ABSTRACT

DAVID SEDGWICK DAVIS. Non-Toxic Particulate Masks: A Quantitative Evaluation of Their Effectiveness During Paint Spraying Operations.

It is commonly known that disposable dust masks offer a worker no protection from solvent vapors. However, they are frequently utilized during paint spraying operations. In one instance a workman wearing a disposable mask died from xylene poisoning while spray painting a boat outdoors. This study examined the possibility that the constant wetting of a dust mask during paint spraying may create an elevated solvent concentration in the breathing zone of a worker.

Tests were conducted in a controlled laboratory system that determined simultaneous xylene concentrations in a mask and in the surrounding ambient air immediately following a paint spray of varying duration. Results consistently indicated a remarkably higher concentration inside the mask for the initial two minutes following the spray of paint. The theoretical dose was as much as 86% greater inside the mask as compared to outside the mask during those two minutes.

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I. INTRODUCTION

In industrial and other occupational environments, regulatory agencies and health professionals frequently stress the importance of proper respiratory protection to reduce an employee's exposure to various air contaminants. Unfortunately, this attitude is not prevalent throughout all of the occupational community. Many individuals do not seek the advice of a health professional regarding respiratory protection and therefore remain ignorant of proper respirator selection and use.

The National Institute for Occupational Safety and Health has gone to great lengths to test and approve a multitude of respiratory protective devices and recommends specific respirators when exposed to specific substances.(7) For example, it is recommended that respirators equipped with activated charcoal filters be used for protection against organic vapors.

Extensive studies have also been conducted that reveal the effectiveness of various respirators during a specific industrial process. A report by the National Institute for Occupational Safety and Health evaluated the performance of respirators used in industrial paint spraying operations throughout the United States.(13) It was concluded that there is widespread misuse of respirators during such operations. In particular, the authors cited a high prevalence of

unapproved dust masks being used for solvent and particulate protection.

In the case of a small boat repair and servicing company in New York, the consequence of improper respirator selection during paint spraying was catastrophic. On March 26, 1981 an employee of this company was spray painting the bottom of a 24 foot sailboat. This particular man was 39 years old, 6 feet 1 inch tall, 220 pounds, and in good health. He was working outside in 60 degree weather and there was a breeze out of the south at 7 to 10 knots.(11)

The employee was using a spray gun to apply a 1 to 1 mixture of marine paint and thinner. The thinner contained 53.3% xylene by weight. In order to prevent the inhalation of paint particulates, the employee wore a 3-M Corporation Non-Toxic Particulate Mask.(11)

After spraying for approximately 30 to 45 minutes, the man fell unconscious. Fifteen minutes later, the victim was discovered by fellow employees. Mouth-to-mouth resuscitation was immediately administered by a nurse who was on the premises. Despite the heroic efforts of the nurse and paramedics, the victim was dead on arrival at the hospital.

Autopsy indicated acute pulmonary edema as the actual cause of death. Subsequent gas chromotographic analysis revealed traces of xylene in the blood, lungs and brain. According to the medical examiner, these results indicate that xylene was the cause of pulmonary edema in the employee. The nurse who attempted to revive the victim reported a strong chemical odor during her mouth-to-mouth resuscitation

efforts.(11)

It is evident that the use of a non-toxic particulate mask during the spraying of a solvent based paint was inappropriate. Although approved respirators should be properly labeled as to appropriate usage and special precautions, an individual worker may fail to heed such instructions. Also, as pointed out in the study by Toney and Barnhart (13), the average respirator user is likely to choose the respirator that is readily obtainable and least expensive rather than an approved respirator that may be more difficult to obtain and more expensive. In addition, some people may be unaware of the hazardous nature of the substance to which they are being exposed. Furthermore, precautionary instructions on labels of paint cans may be ambiguous and confusing to the layman. The warning on the the paint can of the variety used during the accident described above reads:

> "When product is used in confined areas or applied by spraying, wear a respirator jointly approved by the Mining Enforcement and Safety Administration and by the National Institute for Occupational Safety and Health under the provisions of 30 CFR 11"

Some owners of small businesses or home owners may not have access to the Code of Federal Regulations and may ignore such a warning.

Because paint spraying is a common occurance during industrial operations and at home and because there is a likelihood that workers may select improper respiratory protective devices, there is a possibility that another situation could occur similar to the case mentioned above.

Therefore, it is important that an attempt be made to quantify the degree by which an inappropriate respirator may contribute to solvent overexposure during paint spraying operations.

II. BIOLOGICAL EFFECTS OF XYLENE EXPOSURE

A wide variety of solvents are used as diluents in the manufacture of paints and in the application of the paints by spraying techniques to control the viscosity and flow characteristics of the protective coating.(9) In the case described above, however, xylene was the only solvent used. Therefore, a brief overview of the biological effects due to xylene exposure is given below.

Xylene is an aromatic hydrocarbon comprised of ortho, meta, and para isomers. It resembles benzene in many physical and chemical properties, but does not produce the chronic blood diseases characteristic of benzene absorption.(9,1,8)

All organic solvents affect the central nervous system to some extent because they act as depressants and anesthetics.(2) Xylene in particular will create a severe narcotic effect at concentrations above 200 ppm.(9,8) Additionally, xylene can be irritating to the eyes, nose and throat at a similar concentration.(1) Based on this later effect, the American Conference of Governmental Industrial Hygienists have set the Threshold Limit Value for xylene at 100 ppm.(12)

Goldie(5) described the symptoms of 8 workmen who were painting the interior of an unventilated tower with a paint that consisted of 80% xylene. All 8 men experienced headache, vertigo, gastric discomfort, dryness of the throat, and a

slight narcotic effect. One of the workers suffered an epileptiform seizure after cycling home from work.

In another instance Glass(4) reported a man exposed to a solvent containing 75% xylene over a period of 2 months. After work one day the man experienced an acute episode of vomiting and giddiness. For the following week his appetite was poor. Air samples revealed that xylene concentrations in the air at the patients workplace were as high as 270 to 350 ppm.

Extreme concentrations of xylene can lead to unconsciousness, pulmonary edema, and possibly death.(3) Such was the case in an incident reported by Morley.(6) Three workmen were painting the interior of a tank in a ship's engine room with a paint that consisted of 34% xylene by weight. With the exception of a small fan, the tank was unventilated. All three men were found unconscious 18.5 hours after entering the tank. One worker was pronounced dead on arrival at the hospital. Autopsy revealed congestion of the liver, alveolar hemorrhage, and pulmonary edema. The other two workers regained consciousness and eventually recovered but both experienced temporary amnesia regarding the accident. It was estimated that the concentration within the tank was approximatily 10,000 ppm.

Pulmonary edema is an acute response to xylene exposure that is typical of organic solvents in general.(3) Because xylene is sufficiently volatile and water soluble, it can be readily inhaled into the alveolar regions of the lung. It is believed that subsequent covalent binding is a result of the

production of oxygenated intermediaries. The covalent binding may be the mechanism that produces pulmonary edema through cellular necrosis.(3) Concrete dose-response relationships between xylene exposure and onset of pulmonary edema have not been established .(3) Depth of respiration and minute volume have an influence upon the dose received by the lung and vary from individual to individual. Varying working conditions may produce different breathing patterns and, therefore, different solvent exposures. For instance, an individual doing heavy work is more likely to breathe through the mouth which reduces the protection afforded by the upper respiratory tract and increases toxicity. He also will require up to 3 liters of oxygen per minute compared to 0.7 liters per minute for a sedentary individual. This oxygen requirement translates into an approximate minute volume of 40 liters of air per minute for heavy work compared to 7 liters of air per minute required for an individual at rest.(10,2,8) Also, other factors such as age and cigarette smoking contribute to the difficulty of pinpointing a specific dose-response relationship.(3)

Xylene, therefore, can produce severe narcotic effects at concentrations above 200 ppm which may lead to symptoms such as headache, vertigo, gastric discomfort, vomiting and giddiness while at higher concentrations may result in loss of consciousness, pulmonary edema, and death.

III. OBJECTIVES

In the case of the spray painter cited above, the role played by the use of an inappropriate respirator must be questioned. Since the operation was conducted outside and with an appreciable breeze (7-10 knots) it is difficult to imagine that ambient concentrations of xylene could have reached significant levels. It is conceivable , however, that the disposable respirator used could have provided a local point source of xylene vapor that exceeded permissable levels. The NIOSH study by Toney and Barnhart (13) did not include testing of disposable particle masks because of test equipment limitations and also because "the respirator provides protection only against particulate contamination protection and not against vapor exposure". They did not consider the possibility that the masks may cause a higher exposure than if no mask was worn at all.

The purpose of this study, therefore, was to determine if such a condition could occur and if so under what conditions and to what extent. It was therefore necessary to:

1. Simulate the conditions of spray painting in a controlled situation.

2. Simultaneously measure the concentration of xylene inside the mask and in the ambient air.

3. Estimate the dose of xylene vapor that might be delivered to a worker wearing such a mask.

In order to test this hypothesis, a laboratory test system was designed that would simulate conditions during a typical paint spraying operation.

IV. EQUIPMENT AND MATERIALS

A. Test Chamber

To maintain a controlled atmosphere, all tests were performed in a 119.5 cm x 153.5 cm x 58.5 cm plexiglass chamber (approximately 1 cubic meter or 37 cubic feet). The chamber was connected to a ventilation system that exhausted air out one end of the enclosure through a 4 inch duct while make-up air entered through a 4 inch opening in the center of the top (see Figure 2). Both of these openings could be closed as necessary. A traverse of the exhaust duct with an Alnor Thermo-Anemometer indicated an exhaust air flow of 31 cfm. This provided approximately one air exchange per minute in the chamber.

A 45 cm x 60 cm piece of particle board was suspended directly in the center of the chamber parallel to the side walls and approximately 29 cm from each (see Figure 2). This board served as the target upon which the spray paint aerosol was directed. Two sampling ports spaced approximately 20 cm apart were located directly opposite the board. One port was designated as the sampling port for the chamber concentration while the other was used to determine the concentration inside the dust mask.

The mask was positioned on the inside wall of the chamber directly over one of the ports and its outside edge sealed to the chamber wall by a plexiglass bracket (see Figure 3). By

loosening the eight bolts, the masks could easily be removed or inserted for each test.

Approximately 20 cm below the sampling ports was a 6 cm circular opening in the side of the chamber. Through this hole, the paint was sprayed into the chamber. This port could also be sealed with a rubber stopper.

B. Particulate Masks

Four different brands of non-toxic particulate masks were tested. Each mask was a disposable fiber mask equiped with a single rubber head strap and an aluminum nose clip to custom fit the mask to an individual's face. All of the masks were unapproved and were designated for use only with non-toxic dusts. None of the masks contained any sort of media capable of adsorbing organic vapor. All four masks were virtually identical in appearance and construction. The masks tested were:

1. 3-M Corporation Non-Toxic Particlate Mask #8500
2. Gerson Dust Mask #2501N
3. Norton Dust Mask #65076-2
4. Willson Dust Mask #CP-1000C

B. Paint and Paint Thinner

The paints used in this study were marine paints commonly used for the "bottom painting" of boats. Table I lists the ingredients which were identical with the exception of the pigments.(11)

TABLE I

INGREDIENTS STATEMENT OF PETTIT 1290 SUPERSLICK BLUE [1]

Ingredient	Percent
cuprous oxide	40.0
cuprous oxide inerts	21.1
molybdenum disulfide	15.0
phalocyanine blue	1.3
titanium dioxide	8.2
epoxy acrylic ester	5.4
rosin	6.6
xylene	21.4

TABLE II

INGREDIENTS STATEMENT OF PETTIT 1690 SUPERSLICK RED [1]

Ingredient	Percent
cuprous oxide	40.0
cuprous oxide inerts	21.1
molybdenum disulfide	15.0
red iron oxide	9.5
epoxy acrylic ester	5.4
rosin	6.6
xylene	21.4

[1] Pettit Paint Company, Inc., Borough of Rockaway, New Jersey, 07866.

The thinner used contained 53.3% xylene and 46.7% V M&P Naptha .

Both the paints and thinner used during the tests were identical to those used by the worker during the episode described. The paint and thinner were mixed as 4 parts paint and 1 part thinner just as when the accident occured.

D. Paint Spray Gun and Compressor

The spray gun used for the laboratory evaluation was a Bink's Model 7 Spray Gun, serial number 786568 (see Figure 1). This is the same model, although not the same gun, as the sprayer used during the accident. The gun used during testing was connected to a 1 horsepower air compressor by a 25 foot long, 3/8 inch diameter hose and was maintained at a pressure of 55 psi.

