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NAVY EXPERIMENTAL DIVING UNIT

REPORT NO. 7-89

EMERGENCY BREATHING APPARATUS MK 18 MOD 1 CANISTER PERFORMANCE STUDY AT 844 FSW

LCDR M.E. KNAFELC, MC, USN

MAY 1989

NAVY EXPERIMENTAL DIVING UNIT

DEPARTMENT OF THE NAVY
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19. ABSTRACT (Continue on reverse if necessary and identify by block number)

The MK 18 MOD 1 emergency breathing apparatus (EBA) is a semi-closed circuit breathing apparatus designed to operate as a component of a built-in breathing system (BIBS) in a diver support facility. The EBA design includes two gas flow orifices, one to support a working diver, (VO_2) 3.0 slpm, the other to support a resting diver, (VO_2) 0.75 slpm. High Performance Sodasorb or LiOH can be used as the CO_2 absorbants within the canister. The design canister duration was 3 hours. Testing was performed at 844 FSW during an HeO_2 saturation dive at the Navy Experimental Diving Unit, Panama City, FL. The chamber temperature was 28(±) 1°C. The diver performed 15 minutes of work at a 175 watt load on a calibrated bicycle ergometer within a dry chamber. The diver then rested for 105 minutes. The divers' successful completion of the exercise, a canister effluent CO_2 level
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below 1% SEV, and their subjective comments determined the acceptability of the EBA. Only 2 trials were performed using LiOH because of the high inhalation gas temperature of 43°C which restricted the diver's work performance. Four trials were performed using HP Sodasorb. The maximum inhalation gas temperature was 39°C. At rest the gas temperature was approximately 33°C. The CO_2 levels never exceeded 1.5 % surface equivalent value during work or rest. The divers did not find the EBA any more difficult to use than the BIBS.

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ILLUSTRATIONS

I. INTRODUCTION

The MK 18 MOD 1 emergency breathing apparatus (EBA) is a semi-closed circuit breathing apparatus which operates as a component of the built-in breathing system (BIBS) in a diver support facility (DSF). The EBA provides breathing gas to an occupant of a chamber whenever it is necessary to use the BIBS for an extended period of time. This EBA was designed to be gas efficient by using a CO_2 absorbant canister. Because the EBA uses the gas supply from the chamber gas supply system, the true limit for life support will be a function of the CO_2 canister. In addition, it has two orifices, one to support a working diver, $\dot{V}O_2$ 3.0 slpm, the other to support a resting diver, $\dot{V}O_2$ 0.75 slpm. This design allows a tender to retrieve a diver while wearing the EBA in the event of a gas contamination emergency. The design of the MK 18 MOD 1 is intended to support a person working at 75 liters per minute respiratory minute volume (RMV) for 15 minutes, then be at rest, 18 RMV, for 165 minutes.

This study evaluated the ability of the EBA to provide a suitable gas supply for the chamber occupant as specified in the design criteria. Also, the ease of using the EBA was compared to a standard BIBS mask. In addition, two different types of carbon dioxide absorbant materials were also evaluated.

II. METHODS

A. SUBJECTS

The subjects were seven U.S. Navy trained saturation divers participating in a 20-day HeO_2 saturation dive at the Navy Experimental Diving Unit's Ocean Simulation Facility (OSF). All divers participated in an 8-week physical conditioning program designed to increase their aerobic capacity for cycling.

B. EMERGENCY BREATHING APPARATUS

The MK 18 MOD 1 used a supply gas of 95/5% HeO_2 at a pressure of 830 psia, and a freshly packed canister of High Performance Sodasorb (W. R. Grace, Atlanta, GA) or LiOH (Foote Mineral Co., Exton, PA). The EBA's operation was checked prior to each study. The MK 18 MOD 1 EBA canister effluent hose was instrumented for gas sampling with teflon tubing with an I.D. of .032 inch. The inhalation gas temperature was determined using a YSI 700 series probe (Yellow Springs Instrumentation, Yellow Springs, OH).

C. DATA COLLECTION

A Perkin-Elmer MGA 1100 mass spectrometer (Pomona, CA) or an Analox CO_2 monitor, model 00555 (Scottish Anglo Environmental Protection LTD) was used for the canister duration study. The monitors were calibrated prior to, and rechecked after the test according to the manufacturer's recommendation. A HP1000 mini-computer (Hewlett-Packard, Cupertino, CA) recorded the CO_2 concentration (%) every 10 seconds.

D. ANCILLARY EQUIPMENT

A calibrated bicycle ergometer (Collins Pedalmate, Braintree, MA) was installed in a dry chamber of the OSF.

E. PROCEDURE

All exercise was performed on a bicycle ergometer within a dry chamber. Upon completion of the work, the diver moved to an adjacent dry chamber. All chambers were at a simulated depth of 844 FSW.

There were two phases involved in the testing of the MK 18 MOD1. The first phase was a subjective evaluation of the EBA's ability to support a working tender for 15 minutes. Passing criteria included the successful completion of the exercise and favorable subjects' comments. The second phase evaluated the EBA's canister performance. This was performed by monitoring the canister effluent CO_2 during exercise and rest for a total time of 210 minutes or a CO_2 level of 1.5% SEV (surface equivalent value) sustained for a minute. The chamber temperature was 28 $\pm$ 1° C.

