INTER-OFFICE CORRESPONDENCE

Hooker Chemical Company

40.233.01

TO: Gerry Lloyd

DATE: January 6, 1982

COPIES: Jim Boyette
M. R. Zavon
R. J. Schuttler

FROM: T. M. Briggs

SUBJ: VCM MONITORING

The enclosed article from the Journal of the American Industrial Hygiene Association presents a comparison of 3M, DuPont and GASBADGE passive organic vapor monitors with charcoal tubes. The study appears well controlled and the correlations are impressive. I am assembling an extensive literature reference file on passive monitors so if I can be of technical support to you on this matter, please call me.

Jim Boyette at Addis sent me information about their VCM monitors. They have purchased a number of REAL Mini Monitors. The Mini Monitor works on a permeation principle which is less accepted and not as well validated as the diffusion systems mentioned above for organic vapor sampling.

High humidity decreases the adsorption efficiency of charcoal diffusion systems when sampling for light hydrocarbon such as vinyl chloride. This may be an advantage for a permeation system in an area such as Baton Rouge.

Enclosed are two papers on the REAL Mini Monitors.

Since performance characteristics of the Mini Monitor are not fully documented, I suggest that a quality assurance program for sampling and analytical procedures be instituted if this system is to be used. Method validation is a must to have confidence in the results. If I can be of assistance, please call.

I will be at Addis on January 14-15 and I will discuss this with Jim Boyette at that time.

TMB/mrb0110A

Enclosures

The use of passive organic vapor monitors has been suggested as an alternative to the use of charcoal tubes with a portable pump as a method to assess a worker's exposure to organic compounds. This study simultaneously compares DuPont's, Abcor's, and 3M's passive monitors to the charcoal tube method. The study used a well-characterized dynamic exposure system to closely duplicate actual environmental exposure conditions. The solvent vapor generation system provided accurate, stable, and reproducible atmospheres within the exposure chamber. This total system is recommended as a significant improvement over previously reported techniques. Temperature, relative humidity, barometric pressure and air velocity were monitored and held within a small range of variation. Desorption efficiencies were determined for each of the organic compounds on each of the sampling devices used. Statistical analysis determined monitor performance. All three manufacturer's monitors are demonstrated to be an acceptable alternative to the use of charcoal tubes. Several modifications are suggested concerning analysis of these devices. A problem in monitor performance is noted.

A dynamic-flow chamber comparison of three passive organic vapor monitors with charcoal tubes under single and multiple solvent exposure conditions

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introduction

The Occupational Safety and Health Administration has required industry to monitor workers' exposures to various organic compounds and has established permissible levels to minimize possible ill-effects to workers exposed to these chemicals. These exposures are expressed as a time-weighted average (TWA).

When these limits were first established, the National Institute for Occupational Safety and Health (NIOSH) recommended the collection of organic vapors on a charcoal tube using a calibrated pump. The charcoal in these tubes was then analyzed using gas chromatography. This technique has been extensively tested and reported in the literature, and has become the routine collection method for organic vapors.[1-10]

New methods of collection have been developed which employ passive organic vapor dosimeters. These monitors do not require a mechanical pump, but rather use the diffusion principle as the driving force in sample collection. Abcor's Gasbadge, 3M's 3500 organic monitor, with draft shields, and DuPont's Pro-Tek, without any shield, use this principle.

Previous studies to evaluate these dosimeters have been limited in scope because of one-to-one comparisons of charcoal tubes to passive organic vapor monitors. The majority of studies have employed field monitoring[11,12] and have been of limited value because of many uncontrolled parameters complicating interpretation.

The few laboratory controlled studies have restricted themselves to the use of static[13,14] or quasi-dynamic[15] systems to expose these monitors. These exposure systems have several drawbacks which are minimized by the use of dynamic systems with larger exposure chambers and a flow-through design which minimizes the "wall effects" found in many smaller static systems. A constant supply of organic vapors provides a stable concentration which is not reduced as the monitors collect the solvent. In static systems, this reduction can affect chamber concentration significantly at low concentrations.

The study reported here compares the charcoal tube method to passive dosimeters of three major manufacturers: DuPont's Pro-Tek, Abcor's Gasbadge, and 3M's 3500 Organic Vapor Monitor; using a dynamic exposure system capable of generation of organic solvents over a wide range of concentrations. The resulting atmospheres are stable and reproducible. Other parameters known or suspected to interfere with these dosimeters, such as relative humidity, temperature, air velocity, and barometric pressure were monitored and remained within a small range of variation so as to minimize their effects.

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methods and procedures

exposure chamber

Exposures were performed in a $0.25M^3$ Rochester type dynamic flow inhalation chamber constructed of plexiglass. Units of this design are used almost universally for inhalation toxicology studies. Characteristics of these chambers, in terms of uniformity of air flow and contaminant concentra-

The conclusions and suggestions incorporated in this paper are solely those of the above authors. No part of this paper was edited or revised by any of the three corporations which participated in this study. All three corporations were given a copy of the completed manuscript and asked to present their opinions, if any, to be included in the "comments . . ".

tion throughout, are widely documented.[16,17] A vacuum system at the exhaust port created a negative pressure flow system. A Magnehelic gauge installed at this point measured the total flow rate in the chamber, which was controlled by a gate valve. The Magnehelic gauge was calibrated for flow using a 120 liter gas spirometer. A curve relating flow to gauge setting was prepared. This correlated significantly to the theoretical flows calculated for the various differential pressures. A chamber flow of 250 liters per minute (Lpm) was chosen and the corresponding value was set and monitored using the Magnehelic gauge. The chamber's relative humidity and temperature were monitored with an Abbeon Certified Hygrometer and temperature indicator.

A 2.5 cm (1 in) mesh wire was suspended 15.2 cm (6 in) below the top of the chamber and the badges were suspended at eight selected positions 5.1 cm (2 in) below this screen. Thus, all badges to be tested were located on a cross-sectional plane approximately 10.2 cm (4 in) above the mid-section of the chamber. Badges were placed a minimum of 15.2 cm (6 in) apart. In addition to the velocity of test atmosphere provided by the one change per minute (250 Lpm) flow through the chamber, air movement within the chamber was augmented using two 20.3 cm (8 in) fans installed in the upper dome of the chamber. Air velocities at all badge positions were measured with a Kurtz air velocity meter and determined to be greater than 100 fpm at each position.

A 30.5 cm (12 in) stainless steel needle was installed in the chamber and, when attached to a series A-2 Precision Sampling gas syringe, was capable of sampling the atmosphere at positions adjacent to the badges being exposed.

solvent generation system

The solvent generation system employed the principle of a constant vapor concentration at a constant temperature and pressure. The constants for vapor pressure calculations were obtained for the four solvents[18] and their saturated vapor concentrations were determined at 0 °C and 760 mm Hg. By knowing this, and setting the total exposure chamber flow at 250 Lpm, one may calculate the flow necessary for generating 10 and 100 parts per million (ppm). This system was similar to that employed to make the NIOSH Proficiency Analytical Testing Program samples.[19] These flows were acheived using cylinders of purified nitrogen equipped with 2-stage regulators to reduce the pressure to a moderate level. The final flows were individually regulated with a blunt needle valve for each solvent and these flows were monitored by differential pressure manometers equipped with variable orifices and standard manometer fluid. The nitrogen was then directed into gas washing bottles containing each solvent and the saturated vapor was directed into the intake port of the exposure chamber. The solvents in the gas washing bottles were maintained at a constant temperature with an ice-water bath at equilibrium. Figure 1 depicts the exposure chamber and solvent generation system.

analytical conditions

All analytic determinations were performed on a Perkin Elmer 3920 gas chromatograph equipped with a Supelco 3.05 m (10 ft) glass column, 2 mm ID, silane treated and packed with 10% FFAP on 80/100 mesh chromasorb W AW.[1,6,8,10,15] The operating temperatures were set as follows: 160 °C at the injection port, 220 °C at the detector, and 100 °C isothermal column operation. Chromatographic grade nitrogen was used as the carrier gas and the flow was set at 30 cc/min. A flame ionization detector was used. Maximum sensitivity of this detector was determined following the manufacturer's recommended steady state method. The settings determined were 16 pounds per square inch (psi) for the hydrogen and 60 psi for the zero air.

Samples were introduced into the instrument in two ways. Liquid samples were injected following the method recommended by NIOSH.[1,6,10] A Glenco 10 μL syringe is flushed with carbon disulfide several times and 3 μL of carbon disulfide is drawn into the syringe. Then 0.2 μL of air is drawn into the syringe to be used as a marker. Finally, a 5 μL aliquot of sample is drawn into the syringe and the plunger is retracted further to prevent evaporation at the end of the needle.

Air standards and chamber samples were collected with a Precision Sampling Pressure-Lok Series A-2 1.0 mL syringe. Samples were collected with 30.5 cm (12 in) needles compatible with this syringe. The plunger was slowly and completely withdrawn and the syringe flushed. This step was repeated, a sample taken, and the syringe valve was closed. The needle was removed and a 5.1 cm (2 in) needle attached. The valve was reopened, the volume was reduced to 1.0 mL, the valve was closed and the plunger was depressed to 0.2 mL. The needle was then inserted through the septum of the gas chromatograph, the valve was opened and the plunger was simultaneously depressed.

All determinations were made using the peak height as a direct indication of peak area due to the high resolution and narrow width of the peaks.

validation of chamber atmosphere stability

Exposures were conducted to test the temporal stability of the exposure conditions. These exposures were monitored by discrete grab samples which were analyzed by gas chromatography. The variability of chamber concentration for each solvent at both low and high concentrations over six hour intervals was determined. Mean concentrations and standard deviations were determined and are presented in Table I.

Two preliminary studies were conducted to verify uniformity of chamber concentrations and reconfirm that no significant concentration gradients existed in the plane of exposure. For one of the solvents used in this study (trichloroethylene), mean values were determined for 10 positions across a plane in the chamber, each position sampled 3 to 5 times. Relative results of these 10 values gave a mean of 2650 ppm with a standard deviation of 2.9%. Using trichloroethylene for a second series, four points (sampling each position 4 to 5 times) gave a mean value of 3400 ppm with a standard deviation of 0.5%. This degree of uniformity has been a common experience of this laboratory with these chambers in past studies.

