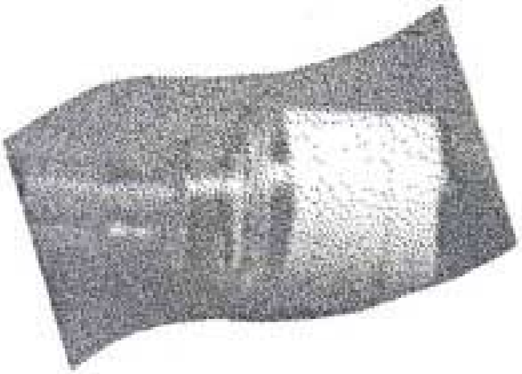
The service life of respirator cartridges



ÉTUDES ET RECHERCHES

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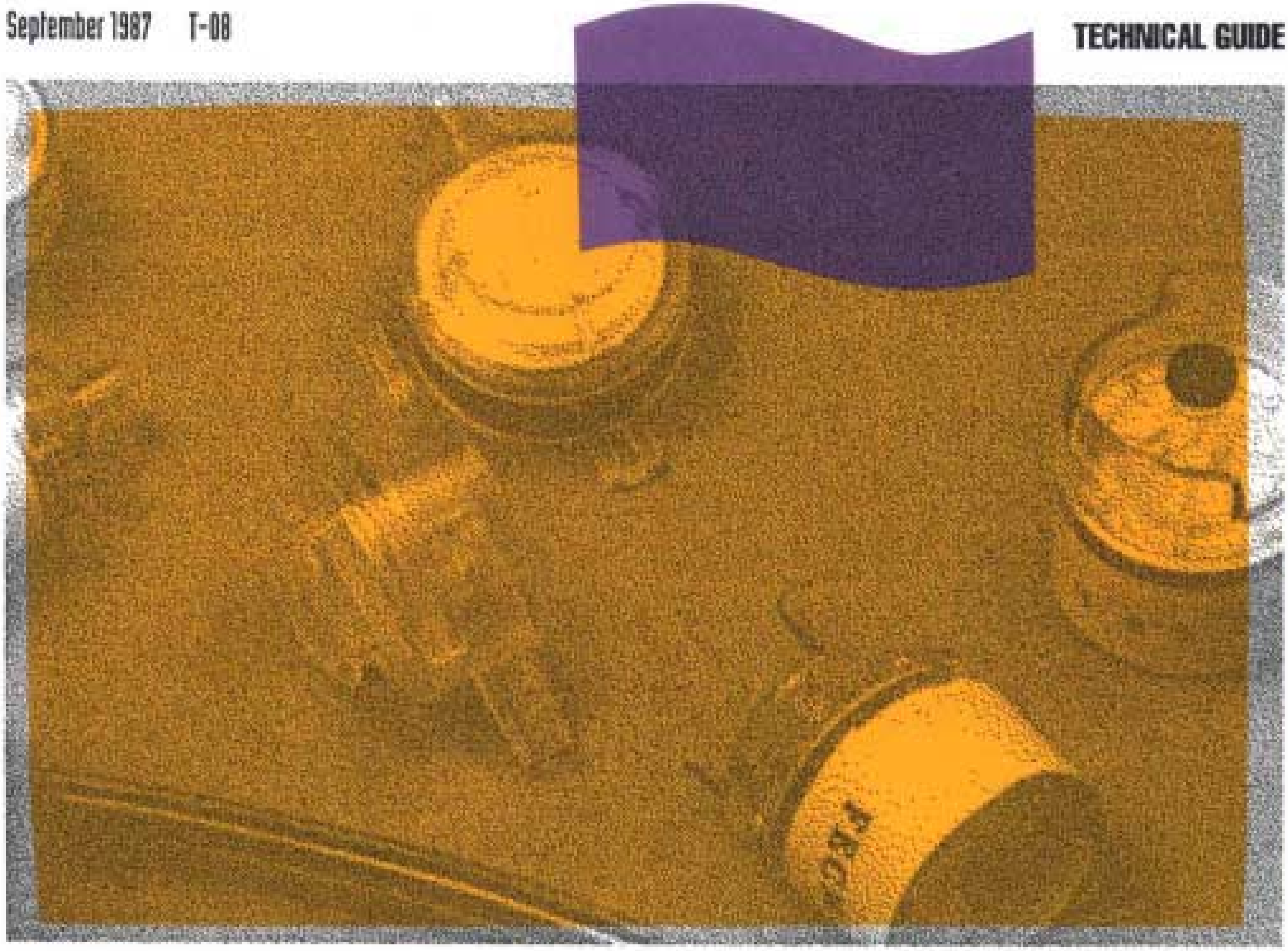
TECHNICAL GUIDE