The EBA canister was packed with either LiOH or HP Sodasorb. Each canister pre-dive weight was recorded to insure consistent absorbant packing. The EBA was connected to supply gas from the diver's supply of 95/5 % HeO_2. The gas supply pressure upstream from the control block was 830 psia (440 psig over bottom).

Prior to starting the study, the diver had a 5-minute warm-up period - pedaling the ergometer at 50 watts. The diver then put on the EBA. After signaling that the EBA was properly donned and functioning with the high flow orifice, he resumed pedaling at 175 watts. The zero time for the canister study started when the divers began cycling at 175 watts. The diver maintained 60 $\pm$ 5 rpms. The CO_2 level and gas temperature was recorded every 10 seconds during the study. In the event of a computer failure the % CO_2 was recorded manually every 5 minutes or less, depending upon the diver's activity.

After 15 minutes of work the diver stopped and when he recovered from the exercise, approximately 1 minute, he switched the EBA to its low flow orifice. He then sat quietly or performed light work within the chamber. Gas sampling from the EBA's inhalation hose continued throughout the study. The diver remained at rest for 195 minutes. The divers were asked to comment on the ease of donning and using the EBA compared to the BIBS mask.

The major risk of this study was hypercapnia which can result in unconciousness. This risk was minimized by the continuous monitoring of the EBA's supply gas CO_2 levels during exercise and during rest. The diver was allowed to stop exercise at any time due to discomfort.

III. RESULTS

Five trials were performed with HP Sodasorb. One run was terminated after 140 minutes because of CO_2 levels between 2 and 5 % CO_2 SEV. The postdive inspection of the EBA revealed that the inhalation check valve was dislodged which probably resulted in the diver rebreathing his exhalation gas. Due to the malfunction of the EBA, this trial was not included in the results . After the inhalation check valve was repaired, the four remaining runs had a maximum level of 0.27 % SEV CO_2 after 210 minutes. During exercise the PCO_2 occasionally spiked to 1.0 % SEV CO_2, and towards the later part of one test CO_2 levels of 1.5 % SEV CO_2 were seen sporadically and lasted for a maximum of 10 seconds. The maximum inhalation temperature seen with the HP Sodasorb was 39° C which occurred during exercise. Overall the divers had little difficulty with the EBA's breathing resistance. The divers reported that the inhalation gas temperature was uncomfortably warm but it did not cause them to stop work. Two divers used the EBA's purge valve occasionally during exercise; the other two divers did not use the purge. The gas temperature while the divers were at rest was approximately 33° C.

Only two trials were performed using LiOH as the carbon dioxide absorbant material because of high gas temperatures. One diver stopped exercise after 10 minutes reporting that he felt that the gas was searing his throat. His gas temperature was 38° C. The other diver completed the work cycle with temperatures of 43° C. However, 3 minutes into the work cycle he maintained a constant purge on the EBA. During exercise the CO_2 momentarily reached 0.48 % SEV but quickly returned to negligible levels. The inhalation gas temperature at rest varied between the two divers but was tolerable to breath.

The following table lists the final % CO_2 for the 120-minute trials.

LiOH	0.018 (0.48 % SEV)
	0.002 (0.05 % SEV)
HP Sodasorb	0.006 (0.16 % SEV)
	0.010 (0.27 % SEV)
	0.004 (0.12 % SEV)
	0.008 (0.21 % SEV)

The CO_2 level and inhalation gas temperature within the EBA versus time for all the trials are in figures 1 through 7.

IV. DISCUSSION

The MK 18 MOD 1 is an emergency breathing apparatus designed to support a tender retrieving a diver from the water. It was presumed by the sponsor that this evolution would take approximately 15 minutes. After recovery of the diver, it was expected that the tender would be at rest. Testing was performed to simulate this scenario.

Though the design specifications were to support a working tender having a VO_2 of 3.0 slpm, and a resting tender having a VO_2 of 0.75 slpm, the EBA was not tested to this specification. An oxygen consumption rate of 2.5 slpm was chosen to reflect the maximum amount of work expected to be seen while recovering a diver (1). This estimated work level is produced when cycling at 175 watts (2). The expected resting VO_2 is 0.35 slpm. The VO_2 can increase to 0.75 slpm if the diver was performing light work while standing (2). Though the testing did not evaluate the MK 18 to its design specifications, it was tested under realistic operational criteria.

To allow for more operational flexibility, two types of carbon dioxide absorbant materials were evaluated, LiOH and HP Sodasorb. However, after 2 trials with LiOH, no further testing was performed because of the high gas temperatures. Not only was the temperature excessive but the divers were continually purging the EBA. Hence, it's doubtful that the diver could perform any useful work. The divers using the EBA with HP Sodasorb stated that the gas was hot but did not limit their ability to work. At rest both absorbent materials produced similar inhalation gas temperatures that were within a tolerable breathing range.