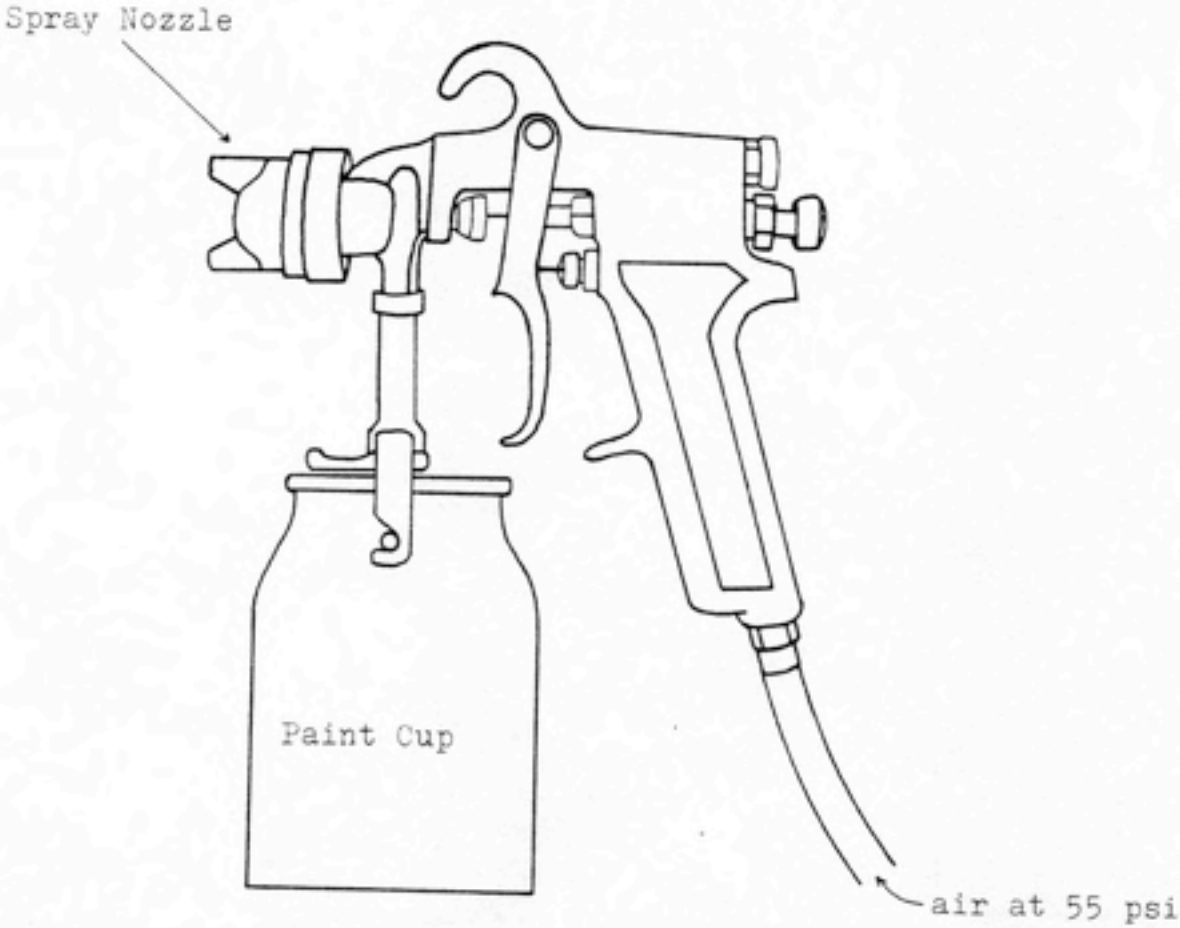


FIGURE 1

Paint Spray Gun and Siphon Cup

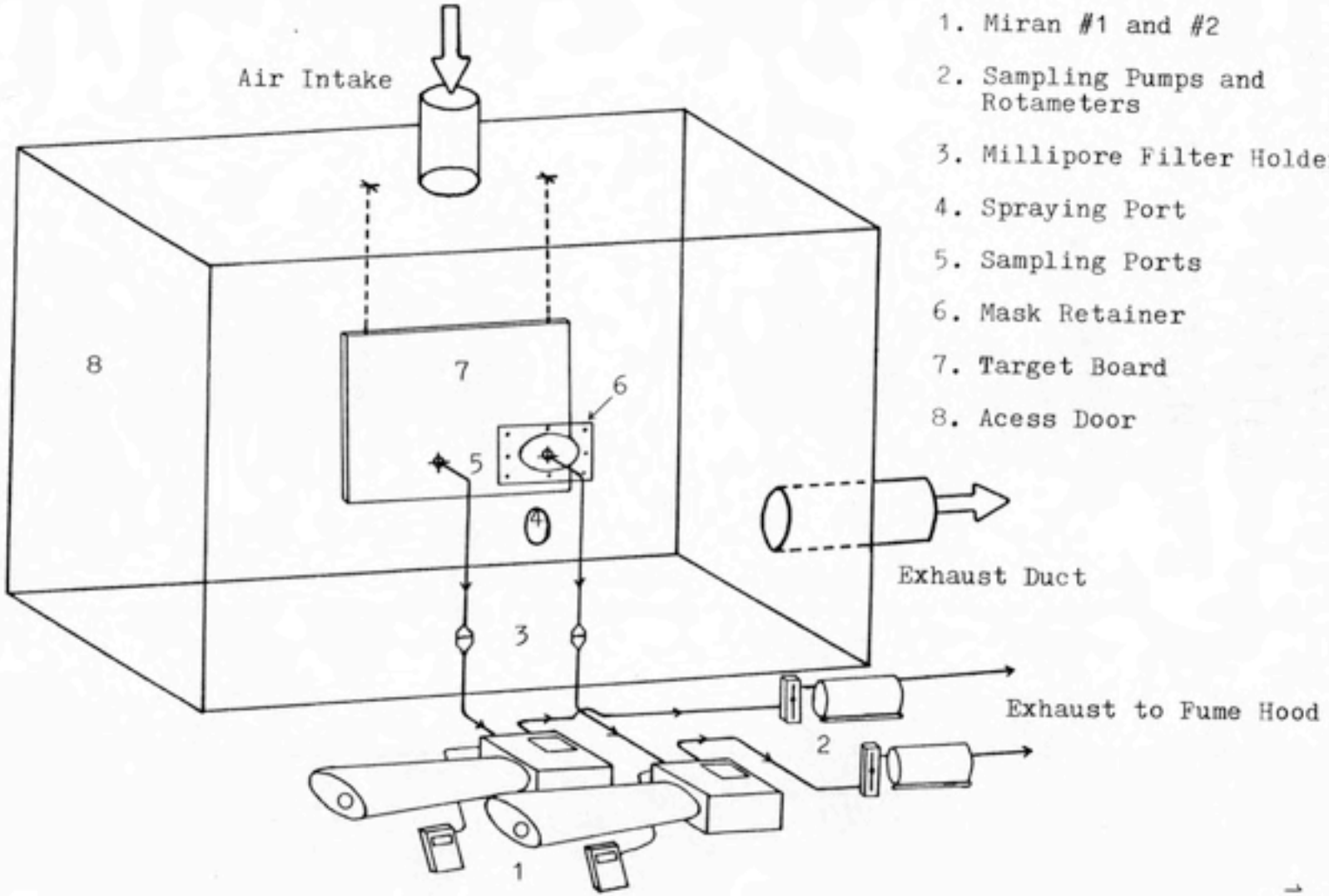


FIGURE 2
Test System

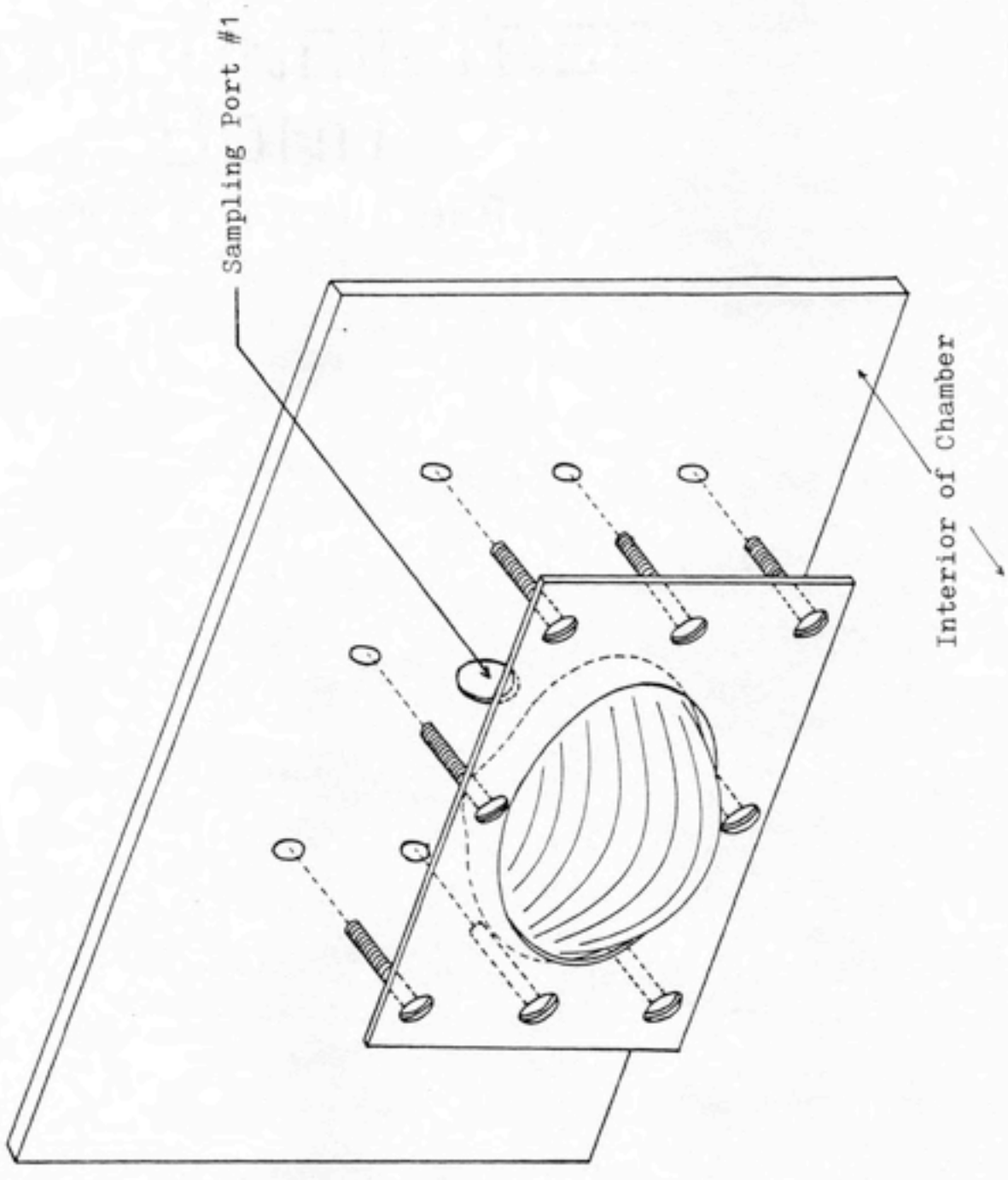


FIGURE 3

Particulate Mask and Retainer

V. PROCEDURES

A. Sampling Procedure

Two Wilk's Miran 1-A Infrared Analyzers were used to monitor the concentration of xylene. Both instruments were calibrated with pure xylene[1]. All calibrations and experiments were conducted under approximate standard conditions.

The calibration was done in a closed loop system that incorporated the Miran analyzer and a small metal bellows pump (flow rate = 5 L/min) connected to the sealed off test chamber via teflon tubing (0.5 cm in diameter and 80 cm in length). A known volume of liquid xylene was injected into the chamber and evaporated with the aid of a small mixing fan. The xylene vapor was then drawn from the chamber, through the Miran and pump and back into the chamber. Both analyzers were connected to the chamber in an identical manner and calibrated simultaneously.

To calculate the volume of xylene necessary to produce a desired concentration in the calibration loop, the following equation was used:

$$Vx = \frac{C \times Vc \times MW \times 298 \times P}{\rho \times 24.45 \times T \times 760 \times 1000}$$

[1]Fisher Scientific, Inc., Fair Lawn, New Jersey, 07410

Where: Vx = Volume of liquid xylene injected

C = Concentration (ppm)

Vc = Volume of closed loop system in liters (1071.3 L)

MW = Molecular weight of xylene (106 g/mole)

P = Pressure in mm Hg (751.9 mm Hg)

ρ = Density of xylene (0.88 g/ml)

T = Absolute temperature in degrees Kelvin (297.5 K)

Both instruments were calibrated between 0 and 3000 ppm. A pathlength of 20.25 meters, wavelength of 12.6 um, and a slot width of 2.0 mm was used. Calibration curves were obtained by plotting absorbance versus concentration (see Appendix A).

During actual testing the Mirans were situated as illustrated in Figure 2. Miran #1 was connected to sampling port #1 for monitoring the concentration of xylene in the chamber. Miran #2 was connected to port #2 and monitored the xylene concentration within the mask. Air was drawn through each analyzer by Gast rotary vane vacuum pumps at a rate of 9 L/min. After leaving the analyzers the contaminated air was exhausted to a chemical fume hood.

The average minute volume of a human being at rest is approximately 5 to 8 L/min.(10) To pull air through the mask at a rate similar to the respiratory rate of a slightly active man, the Miran pumps were maintained at 9 L/min.

By drawing air through the mask at a constant rate, the inspiration and expiration of air during normal breathing is

not taken into consideration. In a real-life situation, the velocity of the air entering the mask would be twice as great since the same amount of air is being inhaled in half the time. The other half of the time is spent exhaling. This study, however, will focus on the total volume of air inhaled per minute rather than the air velocity because of the ease with which it can be controlled and monitored in the test system. The flow rate was constantly monitored with the aid of two rotameters which were calibrated with the pump and Miran connected in line. A two liter soap bubble flow meter was used as the primary standard.

In order to prevent paint particulates and other contaminants from entering the Mirans, a filter holder containing a 47mm, type AA Millipore filter was inserted between the chamber and each analyzer (Figure 2).