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The service life of respirator cartridges

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INTRODUCTION

Workers using air-purifying respirators feel that the coloured sticker (table 1) on the cartridge, reading for example, "Permissible chemical cartridge for organic vapors..." from MSHA/NIOSH is a guarantee of good protection against toxic organic vapours. In reality this is not entirely true.

Users of air-purifying respirators must take two factors into account in addition to the limits for using cartridges (see below), in order to obtain good respiratory protection. The first is a good fit of the respiratory device to the user's face and the other is the service life of the cartridge.

The facepiece fit is extremely important because the contaminated air must pass through the cartridge to allow the sorbent (a granular porous material, generally activated charcoal) to catch the pollutant.

Limitations in the use of air-purifying respirators

Air purifying respirators are not recommended in the following cases:

-oxygen deficient atmospheres (lower than 19.5% oxygen in the air);
-in atmospheres immediately dangerous to life or health (IDLH);
-in cases where the pollutant concentration is unknown;
-if the level of the pollutant concentration exceeds the limits specified on the cartridge by the manufacturer (i.e., 1 000 ppm in the case of organic vapours).

For others details see reference 1.

Table 1. Colour code for the chemical cartridges (ANSI K 13.1-1967)*

Contaminant	**Colour**
Organic vapours	black
Organic vapours/ acid gases	yellow
Acid gases	white
Ammonia gas	green

* For more details see reference 1.

If the facepiece does not fit the wearer, contaminated air can leak inside mask. In this case, the efficiency of protection of the air-purifying device diminishes dramatically. Qualitative and quantitative tests exist that allow the detection of leaks and ensure that the respirator fits properly (ref. 1 to 3).

Regarding cartridge performance evaluation, MSHA/NIOSH uses CCl_4 (carbon tetrachloride) as a reference for testing organic vapours. In order to be approved, the organic vapour cartridges must keep the exit concentration of CCl_4 below 5 ppm for 50 minutes. This test is performed at an air flow rate of 64 L/min for the " as received" cartridges, at 50± 5% relative humidity, 25°C, and 1 000 ppm of CCl_4. This method to approve organic vapour cartridges does not represent real "in the field" situations. The kind of pollutant and air humidity affect the retention efficiency of cartridges. In fact, in a Nelson and Harder study (ref. 4), cartridges were tested against 121 different organic vapours and gases. Of these, 51 produced shorter service lives than CCl_4.

In the field, workers use pollutant odour or irritation as detectors of cartridge saturation as recommended by manufacturers ("when wearers detect any taste, odor or irritation, leave the contamination area and change the cartridge..."). This is poor practice because the olfactory sense is different in each individual. Habituation or olfactory fatigue phenomena can also affect the capacity to detect the pollutant. In addition, the odour threshold of some pollutants is higher than its threshold limit value (TLV) for example: Vinyl Chloride.

For these reasons, the IRSST* has been working for the last two years to develop methods to evaluate the service life of chemical cartridges. An experimental device has been developed that simulates real situations such as different respiratory flows, pollutant concentrations, humidity and temperature.

2. THE IRSST STUDY

The principal goal of this study was to develop a simple and reliable tool to evaluate the service life of chemical cartridges. To perform the test, a completely automated test apparatus was built.

A representation of this test apparatus is shown in Figure 1. It consist of four units, labeled A to D.

Unit A represents the pollutant-generation and the exposure-chamber system. Component 1 represents the air flow, humidity and temperature control system. The pollutant-injection system (2) consist of a motor-controlled syringe, and the exposure-chamber (3), is where the cartridges are exposed to the contaminated air. (Numbers in parentheses refer to system components.)