There is little subject variation of the VO_2 and VCO_2 when at rest (3,4). With the tender at rest 93% of the time during these tests, only 4 runs with HP Sodasorb were necessary to establish that the EBA met the realistic performance criteria at 844 FSW.

The divers did not find the EBA any more difficult to use than the standard BIBS mask.

V. CONCLUSION

A. The MK 18 MOD 1 EBA realistically meets the design performance criteria using HP Sodasorb at a temperature of 28° C at a depth of 844 FSW. The inhalation gas temperature during exercise is marginally acceptable. At rest both CO_2 absorbent materials heated the gas temperature to tolerable levels.

B. The use of LiOH within the EBA produces excessively high inhalation gas temperatures which restricts the diver's ability to work.

C. The EBA is a suitable replacement for an open-circuit BIBS mask where gas supplies are limited.

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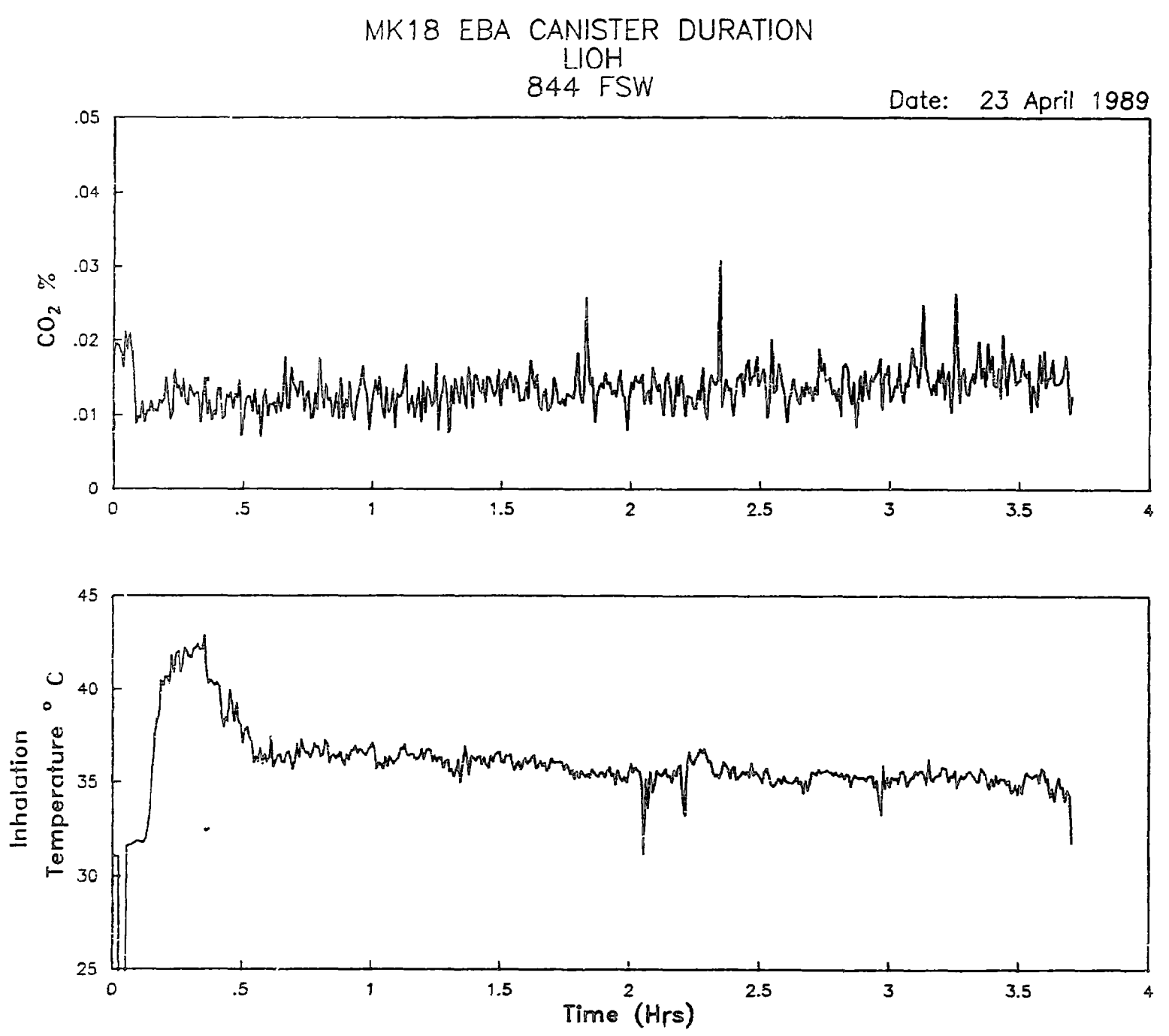

MK18 EBA CANISTER DURATION
LIOH
844 FSW
Date: 23 April 1989
CO_2 %
.05
.04
.03
.02
.01
0
0
.5
1
1.5
2
2.5
3
3.5
4
Inhalation Temperature ° C
45
40
35
30
25
0
.5
1
1.5
2
2.5
3
3.5
4
Time (Hrs)

Figure 1.