B. Test Protocol

The test procedure consisted of two phases for each of the four masks. Both phases were executed in the same manner. The only diffence between the two was the substance being tested. Phase 1 was designed to test the mixture of marine paint and paint thinner. Phase 2, on the other hand, tested the paint thinner. Both phases consisted of 5 tests of varying spray duration (1-5 sec.). For each phase the protocol was as follows:

1. A fresh mask was placed in the holder and the chamber was sealed with the exception of the ventilation inlet and outlet.

2. The Miran instruments were turned on, zeroed and the rotameters adjusted to 9 L/min.
3. The paint or solvent was sprayed against the suspended board in the chamber for the required time (1-5 sec.) and the spray port was sealed.
4. Absorbance readings from Miran #1 and #2 were recorded at intervals of 1, 2, 3, 4 and 5 minutes following the spray period.

VI. RESULTS

Xylene vapor concentrations inside the mask and chamber were recorded as a function of time over a period of 5 minutes for each mask and for each spray duration. A summary of these results has been tabulated for both the spray mixture containing paint and paint thinner (Appendix B) and the 100% paint thinner spray (Appendix C).

These values represent the xylene concentrations inside the Miran analyzer cells and are not the actual concentrations inside the mask and test chamber. Because air was drawn out of the test chamber at a constant rate, the xylene vapor concentration was continually changing. This, conbined with the fact that there was a lag between the moment the paint or thinner was sprayed into the chamber and the time that the vapor reached equilibrium in the detector cell, explains why it was impossible for the analyzers to register an instantaneous absorbance reading of the xylene concentration within the test chamber or particulate mask. However, an estimate of the actual xylene concentration within the mask and chamber was made by using the following dilution ventilation equation.

$$X = \frac{Xm}{1-e^{(-QmT/Vm)}}$$

Where: X = Actual concentration within the mask or chamber.

Xm = Concentration within the Miran cell

Qm = Miran air flow rate (9 L/min)

T = Time elapsed after initial spray

Vm = Volume of the Miran cell (5.6 liters)

All four brands of mask tested were essentially identical in appearance and the test results for each were relatively consistent with one another. For this reason, the mask concentration data and the test chamber concentration data for each mask tested were averaged and compiled into tabular form.

Tables III through VII pertain to Phase 1 of testing using the paint and paint thinner spray mixture. Tables VIII through XII refer to Phase 2 of testing using the 100% thinner spray. The range of concentrations for all four masks was also tabulated. The values in Tables III through XII have been corrected using the dilution ventilation equation.

These average concentrations and their corresponding ranges are shown graphically in Figures 4 through 13. Since no xylene concentrations were recorded prior to the 1 minute mark following the introduction of the spray into the chamber, the behavior of the decay curve preceding that point is estimated. This portion of the curve is represented as a dashed line in Figures 4 through 13. The estimate was made based upon unrecorded visual observation of the Miran readings during test runs and also based upon the shape of the decay curves between the 1 minute and 5 minute mark. The curve for the test chamber concentration during the spraying of the

paint and thinner mixture (Figures 4 through 8) was much more well defined and did not require estimation.

In all tests utilizing the paint and thinner spray mixture (Figures 4 through 8), there was a substantial concentration difference between the mask and surrounding chamber from the moment the aerosol was discharged until approximately 2 minutes following discharge. The concentration differential gradually diminished and was virtually non-existent at the 2 minute mark. At this point the chamber concentration was at its maximum. The mask concentration, however, peaked prior to the one minute mark.

The data shows the test chamber concentration as slightly higher than the mask concentration for the entire length of the decay curves in Figures 9 through 13 which are for the thinner spray. Although the concentrations are statistically different (see Appendix D), they are reasonably close and for the purposes of this study will be considered equal. Also, the mask and chamber concentration were essentially the same for the 2 to 5 minute period following the paint sprays.

Because concentration and exposure time are interelated in terms of dose, it was decided that the data should be expressed as the theoretical dose that one would receive inside the test chamber (with and without a mask). To calculate the dose, the area under each decay curve was determined gravimetrically. Since it was decided that mask and chamber concentrations were approximately equal between the 2 and 5 minute time interval in Figures 4 through 8, only the dose over the first two minutes was calculated. For

comparitive puposes the dose over the initial two minutes in Figures 9 through 13 was also calculated. A summary of xylene dose for each test run can be found in Table XIII for the paint and paint thinner spray mixture and Table XIV for the 100% thinner spray. Also included on both tables is the percent difference between the dose inside the mask and the dose inside the test chamber. Xylene dose is summarized graphically in Figure 14.

TABLE III

COMPARISON OF MASK AND CHAMBER XYLENE CONCENTRATIONS FOLLOWING A ONE SECOND SPRAY OF A PAINT AND PAINT THINNER MIXTURE
(Average of data for all four masks)

Time Elapsed After Spray	Mask Concentration (ppm)		Chamber Concentration (ppm)	
	Average	Range	Average	Range
1 min	78	30	43	21
2 min	45	19	47	22
3 min	25	12	34	17
4 min	16	6	25	11
5 min	9	4	16	8

TABLE IV

COMPARISON OF MASK AND CHAMBER XYLENE CONCENTRATIONS FOLLOWING A TWO SECOND SPRAY OF A PAINT AND PAINT THINNER MIXTURE
(Average of data for all four masks)

	Mask Concentration (ppm)		Chamber Concentration (ppm)	
Time Elapsed After Spray	Average	Range	Average	Range
1 min	168	43	90	12
2 min	96	27	101	14
3 min	54	18	76	5
4 min	33	8	49	2
5 min	23	4	33	5

TABLE V

COMPARISON OF MASK AND CHAMBER XYLENE CONCENTRATIONS FOLLOWING A THREE SECOND SPRAY OF A PAINT AND PAINT THINNER MIXTURE
(Average of data for all four masks)

	Mask Concentration (ppm)		Chamber Concentration (ppm)	
Time Elapsed After Spray	Average	Range	Average	Range
1 min	254	47	138	23
2 min	136	47	158	20
3 min	75	34	117	39
4 min	45	24	75	22
5 min	30	17	50	16

TABLE VI

COMPARISON OF MASK AND CHAMBER XYLENE CONCENTRATIONS FOLLOWING A FOUR SECOND SPRAY OF A PAINT AND PAINT THINNER MIXTURE
(Average of data for all four masks)

Time Elapsed After Spray	Mask Concentration (ppm)		Chamber Concentration (ppm)	
	Average	Range	Average	Range
1 min	345	69	186	52
2 min	189	52	214	26
3 min	106	32	159	28
4 min	65	21	108	30
5 min	44	15	73	18

TABLE VII

COMPARISON OF MASK AND CHAMBER XYLENE CONCENTRATIONS FOLLOWING A FIVE SECOND SPRAY OF A PAINT AND PAINT THINNER MIXTURE
(Average of data for all four masks)

Time Elapsed After Spray	Mask Concentration (ppm)		Chamber Concentration (ppm)	
	Average	Range	Average	Range
1 min	418	12	229	25
2 min	240	41	272	21
3 min	135	22	210	36
4 min	85	21	144	25
5 min	57	11	96	16

Table VIII

COMPARISON OF MASK AND CHAMBER XYLENE CONCENTRATIONS
FOLLOWING A ONE SECOND SPRAY OF 100% PAINT THINNER
(Average of data for all four masks)

Time Elapsed After Spray	Mask Concentration (ppm)		Chamber Concentration (ppm)	
	Average	Range	Average	Range
1 min	376	37	445	62
2 min	159	36	234	73
3 min	59	26	97	56
4 min	22	7	38	32
5 min	8	12	17	22

TABLE IX

COMPARISON OF MASK AND CHAMBER XYLENE CONCENTRATIONS FOLLOWING A TWO SECOND SPRAY OF 100% PAINT THINNER (Average of data for all four masks)

Time Elapsed After Spray	Mask Concentration (ppm)		Chamber Concentration (ppm)	
	Average	Range	Average	Range
1 min	982	200	1150	175
2 min	447	136	594	104
3 min	172	91	256	105
4 min	62	32	103	72
5 min	25	21	41	43

TABLE X

COMPARISON OF MASK AND CHAMBER XYLENE CONCENTRATIONS FOLLOWING A THREE SECOND SPRAY OF 100% PAINT THINNER
(Average of data for all four masks)

Time Elapsed After Spray	Mask Concentration (ppm)		Chamber Concentration (ppm)	
	Average	Range	Average	Range
1 min	1605	626	1711	163
2 min	735	258	962	93
3 min	278	131	442	111
4 min	105	68	189	83
5 min	40	34	79	42

TABLE XI

COMPARISON OF MASK AND CHAMBER XYLENE CONCENTRATIONS FOLLOWING A FOUR SECOND SPRAY OF 100% PAINT THINNER (Average of data for all four masks)

	Mask Concentration (ppm)		Chamber Concentration (ppm)	
Time Elapsed After Spray	Average	Range	Average	Range
1 min	1995	625	2157	250
2 min	925	240	1262	182
3 min	371	131	583	256
4 min	148	67	263	157
5 min	66	42	103	80

TABLE XII

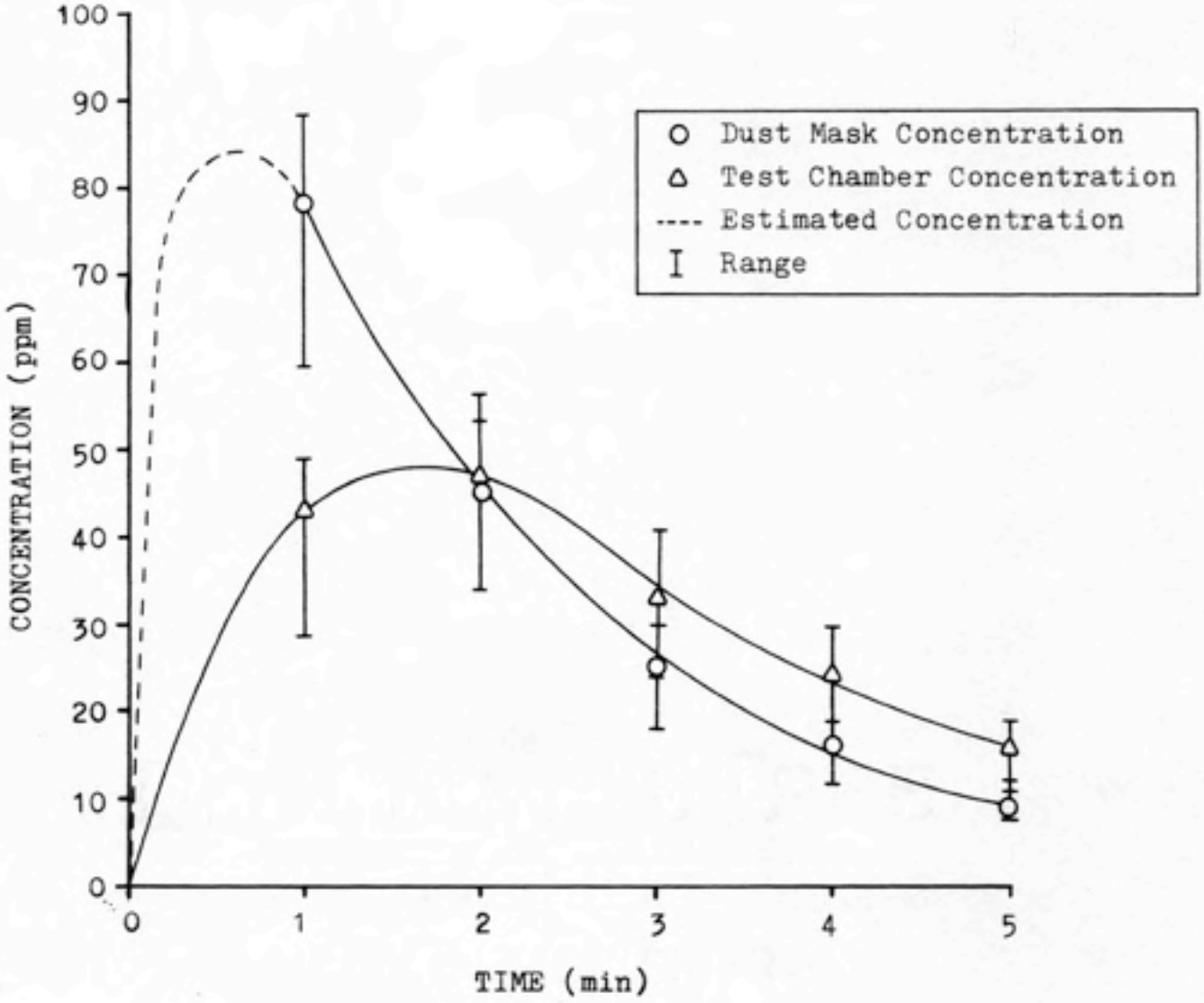
COMPARISON OF MASK AND CHAMBER XYLENE CONCENTRATIONS FOLLOWING A FIVE SECOND SPRAY OF 100% PAINT THINNER (Average of data for all four masks)

Time Elapsed After Spray	Mask Concentration (ppm)		Chamber Concentration (ppm)	
	Average	Range	Average	Range
1 min	2518	501	2783	563
2 min	1180	313	1561	311
3 min	489	65	721	91
4 min	214	80	354	225
5 min	98	54	151	105