Unit B represents the respiratory system that allows the cartridges to be tested at constant air flow (4), or cyclic flow (5), to simulate human respiration, using inspiration flows.

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* Quebec Institute for Research in Occupational Health and Safety

Unit C represents the detection system, which consists of a gas chromatograph with an FID detector (6), and a sample-selecting device (7). This system allows samples to be obtained either from the air passing through the cartridges or from the exposure chamber. Finally, unit D is the controller and the data acquisition system composed of a Hewlett Packard HP 3390 integrator (8), an IBM PC computer (9), and a sample selector controller (10).

Cartridge service life evaluation

The test respiratory apparatus was used to evaluate the service life of four chemical cartridges: two organic vapour cartridges (Wilson R-21 and Scott 642- OV), and two organic vapour/acid gas cartridges (Wilson R-25 and Scott 642-OA). The organic vapours were methylene chloride, trichloroethane, hexane and toluene.

The results presented in this article correspond to evaluations of cartridges mainly at organic vapour concentrations of 500 and 1 000 ppm at 30 % relative humidity, 25°C, and a respiratory flow of 36 L/min. This flow corresponds to an average respiratory flow of a worker carrying out moderate or heavy work.

Figures 2a and 2b show typical examples of the results obtained with the experimental device. Figure 2a shows the percentage of pollutant passing through the cartridge relative to the exposure concentration (breakthrough percentage) as a function of time (min) for the Scott 642-OV organic vapour cartridge exposed to 500 or 1 000 ppm of 1,1,1 - trichloroethane (TCE). TCE is regularly used as a degreasing agent.

This type of plot directly represents the behaviour of a chemical cartridge as a function of time when it is exposed to contaminated air. Initially, no organic vapour passing through the cartridge is detected. As soon as the first traces of TCE are detected, the pollutant-retention efficiency of the cartridge diminishes rapidly. For example, at 1 000 ppm of TCE*, 160 minutes were required to detect the first traces of the organic vapour, and then about 30 minutes were required to go from 10% to 80% breakthrough. For this reason, it is not recommended that cartridges be used at the limits of retention capacity. In our studies on the evaluation of cartridge service life, we consider that for most organic solvents, a 10% breakthrough is safe.

Figure 2b shows the breakthrough time as a function of the concentration of organic vapour at 10% breakthrough. This curve was obtained by testing the cartridges at 10% breakthrough at several TCE concentrations between 250 and 1 000 ppm.

This curve can be represented by a simple equation:

$$Tc\ (10\%) = A \times C^b$$

where Tc (10%) is the breakthrough time at 10% breakthrough;
A and b are constants for a cartridge-solvent pair;
C is the organic vapour concentration in ppm.

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* For TCE, the TLV-TWA is 350 ppm .

The constant values for the tested cartridges and solvents are presented in Table 2. With the equation and the constant values given in the table, graphs similar to Figure 2b can be obtained.- Other examples of this graphical representation are given in Figures 3 to 5. These figures represent the service life at 10% breakthrough of the Scott 642-OV cartridge with methylene chloride, hexane and toluene respectively. Hygienists and/or air-purifying respirator users may thus evaluate the service life of cartridges by calculation using the equation, or graphically.

<u>One example of how to use this information</u>:

The average concentration of methylene chloride in a stripping department is 750 ppm. The workers use an air-purifying respirator with Scott 642-OV cartridges. The constant for the pollutant-cartridge pair is given in Table 2. The service life at 10% breakthrough for this cartridge can be calculated using the equation:

$$Tc\ (10\%) = A \times 750^{b}$$

The calculated service life is 133 minutes, and to ensure a good protection, this time should not be exceeded. A similar result can be obtained directly from Figure 3.

Advantages and limitations of the methods

The results presented in this article are limited to simple pollutants. For complex atmospheres (two or more pollutants) these values are not useful, and experiments for specific cases must be performed. The test respiratory system developed at the IRSST allows any "in the field " atmosphere to be reproduced for gases or vapours.

