

# AMBIENT AND INDUSTRIAL IN-SITU EMISSIONS MONITORING

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**Summary.** Most of the papers presented here deal with remote measurements of pollutants either from an emission source, or in the ambient air. This paper deals with an alternative route: The utilization of rugged, reliable instrumentation located in-situ. This instrumentation, based upon absorption spectroscopy, gives a specific and instantaneous analysis of multiple parameters (typically up to five) without sample handling or conditioning.

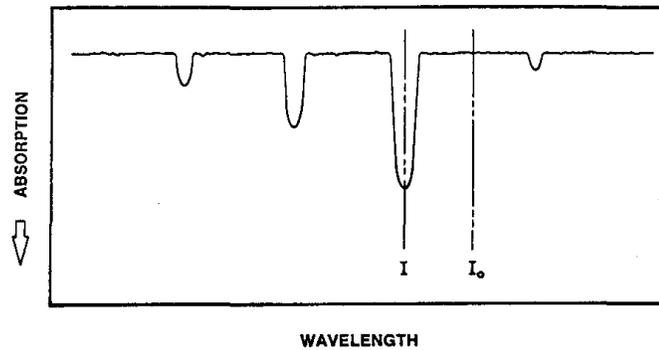
**Introduction.** The industrial instrumentation technology has developed rapidly in the recent past, so that now a broad spectra of devices are available to fit almost all industrial monitoring or analysis requirements. In the environmental field this ranges from the small portable qualitative devices, to the quantitative instruments located in the field for remote analysis, and in the laboratory, or now directly on-stream for rapid, reliable process or emission information.

**Principles of Operation.** The in-situ multi-parameter analyzers operate primarily on the principle of absorption of radiation. In the Environmental Data Corporation system the beam of light is polychromatic. The detection module consists of a means to separate these wavelengths. Both a specific wavelength where the gas uniquely absorbs ( $I$ ) and an adjacent non-absorbing wavelength ( $I_0$ ) are alternately measured, Figure 1, with a single detector. From Beer's law we have

$$I = I_0 e^{-\alpha c l}$$

where  $\alpha$  = absorption coefficient (from cal curve)  
 $c$  = sample concentration (unknown)  
 $l$  = pathlength

The light level will change in the system due to variations in the particulate loading in the gas stream, darkening of the windows, decay of the source, etc. However, since only one light beam is used, the two wavelengths selected (sample and reference) are equally affected by any of these changes. These two wavelengths are then ratioed in our electronics and the result is only dependent upon the concentration of sample in the gas



**Fig. 1. Sample (I) and Background ( $I_0$ ) Wavelengths**

stream. There is a separate detector for each gas allowing simultaneous and continuous monitoring of each parameter.

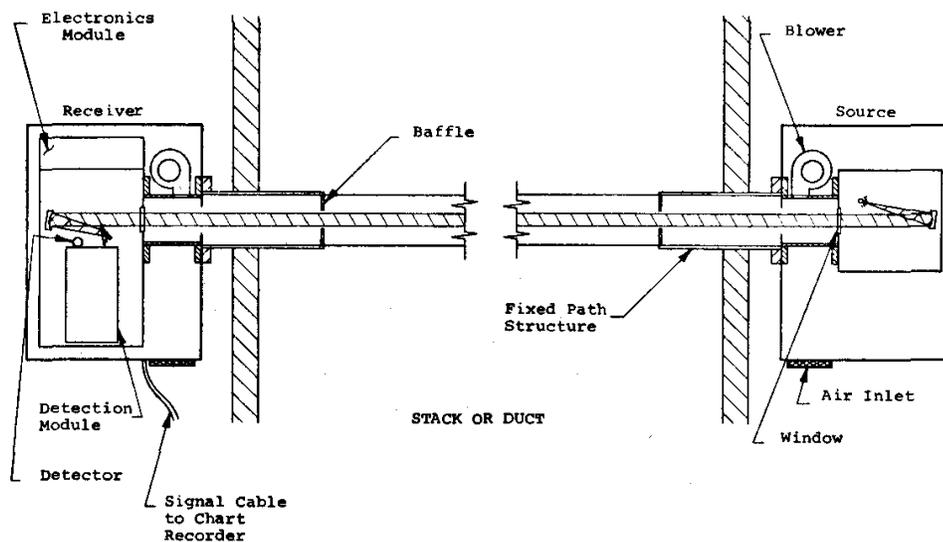
The instrumentation is designed to operate in the ultraviolet, visible, and near infra-red portions of the optical spectrum. A separate source with maximum emission in the appropriate region is utilized. In this way, it has been found that almost every gas of general interest, except  $O_2$ , can be directly measured.