FIGURE 4

XYLENE VAPOR DECAY FOLLOWING PAINT AND THINNER SPRAY*

1 SECOND SPRAY

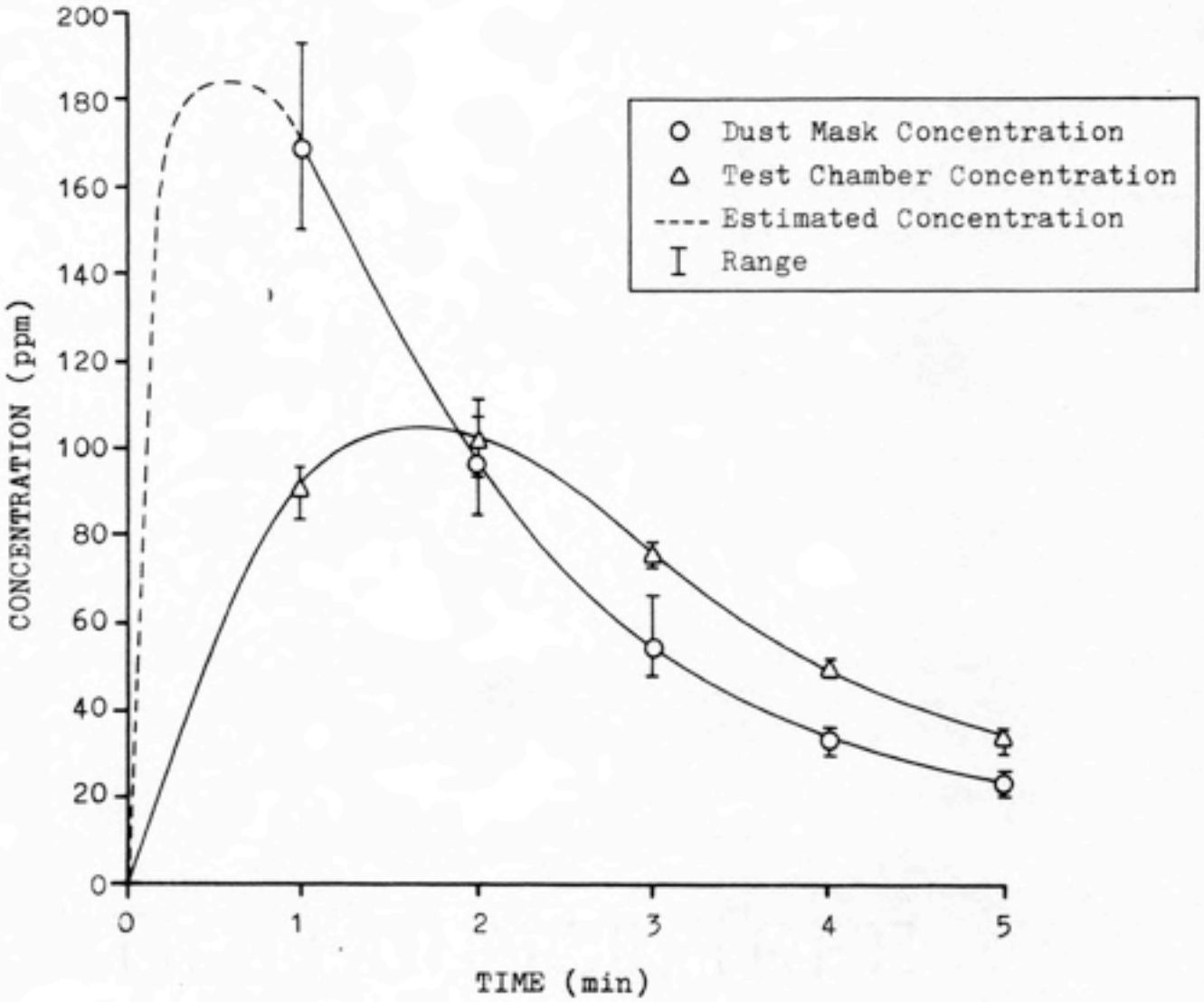


*Values represent an average of data for all four masks

FIGURE 5

XYLENE VAPOR DECAY FOLLOWING PAINT AND THINNER SPRAY*

2 SECOND SPRAY

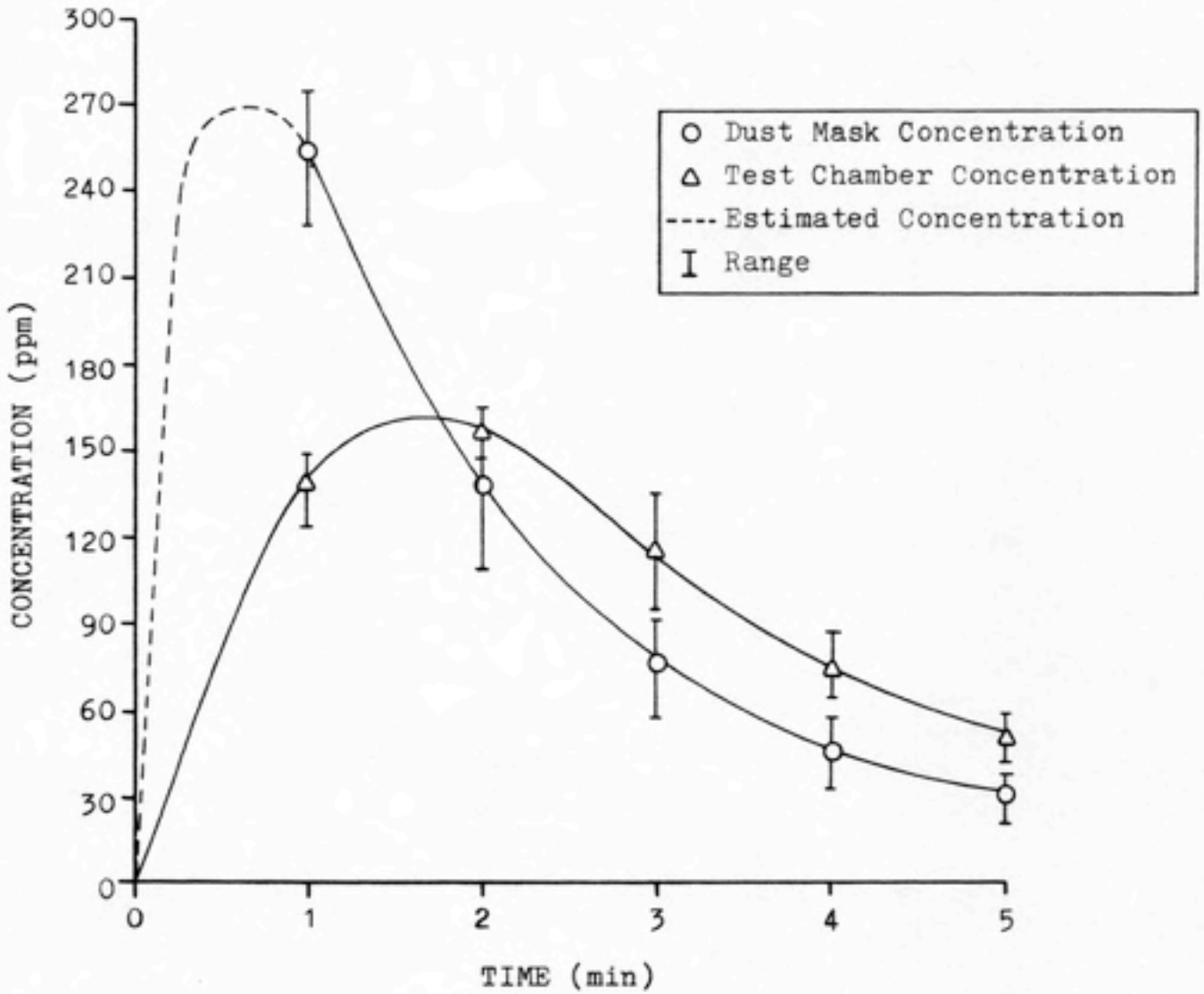


*Values represent an average of data for all four masks

FIGURE 6

XYLENE VAPOR DECAY FOLLOWING PAINT AND THINNER SPRAY*

3 SECOND SPRAY

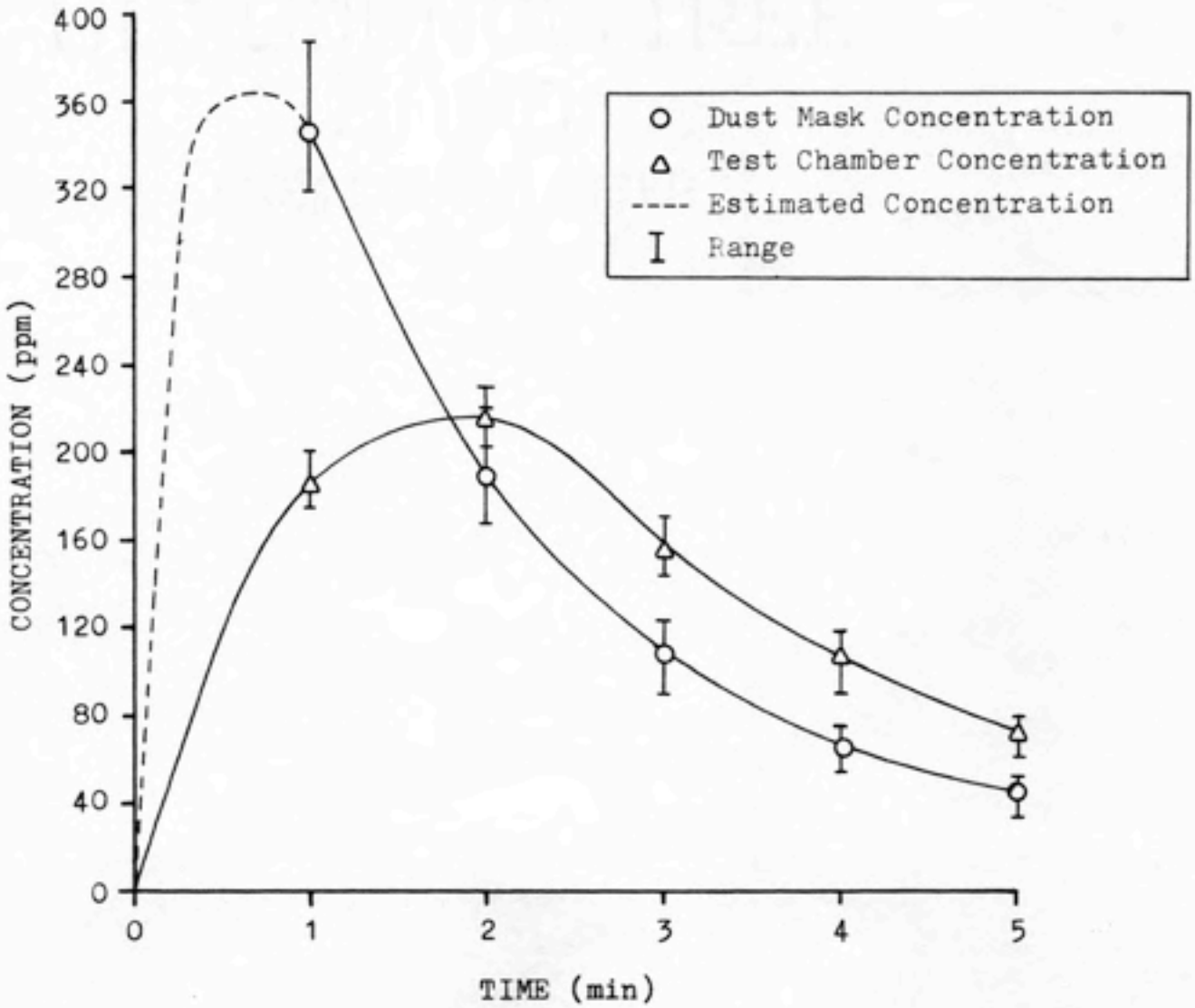


*Values represent an average of data for all four masks

FIGURE 7

XYLENE VAPOR DECAY FOLLOWING PAINT AND THINNER SPRAY*

4 SECOND SPRAY

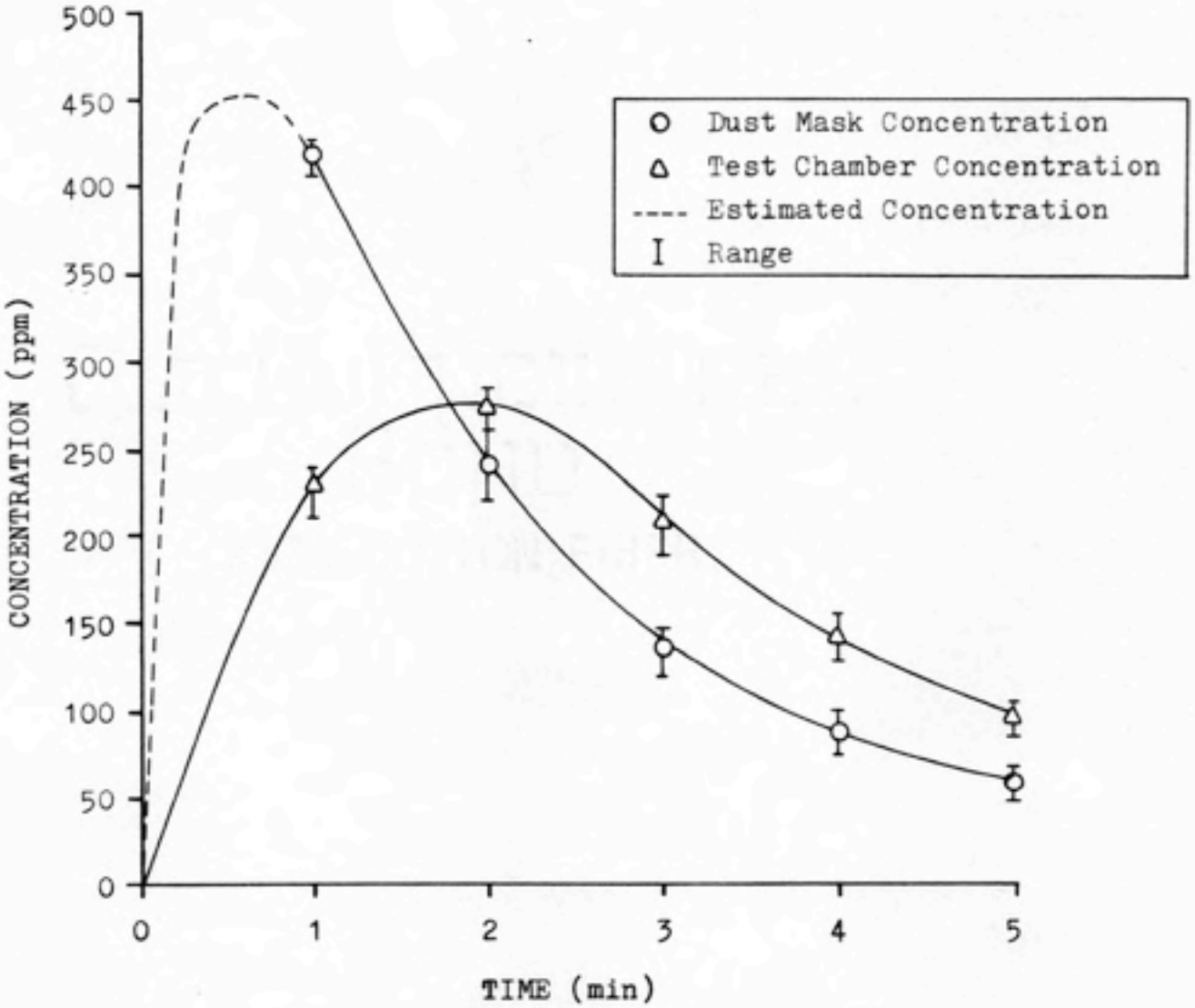


*Values represent an average of data for all four masks

FIGURE 8

XYLENE VAPOR DECAY FOLLOWING PAINT AND THINNER SPRAY*

5 SECOND SPRAY

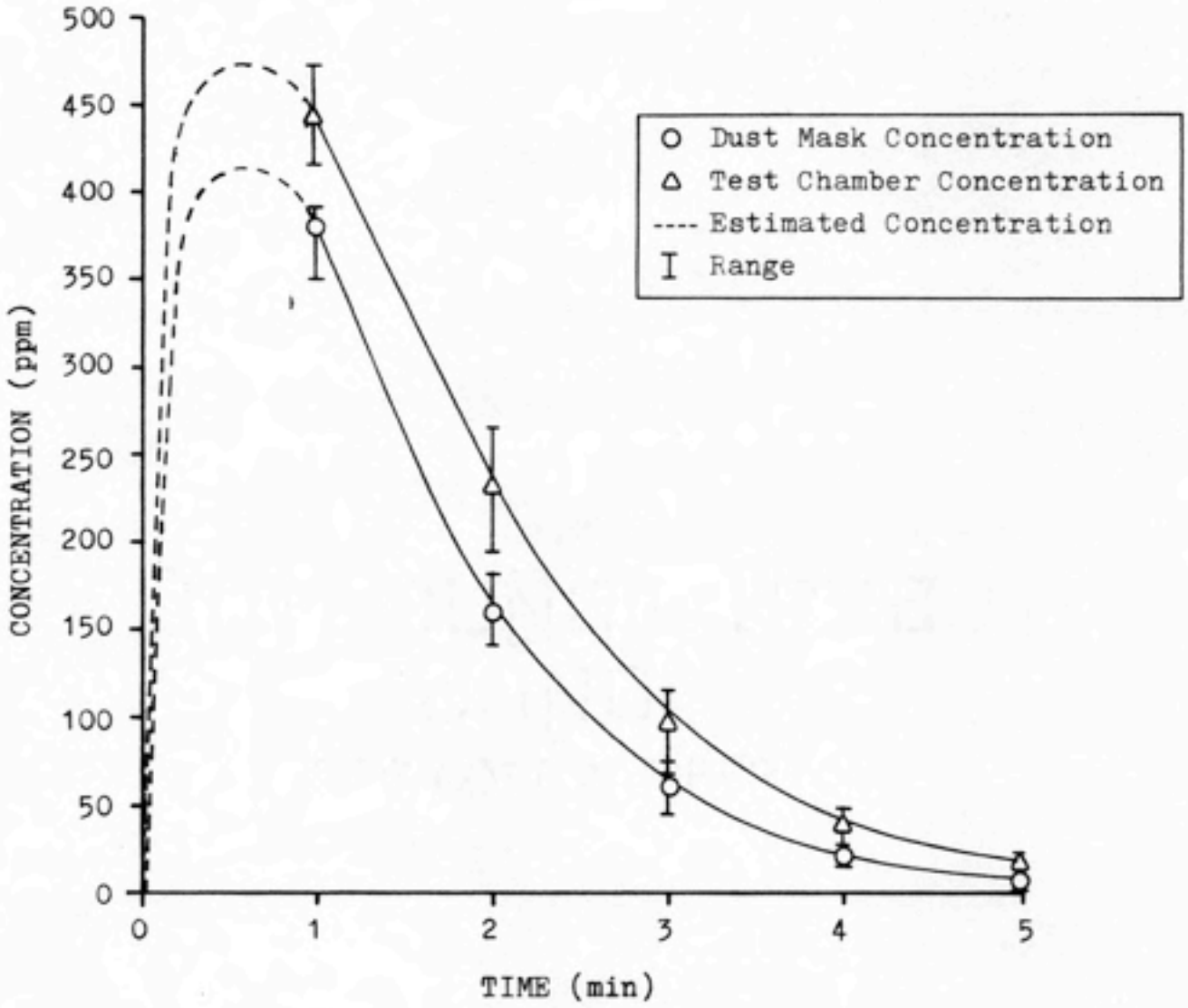


*Values represent an average of data for all four masks

FIGURE 9

XYLENE VAPOR DECAY FOLLOWING THINNER SPRAY*