For simple pollutants (or when one pollutant is at a very high concentration), the method has proven useful. An example of validation of the method in the industrial milieu is shown in Figure 6. In this case, the service life of Scott 642-OV cartridges was evaluated in a paint shop during an airplane-stripping operation. The paint stripper is composed of 70% methylene chloride (TLV-TWA= 100 ppm). The result is compared with the service life evaluation for this cartridge in our laboratory using pure methylene chloride.

In the Figure 6, the dotted lines correspond to the methylene chloride concentration in the working area, and the solid lines correspond to the methylene chloride concentration passing through the cartridge. The concentration peaks labeled A, B and C in this figure correspond to the three applications of the stripper on the airplane surface. The average pollutant concentration for a working period of 5 hours 30 min. was 220 ppm. The calculated service life for 10% breakthrough (22 ppm) is 4h 30 min. The experimental evaluation of the chemical cartridge gave 20% breakthrough (44 ppm) after 4h 30 min. This result is excellent since the service life of the cartridge in the paint shop compares well with our laboratory test. It is known that methanol (10% of the paint stripper) affects the service life of cartridges and can explain the observed difference (ref. 4).

This research is continuing at the IRSST. The results will provide the air-purifying respirator user or hygienist with the necessary information for making decisions regarding chemical cartridge service life.

Table 2

CONSTANT VALUES AT 10% BREAKTHROUGH FOR THE TESTED CARTRIDGES

SOLVENT	**CARTRIDGE**	**$-b \times 10$**	**$A \times 10^{-4}$**
Methylene chloride	642-0A	6.57	0.97
Methylene chloride	R-25	5.20	0.36
Methylene chloride	642-0V	6.02	0.72
Methylene chloride	R-21	4.93	0.34
Hexane	642-0A	9.87	14.77
Hexane	R-25	10.40	18.83
Hexane	642-0V	10.05	16.50
Hexane	R-21	11.33	41.53
Toluene	642-0A	10.35	31.37
Toluene	R-25	7.98	6.28
Toluene	642-0V	9.75	19.41
Toluene	R-21	10.24	28.30
Trichloroethane	642-0A	10.84	34.28
Trichloroethane	R-25	6.86	2.16
Trichloroethane	642-0V	8.57	9.70
Trichloroethane	R-21	9.58	13.21

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FIGURE CAPTIONS

Figure 1: Cartridge test system.

Figure 2: Service life curves for 1,1,1-trichloroethane;

a) Breakthrough percentage as a function of time at 500 and 1 000 ppm of 1,1,1-trichloroethane;

b) Breakthrough time as a function of concentration of 1,1,1-trichloroethane for 10% breakthrough.

Figure 3: Breakthrough time as a function of methylene chloride concentration at 10% breakthrough.

Figure 4: Breakthrough time as a function of toluene concentration at 10% breakthrough.

Figure 5: Breakthrough time as a function of hexane concentration at 10% breakthrough.

Figure 6: Service life evaluation of 642-OV chemical cartridges exposed to paint stripper vapours in a paint shop. See text for details.

