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Effectiveness of Protective Breathing Equipment Filter in Full-Scale Fire Test

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16. Abstract

This report contains the results of measurements to determine the effectiveness of a protective breathing equipment filter. Measurements of gas levels were made of both filtered and unfiltered cabin air during a full-scale C-133 fire test. Measurements of airflow through the filter and pressure differentials across the filters were made to determine the effect, if any, of smoke particulate clogging.

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EXECUTIVE SUMMARY

This report contains the results of experiments performed during a C-133 full-scale fire test to determine the effectiveness of a protective breathing equipment filter. Measurements of oxygen, carbon dioxide, and carbon monoxide were made downstream of the filter, which was connected to a breathing machine, and compared to measurements taken from an unfiltered sample.

Oxygen levels dropped considerably in both the filtered and unfiltered samples; likewise, carbon dioxide and carbon monoxide levels in both samples increased.

The effect of smoke particulate clogging on the filter was also determined, based on measurements of pressure behind the filters and airflow through the filters. The pressure differentials measured across the filters began rising 4 minutes into the test and continued to climb until visability of the manometers ceased due to smoke buildup.

INTRODUCTION

PURPOSE.

This report presents the results determined during the testing of filters typically used in protective breathing equipment (PBE).

BACKGROUND.

During a cabin fire, smoke and toxic fumes may inhibit or prevent passenger escape. As a result of several accidents, protective breathing equipment has been researched as a means of protecting occupants during a cabin fire. In this test, a filter from Mine Safety Appliances (MSA) (Britain) was used. This filter is considered to be state-of-the-art; and although MSA is not the only distributor of this type of filter, it was chosen as being representative. The filter used contains a catalyst which converts carbon monoxide to carbon dioxide, which is important since carbon monoxide poisoning is a leading contributor to deaths in cabin fires. The experiment on the filter was conducted during a full-scale pan fuel fire in a C-133 aircraft.

TEST PROCEDURE

TEST APPARATUS.

A Harvard Apparatus animal ventilator was implemented as a breathing machine to simulate respiration through a filter purchased from MSA. The breathing machine was set to yield a 1.5 liter tidal volume (1.5 L/breath) and a respiration rate of 20 breaths/minute. This produced a minute volume of 30 L which might be obtained in a fire atmosphere. Under normal breathing conditions, a 12 L minute volume can be expected. A constant flow of carbon dioxide (CO_2) was added to the exhalation, yielding a 4 percent CO_2 exhalation mixture.

The filter was attached to an aluminum box through which inhalation and exhalation took place and from which gas measurements were made (figure 1). Gas measurements were also made of unfiltered samples. The locations of the two sampling stations were as follows:

	Filtered	Unfiltered
Height from floor:	5 feet 6 inches	5 feet 6 inches
Distance from front of plane:	880 inches	880 inches
Distance right of center line:	5 feet	0

Mine Safety Appliance filters were also used in the pressure/flow test. Flows were drawn through six filters at three different rates at two heights. The flow rates were 9.4 L/minute, 14.2 L/minute, and 23.6 L/minute. As stated previously, under normal breathing conditions a person breathes at a rate of approximately 12 L/minute. The filters were located at heights of 5 feet 6 inches and 3 feet 6 inches, at 660 inches from the front of the plane, on the left side wall.

Manometers measured the pressure differentials [P_{filter}-P_{cabin}] across the filters located at 5 feet 6 inches (figure 2).

INSTRUMENTATION.

Oxygen, carbon dioxide, and carbon monoxide gas analyzers continuously measured gas levels of both the filtered and unfiltered samples. The signals were sent through an analog to digital converter and stored on a floppy disk. During testing for particulate clogging, pumps were used to draw varying flows through the filters. Flow meters measured the flow rates through all six meters. The manometers and flow meters were housed in a booth adjacent to the fuselage, where video cameras were used to tape any changes taking place.

TEST RESULTS

GAS ANALYSIS.

Analysis of oxygen, carbon dioxide and carbon monoxide in both the filtered and unfiltered samples began 165 seconds after ignition. Gas percentage changes in the filtered sample began approximately 4 minutes into the test and lagged the unfiltered sample by 30 seconds.

The filtered O_2 level reached a minimum of 5.7 percent at 420 seconds. At this time it began to rise again reaching 14 percent after 17 minutes. The unfiltered O_2 reached a minimum at 450 seconds and rose from this point (figure 3).