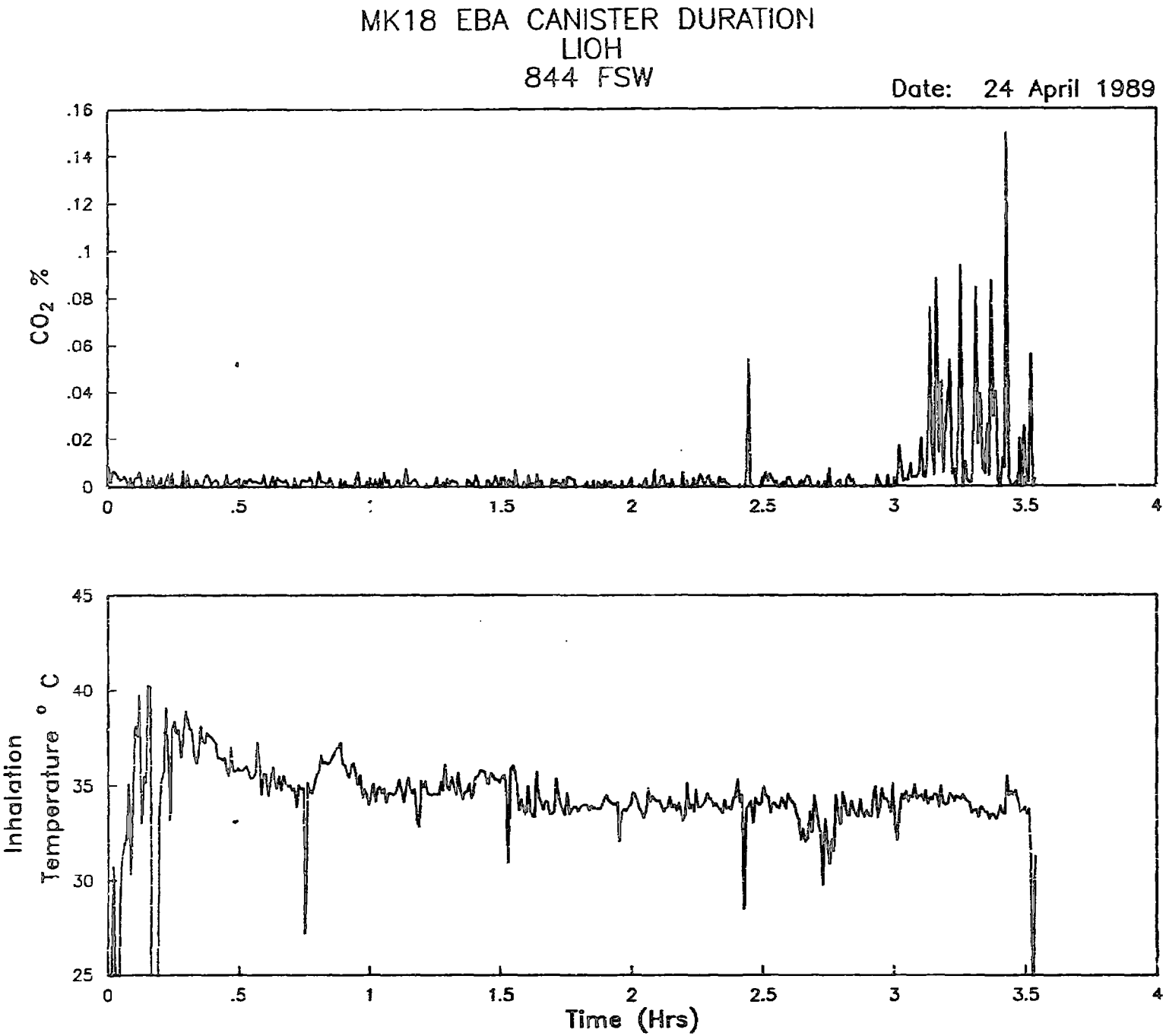

MK18 EBA CANISTER DURATION
LIOH
844 FSW
Date: 24 April 1989
CO_2 %
.16
.14
.12
.1
.08
.06
.04
.02
0
0
.5
1
1.5
2
2.5
3
3.5
4
Inhalation Temperature ° C
45
40
35
30
25
0
.5
1
1.5
2
2.5
3
3.5
4
Time (Hrs)

Figure 2.

