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UNITED STATES AIR FORCE
AFIOH

Sensory Irritation Study in Mice: JP-5, JP-TS, JP-7, DFM, JP-10

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July 2004

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11. SUPPLEMENTARY NOTES

This is the second of two related projects for the quantitative and comparative characterization of the potential of various jet fuels to cause respiratory tract sensory irritation. The first of these projects was reported and released as IERA-RS-BR-SR-2001-0005.

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Approved for public release; distribution unlimited.

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13. ABSTRACT *(Maximum 200 words)*

AFIOH (formerly the Air Force Institute for Environment, Safety and Occupational Health Risk Analysis {AFIERA}), in concert with Army and Navy colleagues, designed a study based on ASTM's "Standard Method E 981-84" to characterize and compare the relative potency of five hydrocarbon fuels to cause respiratory tract sensory irritation. These fuels (JP-5, JP-TS, JP-7, DFM, JP-10) were administered for 30 minute periods by means of a head-only exposure system to groups of 4 male Swiss-Webster mice. Test atmospheres laden with these fuels were presented as vapor/aerosol mixtures to insure that all of each fuel's constituents were represented in the test atmospheres. Analytical sampling data for concentration revealed differences in the prevalence and distribution of these constituents between the vapor and aerosol phases of the test atmospheres. Each fuel was tested at one or more concentrations in air that resulted in minimal to severe decreases in respiratory rate. All fuels evoked breathing patterns that were characteristic of upper airway sensory irritation at all exposure levels. Within the context of this study, there was no apparent evidence of pulmonary (deep lung) irritation or narcosis at any exposure level. The concentration of JP-5 that reduced the respiratory rate by 50% (RD50) was calculated from the data to be 3338 mg/m3. Exposures with the other fuels were targeted for levels near the RD50 for JP-5 and JP-8 in order to compare their relative irritancy. Based on the results of this study, the relative irritancy of the fuels tested in this study may be ranked as follows: DFM > JP-5 >JP-7 > JP-TS > JP-10.

14. SUBJECT TERMS

Upper respiratory tract, sensory irritation, Alarie study, vapor exposure, aerosol exposures, mixed vapor/aerosol exposure, JP-5, JP-TS, JP-7, DFM, JP-10

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ExxonMobil BIOMEDICAL SCIENCES, INC.

FINAL REPORT

PROJECT NUMBER: 112451

TEST SUBSTANCES:

JP-5 (MRD-01-124)
JPTS (MRD-02-357)
JP-7 (MRD-02-358)
DFM (MRD-01-087)
JP-10 (MRD-02-359)

SENSORY IRRITATION STUDY IN MICE

PERFORMED FOR:

Air Force Institute for Environment, Safety,
And Occupational Health Risk Analysis
2513 Kennedy Circle – Bldg 180
Brooks Air force Base, TX 78235-5116

PERFORMED AT:

ExxonMobil Biomedical Sciences, Inc.
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COMPLETION DATE: July 26, 2004

04TP 66

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APPROVAL SIGNATURES

J. J. Freeman, Ph.D., D.A.B.T.
Acting Section Head, Laboratory Operations

26 Jul 04
Date

I hereby accept responsibility for the validity of these data and declare that to the best of my knowledge, the study contained herein was performed under my supervision in compliance with OECD Principles of Good Laboratory Practice except as follows:

The EMBSI Industrial Hygiene Analytical Service Laboratory (IHASL) is not a fully GLP compliant laboratory, although it is accredited by the American Industrial Hygiene Association.

The number of the balance used to dispense test material was not recorded on 7, and 9 October 2002. This deviation from the GLPs should have no adverse effect on the study.

Frederick T. Whitman, M.P.H.
Study Director
ExxonMobil Biomedical Sciences, Inc.
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Annandale, New Jersey 08801-0971

26 JUL 04
Date

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26 Jul 04
Date

QUALITY ASSURANCE STATEMENT

STUDY NUMBER: 112451

TEST SUBSTANCES: MRD-01-124, MRD-01-087, MRD-02-357, MRD-02-358, MRD-02-359

STUDY SPONSOR: Air Force Institute for Environment, Safety, and Occupational Health Risk Analysis

Listed below are the inspections performed by the Quality Assurance Unit of ExxonMobil Biomedical Sciences, Inc., the date(s) of inspection, and the date(s) findings were reported to the Study Director and Management.

Study Phase Inspected	Date(s) of Inspection	Reported to Study Director	Reported to Management
Protocol	29,30 Apr 02	30 Apr 02	14,22 May 02
Particle Sizing	07,21 Oct 02	21 Oct 02	22 Oct 02 & 05 Nov 02
Final Report	07-15 Apr 03	23 Apr 03	07,09 Jul 04
Second Review of Final Report	23 Jan 04, 01-04 Jun 04, 07-11 Jun 04, 14-16 Jun 04	29 Jun 04	14,15 Jul 04
Third Review of Final Report	12,13 Jul 04	14 Jul 04	14,15 Jul 04

The final report accurately reflects the methods, procedures and observations documented in the raw data.

W. James Bover, Ph.D.
Data Integrity & Quality Assurance/Archives
Section Head

26 Jul 04
Date

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Compound Preparation Supervisor:	E. J. Febbo, M.S.
Quality Assurance/Archives Section Head:	W. J. Bover, Ph.D.
Veterinarian:	R. L. Harris, D.V.M.

SUMMARY

This study was conducted to evaluate the sensory irritation potential of the test substances JP-5 (MRD-01-124), JPTS (MRD-02-357), JP-7 (MRD-02-358), DFM (MRD-01-087), and JP-10 (MRD-02-359) in mice during inhalation exposure.

The test substances were administered head-only for 30 minutes to groups of four male Swiss-Webster mice as mixed vapor/aerosol or vapor-only atmospheres. Group mean exposure concentrations were 804, 1285, 2031, 2856, and 13417 mg/m^3 (JP-5), 3622 and 3729 mg/m^3 (JPTS), 2239 and 2419 mg/m^3 (JP-7), 1030 and 2045 mg/m^3 (DFM), and 5412 mg/m^3 (JP-10). Analytical samples for both aerosol and vapor phase concentrations were taken three times during each exposure. One aerosol and one vapor sample from each exposure was analyzed for 28 individual hydrocarbons in order to assess differences in the distribution and relative proportions of individual hydrocarbon species contained in the aerosol and vapor phases. Additional analytical measurements conducted during each exposure included continuous monitoring of test atmosphere stability by on-line vapor and aerosol analyzers. Samples were collected for aerosol particle size analysis during at least one exposure for each test substance.

Each of the five test substances evoked breathing patterns characteristic of upper airway sensory irritation with varying levels of respiratory rate depression. Within the context and limits of this study, examination of the breathing patterns revealed no apparent pulmonary (deep lung) irritation or narcosis at any level for all five substances.

JP-5 was tested over a range of air concentrations that resulted in minimal to extreme respiratory rate decreases (>50% decrease). This allowed calculation of an RD_{50} value for JP-5 of 3338 mg/m^3 with a 95% confidence interval of 1759-6332 mg/m^3.

Exposures with the other four test substances were targeted for levels near the RD_{50} value for JP-5 and a previously tested similar fuel (JP-8) in order to compare their relative irritancy. Based on these results, the relative irritancy of the substances tested in this study may be ranked as follows : DFM > JP-5 > JP-7 > JPTS > JP-10.

INTRODUCTION

This study was conducted in order to evaluate the sensory irritation potential in the Swiss-Webster mouse of JP-5 (MRD-01-124), JPTS (MRD-02-357), JP-7 (MRD-02-358), DFM (MRD-01-087) and JP-10 (MRD-02-359).

Alarie (1966) proposed that a correlation exists between chemicals causing a decrease in respiratory rate in male Swiss-Webster-mice and sensory irritant properties in humans. Measurement of the reflex decrease in respiratory rate that occurs with stimulation of trigeminal nerve endings in the nasal mucosa of mice therefore may be used as a screening tool to predict acceptable exposure concentrations or to help establish threshold limit values, short-term exposure limits, etc. The RD_{50}, defined as the concentration associated with a 50% decrease in respiratory rate, is often used as a benchmark to evaluate airborne chemicals or mixtures of chemicals for sensory irritant effects and has been adopted and standardized by ASTM as a validated method for characterizing respiratory tract irritation (E981-84).

The study was conducted by ExxonMobil Biomedical Sciences, Inc. (EMBSI), Laboratory Operations, Mammalian Toxicology Laboratory, 1545 Route 22 East, P.O. Box 971, Annandale, New Jersey 08801-0971 which is accredited by the Association for the Assessment and Accreditation of Laboratory Animal Care (AAALAC International). The analytical portion of the study was conducted by the EMBSI Industrial Hygiene Analytical Service Laboratory (IHASL), which is accredited by the American Industrial Hygiene Association.

Study Initiation (Protocol Signature Date)

May 31, 2002

Experimental Start and Completion Date

June 26, 2002 and November 13, 2002

Justification for Selection of Test System

Swiss-Webster mice are the strain and species of choice for sensory irritation studies (ASTM E981-84, 1996).

Justification of Dosing Route

Potential human exposure may be by the inhalation route.

INTRODUCTION (CONT'D)

Compliance

This study was conducted in compliance with the following standards:

OECD, Organization for Economic Cooperation and Development, Principles of Good Laboratory Practice, C(97) 186/Final, 1997.

United States Environmental Protection Agency, 40 CFR Part 792, Toxic Substances Control Act (TSCA), Good Laboratory Practice Standards (GLP's), Final Rule 1989.

This study was conducted in general agreement with the following guidelines and standards:

Standard Test Method for Estimating Sensory Irritation of Airborne Chemicals. American Society for Testing and Materials. Designation: E981-84 (Reapproved 1996).

Animal Welfare Act of 1966 (P.L. 89-544), as amended in 1970, 1976, and 1985. Code of Federal Regulations, Title 9 [Animals and Animal Products], Subchapter A - Animal Welfare Parts 1, 2, and 3.

Guide for the Care and Use of Laboratory Animals, Institute of Laboratory Animal Resources, Commission on Life Sciences, National Research Council, National Academy Press, Washington, D.C., 1996.

MATERIALS AND METHODS

TEST SUBSTANCE

Substance Identification

EMBSI ID	Sponsor ID	Description	Receipt	Expiration
JP-5	MRD-01-124	light amber liquid	15Nov01	Nov06
JPTS	MRD-02-357	clear liquid	18Mar02	Mar07
JP-7	MRD-02-358	clear liquid	18Mar02	Mar07
DFM	MRD-01-087	dark amber liquid	02Nov01	Nov06
JP-10	MRD-02-359	clear liquid	18Mar02	Mar07

SUPPLIER

JP-5	JPTS, JP-7	JP-10	DFM
MCAS	Marathon Ashland	Sun Company Inc.	Fleet and Industrial
Miramar	Petroleum, LLC.	Ten Penn Center	Supply Center
BLDG 7209	539 S. Main St.	1801 Market St.	Point Loma Annex
San Diego, CA	Findlay, OH	Phila., PA	San Diego, CA

Storage Conditions: Room temperature

Each test substance, as received, was considered the "pure" substance.

Characterization of Test Substance

Documentation of the methods of synthesis, fabrication, and/or derivation of the test substance, and the stability, identity, purity, and composition or other characteristics which appropriately identify the test substance are the responsibility of the Sponsor (2513 Kennedy Circle - Bldg 180, Brooks AFB, TX 78235-5116).

Analysis of Mixtures

Not applicable to this study.

Solubility

Not applicable to this study.

Sample Retention

Archival samples of the test substances were not retained for this study.

TEST SUBSTANCE (CONT'D)

Carrier

Air

TEST SYSTEM

Test Animal

Species:	Mouse (male)
Strain/stock:	Swiss-Webster
Supplier:	Charles River Laboratories, Inc. Portage, MI Kingston, NY

Animal Receipt Information

Receipt Date:	Control Number:
30 May 2002	2121521
1 August 2002	2155865
11 September 2002	3177995
22 October 2002	1200196

Quarantine and Acclimation Period

At least 7 days; animals were examined for viability at least once daily.

Number and Sex/Group

4 males

Age at Initiation of Dosing

Approximately 5 - 13 weeks

TEST SYSTEM (CONT'D)

Weight at Initiation of Dosing

24 - 30 grams

Animal Identification

Tail tattoo and corresponding cage identification.

Selection

More animals than required for the conduct of the study were purchased and acclimated. Animals determined to be unsuitable for inclusion in the study because of poor health, outlying body weight, or other abnormalities were excluded from selection by the attending veterinarian, Study Director and/or the technical staff. Animals were allocated to study groups immediately prior to exposure on the basis of general health and body weight requirements.

Housing

Room:	PE112
Housing:	Single housed during the study period.
Caging:	Suspended stainless steel and wire mesh with absorbent paper below cages.

Feed

PMI Certified Rodent Diet Checkers 5002

Manufacturer:	PMI Feeds, Richmond, Indiana
Analysis:	Performed by PMI Feeds. Copies of the feed analyses are maintained at the EMBSI Laboratory.
Contaminants:	There were no known contaminants in the feed believed to have been present at levels that may have interfered with this study.

The availability of feed was checked at least once daily for all animals.

TEST SYSTEM (CONT'D)

Water

Automatic Watering System, ad libitum

Supplier:	ExxonMobil Research and Engineering, Potable Water System.
Analysis:	Periodic analysis is the responsibility of EMBSI. A copy of the results is maintained at EMBSI.
Contaminants:	There were no known contaminants in the water believed to have been present at levels that may have interfered with this study.

The availability of water was checked at least once daily for all animals.

Environmental Conditions

Temperature:	64 to 72 degrees Fahrenheit
Humidity:	30 to 70 percent relative humidity
Lighting:	Approximately 12 hours light (0600 to 1800) and 12 hours dark (1800 to 0600) by automatic timer.

Monitored at least once daily. Additionally, a non-validated computerized system monitored the temperature, humidity, and lighting continuously for alarm purposes.

EXPERIMENTAL DESIGN

Preparation of Test Substance

The test substance was administered as received.

Experimental Groups

Test Substance	Mean Analytical Concentration (mg/m^3)	Number of Animals
JP - 5 (MRD-01-124)	804 ± 248	4
JP - 5 (MRD-01-124)	1285 ± 55	4
JP - 5 (MRD-01-124)	2031 ± 148	4
JP - 5 (MRD-01-124)	2856 ± 86	4
JP - 5 (MRD-01-124)	13417 ± 698	4
JPTS (MRD-02-357)	3622 ± 496	4
JPTS (MRD-02-357)	3729 ± 82	4
JP - 7 (MRD-02-358)	2239 ± 131	4
JP - 7 (MRD-02-358)	2419 ± 163	4
DFM (MRD-01-087)	1030 ± 76	4
DFM (MRD-01-087)	2045 ± 33	4
JP - 10 (MRD-02-359)	5412 ± 381	4

EXPERIMENTAL DESIGN (CONT'D)

Administration of Test Substance

Figures 1-3 present schematic drawings of the test atmosphere generation and exposure systems.

The wide range of constituents and modest volatilities exhibited by the fuels tested in this study, combined with the goal of characterizing each fuel's potential to cause upper respiratory tract sensory irritation, required the generation of test atmospheres at levels that exceeded the saturation concentration of some of the fuels' constituents. Nebulization and atomization of these fuels resulted in a mixed atmosphere - each fuel's more volatile constituents were vaporized while its less volatile constituents remained as aerosols. With the single exception of JP-5, all test atmospheres were generated as aerosol-vapor mixtures. For purposes of characterizing its RD_{50}, JP-5 was also tested as an aerosol-vapor mixture. An extra exposure group was added to better characterize the potential of JP-5 vapors (at an exposure level that still represented all of its constituents) to cause respiratory tract irritation.

Initially, for the first three exposures, mixed vapor-liquid droplet aerosol atmospheres for JP-5 were generated using a Collison nebulizer (see Fig 2). The nebulizer's glass reservoir was filled with the test substance to a level just below the top of the liquid feed tube. Compressed air was supplied to the nebulizer, metered by a control valve and pressure gauge to adjust the rate of aerosolization. The Collison nebulizer aspirates liquid at a rate that depends upon the pressure of the air supplied to it. The vapor-aerosol mixture combined with additional room air as both were drawn from the reservoir, through a glass diffuser and into the exposure chamber.

The single vapor-only test atmosphere (JP-5) was generated by using a syringe pump to deliver the test substance to the inside surface of a heated glass "counter current" generator (see Fig. 1). The vapor generator was a cylindrical glass tube impressed with a spiral indentation that served as a channel for the liquid test substance. The spiral indentation was heated with heating tape to a constant temperature (dependent on the target concentration), and continuously monitored by a thermocouple probe and digital thermometer. The test substance volatilized as it flowed down the heated generator. The resulting vapors, representing the entire fuel, mixed with clean room air as both were drawn up the generator, through the glass diffuser, and into the exposure chamber.

In order to improve control and better achieve concentrations targeted for JP-5, JP-7, JPTS, DFM, and JP-10, the remaining aerosol exposures for these fuels were conducted using an alternate air atomizing system (see Fig. 3). The test substances were delivered at a controlled rate governed by a syringe pump (Sage, Model 352) to the spray atomizer (Spraying Systems, Inc.). Compressed air was supplied to the atomizer at approximately 15 psi. The resulting vapor-aerosol mixture then passed through a glass diffuser before being drawn into the glass exposure chamber.

EXPERIMENTAL DESIGN (CONT'D)

Concentration Determinations

Exposure concentrations were determined on both a nominal and analytical basis. The nominal concentration was calculated by dividing the net weight of the test substance used during the exposure by the total volume of air passing through the chamber. Analytical chamber concentrations were determined three times during each exposure by drawing a known volume of chamber air, metered by a critical orifice, through a sampling train consisting of a 25 mm glass fiber filter for analysis of non-volatile aerosol followed by a charcoal sorbent tube for total volatile hydrocarbons (vapor) (see Fig. 4). After sampling, the sorbent tubes were capped and refrigerated. The filter samples were placed in sealed glass vials containing approximately 10 ml carbon disulfide. The sorbent tubes and filters were then submitted to the Industrial Hygiene Analytical Service Laboratory (IHASL) for subsequent analysis.

Both sample types (aerosol and vapor) were analyzed by gas chromatography/FID and each reported as total hydrocarbon concentration (THC). Additionally, one sample set (filter and sorbent tube) from each exposure was analyzed for a standard list of representative hydrocarbons in order to evaluate and compare the distribution of individual components within the aerosol and vapor phases.

The analytical exposure concentrations (THC) were calculated both separately and as the sum of the aerosol and vapor phase concentrations. One sample of each neat test substance also was analyzed for reference and comparison to the chamber samples.

An on-line infrared vapor monitor (MIRAN 1A) was used during each exposure (when practical due to the amount of aerosol present) to monitor the relative levels and stability of the vapor phase of the chamber atmosphere.

An on-line photometric particle monitor (Sibata Model P5) also was used during each exposure to monitor the relative levels and stability of the aerosol present in the chamber atmospheres.

EXPERIMENTAL DESIGN (CONT'D)

Particle Size Analysis

A particle size determination of the aerosol portion of the test atmosphere was conducted for each test substance, during at least one representative animal exposure, using a Sierra Instruments Model 210 Cascade Impactor. Preweighed glass fiber filters were used to collect the aerosol on each stage. A bulk estimation technique was employed to characterize the particle size distribution of the test atmosphere. The change in weight of the filter for each stage was measured and the cumulative percent of the sample collected on each stage was calculated. This information plus the stage constants (size cutoff diameters in microns) for the impactor were used, with the aid of a computer, to calculate the 15.9%, 50.0%, and 84.1% particle sizes (equivalent aerodynamic diameter), the geometric standard deviation, and the estimated percent of the aerosol less than or equal to 1 and 10 microns in size.

Additionally, the filters from the three stages closest to the 15.9%, 50.0%, and 84.1% particle sizes (equivalent aerodynamic diameter) were analyzed by gas chromotography/FID for individual hydrocarbon concentrations.

Animal Exposure Procedures

The chamber used for the exposures was all glass and had a total volume of approximately 4.0 liters. It operated under slight negative pressure to the room at approximately 30.0 liters per minute airflow, regulated by a calibrated differential orifice meter. The theoretical equilibration time (T_{99}) was calculated as 36 seconds, which was approximately 2% of the exposure duration.

The test animals were loaded into body-only plethysmographs, which isolated the animal's head from its body via a latex dam. The plethysmographs were then mounted onto the glass exposure chamber such that the animals received head-only exposures to the test atmosphere.

Each animal was monitored by a differential air pressure transducer that converted the tidal pressure changes produced by the animal's breathing within the plethysmograph into an electrical signal. The signals produced by the tidal pressure changes (animal breathing patterns) were measured using Validyne Very Low Flow pressure transducers, conditioned using Gould transducer signal conditioners (Model 13-6615-50) mounted in a Gould 6600 series 8 channel case, and recorded on a Gould Viper-TA Thermal Array Recorder.

EXPERIMENTAL DESIGN (CONT'D)

Each exposure group was monitored in the following sequence:

Pre-test:	At least 10 minutes of room air to establish baseline rates.
Exposure:	30 minutes of test substance exposure.
Recovery:	At least 10 minutes of room air to monitor return to pre-test levels.

Animal Observations

Individual animal observations were performed before, during and after each exposure.

Termination

All test animals were euthanized via asphyxiation with carbon dioxide after completion of the exposure and discarded without further evaluation.

Animal Response Evaluation

Animal respiratory rates and breathing patterns were determined by examination of the oscillographic record. The average pretest rate and the lowest representative rate during exposure were determined for each animal in a group. The low rate was divided by the pretest rate to obtain a "Percent of Pretest" value. The Percent of Pretest value was subtracted from 100% to yield the animal response (Percent Change in Rate). Individual animals in each group were evaluated first, and then averaged to determine the mean group response. The post-exposure (recovery) rates were similarly evaluated to determine the recovery response - the percent return to pretest rates.

EXPERIMENTAL DESIGN (CONT'D)

Statistical Analysis

Statistical analyses included means and standard deviations for relevant study data. (Snedecor and Cochran, 1989).

The mean group responses and exposure concentrations for JP-5 were entered into a computerized least-squares analysis to determine the concentration of test material required to reduce respiratory rate by 50% (RD_{50}), the 95% confidence limits, the slope function of the plotted data, and the fit of the data from the experiment (Snedecor and Cochran, 1989: Litchfield and Wilcoxon, 1949).

Records

The protocol, all raw data, the final report, computer generated listings of raw data, and supporting documentation are maintained on file in the EMBSI Laboratory Archives. Raw data for the analytical samples will be maintained in the Industrial Hygiene Laboratory files.

RESULTS

EXPOSURE CONCENTRATIONS:

Tables 1-2 and 6-8, and Figures 1A-12A present summaries of the analytical data, analytical methods and sample chromatograms for each of the test substances.

All exposure atmospheres for the five test substances were generated as aerosol/vapor mixtures, except one exposure with JP-5 that was generated as a maximum vapor concentration for comparison purposes. The liquid droplet aerosols initially were mixed with dilution air in a glass mixing vessel, thus allowing them to partition into vapor and aerosol phases for a short period prior to entering the animal exposure chamber. Under the conditions of this study, and since the exposure system used for all exposures was similar, it can be inferred that the relative volatility of the test substances could be ranked as (highest to lowest volatility):

$$\text{JP-10} > \text{JPTS} > \text{JP-5} > \text{JP-7} \geq \text{DFM}$$

As would be expected, there were clear differences in the distribution and relative proportions of individual hydrocarbon species contained in the aerosol and vapor phases with the lighter molecular weight hydrocarbons more abundant in the vapor samples (see Appendix A for individual hydrocarbon analyses and chromatograms).

JP-5 (MRD-01-124)

Five groups of male mice were exposed for 30 minutes to total analytical concentrations of 13417, 2856, 2031, 1285 (mixed aerosol/vapor), or 804 mg/m^3 (vapor only). The aerosol-generated atmospheres were predominantly vapor, with the aerosol portion ranging from 14 to 25% of the total concentration. The 804 mg/m3 exposure level was considered the maximum attainable concentration that still represented the entire fuel at ambient conditions. No aerosol was detected by gravimetric sampling or the on-line photometric particle monitor.

A particle size sample was taken during the exposure at 2031 mg/m3. The results showed a median aerodynamic particle size of 1.76 microns, with 95.5% of the particles less than or equal to 10 microns and 29.2% less than or equal to 1.0 micron. This demonstrates that the aerosol was respirable.

RESULTS (CONT'D)

JPTS (MRD-02-357)

Two groups of male mice were exposed for 30 minutes to total analytical concentrations of 3729 and 3622 mg/m^3. The exposures for this test substance (generated as an aerosol) were predominantly vapor with the proportion of aerosol ranging from 3% to 15%.

A particle size sample was taken during both exposures. For the sample taken at 3729 mg/m^3, there was insufficient aerosol present to accurately calculate a particle size distribution. The results at 3622 mg/m^3 showed a median aerodynamic particle size of 1.61 microns, with 94.7% of the particles less than or equal to 10 microns and 33.6% less than or equal to 1.0 micron. This demonstrates that the aerosol was respirable.

JP-7 (MRD-02-358)

Two groups of male mice were exposed for 30 minutes to total analytical concentrations of 2239 and 2419 mg/m^3. The exposures for this test substance were predominantly vapor with the proportion of aerosol ranging from 27% to 29%.

A particle size sample was taken during the exposure at the 2239 mg/m^3 level. The results of this analysis showed a median aerodynamic particle size of 3.33 microns, with 97.6% of the particles less than or equal to 10 microns and 1.5% less than or equal to 1.0 micron. This demonstrates that the aerosol phase was respirable.

DFM (MRD-01-087)

Two groups of male mice were exposed for 30 minutes to total analytical concentrations of 2045 and 1030 mg/m^3. The aerosol-generated exposures for this test substance were mostly vapor although they included significant amounts of aerosol. The proportion of aerosol was 40% at 2045 mg/m^3 and 24% at 1030 mg/m^3.

A particle size sample was taken during the exposure at the 1030 mg/m^3 level. The results of this analysis showed a median aerodynamic particle size of 2.79 microns, with 98.7% of the particles less than or equal to 10 microns and 3.8% less than or equal to 1.0 micron. This demonstrates that the aerosol was respirable.

JP-10 (MRD-02-359)

One group of male mice was exposed for 30 minutes to a total analytical concentration of 5412 mg/m^3. The exposure for this test substance (generated as an aerosol) was essentially all vapor with an insignificant amount of aerosol (<0.1%) detected.

A particle size sample was taken during the exposure, however the absence of significant aerosol precluded a meaningful analysis.

RESULTS (CONT'D)

ANIMAL RESPONSE DATA:

Tables 3-5 present summaries of the animal response data. Figures 5-15 present graphs of the group mean and individual respiratory rates.

All five test substances elicited breathing patterns and respiratory rate decreases characteristic of sensory irritation at all levels tested. There was no evidence of narcosis (absence of spontaneous animal movements) or pulmonary (deep lung) irritation in any mice at any level for all five test substances.

JP-5 (MRD-01-124)

Group mean respiratory rates were decreased from baseline values 62%, 48%, 46%, and 42% at mean exposure concentrations of 13417, 2856, 2031, and 1285 mg/m^3, respectively. Exposure to vapor also provoked a slight decrease in respiratory rate (13% at 804 mg/m^3). Breathing patterns characteristic of sensory irritation were observed in all mice in the four highest exposure concentrations; only 3 of the 4 mice in the lowest exposure group exhibited slight irritation (1 was normal).

All of the mice in all five groups exhibited a slightly depressed recovery to baseline levels following exposure; the recoveries were 68, 78, 82, 85, and 89 percent of pretest rates at mean exposure concentrations of 13417, 2856, 2031, 1285, and 804 mg/m^3, respectively.

All of the mice in all five groups appeared normal at clinical observations performed prior to, during, and immediately after the exposures.

JPTS (MRD-02-357)

Group mean respiratory rates were decreased from baseline values 36% and 32% at mean exposure concentrations of 3729 and 3622 mg/m^3, respectively. Breathing patterns characteristic of sensory irritation were observed in all mice in both groups.

The post-exposure recovery responses were slightly below normal in both groups, with the mice recovering to 88% of baseline values at both 3729 and 3622 mg/m^3.

The mice in both groups appeared normal at clinical observations performed prior to, during, and immediately after the exposures.

RESULTS (CONT'D)

JP-7 (MRD-02-358)

Group mean respiratory rates were decreased from baseline values 35% and 30% at mean exposure concentrations of 2419 and 2239 mg/m^3, respectively. Breathing patterns characteristic of sensory irritation were observed in all mice in both groups.

The post-exposure recovery responses were slightly below normal for both groups - 80% and 94% of baseline values at 2419 and 2239 mg/m^3, respectively.

The mice in both groups appeared normal at clinical observations performed prior to, during, and immediately after the exposures.

DFM (MRD-01-087)

Group mean respiratory rates were decreased from baseline values 58% and 49% at mean exposure concentrations of 2045 and 1030 mg/m^3, respectively. Breathing patterns characteristic of sensory irritation were observed in all mice in both groups.

All of the mice in both groups exhibited a decreased recovery following exposure with the amount of depression proportional to the exposure concentration 59% and 68% of baseline values at 2045 and 1030 mg/m^3, respectively.

The mice in both groups appeared normal at clinical observations performed prior to, during, and immediately after the exposures.

JP-10 (MRD-02-359)

Group mean respiratory rates were decreased from baseline values 29% at a mean exposure of 5412 mg/m^3. Breathing patterns characteristic of sensory irritation were observed in three of the four mice.

The post-exposure recovery responses were near normal baseline values; 82% at 5412 mg/m^3.

All mice appeared normal at clinical observations performed prior to, during, and immediately after the exposures.

RESULTS (CONT'D)

ANALYSIS OF NEAT TEST SUBSTANCES:

Table 7A, and Figures 1A-6A, present summaries of the analytical data, and sample chromatograms for the neat test substances as well as the neat, used (post-exposure) sample of JP-5. The analysis indicates a very slight decrease in the proportion of lower molecular weight hydrocarbons for the used sample of JP-5, although the overall distribution of individual hydrocarbon species was very similar.

RD_{50} CALCULATION:

Figure 16 presents a graph of the log-exposure concentrations vs. respiratory rate decrease for the JP-5 aerosol exposures. The vapor-only exposure level (804 mg/m^3) was excluded from these calculations.

The exposure concentration of the test substance that would produce a 50% decrease in respiratory rate (RD_{50}) was calculated to be 3338 mg/m^3, with 95% confidence limits of 1759 to 6332 mg/m^3.

DISCUSSION

Exposures to a series of four aerosol-generated test atmospheres of the test substance JP-5 (MRD-01-124) produced breathing patterns characteristic of upper airway sensory irritation in mice. The exposure concentrations ranged from 1285 to 13,417 mg/m^3 and produced group mean maximal respiratory rate decreases of 42% to 62%. The observed rate decreases were linearly related to the corresponding exposure concentrations and allowed calculation of an RD_{50} value of 3338 mg/m^3 for JP-5. This compares to a previously determined RD_{50} value of 2876 mg/m^3 for JP-8. An additional exposure to the maximum attainable vapor-only atmosphere of JP-5 was conducted at 804 mg/m^3 and produced a respiratory rate decrease of 13%. This response is significantly lower than that from the aerosol-generated exposure groups.

Four additional fuels, JPTS, JP-7, DFM, and JP-10 also were evaluated using similar exposure methods. These test substances also produced breathing patterns characteristic of upper airway sensory irritation at all levels tested. The study protocol specified single exposures at a common target concentration (2876 mg/m^3) in order to allow direct comparisons of their relative respiratory irritation potential. Initial exposure concentrations for all four substances did not adequately achieve the targeted level therefore repeat exposures were conducted for JPTS, JP-7, and DFM. The single exposure with JP-10 was considered adequate to characterize its' irritation potential in relation to the other fuels. The three repeat exposures also fell outside the target concentration (JPTS = 26% higher; JP-7 = 16% lower; DFM = 29% lower) however the combined information was considered sufficient to rank the relative irritation potential of the five test substances. The following results were obtained for selected exposure concentrations:

Test Substance	Concentration (mg/m^3)	Respiratory Rate Decrease (%)
JP-10	5412	29
JPTS	3622	32
JP-7	2419	35
JP-5	2031	46
DFM	2045	58

These results suggest the following ranking for relative respiratory irritation potential:

DFM > JP-5 > JP-7 > JPTS > JP-10

DISCUSSION (CONT'D)

This ranking is also consistent with the observed relative volatility of the five fuels, i.e the less volatile (higher aerosol percentage) fuels were more irritating. Examination of the chromatography for the neat fuel samples, as well as the aerosol and vapor phase samples, shows differences in the molecular weight distribution among these complex hydrocarbon mixtures. The increased abundance of higher molecular weight species in the less volatile test substances may drive the observed irritation response. The difference in irritation response was seen both among the fuels and within the one fuel tested as both aerosol-generated and vapor-only atmospheres (JP-5). The vapor-only exposure produced a significantly lower rate decrease compared to the aerosol-containing exposures.

This general observation does not consider other differences among the test substances such as the presence or absence of organic or inorganic chemical additives. The chromatography for JP-10 revealed that unlike the other fuels it is composed principally of a single chemical, thus the observed irritation response can be attributed solely to that chemical.

CONCLUSION

Each of the five test substances evaluated in this study evoked breathing patterns characteristic of upper airway sensory irritation with varying levels of respiratory rate depression. Within the context and limits of this study, examination of the breathing patterns revealed no apparent pulmonary (deep lung) irritation or narcosis at any level for all five substances.

All exposure atmospheres for the five test substances were generated as aerosols, except one exposure with JP-5 that was generated as a maximum vapor concentration for comparison purposes. Particle size analysis was performed for each substance and demonstrated that the aerosol portion was highly respirable. Analytical sampling data demonstrated clear differences in the distribution and relative proportions of individual hydrocarbon species contained in the neat test substances as well as the aerosol and vapor phases of the test atmospheres.

JP-5 was tested over a range of air concentrations that resulted in varying respiratory rate decreases. This allowed calculation of an RD_{50} value for JP-5 of 3338 mg/m^3 with a 95% confidence interval of 1759-6332 mg/m^3.

Exposures with the other four test substances were targeted for levels near the RD_{50} value for JP-5 and a previously tested similar fuel (JP-8) in order to compare their relative irritancy. Based on these results, the relative respiratory irritation ranking of the substances tested in this study could be described as: DFM > JP-5 > JP-7 > JPTS > JP-10.

PROTOCOL EXCEPTIONS

The environmental conditions (animal room temperature, humidity, or airflow) were slightly outside of the ranges specified in the protocol on twelve occasions over the duration of the study.

Some of the animals used were slightly outside of the protocol defined age range of 5-10 weeks.

These slight and transient deviations should not have affected the quality or integrity of the data.

REFERENCES

Additional references for the Alarie sensory irritation assay:

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FIGURE 1 - SCHEMATIC OF GENERATION AND EXPOSURE SYSTEM (COUNTER-CURRENT VAPOR GENERATOR)

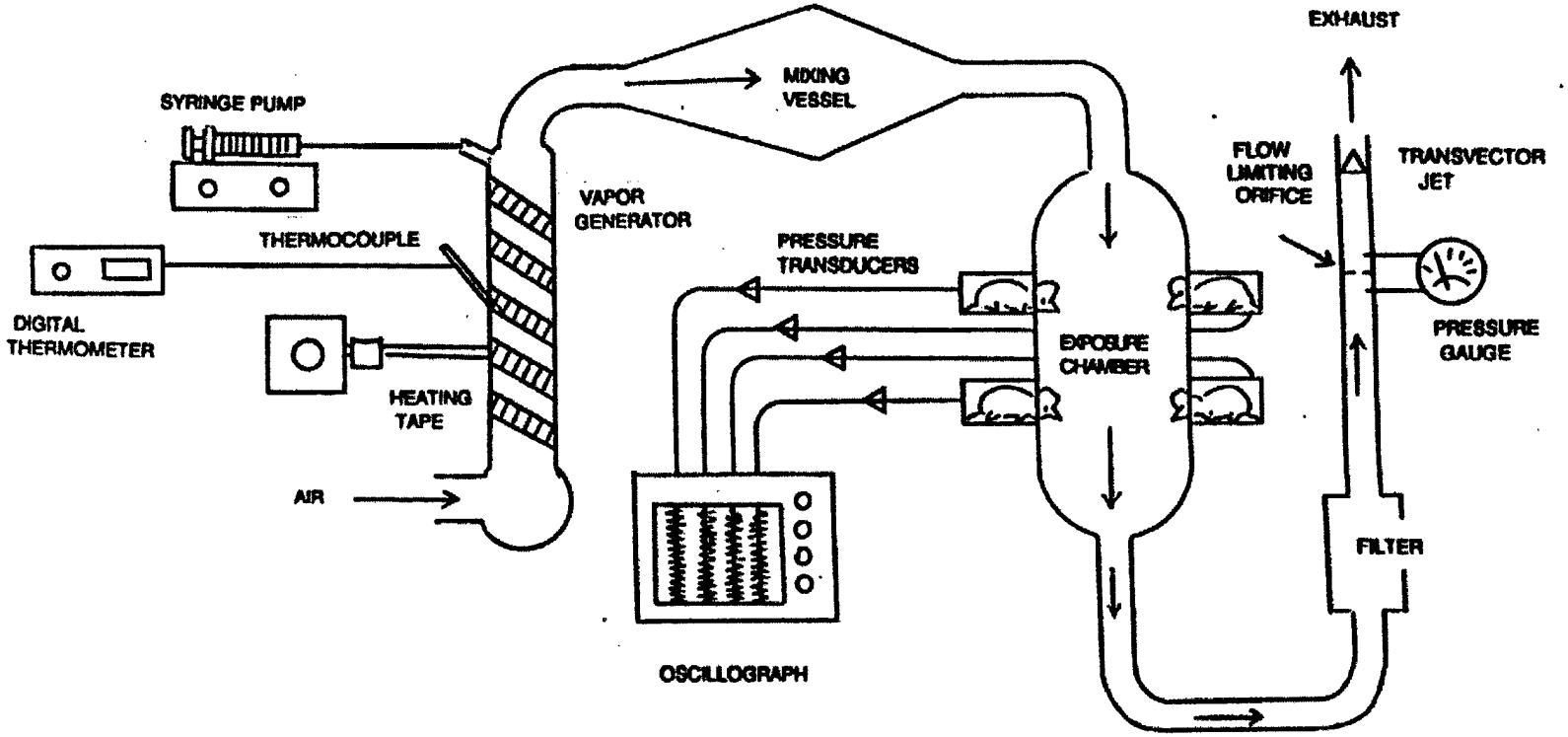


FIGURE 2 - SCHEMATIC OF GENERATION AND EXPOSURE SYSTEM (COLLISON NEBULIZER)

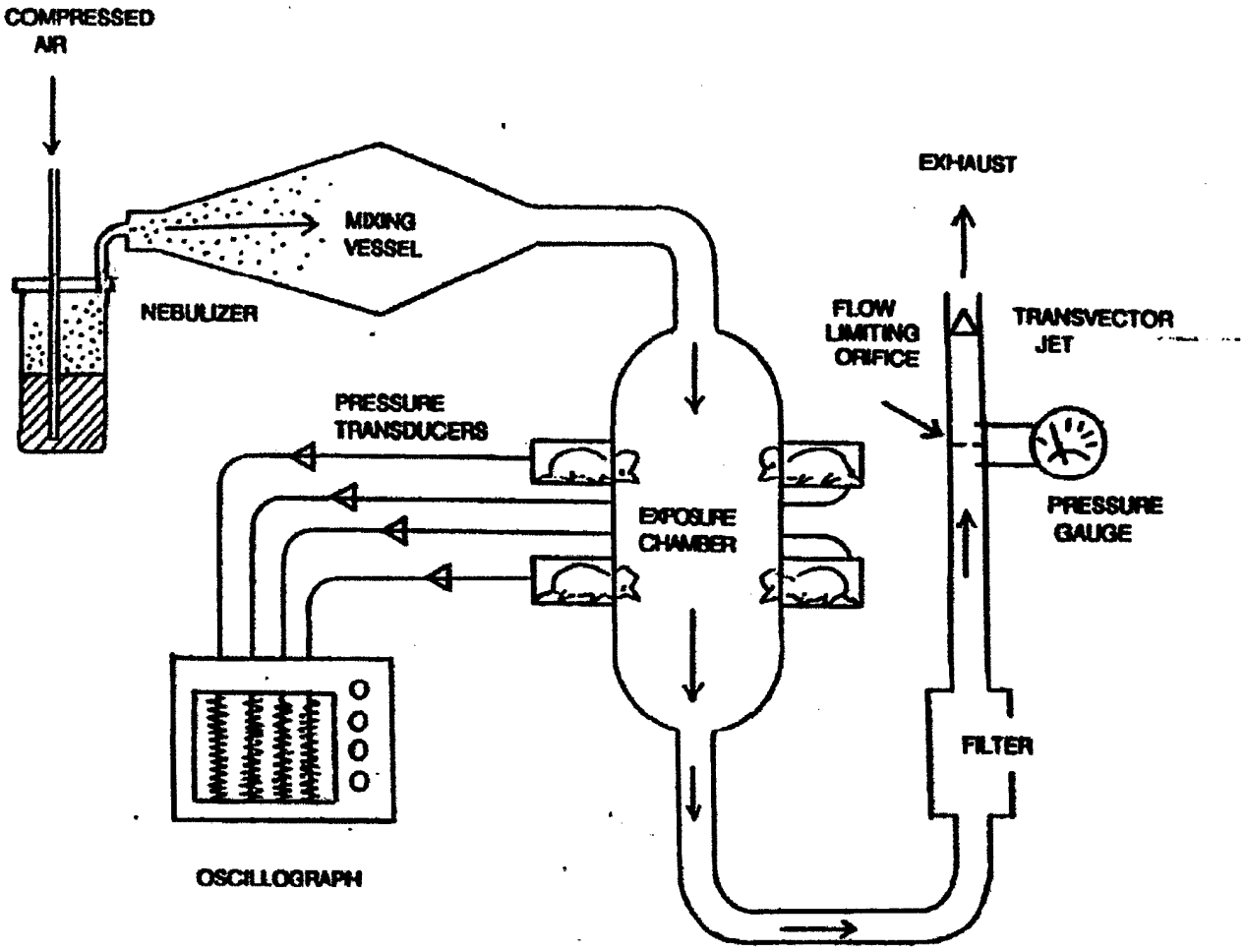


FIGURE 3 - SCHEMATIC OF GENERATION AND EXPOSURE SYSTEM (SPRAYING SYSTEMS ATOMIZER)