The rise in CO_2 levels in the filtered sample went off-scale (approximately 10 percent) at 280 seconds and did not return throughout the 17-minute test. The unfiltered CO_2 went off-scale but returned to below 10 percent at 465 seconds (figure 4).

The filtered CO percentage rose to above 2 percent at 315 seconds and began to fall at 375 seconds, returning eventually to 0 percent near the end of the test. The unfiltered CO level rose above 2 percent at 240 seconds and did not fall below 2 percent through the test (figure 5).

PARTICULATE CLOGGING.

The flowrates through all filters remained constant throughout the first 4 1/2 minutes of the test, after which time the booth housing the meters became filled with smoke, thus obstructing the view of the meters. At 4 minutes into the test the pressure differentials across the filters at 5 feet 6 inches began to rise rapidly (figure 6). After 4 1/2 minutes, the manometers were no longer visible. Table 1 shows beginning pressure differentials and those reached after 4 1/2 minutes for each of the three flow rates. The maximum pressure differentials observed would not have rendered breathing impossible. It is not known, however, to what extent the pressures continued to build throughout the duration of the test.

TABLE 1. PRESSURE DIFFERENTIALS

Flow rate (L/min)	ΔP (in H_2O), t=0	ΔP (in H_2O), t=4 1/2 min
9.4	0.0	0.8
14.2	0.1	1.6
23.6	0.2	4.0