1 SECOND SPRAY

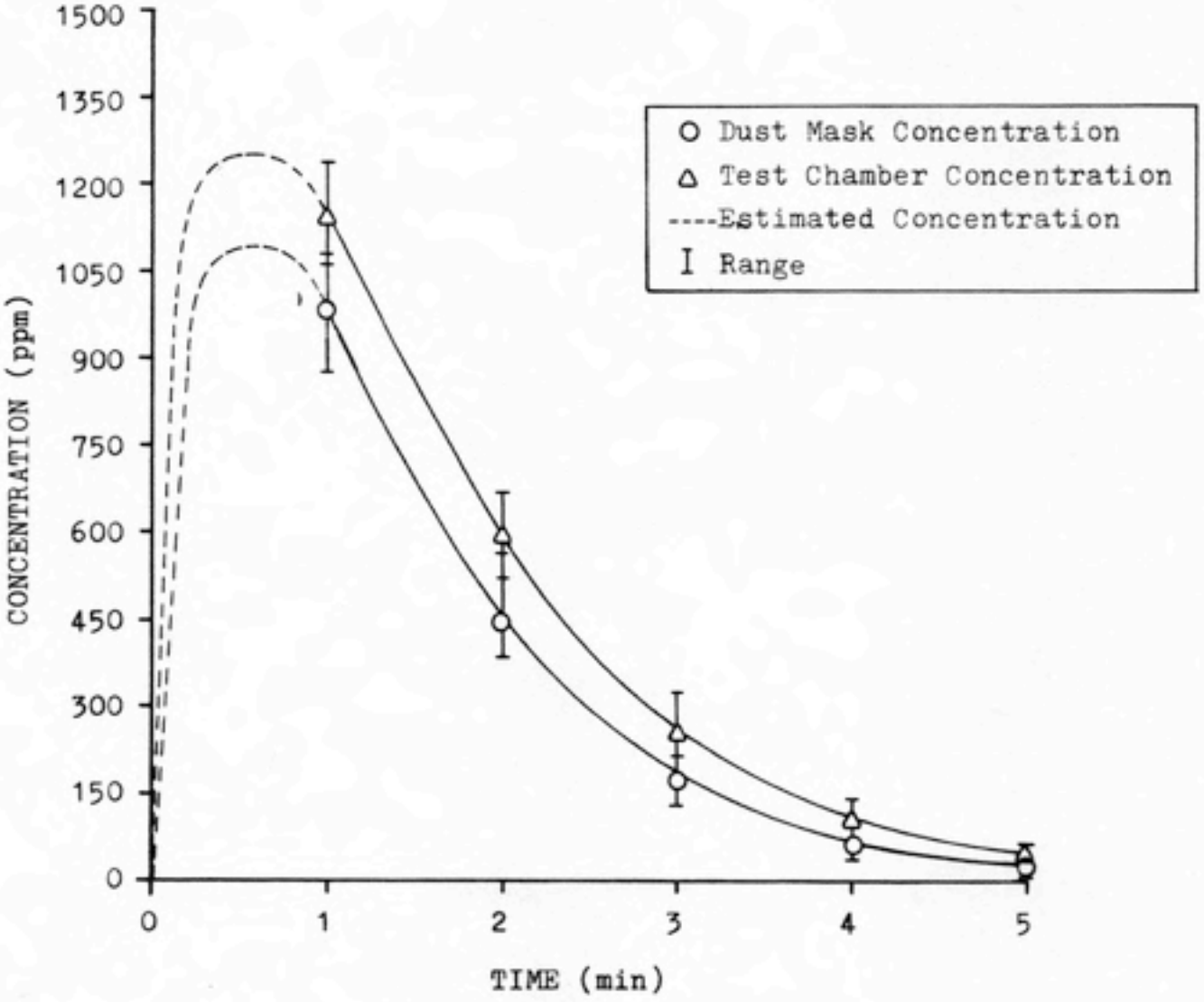


*Values represent an average of data for all four masks

FIGURE 10

XYLENE VAPOR DECAY FOLLOWING THINNER SPRAY*

2 SECOND SPRAY

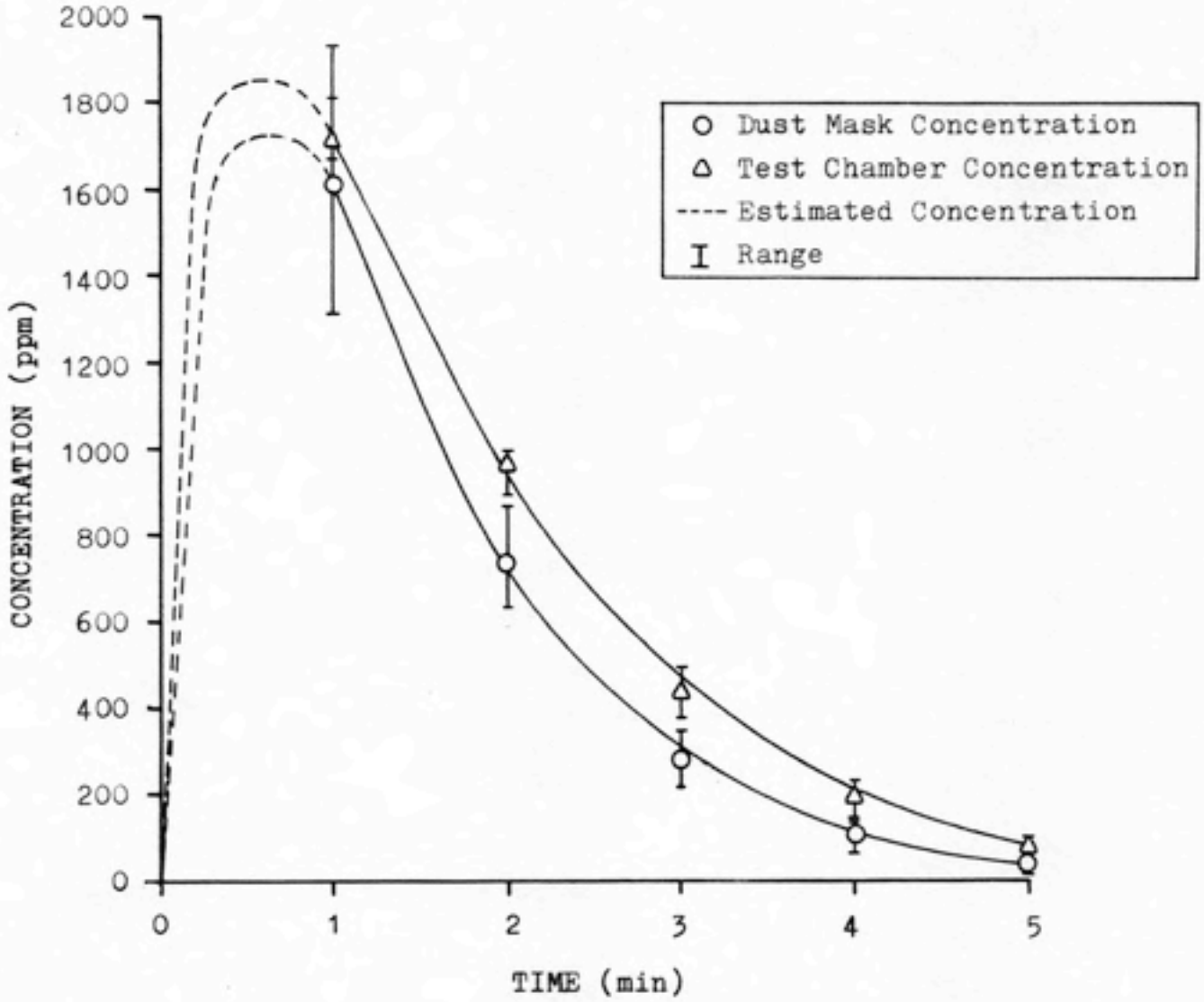


*Values represent an average of data for all four masks

FIGURE 11

XYLENE VAPOR DECAY FOLLOWING THINNER SPRAY*

3 SECOND SPRAY

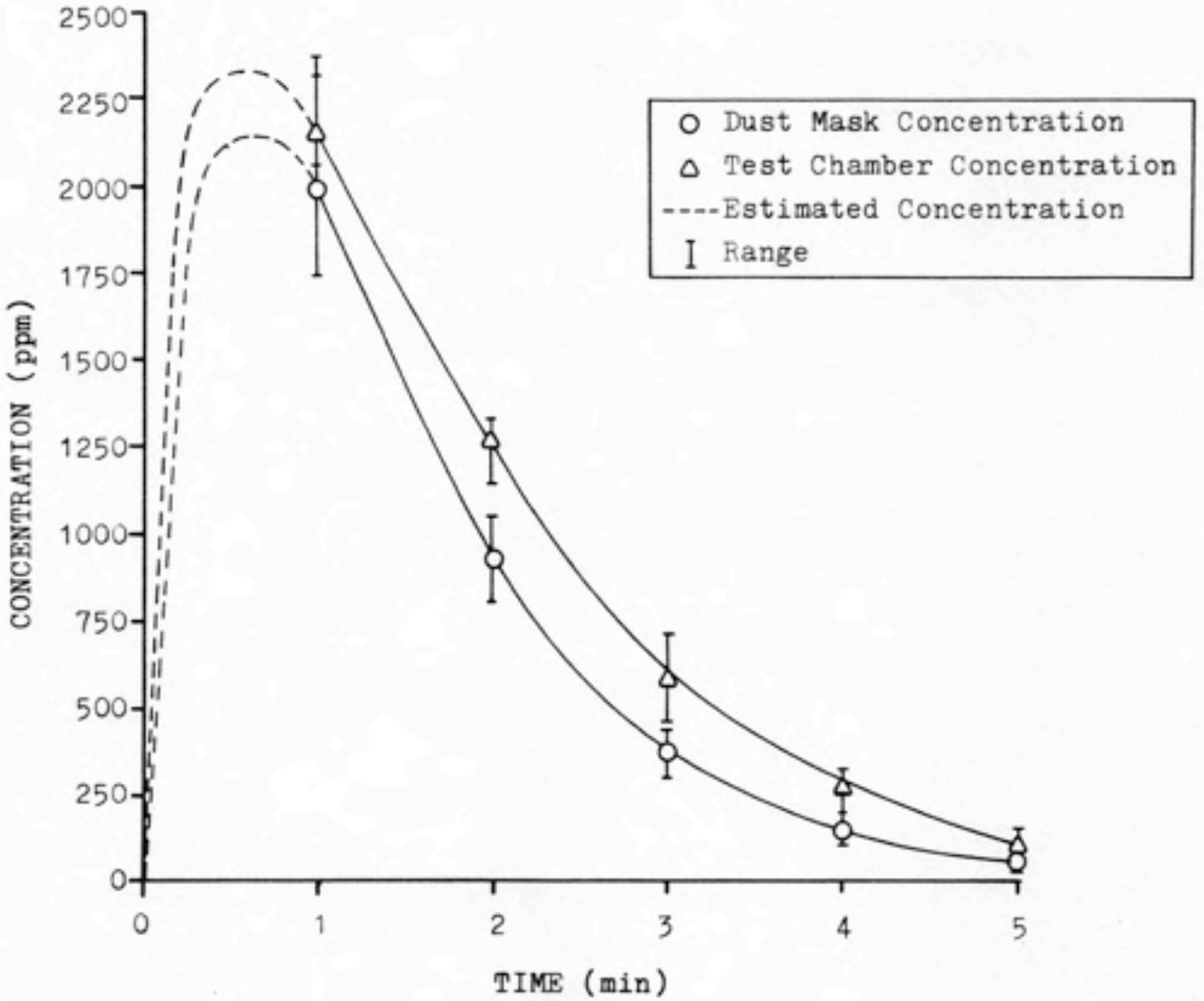


*Values represent an average of data for all four masks

FIGURE 12

XYLENE VAPOR DECAY FOLLOWING THINNER SPRAY*

4 SECOND SPRAY

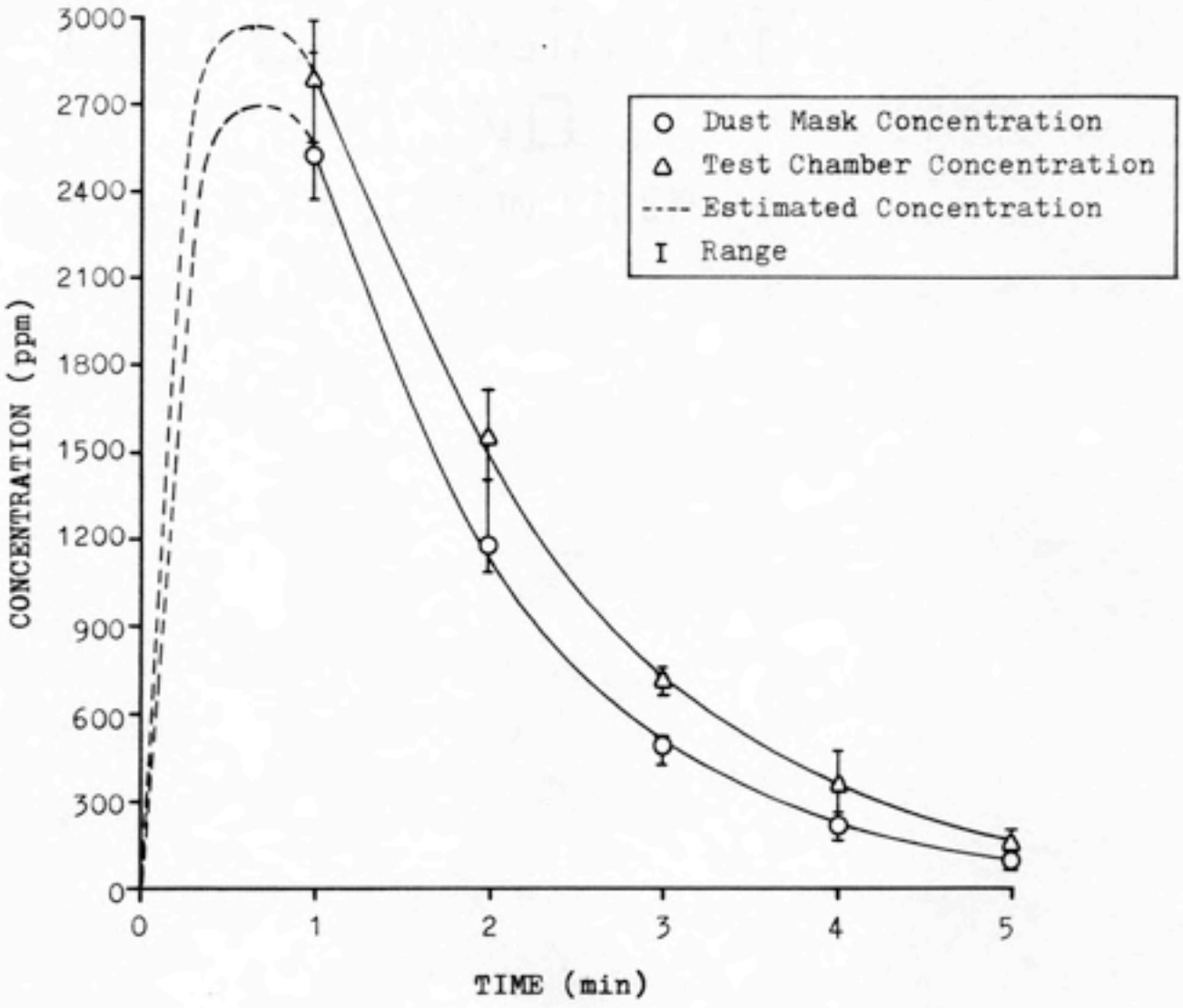


*Values represent an average of data for all four masks

FIGURE 13

XYLENE VAPOR DECAY FOLLOWING THINNER SPRAY*

5 SECOND SPRAY



*Values represent an average of data for all four masks

TABLE XIII

DOSE RECIEVED INSIDE TEST CHAMBER AND PARTICULATE MASK DURING THE TWO MINUTE INTERVAL FOLLOWING A ONE TO FIVE SECOND SPRAY OF A PAINT AND PAINT THINNER MIXTURE
