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CONTINUOUS NO_X MONITORING SYSTEM

[1] J. S. RAO, [2] PRAKASH SAHU

[1] Deputy General Manager, R&D Division of MECON, MECON Limited, Ranchi – 834 002, India.
[2] Assistant Design Engineer, R&D Division of MECON, MECON Limited, Ranchi – 834 002, India.

drjsrao_2000@yahoo.com

ABSTRACT : *Oxides of nitrogen in the atmosphere cause acid rain, smog, and ozone depletion and health hazards. On line NOx monitoring system will help all industries in general to measure the emissions accurately and there by to control the emissions. In this paper we reported indigenously designed and developed on-line NOx Monitoring system using Non Dispersive Infrared (NDIR) principle. Many features in hardware and user friendly software have been incorporated. The developed system has been field tested successfully in different running stacks of a steel plant. NOx concentrations have been continuously recorded, trend graphs have been plotted and results obtained have been stored. Measurements have been validated using a standard imported system. Results obtained are encouraging have been presented and discussed.*

KEY WORDS: NDIR system, NOx Concentration, Infrared light, Gas cell.

1. INTRODUCTION

Monitoring of oxides of nitrogen in flue gas is essential and is one of the recommendations for cleaner production under life cycle assessment study. In view of rapid industrialization and consequent release of industrial effluents into the atmosphere causing immense harm to the society. It has now become mandatory, to on-line and continuously monitor and control the emissions of waste pollutants from ducts/stacks/chimneys with specific requirements from process to process. To asses the emissions accurately, the measurement must be continuous and have reliability.

Oxides of nitrogen (NOx) are found in the emission from industrial factories, automobiles, air crafts etc. and contribute to the production of acid rain, smog and the depletion of the ozone layer. They are considered as most important category of air pollutants. Monitoring of oxides of nitrogen in the flue gases is essential and is one of the recommendations of the national metallurgical laboratories for cleaner production under life assessment study.

Presently most of the industries in India, to the best of our knowledge, are using imported Non Dispersive Infrared (NDIR) [1,2] systems for the measurement. Our aim of the present investigation is to develop indigenous NDIR equipment capable of continuously on-line monitoring of NOx present in the flue gases and the system should be capable to withstand the harsh environmental condition prevailing in industry. The following are the features of the present investigation:

- Continuous on-line and non-contact method
- High reliability
- Display of NOx concentration in ppm
- Video and audio over emission alarms
- Continuous data logging
- No moving parts
- Control of source intensity against aging
- Low maintenance
- Modular design for mechanical mounting of the system
- Simple and versatile to make installation easy and faster.

2. DETAILS OF TECHNOLOGY DEVELOPED

Principle of operation:

The system developed, for the measurement of continuous NOx gas concentration in flue gas, operates on the principle of Infrared Absorption. Infrared radiation interacts with all molecules, except homonuclear diatoms like Oxygen (O2), nitrogen (N2), Hydrogen (H2) and Chlorine (Cl2), by exciting the molecular vibrations and rotations. The oscillating electric field of the infrared radiation interacts with the electric dipole of the molecule, and when the frequency of infrared radiation matches with the natural frequency of the molecules, some of the infrared power is absorbed. The wavelength, 5.3 µm in case of NOx, absorbed identify the molecules in the sample. The strength of absorption at this particular frequency is a measure of NOx concentration.

Accordance to the Lambert-Beer Law [3], the absorbance of the gas is directly proportional to its concentration,

$$A = e.l.c \quad \dots (1)$$

$$I = I_o.10^{-A} = I_o.10^{-e.l.c} \quad \dots (2)$$

Where I_o is the initial light intensity emitted from the infrared radiation source (measured in pure nitrogen or vacuum), I is the intensity of infrared radiation when the sample gas is present in the gas cell. A is the absorbance of the gas, e is the molar extinction coefficient, l is the path length (optical path length of the gas cell) and c is the concentration of the sample gas to be measured.