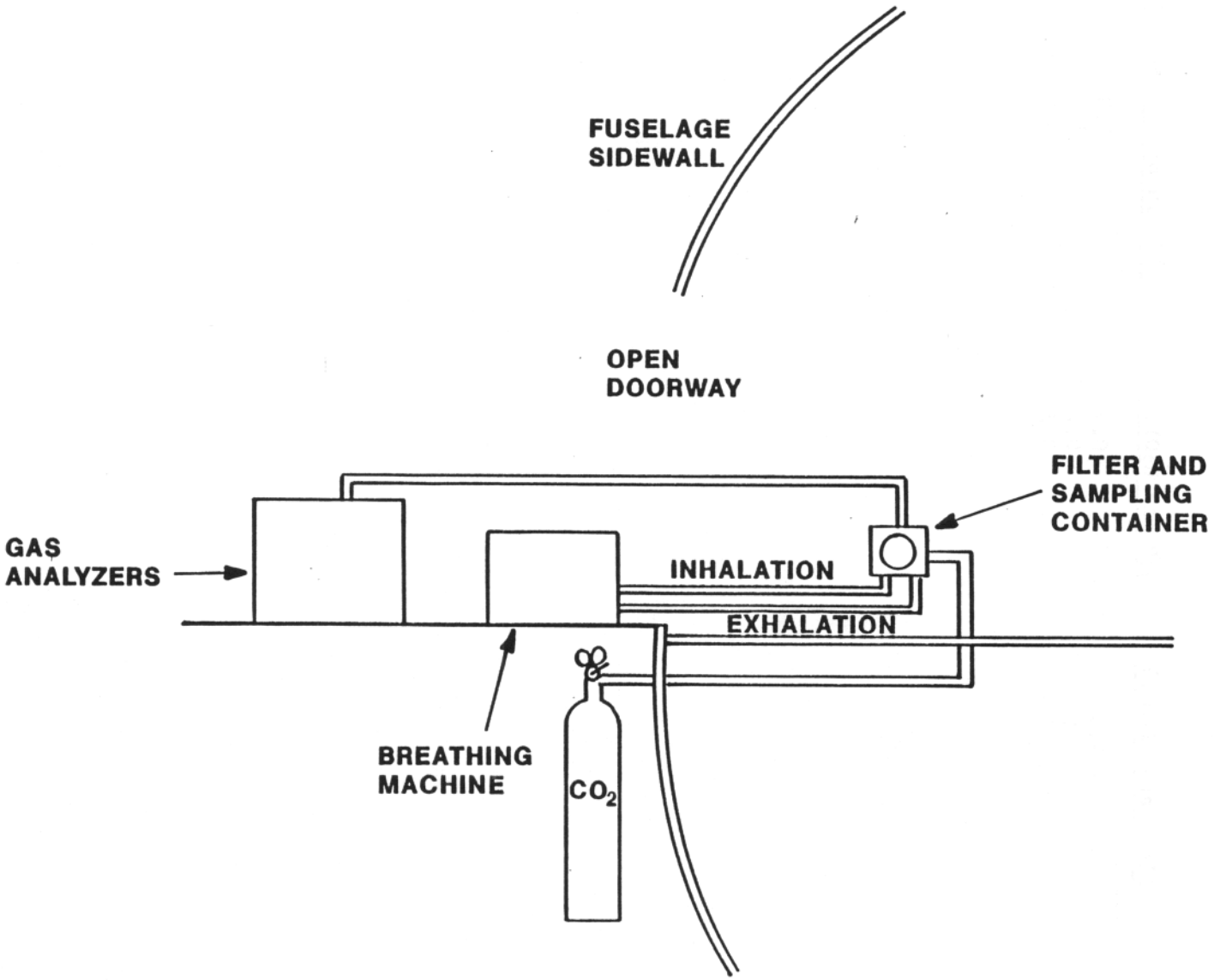

FIGURE 1. TEST SETUP FOR GAS MEASUREMENTS

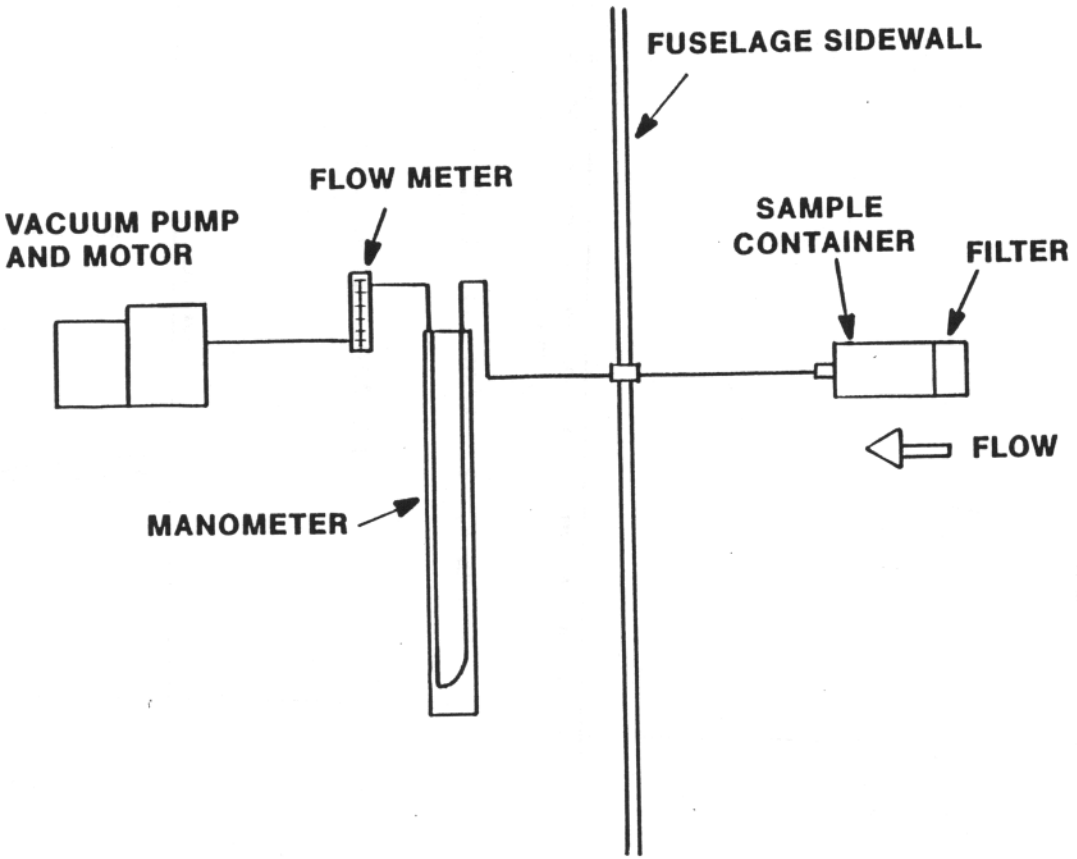

FIGURE 2. TEST SETUP FOR PRESSURE/FLOW MEASUREMENTS