The detection techniques applied vary depending upon the specific absorption features utilized. These techniques include relatively high resolution dispersive spectroscopy, or a variant, correlation spectroscopy. Here a series of slits are selected and positioned to coincide with the absorption features (I), and a second interposing series which coincide with the background ( $I_0$ ). Gas cell correlation provides exactly the same analysis. In this case, a narrow-band pass filter is used to define  $\Delta\lambda$  being used, and a small sealed cell of a high concentration of the gas being studied is alternately cycled into and out of the beam. When the cell is in the beam, all the wavelengths where the gas absorbs are removed, leaving only the interposing non-absorbing wavelengths. When the cell is out of the beam, both the background and the absorption wavelengths are present. Finally, for specific circumstances where one wants to increase signal-to-noise, or to remove the effect of a rapidly changing continuum intensity with wavelength, derivative spectroscopy is used.

By selecting the absorption feature carefully, and matching the detection technique to it, it has been possible to measure each gas desired, in the presence of any other gases, with no interference.

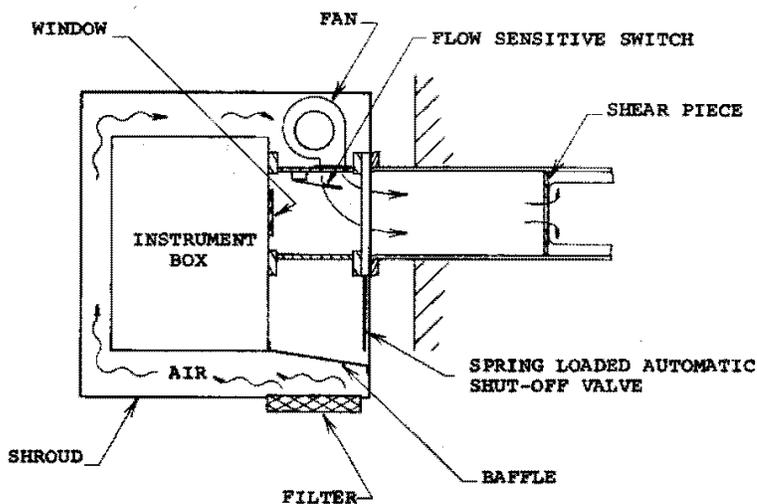
**Instrumentation, Stack Monitoring.** The in-situ analyzer is designed so that there is no sample lead-off, clean-up, or manipulation in any manner. The light beam traverses the sample generating a continuous analog signal out of the analyzer which instantaneously varies with gas concentration.

Either a single or double-pass optical system is usually utilized. In the single-pass system, light from the source is collimated, sent through the gas stream and then focussed onto the detection module, Figure 2. The double pass system sends the collimated light across the gas stream to a retro-reflector which returns the beam upon itself to a beam splitter and then to the detection module.



**Fig. 2. Stack-mounted installation schematic**

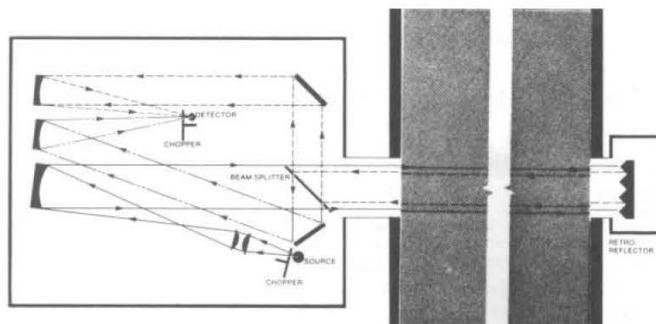
A clean air purge, detailed in Figure 3, is used to maintain the relative cleanliness of the window interface between the analytical system and the stack, since the system is designed to operate only up to an 80-95% reduction in signal. Also, the air draft purges the pipe up to the slot. In this way there is a known and fixed pathlength being measured.



**Fig. 3. Stack-instrument interface schematic**

For gas analysis, a single-pass system is normally utilized. At the present, detection modules for the following gases have been built: NO, NO<sub>2</sub>, NH<sub>3</sub>, CO, CO<sub>2</sub>, hydrocarbons (equivalent to n-hexane sensitized NDIR), SO<sub>2</sub>, and H<sub>2</sub>S. Many other gases are amenable to this analytical technique by merely selecting the appropriate I and I<sub>0</sub>'s.

