OZONE MEASUREMENT IN EXAFS BEAM LINE BL-08 OF INDUS-2

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Abstract

Ozone measurement in experimental hutch of Extended X-ray Absorption Fine Structure (EXAFS) beam line (BL-08) of INDUS-2 is carried out with the objectives of measuring ozone build-up profile at various locations inside the hutch, to check the effectiveness of the existing exhaust blower used to remove the ozone from the hutch and to determine the ozone decay time to reach the safe limit of 0.1 ppm. The results show that the ozone level is less than 0.1 ppm in all measured locations. This paper describes the methodology, experimental set-up and the results of the experiment done in June 2010 at RRCAT.

INTRODUCTION

INDUS-2 is a 2.5 GeV synchrotron radiation facility, designed to operate at critical SR energy 6 keV and average beam current 300 mA. The circumference of the circular ring is 172 m and consists of dipole bending magnets, focusing, defocusing quadrupoles, sextupoles etc [1]. Intense synchrotron radiation beam is generated, when high energy electrons pass through the bending magnets. Ozone in the facility is produced when electrons or photons interact with air molecules, which cause dissociation of oxygen molecules, leading to an active free atom of oxygen. The free oxygen atom further gets attached to an oxygen molecule to form the ozone. The G value (number of molecules produced per 100 eV energy absorbed) is reported to be in the range from 2.7 to 13.8[2].

The ozone is an invisible, colourless toxic gas with high chemical reactivity. The Threshold Limit Value (TLV) for ozone exposure is 0.1 ppm as recommended by OSHA (Occupational Safety and Health Administration). AERB (Atomic Energy Regulatory Board) also has recommended maximum permissible limit for ozone exposure as 0.1 ppm. Exposures to excessive concentration of ozone in workplaces can cause health hazard. Hence appropriate measures must be taken to ensure that personnel working in the facility are not exposed to ozone concentration that exceeds the maximum permissible limits. The present study has been carried out to measure ozone build-up profile at various locations inside the experimental hutch and verify the effectiveness of the existing exhaust blower used to remove the ozone from the hutch.

OZONE PRODUCTION AND BUILD-UP IN EXAFS BEAM LINE

In Extended X-ray Absorption Fine Structure (EXAFS) facility, the synchrotron radiation is tapped from a bending magnet and brought to the experimental hutch through ultra high vacuum beam line (10^{-8} Torr) BL-08, also known as EXAFS. The white synchrotron radiation beam after passing through beryllium vacuum isolation window traverses 15-20 cm in air before entering into the polychromator chamber and subsequently traverses ~100 cm in air before impinging on experimental samples.

There are three possible ways by which ozone is produced in the experimental hutch

i. The white synchrotron radiation beam leaving the Be window interacts with the surrounding air.
ii. A fraction of the white beam while traversing through the vacuum beam line may strike the vacuum chamber and consequential escaped radiation interact with the air surrounding the vacuum chamber.
iii. The secondary radiation (high energy bremsstrahlung or scattered electron) produced by primary electron beam on interaction with vacuum chambers etc interact with the air in the room.

Of these maximum contribution is due to the white beam. The production rate primarily depends on beam current, beam energy and the volume of the air exposed. However at any time ozone concentration depends mainly on three factors such as, ozone production rate, ventilation rate and self chemical decay rate of ozone.

MEASUREMENT TECHNIQUE

Experimental set-up

Figure 1 shows the experimental set-up used for measuring the ozone concentration at various locations inside the experimental hutch. The twin cell, dual beam ozone monitor, model No. 205, supplied by 2B Technology, USA is used for measurement. The ozone monitor is calibrated against a secondary standard ozone calibration source (calibration traceable to the NIST, USA) before conducting the experiment. The output of the calibrator can be varied from 0 to 1000 ppb level within accuracy of 1%. Figure-2 shows the response of the monitor as a function of time at various input concentration (from calibrator). The over all uncertainty of measurement is less than 3%. During experiment the ozone monitors continuously suck ozone mixed air from the hutch through a Teflon-lined Tygon tubing at constant flow rate of 2 l/min. The instantaneous ozone concentration as measured is logged in a personal computer with stamping of date and time.