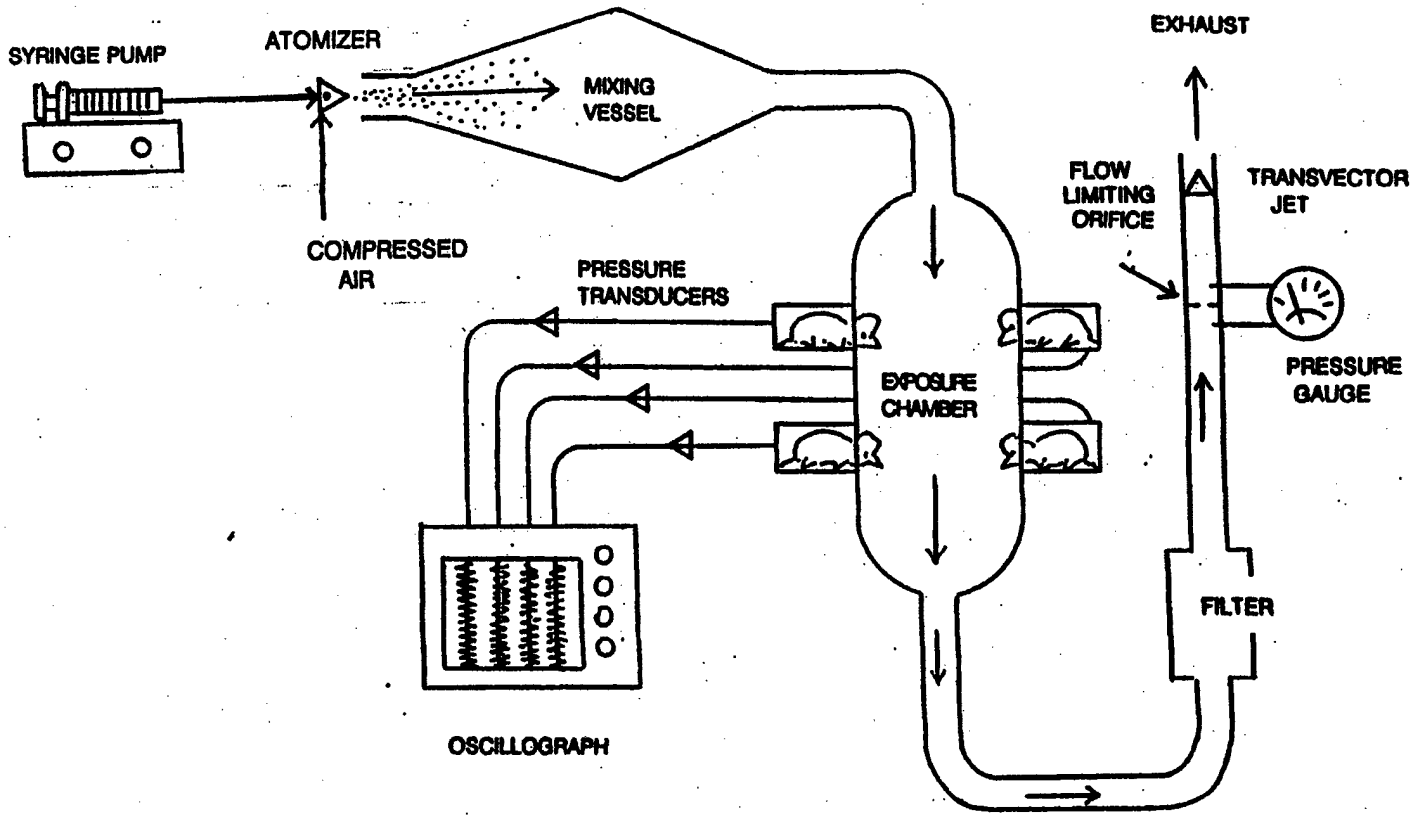


FIGURE 4 - SCHEMATIC OF ANALYTICAL SAMPLING TRAIN

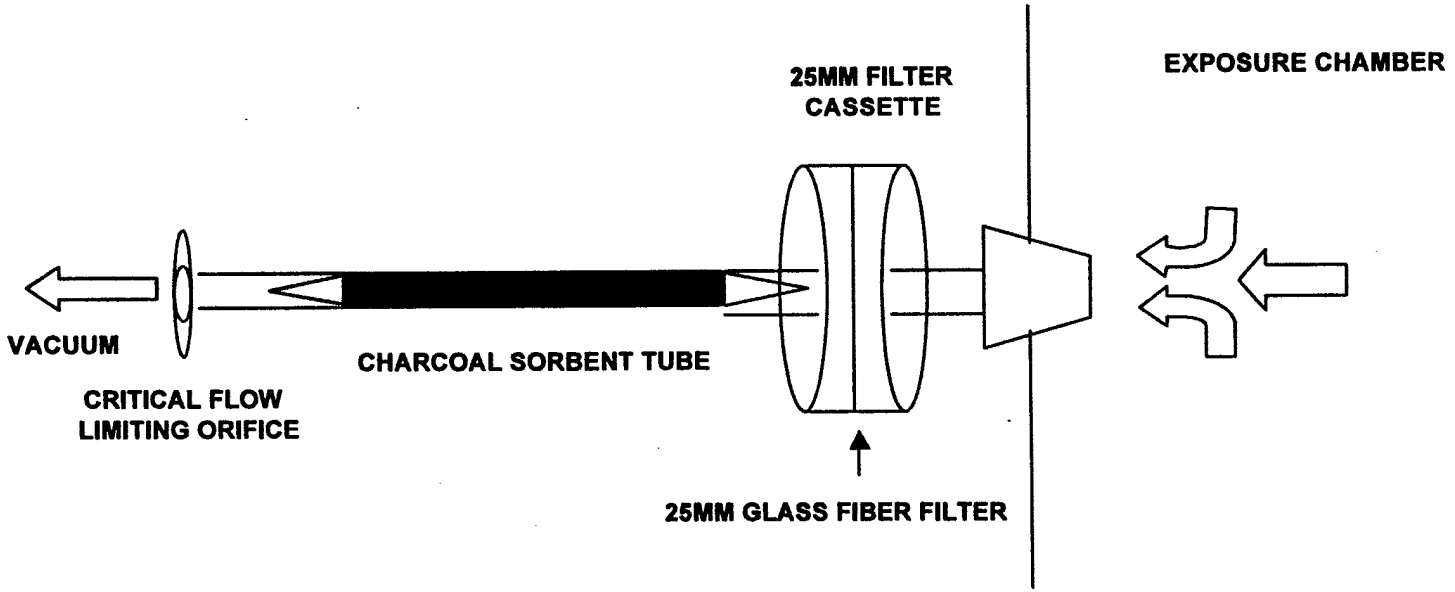


TABLE 1 - SUMMARY OF MEAN STUDY DATA
JP-5 (MRD-01-124)

Test Substance	JP - 5				
Method of Test Atmosphere Generation:	b	b	b	c	a
Total Exposure Concentration:					
Mean Concentration (mg/m^3)	1285	2031	13417	2856	804
Standard Deviation	55	149	698	86	248
Coefficient of Variation (%)	4.3	7.3	5.2	3.0	30.8
Vapor/Aerosol Concentration:					
Vapor Concentration (mg/m^3)	1092	1615	10064	2446	804
Aerosol Concentration (mg/m^3)	193	415	3353	410	0
% Aerosol	15.0	20.4	25.0	14.4	0
Particle Size Analysis:					
Median particle size (um)		1.755			
Geometric Standard Deviation		2.786			
Percent Less Than 10 microns		95.53			
Percent Less Than 1 micron		29.16			
Animal Response Data:					
Percent Respiratory Rate Decrease	-42	-46	-62	-48	-13
Percent Recovery to Baseline	85	82	66	76	89
RD_{50} (mg/m^3)	3338				
95 % Confidence Interval	1759-6332*				

Method of Test Atmosphere Generation:
a - Glass countercurrent vapor generator; see Fig 1.
b - Collison nebulizer; see Fig. 2
c - Spray atomizer; see Fig 3.
* - Does not include 804 mg/m^3 vapor-only exposure

TABLE 2 - SUMMARY OF MEAN STUDY DATA
JPTS (MRD-02-357), JP-7 (MRD-02-358), DFM (MRD-01-087) and JP-10 (MRD-02-359)

Test Substance	JPTS	JPTS	JP-7	JP-7	DFM	DFM	JP-10
Method of Test Atmosphere Generation:	c	c	c	c	c	c	c
Total Exposure Concentration:							
Mean Concentration (mg/m^3)	3729	3622	2239	2419	1030	2045	5412
Standard Deviation	82	496	131	163	74	33	381
Coefficient of Variation (%)	2.2	13.7	5.8	6.7	7.2	1.6	7.0
Vapor/Aerosol Concentration:							
Vapor Concentration (mg/m^3)	3640	3091	1649	1725	786	1227	5407
Aerosol Concentration (mg/m^3)	89	531	589	694	244	818	4
% Aerosol	2.6	14.7	26.3	28.7	23.7	40.0	0.07
Particle Size Analysis:							
Median particle size (um)		1.612	3.328		2.786		*
Geometric Standard Deviation		3.086	1.745		1.782		*
Percent Less Than 10 microns		94.73	97.59		98.65		*
Percent Less Than 1 micron		33.58	1.54		3.81		*
Animal Response Data:							
Percent Respiratory Rate Decrease	-36	-32	-30	-35	-49	-58	-29
Percent Recovery to Baseline	88	88	88	80	68	59	82

Method of Test Atmosphere Generation:
a - Glass countercurrent vapor generator; see Fig 1.
b - Collison nebulizer; see Fig. 2
c - Spray atomizer; see Fig 3.

* insufficient aerosol present for sample analysis.

TABLE 3 - SUMMARY OF ANIMAL RESPONSE DATA
JP-5 (MRD-01-124)

TEST SUBSTANCE CONCENTRATION	ANIMAL NUMBER	BODY WEIGHT (g)	EXPOSURE RESPONSE (%)	RECOVERY RESPONSE (%)	IRRITATION TYPE/ SEVERITY*	GROSS OBSERVATIONS (pretest)	(inchamber)	(postdose)
804 mg/m^3 (Vapor Only)	IFA874	29	-6	94	NONE/NONE	NOA	NOA	NOA
	IFA855	29	-16	89	SENSORY/SLIGHT	NOA	NOA	NOA
	IFA854	26	-19	81	SENSORY/SLIGHT	NOA	NOA	NOA
	IFA870	26	-10	90	SENSORY/NONE	NOA	NOA	NOA
	MEAN	**28**	**-13**	**89**				
	S.D.	**1.7**	**5.9**	**5.4**				
1285 mg/m^3	IFA526	29	-32	95	SENSORY/ MODERATE	NOA	NOA	NOA
	IFA536	29	-39	83	SENSORY/MODERATE	NOA	NOA	NOA
	IFA533	29	-55	82	SENSORY/EXTREME	NOA	NOA	NOA
	IFA534	28	-43	78	SENSORY/MODERATE	NOA	NOA	NOA
	MEAN	**29**	**-42**	**85**				
	S.D.	**0.5**	**9.6**	**7.3**				
2031 mg/m^3	IFA545	28	-52	76	SENSORY/ EXTREME	NOA	NOA	NOA
	IFA538	28	-47	84	SENSORY/MODERATE	NOA	NOA	NOA
	IFA547	29	-39	84	SENSORY/ MODERATE	NOA	NOA	NOA
	IFA549	27	-44	83	SENSORY/MODERATE	NOA	NOA	NOA
	MEAN	**28**	**-46**	**82**				
	S.D.	**0.8**	**5.4**	**3.9**				
2856 mg/m^3	IFA858	25	-55	68	SENSORY/EXTREME	NOA	NOA	NOA
	IFA861	24	-37	89	SENSORY/MODERATE	NOA	NOA	NOA
	IFA871	24	-50	77	SENSORY/EXTREME	NOA	NOA	NOA
	IFA862	24	-50	68	SENSORY/EXTREME	NOA	NOA	NOA
	MEAN	**24**	**-48**	**76**				
	S.D.	**0.5**	**7.7**	**9.9**				
13417 mg/m^3	IFA668	29	-63	68	SENSORY/EXTREME	NOA	NOA	NOA
	IFA656	30	-64	50	SENSORY/EXTREME	NOA	NOA	NOA
	IFA667	28	-60	76	SENSORY/EXTREME	NOA	NOA	NOA
	IFA663	27	-60	68	SENSORY/EXTREME	NOA	NOA	NOA
	MEAN	**29**	**-62**	**66**				
	S.D.	**1.3**	**2.1**	**11.0**				

NOA - NO OBSERVABLE ABNORMALITIES

*** Severity categorized as: slight = 12-19%; moderate = 20-49%; extreme = ≥ 50%.**

TABLE 4 - SUMMARY OF ANIMAL RESPONSE DATA
JPTS (MRD-02-357) and JP-7 (MRD-02-358)

TEST SUBSTANCE CONCENTRATION	ANIMAL NUMBER	BODY WEIGHT (g)	EXPOSURE RESPONSE (%)	RECOVERY RESPONSE (%)	IRRITATION TYPE/ SEVERITY*	GROSS OBSERVATIONS (pretest)	(inchamber)	(postdose)
	IFB184	27	-24	95	SENSORY/MODERATE	NOA	NOA	NOA
JPTS	IFB190	26	-35	75	SENSORY/MODERATE	NOA	NOA	NOA
3622 mg/m^3	IFB179	26	-35	85	SENSORY/MODERATE	NOA	NOA	NOA
	IFB195	26	-35	95	SENSORY/MODERATE	NOA	NOA	NOA
	MEAN	**26**	**-32**	**88**				
	S.D.	**0.5**	**5.5**	**9.6**				
	IFA872	28	-35	83	SENSORY/ MODERATE	NOA	NOA	NOA
JPTS	IFA878	28	-29	100	SENSORY/ MODERATE	NOA	NOA	NOA
3729 mg/m^3	IFA876	29	-40	85	SENSORY/MODERATE	NOA	NOA	NOA
	IFA883	28	-40	85	SENSORY/MODERATE	NOA	NOA	NOA
	MEAN	**28**	**-36**	**88**				
	S.D.	**0.5**	**5.2**	**7.9**				
	IFA881	27	-35	84	SENSORY/ MODERATE	NOA	NOA	NOA
JP-7	IFA866	27	-30	92	SENSORY/ MODERATE	NOA	NOA	NOA
2239 mg/m^3	IFA869	27	-21	85	SENSORY/MODERATE	NOA	NOA	NOA
	IFA873	27	-35	92	SENSORY/MODERATE	NOA	NOA	NOA
	MEAN	**27**	**-30**	**88**				
	S.D.	**0.0**	**6.6**	**4.3**				
	IFB182	28	-30	93	SENSORY/MODERATE	NOA	NOA	NOA
JP-7	IFB196	29	-39	74	SENSORY/MODERATE	NOA	NOA	NOA
2419 mg/m^3	IFB198	28	-28	78	SENSORY/MODERATE	NOA	NOA	NOA
	IFB187	27	-42	76	SENSORY/MODERATE	NOA	NOA	NOA
	MEAN	**28**	**-35**	**80**				
	S.D.	**0.8**	**6.8**	**8.7**				

NOA - NO OBSERVABLE ABNORMALITIES

*** Severity categorized as: slight = 12-19%; moderate = 20-49%; extreme = ≥ 50%.**

TABLE 5 - SUMMARY OF ANIMAL RESPONSE DATA
DFM (MRD-01-087) and JP-10 (MRD-02-359)

TEST SUBSTANCE CONCENTRATION	ANIMAL NUMBER	BODY WEIGHT (g)	EXPOSURE RESPONSE (%)	RECOVERY RESPONSE (%)	IRRITATION TYPE/ SEVERITY*	GROSS OBSERVATIONS (pretest)	(inchamber)	(postdose)
	IFA857	30	-68	41	SENSORY/ EXTREME	NOA	NOA	NOA
DFM	IFA865	30	-43	83	SENSORY/MODERATE	NOA	NOA	NOA
1030 mg/m^3	IFA877	29	-38	82	SENSORY/MODERATE	NOA	NOA	NOA
	IFA868	30	-48	65	SENSORY/MODERATE	NOA	NOA	NOA
	MEAN	**30**	**-49**	**68**				
	S.D.	**0.5**	**13.1**	**19.7**				
	IFB181	30	-50	45	SENSORY/EXTREME	NOA	NOA	NOA
DFM	IFB186	30	-64	73	SENSORY/EXTREME	NOA	NOA	NOA
2045 mg/m^3	IFB192	30	-53	79	SENSORY/EXTREME	NOA	NOA	NOA
	IFB193	30	-63	37	SENSORY/EXTREME	NOA	NOA	NOA
	MEAN	**30**	**-58**	**59**				
	S.D.	**0**	**7.0**	**20.6**				
	IFA853	28	-32	84	SENSORY/MODERATE	NOA	NOA	NOA
JP-10	IFA860	28	-36	77	SENSORY/MODERATE	NOA	NOA	NOA
5412 mg/m^3	IFA879	27	-11	84	SENSORY/SLIGHT	NOA	NOA	NOA
	IFA856	27	-38	83	SENSORY/MODERATE	NOA	NOA	NOA
	MEAN	**28**	**-29**	**82**				
	S.D.	**0.6**	**12.4**	**3.4**				

NOA - NO OBSERVABLE ABNORMALITIES

*** Severity categorized as: slight = 12-19%; moderate = 20-49%; extreme = ≥ 50%.**

FIGURE 5 - GROUP MEAN RESPIRATORY RATES: JP-5 (MRD-01-124)

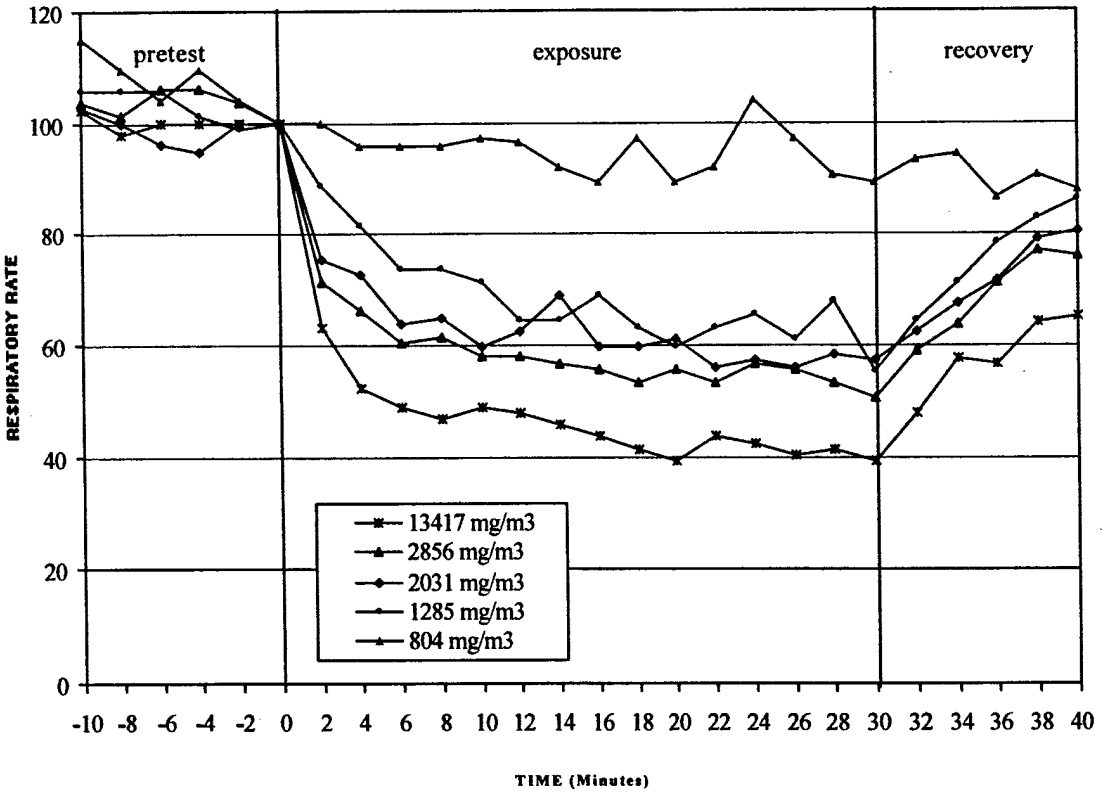


FIGURE 6 - GROUP MEAN RESPIRATORY RATES: JPTS (MRD-02-357)

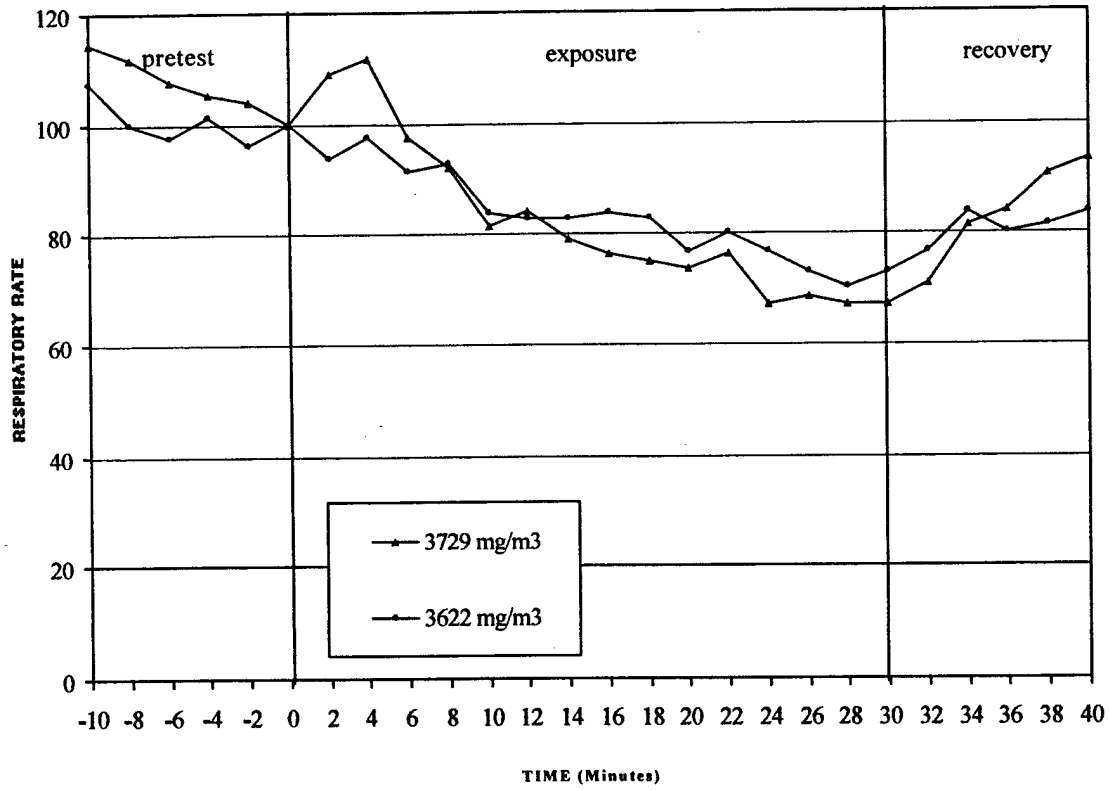


FIGURE 7 - GROUP MEAN RESPIRATORY RATES: JP-7 (MRD-02-358)

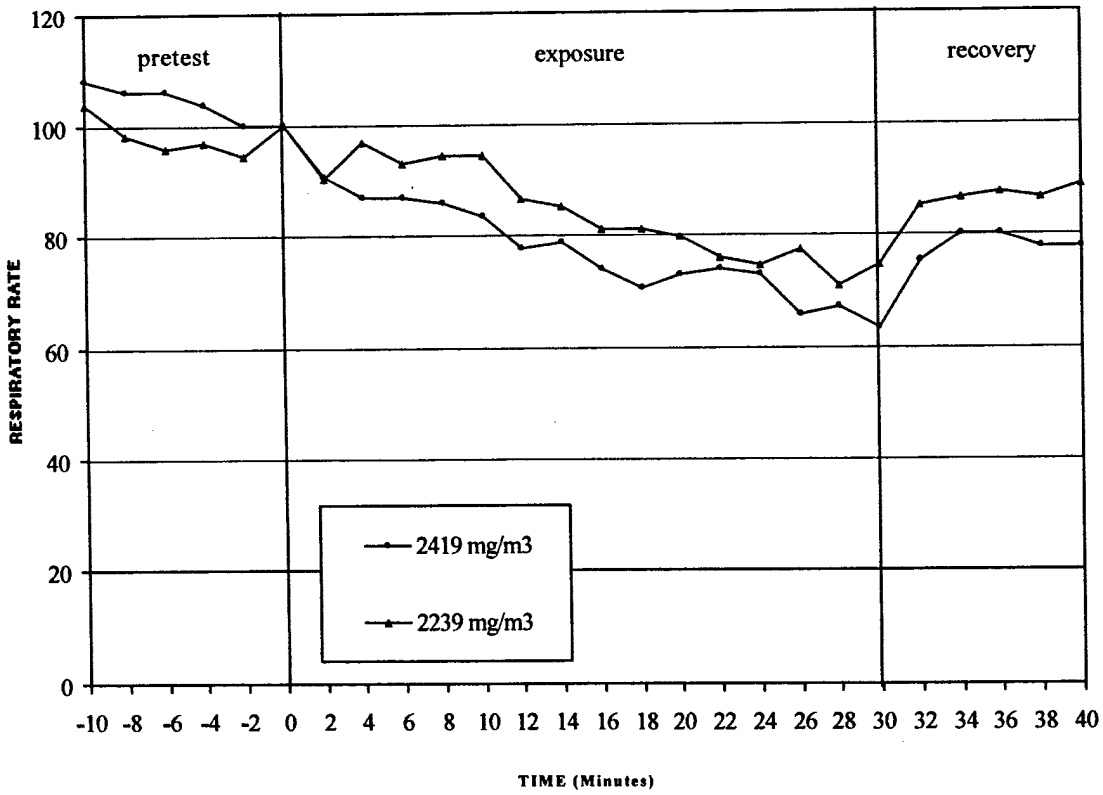


FIGURE 8 - GROUP MEAN RESPIRATORY RATES: DFM (MRD-01-087)

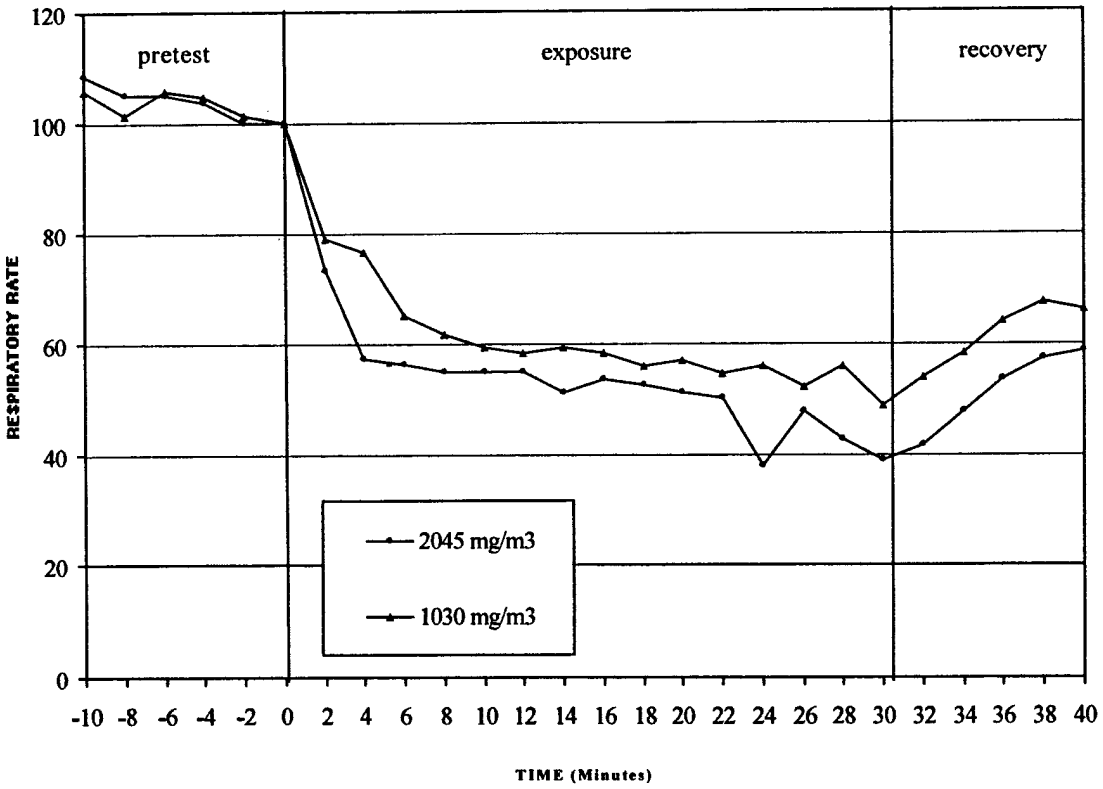


FIGURE 9 - GROUP MEAN RESPIRATORY RATES: JP-10 (MRD-02-359)

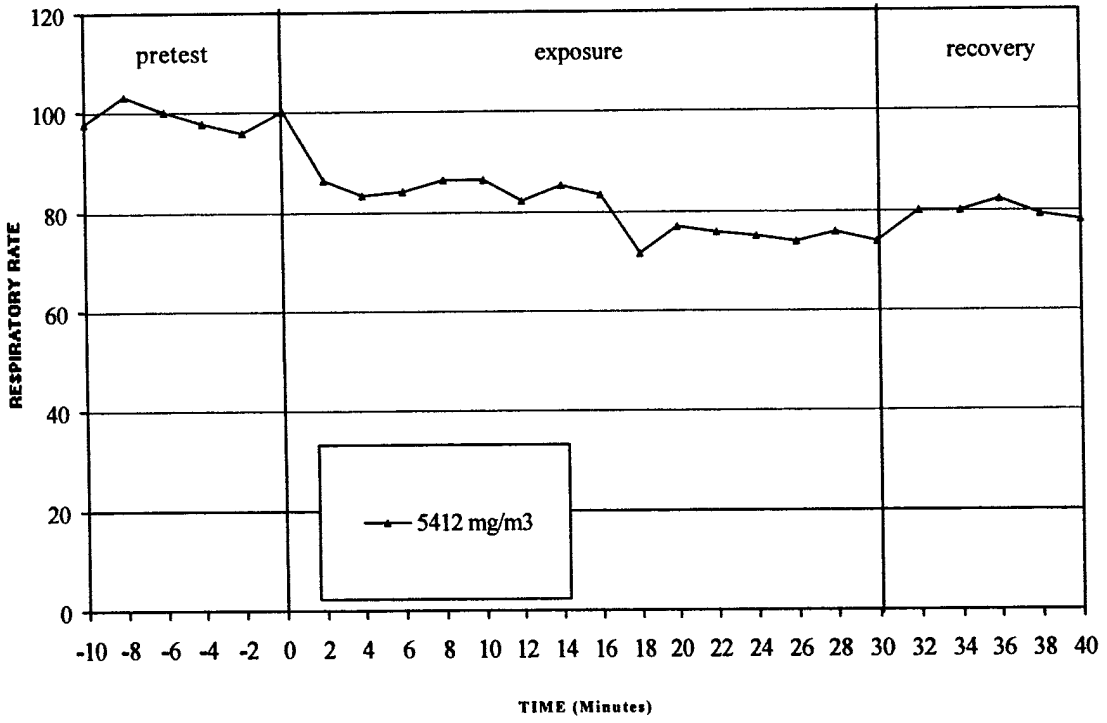


TABLE 6 - SUMMARY OF ANALYTICAL DATA: JP-5 (MRD-01-124)

Test Substance	JP-5														
Generation Method	**b**			**b**			**b**			**c**			**a**		
Sample #	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Aerosol Concentration (filter), mg/m^3	243	165	171	421	413	412	2716	3309	4034	361	353	516	0	0	0
Vapor Concentration (sorbent tube), mg/m^3	1100	1069	1107	1487	1782	1577	9960	10754	9479	2407	2508	2423	708	618	1086
Total Analytical Concentration, mg/m^3	1343	1234	1278	1908	2195	1989	12676	14063	13513	2768	2861	2939	708	618	1086
Mean Analytical Concentration, mg/m^3	1285 ± 55			2031 ± 148			13417 ± 698			2856 ± 86			804 ± 248		
Nominal Concentration, mg/m^3	1267			10378			5622			5989			1556		

Method of Test Atmosphere Generation:
a - Glass countercurrent vapor generator; see Fig 1.
b - Collison nebulizer; see Fig. 2
c - Spray atomizer; see Fig 3.

TABLE 7 - SUMMARY OF ANALYTICAL DATA: JPTS (MRD-02-357) and JP-7 (MRD-02-358)

Test Substance	JPTS						JP-7					
Generation Method	c			c			c			c		
Sample #	1	2	3	1	2	3	1	2	3	1	2	3
Aerosol Concentration (filter), mg/m^3	130	98	39	280	580	733	540	618	610	637	826	618
Vapor Concentration (sorbent tube), mg/m^3	3506	3693	3721	2840	3054	3378	1640	1771	1537	1708	1779	1688
Total Analytical Concentration, mg/m^3	3636	3791	3760	3120	3634	4111	2180	2389	2147	2345	2605	2306
Mean Analytical Concentration, mg/m^3	3729 ± 82			3622 ± 496			2239 ± 131			2419 ± 163		
Nominal Concentration, mg/m^3	8111			5367			4111			4178		

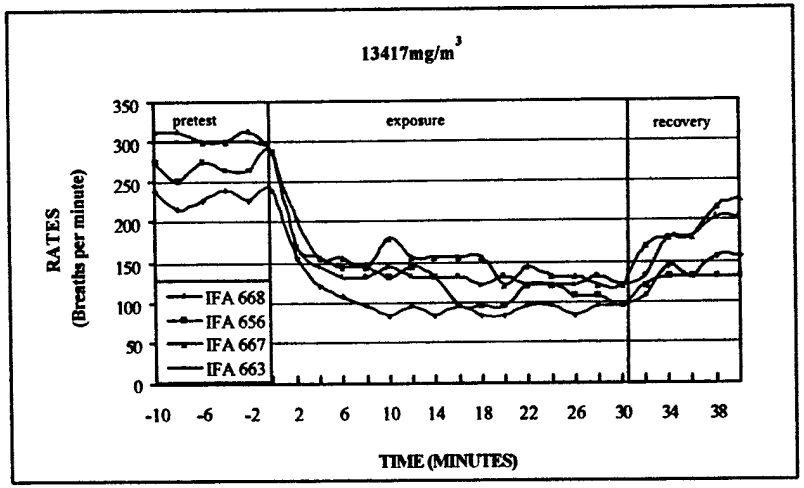
Method of Test Atmosphere Generation:
a - Glass countercurrent vapor generator; see Fig 1.
b - Collison nebulizer; see Fig. 2
c - Spray atomizer; see Fig 3.

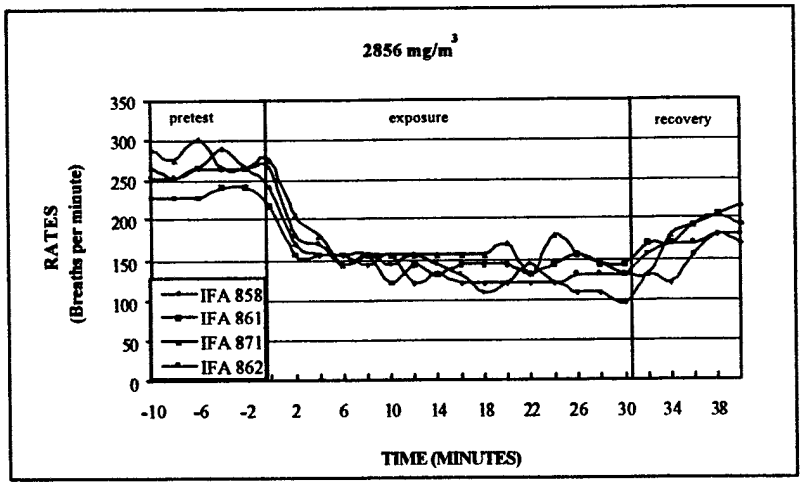
TABLE 8 - SUMMARY OF ANALYTICAL DATA: DFM (MRD-01-087) and JP-10 (MRD-02-359)

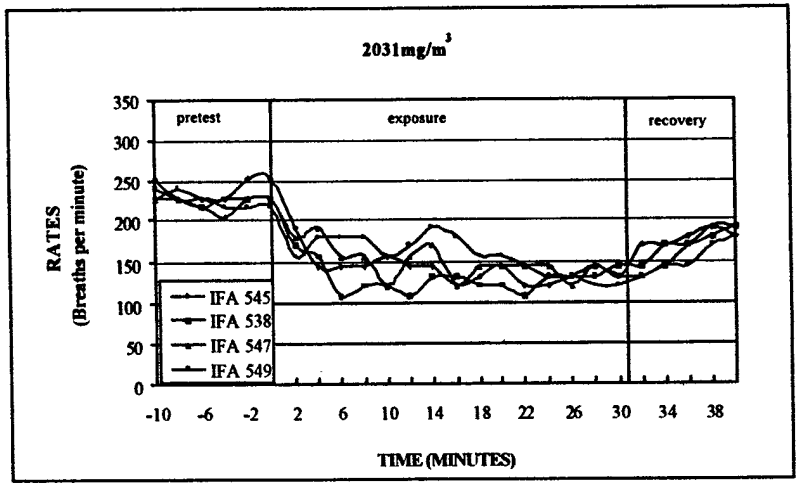
Test Substance	DFM						JP-10		
Generation Method	c			c			c		
Sample #	1	2	3	1	2	3	1	2	3
Aerosol Concentration (filter), mg/m^3	233	239	260	807	768	879	0	13	0
Vapor Concentration (sorbent tube), mg/m^3	763	738	857	1225	1253	1203	5098	5823	5301
Total Analytical Concentration, mg/m^3	996	977	1117	2032	2021	2082	5098	5836	5301
Mean Analytical Concentration, mg/m^3	1030 ± 76			2045 ± 33			5412 ± 381		
Nominal Concentration, mg/m^3	4111			7522			7889		

Method of Test Atmosphere Generation:
a - Glass countercurrent vapor generator; see Fig 1.
b - Collison nebulizer; see Fig. 2
c - Spray atomizer; see Fig 3..

FIGURE 10 - INDIVIDUAL RESPIRATORY RATES: JP-5 (MRD-01-124)







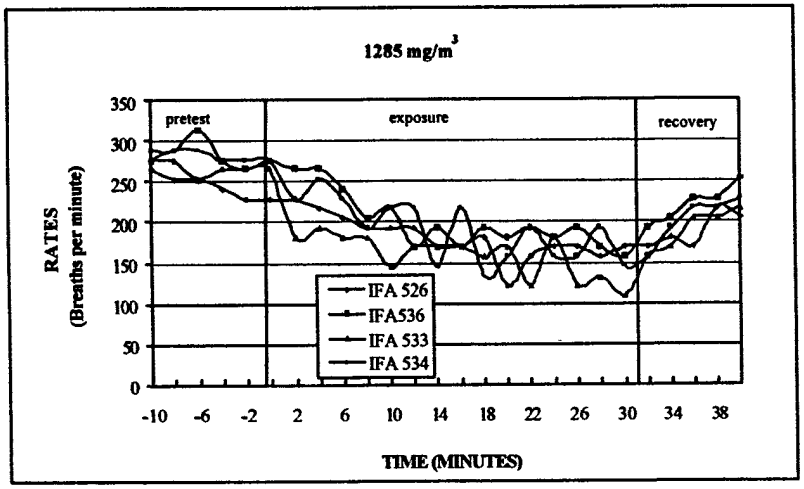


FIGURE 11 - INDIVIDUAL RESPIRATORY RATES: JP-5 (MRD-01-124) Vapor Only Exposure

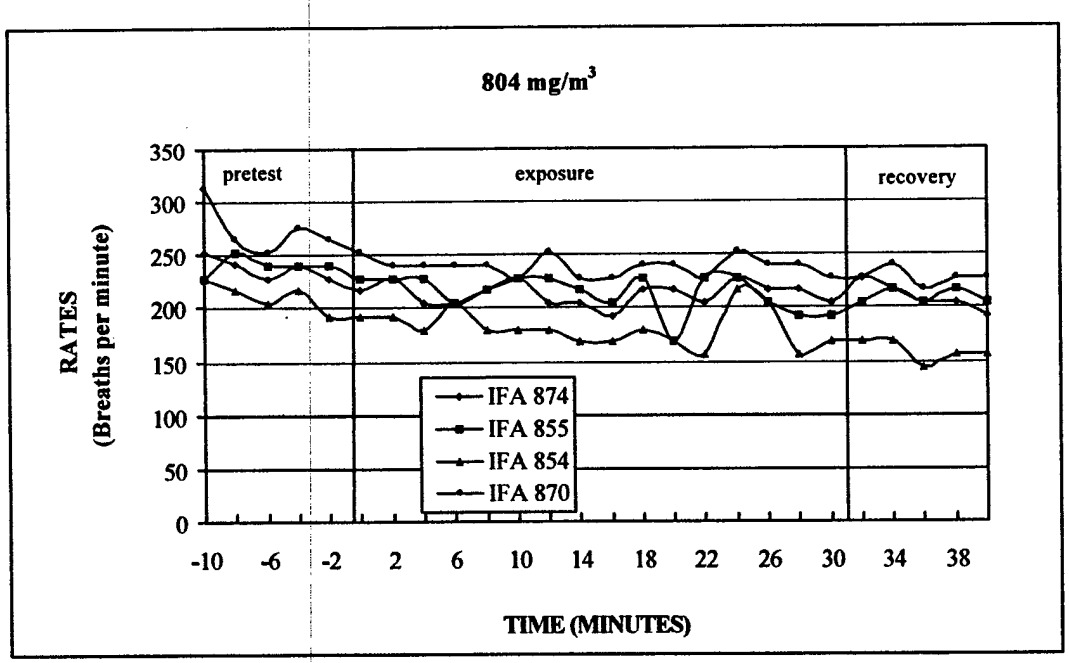
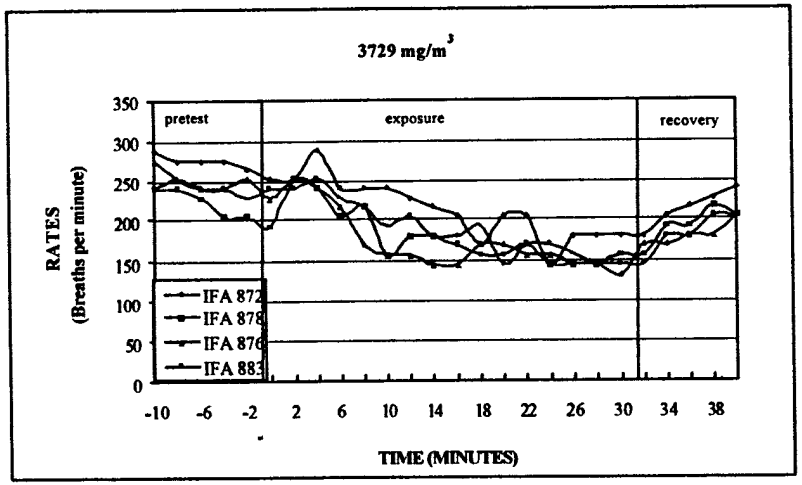


FIGURE 12 - INDIVIDUAL RESPIRATORY RATES: JPTS (MRD-02-357)



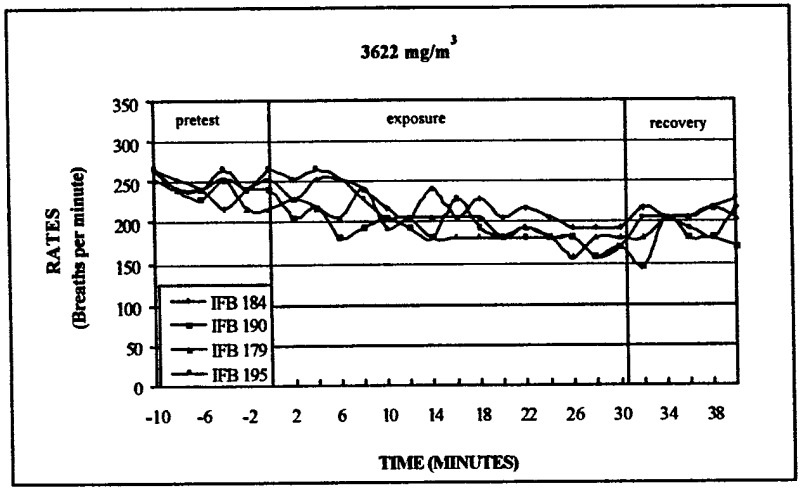
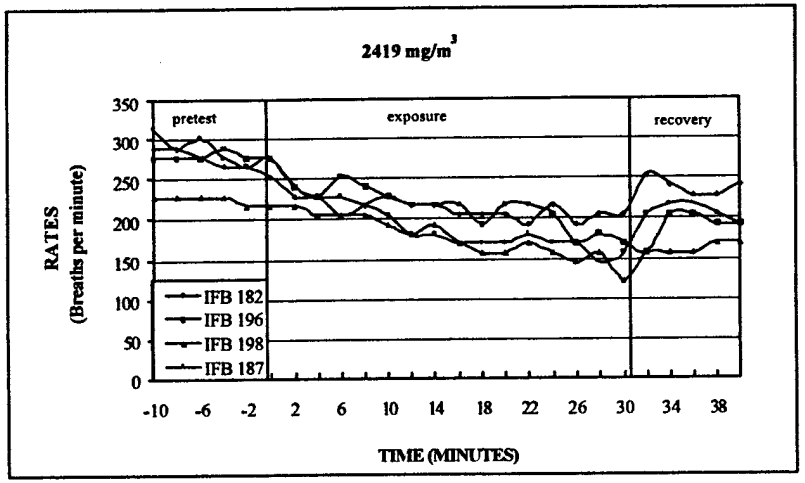


