed through catalytic processing, and the zero gas, enables the stable measurement of CH_4, NMCH, and THC concentrations. **Figure 5** shows the basic principles of the hydrocarbon analyzer using the multi-flow modulation method.

4. Features and Functions of the AP-360 Series

4.1 Features

The AP-360 series features a comprehensive line-up of systems for a range of air pollution measurement needs **(Table 1)**. These include a compact and lightweight 19-inch rack **(Figure 6)** for housing analyzers used for the same measuring application. This allows easy upgrades to multi-component systems and saves on installation space. All AP-360 series analyzers also include an automatic calibration function for periodic calibration, dramatically reducing operation and maintenance work.

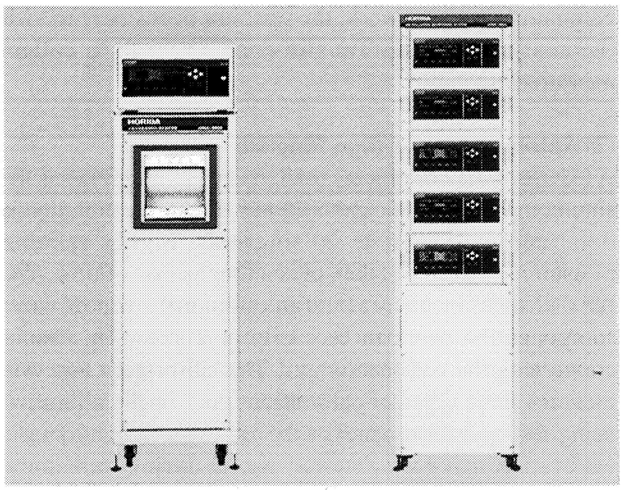

Figure 6 Air Pollution Monitor AP-360 Series

4.2 Functions

The AP-360 series' superior functions and operating capabilities are supported by a central processing unit (CPU). The main functions are introduced below.

(1) Memory function

AP-360 series systems can record and output three types of average values. An entire month's worth of hourly values can be stored at one time, meaning that, even without a data