Figure 1

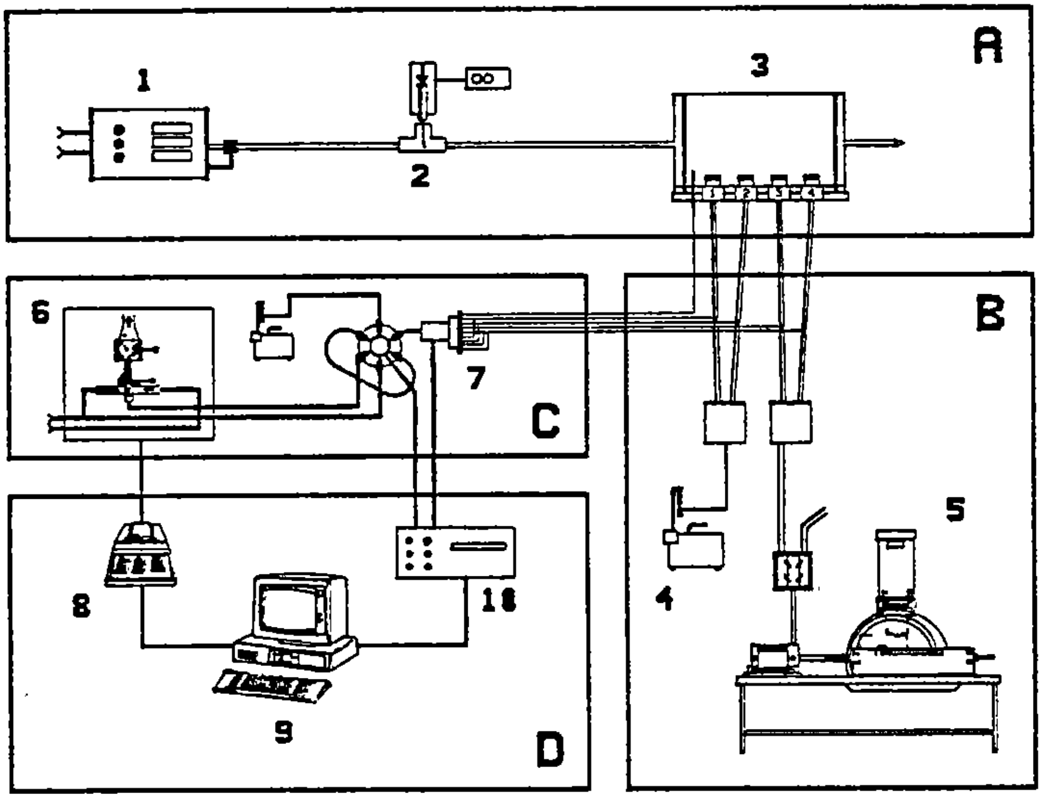
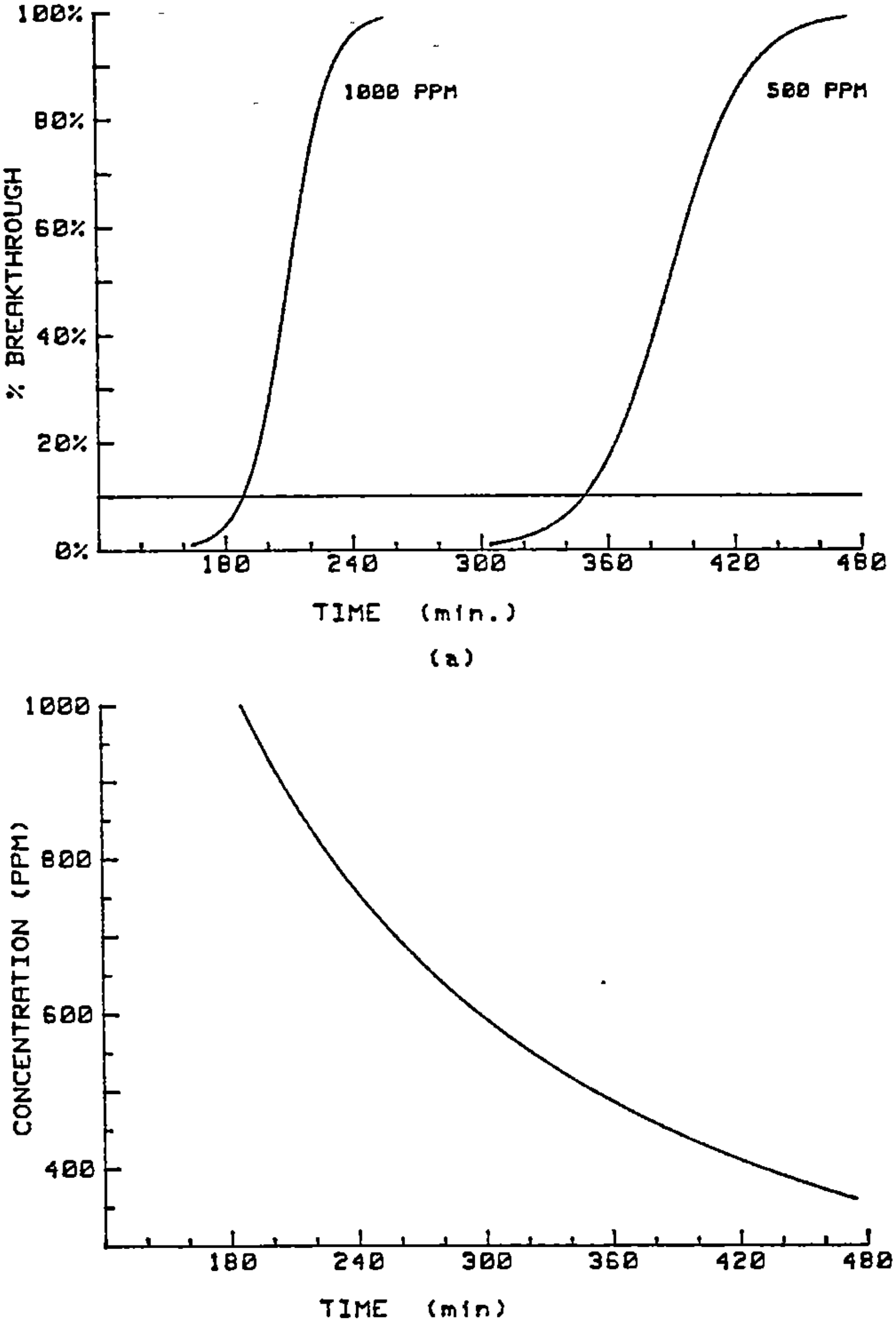