**Instrumentation, Opacity Monitoring.** The opacity monitoring channel is fundamentally different as by definition the measured particulate scattering is limited to the visible portion of the spectrum. Therefore, this band can not be ratioed to another wavelength in a precise and meaningful way. Instead, using the split-beam principle, the light from the source is collimated, and then part is transmitted through the gas sample to a retro-reflector which then returns the beam upon itself. This beam (I) is ratioed with a second beam (I<sub>0</sub>) directly from the source, Figure 4. The detector assembly is designed to match the spectral response of the human eye allowing direct correlation with exit stack Ringelmann readings.



**Fig. 4. Opacity schematic**

**Table 1. Opacity Specifications**

<b>Specifications</b>	<b>EDC 1000A</b>	<b>Typical Agency Requirements</b>
Source Spectral Response:	99% between 400-700 mμ	80% between 400-700 mμ
Source Lifetime:	10,000 hrs.	—
Accuracy:	±2%	±5%
Linearity:	±1%	±3%
Zero Drift:	±2% /30-90 days	±5% /7 days
Span Drift:	±2% /30-90 days	±5% /7 days
System Response:		
Analyzer & Recorder:	< 4 sec.	< 5 sec.
Output to Recorder:	4 to 20 ma 0 to 1V	
Temperature:		
Instrument:	0°F to 150°F	0°F to 150°F
Control Unit & Recorder:	40°F to 125°F	40°F to 125°F
Relative Humidity:	to 90%	to 90%
Line Voltage:	115±10%	±10%

**Instrumentation, Ambient Air Monitoring.** The same analytical technology described above is also utilized for ambient air monitoring. The increased sensitivity is primarily obtained by increasing the pathlength. Depending upon the monitoring application this is done either by merely extending the distance between the source and receiver, or by using a White-type multi-path cell. In the latter case, the source and receiver are at the same location, potentially simplifying operation of the unit.

Furthermore, sensitivity may also be increased by selecting a more strongly absorbing wavelength in the spectrum. Most gases have a variety of absorption features with a wide range of absorption coefficients.  $\text{SO}_2$ , which has a wealth of absorption detail, is particularly amenable to this manipulation.

Instruments are now available to continuously monitor ambient  $\text{SO}_2$ , with ranges of .01 to 0.5 ppm  $\text{SO}_2$ , with 2% sensitivity, and 1 minute system response time for 95% of final reading. Ambient systems are also available for CO, hydrocarbons, and NO.

This equipment is uniquely adapted to this application. Basic system simplicity, with no instrument moving parts except for tuning fork choppers, and no chemical reactions to effect the analysis, results in long-term reliable operation with minimum servicing required. Furthermore, the continuous monitoring of both the absorption wavelengths ( $I$ ), and the background wavelengths ( $I_0$ ), provides real long-term stability. Finally, the addition of automatic calibration, described below, allows for completely unattended operation.

**Calibration.** Since absorption of radiation is proportional to the number of molecules in the light beam, as long as the total pressure is the same, one can simulate stack or ambient concentrations over long paths by using higher concentrations in a shorter path. For periodic calibration, sealed cells containing the concentrations of gases desired are placed in the light beam for the instrument calibration. In this way, zero, full scale and several intermediate points are checked to insure instrument calibration.

For the situation where sample gas is being measured, the calibration can be performed by means of an incremental addition of known concentrations of gas. Since the relationship of gas concentration to instrument response has a continuously changing slope throughout the curve, there is only one set point for both zero and span wherein the addition of these known concentrations will properly add to the existing asread stack concentration. In this way, a dynamic on-stream calibration is performed which uniquely determines both zero and span, and which provides a check on the entire analytical system. This is a calibration in the presence of the sample and all other stack constituents.

An automatic or on-demand calibration check is available also, wherein a known concentration of gas in a sealed allquartz cell is inserted into the light beam for an

incremental addition. The cell is solenoid operated, and actuated by a push button in the control room, or automatically by a preset clock timer. As in the routine calibration, the correct addition of this known gas to the existing sample reading indicates that both zero and span are set properly.

**Conclusion.** The continued pressure for cleaning the environment requires detailed ambient and emissions inventories. Operation of this equipment in over 150 installations monitoring over 450 parameters has shown that in-situ monitoring is capable of long-term, continuous, unattended monitoring. Further work in emissions control will be based upon the data being derived today by instrumentation of this kind.