

COMPUTER CONTROLLED OZONE INHALATION EXPOSURE SYSTEM

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ABSTRACT

Systems used to expose laboratory animals to various gases and aerosols are an important aspect of inhalation toxicology studies. These systems are crucial in controlling the dose of toxicant the animals receive. The object of this project was to develop a computer controlled ozone inhalation exposure system for the evaluation of health risks associated with ozone. The system is capable of a wide range of exposure concentrations (0.1 to 8.0 PPM) and can be used for various exposure times (1-8 hrs). Ozone concentration steady-state error was less than one percent when closed-loop control principles were applied. Additionally, when compared with the open loop response rise time, the step response time was cut in half after closed loop control was implemented.

SYSTEM DESIGN

A block diagram of the ozone inhalation exposure system is shown in Figure 1. An ozone generator (Enment) produced a constant flow (1.2 LPM) of ozone gas which was mixed with conditioned diluent air before entering the exposure chamber. To achieve a homogeneous mixture of ozone within the exposure chamber, ozone was delivered into four holes on the left side of the chamber and exhausted from the four holes on the right side. The custom exposure chamber was constructed of stainless steel and glass, and Teflon tubing was used throughout the system to minimize reactions with the highly reactive ozone gas. The computer controlled the ozone concentration in the chamber by adjusting the amount of diluent air with a mass flow controller

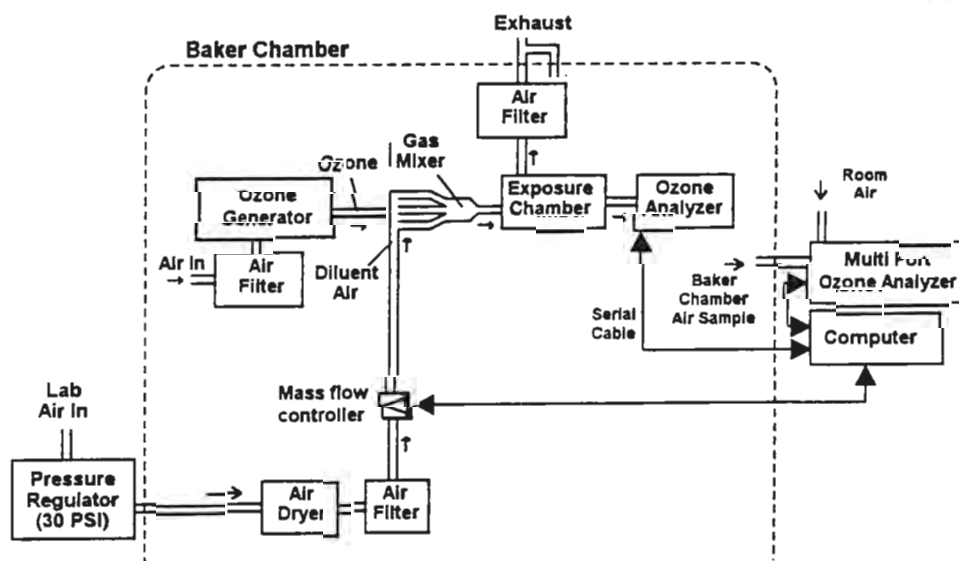


Figure 1. Diagram of Ozone Inhalation Exposure System

to minimize reactions with the highly reactive ozone gas. The computer controlled the ozone concentration in the chamber by adjusting the amount of diluent air with a mass flow controller

(Aalborg). Diluent air flow ranged from 7 to 30 LPM, depending on desired concentration. An API 400a ozone analyzer was used to continuously measure ozone in the exposure chamber. The entire system was placed in a large exposure chamber (Baker), which provided an additional barrier for technician safety during exposure. A second ozone analyzer (API, 450) sampled ozone levels in the Baker chamber and in the laboratory during exposures to alert users of potential leaks.

SYSTEM TEST METHODS

A multi port ozone analyzer (API, 450) was used to sample ozone levels in five locations within the exposure chamber to determine if ozone concentrations were uniform throughout the chamber. The performance of the ozone control system was evaluated in terms of step and steady state responses. A step decrease in concentration was achieved by opening the exposure chamber door after a steady desired concentration (2PPM) had been attained. In half the tests animals were placed in the exposure chamber as the door was opened to mimic exposure conditions. The time required for the concentration to reach 95% of the original desired concentration (2PPM) was termed the rise time. The increase in the concentration above the desired value was used to determine the % overshoot. Steady state tests were conducted to determine how well the system would maintain a constant ozone level during an exposure. The ozone concentrations were recorded for 30 minutes after the initial transient response. The standard deviation and percent error were calculated to investigate the deviation from the desired value.

RESULTS AND DISCUSSION

Differences in ozone concentrations at each test location were less than 1% which insured that all animals within the chamber were exposed to similar concentrations of ozone. If animals are to be exposed to a steady state level of toxins, minimizing the ozone concentration rise time and percent over shoot is desired. The results from the step tests can be seen in Table 1.

Table 1 System Rise Time Test

Response Test	Rise Time 95%	% Over Shoot
Open Loop (no animals in chamber)	25 min	Less than 1%
Closed Loop (no animals in chamber)	12 min	Less than 1%
Open Loop (with animals in chamber)	Never Reached	NA
Closed Loop (with animals in chamber)	19 min	Less than 1%

The data demonstrated that the closed loop control algorithm decreases the rise time by a factor greater than 2 when compared with open loop response. This test also showed that the percent over shoot was always less than 1% of the desired value. The results of the steady state tests are given in Table 2.

Table 2 System Steady State Test

Desired concentration	Actual Mean	STD	%error
1.5 PPM (with animals in chamber)	1.492 PPM	0.077 PPM	0.56%
2.0 PPM (with animals in chamber)	1.997 PPM	0.078 PPM	0.13%

These results demonstrated the successful development of an ozone inhalation exposure system that may serve as a reliable and stable tool for use in future inhalation toxicology studies.

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