Figure 2

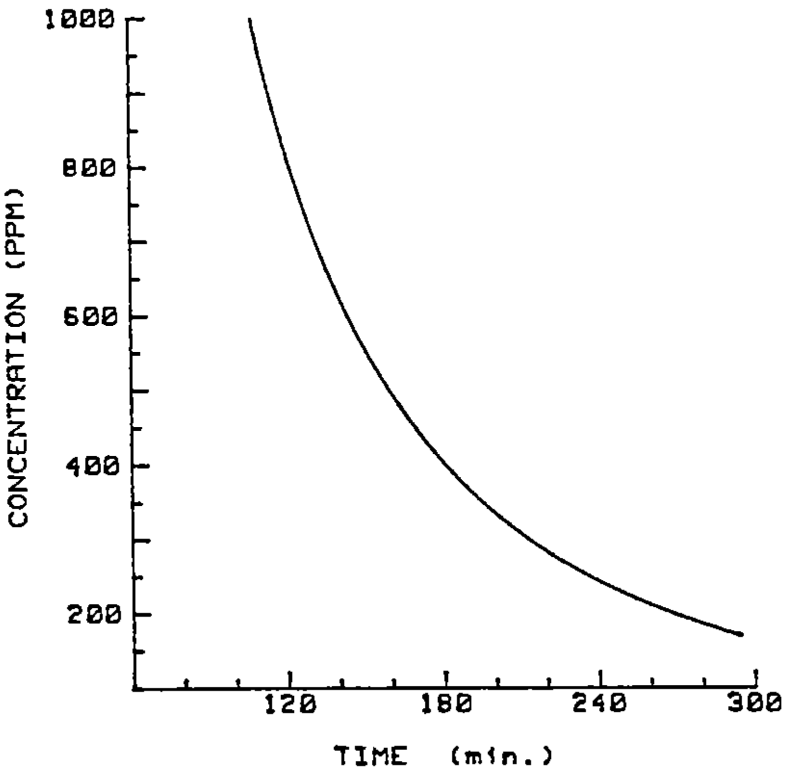


100%
80%
60%
40%
20%
0%
% BREAKTHROUGH
1000 PPM
500 PPM
180
240
300
360
420
480
TIME (min.)
1000
800
600
400
CONCENTRATION (PPM)
180
240
300
360
420
480
TIME (min)

(a)