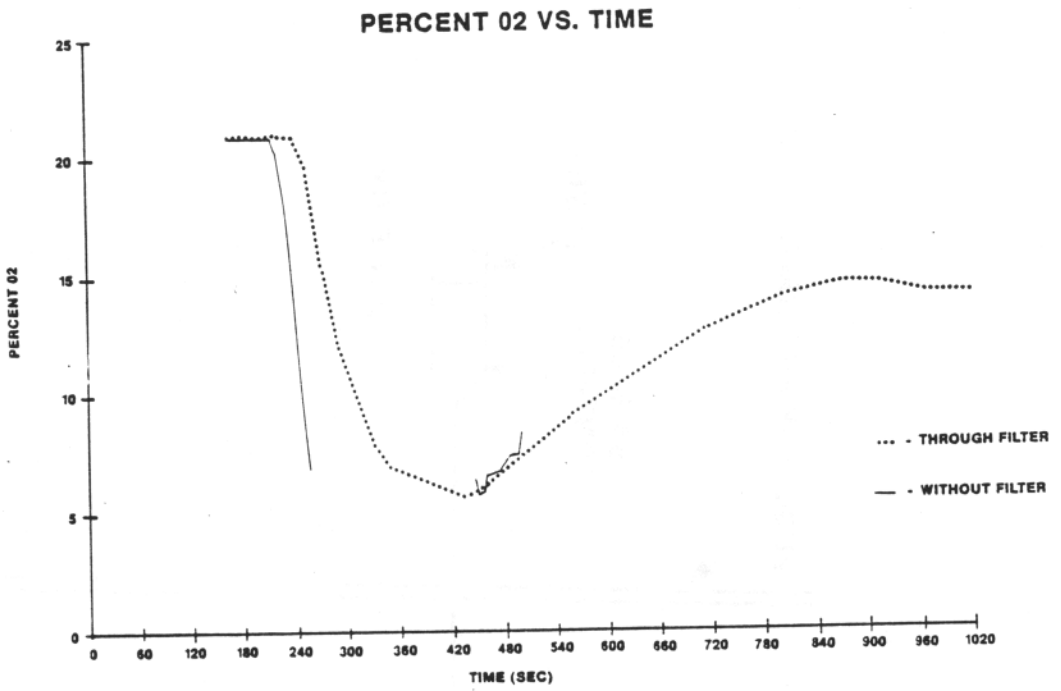

FIGURE 3. FILTERED AND UNFILTERED OXYGEN DEPLETION

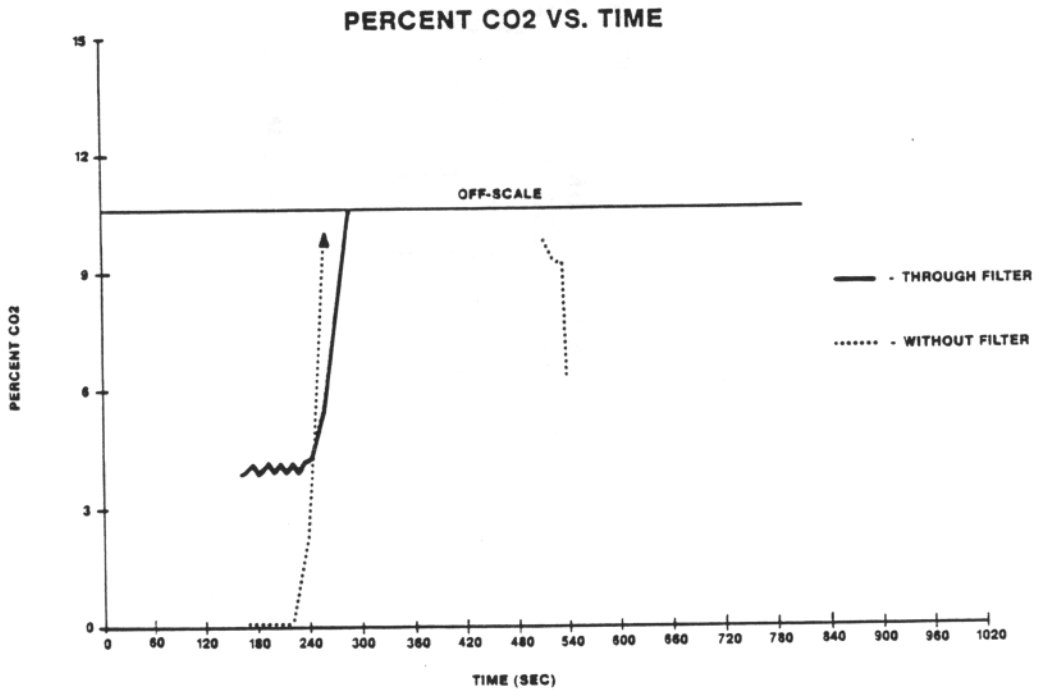

FIGURE 4. FILTERED AND UNFILTERED CARBON DIOXIDE LEVELS