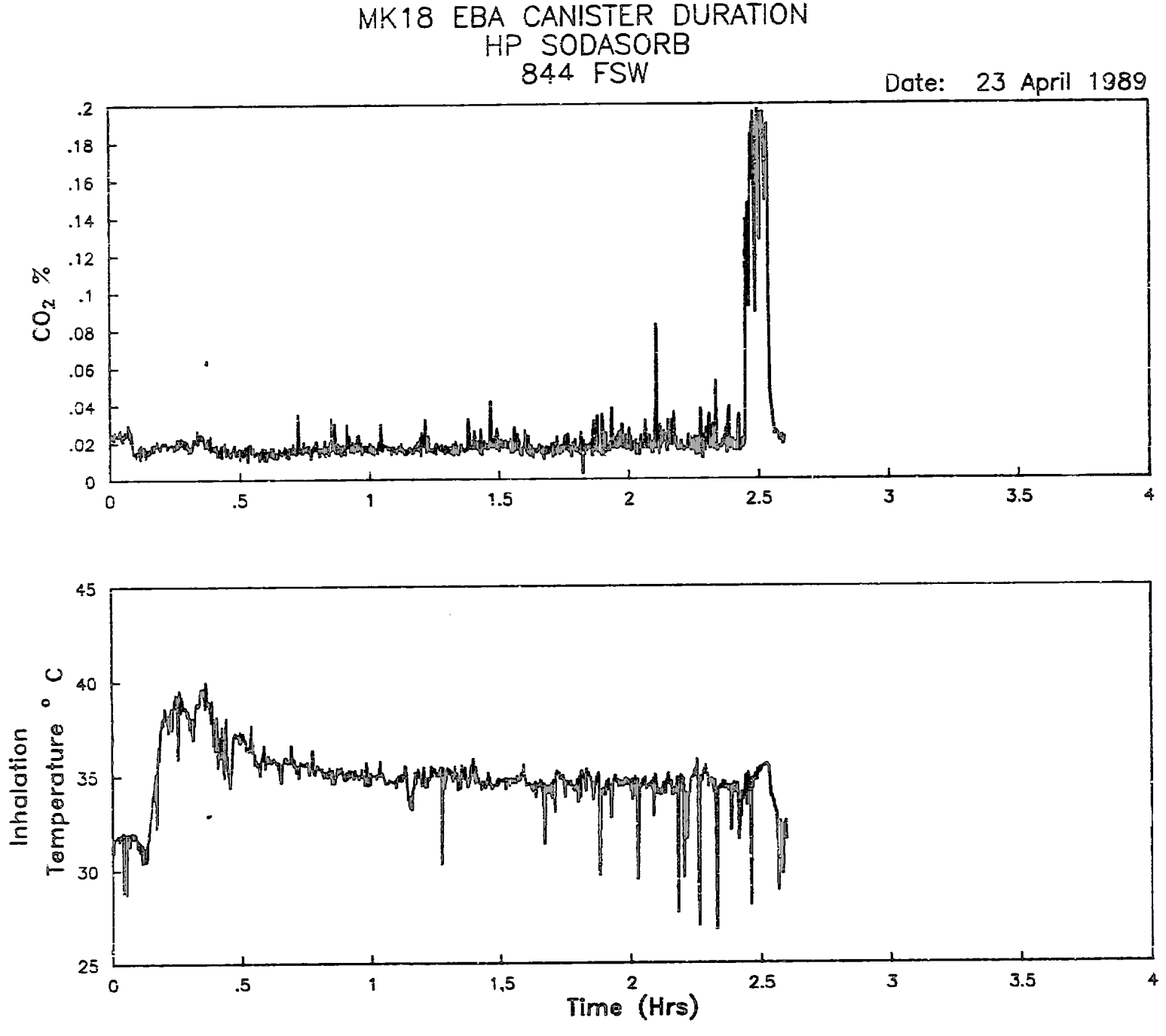

MK18 EBA CANISTER DURATION
HP SODASORB
844 FSW
Date: 23 April 1989
CO_2 %
.2
.18
.16
.14
.12
.1
.08
.06
.04
.02
0
0
.5
1
1.5
2
2.5
3
3.5
4
Inhalation Temperature ° C
45
40
35
30
25
0
.5
1
1,5
2
2.5
3
3.5
4
Time (Hrs)

Figure 3.