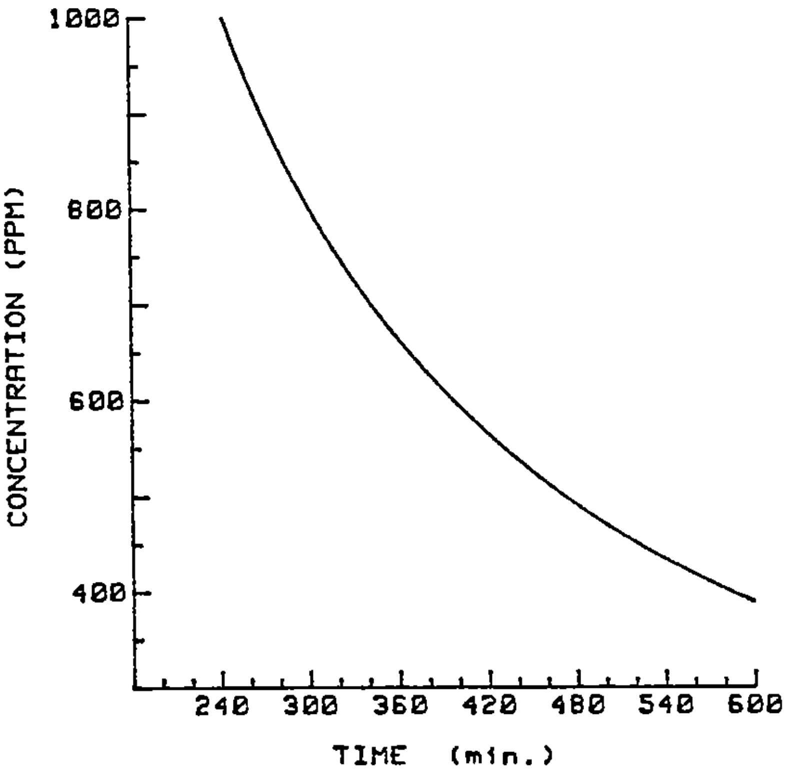
(b)

Figure 3



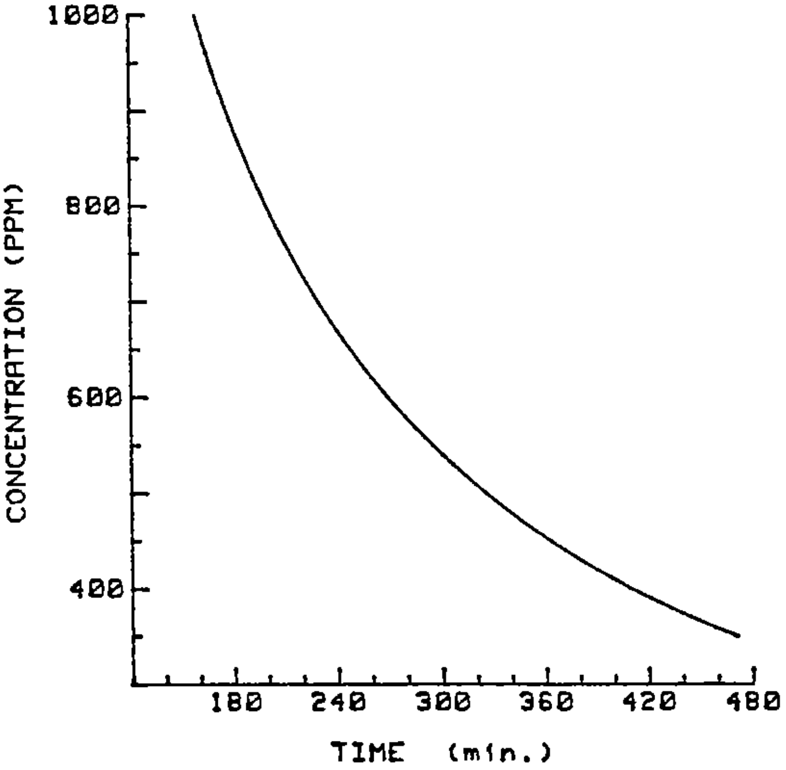
1000
800
600
400
200
CONCENTRATION (PPM)
120
180
240
300
TIME (min.)