FIGURE 13 - INDIVIDUAL RESPIRATORY RATES: JP-7 (MRD-02-358)



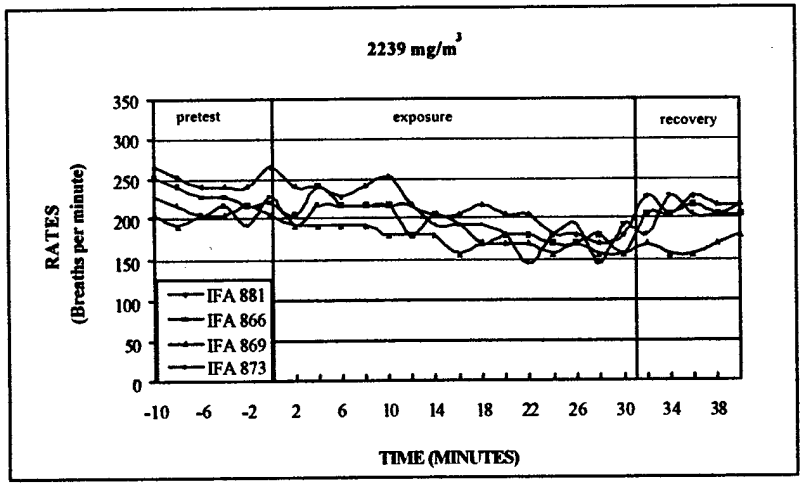
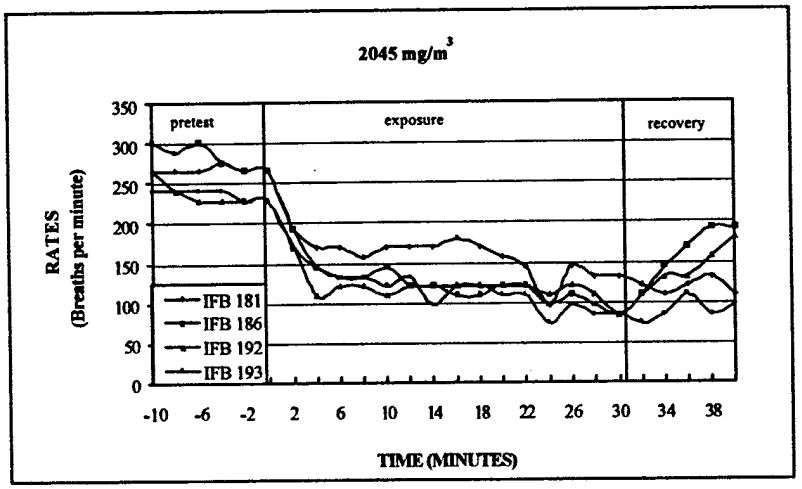


FIGURE 14 - INDIVIDUAL RESPIRATORY RATES: DFM (MRD-01-087)



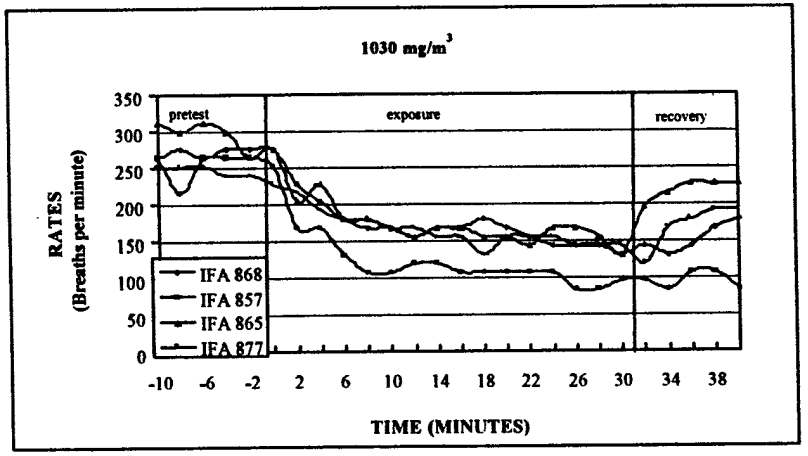


FIGURE 15 - INDIVIDUAL RESPIRATORY RATES: JP-10 (MRD-02-359)

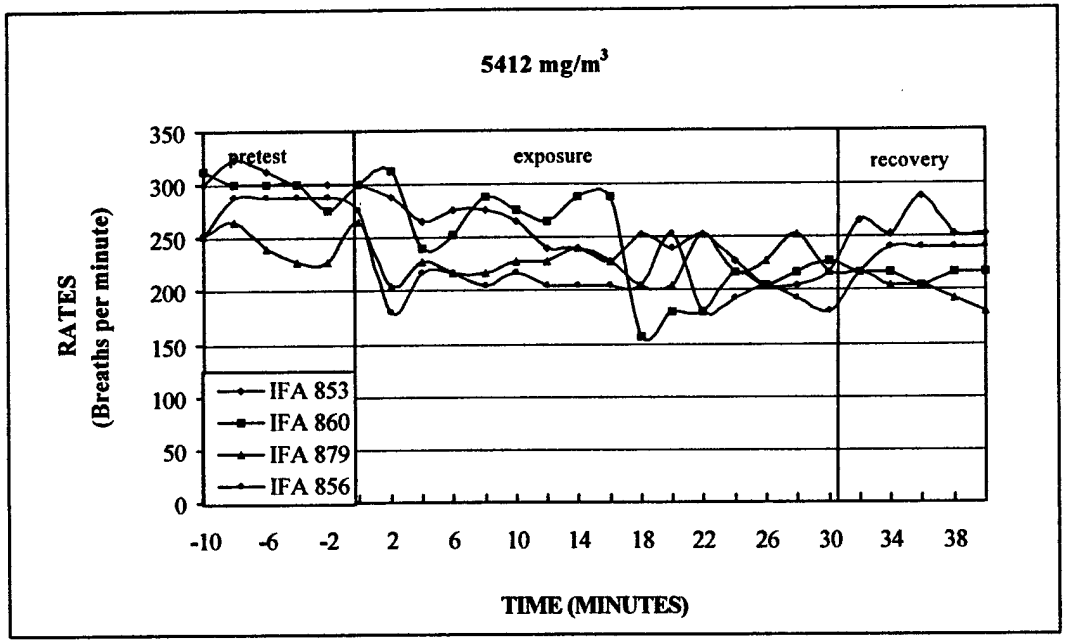


FIGURE 16 - RD $_{50}$ CALCULATION: JP-5 (MRD-01-124)

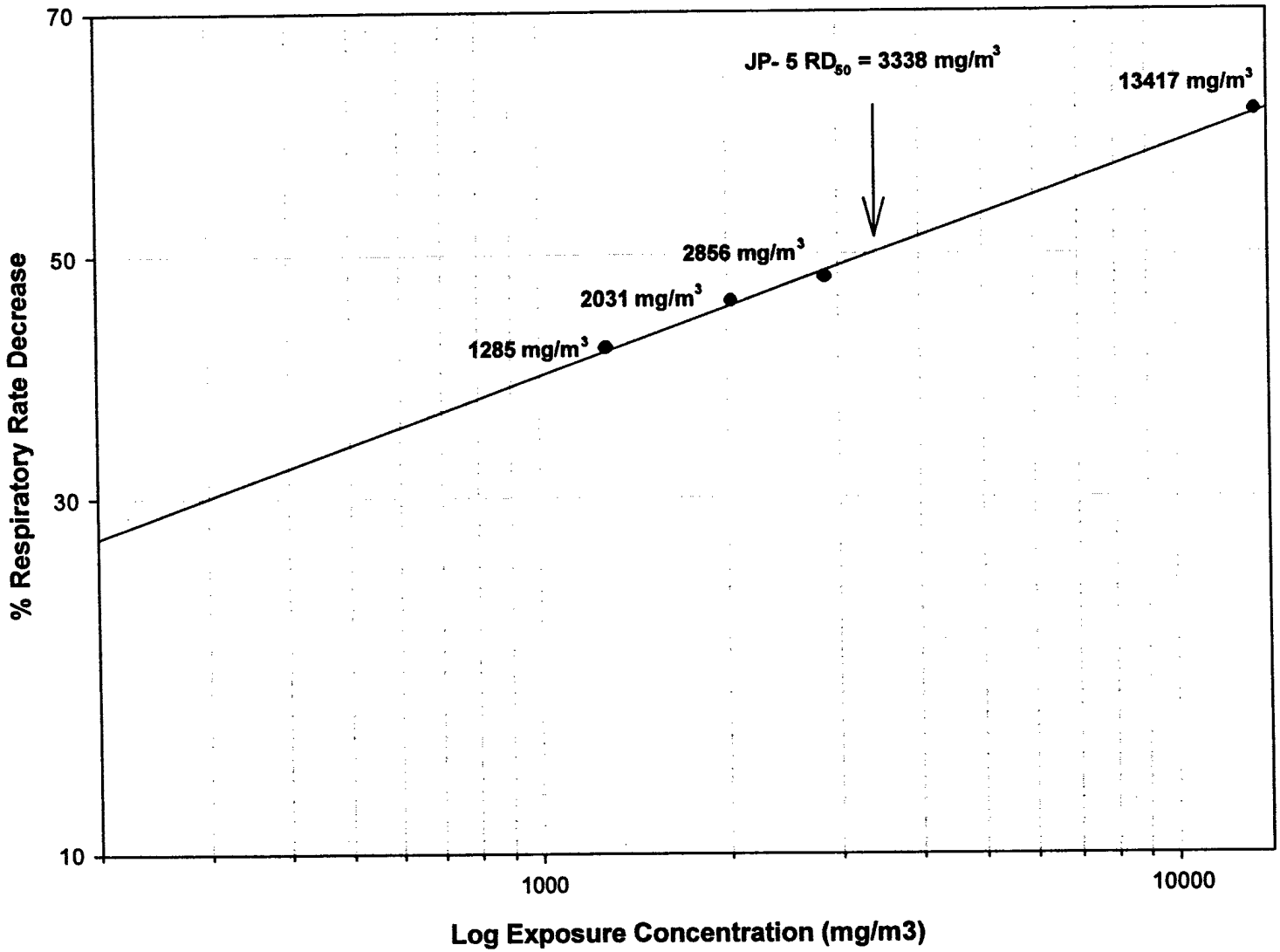
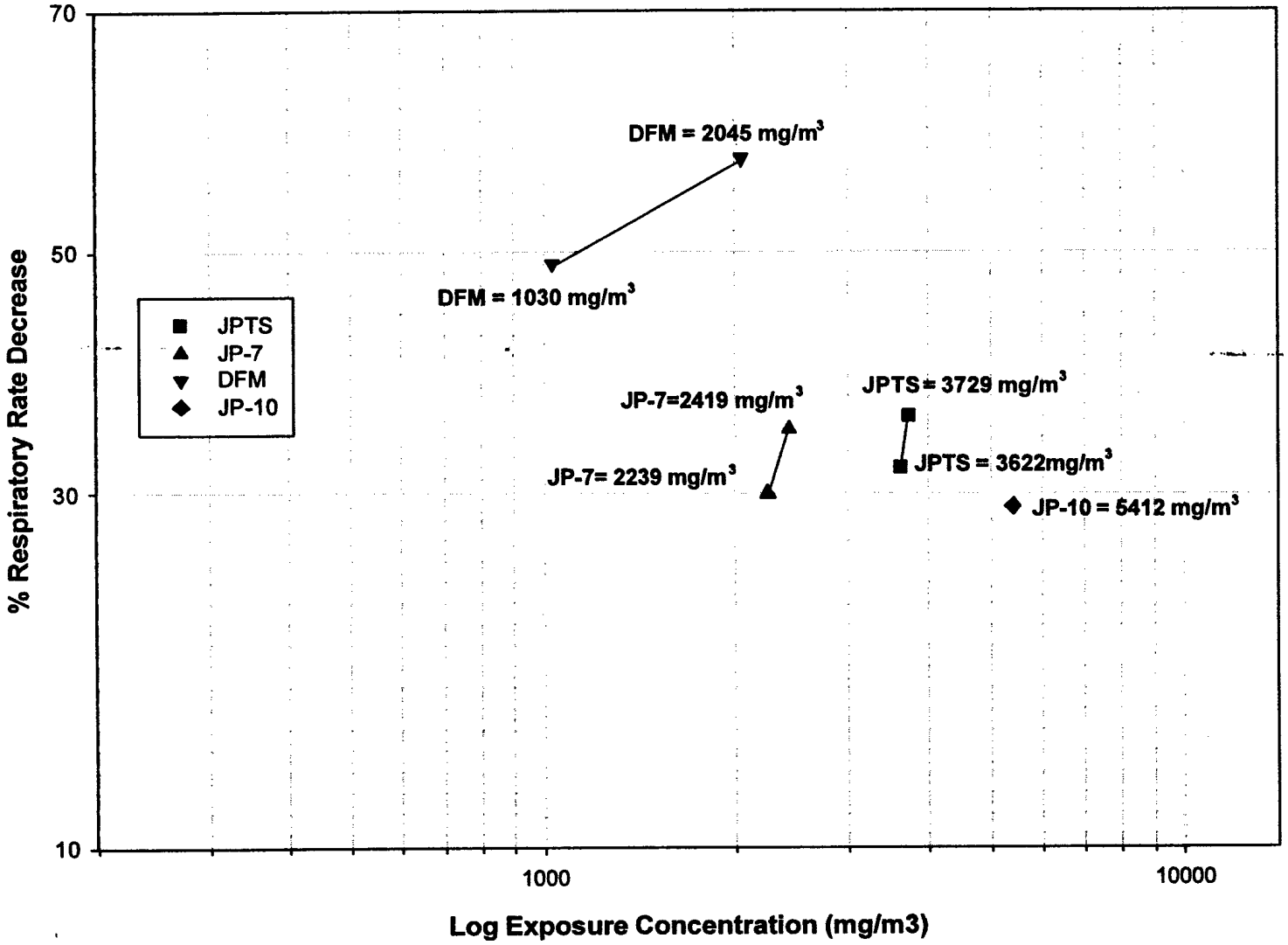


FIGURE 17 - CONCENTRATION-RESPONSES OF JP-7, JPTS, DFM AND JP-10



APPENDIX A

TABLE 1A - ANALYTICAL PROCEDURES AND DETAILED HYDROCARBON ANALYSES

METHOD	Hydrocarbons in Air
SUBSTANCE(S)	(See Chem/Phys Properties)
DETECTION LIMIT:	1ug
MIN.DET.CONC.:	0.1 ppm
IHMC CLASS:	A/B
SAMPLING CONDITIONS	
SAMPLING DEVICE(S):	Charcoal Tubes (400/200mg)
MANUFACTURER:	SKC, Inc.
CATALOG NUMBER:	226-01, 226-09
SAMPLE STABILITY (days):	>28
SHIPMENT/STORAGE:	Dry Ice/Freezer
ANALYTICAL CONDITIONS	
DESORPTION SOLVENT:	Carbon Disulfide (CS2)
VOLUME (mLs)	1 (small tube) 2 (large tube)
DESORPTION CONDITIONS	
TIME (min):	30 min
TEMP:	Ambient
INSTRUMENT:	HP5890 (or equivalent)
COLUMN:	30M x 0.53 mm id CP-Sil 5 CB
TEMPERATURE PROGRAM:	35C (4 min) --> 200 C @ 5C/min
INJECTOR TEMP (C):	200
SAMPLE SIZE (uL)	1.00
DETECTOR	Flame Ionization (FID)
FLOWS:	FUEL - Hydrogen (H2) 30 (cc/min) OXIDANT - Air 375 (cc/min) CARRIER - Helium (He) or Nitrogen (N2) 5-10 (cc/min)

TABLE 1A - ANALYTICAL PROCEDURES AND DETAILED HYDROCARBON ANALYSES (CONT'D)

(Total Hydrocarbons as n-Hexane Equivalents (sum of all peaks minus the solvent peak)

SUBSTANCE	CHEMICAL/PHYSICAL PROPERTIES: DENSITY (gms/mL)	MOL. WT.	APPROXIMATE RETENTION TIME (min)	
			Column A	Column B
Isopentane	0.62	72.15	5.194	4.995
n-Pentane	0.626	72.15	5.992	5.781
2-Methylpentane	0.653	86.17	8.633	8.402
3-Methylpentane	0.664	86.17	9.227	8.974
n-Hexane	0.66	86.17	9.917	9.673
Methylcyclopentane	0.749	84.16	11.151	10.894
Benzene	0.88	78.11	12.181	11.917
Cyclohexane	0.778	84.16	12.613	12.348
3-Methylhexane	0.687	100.21	13.210	12.945
Iso-Octane	0.692	114.22	13.837	13.569
n-Heptane	0.684	100.2	14.215	13.949
Toluene	0.868	92.14	16.682	16.397
3-Methylheptane	0.706	114.22	17.322	17.042
n-Octane	0.703	114.22	18.350	18.066
Ethylbenzene	0.866	106.2	20.497	20.197
p&m-Xylene	0.863	106.2	21.236	20.962
Nonane	0.722	126.2	21.985	21.767
Cumene	0.862	120.19	22.458	22.259
Propylbenzene	0.862	120.19	23.057	22.881
p&m-Ethyltoluene	0.863	120.19	23.193	23.021
1,3,5-Trimethylbenzene	0.864	120.19	23.277	23.132
o-Ethyltoluene	0.881	120.19	23.496	23.334
1,2,4-Trimethylbenzene	0.889	120.19	23.724	23.564
n-Decane	0.73	142.3	23.824	23.673
n-Undecane	0.74	156.31	24.984	24.848
n-Dodecane	0.749	170.34	25.956	25.795
n-Tetradecane	0.763	198.4	28.272	28.004
n-Hexadecane	0.773	226.45	31.981	31.511

TABLE 2A - INDIVIDUAL HYDROCARBON DATA: JP-5 (MRD-01-124)
(all values are mg/m³)

Group Mean Concentration	1285		2031		13417		2856		804	
IndividualSample Concentration	1100	243	1487	421	9960	2716	2407	361	708	0
Sample Media	Tube	Filter	Tube	Filter	Tube	Filter	Tube	Filter	Tube	Filter
Individual Hydrocarbons:	Vapor	Aerosol	Vapor	Aerosol	Vapor	Aerosol	Vapor	Aerosol	Vapor	Aerosol
Isopentane	*	*	*	*	*	*	*	*	*	*
n-Pentane	<1	*	*	*	*	*	*	*	*	*
2-Methylpentane	*	*	*	*	*	*	*	*	*	*
3-Methylpentane	*	*	*	*	*	*	*	*	*	*
n-Hexane	*	*	*	*	1	*	*	*	*	*
Methylcyclopentane	*	*	*	*	1	*	*	*	*	*
Benzene	*	*	*	*	*	*	*	*	*	*
Cyclohexane	*	*	*	*	2	*	1	*	*	*
3-Methylhexane	*	*	<1	*	4	*	1	*	*	*
Isooctane	*	*	*	*	5	*	*	*	*	*
n-Heptane	*	*	1	*	9	*	1	*	<1	*
Toluene	*	*	1	*	8	*	1	*	*	*
3-Methylheptane	<1	*	1	*	9	*	1	*	<1	*
n-Octane	1	*	4	*	29	*	4	*	<1	*
Ethylbenzene	1	*	2	*	18	*	3	*	7	*
Xylenes	4	*	10	*	74	*	16	*	23	*
n-Nonane	5	*	9	*	49	*	14	*	13	*
Cumene	2	*	2	*	*	*	4	*	<1	*
Propylbenzene	7	*	6	*	68	*	10	*	2	*
p-m Ethyltoluene	7	*	12	*	84	*	23	*	4	*
1,3,5-Trimethylbenzene	8	*	14	*	*	*	27	*	5	*
o-Ethyltoluene	*	*	*	*	61	*	9	*	*	*
1,2,4-Trimethylbenzene	15	*	24	*	154	3	81	*	9	*
n-Decane	25	*	40	*	251	7	80	1	15	*
n-Undecane	79	3	113	9	605	57	220	15	54	*
n-Dodecane	74	9	95	30	503	131	156	35	60	*
n-Tetradecane	10	21	7	23	34	80	6	13	5	*
n-Hexadecane	*	21	*	5	*	41	*	*	*	*

* below the analytical limit of detection (0.1-0.2 mg/m3 based on sample volume)

TABLE 3A - INDIVIDUAL HYDROCARBON DATA - JPTS, JP-7
(all values are mg/m^3)

Group Designation	JPTS				JP-7			
Group Mean Concentration	3729		3622		2239		2419	
IndividualSample Concentration	3506	130	2840	280	1640	540	1708	637
Sample Media	Tube	Filter	Tube	Filter	Tube	Filter	Tube	Filter
Individual Hydrocarbons:	Vapor	Aerosol	Vapor	Aerosol	Vapor	Aerosol	Vapor	Aerosol
Isopentane	*	*	*	*	*	*	*	*
n-Pentane	*	*	*	1	*	*	*	*
2-Methylpentane	*	*	*	*	*	*	*	*
3-Methylpentane	*	*	*	*	*	*	*	*
n-Hexane	*	*	1	*	*	*	1	*
Methylcyclopentane	*	*	2	*	*	*	1	*
Benzene	*	*	*	*	*	*	<1	*
Cyclohexane	*	*	1	*	*	*	<1	*
3-Methylhexane	1	*	3	*	*	*	1	*
Isooctane	1	*	*	*	*	*	*	*
n-Heptane	1	*	3	*	*	*	1	*
Toluene	1	*	2	*	4	*	4	*
3-Methylheptane	3	*	4	*	*	*	1	*
n-Octane	11	*	9	*	2	*	3	*
Ethylbenzene	8	*	7	*	2	*	2	*
Xylenes	61	*	57	*	7	*	10	*
n-Nonane	112	*	93	*	8	*	11	*
Cumene	20	*	18	*	1	*	2	*
Propylbenzene	23	*	21	*	4	*	2	*
p-m Ethyltoluene	65	*	47	*	4	*	5	*
1,3,5-Trimethylbenzene	121	*	94	*	8	*	10	*
o-Ethyltoluene	23	*	22	*	2	*	2	7
1,2,4-Trimethylbenzene	110	*	81	14	12	4	15	2
n-Decane	307	3	221	*	64	4	69	6
n-Undecane	301	8	243	16	261	29	250	33
n-Dodecane	77	7	79	13	109	45	114	45
n-Tetradecane	6	8	7	25	5	26	6	32
n-Hexadecane	1	*	*	6	*	*	*	6

* below the analytical limit of detection (0.1-0.2 mg/m3 based on sample volume)

TABLE 4A - INDIVIDUAL HYDROCARBON DATA - DFM, JP-10
(all values are mg/m^3)

Group Designation	DFM				JP-10	
Group Mean Concentration	1030		2045		5412	
IndividualSample Concentration	763	233	1225	807	5098	0
Sample Media	Tube	Filter	Tube	Filter	Tube	Filter
Individual Hydrocarbons:	Vapor	Aerosol	Vapor	Aerosol	Vapor	Aerosol
Isopentane	5	*	6	*	*	*
n-Pentane	3	*	*	*	*	*
2-Methylpentane	3	*	4	*	*	*
3-Methylpentane	3	*	3	*	*	*
n-Hexane	4	*	6	*	<1	*
Methylcyclopentane	4	*	7	*	*	*
Benzene	2	*	3	*	<1	*
Cyclohexane	3	*	7	*	*	*
3-Methylhexane	3	*	5	*	*	*
Isooctane	4	*	7	*	*	*
n-Heptane	5	*	11	*	*	*
Toluene	7	*	17	*	1	*
3-Methylheptane	3	*	6	*	*	*
n-Octane	9	*	21	*	*	*
Ethylbenzene	6	*	11	*	*	*
Xylenes	24	*	51	*	2	*
n-Nonane	20	*	38	*	<1	*
Cumene	4	*	7	*	*	*
Propylbenzene	6	*	10	*	*	*
p-m Ethyltoluene	11	*	23	*	<1	*
1,3,5-Trimethylbenzene	9	*	20	*	1	*
o-Ethyltoluene	4	*	6	*	*	*
1,2,4-Trimethylbenzene	15	*	28	*	2	*
n-Decane	29	1	45	2	3	*
n-Undecane	47	4	67	12	10	*
n-Dodecane	30	7	45	26	11	*
n-Tetradecane	4	10	6	34	3	*
n-Hexadecane	*	17	1	42	*	*

* below the analytical limit of detection (0.1-0.2 mg/m3 based on sample volume)

TABLE 5A - INDIVIDUAL HYDROCARBON DATA - PARTICLE SIZE SAMPLES JP-5, JPTS, JP-7
(all values are mg/m^3)

Test Substance	JP-5			JPTS			JP-7		
Total Exposure Concentration	2031 mg/m^3			3729 mg/m^3			2239 mg/m^3		
Aerosol Concentration	415 mg/m^3			97 mg/m^3			596 mg/m^3		
Stage Constant (cutoff diameter)	0.54 um	1.50 um	4.10 um	1.50 um	4.10 um	6.80 um	1.50 um	2.60 um	4.10 um
% weight size	15.9	50.0	84.1	15.9	50.0	84.1	15.9	50.0	84.1
Individual Hydrocarbons:									
Isopentane	a	*	a	a	*	a	a	*	a
n-Pentane	a	*	a	a	*	a	a	*	a
2-Methylpentane	a	*	a	a	*	a	a	*	a
3-Methylpentane	a	*	a	a	*	a	a	*	a
n-Hexane	a	*	a	a	*	a	a	*	a
Methylcyclopentane	a	*	a	a	*	a	a	*	a
Benzene	a	*	a	a	*	a	a	*	a
Cyclohexane	a	*	a	a	*	a	a	*	a
3-Methylhexane	a	*	a	a	*	a	a	*	a
Isooctane	a	*	a	a	*	a	a	*	a
n-Heptane	a	*	a	a	*	a	a	*	a
Toluene	a	*	a	a	*	a	a	*	a
3-Methylheptane	a	*	a	a	*	a	a	*	a
n-Octane	a	*	a	a	*	a	a	*	a
Ethylbenzene	a	*	a	a	*	a	a	*	a
Xylenes	a	*	a	a	*	a	a	*	a
n-Nonane	a	*	a	a	*	a	a	*	a
Cumene	a	*	a	a	<1	a	a	*	a
Propylbenzene	a	*	a	a	*	a	a	*	a
p-m Ethyltoluene	a	*	a	a	*	a	a	*	a
1,3,5-Trimethylbenzene	a	*	a	a	*	a	a	<1	a
o-Ethyltoluene	a	*	a	a	<1	a	a	*	a
1,2,4-Trimethylbenzene	a	*	a	a	*	a	a	<1	a
n-Decane	a	*	a	a	2	a	a	2	a
n-Undecane	a	1	a	a	6	a	a	20	a
n-Dodecane	a	5	a	a	5	a	a	30	a
n-Tetradecane	a	5	a	a	7	a	a	19	a
n-Hexadecane	a	*	a	a	*	a	a	<1	a
TOTAL HYDROCARBONS	0	78	94	393	98	28	426	351	91

* below the analytical limit of detection (0.1-0.2 mg/m3 based on sample volume) a - Sample analyzed for total hydrocarbons only

TABLE 6A - INDIVIDUAL HYDROCARBON DATA: PARTICLE SIZE SAMPLES DFM, JP-10

Test Substance	DFM			JP-10		
Total Exposure Concentration	1030 mg/m^3			5412 mg/m^3		
Aerosol Concentration	694 mg/m^3			4 mg/m^3		
Stage Constant (cutoff diameter)	0.84 um	1.50 um	2.60 um	0.54 um	0.84 um	1.50 um
% weight size	15.9	50.0	84.1	15.9	50.0	84.1
Individual Hydrocarbons:						
Isopentane	a	*	a	a	*	a
n-Pentane	a	*	a	a	*	a
2-Methylpentane	a	*	a	a	*	a
3-Methylpentane	a	*	a	a	*	a
n-Hexane	a	*	a	a	*	a
Methylcyclopentane	a	*	a	a	*	a
Benzene	a	*	a	a	*	a
Cyclohexane	a	*	a	a	*	a
3-Methylhexane	a	*	a	a	*	a
Isooctane	a	*	a	a	*	a
n-Heptane	a	*	a	a	*	a
Toluene	a	*	a	a	*	a
3-Methylheptane	a	*	a	a	*	a
n-Octane	a	*	a	a	*	a
Ethylbenzene	a	*	a	a	*	a
Xylenes	a	*	a	a	*	a
n-Nonane	a	*	a	a	*	a
Cumene	a	*	a	a	*	a
Propylbenzene	a	*	a	a	*	a
p-m Ethyltoluene	a	*	a	a	*	a
1,3,5-Trimethylbenzene	a	*	a	a	*	a
o-Ethyltoluene	a	*	a	a	*	a
1,2,4-Trimethylbenzene	a	*	a	a	*	a
n-Decane	a	*	a	a	*	a
n-Undecane	a	<1	a	a	*	a
n-Dodecane	a	3	a	a	*	a
n-Tetradecane	a	6	a	a	*	a
n-Hexadecane	a	9	a	a	*	a
TOTAL HYDROCARBONS	17	118	240	0	*	0

* - below the analytical limit of detection (0.1-0.2 mg/m3) based on sample volume. a - sample analyzed for total hydrocarbons only

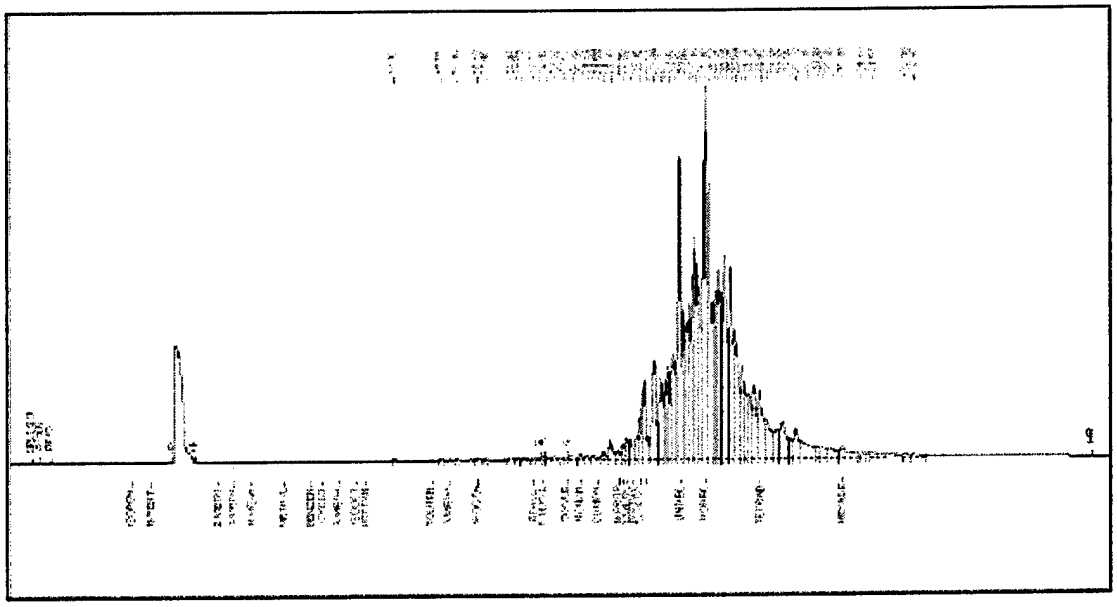
TABLE 7A - INDIVIDUAL HYDROCARBON DATA - NEAT TEST SUBSTANCES

Individual Hydrocarbons: (Percent By Volume*)	JP-5 (Neat)	JP-5 (Neat, used)	JPTS	JP-7	JP -10	DFM
	MRD-01-124	MRD-01-124	MRD-02-357	MRD-02-358	MRD-03-359	MRD-01-087
Isopentane	ND	ND	0.011	ND	ND	ND
n-Pentane	ND	ND	0.014	ND	0.011	ND
2-Methylpentane	ND	ND	0.007	ND	ND	ND
3-Methylpentane	ND	ND	0.005	ND	ND	ND
n-Hexane	ND	ND	0.014	ND	ND	ND
Methylcyclopentane	ND	ND	0.019	ND	ND	ND
Benzene	ND	ND	0.007	ND	ND	ND
Cyclohexane	ND	ND	0.021	ND	ND	ND
3-Methylhexane	ND	ND	0.014	ND	ND	ND
Isooctane	ND	ND	0.029	ND	ND	ND
n-Heptane	ND	ND	0.031	ND	ND	ND
Toluene	ND	ND	0.071	ND	0.013	ND
3-Methylheptane	ND	ND	0.022	ND	ND	ND
n-Octane	0.024	ND	0.108	ND	ND	0.089
Ethylbenzene	0.016	ND	0.056	ND	ND	0.084
p-m Xylene	0.108	0.038	0.236	ND	0.011	0.525
n-Nonane	0.133	0.075	0.216	0.010	ND	1.588
Cumene	0.041	0.021	0.042	ND	ND	0.289
Propylbenzene	0.224	0.100	0.131	ND	0.007	1.214
p-m Ethyltoluene	0.275	0.192	0.171	0.012	0.013	1.138
1,3,5-Trimethylbenzene	0.326	0.263	0.262	0.077	0.015	2.866
o-Ethyltoluene	0.450	0.341	0.108	0.057	0.016	1.125
1,2,4-Trimethylbenzene	0.689	0.556	0.284	0.243	0.028	2.194
n-Decane	1.142	0.979	0.433	1.075	0.010	5.594
n-Undecane	4.900	4.825	0.982	8.665	0.768	7.508
n-Dodecane	6.735	6.699	1.476	8.806	0.023	3.542
n-Tetradecane	2.013	2.043	2.144	5.217	ND	2.959
n-Hexadecane	0.706	0.922	2.698	0.326	ND	0.049
Total Analytes*	97.035	93.254	75.094	103.67	98.075	95.574

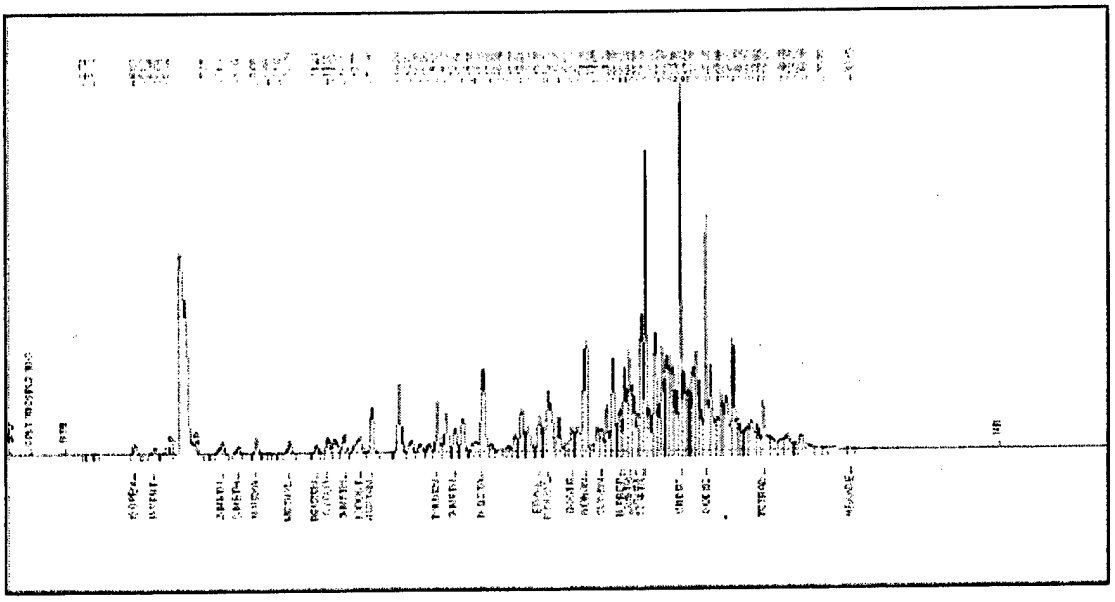
* Percent of total test substance analyzed. Total analytes = sum of the 28 individual hydrocarbons; remainder is other unidentified hydrocarbons.
ND - None Detected

APPENDIX B - SAMPLE CHROMATOGRAMS

JP5
MRD 01-124 NEAT MATERIAL

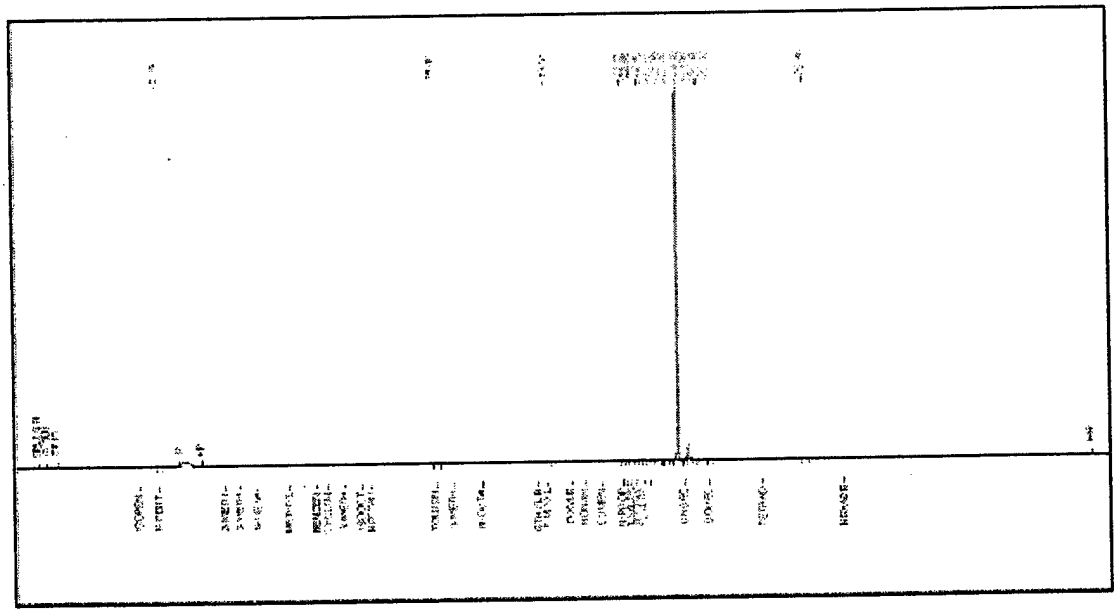


JP5
MRD 01-124 NEAT MATERIAL (USED)

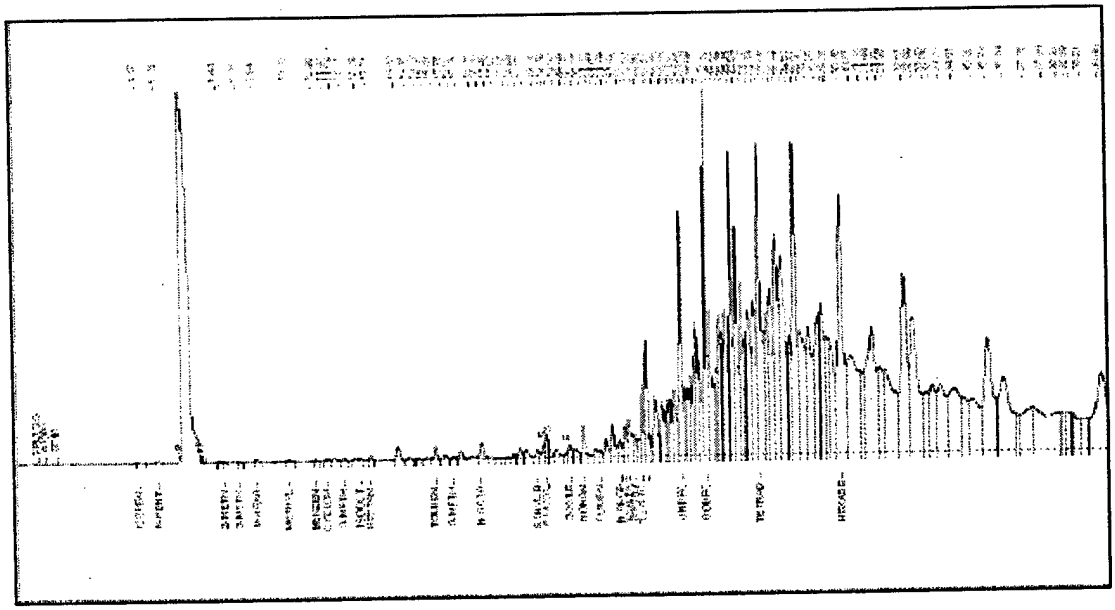


APPENDIX B - SAMPLE CHROMATOGRAMS

JP10
MRD 02-359 NEAT MATERIAL



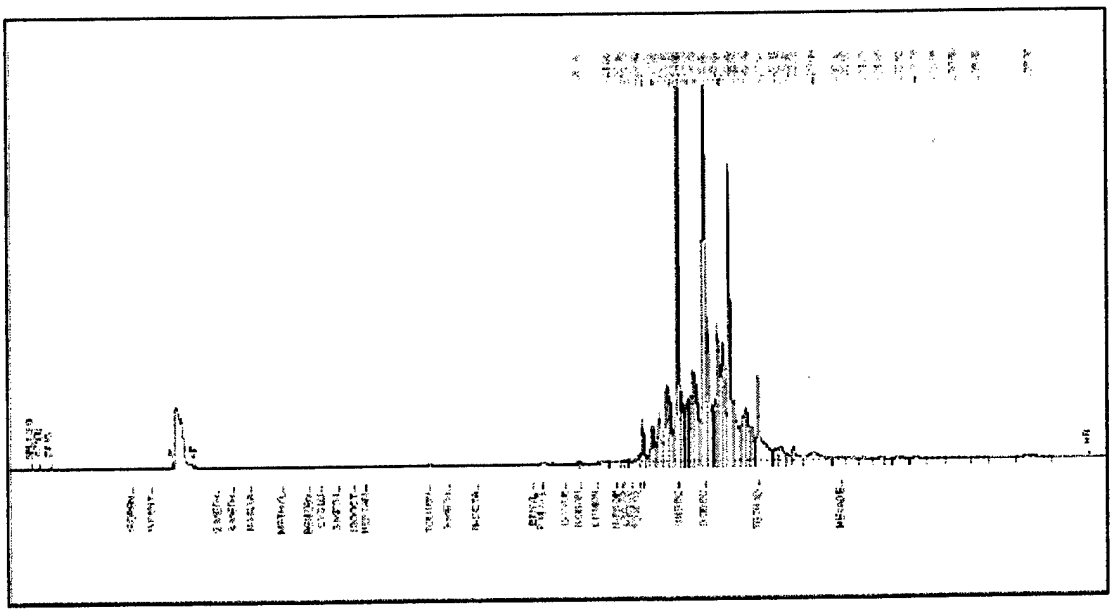
DFM
MRD 01-087 NEAT MATERIAL



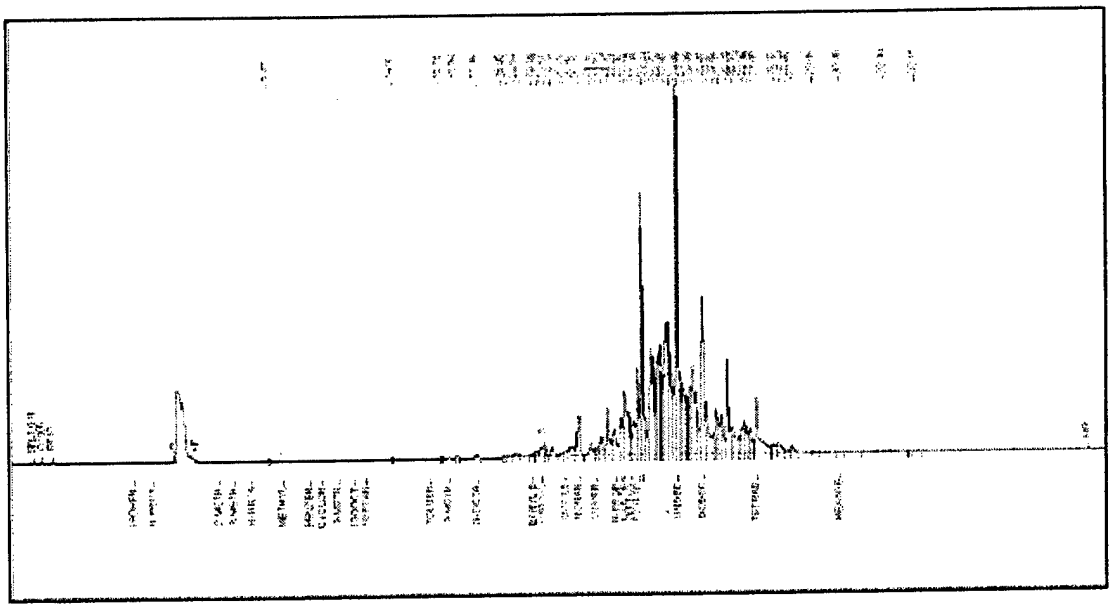
Please note: Sample contained many heavy hydrocarbons causing a distorted and incomplete chromatogram.