EXPOSURE SYSTEM

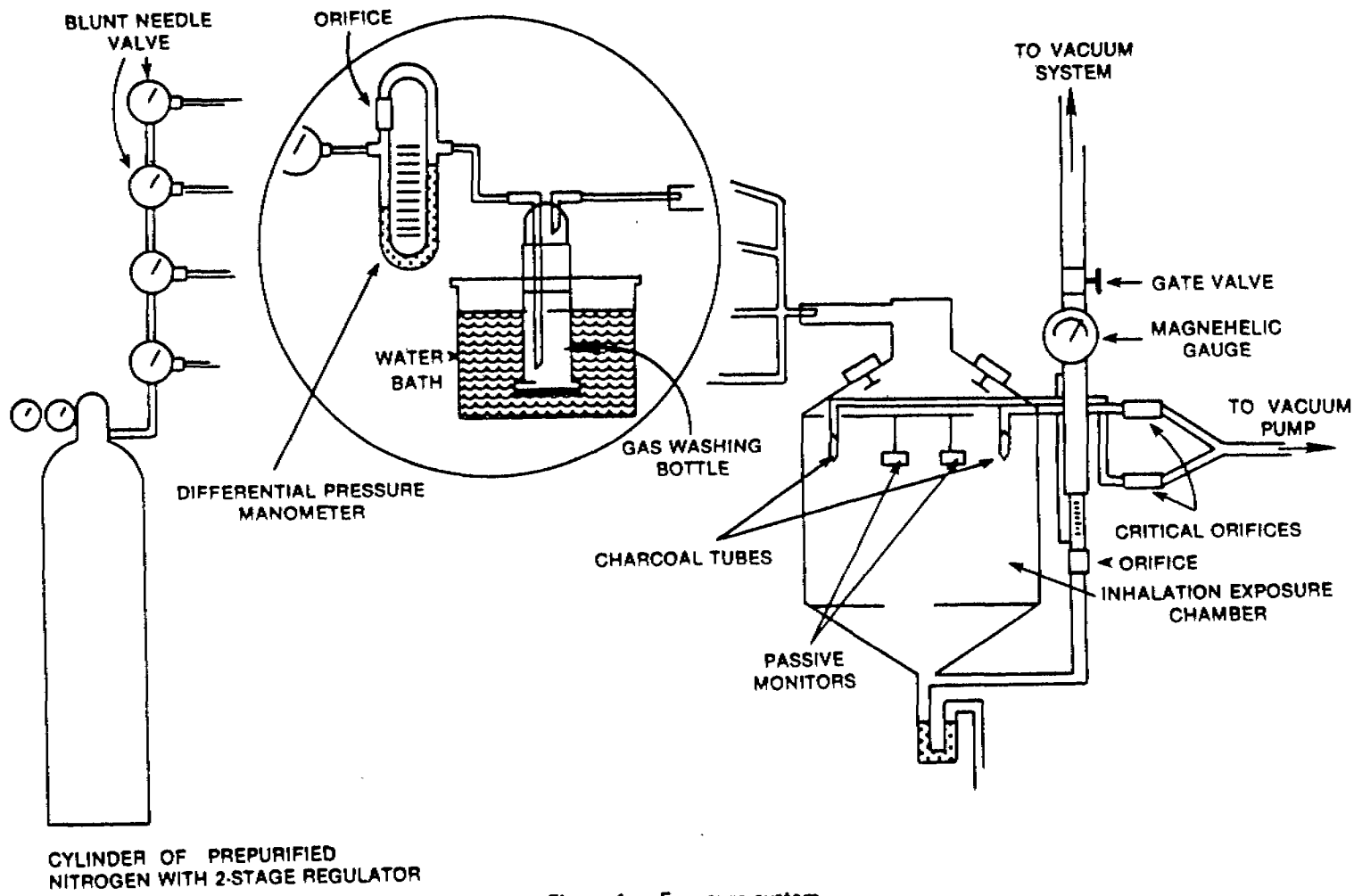

Figure 1 — Exposure system.

Determination of desorption efficiencies

Desorption efficiencies for the charcoal tubes and all three manufacturer's dosimeters followed the same basic steps outlined in NIOSH P and CAM 127 (subject to the modifications by each manufacturer).

Placing the charcoal or collection element in a septum capped vial, the analyst injected the solvent(s) of interest onto the collection medium. The sample was allowed to stand overnight. The following day the appropriate amount of carbon disulfide solution was added, the sample gently agitated for 30 minutes and an aliquot injected into a gas chromatograph. Standards and blanks were treated similarly. Desorption efficiencies were determined using the equation:

$$\text{desorption efficiency} = \frac{\text{area sample} - \text{area blank}}{\text{area standard}}$$

All corrected sample values were divided by each of the standard values and these were averaged to give the most representative desorption efficiency for each solvent.

Desorption of all solvents on all collection mediums was accomplished using a solution of 3% n-butanol in carbon disulfide. This is recommended by NIOSH and Abcor to improve the recovery of isopropanol.[2] All standards and samples were run a minimum of five times each and averaged to accurately reflect the actual value.

Desorption efficiencies for the charcoal tubes were performed first. A 100 mg sample of charcoal from the charcoal tubes was placed into a 1.0 mL mini-vial and capped using microsep F-138 teflon lined septa, the solvent was then injected into the charcoal. The amount used was determined "to represent that present in a 10-liter sample at a concentration equal to the federal standard."[1] Four samples and two blanks were prepared for each solvent and allowed to stand overnight. These samples were desorbed by injecting 1.0 mL of the carbon disulfide solution into each sample. Duplicate standards were made for each solvent by injecting 10 times the amount used on the samples into 10 mL of carbon disulfide.

The desorption efficiencies for each of the four solvents on the charcoal tubes were determined separately twice. A mixture of these four solvents, in the same volume to volume proportions, was prepared and the amount used for the multiple solvent samples was equal to the sum of the volumes used for each of the previous single solvent samples. A statistical analysis of the desorption efficiencies determined by this method showed no difference between those determined one at a time.[6] Therefore, to conserve time and collection elements this later method was adopted for the rest of the determinations.

Desorption efficiencies for Abcor were determined similarly. The collection elements were placed in the vials provided by Abcor. These elements become overloaded at 15 mg of solvent so 13 μL of the solvent mix was used (11.4 mg) to prepare each sample. Private correspondence with Abcor recommended using 3.0 mL of the CS_2 solution for desorption.[21] Standards were prepared by injecting 43.3 μL of mix ($13 \times 10/3$) into 10 mL of CS_2. Two standards and four samples were run.

Desorption efficiencies for the DuPont badges were determined by placing the collection elements into 2.0 mL mini-vials. 26 μL of the solvent mix was used to prepare each sample. Three standards and four samples were run.

3M recommends that the CS_2 solution be placed into their badges and samples be withdrawn directly. This method was difficult to reproduce and the desorption efficiencies determined were much higher than 100% due to the large amount of air space within the badge. To determine the desorption efficiencies for the 3M badge, the collection element was removed and placed into a 2.0 mL mini-vial. 3M recommends the amount of solvent used be determined by the amount of solvent present in a 7-liter sample at one-half the TLV. This was determined to be equivalent to 9.1 μL of the solvent mixture. The lowest overload value reported was 8.5 mg for hexane and the total for the 9.1 μL was 7.9 mg. Standards were prepared by injecting 60.7 μL of the solvent mix into 10 mL CS_2. A 1.5 mL aliquot of the CS_2 solution was used to desorb the elements, as recommended by 3M. Three standards and three samples were run.

For all analyses, the attenuation was adjusted for each compound to provide for a reasonable peak height. The desorption efficiencies which were determined are presented in Table II.

exposure procedures

This study consisted of sixteen exposures, each run included duplicate sampling using both charcoal tubes and each of the three brands of passive monitors.

Eight positions were selected within the chamber at the cross-sectional plane described above. Constraints were imposed that badges should be separated from each other and the walls by 15.2 cm (6 in.) and air velocity should equal or exceed 0.508 m/s (100 fpm). This specific velocity was recommended in NIOSH's protocol for the evaluation of

TABLE I
Chamber Stability

Compound	Concentration (ppm)	
Hexane	17.0 ± 0.5 (n=27)	91 ± 2 (n=35)
Isopropanol	13.6 ± 0.6 (n=19)	76 ± 2 (n=35)
Trichloroethylene	14.3 ± 0.4 (n=34)	89 ± 2 (n=23)
Toluene	13.9 ± 0.7 (n=35)	102 ± 2 (n=23)

TABLE II
Desorption Efficiencies for Various Organic Vapor Monitors

Compound	Charcoal Tube	Passive Monitors		
		DuPont	Abcor	3M
Hexane	1.02	1.02	1.01	0.96
Isopropanol	0.98	0.71	0.93	0.85
Trichloroethylene	1.03	0.96	1.02	0.95
Toluene	1.01	0.94	1.01	0.96

TABLE III
Summary of Statistical Analysis Comparing Charcoal Tube vs. Passive Monitors[A]

	Intercept			Slope			r^2	n
	Estimated Intercept (a)	Standard Deviation	t_0[B]	Estimated Slope (b)	Standard Deviation	t_1[C]	Corrected	
DuPont								
Hexane	−0.136	0.137	−1.00	1.0568	0.0791	0.72	0.903	20
Isopropanol	−0.1179	0.0902	−1.31	1.1292	0.0584	2.21[D]	0.952	20
Trichloroethylene	0.1168	0.0412	2.84[D]	0.9478	0.0276	−1.89	0.984	20
Toluene	0.0159	0.0405	0.39	0.9610	0.0262	−1.49	0.986	20
Abcor								
Hexane	−0.215	0.100	−2.14[D]	1.1210	0.0602	2.01	0.953	18
Isopropanol	0.396	0.130	3.05[E]	0.8429	0.0848	−1.85	0.852	18
Trichloroethylene	0.1474	0.0520	2.83[D]	0.9140	0.0357	−2.41[D]	0.976	18
Toluene	0.0191	0.0328	0.58	0.9644	0.0208	−1.71	0.992	18
3M								
Hexane	−0.1514	0.0900	−1.68	1.0772	0.0527	1.46	0.956	20
Isopropanol	−0.0437	0.0613	−0.71	1.0009	0.0367	0.02	0.975	20
Trichloroethylene	0.0560	0.0303	1.85	0.9318	0.0191	−3.57[E]	0.992	20
Toluene	−0.0096	0.0293	−0.33	0.9811	0.0190	−0.99	0.993	20

[A]Data were analyzed using the model $\log y = a + b \log x$

[B] $t_0 = \frac{a - 0}{\text{S.D. } a}$

[C] $t_1 = \frac{b - 1}{\text{S.D. } b}$

[D]Statistically significant at $p < .05$

[E]Statistically significant at $p < .01$

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passive dosimeters.[20] Manufacturers' criteria establishes a minimum velocity exposure well below the velocity used in this study.[22]

At two of the locations in the chamber, charcoal tubes were placed in a vertical position and tubing was run to the outside of the chamber to a vacuum pump. Critical orifices were made, calibrated, and installed in these lines to accurately control the sampling rates of the charcoal tubes at 0.294 and 0.286 Lpm. A single charcoal tube was used at each position for the single solvent low concentration exposures, two for the single solvent high concentration (three for isopropanol), and four for the mixed exposures. These charcoal tubes were changed at regular intervals to prevent overloading and loss of sample. To ensure complete collection, four charcoal tubes were joined in series to sample during each of the two spiked exposures.

Placement of the passive monitors at the other six positions was randomly determined prior to the first exposure and then held constant for subsequent exposures. The rationale for this was based on the previously determined uniformity of solvent concentration across the plane of exposure.

The first four exposures were low concentration (approximately 10 ppm), and of six hours duration; each exposure utilizing one of the four solvents from this study. To determine the required flows of organic solvents to the chamber necessary to achieve the desired concentrations, a series of standards was prepared. A curve was established which related concentration to peak height and the appropriate peak height representing a 10 ppm concentration was determined. Flows to the chamber were adjusted until the sample obtained duplicated this peak. The standards used for this series of exposures were made at 5, 10, and 15 ppm. These standards were prepared by injecting solvents into calibrated, sealed 20 L pyrex bottles. This container was fitted with a 30.5 cm (12 in) stainless steel needle. A 1.0 mL Series A-2 Precision gas sampling syringe was used to sample these standards.

The second four exposures were high concentration (approximately 100 ppm), and of six hours duration; each exposure utilizing one of the four solvents from this study. The procedure was the same as above, using standards of 50 and 100 ppm.

The third series consisted of six exposures. Each exposure was six hours in duration, with two solvents at the low concentration and two solvents at the high concentration. All six possible combinations were used. Flows were set using the volume which best reflected the above single solvent exposures on the differential orifice manometers. Standards were made at 10 and 100 ppm for this series.

Two final exposures were conducted to evaluate the effect of a short interval, high solvent concentration on a generally low background concentration exposure sequence since it was considered that the time of the spike might influence the apparent performance of the passive monitors relative to the performance of the charcoal tubes. These exposures involved subjecting the monitors for six hours to all four solvents at a low background level on which a spiked concentration was imposed for 36 minutes. The first of these exposures

involved spiking one hour after the start of the run while the second exposure involved spiking just prior to the last hour of the run. Solvent concentrations for both the background and spike were established solely by consideration of total monitor loading to preclude saturation. These concentrations were in the range of 10 and 100 ppm, respectively.

calculations

Exposures were conducted in the four groups as mentioned in the exposure procedures section. The exposed charcoal tubes and monitors were removed immediately from the chamber after the six-hour exposure, sealed according to the appropriate manufacturer's instructions, and refrigerated at 2-4 °C for up to two weeks prior to analysis.

After each group of exposures had been completed, the samples were analyzed using the procedures previously described. Samples were analyzed three to five times each and averaged to reduce possible error. A series of standards was prepared in concentrations spanning the range of loadings for each monitor and analyzed each day with the samples.

For each day of analysis, a curve relating chromatographic peak height to concentration of the standards was determined by linear regression with the restriction the line must pass through the origin. There were several reasons for this restriction. Theoretically, the curve should pass through this point and the higher the concentration of the standards the more accurately the standard could be made. Also, when certain combinations of two solvents at high concentration and two at low concentration occurred, attenuation could not be adjusted to give a large peak for all four compounds because of dramatic shifting in the baseline. Peaks smaller in size but with a stable baseline were preferred. For smaller peaks, a small change in the y-intercept could cause a large change in the calculated value for the monitor. This limitation was most pronounced for Abcor's and 3M's monitors because of the lower loadings and larger amounts of carbon disulfide used to desorb the samples. Calculations to determine average exposures in ppm were carried out using the equations supplied by each manufacturer.