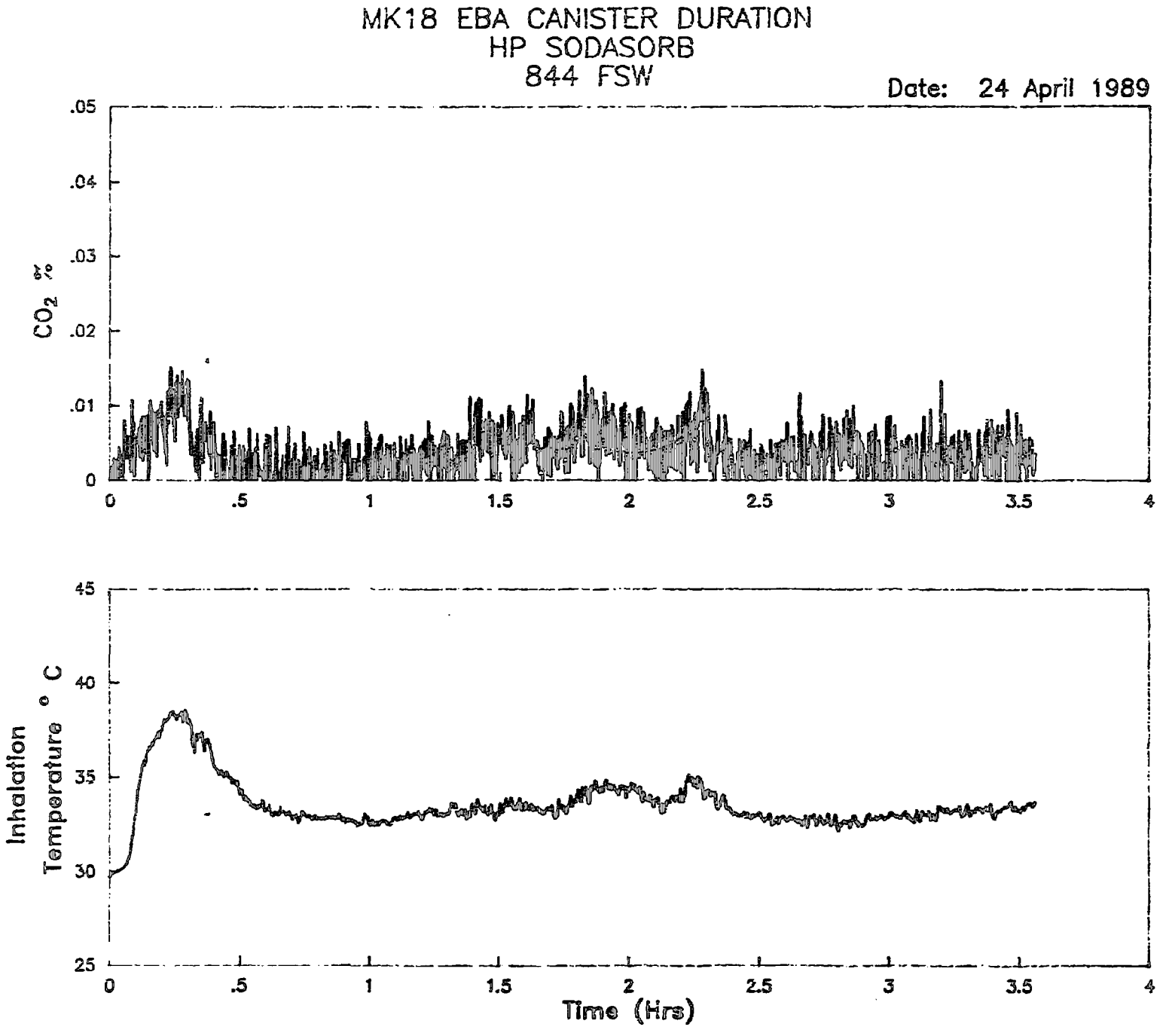

MK18 EBA CANISTER DURATION
HP SODASORB
844 FSW
Date: 24 April 1989
CO_2 %
.05
.04
.03
.02
.01
0
0
.5
1
1.5
2
2.5
3
3.5
4
Inhalation Temperature ° C
45
40
35
30
25
Time (Hrs)

Figure 4.