APPENDIX B - SAMPLE CHROMATOGRAMS

JP7
MRD 02-358 NEAT MATERIAL

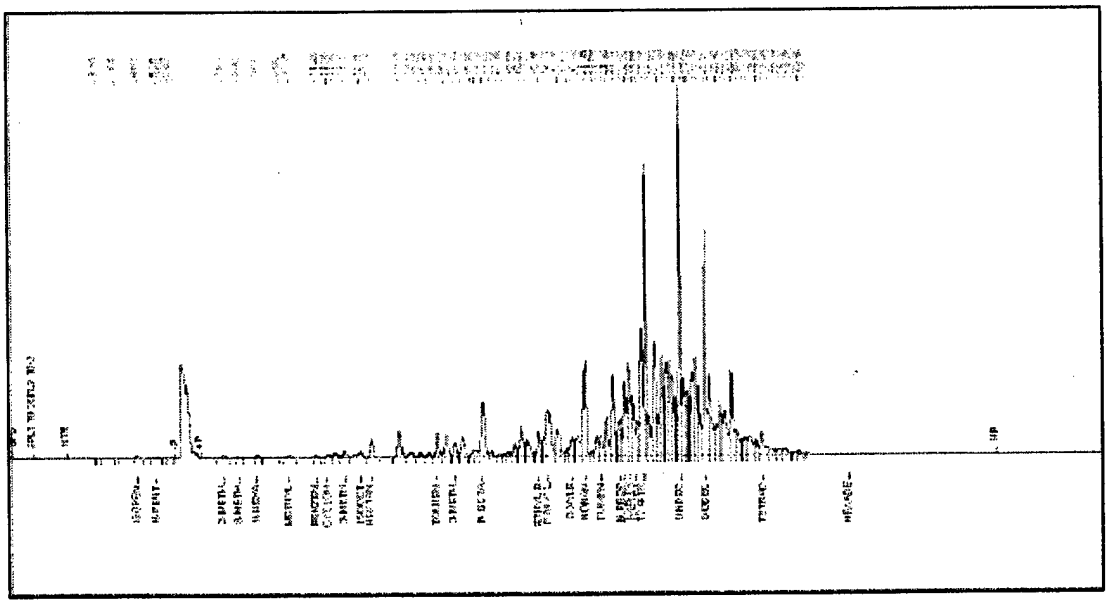


JPTS
MRD 02-357 NEAT MATERIAL

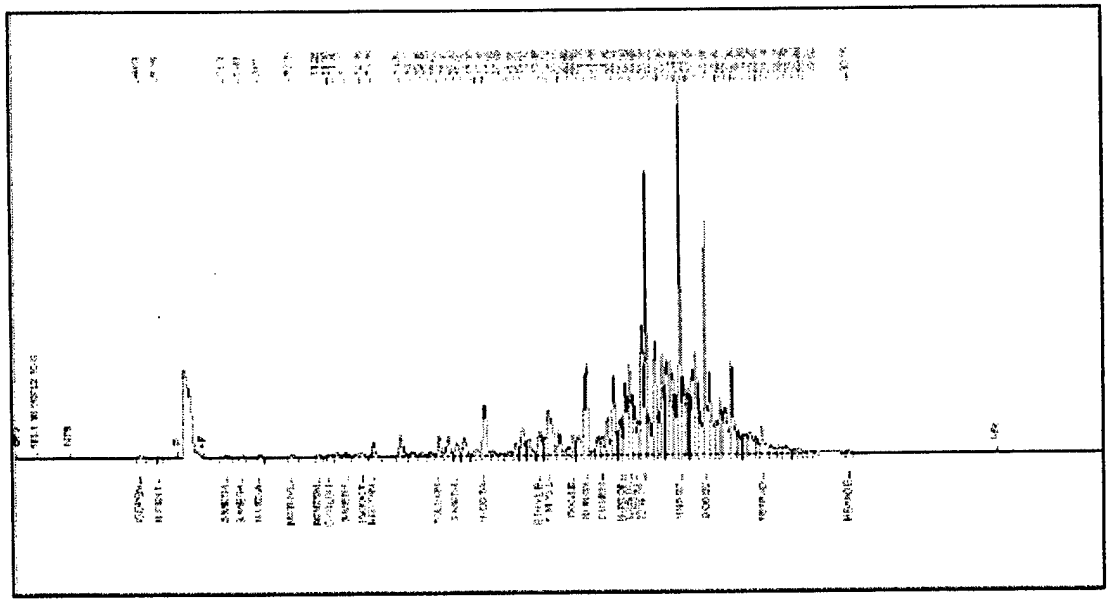


APPENDIX B - SAMPLE CHROMATOGRAMS

JP5
Mean Exposure Concentration - 1285 mg/m^3
Sample 1 - 243 mg/m^3 Aerosol
GLASS FIBER FILTER

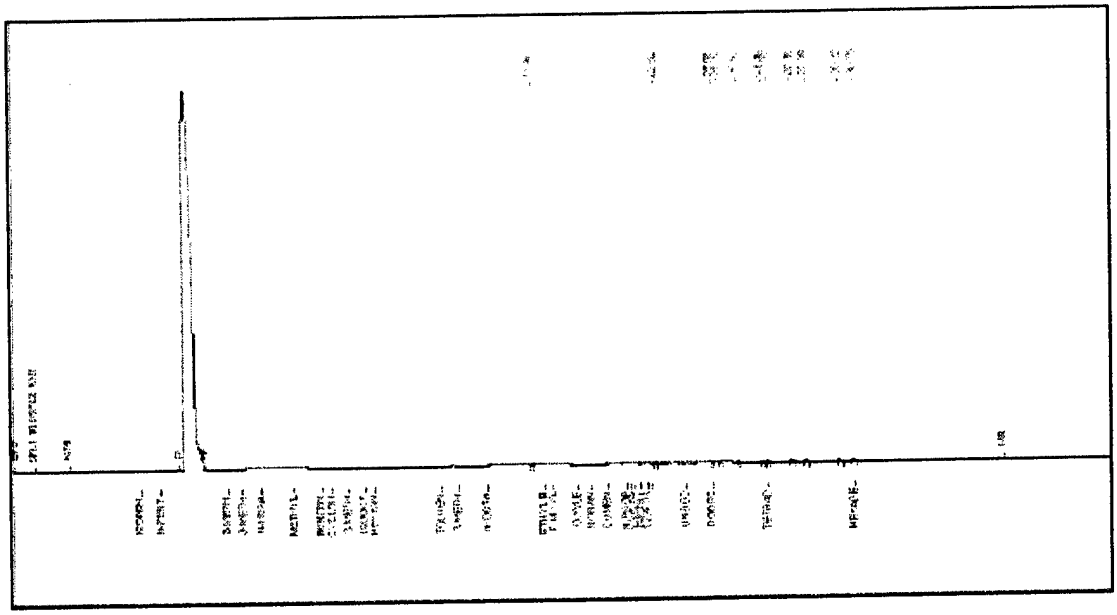


JP5
Mean Exposure Concentration - 1285 mg/m^3
Sample 2 - 165 mg/m^3 Aerosol
GLASS FIBER FILTER

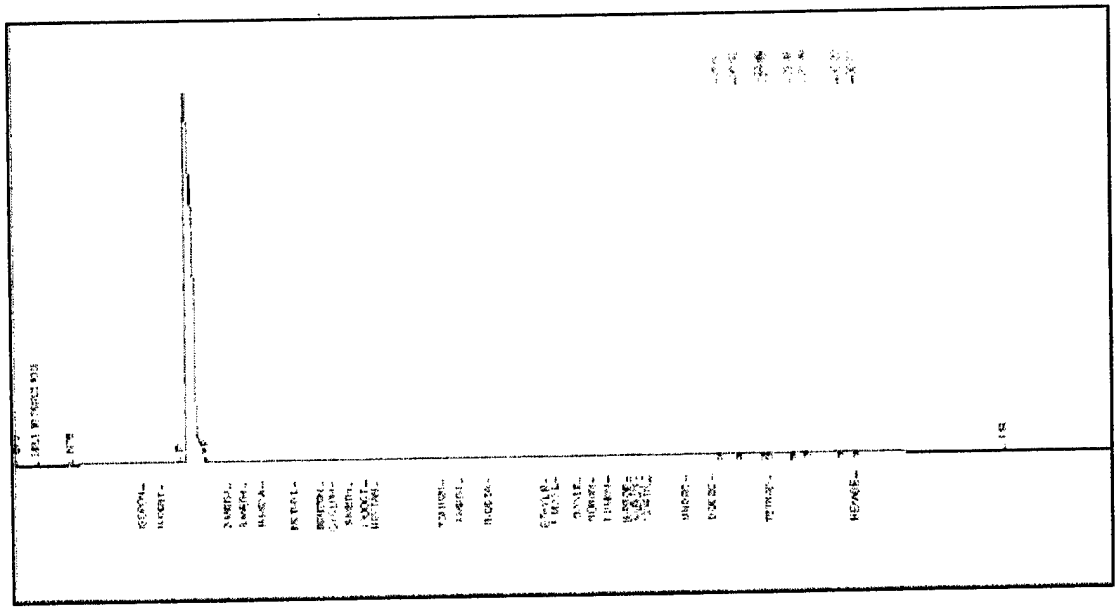


APPENDIX B - SAMPLE CHROMATOGRAMS

JP5
Mean Exposure Concentration - 1285 mg/m^3
Sample 3 - 171 mg/m^3 Aerosol
GLASS FIBER FILTER

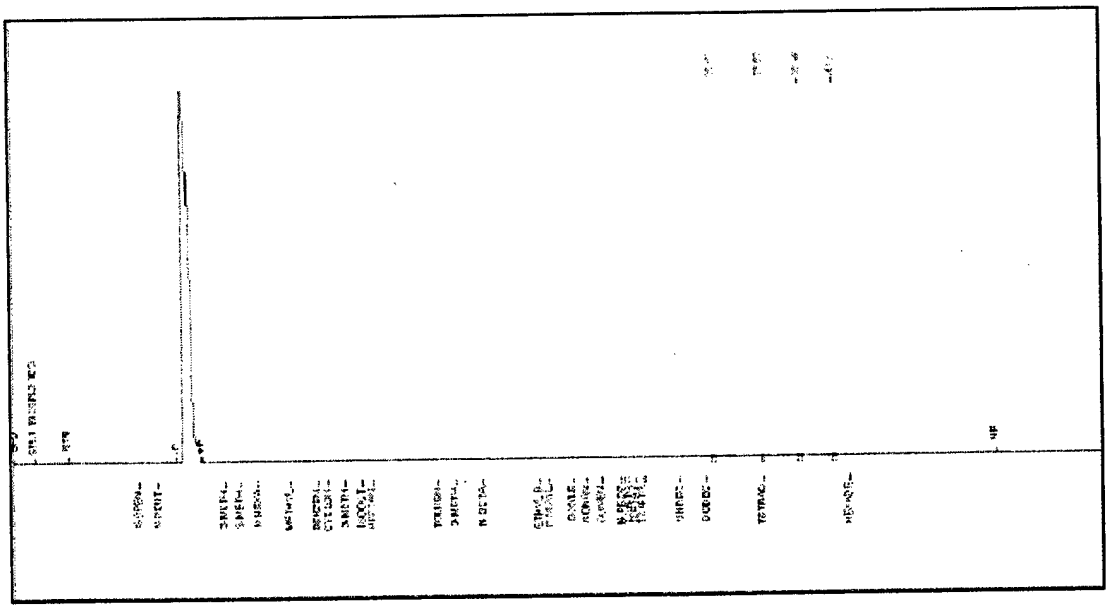


Mean Exposure Concentration - 1285 mg/m^3
Sample 1 - 1100 mg/m^3 Vapor
CHARCOAL TUBE

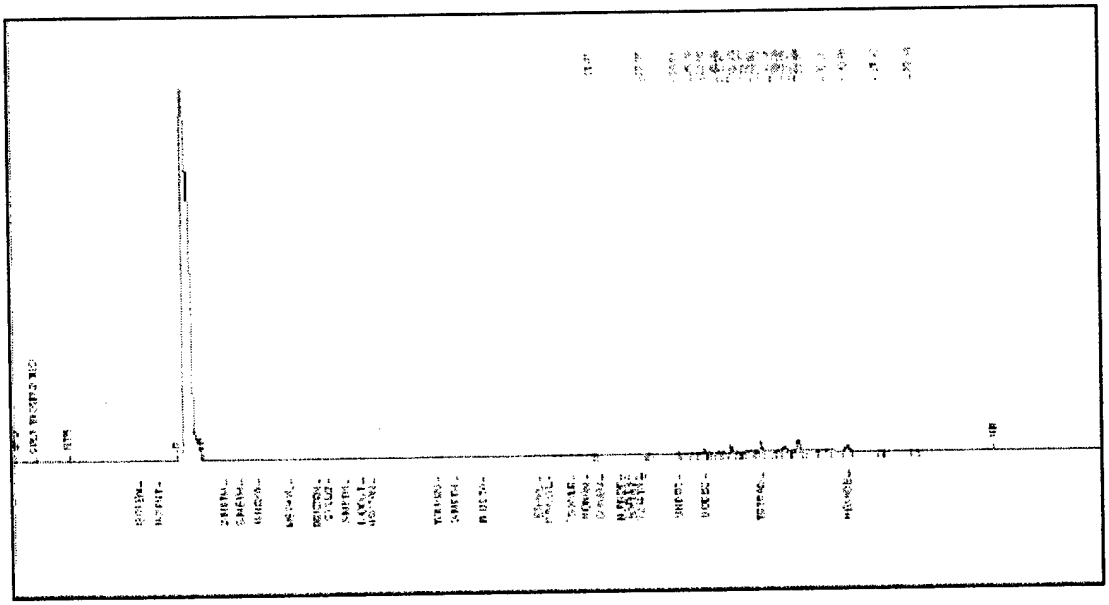


APPENDIX B - SAMPLE CHROMATOGRAMS

JP5
Mean Exposure Concentration - 1285 mg/m^3
Sample 2 - 1069 mg/m^3 Vapor
CHARCOAL TUBE

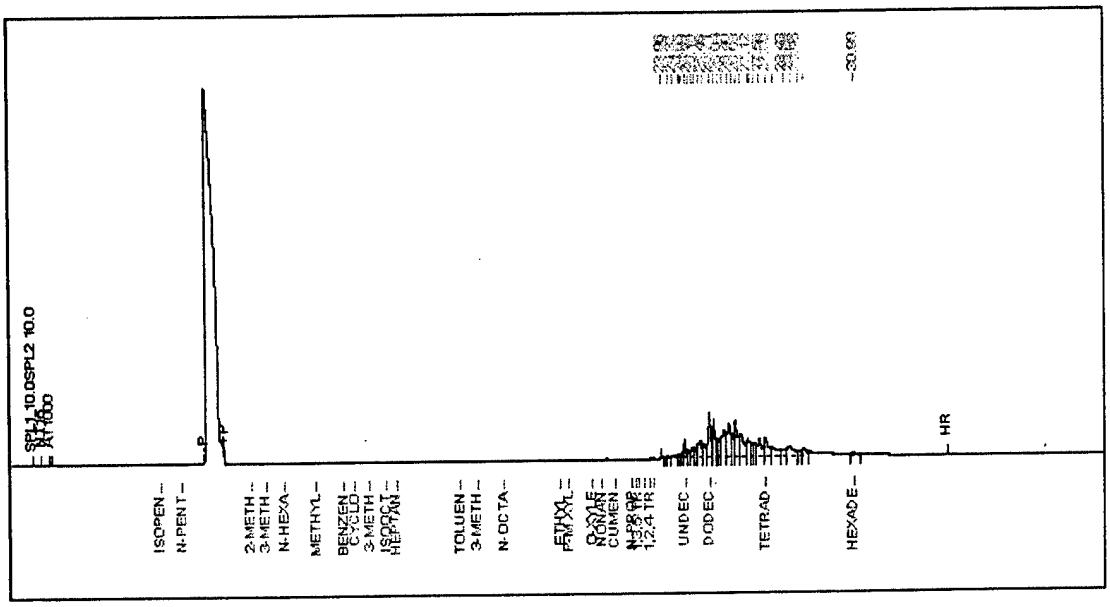


JP5
Mean Exposure Concentration - 1285 mg/m^3
Sample 3 - 1107 mg/m^3 Vapor
CHARCOAL TUBE

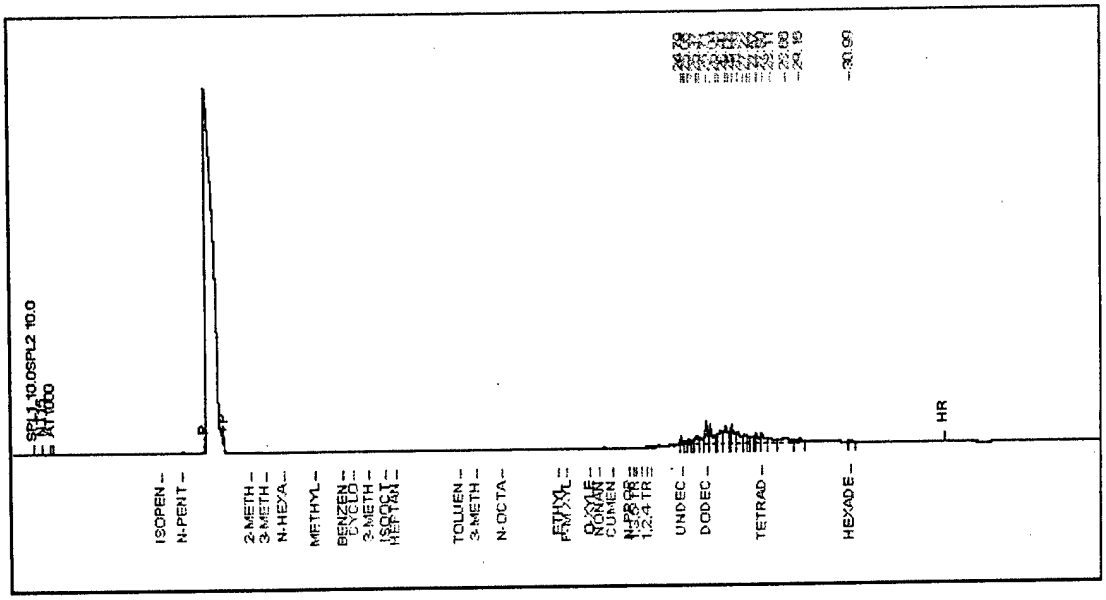


APPENDIX B - SAMPLE CHROMATOGRAMS

JP5
Mean Exposure Concentration - 2031 mg/m^3
Sample 1 - 421 mg/m^3 Aerosol
GLASS FIBER FILTER

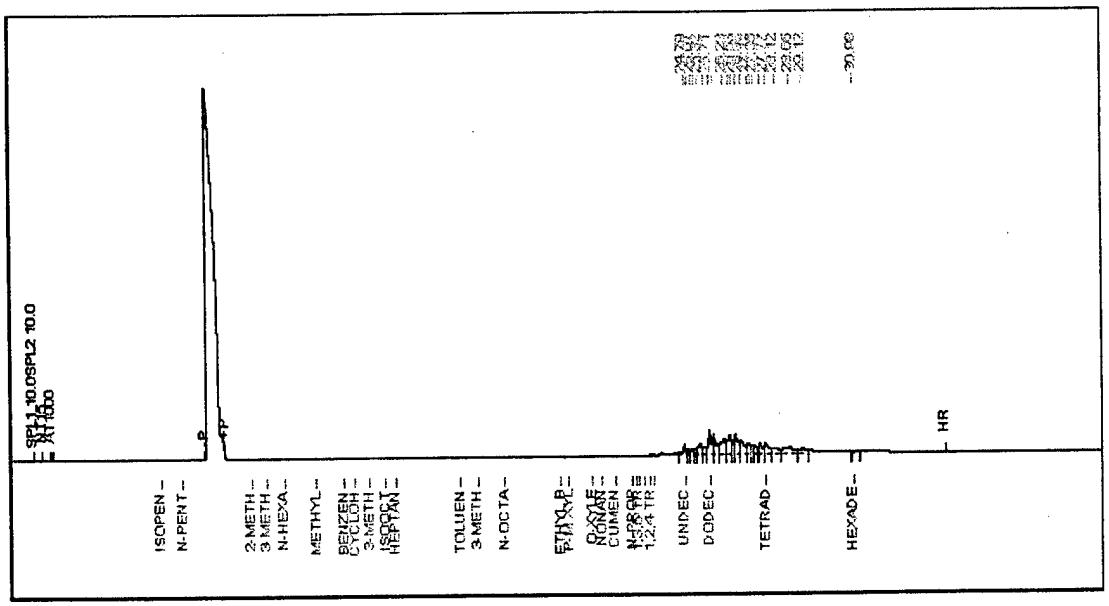


JP5
Mean Exposure Concentration - 2031 mg/m^3
Sample 2 - 413 mg/m^3 Aerosol
GLASS FIBER FILTER

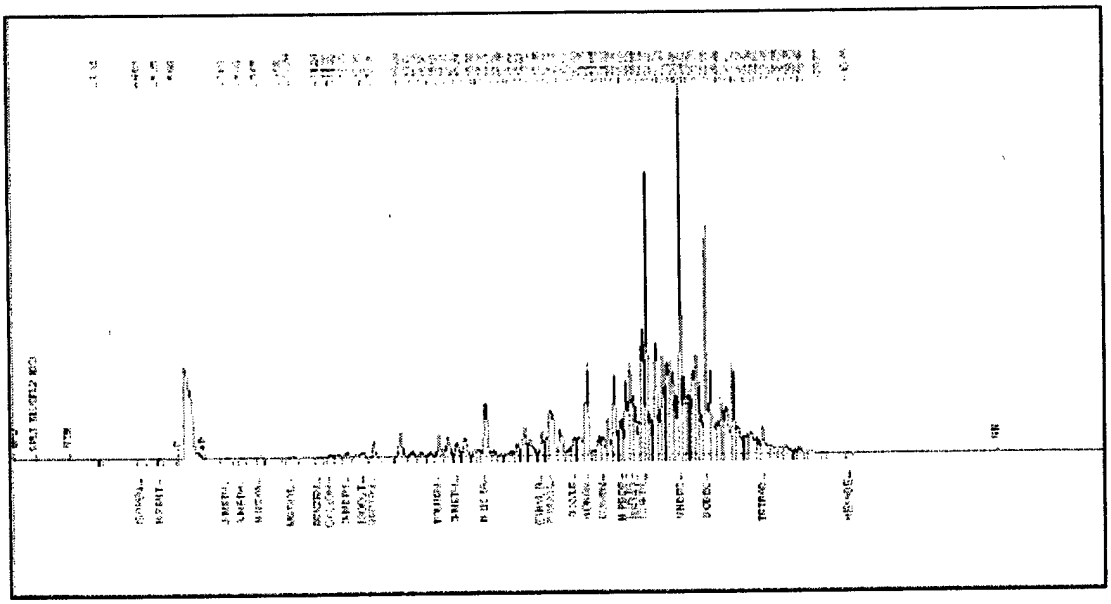


APPENDIX B - SAMPLE CHROMATOGRAMS

JP5
Mean Exposure Concentration - 2031 mg/m^3
Sample 3 - 412 mg/m^3 Aerosol
GLASS FIBER FILTER

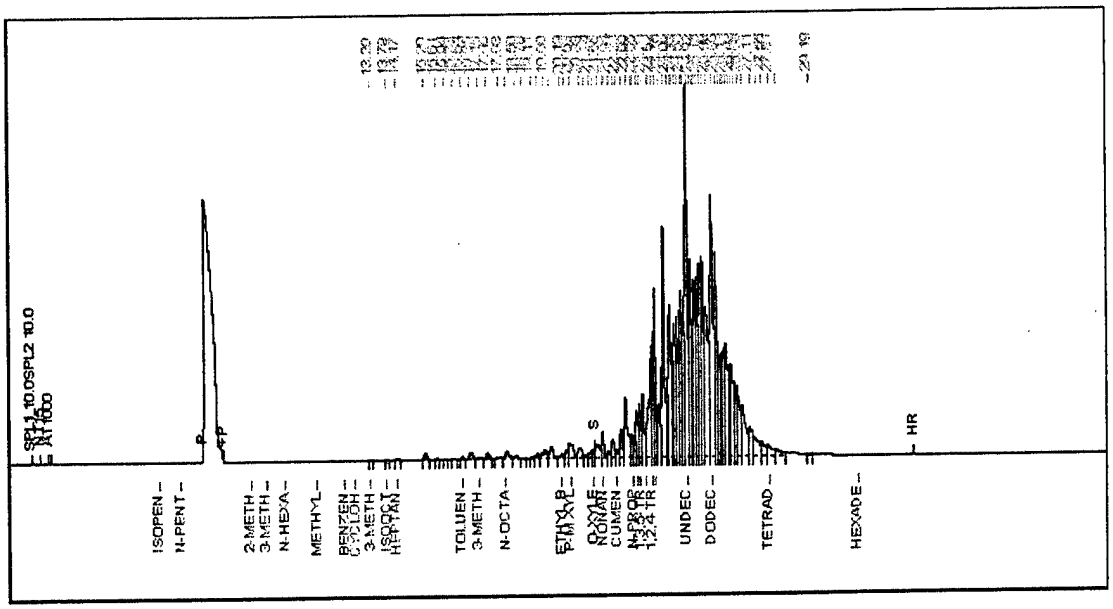


JP5
Mean Exposure Concentration - 2031 mg/m^3
Sample 1 - 1487 mg/m^3 Vapor
CHARCOAL TUBE

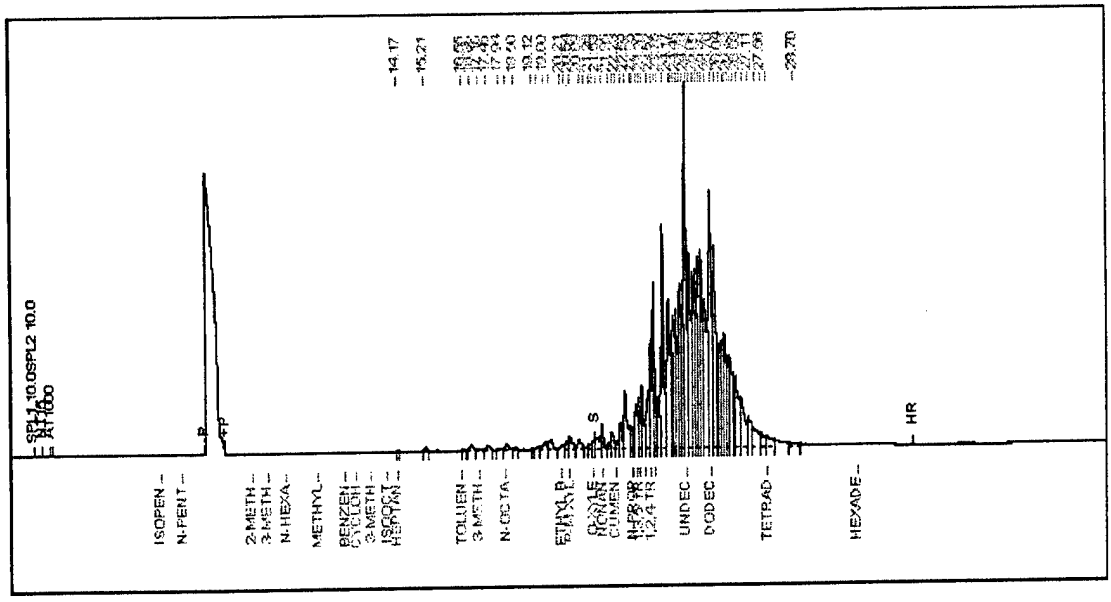


APPENDIX B - SAMPLE CHROMATOGRAMS

JP5
Mean Exposure Concentration - 2031 mg/m^3
Sample 2 - 1782 mg/m^3 Vapor
CHARCOAL TUBE

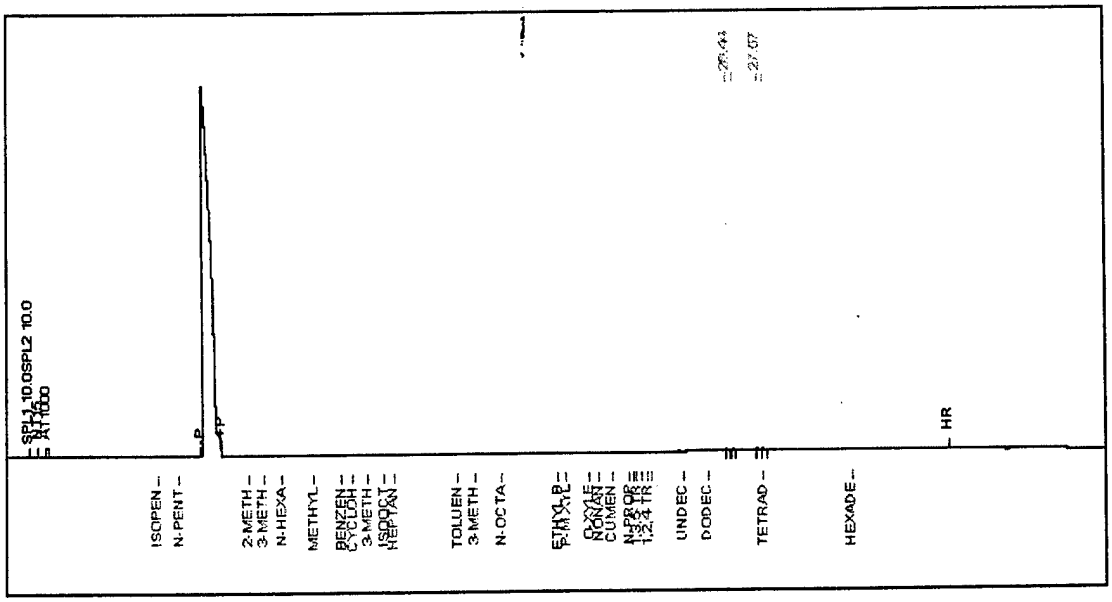


JP5
Mean Exposure Concentration - 2031 mg/m^3
Sample 3 - 1577 mg/m^3 Vapor
CHARCOAL TUBE

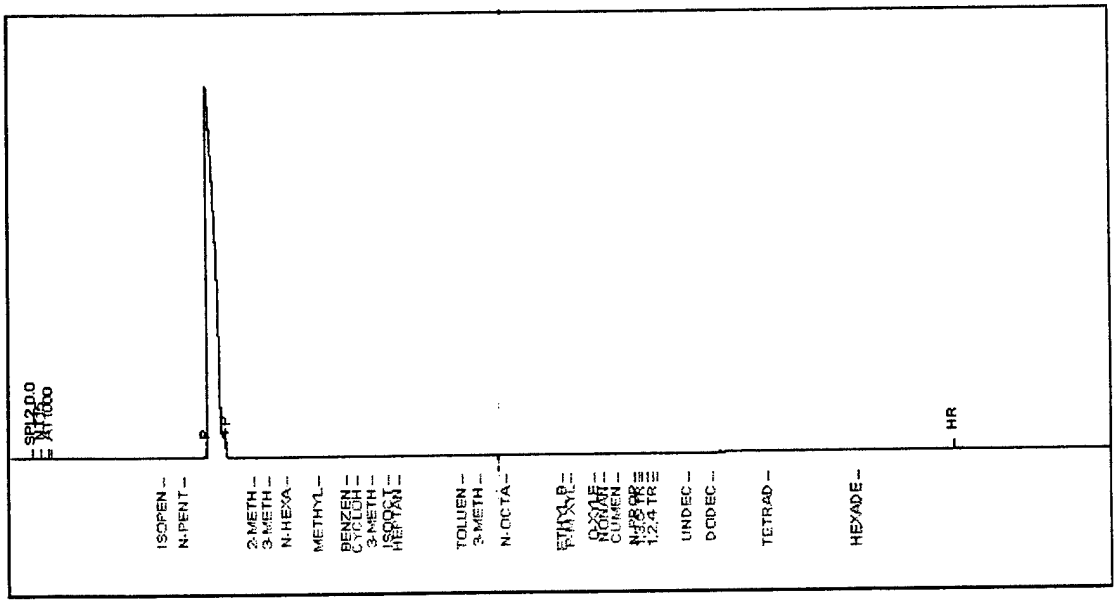


APPENDIX B - SAMPLE CHROMATOGRAMS

JP5 - Particle Size
Mean Exposure Concentration - 2031 mg/m^3
Stage Constant - 28.0 um
GLASS FIBER FILTER

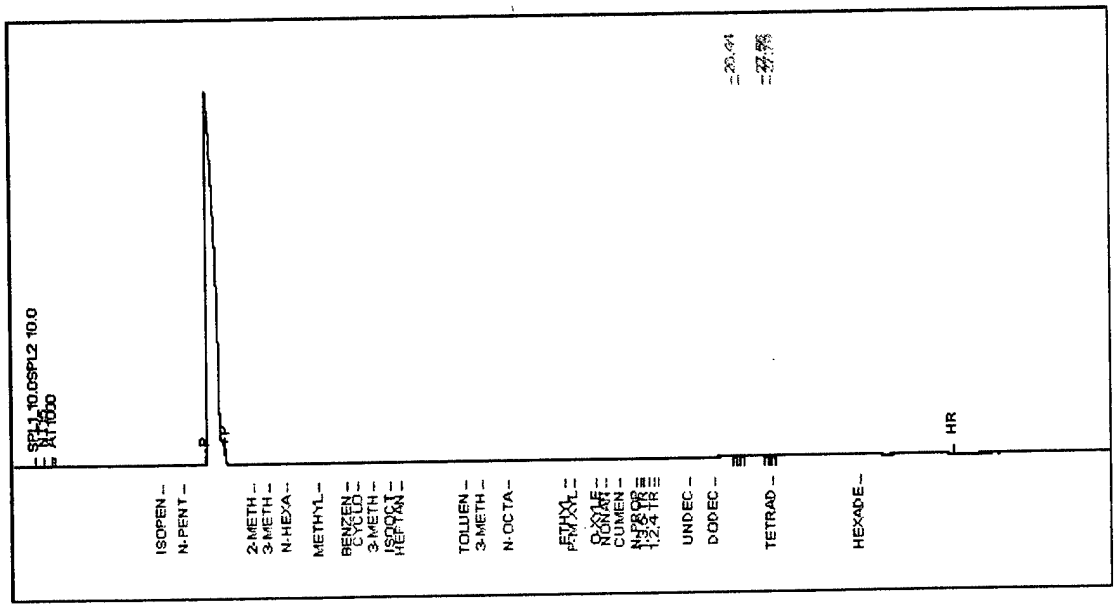


JP5 - Particle Size
Mean Exposure Concentration - 2031 mg/m^3
Stage Constant - 17.0 um
GLASS FIBER FILTER

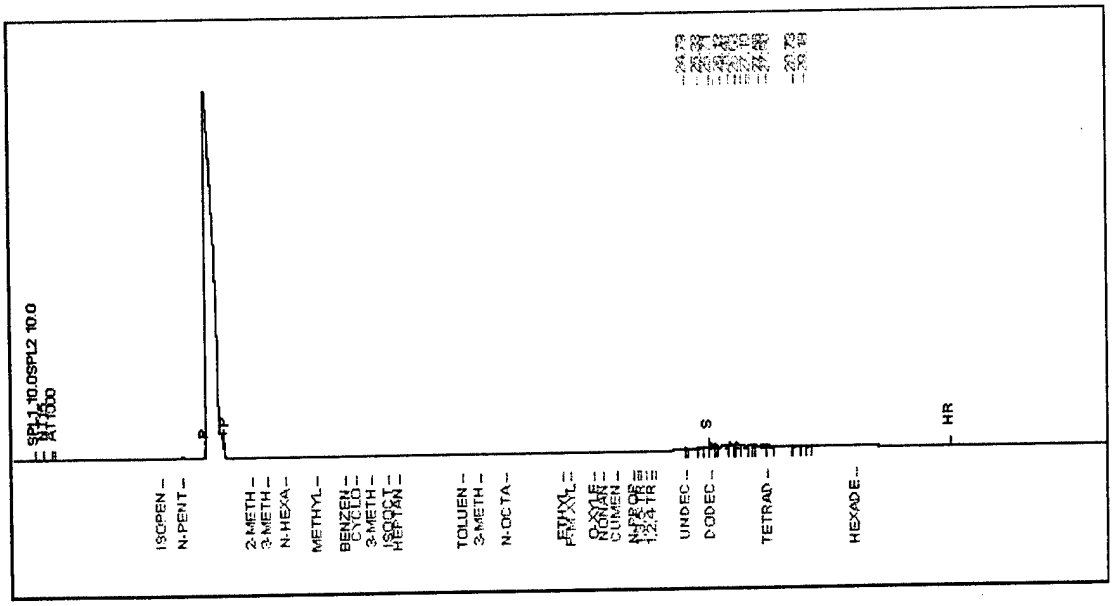


APPENDIX B - SAMPLE CHROMATOGRAMS

JP5 - Particle Size
Mean Exposure Concentration - 2031 mg/m^3
Stage Constant - 6.80 um
GLASS FIBER FILTER

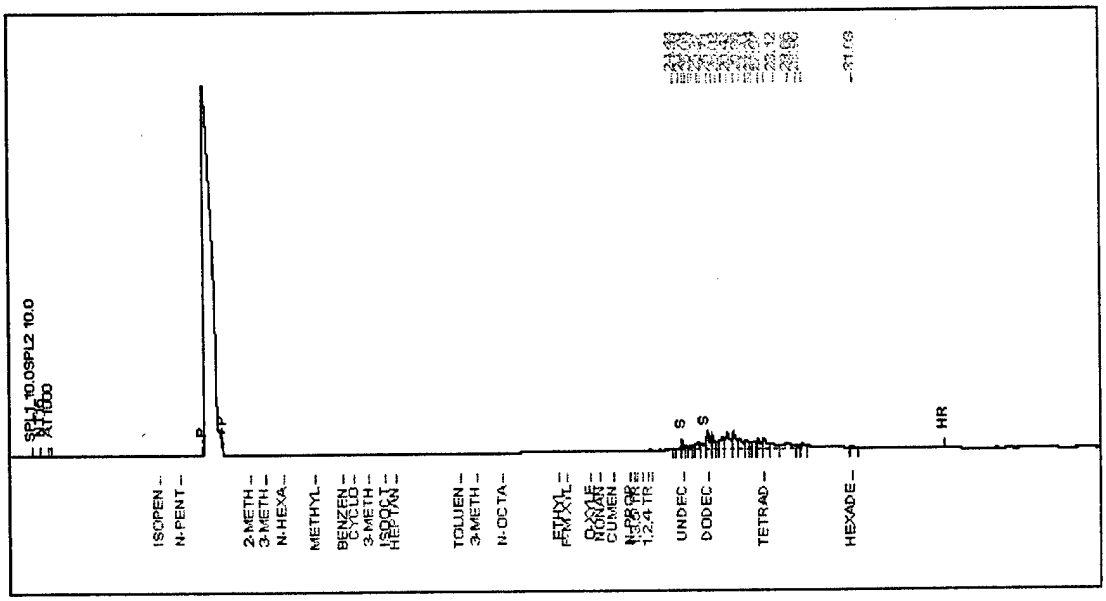


JP5 - Particle Size
Mean Exposure Concentration - 2031 mg/m^3
Stage Constant - 4.10 um
GLASS FIBER FILTER

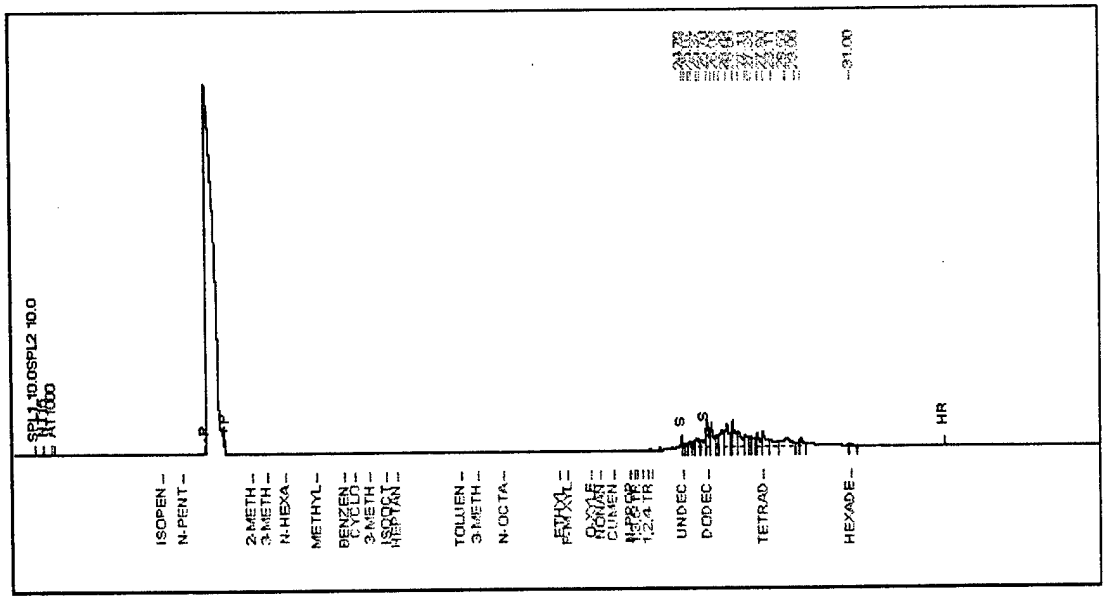


APPENDIX B - SAMPLE CHROMATOGRAMS

JP5 - Particle Size
Mean Exposure Concentration - 2031 mg/m^3
Stage Constant - 2.60 um
GLASS FIBER FILTER

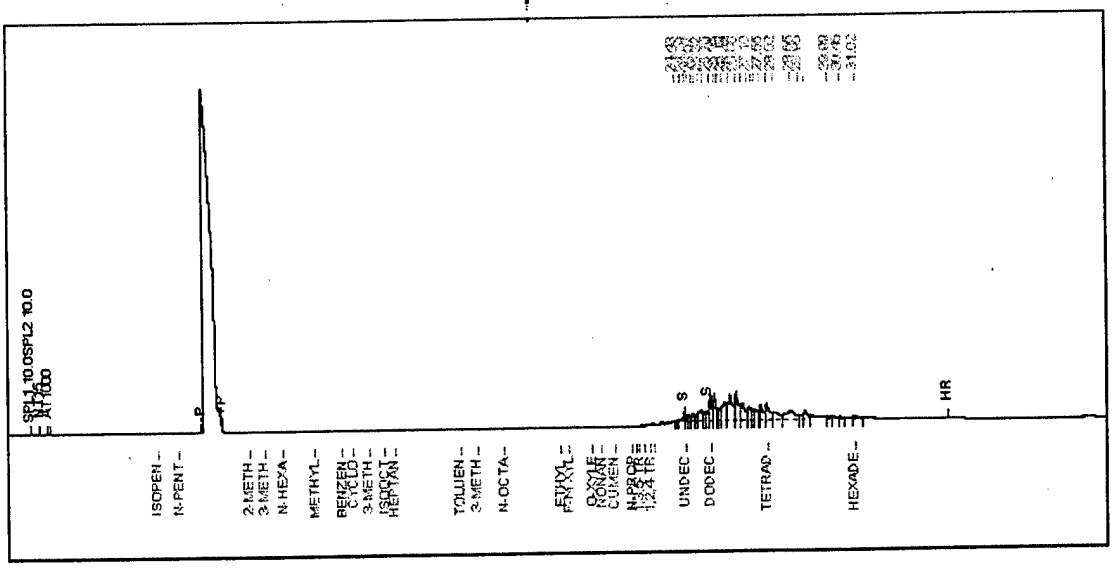


JP5 - Particle Size
Mean Exposure Concentration - 2031 mg/m^3
Stage Constant - 1.50 um
GLASS FIBER FILTER