TABLE IV
Comparison of Results by Chamber Position

Compound	Charcoal Tube			DuPont Monitor		
	4>2[A]	n	p Value[B]	6>3[C]	n	p Value[B]
Hexane	6	10	.754	0	9	0.004
Isopropanol	4	10	.754	0	9	0.004
Trichloroethylene	4	10	.754	0	9	0.004
Toluene	6	10	.754	1	9	0.039

[A]Number of exposures where the value at position 4 was greater than the value at position 2.

[B]Two-tailed sign test.

[C]Number of exposures where the value at position 6 was greater than the value at position 3

statistical analyses

Separate comparison was made between the average of the charcoal tube values and each of the values from both of the passive monitors. Linear regression was used to compare the data. The model: $\log y = a + b \log x$ was chosen, with y reflecting data from the charcoal tubes and x reflecting data from the passive monitors. As the concentration of a solvent increased the absolute variation also increased. By the use of logarithms, this phenomenon became more pronounced. Zero values were omitted for this analysis. The results of these calculations are shown in Table III. Separate comparisons were made between the average of the charcoal tube values and the higher value in each pair of values for the passive monitors and then repeated using the lower value of each pair. These sets of analyses gave results similar to the analysis encompassing all the data.

Values for the charcoal tubes and DuPont's monitors were tested to determine if chamber position affected sampler performance. This determination was made using the sign test. The results of this are presented in Table IV.

results

Table I shows the results of testing the stability of the solvent atmospheres generated for the exposure chamber.

Temperature, relative humidity and barometric pressure were monitored for the sixteen exposures in this study. Mean values for these chamber parameters were: temperature 23.2 °C (with a standard deviation of 1.1 °C), 46% relative humidity (with a standard deviation of 7%), and 752 mm Hg barometric pressure (with a standard deviation of 3 mm Hg).

The results of determining desorption efficiencies are presented in Table II. Comparison of individual passive monitor performance to charcoal tube performance is presented in Table III. Comparison of results by chamber position are presented in Table IV. Data for the series of the sixteen exposures which were used in the statistical analysis of this paper can be found in Appendix "A" of the unpublished master's thesis.[21]

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discussion

Chamber atmospheres were monitored for six hours for each solvent at both low and high concentrations to determine the temporal stability of the system. The results are presented in Table I. Absolute variability increased as the concentration increased while relative variability remained within ± 5%. Results of the preliminary studies on the planar uniformity of atmospheres are indicative of the performance of these chambers, the design of which has been used routinely in toxicology investigations for over 30 years. The results demonstrated by this investigation show the feasibility and desirability of generating organic solvent atmospheres for exposure chambers by the system described in this study.

Desorption efficiencies were determined for each solvent for each monitoring device and are presented in Table II. Desorption efficiencies determined on charcoal tubes were

individually compared against those determined in a matrix and no significant difference was found. This finding had been reported earlier.[6] The desorption efficiencies for all the passive monitors were determined for all solvents simultaneously.

Desorption efficiencies for DuPont were run twice to confirm the low desorption efficiency determined for isopropanol. Seventy-one percent was determined each time and was accepted because of its reproducibility.

Determination of desorption efficiencies for the 3M monitors was attempted twice using the 3M recommended method. Results were consistently above 100% recovery. No problems were experienced when the charcoal pads were removed from the badges and analyzed in 2 mL vials.

In cases where there are solvents at both high and low concentrations, it is difficult to change attenuation on the gas chromatograph to give a large peak due to dramatic shifting in the baseline. This limitation was most pronounced for Abcor's and 3M's monitors due to the lower loadings and larger amounts of carbon disulfide used. Loadings, because of higher concentrations of other solvents, could not be increased without overloading the monitors.

Since the peaks for some of the compounds were small, a change in the y-intercept could cause a large change in the value calculated for the monitor. Therefore, the standard curves were calculated with the restriction that the curve pass through the origin. Theoretically, the line should pass through this point. In addition, standards prepared at low concentrations could not be made with as much accuracy as those at higher concentrations. This made it difficult to determine where the curve should pass at the lower end of these curves.

Because of the problems encountered with solvents at these lower concentrations it is suggested that smaller amounts of carbon disulfide be used for desorption. The slight increase in desorption efficiency does not appear to outweigh the disadvantage of smaller peaks.

Difficulties were also encountered at lower concentrations with the quantification of isopropanol due to a severe interference by carbon disulfide which made baseline determinations difficult. If this problem is expected, analysis by a different chromatographic column, which will give better resolution, is recommended.

Exposures within the chamber were all conducted with air velocities in excess of 0.508 m/s (100 fpm) as is recommended by NIOSH. DuPont stated that for the testing of their Pro-Tek organic vapor monitors, their badges were more sensitive to inadequate face velocities than Abcor's or 3M's monitors.[22] For this reason, DuPont's badges were placed at the two positions with the highest velocity. One position averaged 0.762 m/s (150 fpm) and the other position averaged 0.635 m/s (125 fpm). No difference was expected since DuPont stated these monitors were calibrated to accurately measure between 0.169 m/s and 2.032 m/s (35 to 400 fpm). After analysis of the first four exposures, a noticable difference in values was observed. Positions of the DuPont monitors were recorded for the last twelve exposures. Results by position were compared for charcoal tubes and the DuPont monitors. These results are presented in Table IV. It is clear that there is no significant difference in positions for the charcoal tubes while there is a significant difference in position demonstrated for the DuPont monitors. It appears that these monitors are sensitive to differences in velocities of the surrounding air since all other variables were kept constant at both positions. These monitors, unlike Abcor's and 3M's monitors, do not have a draft shield. This could explain the difference in monitor performance. It is also possible that chamber concentration at these locations varied since they were not monitored during actual exposures. Data previously presented on uniformity of solvent concentration within the chamber minimize this as a possible explanation. It should be emphasized that positions were not recorded for the Abcor and 3M monitors and therfore similar comparisons could not be made.

Comparison of monitor performance to charcoal tube performance is the most widely recognized method for validation of passive monitors. Comparison was made using the model: $\log y = a + b \log x$ where the y value was the average value for the charcoal tubes which was paired against each of the values calculated from the passive monitors for the same exposure. This series is summarized in Table III. Comparison was repeated using the average value for the charcoal tubes and the higher value in each pair for each organic monitor. Comparison was made substituting the lower values for the higher. Little difference was noted for these three series of analysis which demonstrated both organic vapor monitors and charcoal tubes would give a good representation of the exposure. Table III shows that all three brands of passive monitors should be considered an acceptable alternative to the recognized charcoal tube method. All three companies' monitors had y-intercepts close to the origin. For the determination of higher concentrations closer to the TWA's of these compounds, the slope of the regression line becomes increasingly important. While all three companies' monitors have fairly good correlations with the results from the charcoal tubes, 3M's monitor gave the best slope in two out of four cases and showed the smallest variation every time as is demonstrated by examination of the standard deviation. 3M's monitor did not perform as well as DuPont's monitor for trichloroethylene and hexane. A poor correlation between charcoal tubes and Abcor's monitors pertaining to isopropanol could be due to problems with baseline determination discussed earlier.

conclusions

1. Under conditions similar to those of this study, DuPont's, Abcor's, and 3M's passive organic vapor monitors are an acceptable alternate to the charcoal tube method for assessment of a worker's exposure to organic solvents, as is demonstrated by the good correlation between each monitor with the results obtained by the charcoal tubes.

2. Significant differences between monitor performance were noted for DuPont's monitors. Sensitiv-

ity to velocities surrounding the monitor is suspected as the reason.

When isopropanol is monitored at low concentrations, especially in the presence of high concentrations of other compounds, selection of chromatographic columns becomes important if one wishes to minimize interference by carbon disulfide.

4. Analysis of 3M's monitors is improved by removing the charcoal pad and placing it into a 2 mL septum capped vial.
5. Desorption efficiencies can be determined for several solvents simultaneously with no significant difference over determination of each solvent individually, provided the charcoal device is not over-loaded with solvents.
6. The exposure system, including the organic solvent generation system described in this paper, is recommended as a significant improvement over previously reported exposure techniques for the determination of monitor performance.

It should be emphasized that this study was a laboratory controlled experiment which, while examining several important parameters, kept several other equally important parameters constant. The conclusions drawn in this paper should only be considered valid when the conditions of exposure have been met. This is the first of what should be a series of studies which need to be conducted to verify whether these conclusions can be extended to conditions such as elevated relative humidity and extremes in temperature.

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OCC 8222

Comments . . .

A dynamic flow chamber comparison of three passive organic vapor monitors with charcoal tubes under single and multiple solvent exposure conditions

Thank you for the opportunity to review and comment on "A dynamic flow chamber comparison of three passive organic vapor monitors with charcoal tubes under single and multiple solvent exposure conditions," by D.R. Voelte and F.W. Weir. We find it, in general, technically sound, and offer the following comments:

1. In calibrating their gas chromatograph, the authors chose to draw all standard curves as linear and through the origin. In our experience, solvent or baseline interferences often have yielded non-zero intercepts for multipoint linear calibration curves, especially at low analyte levels when a flame ionization detector is used. Such interferences are suspected in the low level calibration for isopropanol; it is our belief that the standard curves should not have been forced through the origin.
2. The authors reported severe baseline jumps when making large attenuation changes during a run. This problem, if not associated with detector or injector contamination, can often be minimized by employing dual column differential compensation.
3. The authors concluded, based on statistical arguments (Table III), that the 3M monitor was somewhat superior in performance to the Gasbadge™ dosimeter. As evidenced by the slope data for materials other than isopropanol, the 3M monitor showed an average relative standard deviation (RSD) of ± 2.9% while the Gasbadge averaged ± 3.8% RSD. Since the RSD for repeat injections of identical GC standard is approximately ± 2.0% under ideal conditions, we feel that the deviations for the two dosimeters agree within the systematic error of the analytical procedure. Because of baseline problems, the isopropanol data should not be considered in a side-by-side comparison of the two draftshield type dosimeters.
4. We agree with the authors that based on their data, all 3 dosimeters tested showed acceptable accuracy.

Again, we thank you for the opportunity to present our comments on this work.

Michael S. Young
Project Chemist
Jamie P. Monat, Ph.D.
Manager, Environmental Engineering Department
Walden Division of Abcor Inc.

We have reviewed the final draft of "A Dynamic Flow Chamber Comparison of Three Passive Organic Vapor Monitors with Charcoal Tubes Under Single and Multiple Exposure Conditions," by D.R. Voelte and F.W. Weir and have prepared the following comments for concurrent publication.

Du Pont is pleased to see another report on the overall good performance of passive dosimeters and appreciates the opportunity to comment on the results obtained by Prof. Weir and Mr. D.R. Voelte. The points we feel are important for the reader to consider are:

1. Du Pont has thoroughly tested the GAA Organic Vapor Monitoring Badges under various conditions prior to commercialization in chambers specifically designed to minimize concentration and flow gradients as well as insidious wall effects. Our experimental data presented below show no face velocity effects over the range of 32.5 to 325 feet/minute verifying the theoretical concepts used in initial badge design. The data is presented in sampling rate (DA/L) (cm^3/minute) versus face velocity over the concentration range of 3.2 to 35.8 ppm benzene in air.

Test No.	ppm C_6H_6	Face Vel. (ft/min)	Sampling Time (DA/L) (cm^3/min)
1	35.8	32.5	93.4
2	35.8	32.5	83.4
3	6.7	162.5	88.8
4	6.7	162.5	85.5
5	3.2	325.0	97.3
6	3.2	325.0	92.8
			$\bar{X}$ = 90.2
			S.D = 5.25
			C.V. = 0.0582

2. We agree with other statements made by the authors, especially concerning the apparent face velocity observed with Du Pont badges. They did not monitor chamber concentrations at these locations as diligently as at the 3M and Abcor locations. Additional experiments in which badges were randomly distributed among the test positions would be helpful.
3. A recent article in the AIHA Journal [Koizumi, A. and M. Ikeda, American Industrial Hygiene Association Journal *42*:417-425 (1981)] emphasizes the need for more elaborate controls, as well as the use of inert chamber construction, to minimize concentration gradients in the chamber type used by Voelte and Weir.