(Average of all four masks)

Spray Duration	Mask Dose (ppm-min)	Chamber Dose (ppm-min)	% Difference
1 sec.	132	74	+78%
2 sec.	302	162	+86%
3 sec.	424	239	+78%
4 sec.	570	319	+79%
5 sec.	693	387	+79%

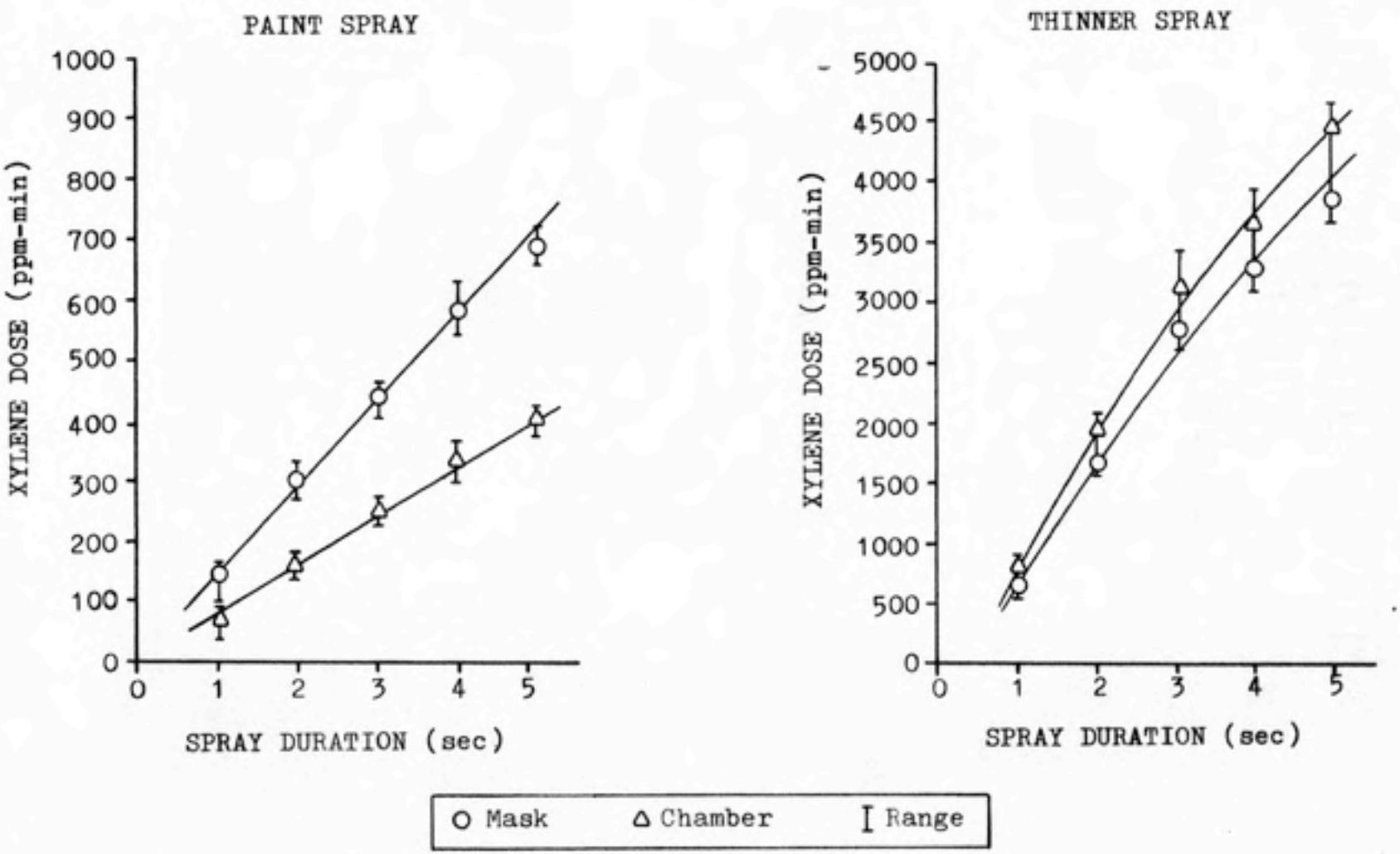
TABLE XIV

DOSE RECIEVED INSIDE TEST CHAMBER AND PARTICULATE MASK DURING THE TWO MINUTE INTERVAL FOLLOWING A ONE TO FIVE SECOND SPRAY OF 100% PAINT THINNER
(Average of all four masks)

Spray Duration	Mask Dose (ppm-min)	Chamber Dose (ppm-min)	% Difference
1 sec.	645	789	-22%
2 sec.	1652	1946	-18%
3 sec.	2716	3158	-16%
4 sec.	3286	3639	-11%
5 sec.	3739	4488	-20%

FIGURE 14

XYLENE DOSE RECIEVED INSIDE TEST CHAMBER AND PARTICULATE MASK DURING THE TWO MINUTE INTERVAL FOLLOWING A ONE TO FIVE SECOND SPRAY



VII. DISCUSSION OF RESULTS

As indicated in Figures 4 through 8 and 9 through 13, a very consistent pattern of concentration fluctuation emerged regardless of the duration of the spray.