Measurement principle

The Ozone monitor works on the principle of UV photometry which is a reference method of ozone measurement as per ASTM D4575. Principle of ozone measurement is illustrated in Figure 4. The air sample sucked from hutch passes through two measuring cells

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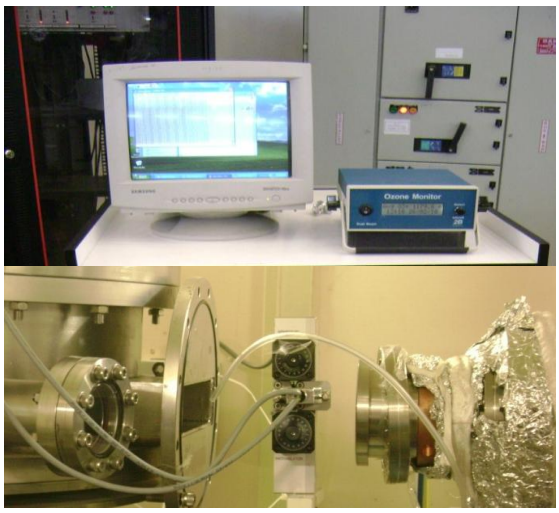

Figure 1: Experimental Set-up for measurements

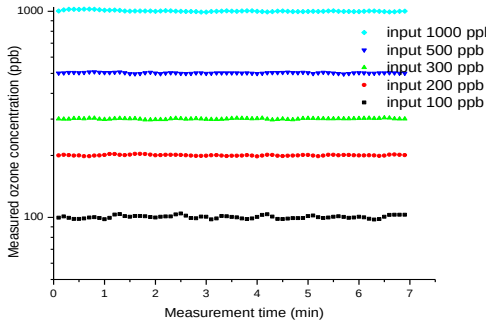

Figure 2: Monitor response for known input concentration

Cell-1 and Cell-2, each illuminated with UV lamp at wavelength of 254 nm. The ozone free air sample (obtained by passing the sample through ozone scrubber) and ozone containing air passes through Cell-1 Cell 2 respectively and corresponding intensity I_0 and I_t are measured with photo diode. Ozone concentration C is calculated as (Beer-Lambert Law):

$$C = \frac{1}{\alpha L} \ln \frac{I_0}{I_t} * \frac{T}{T_0} * \frac{P_0}{P}$$

Where α=Ozone absorption co-efficient (308 cm-1), L= Measuring cell length (15 cm), T_0 =273K, Reference temperature, T = Sample temperature, P_0 = 1031 mb, Reference pressure, P = Sample pressure.

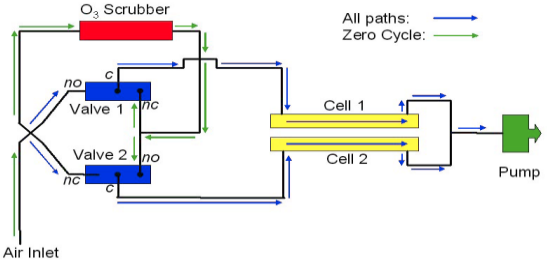

Figure 3: Principal of ozone measurement

RESULTS

Ozone concentration measured at various locations as a function of beam on time is shown in Figure 4 (A-C).

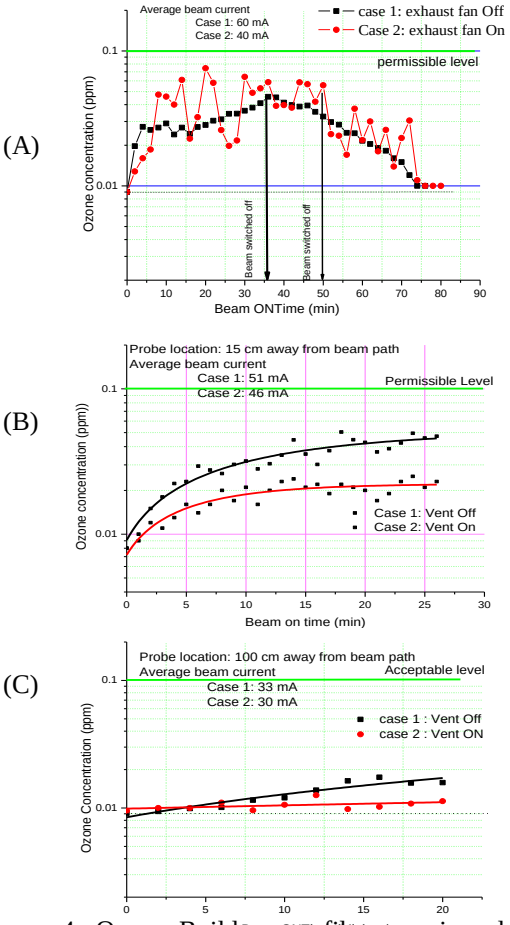

Figure 4: Ozone Build-up profile at various locations: (A) Near experimental station (B) 15 cm away from beam path (C) 100 cm away from beam path.

CONCLUSION

Ozone concentration has been measured at various locations inside the hutch of EXAFS beam line BL-08. When exhaust blower is ON, and beam is continuously ON for 30 min at beam current less than 100 mA, the ozone concentration at various locations is less than the 0.1 ppm. Hence the existing exhaust blower is sufficient to maintain the ozone level inside the hutch below the permissible limit.

ACKNOWLEDGEMENT

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