Clairbourne D. Smith
Manager, Applied Technology Division
Du Pont Company

OCC 8223

The conclusions of "A Dynamic Flow Chamber Comparison of Three Passive Organic Vapor Monitors with Charcoal Tubes Under Single and Multiple Exposure Conditions," by D.R. Voelte and F.W. Weir, appear to establish the validity of passive dosimetry as an alternative to the charcoal tube method. The possible problems mentioned in the study as they pertain to the GASBADGE are currently under investigation. In addition, the application of the GASBADGE to a wider range of solvents is under consideration.

Ford Stoll, Jr.
National Mine Service Company

author's reply . . .

The following are the responses to comments of Abcor and DuPont regarding the Voelte-Weir Study:

Abcor:

It is possible that the results of isopropanol on the Abcor badge may have been improved if we had not used the restriction that the calibration curve should go through the origin. Improvements in determinations of monitor performance could also be improved by:

A. Increasing the amount of isopropanol collected, when possible, but avoid overloading the collection element.
B. Decreasing the amount of carbon disulfide used to desorb the collection element.
C. Decrease gas chromatograph interferences as discussed below.

These three steps would improve the analytical results and shift the determinations further from the origin, thus minimizing its effect.

We agree that the suggested use of dual column differential compensation would have reduced the problems encountered when analyzing for low concentrations of isopropanol and is probably preferrable to the use of an alternate packed column.

Our paper states all three monitors are acceptable as an alternative to the use of charcoal tubes. Each company's monitor has its particular performance characteristics such as rate of collection and amount of solvent used to desorb badges.

The major problem with the Abcor badge was due to the small amount of isopropanol collected and the high dilution due to the large amount of carbon disulfide used to desorb the collection element. Under the conditions of this study, the Abcor badge was the most difficult to use to determine low level concentrations of isopropanol when other solvents are present at higher levels.

Dupont:

A major purpose in conducting our investigation was to demonstrate the relative utility of passive dosimeters as compared to charcoal tubes using conventional inhalation toxicology methodology that should reflect probable use conditions. Our exposure chambers, used in the manner described in our paper, are well characterized regarding uniformity of concentrations throughout the exposure zone. They represent a design that has been widely accepted for use in this field.

The Koizumi and Ikeda Study (AIHA 42:417-425 (1981)) referred to in the DuPont comments utilized a chamber similar to the one used in our study. Although they used stainless steel for construction they did not discount the utility of plexiglass as suggested by the DuPont comments. Further, Koizumi and Ikeda modified their inlet port to create laminar flow through their chamber for the special purposes of their study. Our chamber inlet was similar to the original widely accepted "New York University type". This inlet design provides very uniform mixing of influent gas streams before entry into the exposure zone of the chamber. Fans were added in our chamber solely for the purpose of increasing general air velocity in an effort to more closely simulate conditions expected during industrial use of the monitors.

Unpublished observations from our laboratory on performance of these passive dosimeters utilizing equipment and conditions similar to those reported above by DuPont concur with their results. We have no argument regarding DuPont's results. However, we continue to think that the exposure chambers and circumstances reported in our study reflect probable industrial use conditions more reliably than does the very specialized equipment, providing precisely defined laminar flow velocities presented in a uniform direction to the face of the subject badges, used as described by DuPont in their investigation.

It should be noted that these DuPont data represent the first publicly presented to support their claim that face velocity does not affect badge performance. While our paper suggests that face velocity may affect badge performance, we do recommend that further work is needed to explore the problem. We hope that independent sources will be able to resolve this issue.

In any event, our basic position remains that, even if sampling rates vary somewhat with face velocity as suggested by our data, the DuPont badge should be considered to be an acceptable alternative to sampling with charcoal tubes, at least over the range of conditions used in this study.

We appreciate comments from the suppliers of these monitors as well as their participation in this study. It is noteworthy that all parties have indicated general agreement concerning our results.

Francis W. Weir
David R. Voelte

A passive dosimeter-type personal monitor for vinyl chloride has undergone extensive field testing. Collaborative studies by a number of laboratories confirm the accuracy, reliability, convenience and general acceptability of personal monitors utilizing gas permeation for sample collection and quantification. Data are generated as timeweighted averages and response is linear from 5 ppb to 50 ppm. The monitors which weigh only 35 g are unaffected by variations in environmental conditions.

Field tests of a permeation-type personal monitor for vinyl chloride

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introduction

The analytic process begins with a need, whether real or imagined. The analysis itself may involve a number of steps including sampling, sample stabilization, preparation, concentration, separations and finally, the desired determination or measurement. The analytic process also involves data processing and, very possibly, validation. Unfortunately, measurement is often considered to be synonymous with analysis and much of the emphasis in the past has been on the measurement step under the assumption that this was the most critical part of the analysis. In reality, however, sampling is often the most difficult and subject to the most error. For industrial hygiene studies the sampling of the workplace atmosphere is of utmost importance. It is especially important that a convenient, reliable method for personal monitoring be used so that valid information be provided for the protection of the individual and for the extension of factual knowledge required in the evaluation of hazards.

In a general sense, sampling can be classified as either active or passive. The sampling of atmospheres has most generally been accomplished by means of some mechanical or active process, such as the use of a pump for pulling the sample through some metering device and a collection medium such as an adsorber or absorber. Although such active sampling techniques are standard, they do present certain difficulties. The use of motors, pumps, power sources and collectors when incorporated into personal monitoring devices tend to present a cumbersome and often unreliable sampling mechanism. Such mechanical devices tend to break down or wear out and they are relatively expensive. The recent introduction of passive sampling by means of permeation offers a simple, reliable, convenient and low-cost alternative.

OSHA regulations are based primarily on NIOSH recommendations. For gaseous hazards such as vinyl chloride, the collection and stabilization by charcoal tubes has been specified. No specifications have been promulgated regarding motors, pumps, metering devices or other components that would normally be considered integral parts of personal monitors. Thus the collection of samples by means of permeation should be considered valid provided the quantification is accurate and falls within specified confidence limits. The device for the personal monitoring of vinyl chloride employs charcoal as recommended by NIOSH. The measurement step, likewise, is the same as that already in use whereby the collected sample on charcoal can be eluted using carbon disulfide and the amount determined by conventional gas chromatography. Also, the personal monitor meets requirements because laboratory and field tests show accuracies achieved with permeation are well within specified limits.

Because the unique and critical feature of the permeation device for vinyl chloride is the permeation process itself, a brief summary describing the process is presented.

The terms permeation and diffusion are familiar. Although there are similarities between

permeation and diffusion, there are subtle but at times important differences. Basically, diffusion represents the passage of molecules through holes in a discrete barrier whereby turbulence is minimized. Beyond the barrier or draft shield a stagnant air layer provides a means for mass transfer to a collecting medium with quantification of the transport following Fick's Law of Diffusion:

$$N = -DA(dc\ dx)$$

where,

- N = rate of diffusive transport, moles/sec
- D = diffusivity of contaminant, cm^2/sec
- A = area of diffusion path, cm^2
- x = length of diffusion path, cm
- c = concentration of contaminant, moles/cm^3

The Walden "GasBadge" utilizes the diffusion principle.[1]

For permeation, a barrier to ambient atmospheres is also involved but its function is to serve in the direct quantification of contaminant species. In this case there are no holes in the barrier. Instead, a polymeric membrane is utilized and gaseous contaminants contact the membrane and dissolve, permeate and thus are transported through the membrane to a collection and stabilization medium such as charcoal. The permeation constant, k, for the membrane used and for a given contaminant permits the determination of the time-weighted-average concentration for the contaminants,

$$C = wk/t$$

where,

- C = concentration, ppm
- w = weight of contaminant, μg
- t = exposure time, hrs

The permeation constant is first determined by calibration using appropriate contaminant concentrations in an exposure chamber. The first use of permeation for sample collection was for the determination of sulfur dioxide in ambient air.[2] Its use in personal monitoring for vinyl chloride exposures has been described recently[3] and a commercially produced dosimeter, the MINIMONITOR, is now available (REAL Inc., Box 3341, Baton Rouge, LA 70821).

Consideration of mathematic expressions relating to diffusion and permeation fails to disclose effects that might result from non-ideal parameters. For personal monitors, for example, what is the effect of movement relating the atmosphere being sampled to the collecting interface? What is the effect of humidity? Of temperature? Do particulates or various coexisting gases have effects? In our studies, both in the laboratory and in the field, the permeation approach has proven to be the method of choice. Air movement, or lack of it, was of no significance nor were changes in humidity nor was the coexistance of various gaseous or particulate species. Permeation rates were known to vary according to temperature but this problem was negated by use of special membranes having properties that were altered but little by varying temperatures. For example, the vinyl chloride monitor exhibited essentially no temperature dependence over the range of zero to 40°C.

experimental

permeation device

The permeation-type personal monitor used for the evaluation studies was the same as that described previously[3] with only minor modifications (Figure 1). It consisted of a hollowed out aluminum plate which served as a reservoir for activated charcoal, a silicone permeable membrane for quantification of gas collection, and a front grid which protected the membrane from physical abuse.

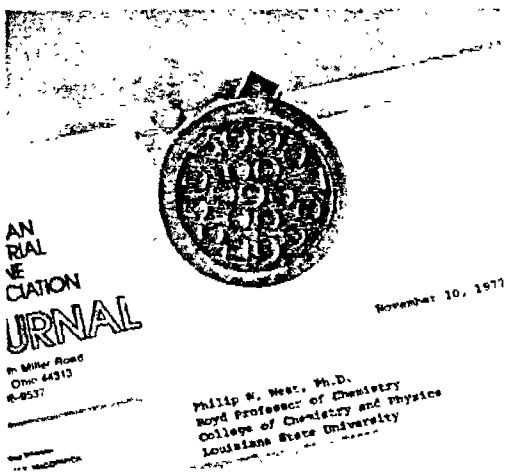

Figure 1 — Permeation personal monitor.

TABLE I

Preliminary Field Evaluation (4hr TWA)

Sample	Conventional Monitor	Vinyl Chloride, ppm ASTM Monitor	Permeation Monitor
	(ppm VCl)	(ppm VCl)	(ppm VCl)
1	1.00	1.00	1.19
2	0.10	0 12	0 19
3	0.12	0.14	0 10
4	0.12	0.13	0.17
5	0.34	0.37	0 51
6	0.04	0 05	0 07
7	< 0 02	< 0.02	< 0.02

TABLE II

Contributed Field Data, USA

Temp °C (°F) % Humidity	Vinyl Chloride, ppm Permeation Device No 2	No 4	Sipin Pump Sampler
29 (84)/80	0 11		0.08
26 (78)/87		0.11	0.15
24 (76)/91	0.09		0 12
29 (85)/74	0 44		0.47
31 (87)/67	0.32		0.35
24 (76)/71*		0.32	0.33
24 (76)/71*	0.29		0 36
23 (73)/73*	1.28		1.80

*7 hr exposure in fixed location (VCM Lab.) PD adjacent to sampler carbon tube

Calibration of the monitors was done by the cooperating laboratories in accordance with their respective preferences. Permeation tubes and standard gas mixtures were used, the choice being a matter of company practice. The activated charcoal used for the sample adsorption in each case was similar to that used in the pump-charcoal tube monitors used for comparison. The analytic finish in all cases was by means of standard gas chromatography following sample desorption using carbon disulfide. Calibration, therefore, consisted of exposing the monitors in a standard gas atmosphere containing vinyl chloride and determining the weight of material collected over the exposure period,

$$k = ct/w$$

where,

k = device permeation constant
c = known concentration of vinyl chloride
t = time of exposure
w = weight of vinyl chloride adsorbed

validation

A test program was organized to determine the characteristics of a badge-type personal monitor for vinyl chloride. The original laboratory studies were backed up with field studies. Both the laboratory and field work have now been extended by independent investigations carried out in a number of plants and laboratories in the United Kingdom, as well as in Canada and the United States. The findings are presented here without identifying the cooperating individuals and laboratories. The data presented were contributed as a means of furthering the protection of colleagues throughout the world who might be exposed to potentially hazardous concentrations of toxic materials such as vinyl chloride.