Table 1 AP-360 specifications

Application	CO	SO_2	O_2	NO_x, NO_2, NO	THC, NMHC, CH_3	SPM
Model	APMA-360	APSA-360	APOA-360	APNA-360	APHA-360	APDA-360
Principle	Cross-flow modulation, infrared absorption technology (NDIR)	UV fluorescence (UVF)	Cross- flow modulation, Ultra-violet absorption method (NDUV)	Cross-flow modulation, reduced pressure chemil uminescence (CLD)	Cross-flow modulation, Flame ionization detection (FID) with selective combustion	Beta ray absorption
Range	0-10/20/50/100 ppm, 0-5/10/20/50 ppm, 4 ranges selectable from 0-100 ppm, within 10 times range ratio; Minimum range:0-5 ppm	0-0.05/0.1/0.2/0.5 ppm 4 ranges selectable from 0-10 ppm, within 10 times range ratio Minimum range: 0-0.05 ppm	0-0.1/0.2/0.5/1.0 ppm 4 ranges selectable from 0-10 ppm, within 10 times range ratio Minimum range: 0-0.1 ppm	0-0.1/0.2/0.5/1.0 ppm 4 ranges selectable from 0-10 ppm, within 10 times range ratio Minimum range: 0-0.1 ppm	0-5/10/25/50 ppmC 4 ranges selectable from 0-100 ppmC, within 10 times range ratio Minimum range: 0-5 ppmC	0-0.25/0.5/1.0/5.0 mg/m³, 30 min/1/3/12/24, switch selectable
Lower detectable limit	0.05 ppm (2 sigma)	0.5 ppb (2 sigma)			0.05 ppmC (2 sigma)	whichever is greater10 mg/m³ (one-hour measurement)
Repeatability	±1.0% F.S.					±2.0 %F.S. (equivalent membrane)
Linearity	±1.0% F.S.		±2.0 %F.S.	±1.0 %F.S.		±10 mg/m³ or ±10% of reading,
Zero drift	±0.1 ppm/day or ±2.0 %F.S./day, whichever value is the greatest ±0.2 ppm/1 week or ±4.0 %F.S./1 week, whichever value is the greatest	±1.0 ppb/day or ±1.0 %F.S./day, whichever value is the greatest ±2.0 ppb/1 week or ±2.0 %F.S./1 week, whichever value is the greatest		±1.0 ppb/day or ±1.0 % F.S./day, whichever value is the greatest ±2.0 ppb/1 week or ±2.0 %F.S./1 week, whichever value is the greatest	±0.1 ppmC/day or ±2.0 % F.S./day, whichever value is the greatest ±0.2 ppmC/1 week or ±4.0 %F.S./1 week, whichever value is t he greatest	2.0 %F.S./day
Span drift	±2.0% F.S./day, ±3.0% F.S./1 week	±1.0 %F.S./day, ±2.0 %F.S./1 week			±2.0 %F.S./day, ±4.0 %F.S./1 week	±3.0 %F.S./day (equivalent membrane)
Response time (T^{90})	Within 60 seconds	Within 180 sec.	Within 120 sec.		Within 60 sec.	—
Interference	±0.4% F.S. (by 2% H_2O or 1,000 ppm CO_2)	±3.0 ppb (by 2% H_2O or 0.14 ppm NO)	±2.0 ppb (by 2% H_2O or 1 ppm Toluene)	2.0 ppb (by 2% H_2O or 0.2 ppm NH_3)	±0.2 ppmC (by 2% H_2O)	—
Supplemental gas	None				H_2 (fuel gas)	None
Indication	Measured value, range, alarm, maintenance screen					
Alarm	CAL, PRES, POWER, BATT, CAT, FLOW	CAL, PRES, LAMP, BATT, CAT, POWER, FLOW	CAL, PRES, LAMP, BATT, DO, POWER, FLOW	CAL, PRES, POWER, BATT, CONV, FLOW	CAL, PRES, FLAM, BATT, PUR, POWER,FLOW, NMC	FLOW, COUNT, FILTER, POWER
Input/output	• 0-1 V/0-10V/4-20 mA, to be specified (2 systems: either (1) momentary value and integrated or (2) moving average value) • Contact input/output • RS-232C					0-1/10V, 4-20 mA

communications network, the operator needs only to visit the analyzer installation site once a month to collect measurement data.

(2) Automatic calibration function
A feature of the dry process used in t he AP-360 series is the simplicity of automatic calibration.[1] Because calibration is done automatically at set intervals, highly reliable measurements can be taken over a long period of time. The AP-360 series includes a built-in calibration solenoid valve so that calibration can be easily performed by simply connecting the calibration gas. The calibration function includes three types of calibration: one-touch calibration using the operation panel at the site, external automatic calibration using an external signal during unmanned operation, and internal automatic calibration using the internal calendar timer.

(3) Automatic diagnostic function
In addition to the alarm function shown in Table 1, a digital display shows the power-on time for major components (solenoid valve, pump, catalysts, etc.), temperature, pressure, and other information. A graphic display shows the changes in the quantity of light from the light source over time. These digital and graphic displays greatly facilitate maintenance.

(4) Data calculation and output function
The measurement data can be calculated in four ways to produce momentary values, integrated values, moving averages, and simple averages. Any two of these calculated values can be selected for output. The measurement ranges for both the momentary and average values can be automatically changed so that sudden changes in concentration can be detected with reliability.

(5) External input/output function using RS-232C
A serial interface in a daisy-chain structure based on the RS-232C standard can be used as for external input and output. As shown in **Figure 7**, a single RS-232C cable can be used to communicate with several AP-360 series systems. The data can include momentary values, average values, ranges, alarms, changing measurement ranges, and calibration start commands. In addition, the screen display supports four languages: Japanese, English, German, and French. The unit of measurement can also be switched from ppm to mg/m^3.

5. Air Pollution Monitoring System

The air pollution monitoring system includes the following sub-systems: a data transmission system (collection system), a data processing system (analysis system), a data exchange system, and a simultaneous communication system. Conventionally, large main-frame computers are used at host stations to obtain the necessary processing speed and data capacity for online and offline data processing. However, recent advancements in computer technology have allowed personal computers to be used for all of these processes. A system using PCs has key advantages:
- Low cost and reduced installation space
- Changes or additions to the system are easy
- Commercial software can be used for analyzing and organizing data.