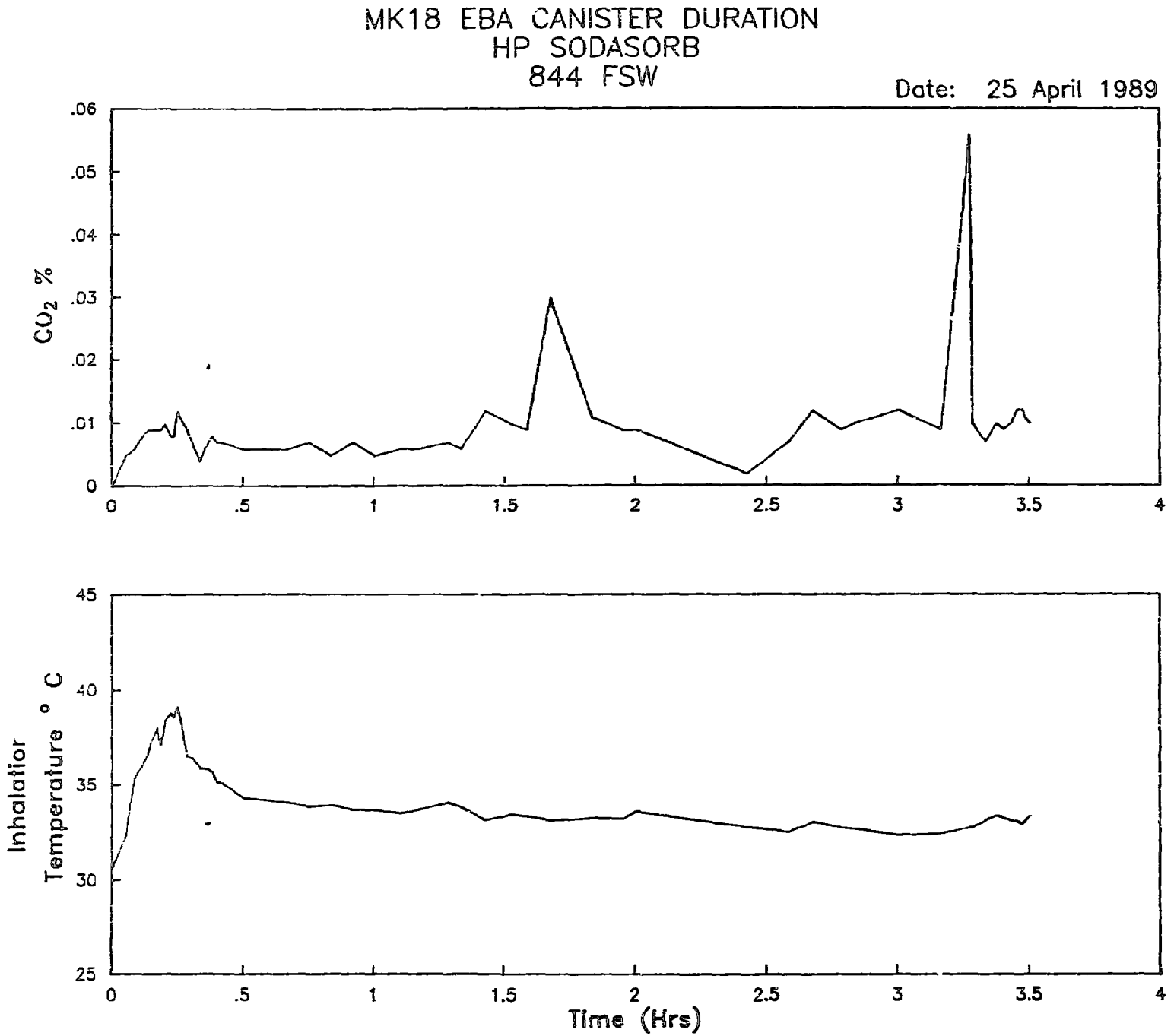

MK18 EBA CANISTER DURATION
HP SODASORB
844 FSW
Date: 25 April 1989
CO_2 %
.06
.05
.04
.03
.02
.01
0
0
.5
1
1.5
2
2.5
3
3.5
4
Inhalation Temperature ° C
45
40
35
30
25
Time (Hrs)

Figure 5.