A local manufacturer of vinyl chloride contributed data from a preliminary field evaluation (Table I) in which ASTM and conventional pump monitors were compared with permeation-type monitors. The results were obviously good. Further studies were made under differing conditions of temperature and humidity. As shown in Table II, values obtained on days with temperatures ranging from 22.8 to 30.6°C and humidities of 67 to 91% gave excellent agreement and confirmed laboratory findings that there was essentially no temperature effect over a range of zero to 40°C nor any due to humidity over the range of 100% to less than 10%. An additional set of data presented in Table III simply confirms those given in Table I. The two studies were made at different times and under somewhat different conditions.

A second company located in the Gulf Coast area submitted the data shown in Table IV. Again, the results confirm the reliability of the permeation approach for sample collection. It is of interest to note that all data presented in the four tables were generated in a very complex industrial region where a wide variety of organic and inorganic manufacturing or processing operations were always in progress.

Collaborative studies conducted in the United Kingdom were initiated by the committee on vinyl chloride and were performed in a number

TABLE III

Vinyl Chloride Personal Monitor Data

Sample	Vinyl Chloride (ppm) Conventional Monitor	Permeation Monitor	Monitor Number
2	0 83	0 98	2
3	0 10	0 17	3
5	0 05	0 16	2
6	0 10	0 15	3
7	0 07	0 12, 0 11	2; 5
8	0 07	0 05; 0 08	3, 4
9	0 50	0.51; 0 49	2; 5
10	0 41	0 42, 0 48	3, 4
11	0 02	< 0 05; < 0 05	2; 3
12	0.88	0.92, 0.97	4; 5

Note Sample 1 gave the following results: 6.9 ppm by conventional and 8 9 ppm by permeation monitor (monitor no. 1) and Sample 4 gave 3.6 ppm by conventional and 5.1 ppm by permeation monitor (monitor no. 1). Due to the difference in the results, they are not included in the Table (difference may be due to a calibraton error)

TABLE IV

Contributed Data, USA - No. 2

Date	Ambient Temp °C (°F)	Relative Humidity, %	Vinyl Chloride, ppm Permeation[3] Device No 2	Permeation[3] Device No 4	Pump Sampler
6/16/76[1,4]	28 (83)	86	1.31		1.07
6/1	28 (83)	86		0 12	0.12
6/17	-	73	0 12		0.23
6/21	32 (90)	82		0.59	0.34
6/21	32 (90)	82	0 97		0.50
6/24	29 (85)	70	0 40		0.49
6/25	31 (88)	60		0 95	0.38
6/28	-	-		0 84	0.82
6/28	-	-	0.18		0.16
6/29	27 (80)	73	0.27		0.30
6/29	-	-		1.40	1.75
6/30	-	-		0 41	0.33
6/30	-	-	0.63		0.65
7/1	30 (86)	61	0 10		0 05
7/1	-	-		0.11	0.06
7/2[1,4]	-	-	0 16		0 11
7/2	-	-		0 90	0 90
7/6	-	-	0 17		0 08
7/6	-	-		1 18	0.23
7/7	29 (84)	80	0 11		0.08
7/7	29 (84)	80		0.11	0.08
7/8	26 (78)	87		0 11	0 15
7/8	26 (78)	87	0 15		0 19
7/9	24 (76)	91	0 09	0 09	0 12
7/12	-	-		0 25	0.25
7/12	-	-	0 23		0 48
7/13	28 (83)	72	0 47		0 53
7/14	29 (85)	74	0 44		0.47
7/14	29 (85)	74		0 99	0 86
7/15	31 (87)	67	0 32		0.35
7/15	31 (87)	67		0.36	0.35
7/16	-	-	0 09		0 10
7/16	-	-		1.01	0 86

7/19	-	-		0 35	0 69
7/20*	-	-	0 11		0.12
7/20*	-	-		0 13	0.12
7/26*	24 (76)	71		0.32	0.33
7/26*	24 (76)	71	0.29		0.36
7/27*	23 (73)	73	1.28		1.80

[1]PD placed on one side of collar, pump on other.
[2]PD placed adjacent to pump on same side of collar
[3]Monitors were calibrated at LSU
*7 hr exposure in fixed location (VMC Lab.). PD adjacent to sampler carbon tube.

TABLE V

Contributed Data, United Kingdom

VCM present, ppm v/v	VCM concentration found—ppm v/v			
	A	B	C	D
1.5	1.4	1.4	1.3	1.5
1.9	2 1	2.2	2.1	2.1
3.7	3.4	3.2	3.6	3.3
3.9	3.9	4.0	4.1	3.8
3.9	4.0	3.9	4 0	3.7
4.0	3 9	3.8	3.7	3.9
5.7	5.7	5.8	5.9	5.3
7.5	7.8	7 8	7.6	7.6
13.9	14.3	14.1	13.2	13 1

f laboratories. The results presented in Table V give replicate values obtained using four permeation devices. As a matter of interest, a sample calibration graph submitted by the U. K. committee is shown in Figure 2, (also see Table VI). Of special significance are the conclusions and recommendations which are quoted as follows:

conclusions

"Convention would require the laboratory work recorded here to precede plant trials. The results from the plant trials have already been acknowledged to be encouraging; the calibration series now completed further justifies the faith inspired by the badges from the outset. A fair spread of time/concentration combinations has been covered, without revealing any weakness likely to arise in the conditions met in personal monitoring.

We feel curiosity, rather than concern, that the permeation constant, K, found here may differ from those established elsewhere.

recommendations

The Louisiana badge and the Century Systems programed thermal desorber have undergone independent evaluation, with favourable results. There is no reason to be apprehensive about using the two together, but a limited series of laboratory trials should be run when the Automatic Injection valve becomes available for the P-D. This system promises to be the best and most economic for future personal and similar monitoring."

discussions and conclusions

The validation studies contributed by impartial industrial laboratories have confirmed the accuracy and reliability of the permeation approach for personal monitoring. The permeation-type monitors showed a small positive bias in the field studies which did not

TABLE VI

Plant Trials, United Kingdom

Date	Pump VCM, ppm	Permeation VCM, ppm
5/4/76	2 96	3 78
5/6	2 16	2 25
5/7	2 32	2.33
5/8	2 44	2 90
5/9	pump broke	8 40
5/10	2 72	3 11
5/10	8 36	10 91
5/11	8 21	10 11
5/11	2.11	2 59
5/12	3 48	3.77
5/12	5.85	11.00
5/13	4 92	5.14
5/13	1 48	2 27
5/14	16 7	21 0
5/14	16 3	15 8
5/17	5 97	7.54
5/18	8 74	9 84
5/18	6.99	7.36
5/18	4 54	4 76
6/22	14 4	12.1
6/22	4 1	3 9
6/23	16 4	19 4
6/23	pump broke	7.50
6/25	6 2	6 5
6/25	12 4	14 5
6/28	8 5	9 1

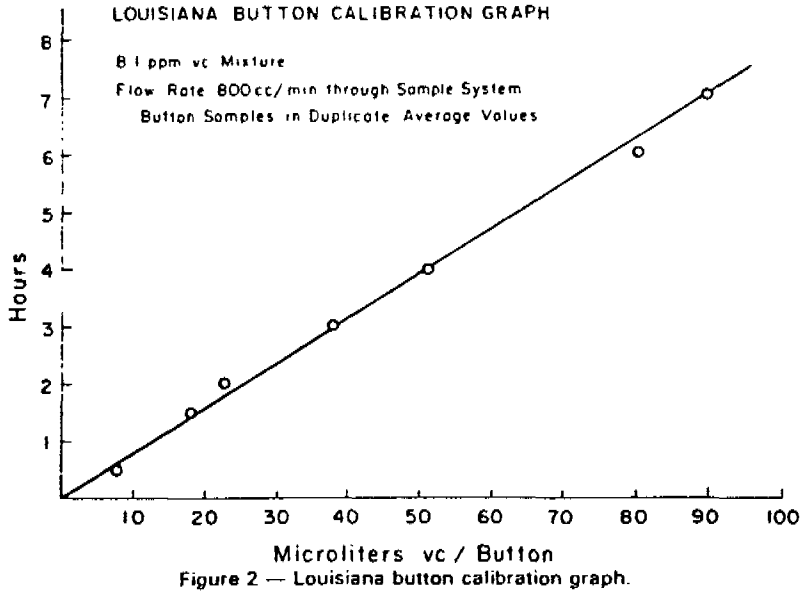

Figure 2 — Louisiana button calibration graph.

appear in laboratory evaluations. The only explanation proposed for the lower results obtained in the field with pump-type monitors was the possibility that battery driven motors were used and battery fatigue might have caused smaller than expected samples to result.

There were no failures nor malfunctions reported in the use of the permeation-type monitors. This was in contrast to the experiences reported with the conventional monitors. The latter were beset with pump failures as well as occasional motor and battery problems.

In addition to the low cost and reliability of the permeation approach, the great advantage of convenience made the permeation-type monitors completely acceptable to the wearers as contrasted to the objectionable discomfort reported by personnel forced to wear conventional equipment.

A final matter of interest is that of cost. The permeation approach makes it possible to provide monitors which are essentially indestructible and which cost less than $50 each.

acknowledgements

We wish to acknowledge the partial support of the National Institute for Occupational Safety and Health, USPH Grant R10H-00666A. We are indebted, also, to the many individuals and industrial companies that advised and collaborated in the test program.

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Accepted Jan. 5, 1978

Reprinted from
American Laboratory, July 1980

By Philip W. West

Passive monitoring of personal exposures to gaseous toxins

THE BENEFITS the chemical age has brought to humanity would not have been imagined even fifty years ago. However, we have come to recognize that certain hazards are inherent in the widespread production and use of chemicals, many of which are known or at least suspected to be toxic. The acute toxins, whose effects are often spectacular and final, are known even to the general public. However, many acute toxins such as hydrogen sulfide, sulfur dioxide, and chlorine can be tolerated for years at sublethal concentrations without any apparent harm. For example, most of the professors exposed to high daily concentrations of hydrogen sulfide in the qualitative analysis laboratories years ago seem to have lived to healthy old age. Cumulative and additive toxins, on the other hand, are more insidious in their impact and it appears that exposure to even minute amounts of such materials over long periods may have lasting effects on the individual. Metabolic changes occur and carcinogenic manifestations develop.

Many exposure hazards from toxins in the workplace have been recognized and evaluated by various monitoring methods. In general, the evaluations have been limited to the sampling and analysis of the general atmosphere in the workplace, although it is obvious that the appraisal of risk should be based on the content of the air actually breathed by the individuals rather than on the composition of the surrounding ambient air. Because cumulative and additive toxins are long-term hazards, it is the time-weighted-average exposure that should be monitored through exposure studies extending for weeks, months, and even years.

Personal monitoring in the community also is needed. Because of the transient nature of many of the exposures encountered in the ambient atmosphere, background information on individual exposures could be very informative. Away from the place of employment individuals are more mobile, and thus data on the total exposure of persons living in high-risk or suspect areas would be exceptionally valuable.

Some criteria for ideal monitors are obvious. Reliability and convenience head the list, but because of the low concentration that must be monitored, or at least averaged during the lengthy periods of study required, the sensitivity of detection and determination must be high. Cost may pose a limitation.

The only present type of monitor that meets the criteria is some form of passive device. Active monitors requiring power sources and mechanical components such as motors, pumps, and metering devices impose too many restrictions for their projected applications in the long-range personal monitoring of low concentrations of toxic gases.

Active devices

The initial approach to personal monitoring has been based on the use of devices consisting of a battery-pack to power a motor-driven pump that pulls ambient samples through a metering unit. The sample itself is usually collected on a tube of activated charcoal, although in some modifications the sample is absorbed in an appropriate buffered or complexing solution or is simply pumped into a collection bag. Active sampling monitors have provided most of the data for the pioneer studies that have been done thus far. Such monitors have serious limitations, however; they are quite expensive, the pumps have relatively short service periods before repair or replacement is necessary, use is limited to the length of time that a charge can be maintained on the batteries, and the monitors have tended to be a nuisance to the wearer because of their bulk, weight, and the noise generated by the pump. These problems contribute to a lack of cooperation by wearers who resent the device and may in some cases lead to deliberate distortion of the samples and consequent invalidation of the results obtained.