Since l and e are fixed measuring the light intensity ratio I/Io gives the concentration of the sample gas.

Optical schematic:

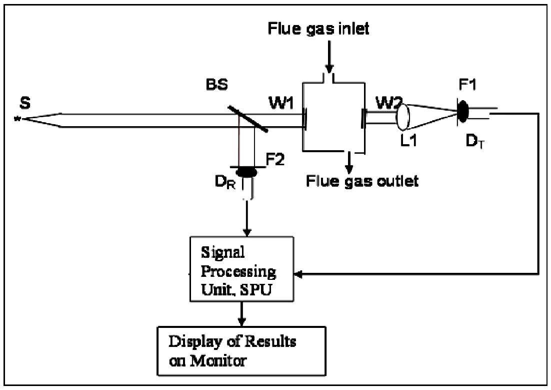

Figure 1 Optical schematic of the NDIR NOx Monitor

The optical schematic of the NDIR NOx monitor set up is shown in Fig. 1.The broad band infrared light source S, with built in parabolic reflector and filter, emits parallel infrared light beam [4] containing the absorption wavelength of NOx gas. The emitted infrared beam is then split into two beams by the beam splitter BS. The transmitted beam from beam splitter is then passed through the sample gas cell as entering through window W1 and leaving from window W2, and is focused on to the sample detector DT by the IR lens L1. This detector DT measures the intensity Io when there is no NOx gas, and stores the value in memory. This detector also continuously measures intensity I when there is sample gas in the gas cell. The narrow band NOX filter F1 is built onto the detector DT which detects only the presence of NOx gas and eliminates the detection of all interfering gases.

The reflected infrared beam from the beam splitter, BS, is adjusted to fall on to the reference detector DR. The narrow band NOx Filter F2 is built onto the detector DR. This detector is used to check the aging of the IR light source by means of a knob provided out side the signal processor unit, SPU. Fig. 2. Shows various components mounted on bread board as par Fig. 1

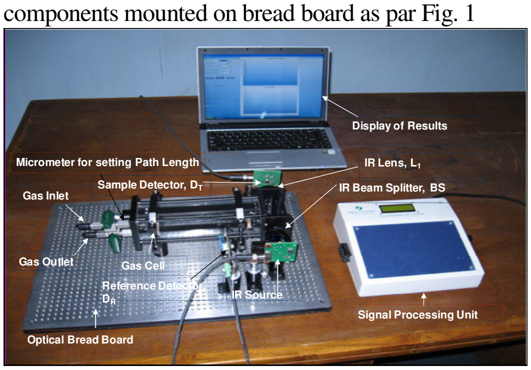

Figure 2 Various components of Continuous NOx Monitoring System

The SPU supplies the required power to the infrared source S, sample detector DT and reference detector DR. SPU contains all designed and fabricated electronics to receive the signal from the sample detector DT and reference detector DR. The SPU process the signal of DT when there is zero gas, I0, and when there is NOx gas, I, and computes the signals ratio I/I0 to give the NOx gas concentration. Dedicated Software is developed in VB and is loaded in the computer which plots the calibration curve for a selected path length. This selects the intensity ratio from the measured signals, I/Io for each fixed integration time and displays on-line results - gas concentration in ppm and generate the trend graphs and reports.

Signal Processing Unit (SPU):

This is the heart of the total system. This unit contains the total electronic components and circuits required are designed and developed for the system. SPU supplies required input power to the source, detectors and also receives the signals from both the detectors.