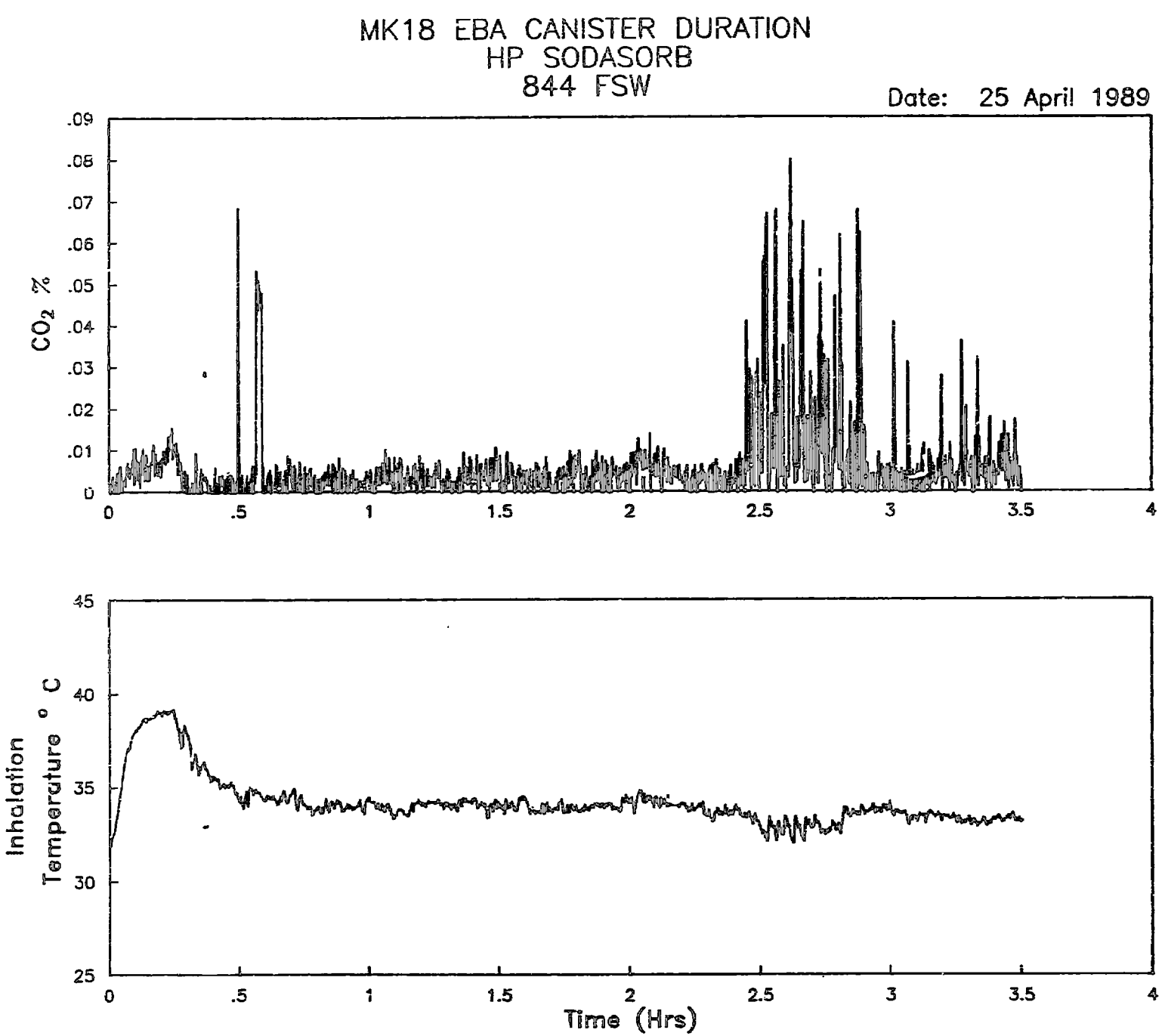
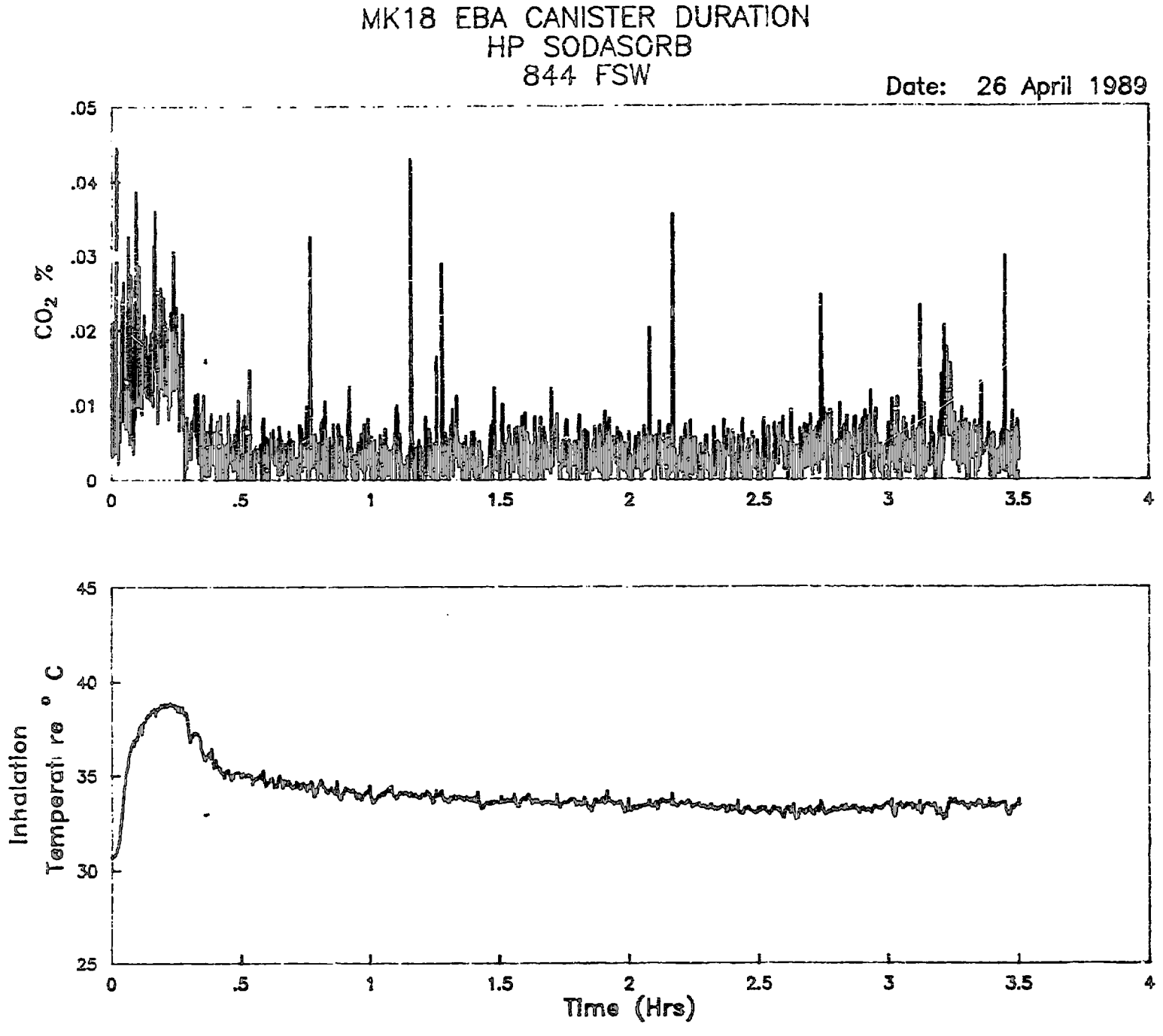

MK18 EBA CANISTER DURATION
HP SODASORB
844 FSW
Date: 25 April 1989
CO_2 %
.09
.08
.07
.06
.05
.04
.03
.02
.01
0
0
.5
1
1.5
2
2.5
3
3.5
4
Inhalation Temperature ° C
45
40
35
30
25
0
.5
1
1.5
2
2.5
3
3.5
4
Time (Hrs)

Figure 6.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HP SODASORB
844 FSW
Date: 26 April 1989
CO_2 %
.05
.04
.03
.02
.01
0
0
.5
1
1.5
2
2.5
3
3.5
4
Inhalation
Temperature ° C
45
40
35
30
25
Time (Hrs)

Figure 7.