Figure 4

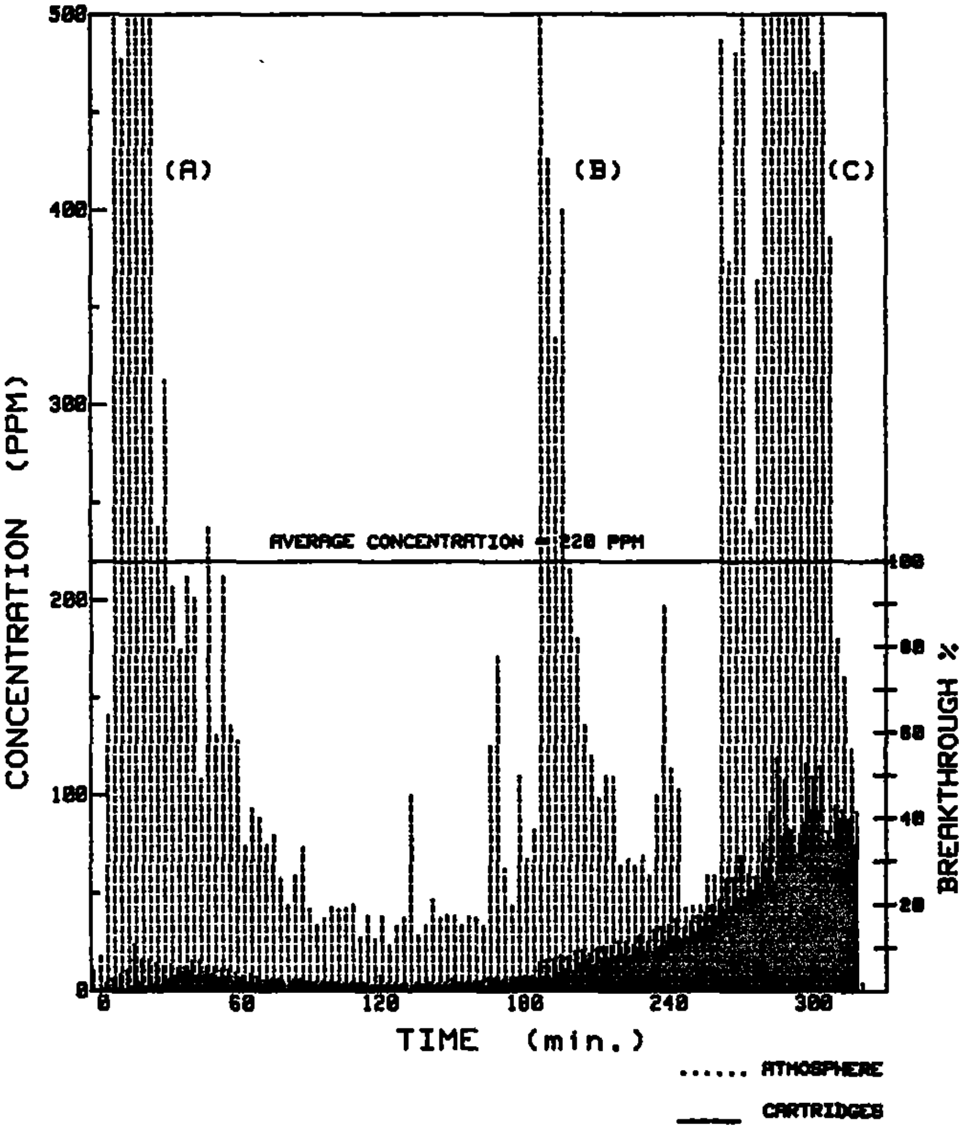


1000
800
600
400
CONCENTRATION (PPM)
240
300
360
420
480
540
600
TIME (min.)

Figure 5



1000
800
600
400
CONCENTRATION (PPM)
180
240
300
360
420
480
TIME (min.)



500
400
300
200
100
0
CONCENTRATION (PPM)
(A)
(B)
(C)
AVERAGE CONCENTRATION = 220 PPM
100
80
60
40
20
BREAKTHROUGH %
0
60
120
180
240
300
TIME (min.)
...... ATMOSPHERE
____ CARTRIDGES