Passive devices

Personal monitors for determining toxic exposures in residential areas as well as in the workplace

Dr. West is Boyd Professor of Chemistry, Environmental Sciences Institute, Chemistry Department, Louisiana State University.

must be convenient and low in cost. The monitors must provide the necessary sensitivity, accuracy, and reliability for obtaining sufficient usable data. Passive monitors are ideally suited for such applications because of their convenience, simplicity, and relatively low cost. Gas permeation through polymer membranes is an attractive approach for quantifying the collection of gaseous samples in passive monitors. Monitors using this technique are unique because environmental variations induce little, if any, error. The devices also can be adapted to a variety of analytic systems, including sample adsorption on solid substrates such as activated charcoal or silica gel, and samples can be collected in solutions containing reactive species for the fixation and stabilization of the toxins of interest. Permeation-type monitors correspond in size, weight, and convenience to the familiar radiation dosimeters.

Although this paper will emphasize permeation-type monitors, some discussion of other passive devices is appropriate. In a sense, effects measurements, such as those obtained with corrosion coupons, lead peroxide candles, or sulfation plates, present the simplest approach to passive monitoring. However, these provide no means for quantifying the results in terms of concentration and therefore must be considered only as qualitative indicators of the presence of corrosive agents or sulfur dioxide. Evacuated vessels have been used for the collection of air samples. Although this approach has no power and mechanical requirements, it is limited by the small size of the sample that can be collected. The most widely used approach for passive monitoring is based on the collection of samples by means of diffusion which can be quantified by application of Fick's Law.

Permeation and diffusion are similar in many respects, yet involve certain important differences, principally in the mode of action. Whereby diffusion represents an application of Graham's Law in which gas molecules pass through tubes or holes, permeation is essentially a solution process in which gas or liquid molecules come in contact with a solid or liquid barrier, where they dissolve and penetrate and ultimately saturate the barrier.

In diffusion, the holes serve to minimize turbulence as the gas molecules pass through the exposed orifice. Beyond the orifice, mass transfer takes place across a stagnant space to a collecting surface. The quantification of the collection process is provided by Fick's Law of diffusion:

$$N = -DA\,(dc/dx)$$

where N = rate of diffusive transport (mol/sec), D = diffusivity of the species (cm^2/sec), A = area of diffusion path (cm^2), x = path length (cm), and c = concentration of species (mol/cm^2).

Collection of diffused molecules usually is achieved by adsorption on the surface of an activated charcoal fabric, as advocated by the 3M Corporation as well as by the British Defense Ministry at Porton Down. Palmes[1,2] has developed a monitor for nitrogen dioxide that eliminates the dependence on charcoal fabrics, an approach that shows promise for other applications. Commercial diffusion-type monitors are convenient, require no calibration, and are quite versatile, although they are generally limited to the monitoring of those organic gases that adsorb strongly on charcoal surfaces. The monitors are discarded after a single use because the units can be mass-produced and cost only a few dollars each. Although such costs may be modest they may be a significant factor if long-range studies are contemplated involving a large number of subjects. Monitor evaluations performed in the United Kingdom[3] have indicated that relative air movement and humidity variations each introduced some error.

Permeation devices

Permeation was introduced by O'Keeffe and Ortman[4] as a means of preparing standard gas mixtures. The reverse of this process was introduced by Reiszner and West[5] for quantitatively collecting sulfur dioxide from the ambient atmosphere. This application was based on the fact that the rate at which a given gas permeates a given membrane is a fixed value, and that the total mass of the gas that is transported through the membrane becomes a function of the concentration of that gas in the ambient atmosphere and the time of exposure. The collecting mechanism for transported gases can be an adsorption medium, such as activated charcoal or silica gel, or it can be an absorption system involving a solution that captures and stabilizes the permeated species. In the case of SO_2 the capture and stabilization was achieved by absorption in a solution of tetrachloromercurate (II) to form the very stable sulfitodichloromercurate (II) complex. The amount of SO_2 in the collected sample was measured by the color that developed upon addition of acid-bleached pararosaniline and formaldahyde, as used in the original West-Gaeke procedure. Knowing the amount of gas collected and the exposure time permits the calculation of the time-weighted-average concentration, C; thus

$$C = wk/t$$

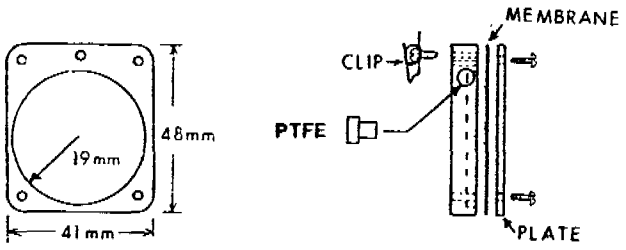

Figure 1 *Design of permeation-type personal monitor.*

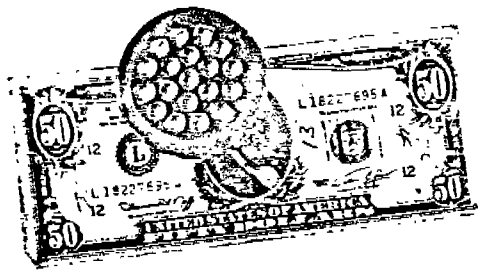

Figure 2 *Personal monitor for vinyl chloride.*

where w is the weight of collected gas (μg), t is the time of exposure, and k is the permeation constant. The permeation constant, or more properly the calibration constant, is characteristic of each membrane and gas and is determined simply by exposing the device or membrane to a standard atmosphere of the gas of interest for an appropriate time. From the weight of gas collected, the constant is calculated:

$$k = Ct/w$$

Once calibrated, a permeation device can be used indefinitely without recalibration or servicing other than to remove the collected samples and recharge with the appropriate sorbing material.

Permeation-type monitors are durable, versatile, convenient, accurate, and reliable. Nothing wears out or degrades, so long-term service can be expected. Its versatility is evident in the wide choice of sorbing systems that can be incorporated—solids such as activated charcoal, silica gel, ion exchange granules, or their mixtures can be used, and also solvent or solution absorbers. Samples are contacted rather than drawn through the sorbing media, eliminating any breakthrough problems. Sloshing or spilling problems are avoided by close containment of liquids. It is the author's opinion, based on theory and experience, that sample collection of gases by means of permeation is as accurate, or more so, as any sampling technique now in use. Primary gas standards provided in the form of permeation tubes contribute to the accuracy of the method. The reverse process utilizing permeation for gas sampling is also accurate.

There are no known interferences with the sampling process itself due to copollutants. The analytic finish of the collected samples includes any deficiencies inherent in the particular process used, whether it be gas chromatography, spectrophotometry, or any other applicable technique. Permeation-type sampling is essentially free from environmental stresses. Neither relative air movement nor humidity has an effect and temperature effects can be minimized or eliminated by use of membranes made of silicone polymers.

The principal deficiency of personal monitors based on permeation is the need to calibrate each device for the toxin to be sampled. Once calibrated, however, the device can be used for months or even years without recalibration. A second drawback may be cost. A calibrated monitor costs about ten times as much as a diffusion-type unit, but this is quickly offset because it can be repeatedly reused. Thus, even for a two-week study, it has cost advantages. Charcoal and pump devices may cost ten times as much and have relatively high repair and replacement costs.

The first personal monitor using permeation was the vinyl chloride monitor,[6] which was widely evaluated in field studies in the United States as well as abroad.[7] The essential details of construction of a permeation-type personal monitor are shown in *Figure 1*, and *Figure 2* is a photograph of a manufactured monitor (Real Inc., West-Paine Laboratories).

To date, monitors fo eight different toxins have been developed. Design and performance details are given in *Table 1*. Typical results of field tests are listed in *Table 2*. Studies are being performed on the development of monitors for hydrogen fluoride and for formaldehyde. Potentially, permeation-type monitors should be possible for all gaseous toxins, both organic and inorganic. Highly sensitive and high-capacity long-range units and permeation applications for high concentration alarm devices are foreseeable in the future.

OCC 8233

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Table 1 **Permeation-type personal monitors for selected toxins**

Toxin	Membrane	Sorber	Analytic finish	Sensitivity	Remarks
Chlorine[8]	Dimethyl silicone (DMS) (single-backed)	Buffered (pH 7) Fluorescein 0.005‰ NaBr (0.31%)	Spectrophotometric (eosin produced)	0.013 ppm (8-hr exposure)	Environ. effects: none On the spot colorimetry inherent
Sulfur dioxide[5]	DMS (single-backed)	Tetrachloro-mercurate(II)	West-Gaeke (spectro-photometric)	0.01 ppm (8-hr exposure)	Temp. effect: – 0.05% per °C Other environ. effects: none 1–4 weeks sampling possible
Vinyl chloride[9]	DMS (single-backed)	Act. charcoal (CS_2 desorption)	Gas chromato-graph	0.02 ppm (linear to 50 ppm +)	Environ. effects: none Thoroughly field tested
Alkyl lead[9]	DMS (unbacked)	Silica gel (IC1 desorption)	Spectrophotometric (dithizone) or AAS	0.2 μg	Temp. effect: – 0.66% °C/ TEL + 0.11% per °C/TML Other environ. effects: none
Benzene[10]	Silicone polycarbonate	Act. charcoal (CS_2 desorption)	Gas chromato-graph	0.02 ppm (8-hr exposure)	Temp. effect: – 1.2% ppm °C Other environ. effects: none
Ammonia[11]	Vinyl silicone	0.6% Boric acid	Spectrophoto-metric (Nessler's reagent)	0.4 ppm (8-hr exposure)	Temp. effect: + 0.57%/°C Other environ. effects: none
Hydrogen sulfide[12]	DMS (single-backed)	0.2N NaOH, 0.003M EDTA	Spectrophoto-metric (methylene blue method)	0.01 ppm	Environ. effects: none
Hydrogen cyanide[13]	DMS (single-backed)	0.1N NaOH	Spectrophoto-metric (pyridine-barbiturate acid reagent)	0.01 ppm (8-hr exposure)	Temp. effects: – 0.2% per °C Other environ. effects: none

Table 2 **Results of typical field tests**

Sulfur dioxide (area monitoring), μg/m³

Permeation device	West-Gaeke	Coulometric
<5	<2	<25
156	—	144
156	158	
132	128	
17		<25
386	382	

Chlorine, ppm Cl_2

Permeation device	Impinger
0.47	0.52 0.67 0.56
1.10	1.10 1.20
0.80	0.80 0.90 0.90
0.90	0.40 0.20 0.30
0.93	0.97 1.10 1.10

Vinyl chloride, ppm

Permeation device	Pump — charcoal tube
0.98	0.83
0.12 0.11	0.07
0.05 0.08	0.07
0.92 0.97	0.88

Occidental Chemical Corporation

Environment, Health & Safety

40.236

MEMO

To W. E. Driscoll Date April 15, 1986

From R. L. Comboy BLC

Subject Industrial Hygiene Assessment Action Plan Dates - Pottstown

On January 28, 1986 I visited Pottstown to assist G. D. Lloyd in locating sampling points for monitoring the ventilation systems. At that time I reviewed the status of recommendations submitted as a result of our last industrial hygiene assessment which was conducted May 7-9, 1985. At that time I asked G. D. Lloyd to send me new action plan dates as several of the action dates had passed with no progress on the recommendation.

Since January 28, I have asked G. D. Lloyd several times by telephone to give me new action dates on the outstanding recommendations. I made a formal request in writing on April 2, 1986.

To date I have not received a response.

4/25/86
Ken Garner
Ken
If there is any problem with moving on these issues please let me know as I believe they do need attention.
Take Care
Bill

RLC:blp
6888E-30

40.236

Occidental Chemical Corporation

Environment, Health & Safety

MEMO

To K. H. Garner/R. M. Zelley Date May 14, 1985

From R. L. Comboy R L Comboy

Subject Industrial Hygiene Assessment - 1985

cc: D. L. Lull
J. M. Coburn
W. E. Driscoll
J. W. Swanson
G. D. Lloyd

Attached please find the industrial hygiene assessment which was recently conducted in your facility. The action dates in the recommendation section of the report were agreed upon during the closing conference.

If you have any questions, please do not hesitate to contact me.