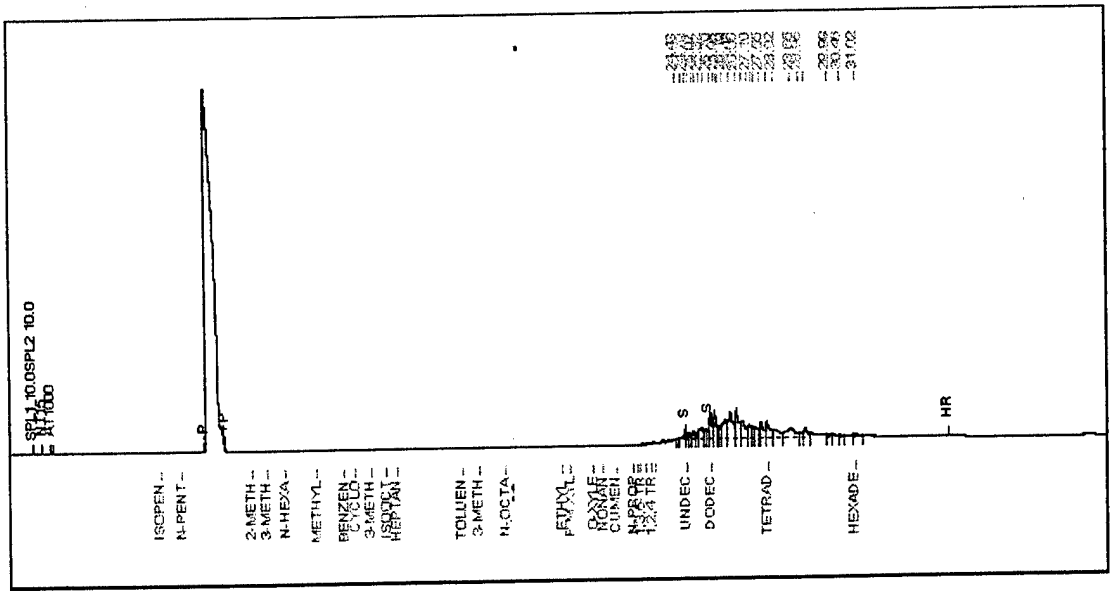


APPENDIX B - SAMPLE CHROMATOGRAMS

JP5 - Particle Size
Mean Exposure Concentration - 2031 mg/m^3
Stage Constant - 0.84 um
GLASS FIBER FILTER

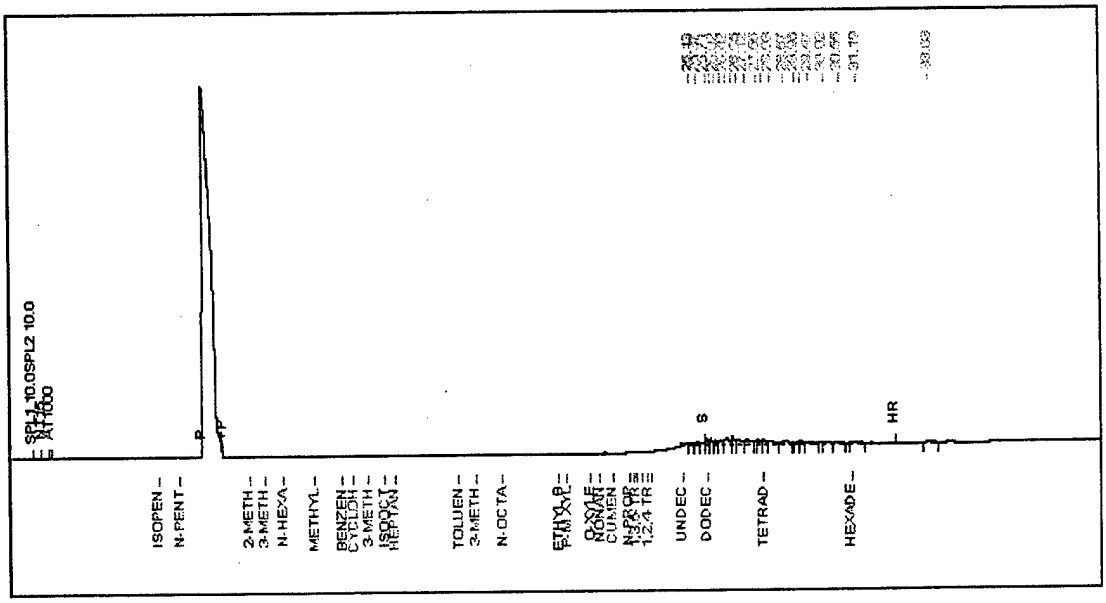


JP5 - Particle Size
Mean Exposure Concentration - 2031 mg/m^3
Stage Constant - 0.54 um
GLASS FIBER FILTER

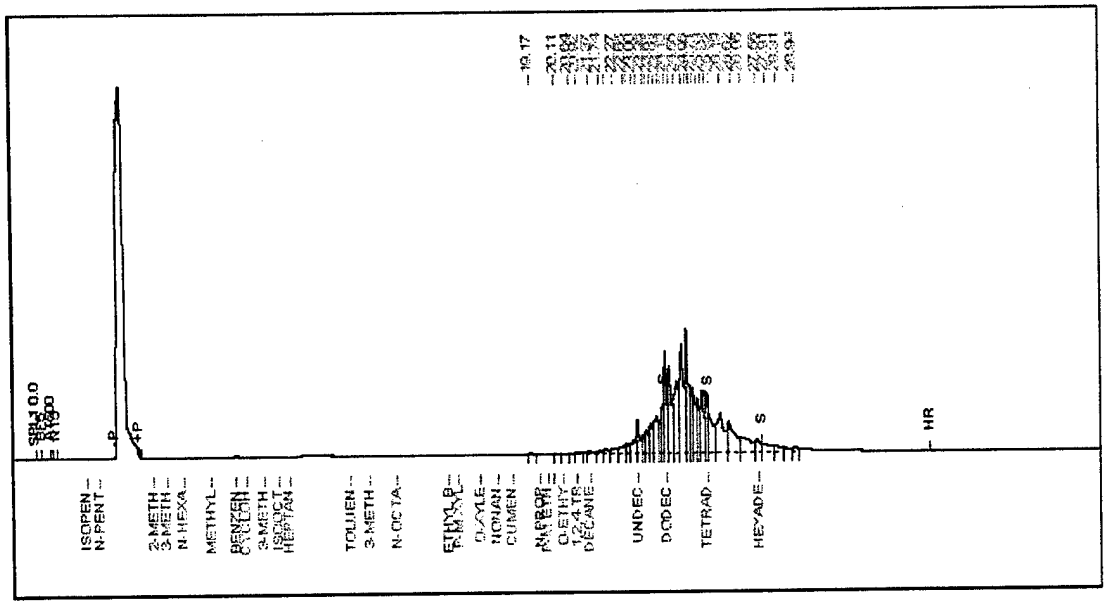


APPENDIX B - SAMPLE CHROMATOGRAMS

JP5 - Particle Size
Mean Exposure Concentration - 2031 mg/m^3
Filter
GLASS FIBER FILTER

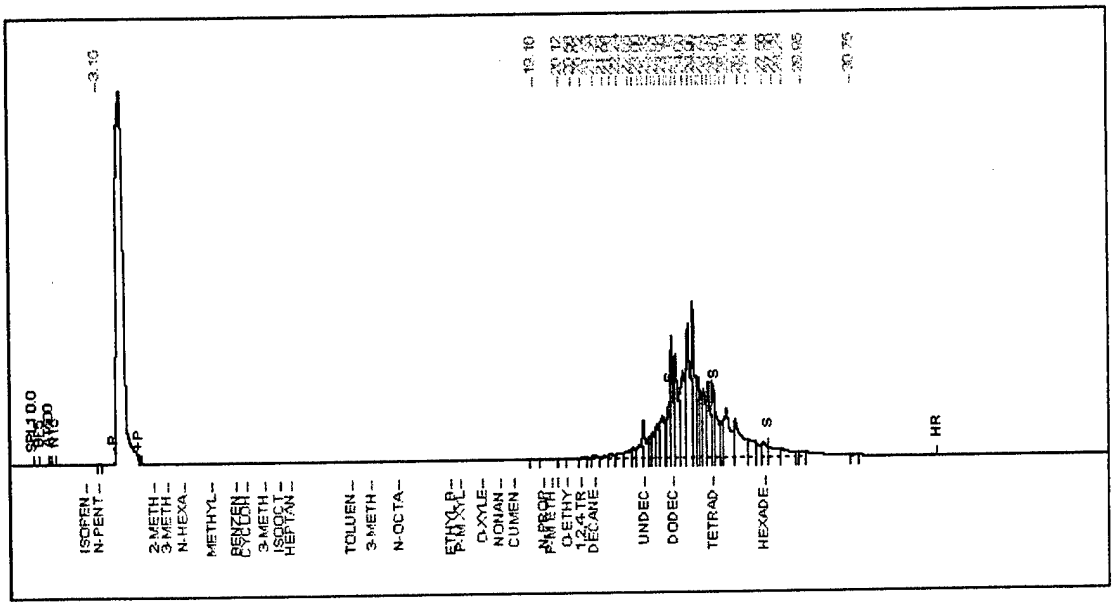


JP5
Mean Exposure Concentration - 13417 mg/m^3
Sample 1 - 2716 mg/m^3 Aerosol
GLASS FIBER FILTER

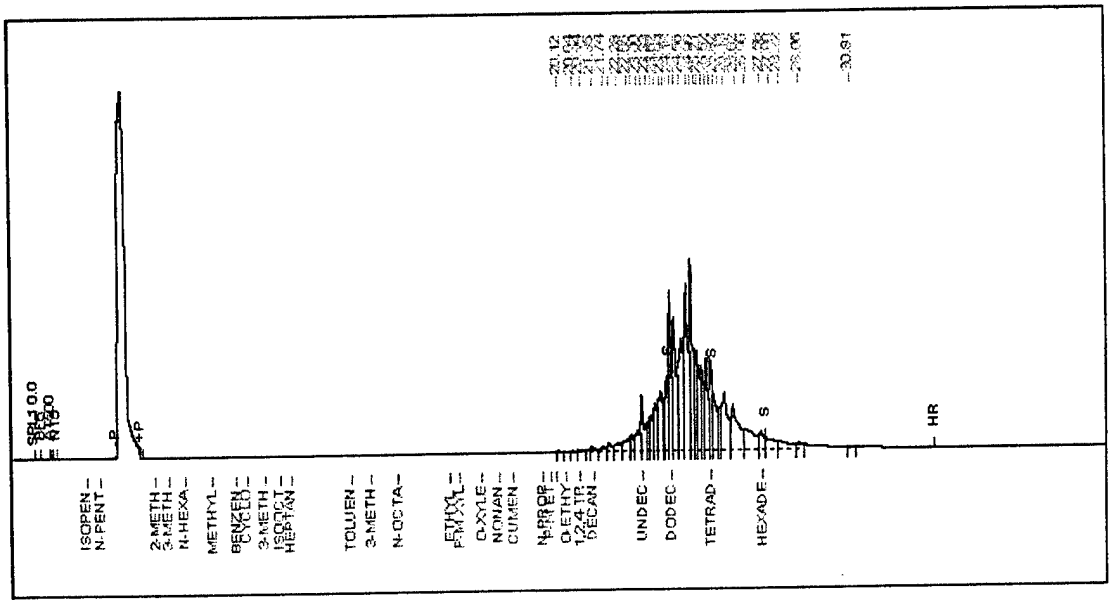


APPENDIX B - SAMPLE CHROMATOGRAMS

JP5
Mean Exposure Concentration - 13417 mg/m^3
Sample 2 - 3309 mg/m^3 Aerosol
GLASS FIBER FILTER

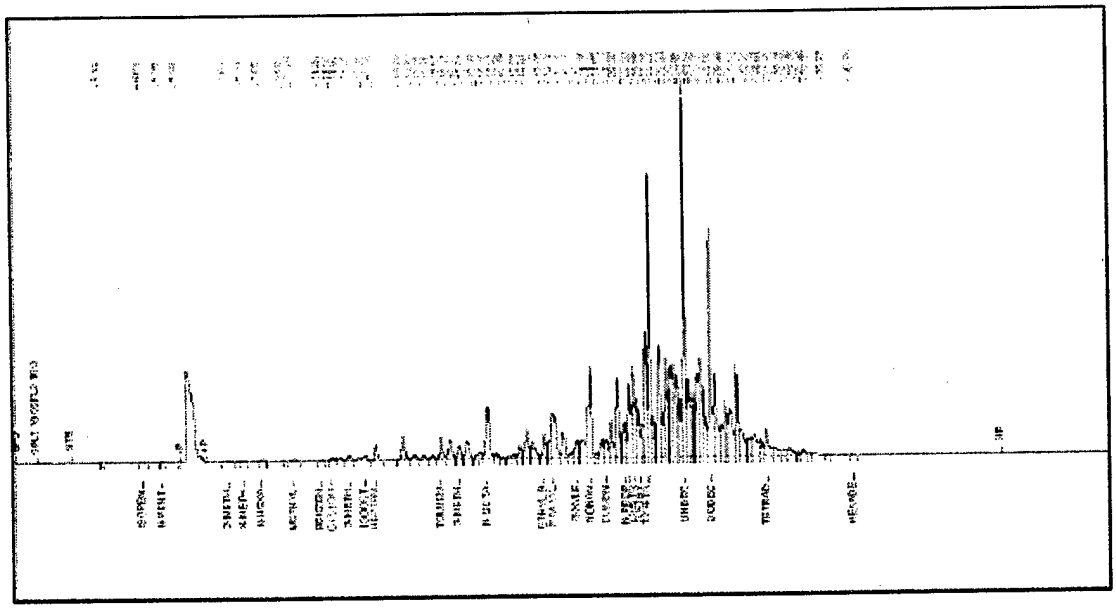


JP5
Mean Exposure Concentration - 13417 mg/m^3
Sample 3 - 4034 mg/m^3 Aerosol
GLASS FIBER FILTER

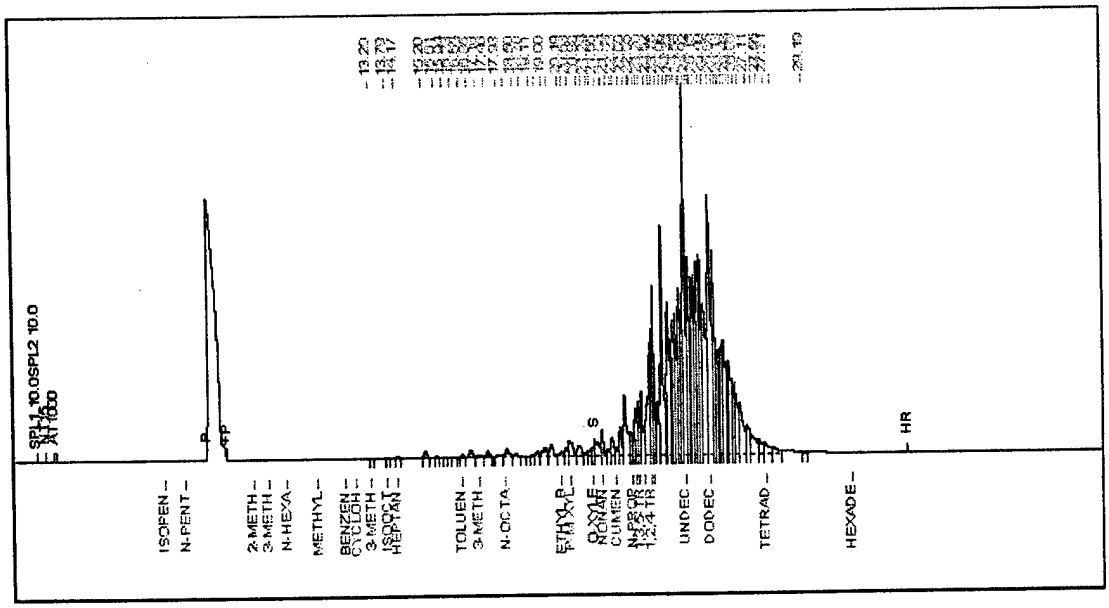


APPENDIX B - SAMPLE CHROMATOGRAMS

JP5
Mean Exposure Concentration - 13417 mg/m^3
Sample 1 - 9960 mg/m^3 Vapor
CHARCOAL TUBE

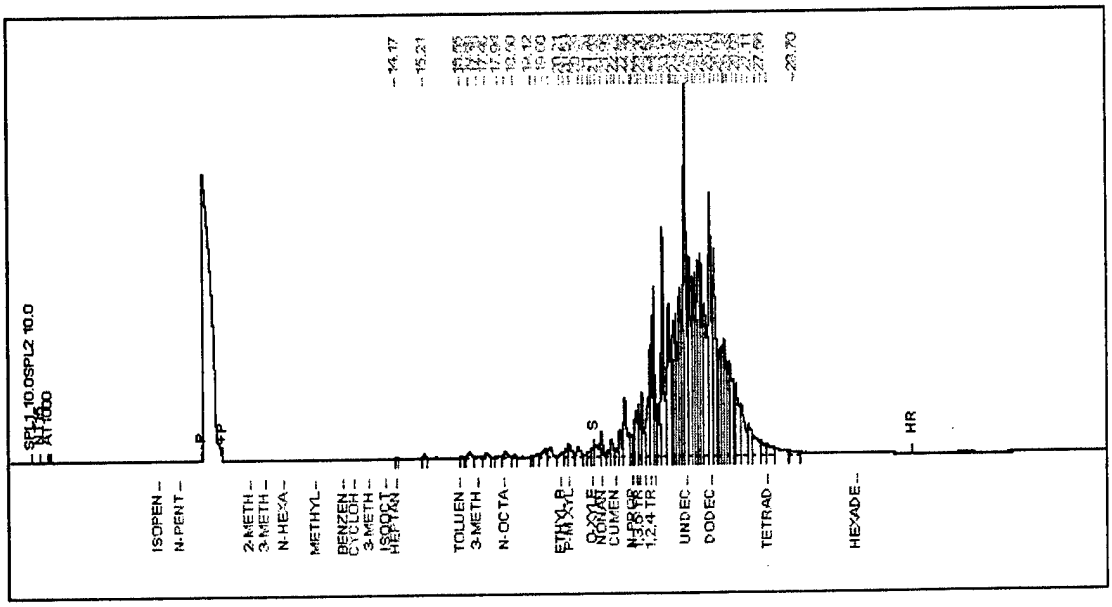


JP5
Mean Exposure Concentration - 13417 mg/m^3
Sample 2 - 10754 mg/m^3 Vapor
CHARCOAL TUBE

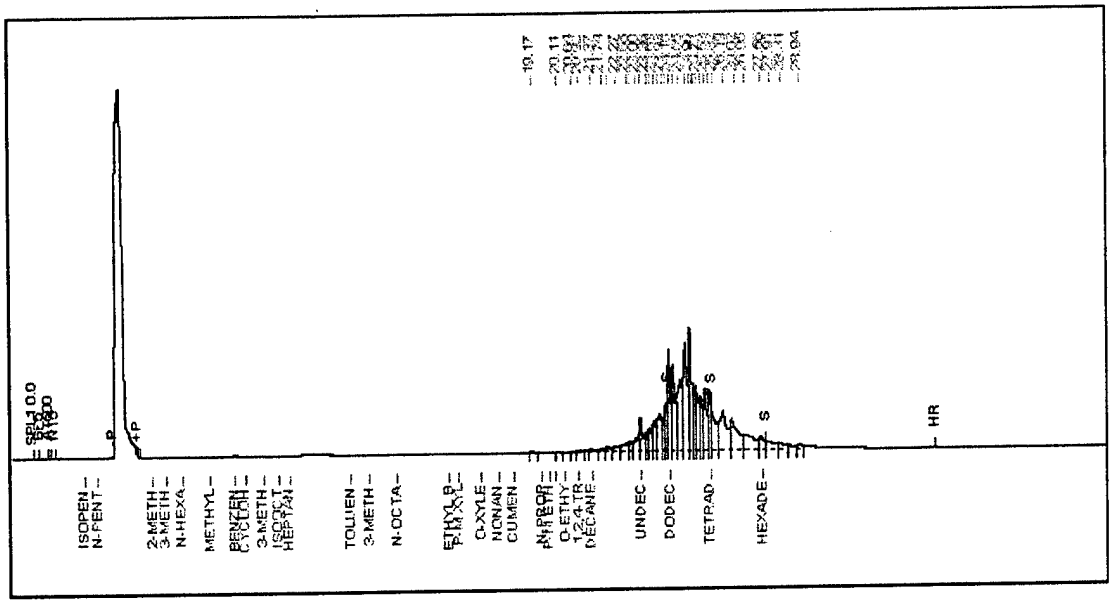


APPENDIX B - SAMPLE CHROMATOGRAMS

JP5
Mean Exposure Concentration - 13417 mg/m^3
Sample 3 - 9479 mg/m^3 Vapor
CHARCOAL TUBE

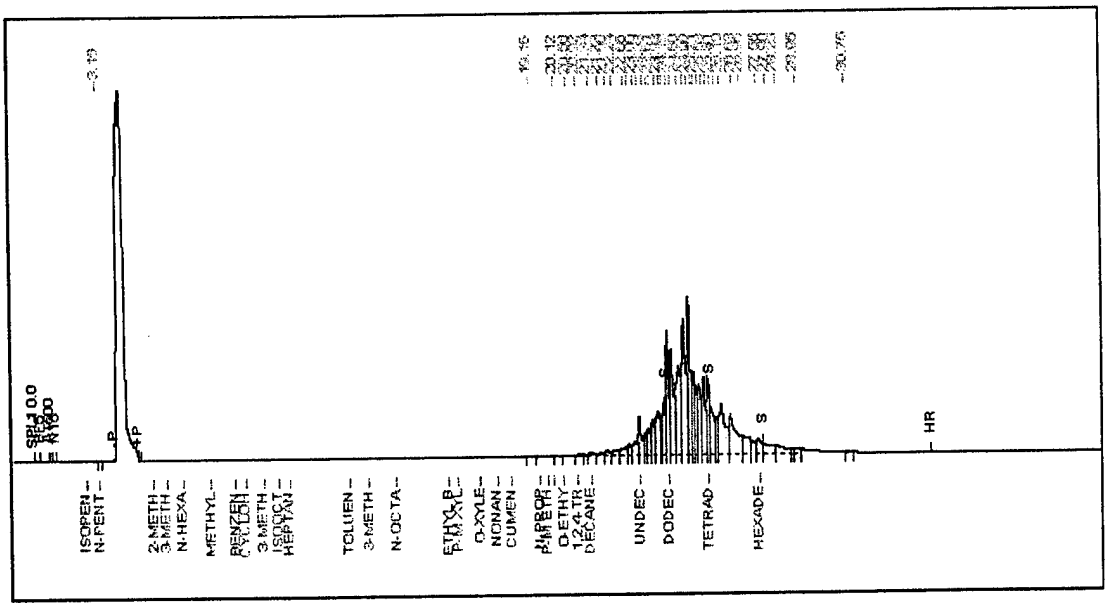


JP5
Mean Exposure Concentration - 2856 mg/m^3
Sample 1 - 361 mg/m^3 Aerosol
GLASS FIBER FILTER

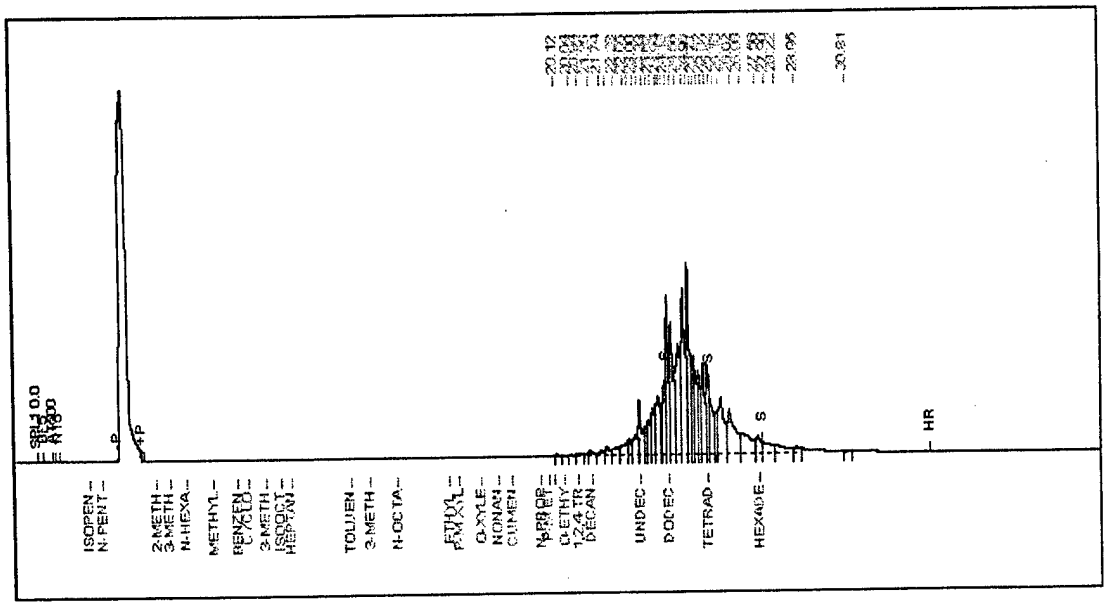


APPENDIX B - SAMPLE CHROMATOGRAMS

JP5
Mean Exposure Concentration - 2856 mg/m^3
Sample 2 - 353 mg/m^3 Aerosol
GLASS FIBER FILTER

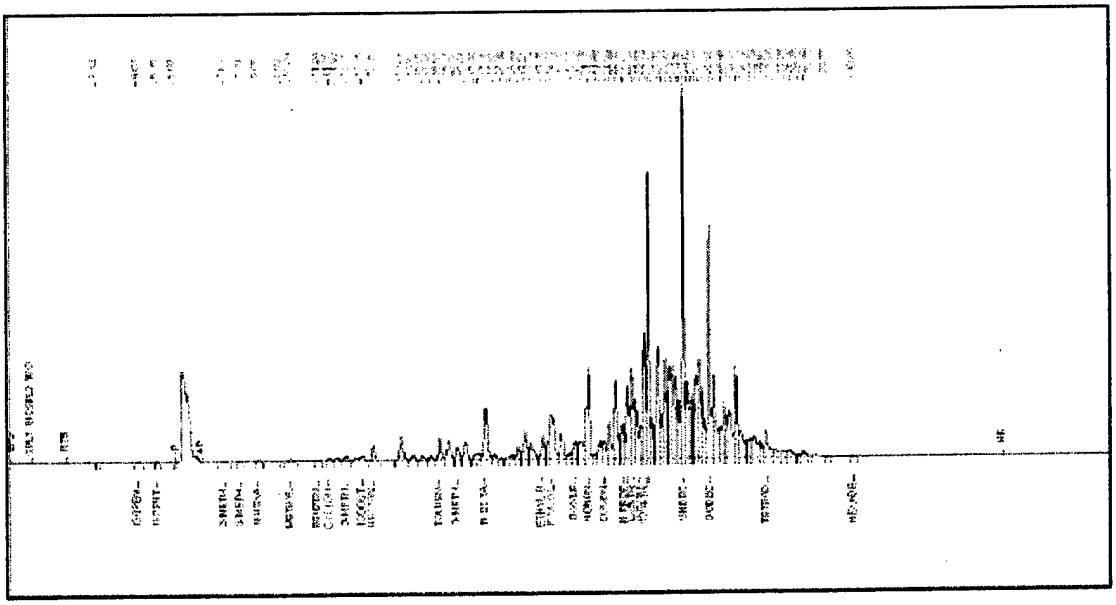


JP5
Mean Exposure Concentration - 2856 mg/m^3
Sample 3 - 516 mg/m^3 Aerosol
GLASS FIBER FILTER

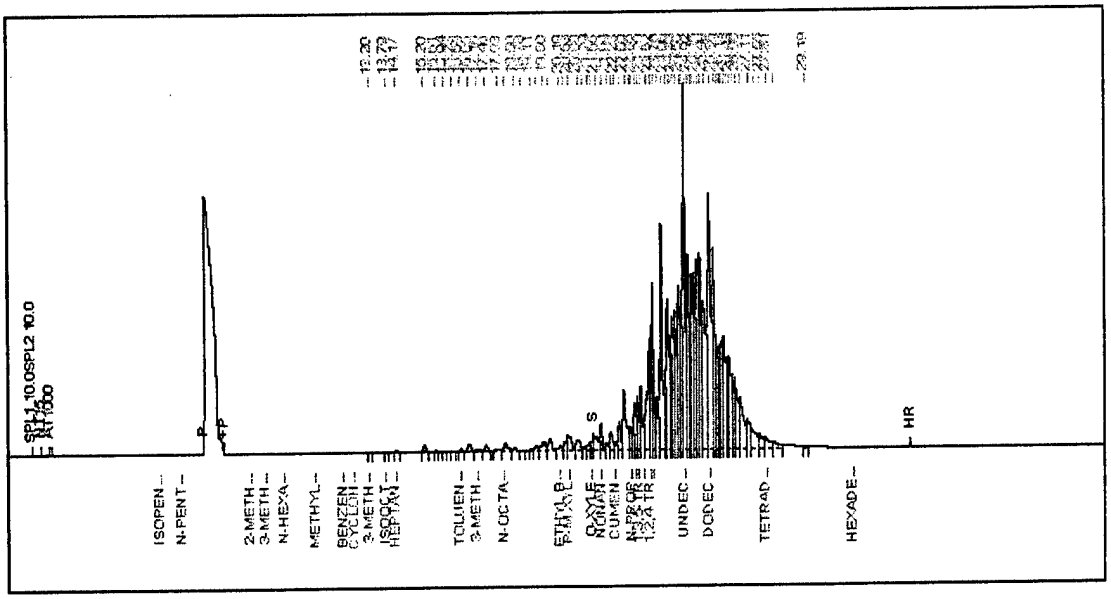


APPENDIX B - SAMPLE CHROMATOGRAMS

JP5
Mean Exposure Concentration - 2856 mg/m^3
Sample 1 - 2407 mg/m^3 Vapor
CHARCOAL TUBE

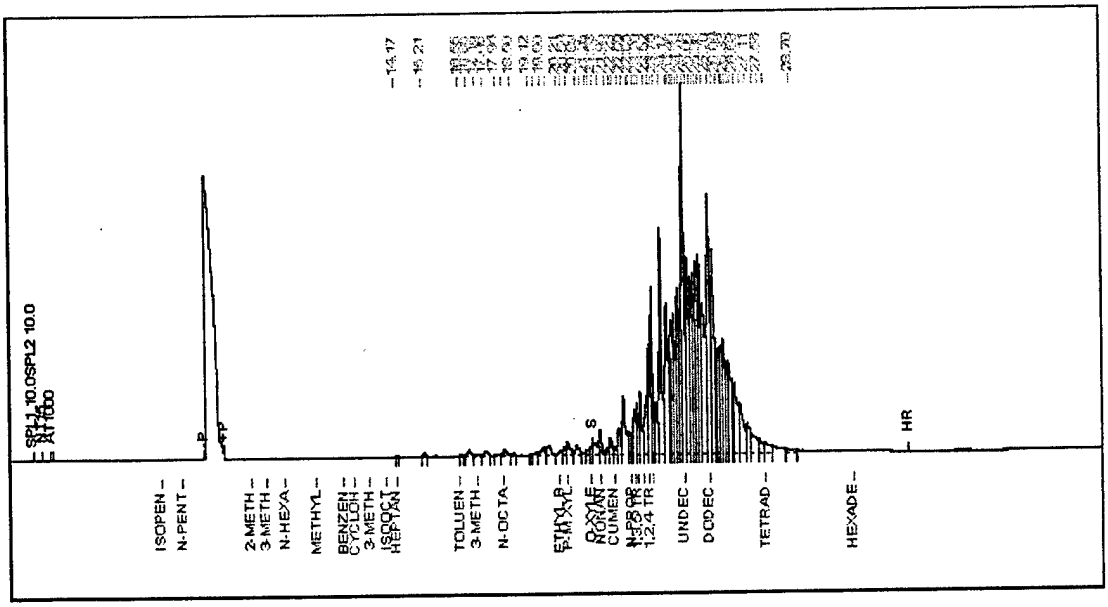


JP5
Mean Concentration - 2856 mg/m^3
Sample 2 - 2508 mg/m^3 Vapor
CHARCOAL TUBE

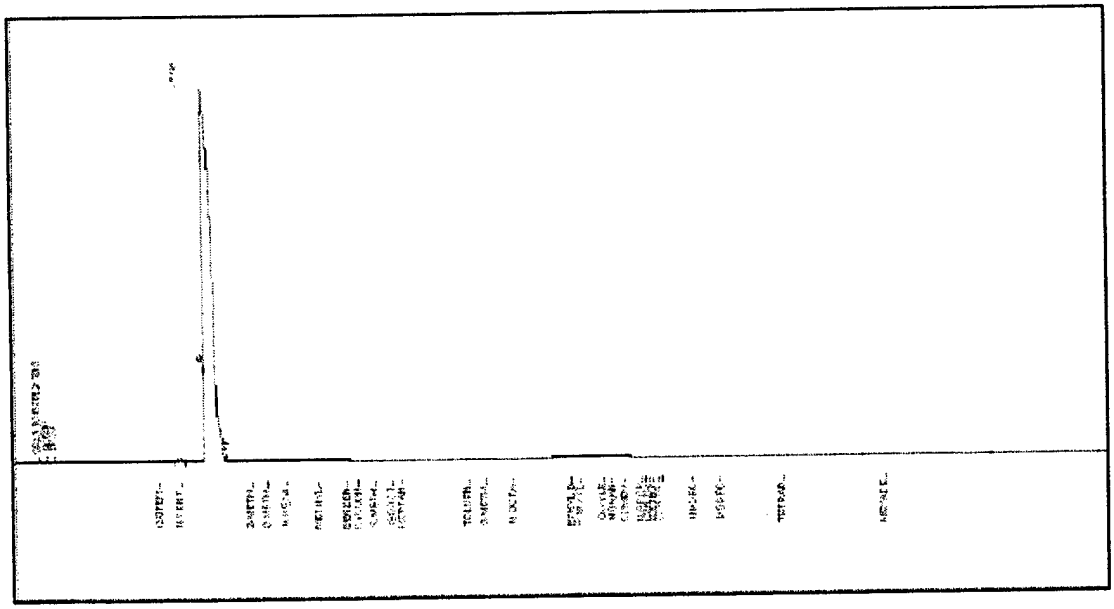


APPENDIX B - SAMPLE CHROMATOGRAMS

JP5
Mean Exposure Concentration - 2856 mg/m^3
Sample 3 - 2423 mg/m^3 Vapor
CHARCOAL TUBE

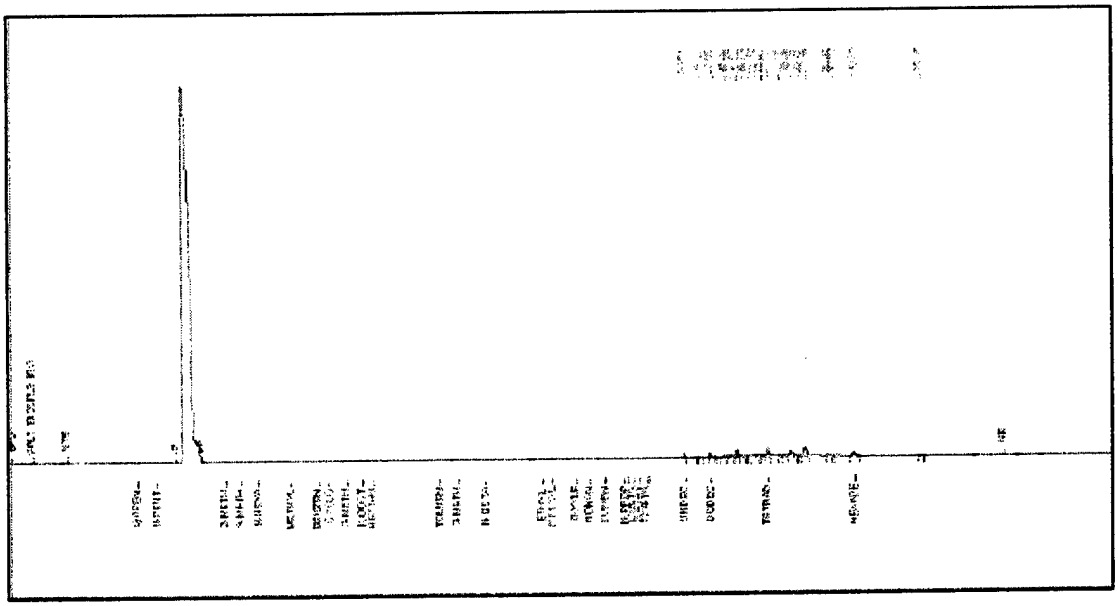


JP5
Mean Exposure Concentration - 804 mg/m^3
Sample 1 - 0 mg/m^3 Aerosol
GLASS FIBER FILTER

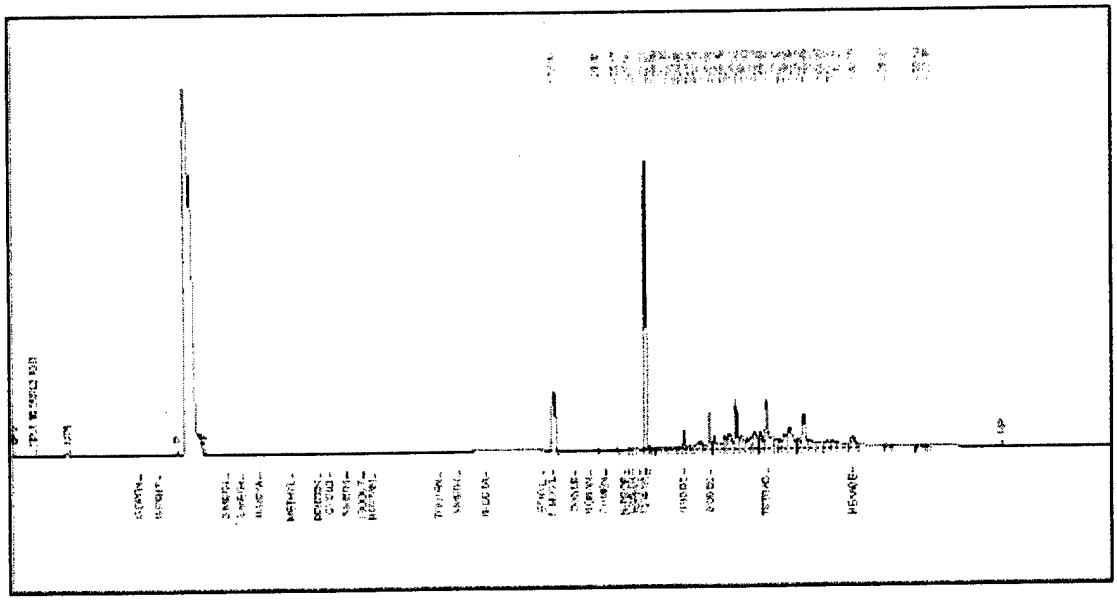


APPENDIX B - SAMPLE CHROMATOGRAMS

JP5
Mean Concentration - 804 mg/m^3
Sample 2 - 0 mg/m^3 Aerosol
GLASS FIBER FILTER

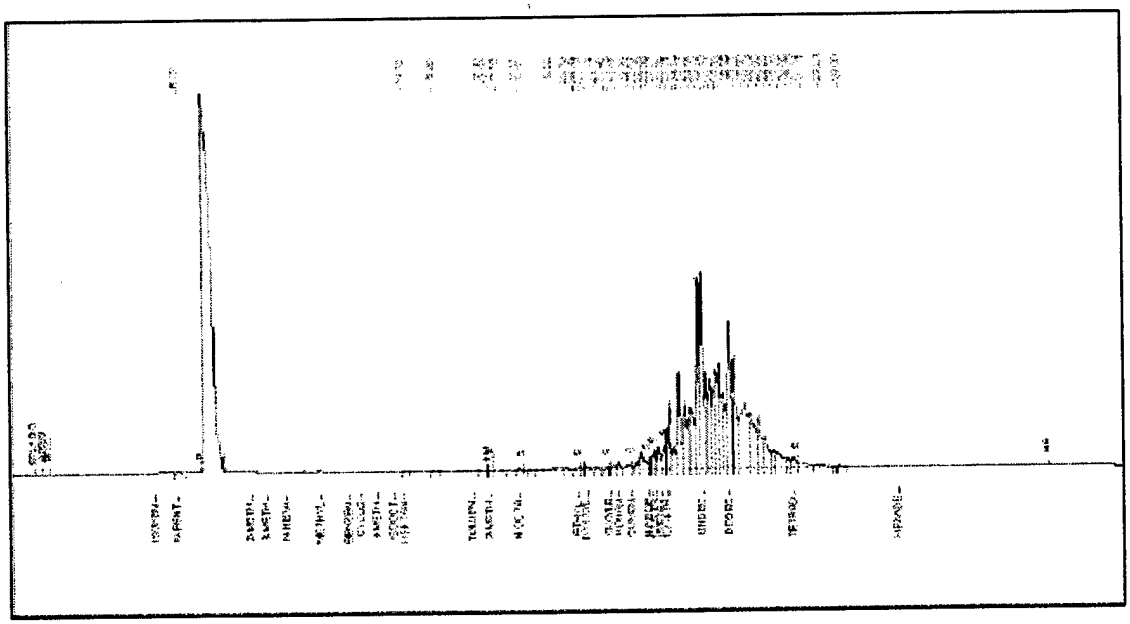


JP5
Mean Exposure Concentration - 804 mg/m^3
Sample 3 - 0 mg/m^3 Aerosol
GLASS FIBER FILTER

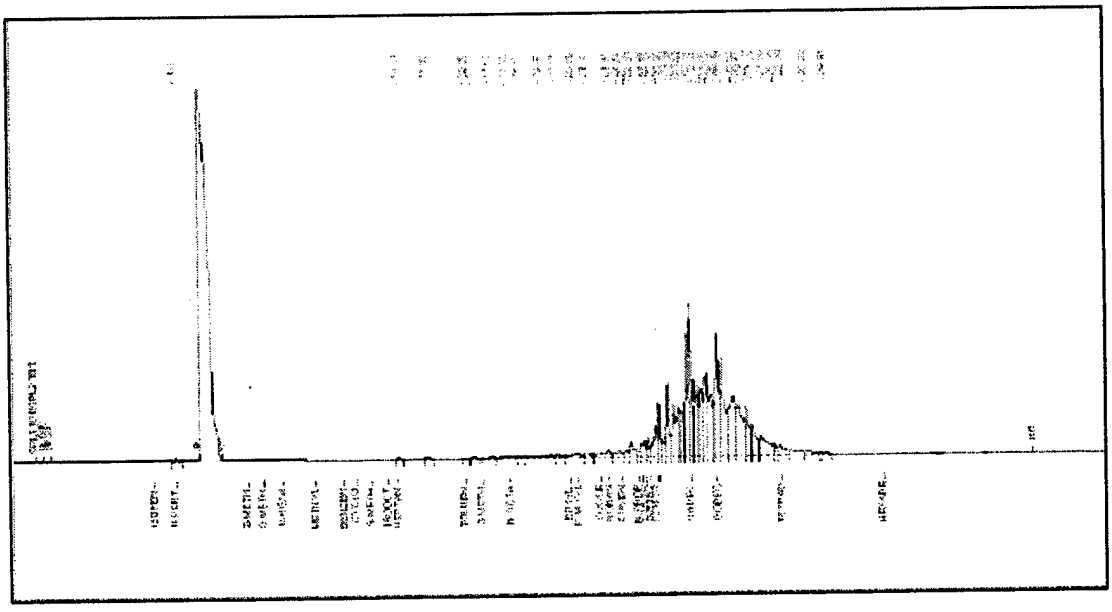


APPENDIX B - SAMPLE CHROMATOGRAMS

JP5
Mean Exposure Concentration - 804 mg/m^3
Sample 1 - 708 mg/m^3 Vapor
CHARCOAL TUBE