The total NOx monitoring system is shown in Fig. 3

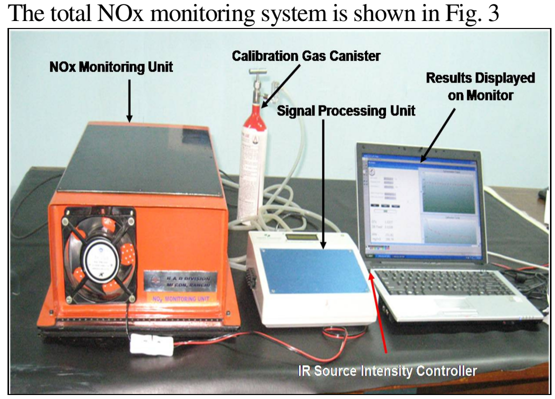

Figure 3 Continuous NOx Monitoring System

Software:

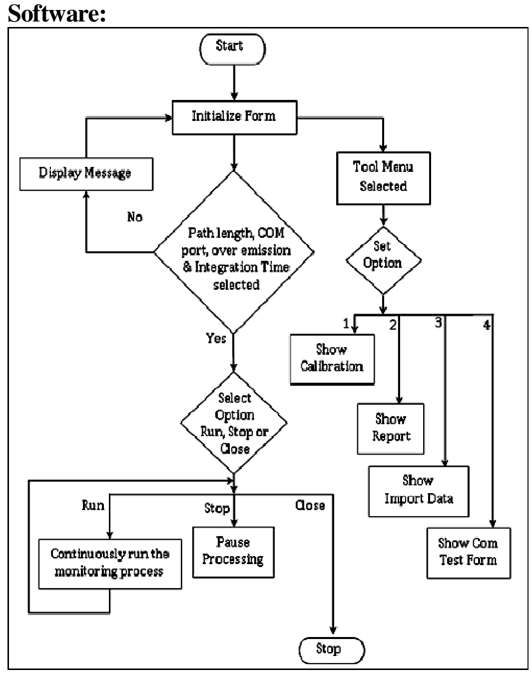

Figure 4 Software flow chart of NOx Monitoring System

Dedicated software developed takes care of all computations, calibration of the system with standard gases and the displays the results on the monitor. The output from the detectors is fed to the signal processing unit and using the custom made software, developed in VB does the rest. The PC on-line monitors, stores and display the results. The flow chart of the software is shown in Fig. 4.

Features of Software:
Please refer to Fig. 4.
Path length - As soon as the software is on, a parameter 'path length' appears with the box on the screen. It contains all the path lengths for which the calibration curves were plotted. Select one path length for monitoring.

TABLE 1 : **Features of Software:**

Integration Time	-	Select any 'Integration Time' value from 1 to 30 minutes. This need not be the same as calibration integration time
Over emission	-	Enter the value of 'over emission' as suggested by the plant authorities. When this value crosses the set over emission value Video message will appear on the monitor as OVER EMISSION and at the same time audio alarm will ring.
Select a mode to run	-	Select 'monitoring' for on-line monitoring of the NOx concentration in flue gas.
DTo	-	Value of the sample detector 'D_{T0}' when there is zero gas / no NO gas in the gas cell.
D_R Fixed	-	This is fixed before calibrating the system for various NO gas concentrations. Due aging of the IR source this value may fall and to bring the value to the original value, 'D_R Fixed', a knob is provided on the SPU. This avoids the process of recalibrating the system.
ppm	-	Display of the current value of NOx in ppm
Tools	-	Once the tools is clicked the following parameters will appear
Comtest		For testing and selecting the communication port
Reports		To see the reports generated when the system is continuously monitoring. The report generated contains date, time, path length in meters, ppm and integration time (minutes) as shown in Table 2.
Import earlier data	-	To import all earlier data
Backup current data	-	To get all the current data

Table 2. A portion of report generated during field trials

Date	Time	Path Length in (Meters)	Integration Time (Minutes)	PPM
4/2/2013	15:29	3	1	93.83
4/2/2013	15:30	3	1	94.16
4/2/2013	15:31	3	1	96.16
4/2/2013	15:32	3	1	98.06
4/2/2013	15:33	3	1	99.54
4/2/2013	15:34	3	1	101.14
4/2/2013	15:35	3	1	107.52
4/2/2013	15:36	3	1	97.73
4/2/2013	15:37	3	1	99.38

Calibration:

The system developed has been calibrated using some known concentrations of the test gas, NO gas, and a calibration curve plotted for the system. This calibration curve will remain valid till any component of the system is changed. First the system is calibrated for zero concentration / when there is no NO gas in gas cell. To measure the unknown concentration of the flue gas, the system was calibrated first using some unknown concentrations of the NO gas and a calibration curve was plotted with normalized detector reading of the detector DT Vs the concentration of the NO gas. For unknown concentration of the gas normalized detector reading of DT is measured and the unknown concentrations are obtained which corresponds to this detector reading for a particular calibration.