RLC/blp
5842E-28

Attachment

Industrial Hygiene Assessment
Pottstown Plant
Armand Hammer Boulevard
Pottstown, PA 19464
May 7-9, 1985
Conducted by
R. L. Comboy - Corporate Industrial Hygiene

On the above dates, an industrial hygiene assessment was conducted in the Pottstown facility. The purpose of the assessment was to review the effectiveness of industrial hygiene activities and program elements including management structure, workplace hazard recognition, the monitoring program and the adequacy of control for potential health hazards.

This report is based on extensive discussions with Gerry Lloyd, Manager - Safety, observation of all plant operations, and review of industrial hygiene sampling records.

Recommendations, discussion and the pre-assessment questionnaire will be found on the attached pages.

Status of Previous
Industrial Hygiene Recommendations
December 1982
Pottstown Facility

1. All locations in the plant with noise levels in excess of 90 dBA should be posted as hearing protection areas. (Complete)

2. In accordance with OCC Procedure #04:01:02:032, all employees must be notified of their industrial hygiene sample results even though the result is below the allowable exposure limit. (Complete but needs to be reinstituted.)

3. The respirator program should be changed to reflect the following:

   a. Scott canister seals will not be removed unless the respirator is to be used. (Complete)

   b. Canisters will be dated as to when they are put into service and will be disgarded 12 months later even though the seal has not been removed. (Complete)

4. The written respirator program for the Calender Plant needs to be formally updated to reflect the current usage of disposable respirators. (Complete)

5. The written respirator programs need to be updated to reflect the currently used fit testing procedures. (Complete)

6. A formal program to document an employee's medical ability to wear a respirator must be instituted. (Incomplete - see current recommendations.)

7. Laboratory hoods in the R&D area should be operated with the sashes lowered as much as possible to maximize the inflow air velocities. Current inflow air velocity are substandard and consideration should be given to upgrading this system. (Incomplete - see current recommendations.)

8. A formal program to periodically evaluate all ventilation systems to determine performance, needs to be instituted. (Incomplete - see current recommendations.)

9. A formal laboratory quality control program with an outside laboratory needs to be implemented. (Complete)

RECOMMENDATIONS

		Agreed Action Date
1.	A formal program to document an employee's medical ability to wear a respirator must be instituted.	August 1, 1985 (Implemented)
2.	In order to obtain a proper respirator fit, facial hair must not interfere with the respirator seal. A policy must be developed and implemented prohibiting the growth of facial hair which interferes with the respirator seal for those employees who may have to wear a negative pressure respirator.	January 1, 1986 (Implemented)
3.	The welding shop in the Resins Plant must be provided with adequate local exhaust ventilation.	November 1, 1985 (Completed)
4.	A formal program to periodically evaluate the efficiency of ventilation systems must be implemented. Corporate will assist.	October 1, 1985 (Program developed)
5.	The industrial hygiene database for VCM monitoring must be brought up-to-date so that the procedure for notifying employees of sample results below 1 ppm can be reinstituted. Corporate will assist.	September 1, 1985 (Completed)
6.	The Job Code Dictionary in the industrial hygiene database must be updated to accurately reflect employee activities during the sampling period.	June 1, 1985 (Completed)
7.	Housekeeping on the blender level in the Calender Plant must be improved.	Immediate
8.	Proper storage must be provided for respirators used by employees on the blender and banbury decks in the Calender Plant.	July 1, 1985 (Completed)
9.	Since inflow air velocities in the R&D laboratories are substandard, a procedure must be implemented to insure that hood sashes are lowered as far as feasible at all times to minimize potential employee exposures.	July 1, 1985 (Implemented)

DISCUSSION

Medical Ability to Wear a Respirator

OCC Safety Procedure #04:01:03:05 and OSHA regulations require that employees be medically evaluated for their ability to wear a respirator. A means of meeting this requirement will be found in Attachment I of this procedure. It was agreed that this procedure would be implemented by August 1, 1985.

Facial Hair Policy

In order to obtain a proper face to facepiece seal with a negative pressure respirator there must be no facial hair in the area of the seal which would reduce the effectiveness of the respirator. This requirement will be found in OCC Safety Procedure #04:01:03:05 and in the OSHA regulations, Section 1910.134.

A policy must be developed by the facility whereby facial hair will not be permitted in the area of the respirator seal for those employees who may have occasion to wear a respirator.

It was agreed that such a policy would be developed and implemented by January 1, 1986.

Welding Shop

At the present time the welding shop in the Resins Plant is located in a small room with four welding stations. General exhaust ventilation is provided at one end of the shop. No local exhaust is provided at the welding stations.

It is my understanding that an AFE has been written to relocate this shop to a larger area and provide local exhaust ventilation at the welding stations. The AFE is currently in the approval stage.

If for some reason this AFE is not approved, local exhaust ventilation must be provided at the welding stations in the present shop.

It was agreed that this project would be completed by November 1, 1985.

Ventilation Systems

A routine evaluation program is needed for all local ventilation systems. Initial design data and, ideally, initial air flow measurements are needed as baseline performance data. Regular air flow measurements should be performed on all systems to identify changes in system performance. These data can then be used to recommend specific corrective action as needed to maintain acceptable ventilation rates.

Scheduled monitoring of ventilation systems is particularly important in the R&D area where good local exhaust ventilation is the primary control to limit employee exposure.

DISCUSSION (Continued)

It was agreed that this monitoring program would be developed by October 1, 1985 and that Corporate would assist.

VCM Industrial Hygiene Database

For a number of reasons including lack of computer space and personnel changes, the VCM database is not current. Subsequently, the procedure for notifying employees of their sample results when the result is less than 1 ppm has not been utilized. In order to reactivate this procedure this database must be brought up to date.

It was agreed that Pottstown would input current data and that Corporate would input the remainder of the data. This project should be completed by September 1, 1985.

One element in this database is a job code which reflects the employee activities during the sampling period. This Job Code Dictionary needs to be updated. It was agreed that Pottstown would input these data by June 1, 1985.

Housekeeping

Housekeeping throughout the facility was generally good except for the blender level in the Calender Plant. It was agreed that this item would receive immediate attention.

Respirators

Disposable dust respirators are used for comfort in the Calender Plant. When not in use, these respirators must be stored in a contaminant-free environment such as in a plastic bag. At the time of the survey we observed at least 17 improperly stored respirators on the blender and banbury decks.

The OCC Respirator Procedure and OSHA regulations require proper storage of respirators when not in use.

It was agreed that this item would be completed by July 1, 1985.

R&D Laboratories

The inflow air velocities for the laboratory hoods in the Research and Development area are substandard when the sashes are raised to the top. For this reason it is imperative that these sashes be lowered as much as possible to maximize the use of the volume of air available. R&D employees should be instructed to lower the hood sashes as much as is practical to minimize the possibility of vapors or fumes from the hoods escaping into the laboratory.

It was agreed that this procedure would be implemented by July 1, 1985.

INDUSTRIAL HYGIENE PROGRAM REVIEW Date 5/9/85

Facility Pottstown Respondent G. D. Lloyd

Title Manager - Safety

Circle appropriate response where indicated.

1. Is there a written policy for industrial hygiene?

   (a) Yes
   b. No.
   c. No, but one is being prepared
   d. Part of the Safety Policy

2. The individual in charge of the industrial hygiene section reports directly to (Check each applicable term or statement)

   (a) Plant Manager
   b. Director of Occupational Health Program
   c. The Personnel Manager
   d. The Safety Manager
   e. The Plant Engineer
   f. Other - Specify_____

3. Who is responsible for industrial hygiene sampling?

   a. Equipment calibration G. D. Lloyd and J. Sprat
   b. Sample collection G. D. Lloyd and J. Sprat
   c. Employee observation during sampling G. D. Lloyd and J. Sprat
   d. Recording production and exposure information G. D. Lloyd/J. Sprat

4. How frequently are airflow calibrations of air samplers made? (Check each applicable term or statement)

   a. Annually
   (b) Other periodic frequency (specify)
   Before and after each sample
   Fixed monitors - daily

5. Where are air samples analyzed? (Check each applicable term or statement)

   (a) Plant laboratory
   b. Commercial laboratory (names) NATLSCO

6. Is there an active laboratory quality control program associated with industrial hygiene analyses? Please describe on a separate sheet of paper or attach protocol. Yes

7. Who is responsible for the review and maintenance of industrial hygiene sampling documentation? G. D. Lloyd and J. Sprat
   Attach a copy of the sample documentation form currently in use.

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8. How frequently are all noise survey equipment calibrated?

   Specify Before and after each use

9. How are employees specifically informed about the industrial hygiene hazards of their jobs?
   Safety meetings

10. Is there a health and safety committee in this facility?

    (a) Yes
    b. No

11. How often does this committee meet?

    Monthly

12. List job titles of current members.

    Safety Manager
    3 - Union Reps.
    2 - Company Reps.

13. Have all processes been reviewed for all potential health hazards?

    (a) Yes
    b. No
    c. Don't know

14. Are regular walk-through surveys performed to note the presence of potential health hazards?

    (a) Yes
    b. No

    How frequently? (e.g., annually, etc.)
    At least bi-weekly

    By whom? Safety Manager, Plant Manager

15. How often is worker noise exposure monitored?

    Specify Every 2 years

16. What do you consider to be your problem materials and/or physical hazards? List in order of decreasing importance and indicate estimated number of people at risk to each material or hazard.

Material or Hazard	Number of People at Risk
VCM	300

17. To whom are reports of worker exposure determinations routinely sent? (Check each applicable term or statement)

(a) Worker's department
(b) Medical department — on need to know basis
(c) Plant engineering
(d) Establishment superintendent
(e) Labor - Management Health & Safety Committee
(f) Corporate medical or industrial hygiene office
g. Other _____

18. Are local exhaust ventilation hoods and area ventilation inspected periodically for integrity and/or need for maintenance?

a. Yes
(b) No, but will develop action plan
c. There are no local exhaust hoods

If yes, how often and by whom?

_____
_____

19. Is there a written respirator program?

(a) Yes - attach copy
b. No

20. Are earmuffs and/or plugs provided when noise exposures are above 90 dBA?

(a) Yes
b. No
c. Other actions taken

_____
_____

21. Are work practices observed periodically to assure that proper methods are being used?

(a) Yes (Give approximate interval) _____
b. No
c. Not applicable

22. Are records of significant worker exposure to toxic materials kept so that each worker's exposure can be estimated?

(a) Yes
b. No

23. Is there a written Industrial Hygiene Sampling Program for this facility?

(a) Yes
b. No

40.236 ~~AAR~~ EVF Pls Return BP CF

Occid ntal Chemical Corporation
PVC Resins/PVC Fabricated Products

MEMO

To MR. R. L. COMBOY Date July 20, 1983

Fr m SAFETY DEPARTMENT - PVC RESINS DIVISION

Subject INDUSTRIAL HYGIENE AUDIT - POTTSTOWN - 12/83

We are in the process of completing the items listed in your audit report for Pottstown. We have had a number of discussions on how to handle your item #8 - periodic evaluation of ventilation systems.

Our review indicates that this job will be a very costly and time consuming project. What we need at this point is a clarification from you on what exactly you want done and how you feel the checks should be made. As you know, we have a great number of ventilation systems and wall fans and we need your input on how exactly to check their performance.

Would you please drop me a line listing some specifics on how you think we should check ducted air systems, wall fans, etc., and with what so that the cost and time consumption would not be prohibitive.

Thanks for your help.

G. D. Lloyd

G. D. Lloyd

GDL:mas

cc: Mr. K. H. Garner
Mr. R. H. Zelley
Mr. T. E. Moses

RECEIVED
JUL 22 1983
ENVIRONMENT, HEALTH & SAFETY

OCC 8246

IH.W. Pottstown

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Occidental Chemical Corporation
Environment, Health & Safety

MEMO

To Jerry Wilkenfeld **Date** May 17, 1983

From Mitchell Zavon

Subject Pottstown Industrial Hygiene Assessment
Your Memo May 3, 1983

You asked about two points. I have discussed both points with Bob Comboy who in turn has discussed this with Gerry Lloyd, the Safety and Health Director for the Pottstown plant.