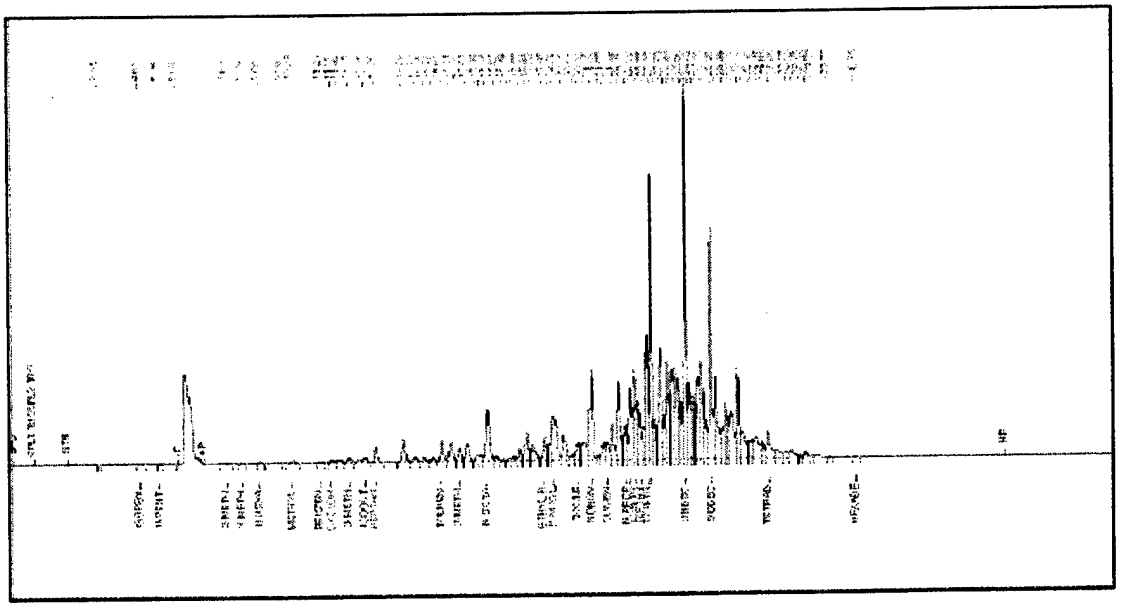


JP5
Mean Exposure Concentration - 804 mg/m^3
Sample 2 - 618 mg/m^3 Vapor
CHARCOAL TUBE

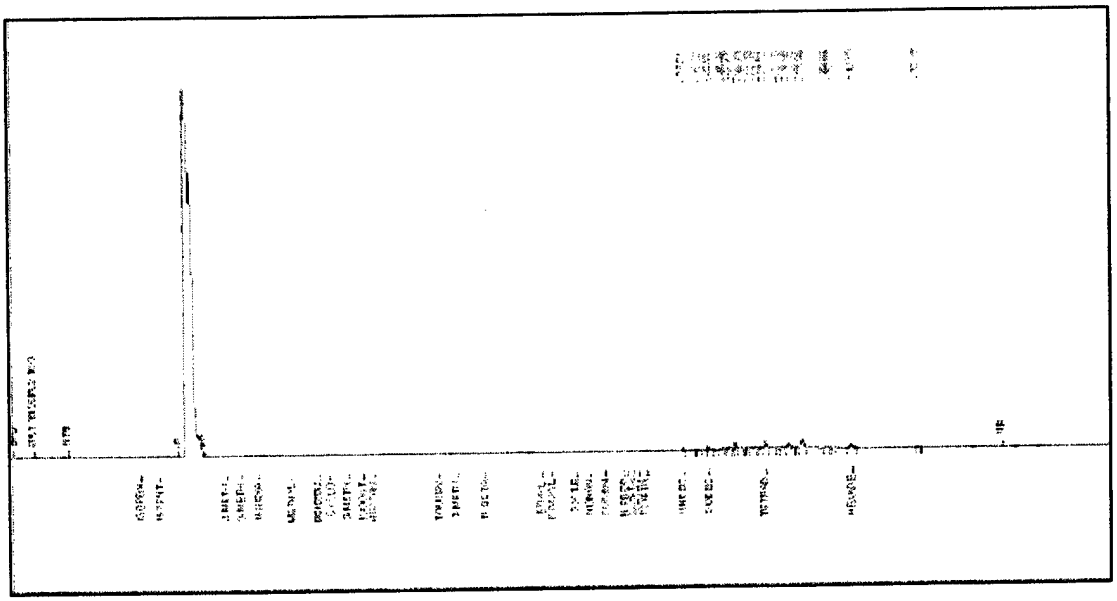


APPENDIX B - SAMPLE CHROMATOGRAMS

JP5
Mean Exposure Concentration - 804 mg/m^3
1086 mg/m^3 Vapor
CHARCOAL TUBE

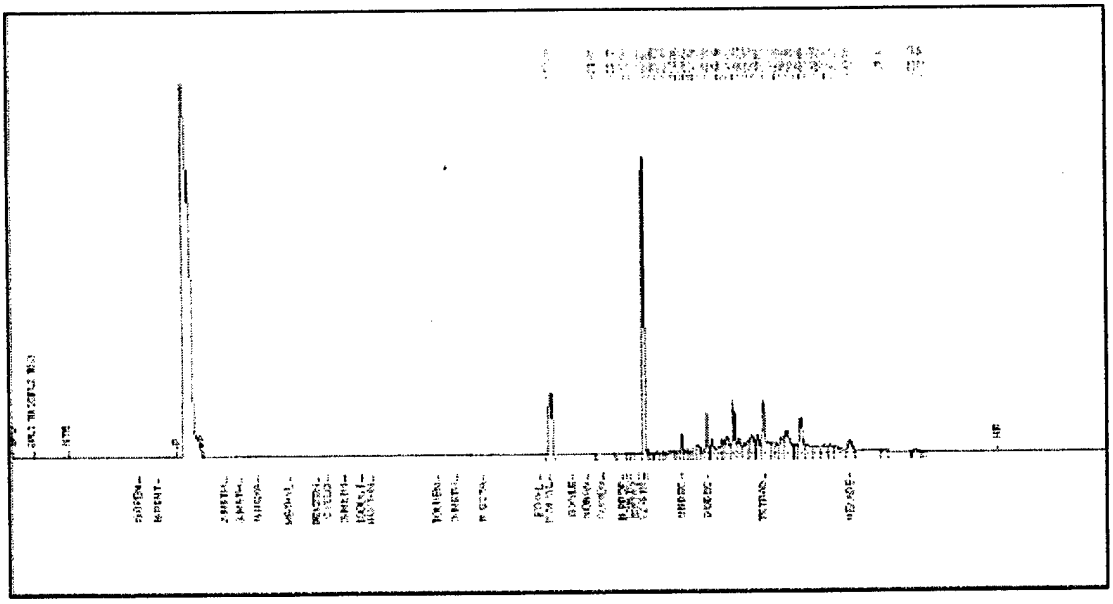


JPTS
Mean Exposure Concentration - 3729 mg/m^3
Sample 1 - 130 mg/m^3 Aerosol
GLASS FIBER FILTER

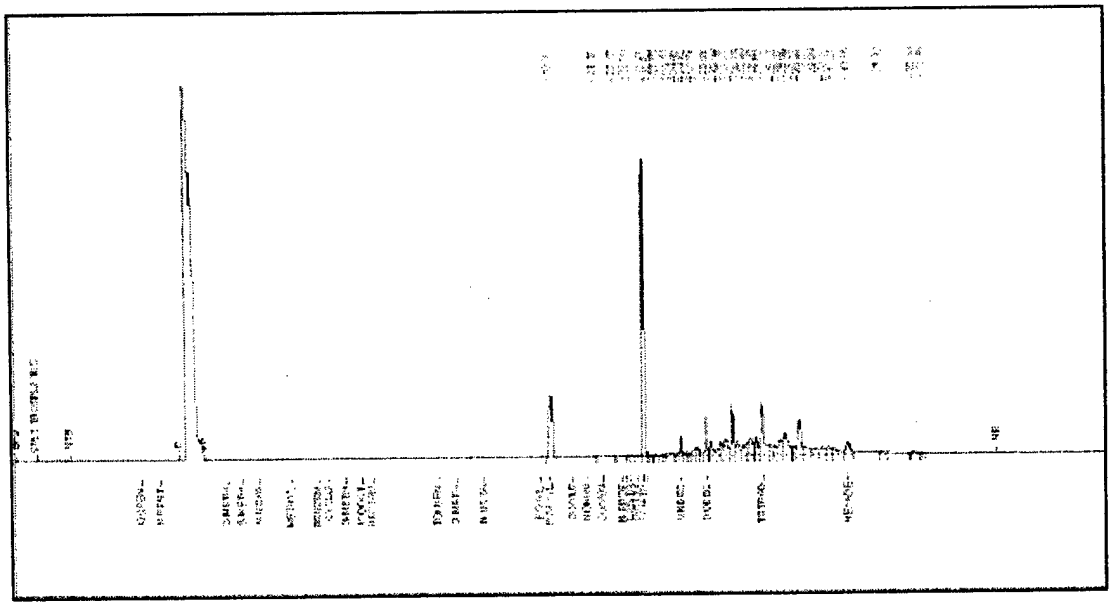


APPENDIX B - SAMPLE CHROMATOGRAMS

JPTS
Mean Exposure Concentration - 3729 mg/m^3
Sample 2 - 98 mg/m^3 Aerosol
GLASS FIBER FILTER

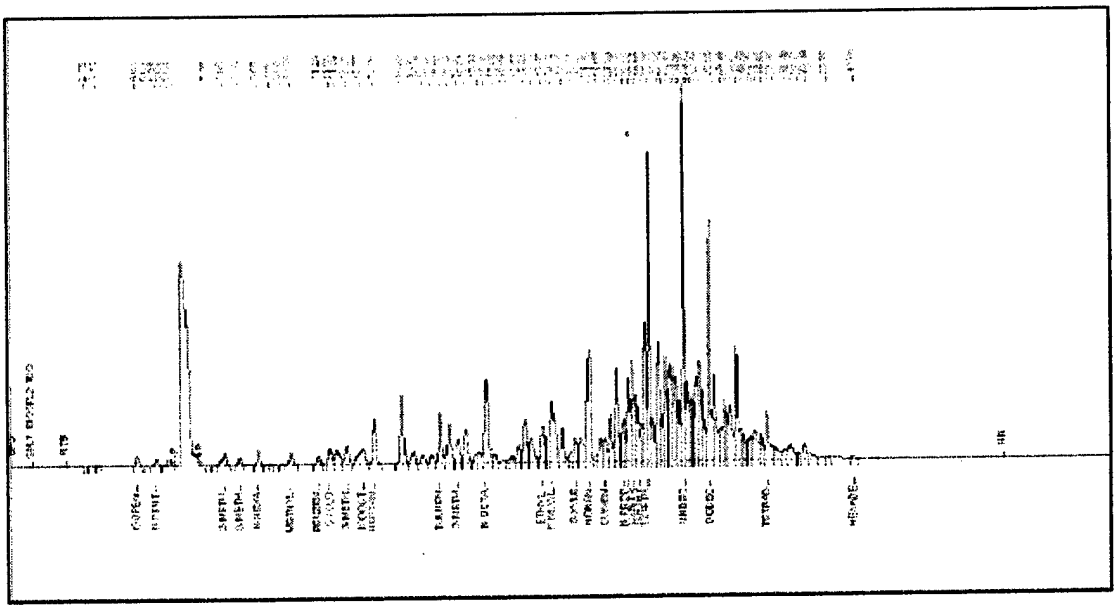


JPTS
Mean Exposure Concentration - 3729 mg/m^3
Sample 3- 39 mg/m^3 Aerosol
GLASS FIBER FILTER

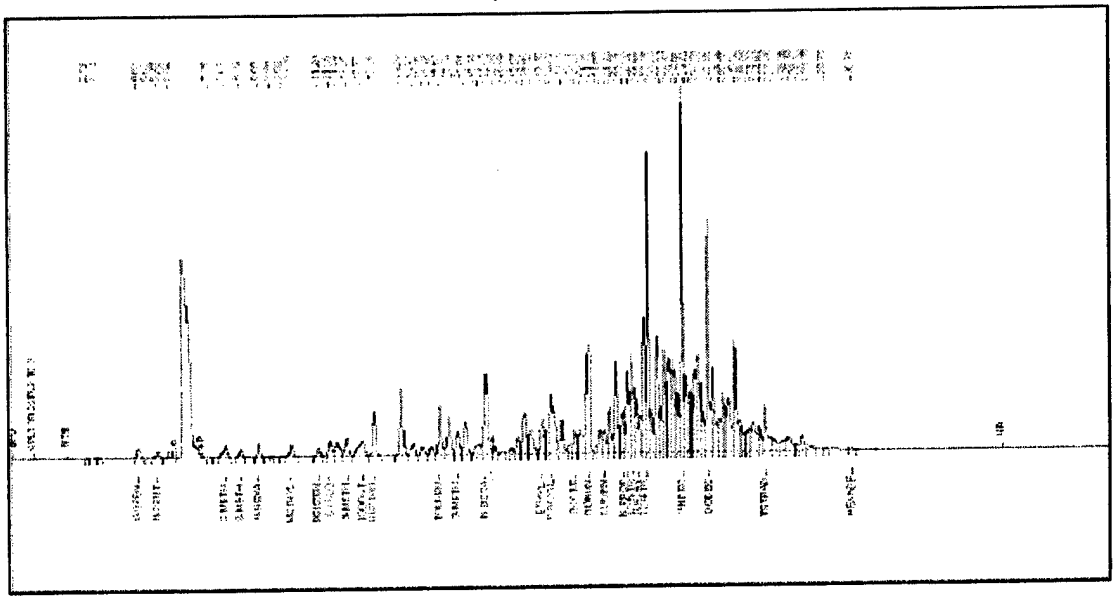


APPENDIX B - SAMPLE CHROMATOGRAMS

JPTS
Mean Exposure Concentration - 3729 mg/m^3
Sample 1 - 3506 mg/m^3 Vapor
CHARCOAL TUBE

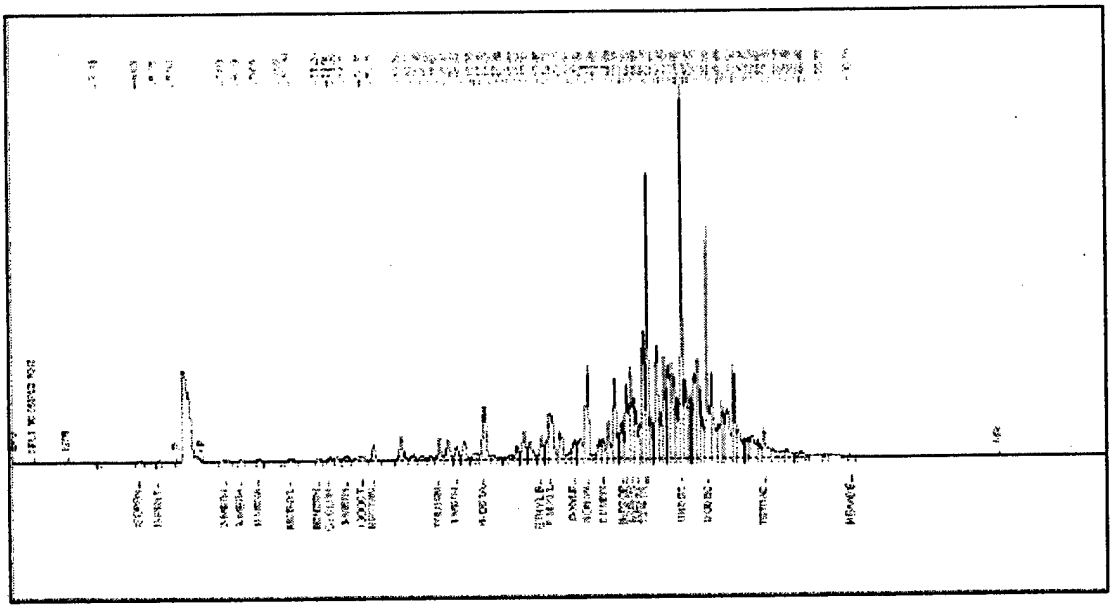


JPTS
Mean Exposure Concentration - 3729 mg/m^3
Sample 2 - 3693 mg/m^3 Vapor
CHARCOAL TUBE

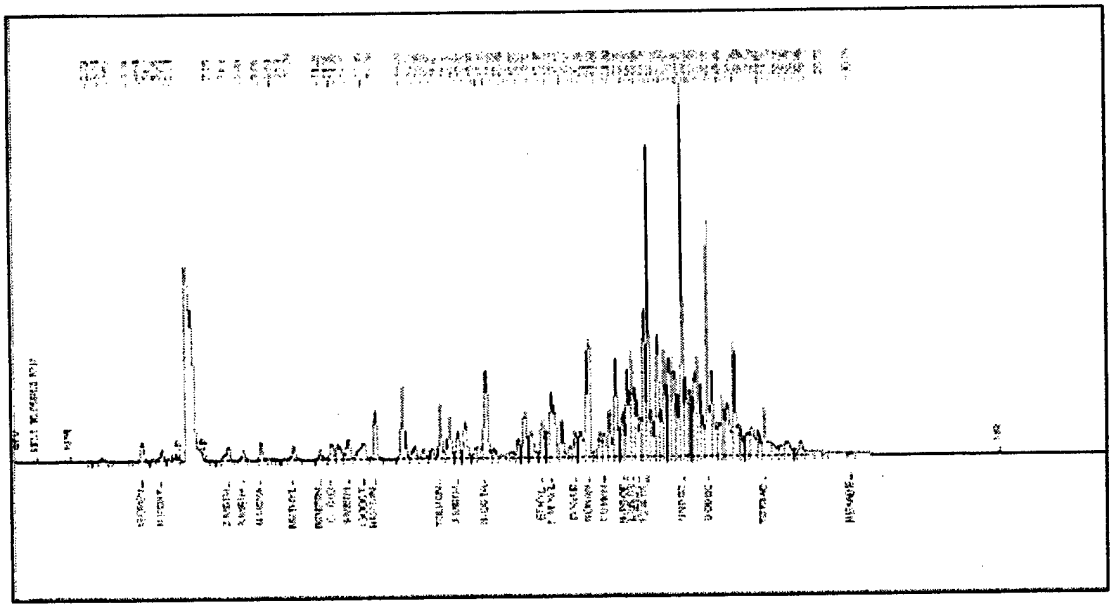


APPENDIX B - SAMPLE CHROMATOGRAMS

JPTS
Mean Exposure Concentration - 3729 mg/m^3
Sample 3 - 3721 mg/m^3 Vapor
CHARCOAL TUBE

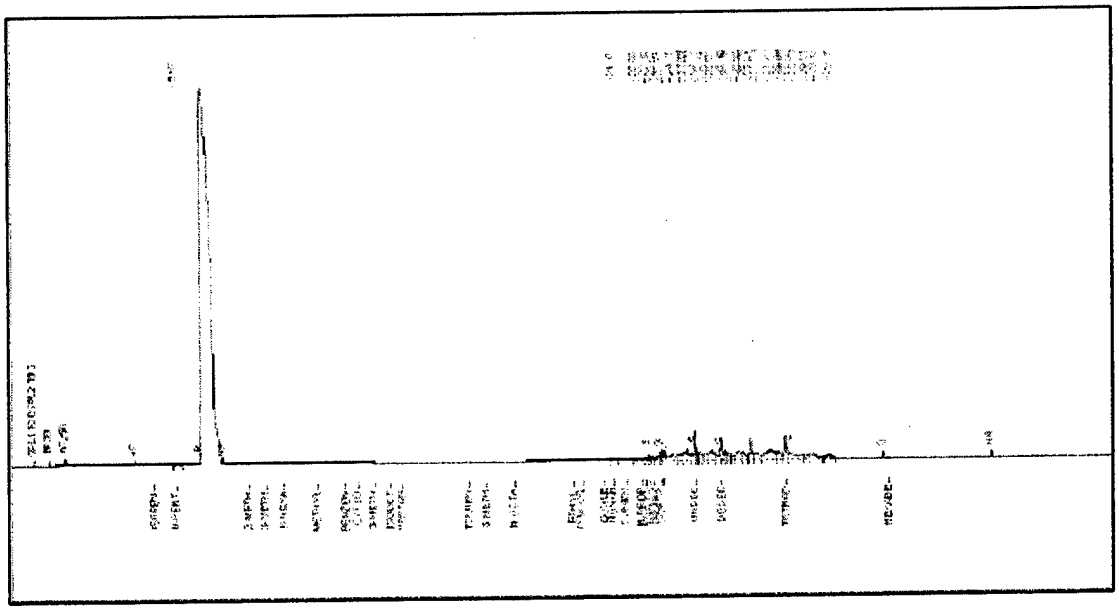


JPTS - Particle Size
Mean Exposure Concentration - 3737 mg/m^3
Stage Constant - 4.10 um
GLASS FIBER FILTER

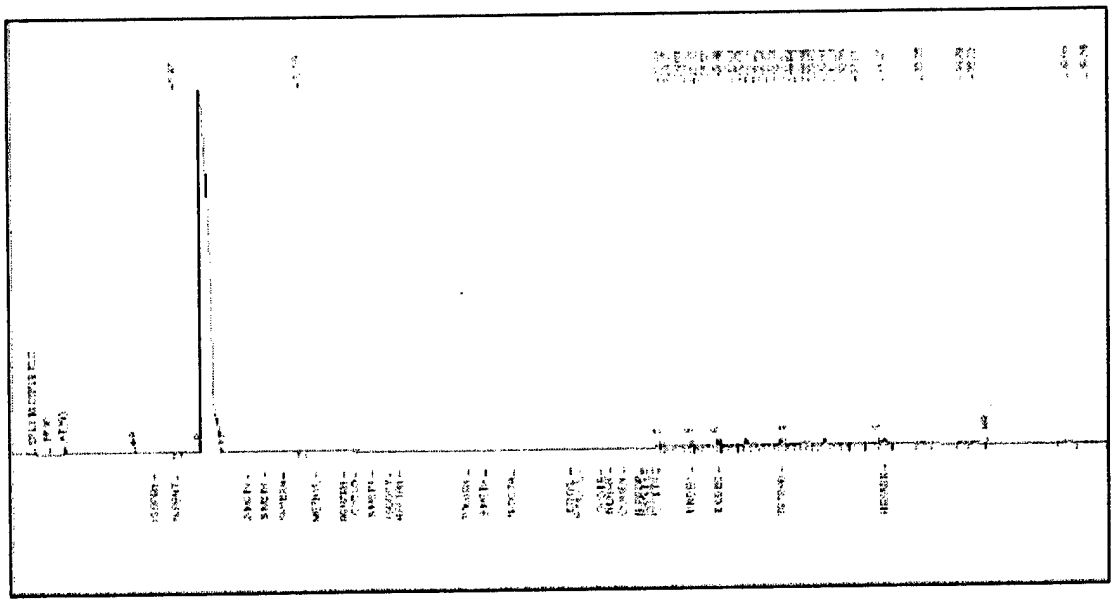


APPENDIX B - SAMPLE CHROMATOGRAMS

JPTS - Particle Size
Mean Exposure Concentration - 3737 mg/m^3
Stage Constant - 2.60 um
GLASS FIBER FILTER

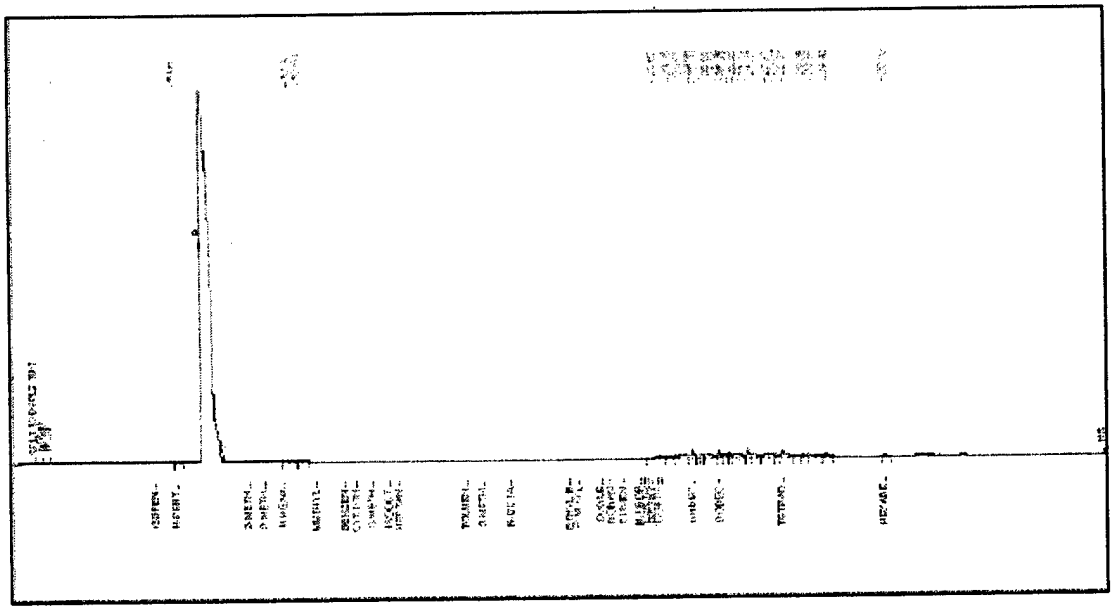


JPTS - Particle Size
Mean Exposure Concentration - 3737 mg/m^3
Stage Constant - 1.50 um
GLASS FIBER FILTER

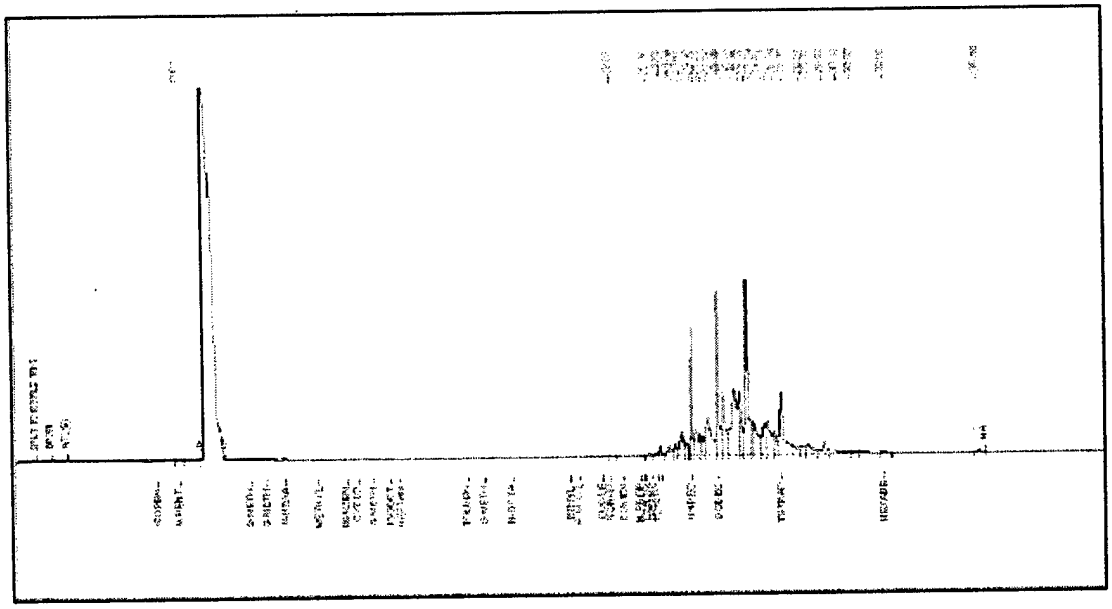


APPENDIX B - SAMPLE CHROMATOGRAMS

JPTS
Mean Exposure Concentration - 3622 mg/m^3
Sample 1 - 280 mg/m^3 Aerosol
Glass Fiber Filter

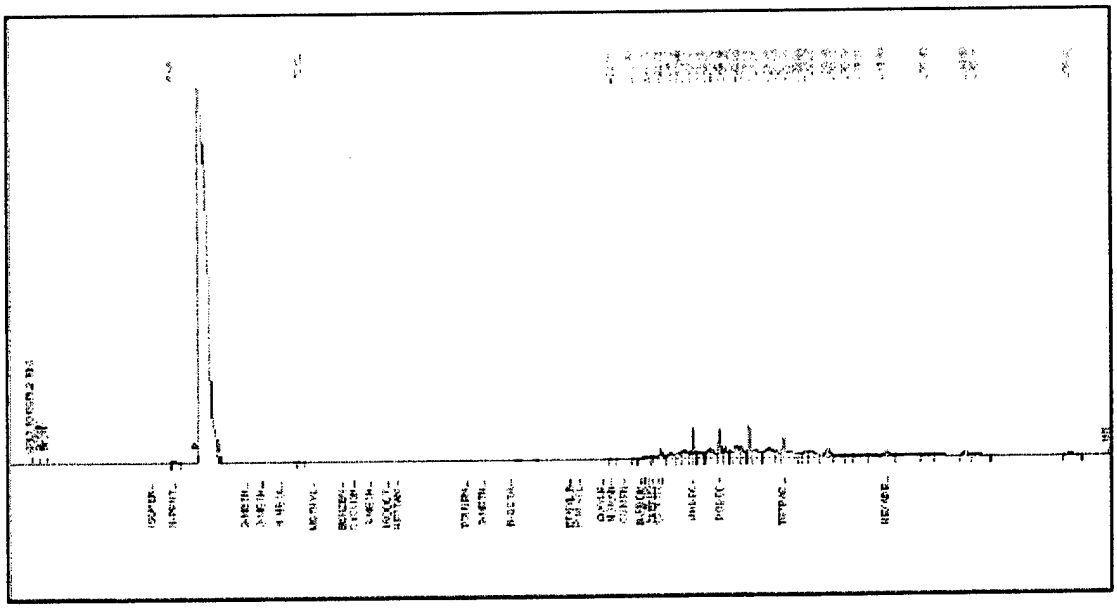


JPTS
Mean Exposure Concentration - 3622 mg/m^3
Sample 2 - 580 mg/m^3 Aerosol
Glass Fiber Filter

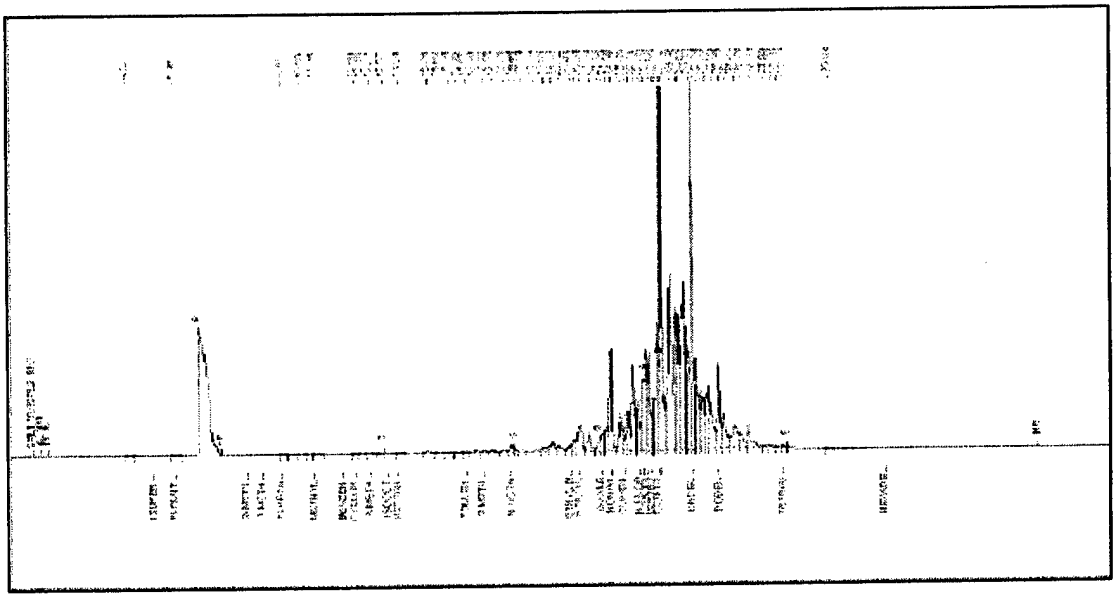


APPENDIX B - SAMPLE CHROMATOGRAMS

JPTS
Mean Exposure Concentration - 3622 mg/m^3
Sample 3 - 733 mg/m^3 Aerosol
Glass Fiber Filter

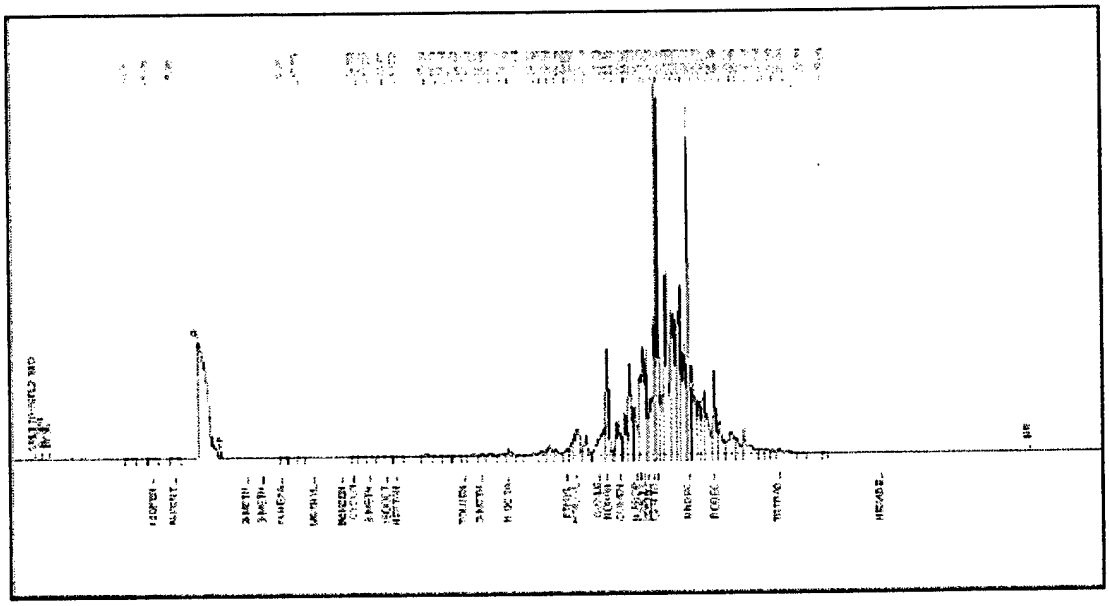


JPTS
Mean Exposure Concentration - 3622 mg/m^3
Sample 1 - 2840 mg/m^3 Vapor
Charcoal Tube

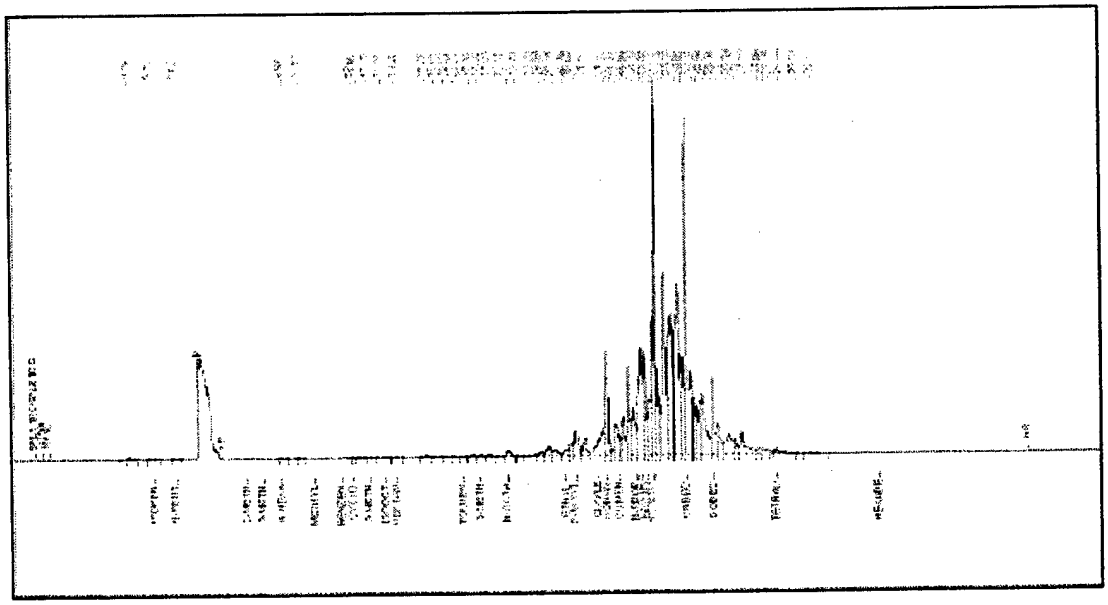


APPENDIX B - SAMPLE CHROMATOGRAMS

JPTS
Mean Exposure Concentration - 3622 mg/m^3
Sample 2 - 3054 mg/m3 Vapor
Charcoal Tube

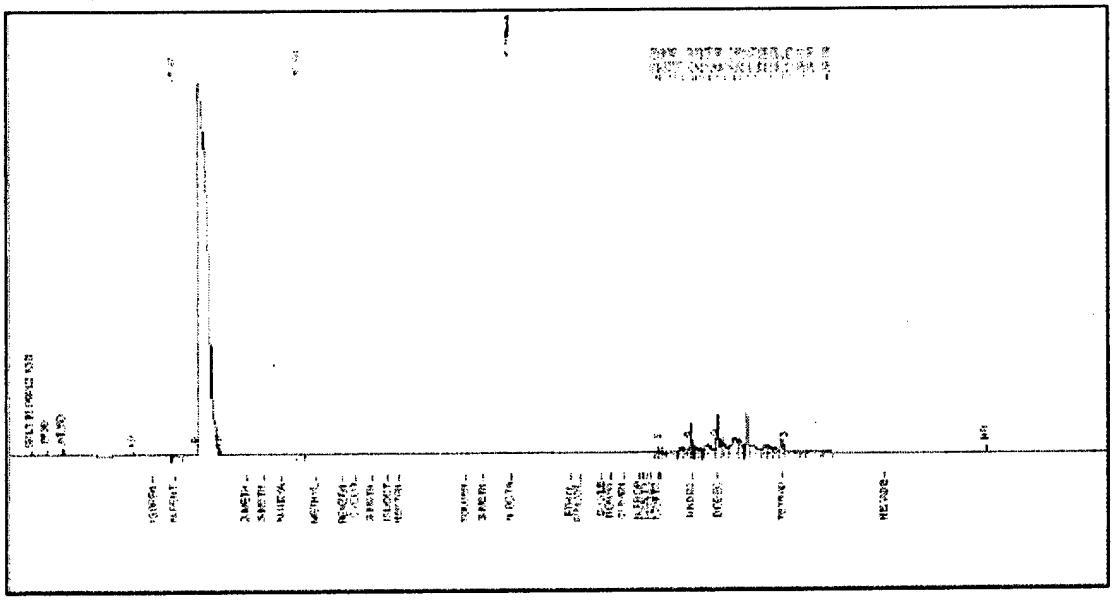


JPTS
Mean Exposure Concentration - 3622 mg/m^3
Sample 3 - 3378mg/m^3 Vapor
Charcoal Tube

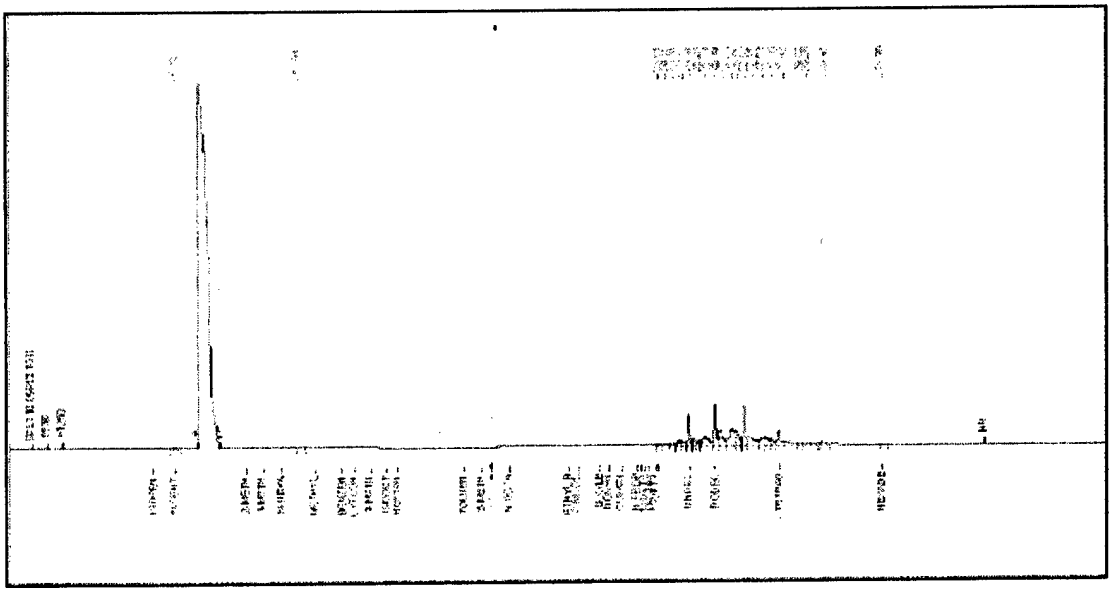


APPENDIX B - SAMPLE CHROMATOGRAMS

JP7
Mean Expsoure Concentration - 2239 mg/m^3
Sample 1 - 540 mg/m^3 Aerosol
Glass Fiber Filter

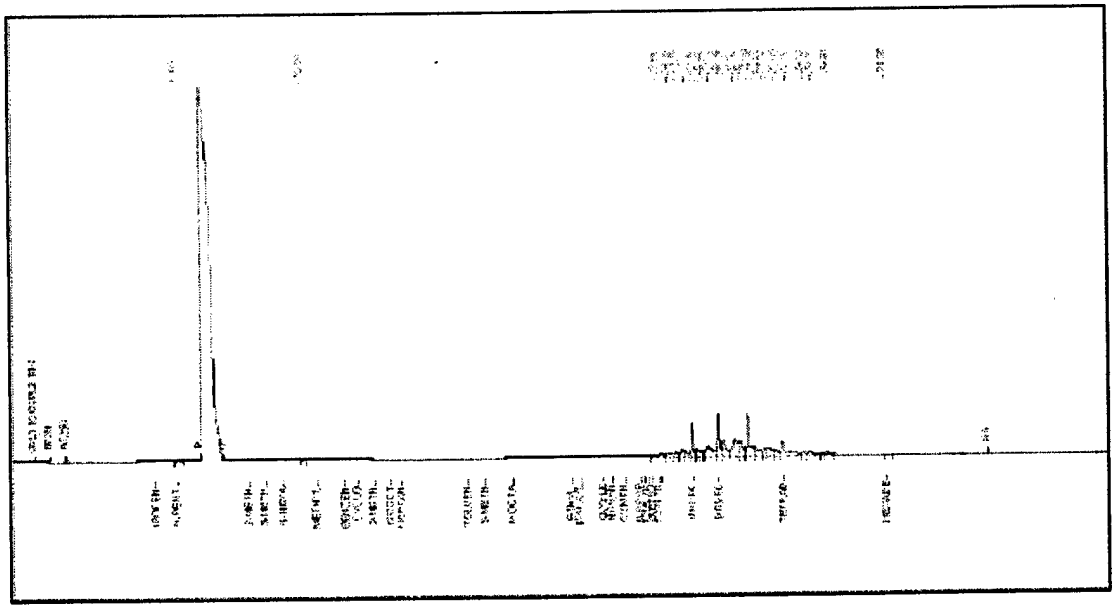


JP7
Mean Exposure Concentration - 2239 mg/m^3
Sample 2 - 618 mg/m^3 Aerosol
Glass Fiber Filter