In all 5 test runs with the paint mixture, the concentration inside the mask was consistently higher during the first 2 minutes following the spray than the concentration inside the chamber. For instance, 1 minute following the 2 second spray, the average concentration for all four masks was recorded as 168 ppm while the chamber concentration was only 90 ppm. This represents an 87% concentration increase at that point (see Table IV). Also, according to Table XIII, the dose over the first 2 minutes was at least 78% higher inside the mask during all 5 runs. The greatest increase was 86% following the 2 second spray.

Immediately following the introduction of the paint aerosol into the chamber, the Miran monitoring the mask concentration registered a sharp xylene concentration increase. This is clearly illustrated in Figures 4 through 8. On the other hand, the Miran monitoring the chamber concentration registered a slower, more gradual xylene concentration increase and peaked at approximately 2 minutes. Prior to the 1 minute mark following the spray, the concentration inside the mask peaked and began a steady decline. At the same time the chamber concentration leveled

off until both the mask concentration and chamber concentration were approximately equal at the 2 minute mark. Following the 2 minute mark, both concentrations remained fairly equal.

A possible explaination for this behavior may be derived by examinimg the sources of xylene vapor in the chamber. There were essentially 2 vapor sources. The first source was solvent vaporization from the wetted target board. When the paint was sprayed under pressure at the target board some of the aerosol rebounded back toward the mask and the remainder was dispersed throughout the chamber. The paint aerosol circulating in the chamber slowly released solvent vapor which was constantly evacuated through the exhaust duct. This, and the fact that xylene vapor was slowly released from the board as it dried, explains the gradual xylene concentration buildup in the chamber during the 2 minutes after the spray. Some of the paint, however, rebounded off of the board and wetted the mask. The xylene that vaporized on the mask was quickly drawn into the adjacent sampling port. This, combined with xylene vapor being drawn in from the rest of the chamber, created a sharp concentration increase that peaked prior to the one minute mark. In other words, the paint aerosol that collected on the mask behaved as a solvent point source and increased the xylene concentration around sampling port #2.

At a point somewhere between 1 minute and 2 minutes following the spray, it is evident that most of the xylene in the paint aerosol and on the target board had become volatilized. This caused the xylene concentration within the

mask and chamber to eventually equalize at approximately the 2 minute mark. From that point on, both concentrations steadily diminished as air was exhausted from the chamber.

In all 5 test runs using the 100% paint thinner, the xylene concentrations within the mask and test chamber behaved in virtually an identical manner. This is dramatically illustrated in Table X. The average chamber concentration one minute following a 3 second thinner spray was 1711 ppm. The average concentration inside the mask at the same point in time was 1605 ppm. This represents a 7% concentration differential. Also, as shown in Table XIV, the dose in the chamber for the 2 minutes following the 4 second spray was only 11% higher than the mask dose. The maximum dose differential was only 22% following the 1 second spray.

The moment that the thinner was sprayed into the chamber both Mirans registered a sharp xylene concentration buildup (see Figures 9 through 13). Since the aerosol was pure solvent, the xylene was vaporized very quickly throughout the chamber and mask in comparison to the slow gradual vaporization in the chamber during testing with the paint mixture. Therefore, a sharp xylene concentration peak was immediately attained following the spray. At that juncture, the xylene had vaporized from the thinner sprayed into the chamber and wetting the target board. The concentration then declined as air was evacuated from the chamber.

A possible explaination of why the mask concentration was not higher than the chamber concentration during Phase 2 may be due to the aerosol composition. Since the aerosol

contained no paint to retard solvent vaporization as in Phase 1, the xylene was completely liberated by the time it reached the mask. Therefore, the mask was not wetted with xylene and did not act as a point source. The reason that the chamber concentration was slightly higher rather than equal to the mask concentration during the entire 5 minute period was probably because of the pressure drop across the mask. This would create a lower pressure inside the detector cell. Therefore, fewer vapor molecules would be present and would result in a lower absorbance reading. Also, this is most likely true for the 2 to 5 minute time period during the tests using the paint mixture.

According to Figures 4 through 13, there is a wide discrepancy between the peak concentration after the paint spray and the peak concentration after the thinner spray. For instance, Figure 4 shows a peak xylene concentration of approximately 85 ppm in the mask. On the other hand, Figure 9 indicates a peak concentration of approximately 410 ppm in the mask. This represents a 380% concentration difference even though both the paint and the thinner were sprayed for 1 second. The most reasonable explaination for this difference would be that the thinner contained 380% more xylene than the paint mixture. However, the thinner had only twice as much xylene as the paint mixture. Therefore, the difference in concentration magnitude was probably due to the viscosity of the paint mixture as compared to the thinner. Since the paint was more viscous, a smaller volume was delivered through the gun.

Based upon the results obtained for a 1 to 5 second spray of a paint and thinner mixture, it seems reasonable to hypothesize that a continuous spray would maintain the concentration differential between mask and chamber for the entire duration of the spray. As long as one sprayed, the mask would continually be wetted with paint and would serve as a point source. Only when the spraying stopped would the concentrations inside the mask and chamber equilibrate and gradually diminish. When one considers a real-life paint spraying task that typically requires many minutes of continuous spraying, the hazardous nature of this act becomes apparent.

The ventilation rate used during this study was relatively low. A higher air flow would immediately evacuate the paint spray from the chamber, maintaining a concentration that was essentially zero. However, the wetting of the mask would still occur which would create an elevated mask concentration even when the surrounding concentration was zero.

Under the conditions of this experiment, when the chamber concentration approximated the short term exposure limit of 150 ppm 1 minute following the 3 second paint spray, a worker wearing the mask would have been exposed to almost twice this concentration (see Table V). If the spray painting was done out of doors as in the case described, the ambient concentration reported by air sampling could be even lower while the mask concentration could be at or even above 254 ppm. If the painting was continued for a period of 30 minutes

this concentration would be maintained for the entire duration. This concept is graphically illustratied in Figure 15. Even a spraying period of 30 minutes at a concentration of 254 ppm would deliver a dose of 300 mg of xylene to the lungs of the painter. If this 30 minute interval of spraying were repeated 5 times in the course of a day, 1500 mg or almost 2 ml of xylene would be delivered to the lungs of the painter. This is a conservative estimate based on a mask concentration of only 254 ppm.

VIII. CONCLUSIONS AND RECOMMENDATIONS

The results from this study indicate that under the laboratory conditions used and for the particular paint and thinner tested, the solvent dose received inside a particulate mask is remarkably higher than the dose one would receive in the surrounding ambient air during the 2 minutes following a paint spray.

Real-life situations and conditions are ever-changing and unpredictable. However, all results obtained during this study strongly imply that not only will a particulate mask not protect a worker from solvent vapors during paint spraying, it may increase the worker's exposure. In other words, a worker would receive a higher solvent exposure while wearing a non-toxic particulate mask than if he wore no respiratory protection at all.

Based upon this information, the following recommendations are suggested to prevent future use of non-toxic particulate masks during paint spraying.

1. All paint and paint products that require respiratory protection during their use should be labled with specific guidelines regarding respirator type. A vague reference to 30 CFR 11 is not adequate for someone who is not familiar with the regulation.

2. Warning labels on non-toxic particulate mask packages

should contain a statement that the respirators are not suitable for paint spraying or under conditions where exposure to solvent vapors may occur.

3. Anyone who sells respiratory equipment to small businesses and the general public should be required to obtain an OSHA certified license to do so. The conditions for receiving such a license would be attendance at a respiratory protection seminar and successfully passing an examination. Such a requirement would better enable store owners to make recommendations to their customers regarding proper respirator selection.

Additional tests are recommended that might further substantiate the results obtained in this study. Ventilation exhaust rates within the test chamber could be increased to see if a concentration differential is still maintained. Also, the spray duration could be lenghtened to several minutes in order to more accuratly mimic a real-life paint spraying task. It is reasonable to suspect that the concentration differential would be maintained or even increased as long as the spray continued.

Since xylene based paint and thinner was the only substance tested, other solvent based paint products should be tested. If a paint is tested that contains a solvent with a higher or lower vapor pressure than xylene, the results might be substantially different than those found here.

A method of drawing air through the mask should be

devised that would more closely simulate man's natural breathing pattern rather than the continuous flow utilized in this study. In addition, the effects of humidity on the solvent concentration inside a particulate mask should be examined.

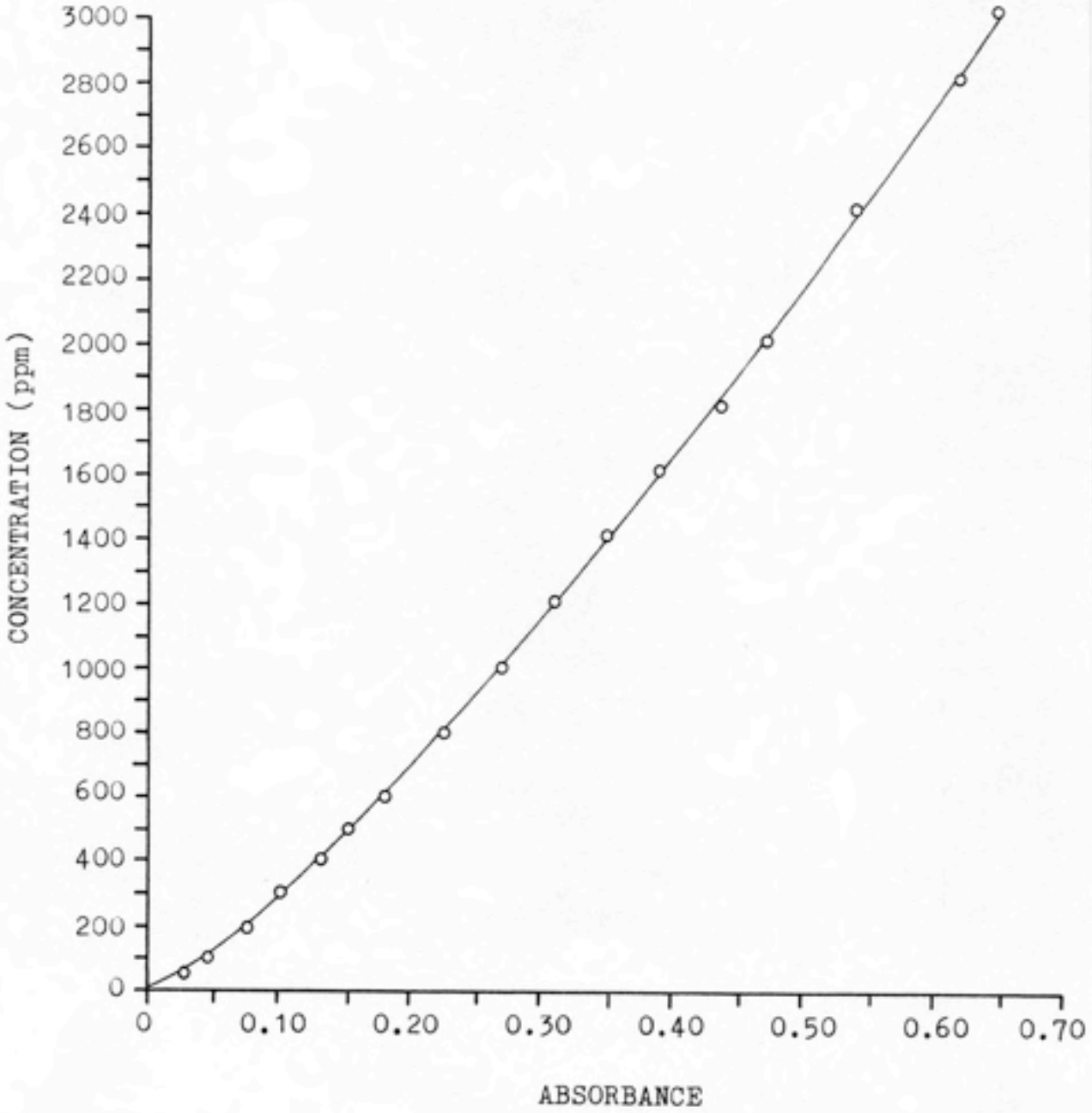
The use of non-toxic particulate masks in conjunction with paint spraying operations should be prohibited. Such a practice may create a dangerously elevated solvent concentration within the breathing zone of a worker.