As soon as the software is on it will display "select a mode to run", where in two parameters calibration and monitoring will be displayed. Select Calibration for calibrating the system Enter the value of path length say - 3 meters, integration value –1 minute and gas concentration – zero and run the software. The computer store the value Io for zero concentration and plots the value of Transmission Tx = Io/Io on the Y-axis and concentration on X-axis of the calibration curve. This is repeated with known concentrations of the calibration gas NO keeping, the path length, integration time same. Final calibration curve has been plotted automatically as shown in Fig.4. For each concentration the computer calculates the transmission Tx = I/Io.

Variable path length gas cell is used in the system for different gas sensitivities. For this purpose different calibration curves were plotted for various path lengths from 0.6 meters to 7.2 meters with 0.6 meters steps.

NO to NOx Conversion:

In the present investigation nitric oxide, NO, is measured experimentally and there by NOx concentration was calculated.

It is generally assumed that nitric oxide, NO, contained in combustion gases makes up about 95% of the total amount of nitrogen oxides NOx. Some combustion analyzers calculate the total concentration of nitrogen oxides NOx according to the formula

NOx [ppm] = NO [ppm] / 0.95 … (3)

If the analyzer is fitted with NO sensor there is no need to reduce NO2 to NO to measure NOx concentration.

Calculation of NOx from NO is possible if there is a reliable and known ratio between NO and NO2 in the test gas. In general there is a common ratio is fixed in the standards of most countries. This ratio is not always the same in all countries and NOx measurements must therefore state clearly what ratio of nitric oxide to nitrogen oxides or nitric oxide in NOx was applied for the results.

3. RESULTS AND DISCUSSION

The continuous NOx Monitoring System developed has been field tested in different locations of a steel plant. The trend graphs generated during testing is shown in Fig. 5. and the report generated is shown in Table 2. These results have been validated with the imported equipment of M/s Endee PA-4200 non continuous multi gas analyzer based on chemical analysis.

Results obtained are very encouraging as predicted. The selection of components, design of electronic circuits, software development, integration of Hardware and Software and final installation of the system for field trials has worked out as per our plan. The knowledge and confidence gained during development and execution would definitely help us in developing some higher version of the system and for other gases.

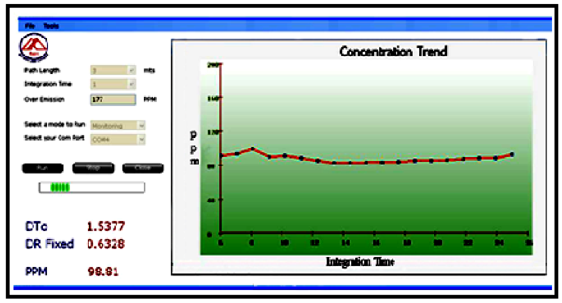

Fig. 5. NOx trend curve generated during field trials

4. SCOPE FOR FEATURE WORK

Our team gained a lot of experience and knowledge in developing the continuous NOx monitoring system. This experience will help us in further development of single and multi gas analyzers for CO,CO2, SOx and NOx, or a choice of any four gases, using a single unit. It is also possible to develop monitoring systems for other single gases like N2O, HCl, and Hydrocarbons etc.

RS-232 provision can be given on the SPU itself along with LCD display of current data in ppm, over emission signals. This provision will help the authorities to down load the reports generated at any time they need.

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