Horiba's systems are built around the data transmission and processing systems, essential components of any air pollution monitoring system. These systems feature a range of functions for external data reading, document output parameters, document output, screen display, data editing, and data management. A data exchange system and

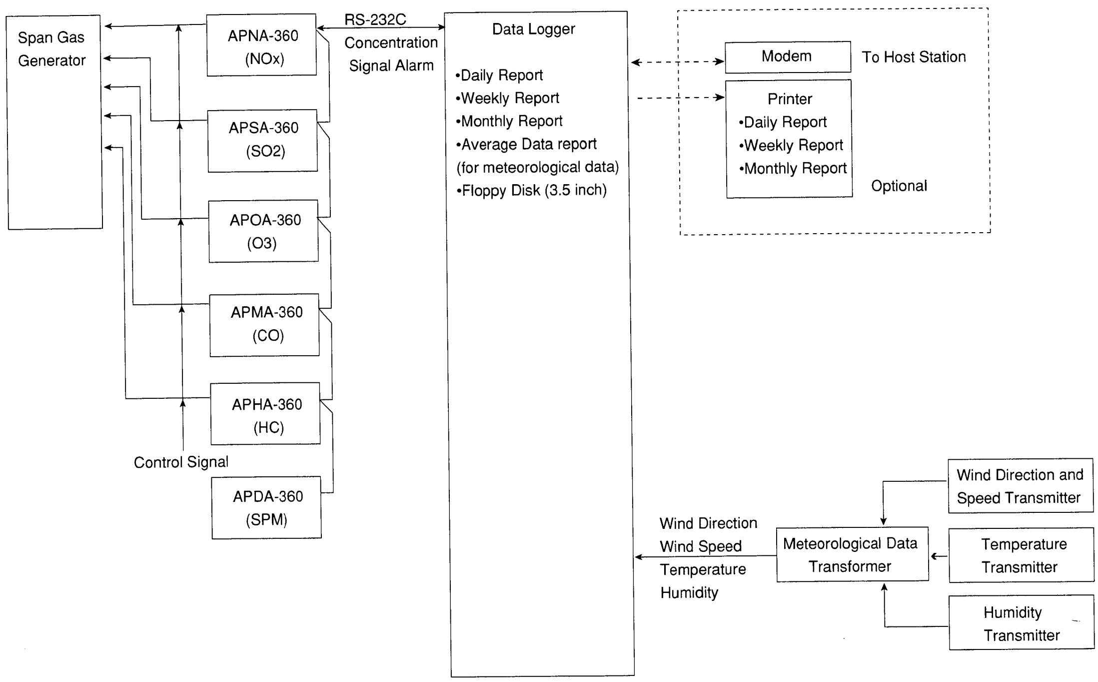

Figure 7 Data Communication System of AP-360

simultaneous communication system can be expanded in larger scale by installing a second PC. Although this system was developed to serve ten or less local stations it is capable of serving up to 20 to 30.
In addition to the points described above, the system features:

- Dialogue-box screen interfaces for easy operation
- Compatibility with the Windows[2] operating system, allowing a wide range of personal computers to be used
- Data collection and storage can be performed off-line (processing of data from mobile stations and measurement stations in other regions can be performed)
- 14 types of documents can be output, including monthly reports and wind roses, for easy preparation of reports and documents.
- Bilingual support for Japanese and English

These outstanding features make it possible for regions which have been without air pollution monitoring systems to quickly and easily install an advanced air pollution monitoring system at little cost.

Conclusion

Today, air pollution monitoring systems using dry process measurement have come into widespread use in Japan and worldwide due to their high measurement accuracy and easy maintenance. Horiba's AP-360 series of dry process measurement systems, thanks to the cross-flow modulation method, offers exceptional long-term stability, an important factor when monitoring air pollution. Horiba hopes that these measuring systems will contribute to preserving the global environment through accurate data collection, analysis, and exchange around the world.

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