APPENDIX A

XYLENE CALIBRATION CURVE FOR MIRAN INFRARED ANALYZER

MIRAN No.1

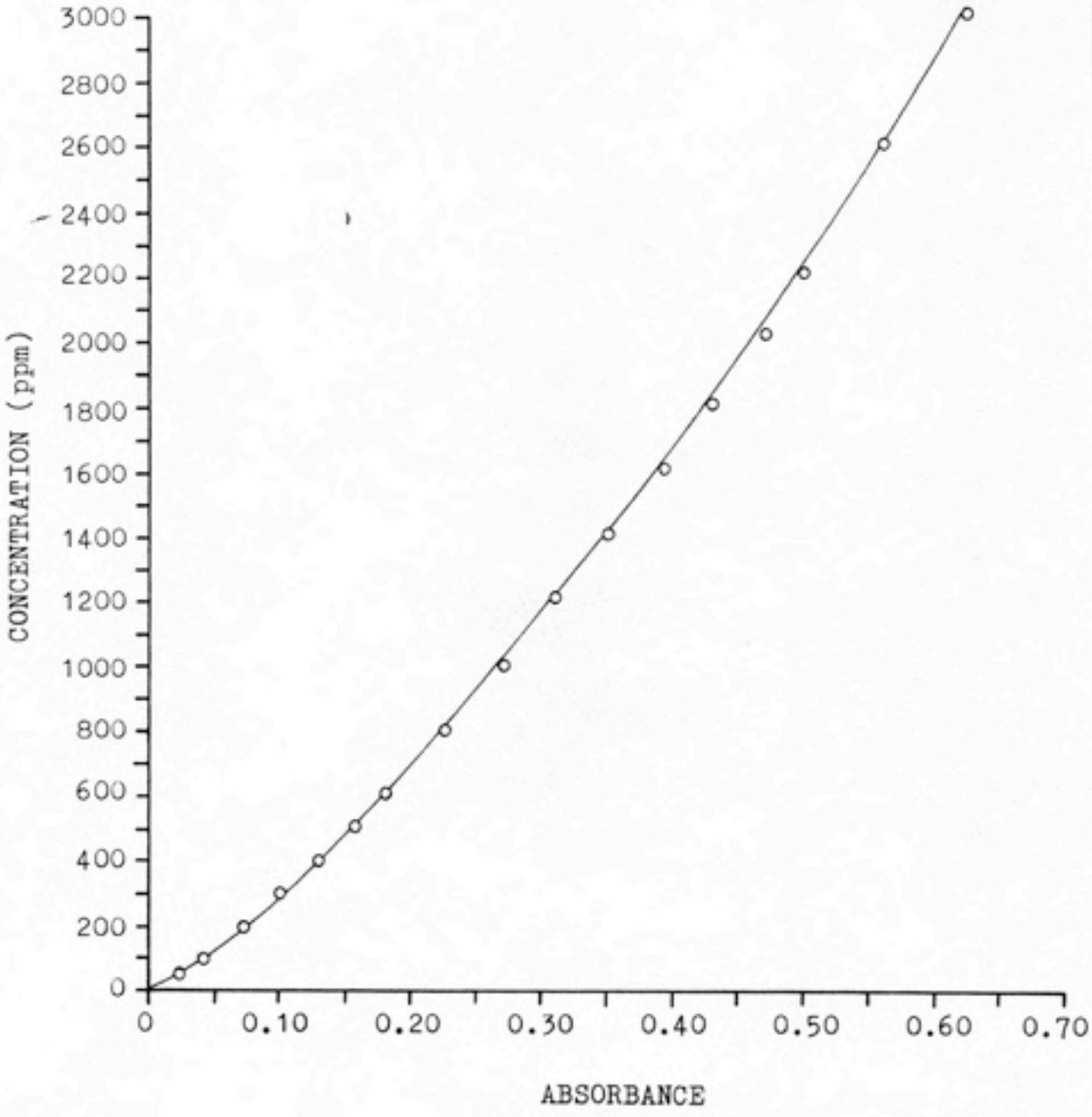
Serial # 1783



XYLENE CALIBRATION CURVE FOR MIRAN INFRARED ANALYZER

MIRAN No.2

Serial # 78857



APPENDIX B

SUMMARY OF MASK AND CHAMBER XYLENE CONCENTRATIONS FOLLOWING A ONE SECOND SPRAY OF A PAINT AND PAINT THINNER MIXTURE
(Original, uncorrected Miran data)

		XYLENE CONCENTRATION				
		Time Elapsed Following Spray				
Mask Brand		1 min	2 min	3 min	4 min	5 min
3-M	MASK CONC. (ppm)	70	51	30	18	12
	CHAMBER CONC. (ppm)	40	53	40	30	19
Norton	MASK CONC. (ppm)	70	48	30	18	10
	CHAMBER CONC. (ppm)	40	54	41	30	19
Gerson	MASK CONC. (ppm)	60	40	23	14	8
	CHAMBER CONC. (ppm)	33	40	31	22	11
Willson	MASK CONC. (ppm)	46	33	18	12	8
	CHAMBER CONC. (ppm)	22	33	24	19	13

SUMMARY OF MASK AND CHAMBER XYLENE CONCENTRATIONS FOLLOWING A TWO SECOND SPRAY OF A PAINT AND PAINT THINNER MIXTURE
(Original, uncorrected Miran data)

		XYLENE CONCENTRATION				
		Time Elapsed Following Spray				
Mask Brand		1 min	2 min	3 min	4 min	5 min
3-M	MASK CONC. (ppm)	135	94	54	35	23
	CHAMBER CONC. (ppm)	67	95	75	48	30
Norton	MASK CONC. (ppm)	125	85	48	30	21
	CHAMBER CONC. (ppm)	75	100	75	50	35
Gerson	MASK CONC. (ppm)	120	80	48	30	21
	CHAMBER CONC. (ppm)	67	90	73	48	30
Willson	MASK CONC. (ppm)	155	107	65	38	25
	CHAMBER CONC. (ppm)	77	103	77	50	35

SUMMARY OF MASK AND CHAMBER XYLENE CONCENTRATIONS FOLLOWING A THREE SECOND SPRAY OF A PAINT AND PAINT THINNER MIXTURE
(Original, uncorrected Miran data)

		XYLENE CONCENTRATION				
		Time Elapsed Following Spray				
Mask Brand		1 min	2 min	3 min	4 min	5 min
3-M	MASK CONC. (ppm)	220	150	90	57	38
	CHAMBER CONC. (ppm)	118	157	134	87	59
Norton	MASK CONC. (ppm)	190	130	75	46	30
	CHAMBER CONC. (ppm)	105	155	118	77	53
Gerson	MASK CONC. (ppm)	182	105	57	33	21
	CHAMBER CONC. (ppm)	100	140	95	65	43
Willson	MASK CONC. (ppm)	220	137	72	43	30
	CHAMBER CONC. (ppm)	115	155	115	70	43

SUMMARY OF MASK AND CHAMBER XYLENE CONCENTRATIONS FOLLOWING A FOUR SECOND SPRAY OF A PAINT AND PAINT THINNER MIXTURE
(Original, uncorrected Miran data)

		XYLENE CONCENTRATION				
		Time Elapsed Following Spray				
Mask Brand		1 min	2 min	3 min	4 min	5 min
3-M	MASK CONC. (ppm)	280	185	103	67	46
	CHAMBER CONC. (ppm)	140	195	149	105	70
Norton	MASK CONC. (ppm)	260	170	103	65	43
	CHAMBER CONC. (ppm)	157	210	170	118	80
Gerson	MASK CONC. (ppm)	255	160	90	54	35
	CHAMBER CONC. (ppm)	140	195	142	90	62
Willson	MASK CONC. (ppm)	310	210	122	75	50
	CHAMBER CONC. (ppm)	190	260	205	140	90

SUMMARY OF MASK AND CHAMBER XYLENE CONCENTRATIONS FOLLOWING A FIVE SECOND SPRAY OF A PAINT AND PAINT THINNER MIXTURE
(Original, uncorrected Miran data)

		XYLENE CONCENTRATION				
		Time Elapsed Following Spray				
Mask Brand		1 min	2 min	3 min	4 min	5 min
3-M	MASK CONC. (ppm)	340	228	137	85	54
	CHAMBER CONC. (ppm)	190	265	220	150	102
Norton	MASK CONC. (ppm)	330	230	136	87	62
	CHAMBER CONC. (ppm)	180	270	220	155	103
Gerson	MASK CONC. (ppm)	330	210	120	73	51
	CHAMBER CONC. (ppm)	170	250	185	130	87
Willson	MASK CONC. (ppm)	335	250	142	94	62
	CHAMBER CONC. (ppm)	190	260	205	140	90

APPENDIX C

SUMMARY OF MASK AND CHAMBER XYLENE CONCENTRATIONS
FOLLOWING A ONE SECOND SPRAY OF 100% PAINT THINNER
(Original, uncorrected Miran data)

		XYLENE CONCENTRATION				
		Time Elapsed Following Spray				
Mask Brand		1 min	2 min	3 min	4 min	5 min
3-M	MASK CONC. (ppm)	280	135	53	21	8
	CHAMBER CONC. (ppm)	380	235	105	48	22
Norton	MASK CONC. (ppm)	310	170	73	30	16
	CHAMBER CONC. (ppm)	360	255	115	48	30
Gerson	MASK CONC. (ppm)	310	143	48	16	4
	CHAMBER CONC. (ppm)	330	185	60	16	0
Willson	MASK CONC. (ppm)	305	165	63	23	6
	CHAMBER CONC. (ppm)	330	225	105	40	15

SUMMARY OF MASK AND CHAMBER XYLENE CONCENTRATIONS
FOLLOWING A TWO SECOND SPRAY OF 100% PAINT THINNER
(Original, uncorrected Miran data)

		XYLENE CONCENTRATION				
		Time Elapsed Following Spray				
Mask Brand		1 min	2 min	3 min	4 min	5 min
3-M	MASK CONC. (ppm)	860	470	220	75	35
	CHAMBER CONC. (ppm)	850	540	250	105	54
Norton	MASK CONC. (ppm)	700	370	135	50	19
	CHAMBER CONC. (ppm)	850	540	220	88	35
Gerson	MASK CONC. (ppm)	740	375	130	43	14
	CHAMBER CONC. (ppm)	990	560	220	73	16
Willson	MASK CONC. (ppm)	840	500	200	78	33
	CHAMBER CONC. (ppm)	900	640	325	145	59

SUMMARY OF MASK AND CHAMBER XYLENE CONCENTRATIONS
FOLLOWING A THREE SECOND SPRAY OF 100% PAINT THINNER
(Original, uncorrected Miran data)

		XYLENE CONCENTRATION				
		Time Elapsed Following Spray				
Mask Brand		1 min	2 min	3 min	4 min	5 min
3-M	MASK CONC. (ppm)	1550	770	340	135	49
	CHAMBER CONC. (ppm)	1450	950	440	180	80
Norton	MASK CONC. (ppm)	1050	580	245	90	38
	CHAMBER CONC. (ppm)	1320	860	380	147	58
Gerson	MASK CONC. (ppm)	1280	740	210	67	20
	CHAMBER CONC. (ppm)	1350	930	440	200	77
Willson	MASK CONC. (ppm)	1250	730	310	127	54
	CHAMBER CONC. (ppm)	1350	950	490	230	100

SUMMARY OF MASK AND CHAMBER XYLENE CONCENTRATIONS
FOLLOWING A FOUR SECOND SPRAY OF 100% PAINT THINNER
(Original, uncorrected Miran data)

		XYLENE CONCENTRATION				
		Time Elapsed Following Spray				
Mask Brand		1 min	2 min	3 min	4 min	5 min
3-M	MASK CONC. (ppm)	1900	1000	430	170	70
	CHAMBER CONC. (ppm)	1850	1200	540	230	95
Norton	MASK CONC. (ppm)	1400	770	300	103	43
	CHAMBER CONC. (ppm)	1650	1100	460	168	65
Gerson	MASK CONC. (ppm)	1600	930	360	165	85
	CHAMBER CONC. (ppm)	1700	1270	600	325	105
Willson	MASK CONC. (ppm)	1480	850	380	155	65
	CHAMBER CONC. (ppm)	1700	1270	710	330	145

SUMMARY OF MASK AND CHAMBER XYLENE CONCENTRATIONS
FOLLOWING A FIVE SECOND SPRAY OF 100% PAINT THINNER
(Original, uncorrected Miran data)

		XYLENE CONCENTRATION				
		Time Elapsed Following Spray				
Mask Brand		1 min	2 min	3 min	4 min	5 min
3-M	MASK CONC. (ppm)	2300	1350	505	230	105
	CHAMBER CONC. (ppm)	2500	1650	700	330	140
Norton	MASK CONC. (ppm)	1900	1080	440	170	68
	CHAMBER CONC. (ppm)	2250	1600	670	255	95
Gerson	MASK CONC. (ppm)	1950	1050	500	250	122
	CHAMBER CONC. (ppm)	2100	1352	730	480	200
Willson	MASK CONC. (ppm)	1900	1050	495	205	97
	CHAMBER CONC. (ppm)	2050	1390	760	348	170

APPENDIX D

Summary of Statistical Analysis of Variability Between Mask and Chamber Concentration Following Thinner Spray

The statistical test utilized was a two-way analysis of variance for the log ratios of mask and chamber concentrations.

Ho : No significant effect of spray duration or time elapsed after spray.

log(chamber conc./mask conc.) = 0

Reject Ho : If p-value is $\leq$ 0.05

Effect of spray duration: p-value = 0.049

Effect of time elapsed: p-value = 0.0001

Therefore, Ho is rejected.

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