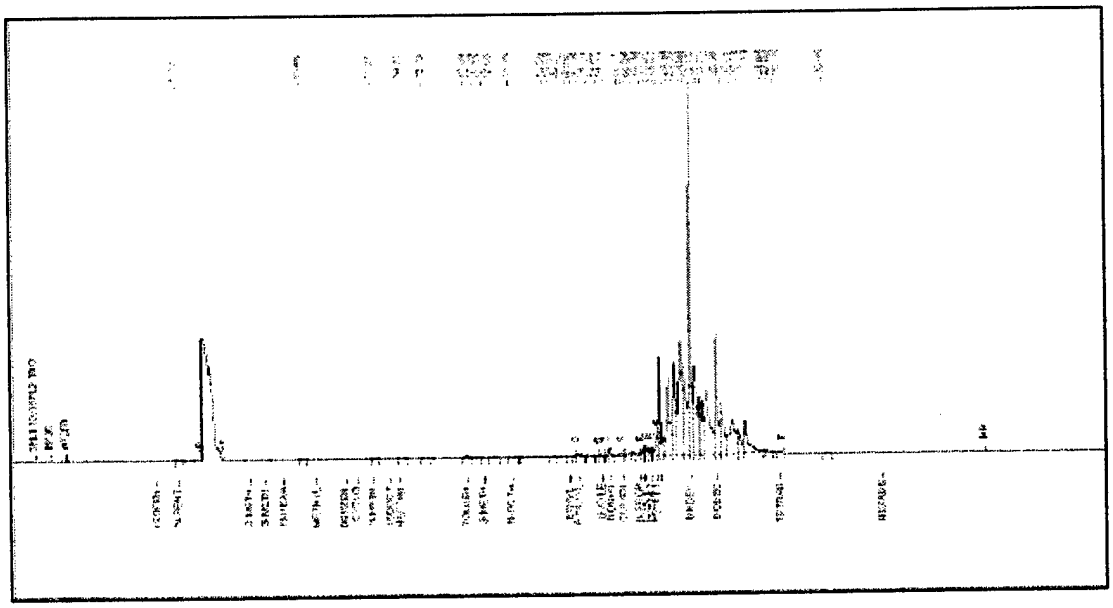


APPENDIX B - SAMPLE CHROMATOGRAMS

JP7
Mean Exposure Concentration - 2239 mg/m^3
Sample 3 - 610 mg/m^3 Aerosol
Glass Fiber Filter

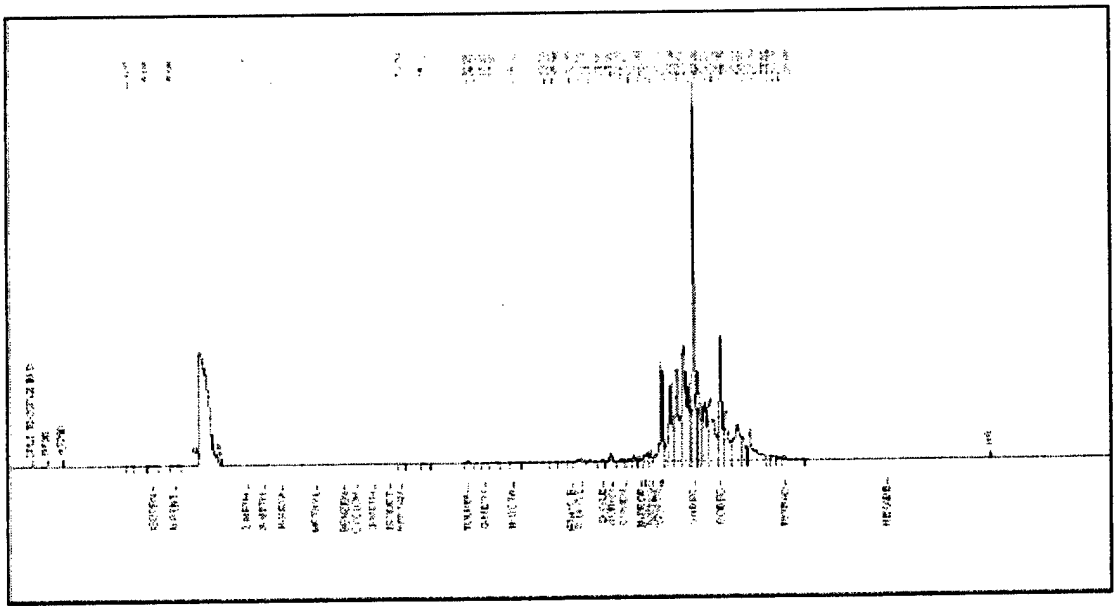


JP7
Mean Exposure Concentration - 2239 mg/m^3
Sample 1 - 1601 mg/m^3 Vapor
Charcoal Tube

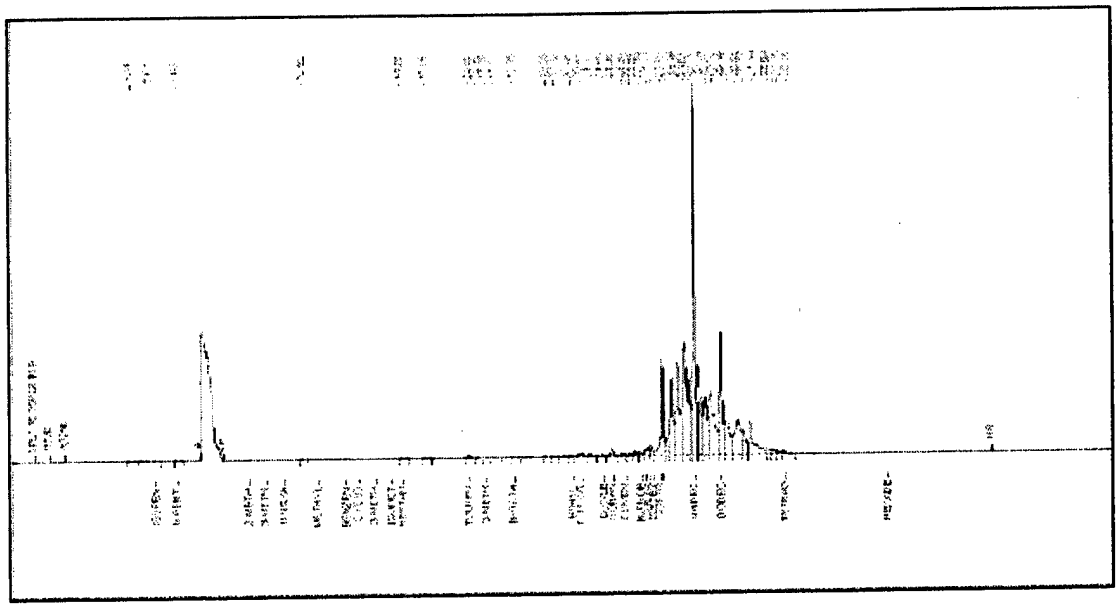


APPENDIX B - SAMPLE CHROMATOGRAMS

JP7
Mean Exposure Concentration - 2239 mg/m^3
Sample 2- 1771 mg/m^3 Vapor
Charcoal Tube

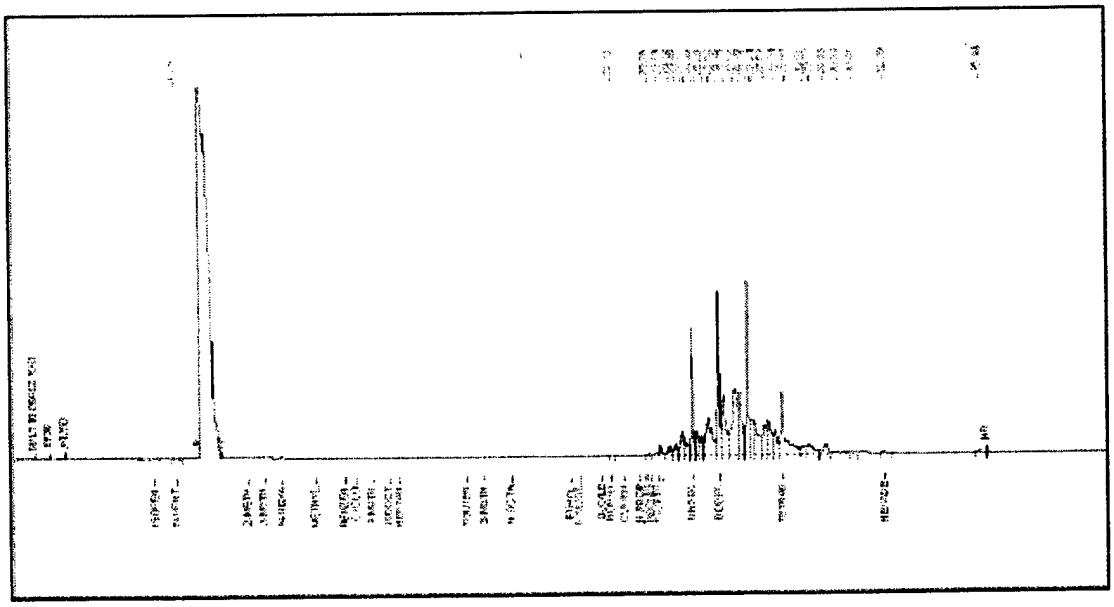


JP7
Mean Exposure Concentration - 2239 mg/m^3
Sample 3 - 1537 mg/m^3 Vapor
Charcoal Tube

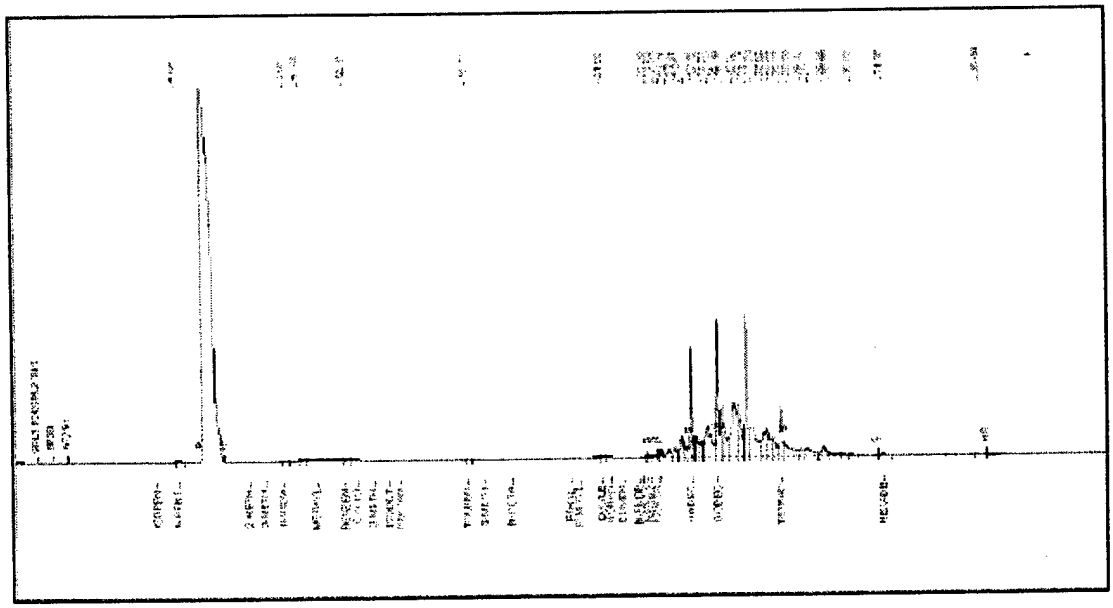


APPENDIX B - SAMPLE CHROMATOGRAMS

JP7 Particle Size
Mean Exposure Concentration - 2239 mg/m^3
Stage Constant - 4.10 um
Glass Fiber Filter

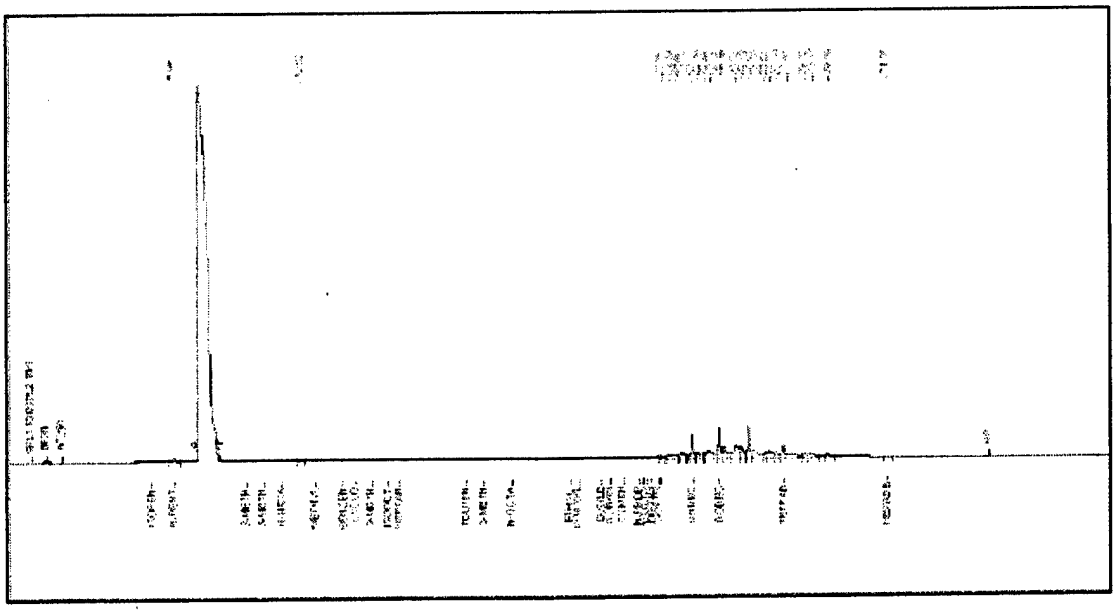


JP7 Particle Size
Mean Exposure Concentration - 2239 mg/m^3
Stage Constant - 1.50 um
Glass Fiber Filter

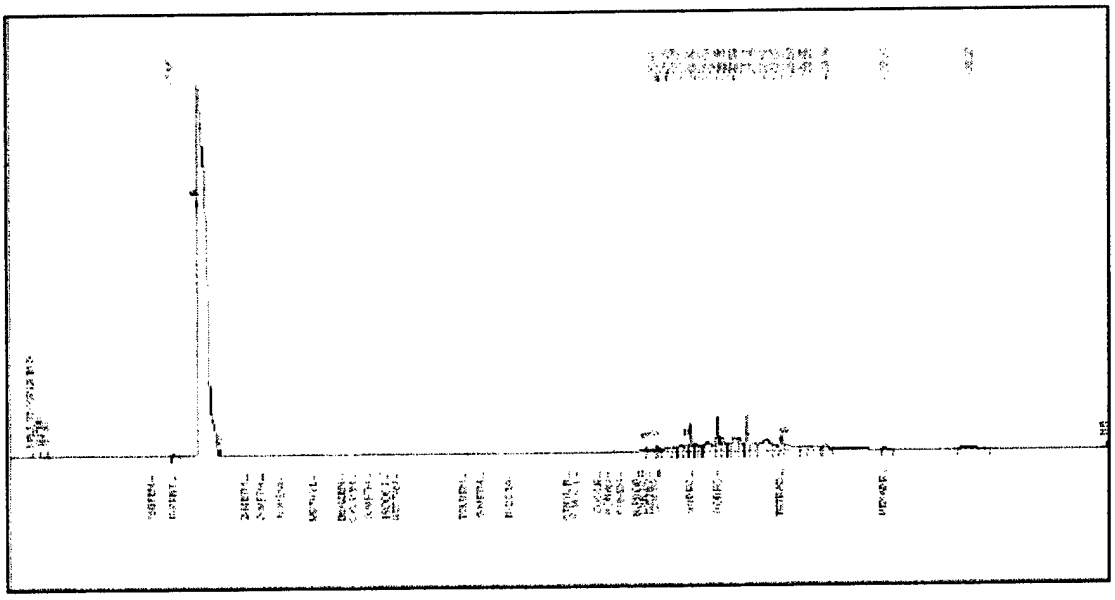


APPENDIX B - SAMPLE CHROMATOGRAMS

JP7 Particle Size
Mean Exposure Concentration - 2239 mg/m^3
Stage Constant - 0.84 um
Glass Fiber Filter

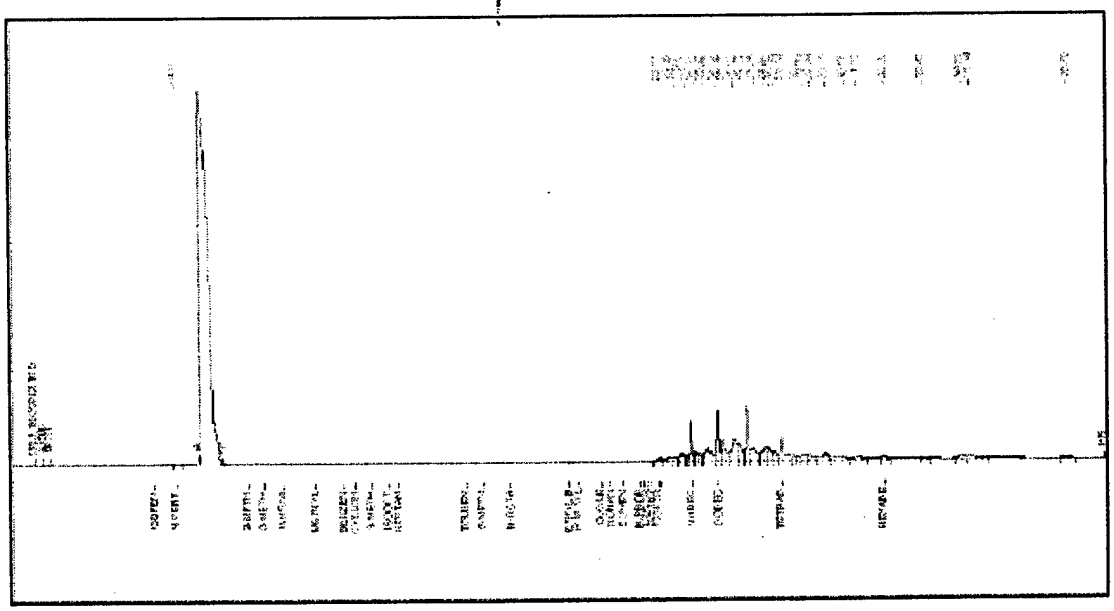


JP7
Mean Exposure Concentration - 2419 mg/m^3
Sample 1 - 637 mg/m^3 Aerosol
Glass Fiber Filter

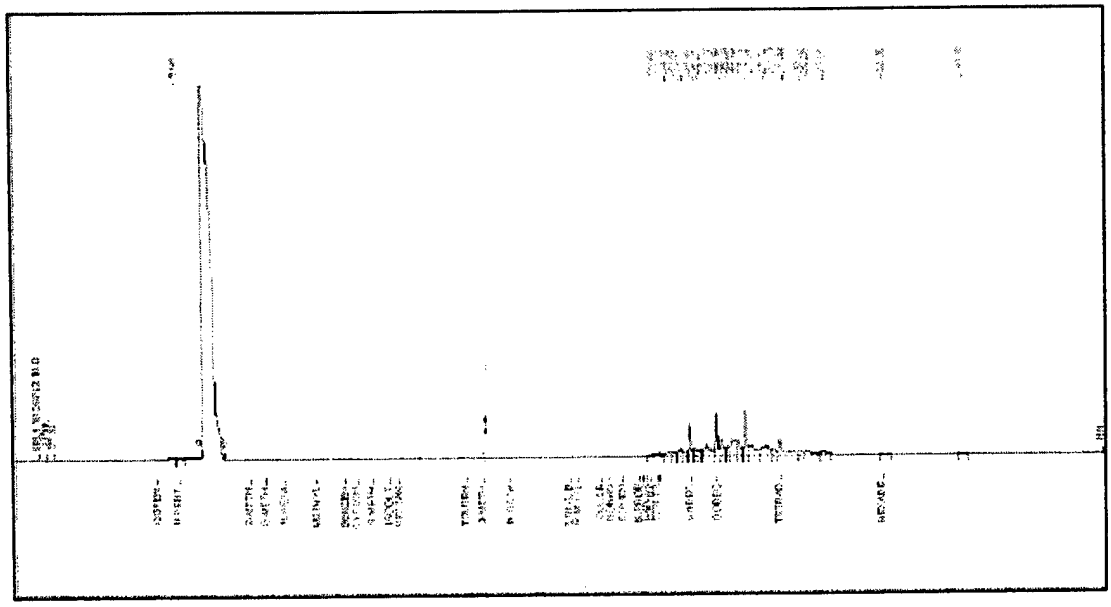


APPENDIX B - SAMPLE CHROMATOGRAMS

JP7
Mean Exposure Concentration - 2419 mg/m^3
Sample 2 - 826 mg/m^3 Aerosol
Glass Fiber Filter

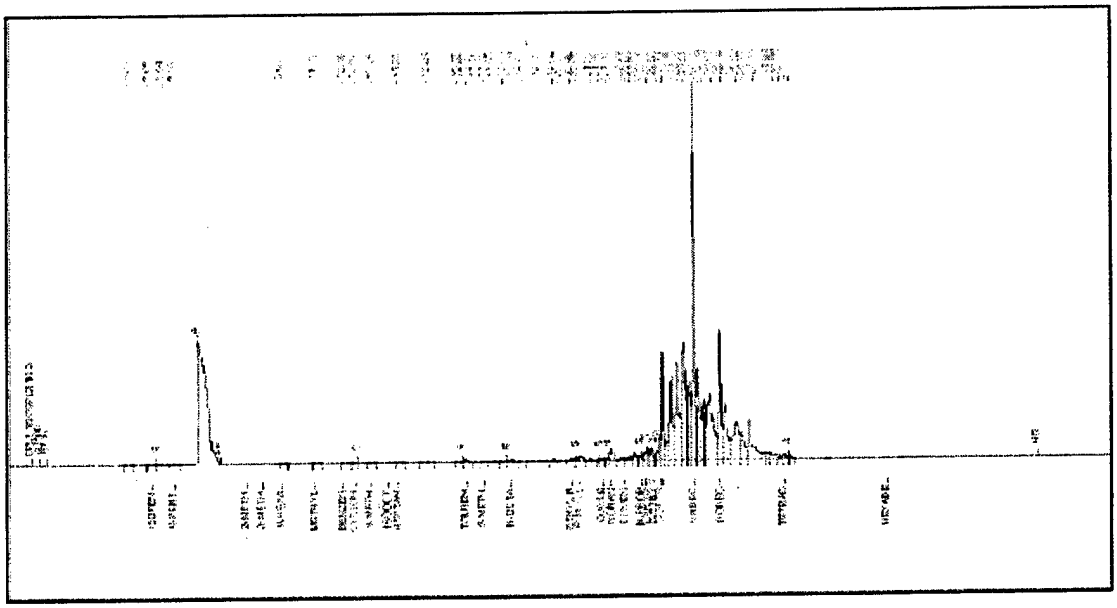


JP7
Mean Exposure Concentration - 2419 mg/m^3
Sample 3 - 618 mg/m^3 Aerosol
Glass Fiber Filter

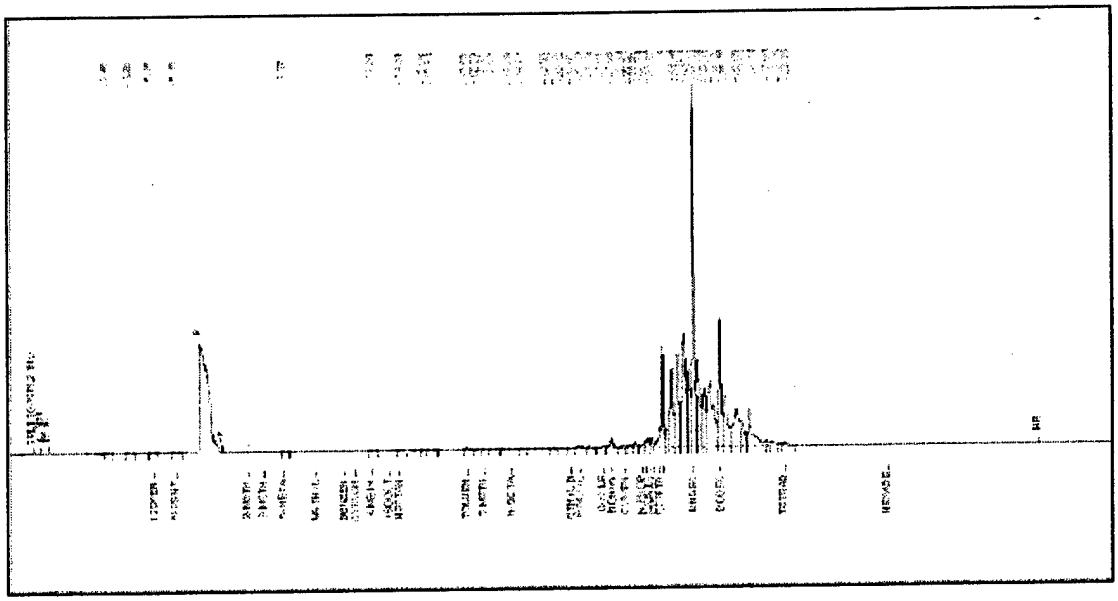


APPENDIX B - SAMPLE CHROMATOGRAMS

JP7
Mean Exposure Concentration - 2419 mg/m^3
Sample 1 - 1708 mg/m^3 Vapor
Charcoal Tube

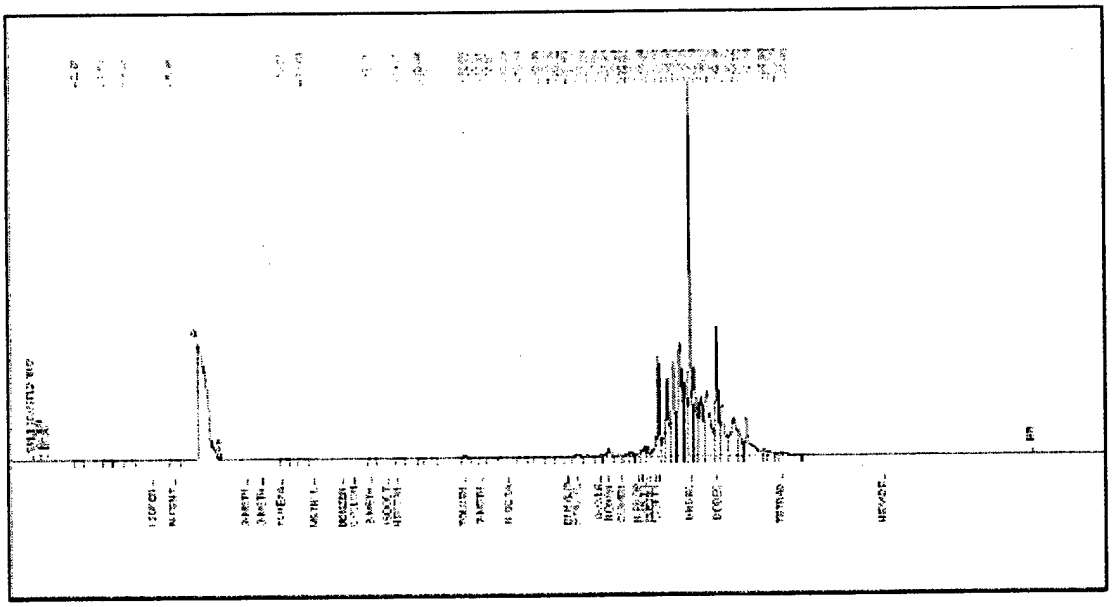


JP7
Mean Exposure Concentration - 2419 mg/m^3
Sample 2 - 1779 mg/m^3 Vapor
Charcoal Tube

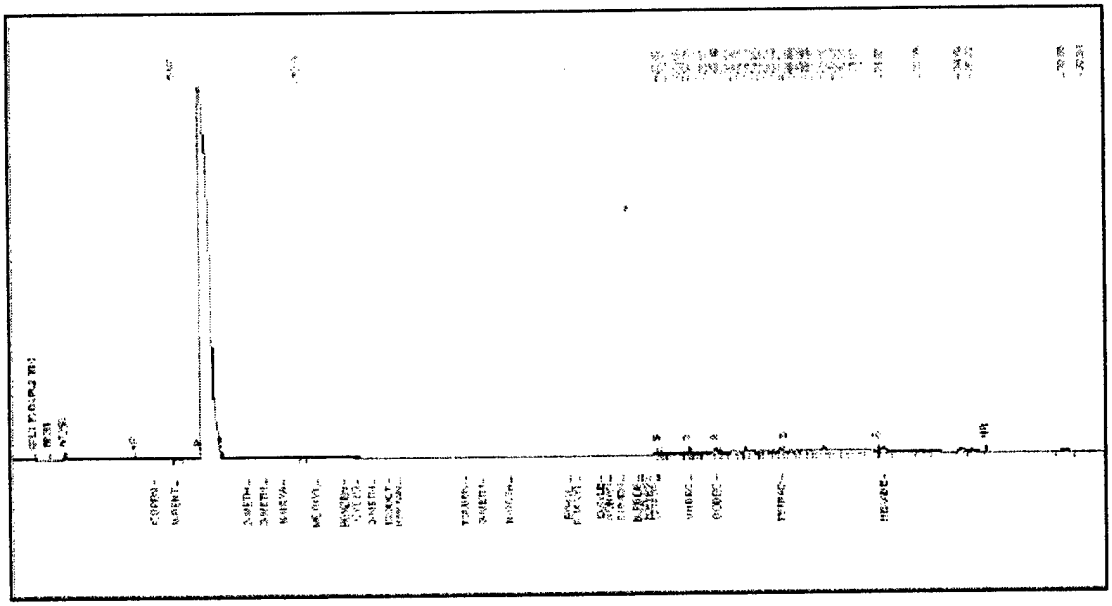


APPENDIX B - SAMPLE CHROMATOGRAMS

JP7
Mean Exposure Concentration - 2419 mg/m^3
Sample 3 - 1688mg/m^3 Vapor
Charcoal Tube

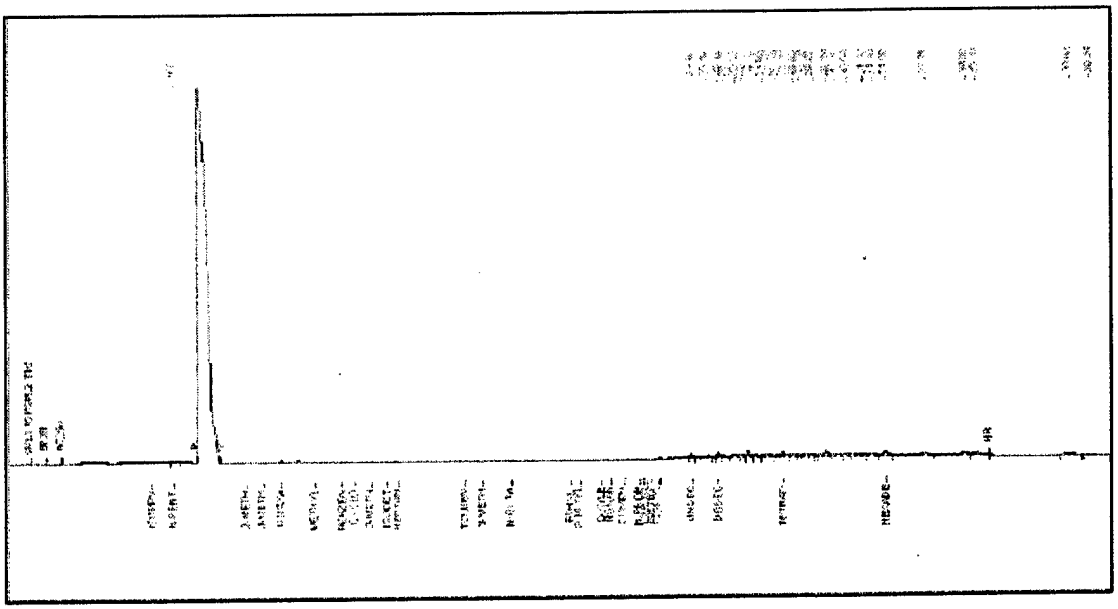


DFM
Mean Exposure Concentration - 1030 mg/m^3
Sample 1 - 233 mg/m^3 Aerosol
Glass Fiber Filter

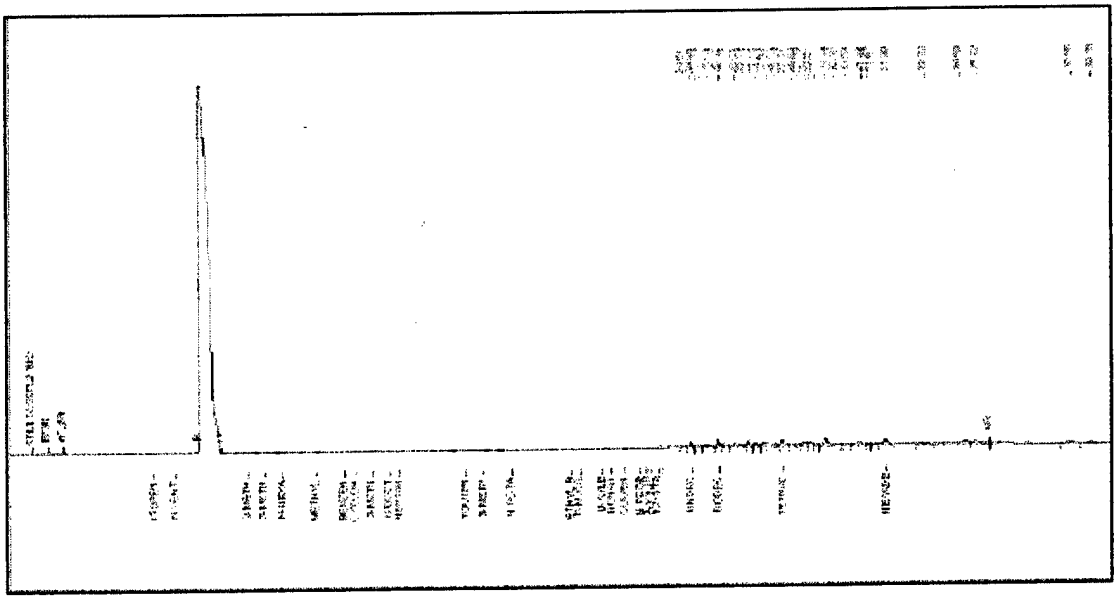


APPENDIX B - SAMPLE CHROMATOGRAMS

DFM
Mean Exposure Concentration - 1030 mg/m^3
Sample 2 - 239 mg/m^3 Aerosol
Glass Fiber Filter

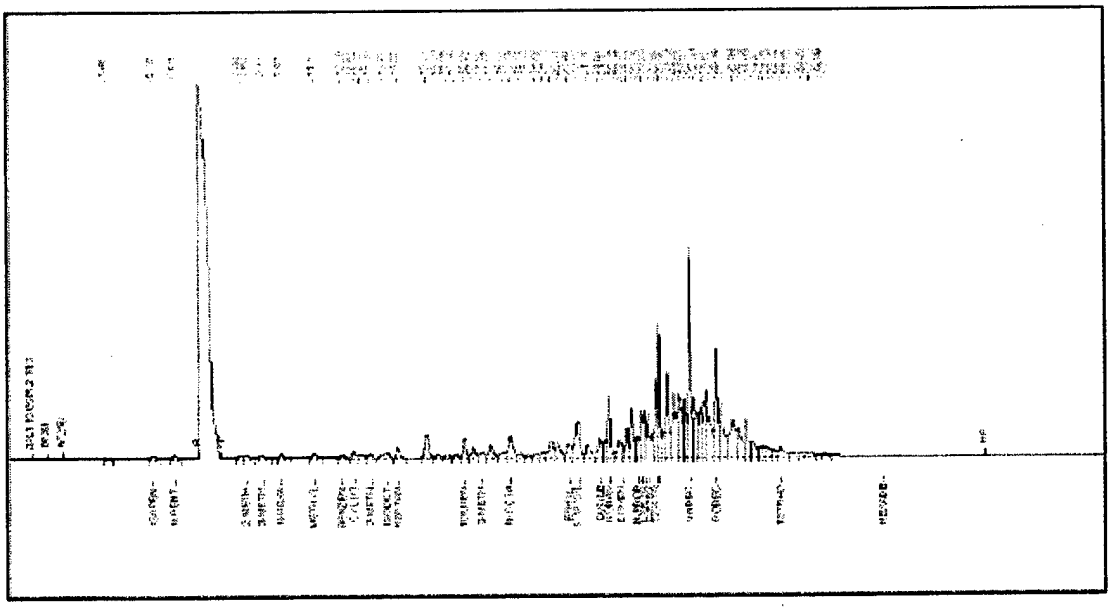


DFM
Mean Exposure Concentration - 1030 mg/m^3
Sample 3 - 260 mg/m^3 Aerosol
Glass Fiber Filter

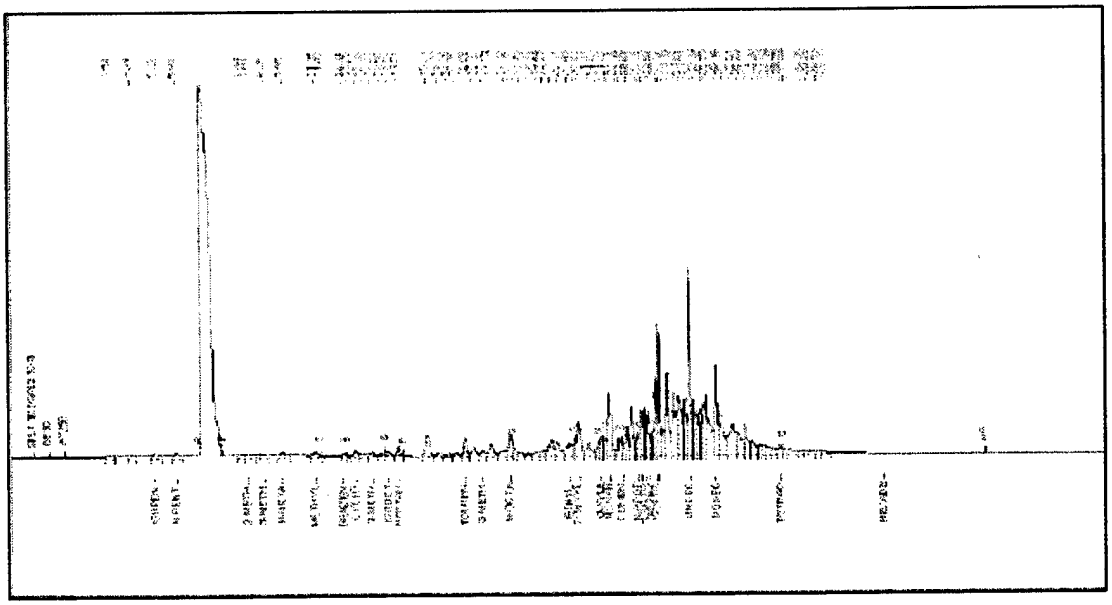


APPENDIX B - SAMPLE CHROMATOGRAMS

DFM
Mean Exposure Concentration - 1030 mg/m^3
Sample 1 - 763mg/m^3 Vapor
Charcoal Tube

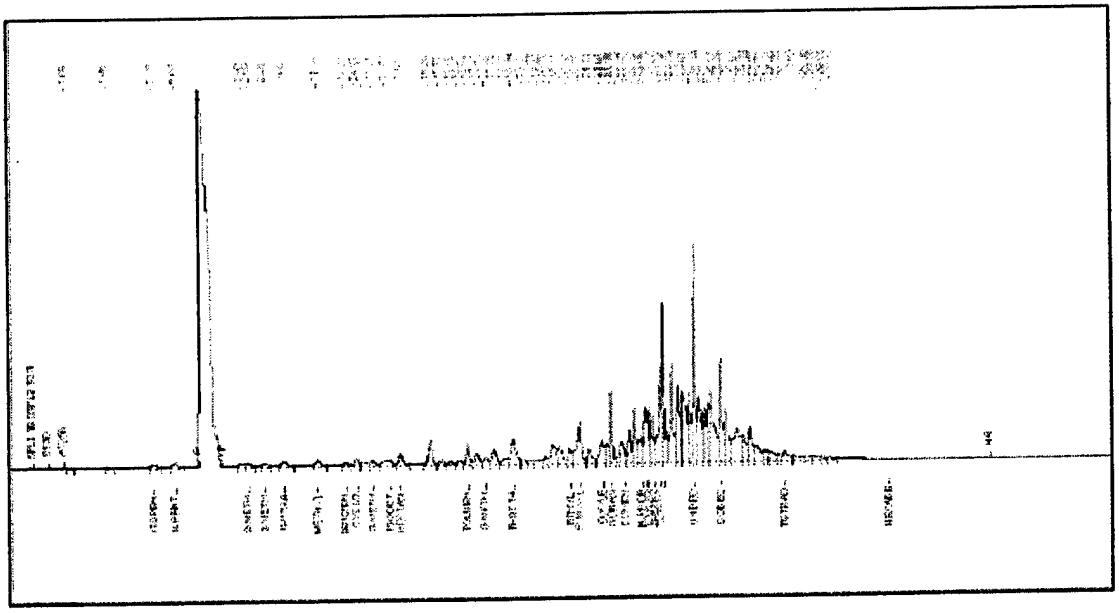


DFM
Mean Exposure Concentration - 1030 mg/m^3
Sample 2 - 738 mg/m^3 Vapor
Charcoal Tube

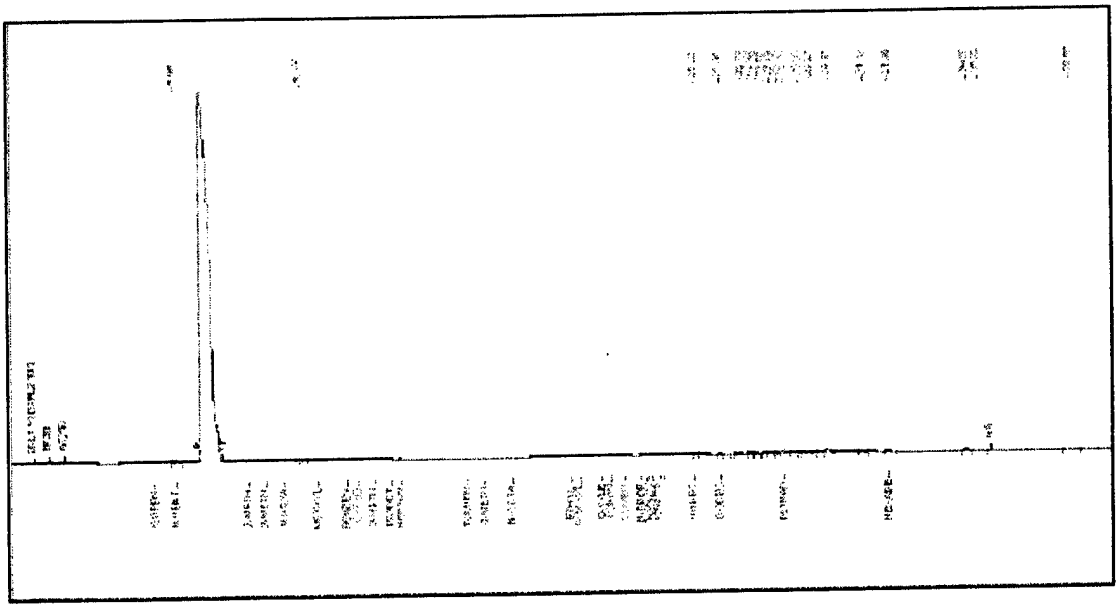


APPENDIX B - SAMPLE CHROMATOGRAMS

DFM
Mean Exposure Concentration - 1030 mg/m^3
Sample 3 - 857 mg/m^3 Vapor
Charcoal Tube