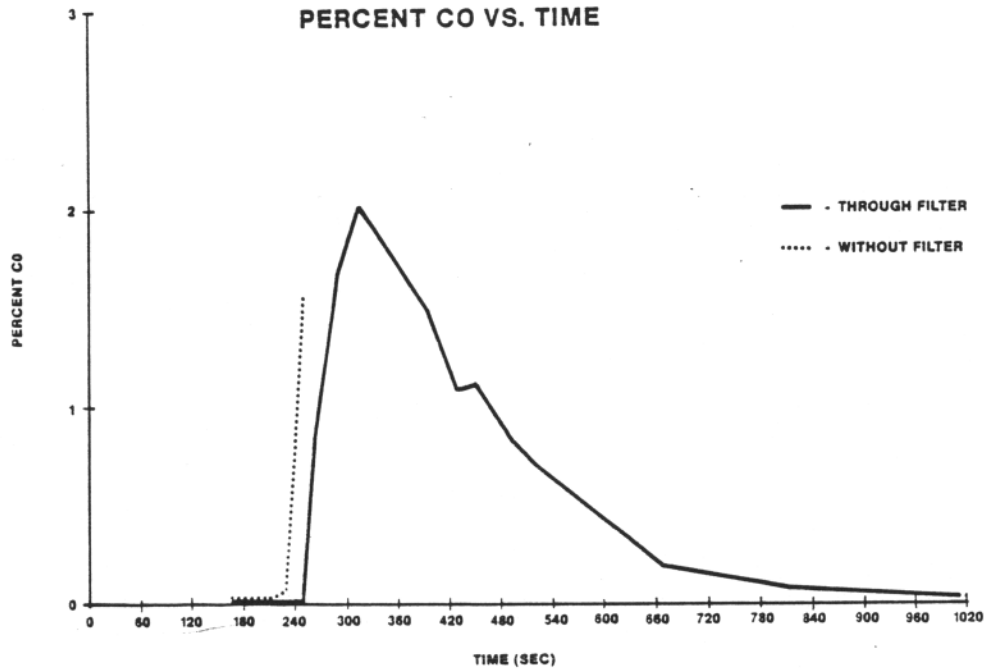

FIGURE 5. FILTERED AND UNFILTERED CARBON MONOXIDE LEVELS

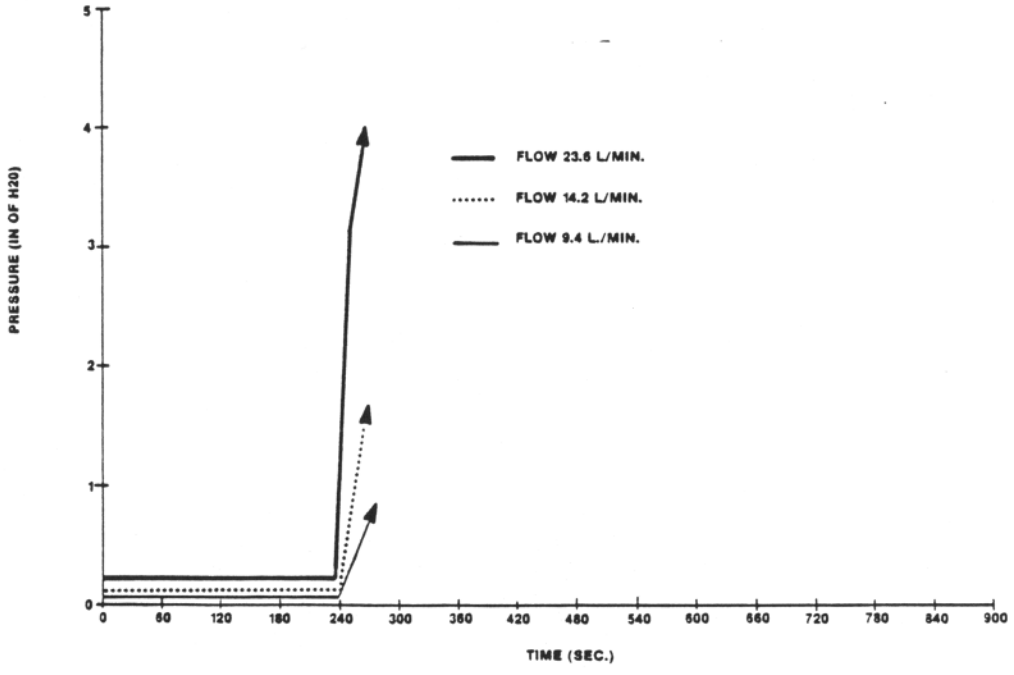

FIGURE 6. FULL-SCALE TEST DATA FILTER PRESSURE DROP