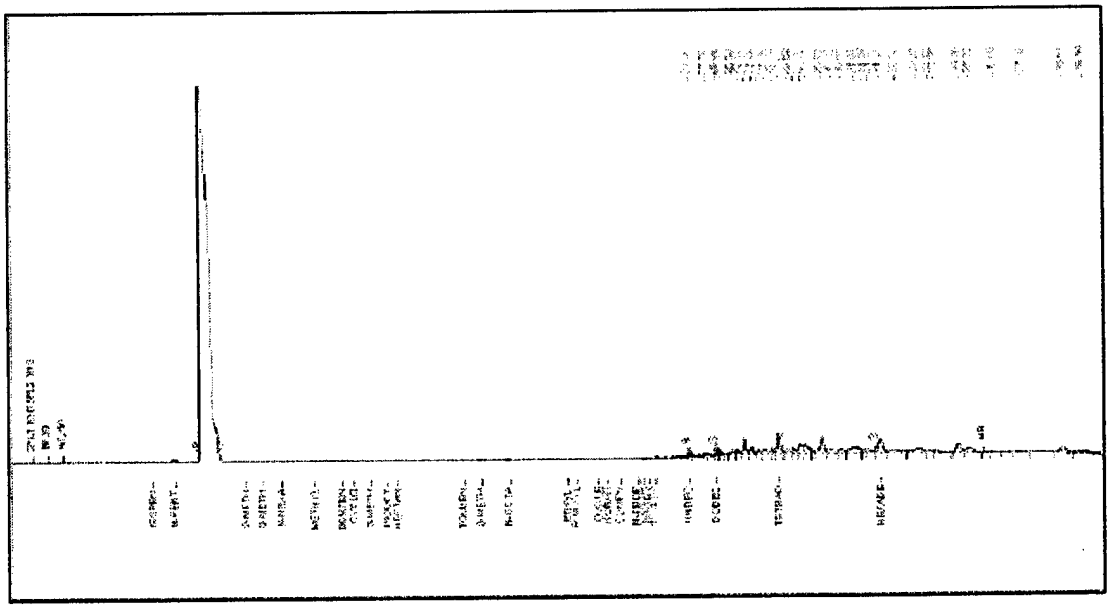


DFM - Particle Size
Mean Exposure Concentration - 1030 mg/m^3
Stage Constant - 6.80 um
Glass Fiber Filter

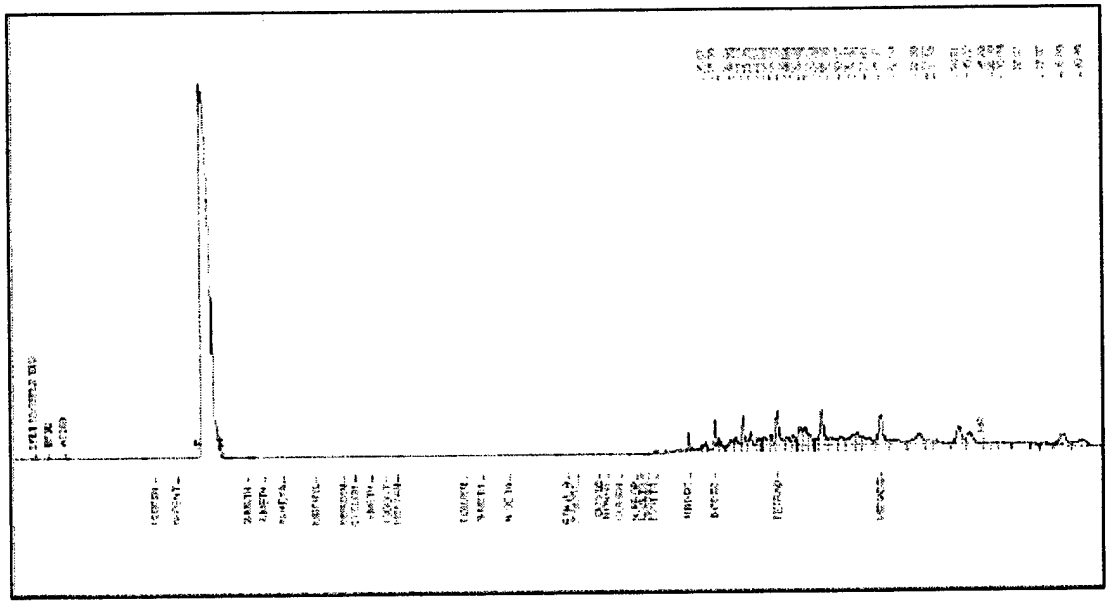


APPENDIX B - SAMPLE CHROMATOGRAMS

DFM - Particle Size
Mean Exposure Concentration - 1030 mg/m^3
Stage Constant - 4.10 um
Glass Fiber Filter

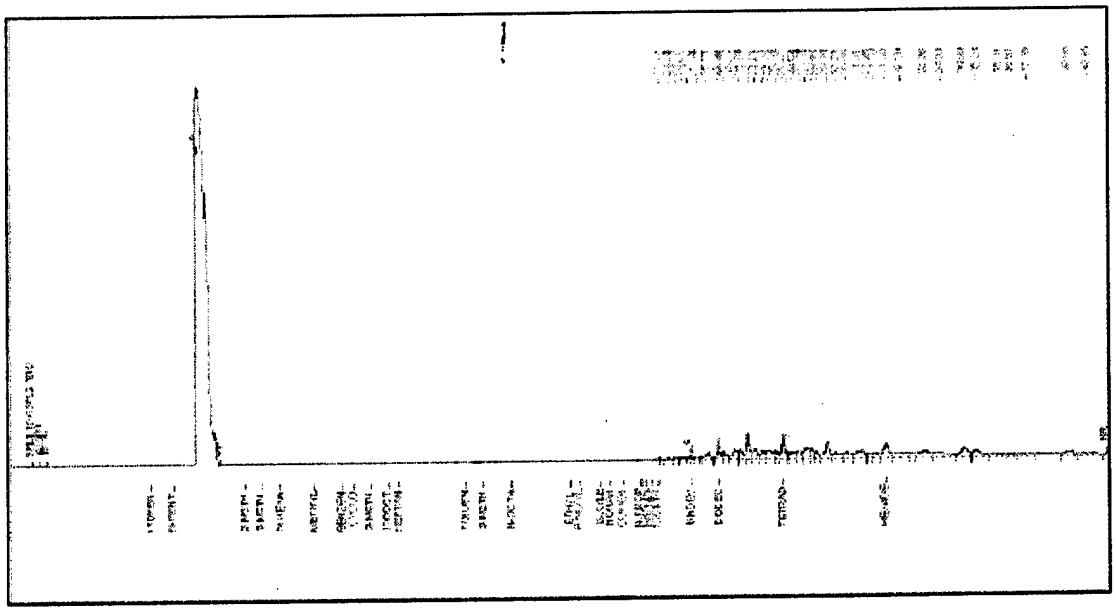


DFM - Particle Size
Mean Exposure Concentration - 1030 mg/m^3
Stage Constant - 2.60 um
Glass Fiber Filter

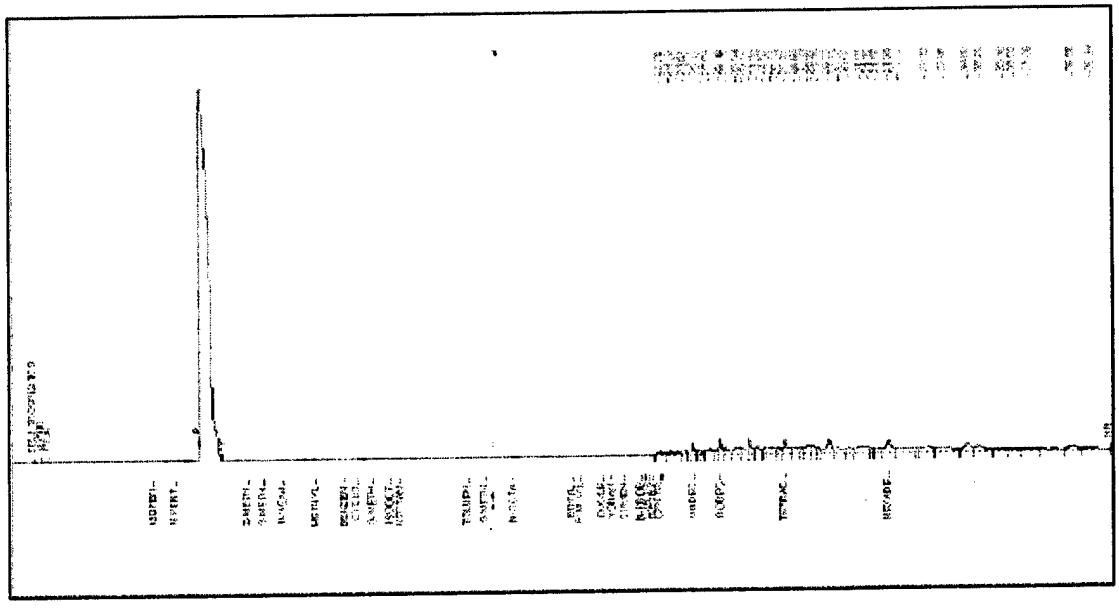


APPENDIX B - SAMPLE CHROMATOGRAMS

DFM
Mean Exposure Concentration - 2045 mg/m^3
Sample 1 - 807 mg/m^3 Aerosol
Glass Fiber Filter

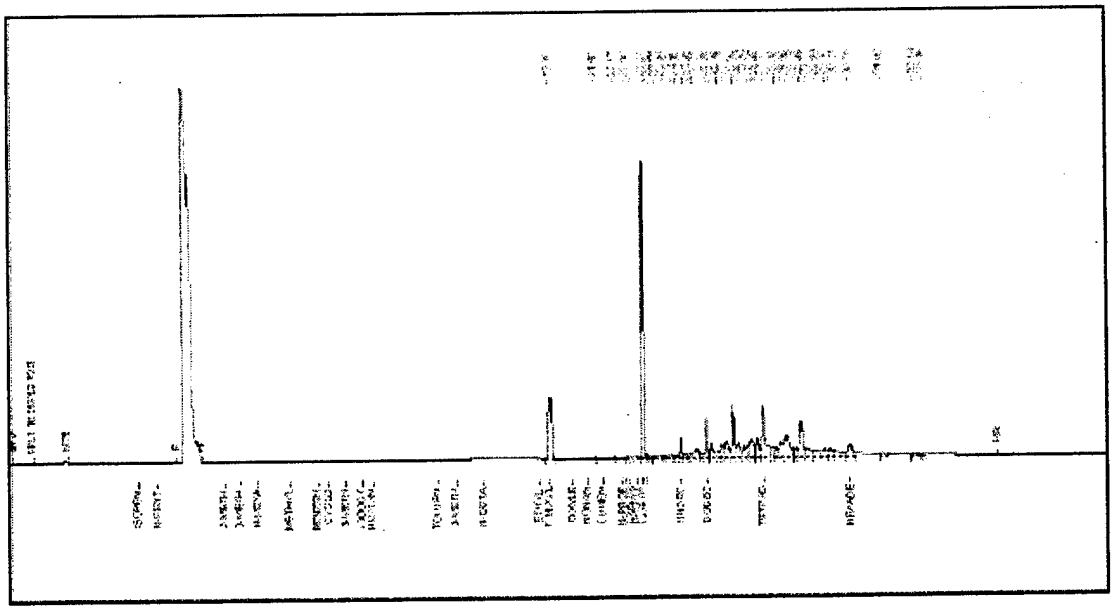


DFM
Mean Exposure Concentration - 2045 mg/m^3
Sample 2 - 768 mg/m^3 Aerosol
Glass Fiber Filter

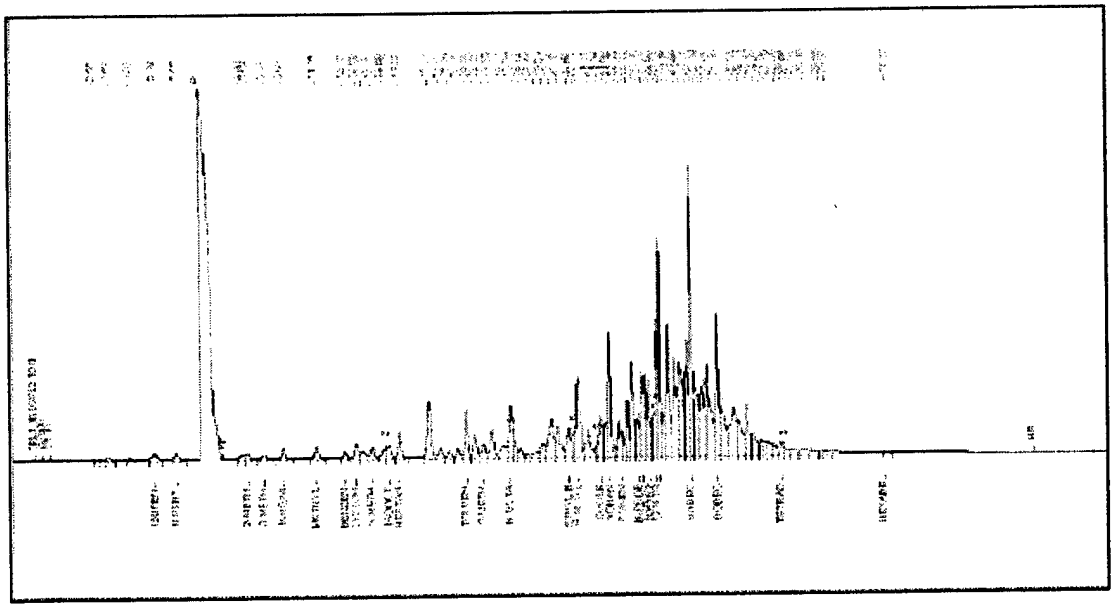


APPENDIX B - SAMPLE CHROMATOGRAMS

DFM
Mean Exposure Concentration - 2045 mg/m^3
Sample 3 - 879 mg/m^3 Aerosol
Glass Fiber Filter

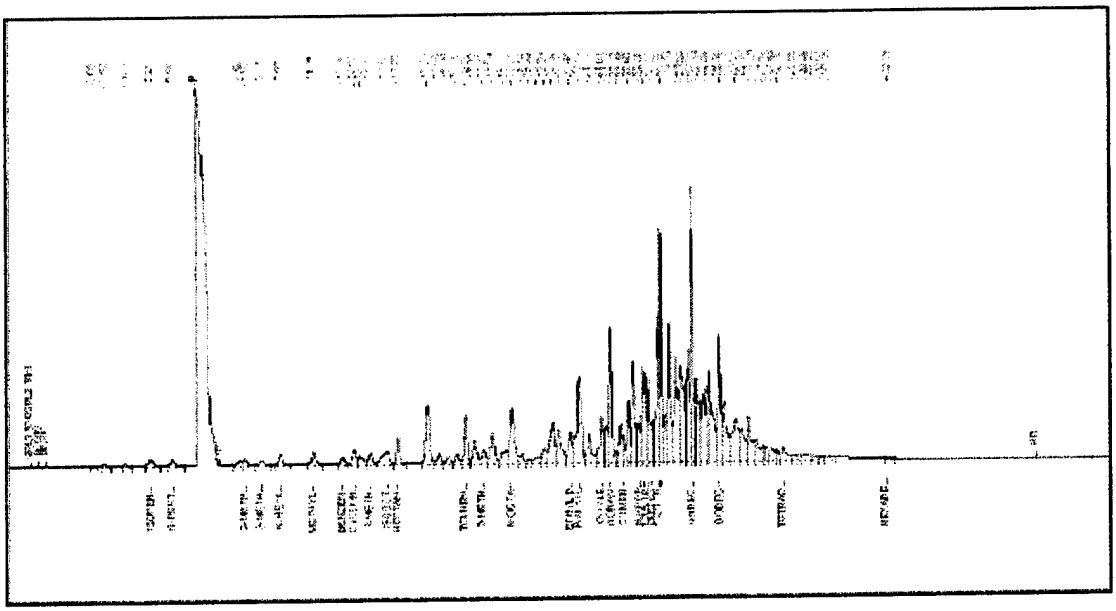


DFM
Mean Exposure Concentration - 2045 mg/m^3
Sample 1 - 1225mg/m^3 Vapor
Charcoal Tube

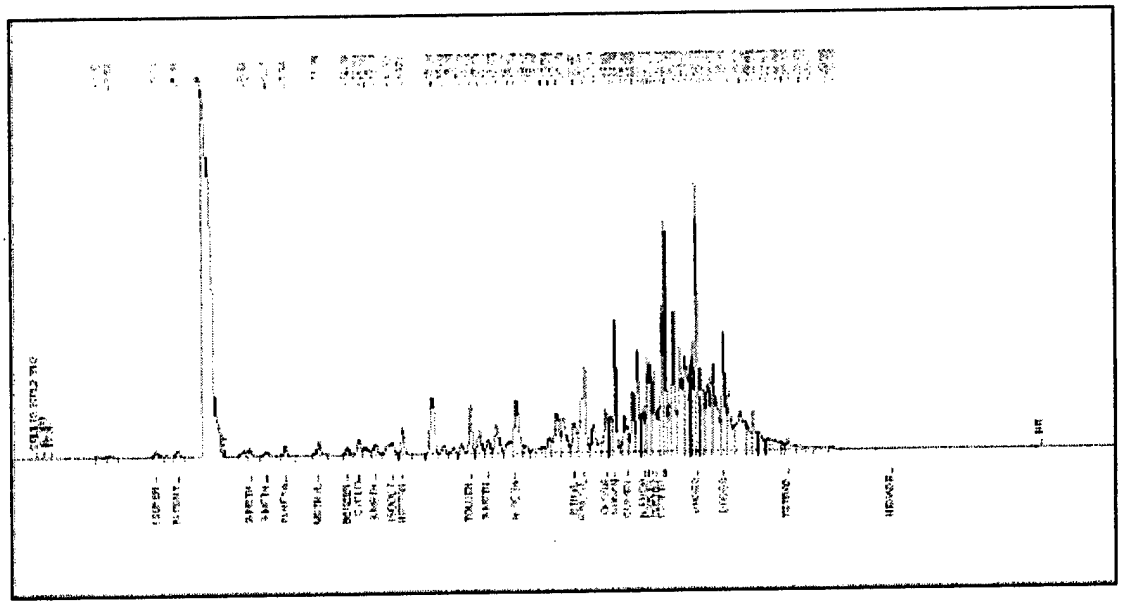


APPENDIX B - SAMPLE CHROMATOGRAMS

DFM
Mean Exposure Concentration - 2045 mg/m^3
Sample 2 - 1253 mg/m^3 Vapor
Charcoal Tube

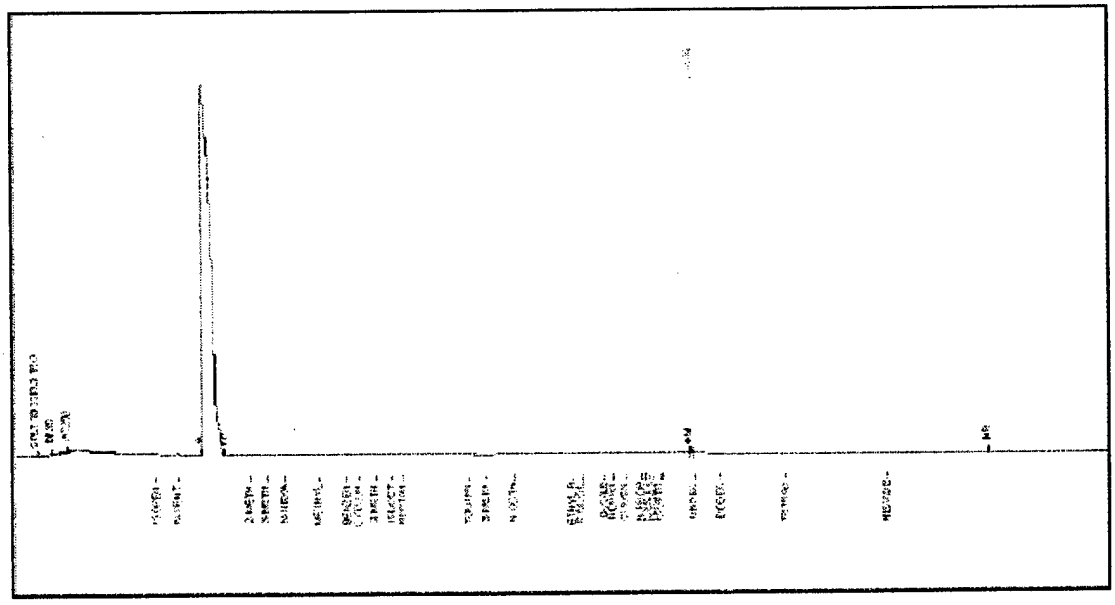


DFM
Mean Exposure Concentration - 2045 mg/m^3
Sample 3 - 1203mg/m^3 Vapor
Charcoal Tube

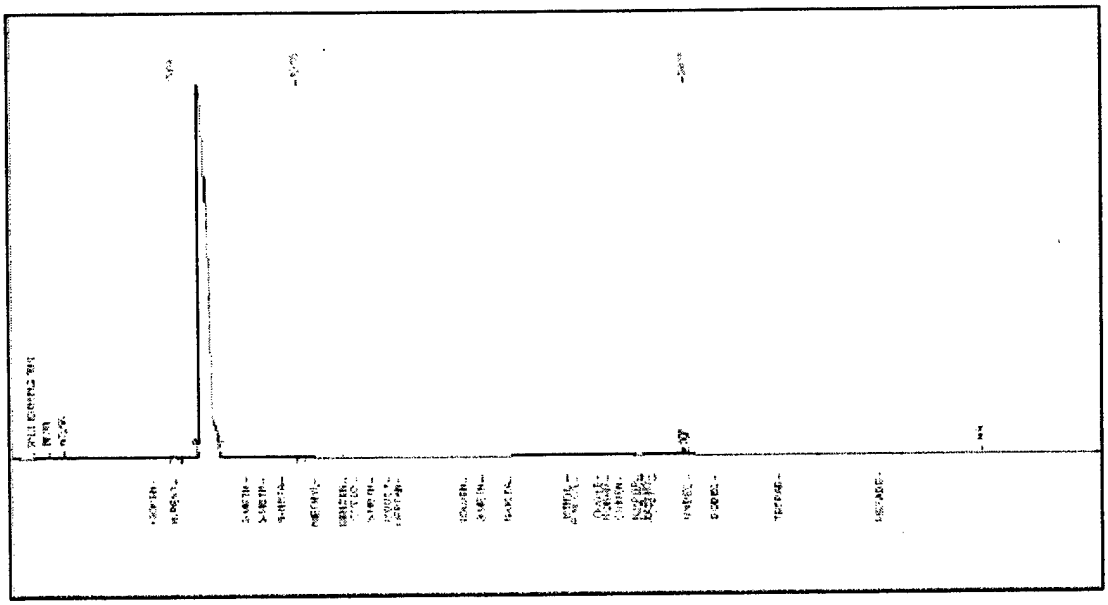


APPENDIX B - SAMPLE CHROMATOGRAMS

JP10
Mean Exposure Concentration - 5412 mg/m^3
Sample 1 - 0 mg/m^3 Aerosol
Glass Fiber Filter

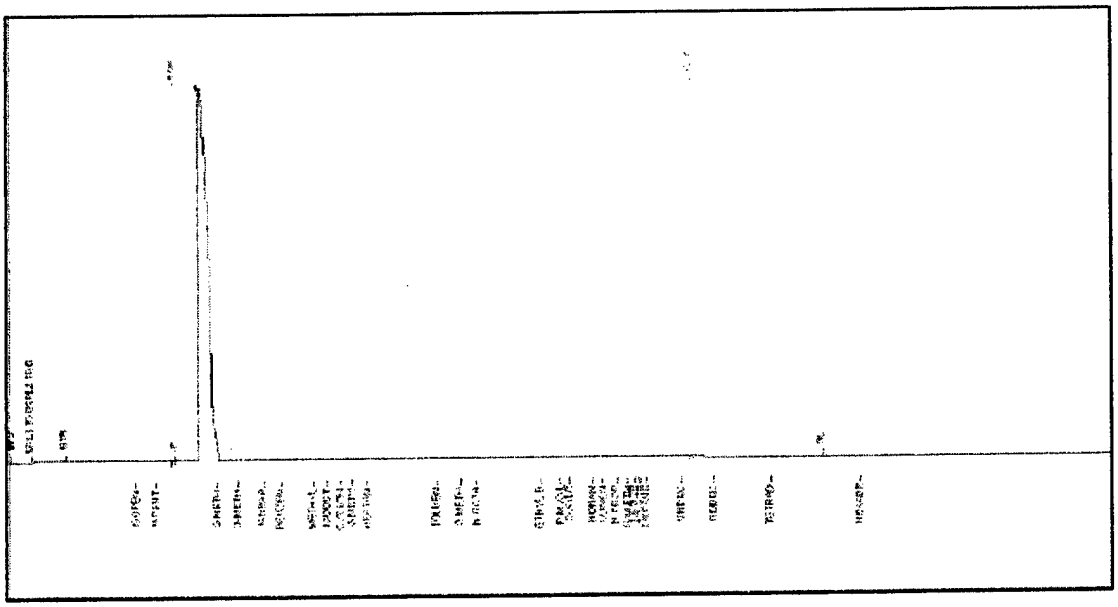


JP10
Mean Exposure Concentration - 5412 mg/m^3
Sample 2 - 13 mg/m^3 Aerosol
Glass Fiber Filter

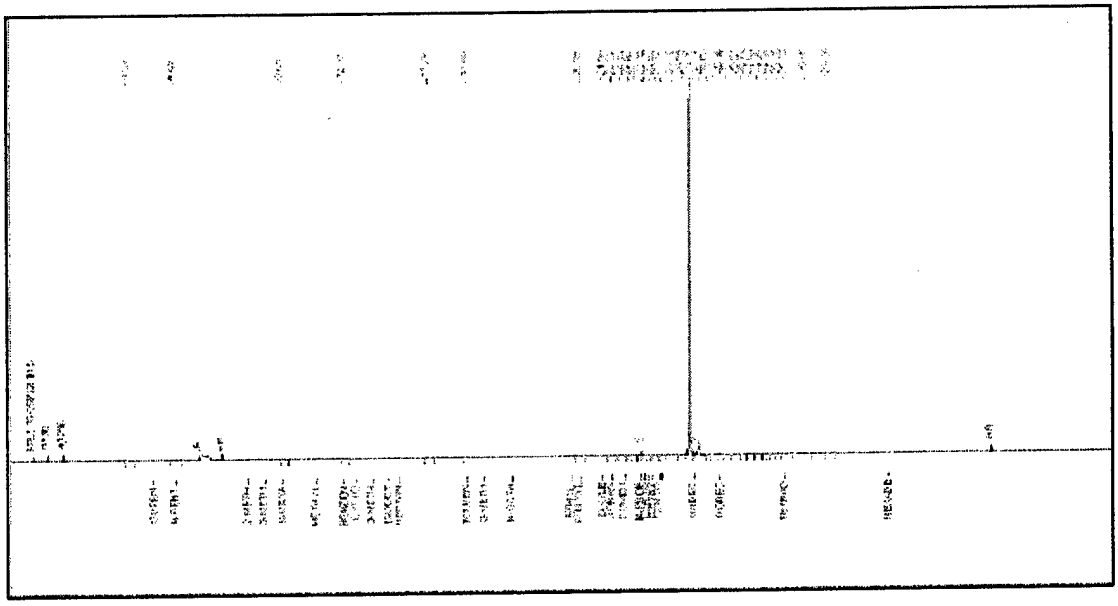


APPENDIX B - SAMPLE CHROMATOGRAMS

JP10
Mean Exposure Concentration - 5412 mg/m^3
Sample 3 - 0 mg/m^3 Aerosol
Glass Fiber Filter

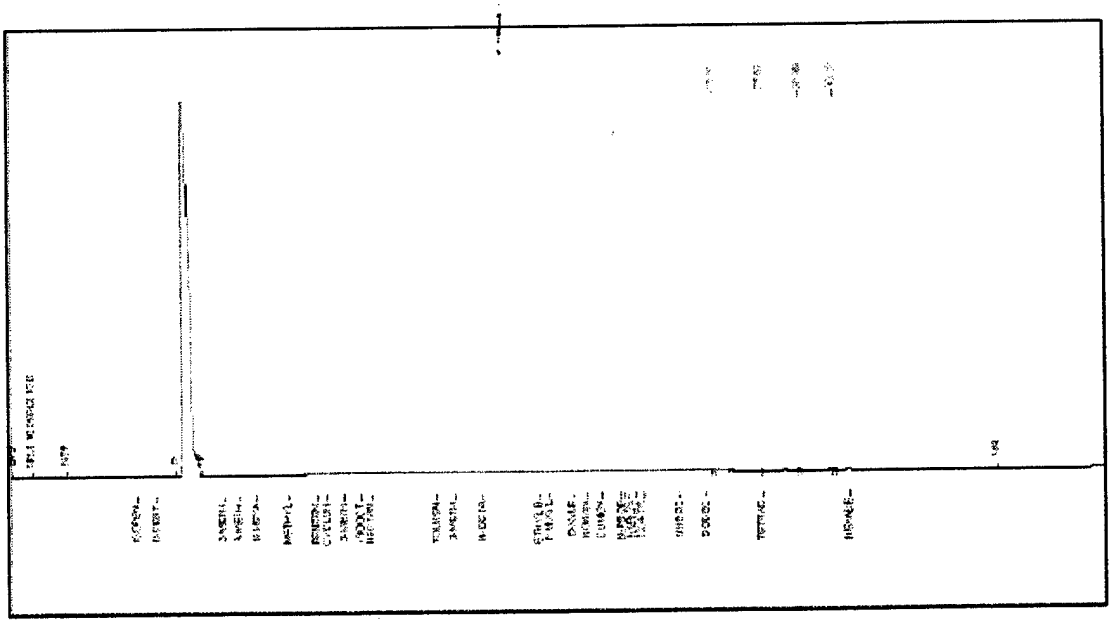


JP10
Mean Exposure Concentration - 5412 mg/m^3
Sample 1 - 5098mg/m^3 Vapor
Charcoal Tube

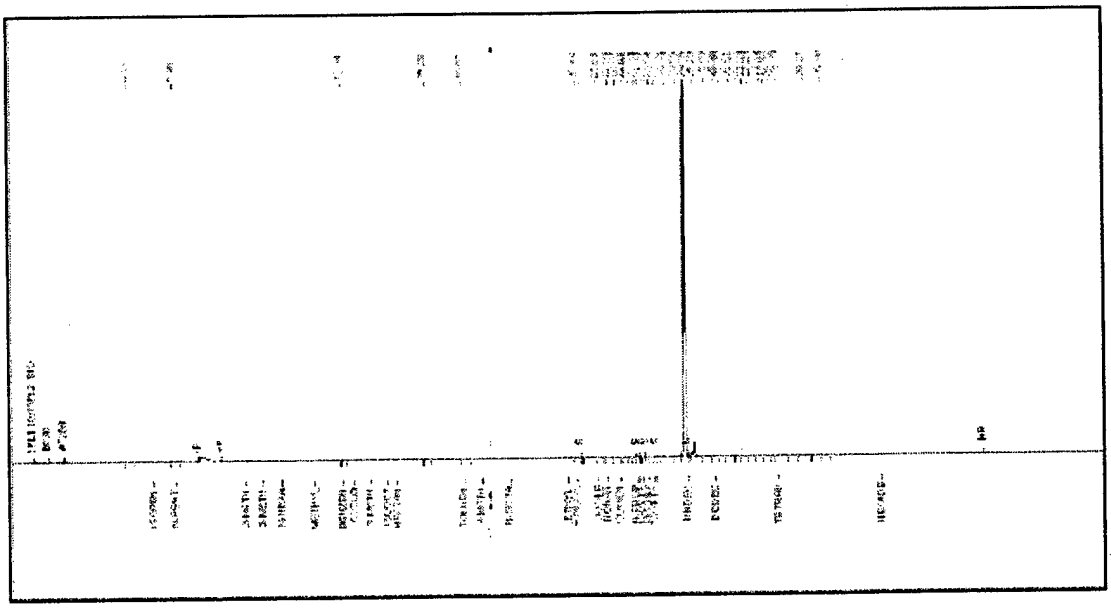


APPENDIX B - SAMPLE CHROMATOGRAMS

JP10
Mean Exposure Concentration - 5412 mg/m^3
Sample 2 - 5823mg/m^3 Vapor
Charcoal Tube

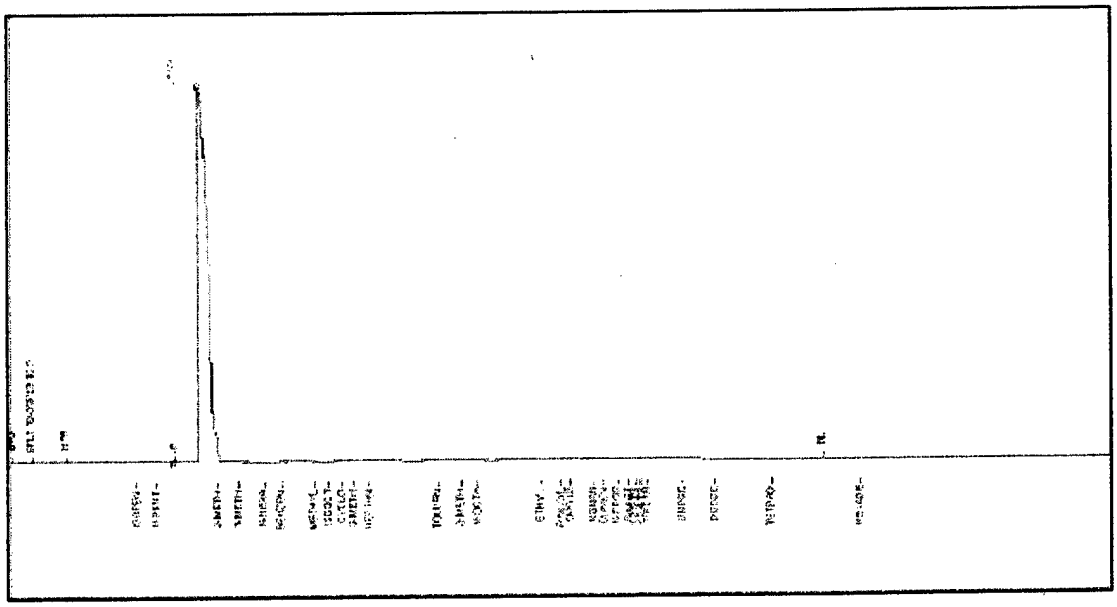


JP10
Mean Exposure Concentration - 5412 mg/m^3
Sample 3 - 5301mg/m^3 Vapor
Charcoal Tube

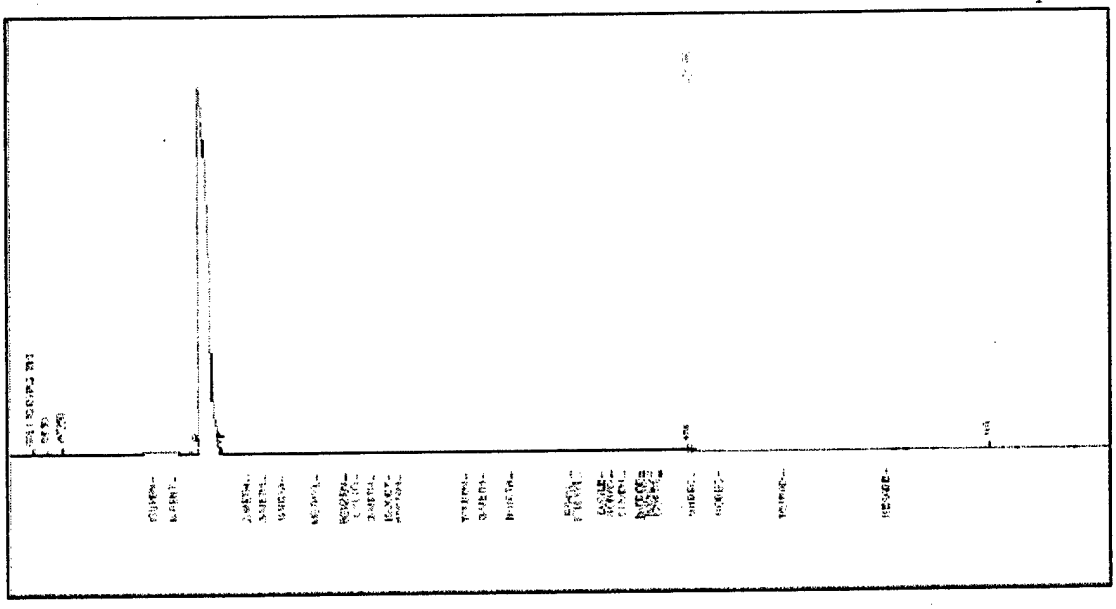


APPENDIX B - SAMPLE CHROMATOGRAMS

JP10 - Particle Size
Mean Exposure Concentration - 5412 mg/m^3
Stage Constant - 17.0 um
Glass Fiber Filter

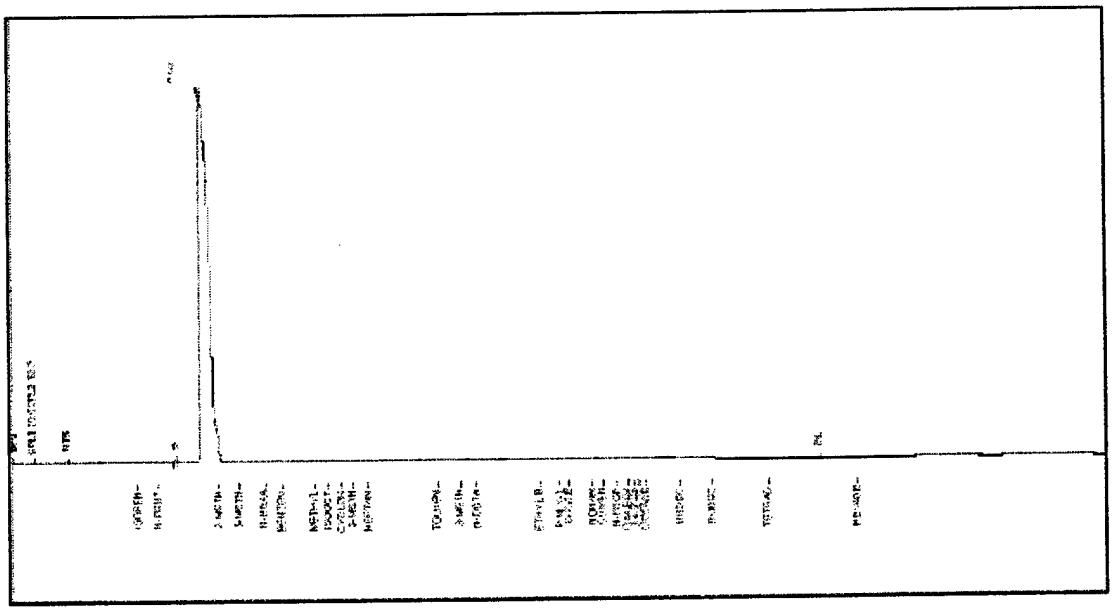


JP10 - Particle Size
Mean Exposure Concentration - 5412 mg/m^3
Stage Constant - 6.80 um
Glass Fiber Filter



APPENDIX B - SAMPLE CHROMATOGRAMS

JP10 - Particle Size
Mean Exposure Concentration - 5412 mg/m^3
Stage Constant - 4.10 um
Glass Fiber Filter



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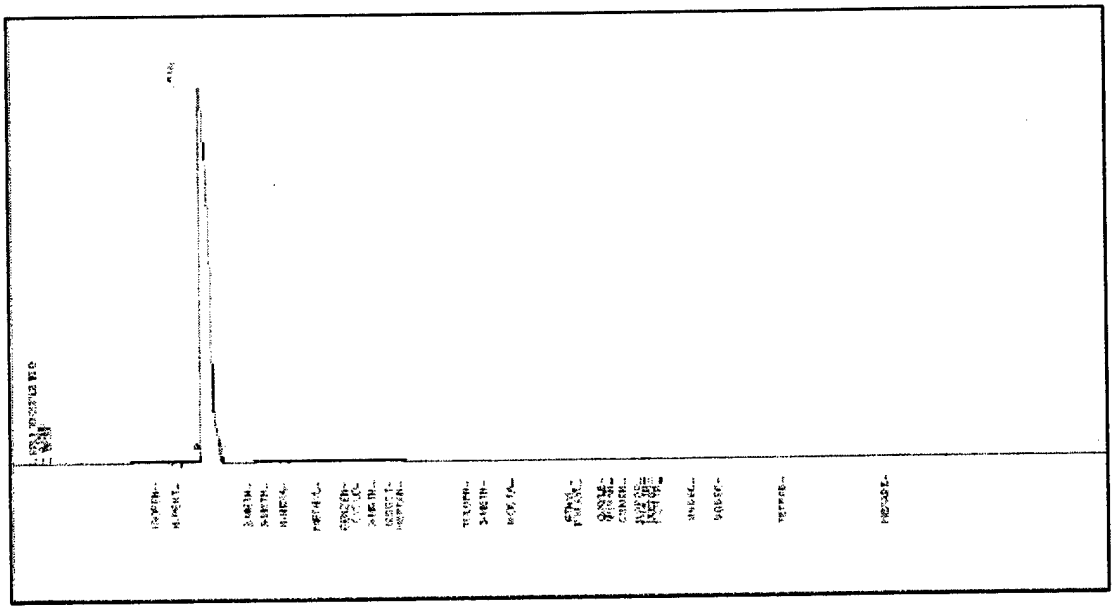
GLASS FIBER FILTER



APPENDIX B - SAMPLE CHROMATOGRAMS

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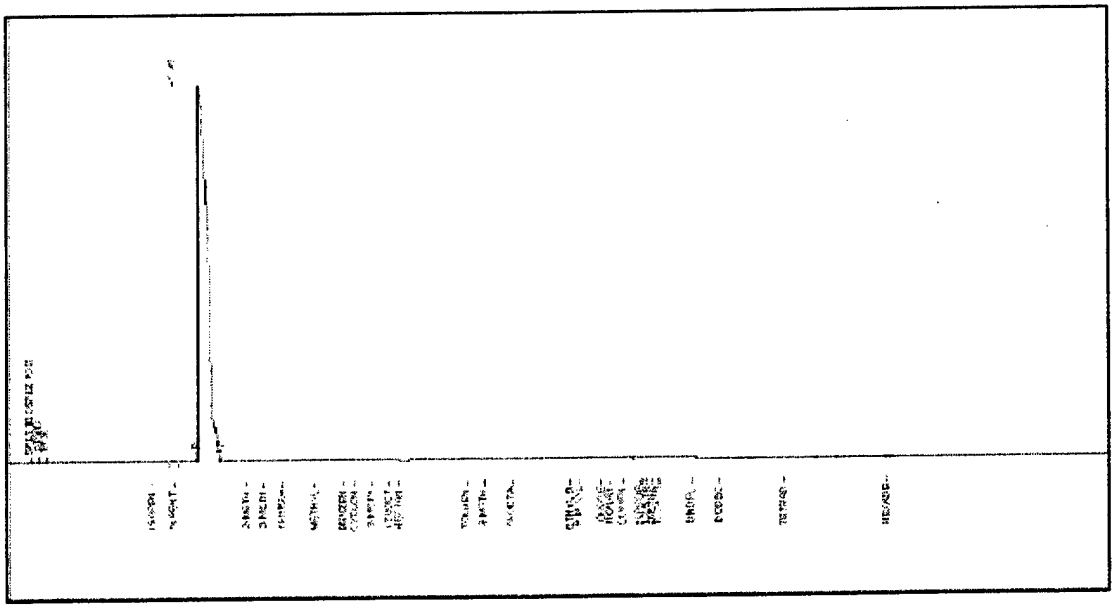
GLASS FIBER FILTER
Particle Size



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CHARCOAL TUBE