The OSHA vinyl chloride regulation states that a sampling program will be conducted "without regard to the use of respirators". Many jobs in this facility require the use of respirators. For example, a respirator is needed on reactor entry. If an employee is wearing a monitor the day he does a job requiring use of a respirator, the monitor will record a VCM exposure but the employee is protected by a respirator, usually an air line respirator. We are complying with the OSHA dicta but it would not be practical to put someone on the job of monitoring the individuals in order to record that at a certain time they were wearing a respirator when the monitor recorded excessive exposure. During the seventies, 8 to 10MM was spent on engineering controls to reduce the VCM exposure in this plant. At the present time controls appear to be reasonably adequate.

You also asked about the noise exposure and the hearing conservation program. There is only one area in the calender department where an employee's noise exposure may exceed 85 dBA on a time weighted basis. Other areas of the plant that are above 90 dBA are not normal work areas. Since these areas are entered infrequently, hearing protective devices will suffice.

Now that we have had a year or more of more intensive assessment, perhaps the first real assessments in industrial hygiene that have been done in this company, we will be taking a second and still more intensive look at specific plants and specific processes within the plant. This will not indicate that the situation has deteriorated but rather that we are trying, by careful evaluation and targeting our analyses, to upgrade the standard of health protection throughout the operations.

3126E-1

ct 40,236

10889 WILSHIRE BOULEVARD
SUITE 1500
LOS ANGELES, CALIFORNIA 90024

MEMO

PHONE: 879-1700
208-8800

OCCIDENTAL PETROLEUM CORPORATION

To Mitch Zavon

From Jerry Wilkenfeld

Date May 3, 1983

cc: J. Tinkler
F. Friedman
D. Giannotti

Subject: Pottstown Industrial Hygiene Assessment
December 14-15, 1982

In reviewing the above named assessment and the facility response to the recommendations two items are noted which need further elaboration. These are in the discussion section on page 3.

1. Under Employee Notification it is stated that "A review of the VCM data for 1982 indicates that more than half of the samples taken currently require employee notification." Since employees are only notified when measurements exceed the personal exposure limit, I would appreciate receiving further information on the plant's program aimed at reducing this rate.

2. Under Hearing Conservation Program it is noted that some of the areas of the plant exceed 90 dBA and are posted as hearing protection areas. Please advise if these areas have been reviewed to determine whether utilization of hearing protection is adequate or if engineering controls should be considered.

JW/ym
Attachment

40,236 GF

Occid ntal Chemical Corporation

Envir nment, Health & Safety

MEMO

T K. Garner
E. Lapreziosa

Date March 3, 1983

From M. R. Zavon, M.D.

Subj ct Industrial Hygiene Assessment - Pottstown

cc: F. F. Hoy
J. T. Wolfsperger
R. J. Schuttler
G. D. Lloyd - w/o Appendices
H. F. Dubec - w/o Appendices

The attached assessment has been discussed in detail with Gerry Lloyd but an action program in response to the recommendations needs to be furnished. Would you please have the written program to me within 60 days.

2689E-1

Attachment

Industrial Hygiene Assessment
Pottstown Plant
Armand Hammer Boulevard
Pottstown, PA 19464
December 14-15, 1982
Conducted by
R. L. Comboy - Corporate Industrial Hygiene

On the above dates, an industrial hygiene assessment was conducted in the Pottstown facility. The purpose of the assessment was to review the effectiveness of industrial hygiene activities and program elements including management structure, workplace hazard recognition, the monitoring program and the adequacy of control for potential health hazards.

This report is based on extensive discussions with Gerry Lloyd, Manager - Safety-PVC Resins Division, observation of all plant operations, and review of industrial hygiene sampling records.

At the time of the assessment the plant employed 432 in the Resins Department, 230 in the Fabricated Products Department and 75 were employed in Finance, Administration and Employee Relations.

Recommendations and discussion will be found on the attached pages. The pre-assessment questionnaire, organization chart, process description, plant layout and ventilation testing program will be found in the Appendices.

RECOMMENDATIONS

1. All locations in the plant with noise levels in excess of 90 dBA should be posted as hearing protection areas.

2. In accordance with OCC Procedure #04:01:02:032, all employees must be notified of their industrial hygiene sample results even though the result is below the allowable exposure limit.

3. The respirator program should be changed to reflect the following:

   a. Scott canister seals will not be removed unless the respirator is to be used.

   b. Canisters will be dated as to when they are put into service and will be disgarded 12 months later even though the seal has not been removed.

4. The written respirator program for the Calender Plant needs to be formally updated to reflect the current usage of disposable respirators.

5. The written respirator programs need to be updated to reflect the currently used fit testing procedures.

6. A formal program to document an employees medical ability to wear a respirator must be instituted.

7. Laboratory hoods in the R&D area should be operated with the sashes lowered as much as possible to maximize the inflow air velocities. Current inflow air velocity are substandard and consideration should be given to upgrading this system.

8. A formal program to periodically evaluate all ventilation systems to determine performance, needs to be instituted.

9. A formal laboratory quality control program with an outside laboratory needs to be implemented.

DISCUSSION

Hearing Conservation Program

The plant has been surveyed for noise and where it was suspected that employee exposure may exceed the eight hour time weighted average of 85 dBA, noise dosimetry has been conducted. Regular audiometric examinations have been offered for some time.

Though the areas where employee time weighted average exposure exceeds 85 dBA have generally been posted; areas above 90 dBA which are not routine employee work areas have not been posted.

Data from the plant noise survey should be reviewed to identify those areas which exceed 90 dBA. These areas should then be posted as hearing protection areas. The employees need to be trained and the warning signs worded so that everyone knows that hearing protection is required while working in exposures of greater than 90 dBA regardless of the time spent in these areas.

Employee Notification

The plant routinely monitors for vinyl chloride monomer (VCM) in accordance with Federal regulation 1910.1017. The custom at this facility has been to formally notify the employee in writing only if the sample result exceeded the permissible exposure limit. The employees are, however, aware that they can have access to their sample results at any time.

A review of the VCM data for 1982 indicates that more than half of the samples taken currently require employee notification. To insure that all employees are aware of their VCM exposure and to comply with the OCC Employee Notification Procedure #04:01:02:032 all employees should be notified of their sample results. The facility may want to consider posting these results (those below 1 ppm) as opposed to individually notifying employees in writing.

Respirator Program

Dust Respirators

The Pottstown facility has a detailed written respirator program for both the Resins Plant and the Fabricated Products Plant. Since this program was written, there has been a change in the type of dust respirator used in the Fabricated Products Plant. The written program should be updated to reflect this change in respirator usage.

Medical Ability to Wear a Respirator

In accordance with OCC Procedure #04:01:03:05, Respiratory Protection, and OSHA 1910.134, a program to medically evaluate an employee's ability to wear a respirator must be instituted. The OCC procedure describes how this is to be done.

Scott VCM Respirator

At the present time the Resins Plant is using a Scott canister for VCM protection. This canister is Catalog #08H-VC-L with NIOSH approval #TC-14G-85. The limitations on this canister imposed by the NIOSH certification are:

1. May not be used in VCM concentrations exceeding 25 ppm.

2. Must be discarded at the end of the shift during which it is used regardless of actual usage if seal has been broken.

Currently some employees remove the seal at the beginning of a shift and discard the canister 8 hours later or after 4 hours of use. The canisters cost $14.50 each.

Considerable money can be saved if the seals are not removed unless the respirators were actually going to be used. Employees are instructed to leave the area when the alarm sounds unless they must be there and then only with an airline respirator.

It is therefore recommended that the respirator program be changed to reflect the following:

1. Scott canister seals will not be removed unless the respirator is to be used.

2. Canisters will be dated as to when they are put into service and will be discarded 12 months later even though the seal has not been removed.

R&D Laboratories

The inflow air velocities for the laboratory hoods in the Research and Development area are substandard when the sashes are raised to the top. For this reason it is imperative that these sashes be lowered as much as possible to maximize the use of the volume of air available. R&D employees should be instructed to lower the hood sashes as much as is practical to minimize the possibility of vapors or fumes from the hoods escaping into the laboratory.

Routine ventilation testing is discussed in the next section and applies to the R&D facility.

Ventilation Systems

A routine ventilation evaluation program is needed for all local ventilation systems and building or general ventilation. Initial design data and, ideally, initial air flow measurements are needed as baseline performance data. Regular air flow measurements should be performed on all systems to identify changes in system performance. These data can then be used to recommend specific corrective action as needed to maintain acceptable ventilation rates.

Scheduled monitoring of ventilation systems is particularly important in the R&D area where good local exhaust ventilation is one of our primary controls to limit employee exposure.

Appendix II presents a proposed ventilation testing program extracted from the OCC Industrial Hygiene Field Manual.

Laboratory Quality Control

To assure ourselves that we are obtaining good data, a laboratory quality assurance program is essential. In the past the laboratory has exchanged samples with other OCC laboratories. While this practice is commendable, it does not provide an independent third party check on the data.

One or two samples for each type of analysis we perform in-house should be sent to an accredited industrial hygiene laboratory at least on an annual basis for verification of results. An accredited laboratory must be used because it will already be in a national laboratory quality control program where their proficiency is already demonstrated and documented.

APPENDIX I

INDUSTRIAL HYGIENE PROGRAM REVIEW Date 12/2/82

Facility Occidental Chemical Corp. Respondent G. D. Lloyd

Location Pottstown Title Manager - Safety
PVC Resins Division

Circle appropriate response where indicated.

1. Is there a written policy for industrial hygiene?

   a. Yes
   b. No.
   (c) No, but one is being prepared (Copy of White Springs Policy sent to G. D. Lloyd)
   d. Part of the Safety Policy

2. Is there a procedure for review and response to industrial hygiene recommendations by the affected operating group?

   (a) Formal
   b. Informal
   c. No

3. The individual responsible for industrial hygiene is:
   (Check each applicable term or statement)

   a. An experienced industrial hygienist.

   (b) Primarily responsible for other functions. (Safety, Medical Training)

4. The individual in charge of industrial hygiene has had this responsibility for:
   (Check applicable term or statement)

   a. Less than one year
   b. One to five years
   (c) More than five years (18 years)

5. The individual in charge of the industrial hygiene section reports directly to (Check each applicable term or statement)

   a. Plant Manager
   b. Director of Occupational Health Program
   c. The Personnel Manager
   d. The Safety Manager
   e. The Plant Engineer
   (f) Other - Specify Director of Manufacturing

6. The industrial hygiene staff consists of:
   (Check each applicable term or statement and give number in each category)

   a. Full time industrial hygienist(s)
   (b) Industrial hygienist(s) or other professional who spends a portion of his time on industrial hygiene problems
   c. Full time technician(s)
   d. Part time technician(s)

7. Consultative services are obtained from the following source or sources and with the following frequency:
(Check each applicable term or statement and list consultants used)

	As Problems Arise	Other Specify
a. Insurance companies		
b. Independent Consultants		None utilized to date

8. Arrangements have been made for the industrial hygiene section to obtain service from other staff or assistance in the following areas:
(Check each applicable term or statement and state source of service)

a. Noise Engineering

b. Ventilation "

c. Ionizing radiation "

d. Air analysis R&D and Analytical Lab

e. Engineering control Engineering

f. Other (describe) _____

9. If Industrial Hygiene Sampling is performed in-house, is the following available:
(Check each applicable term or statement)

(a) An office area for industrial hygiene staff
(b) A storage area for equipment
(c) A laboratory area for equipment, calibration and sample analysis

10. Who is responsible for industrial hygiene sampling?

a. Equipment calibration G. D. Lloyd
b. Sample collection G. D. Lloyd
c. Employee observation during sampling G. D. Lloyd
d. Recording production and exposure information G. D. Lloyd

11. How frequently are airflow calibrations of air samplers made?
(Check each applicable term or statement)

a. Annually
b. Other periodic frequency (specify)
Before and after each use

12. Where are air samples analyzed?
(Check each applicable term or statement)

(a) Plant laboratory
b. Commercial laboratory (names) To select one

13. Is there an active laboratory quality control program associated with industrial hygiene analyses? If yes, please describe on a separate sheet of paper or attach protocol.

14. Who is responsible for the review and maintenance of industrial hygiene sampling documentation? G. D. Lloyd
Attach a copy of the sample documentation form currently in use.

15. Please indicate the air sampling instruments available to take samples for subsequent laboratory analyses on a separate sheet of paper.
See Page 11

16. Please list the portable direct reading instruments for air analysis which are available for use by the industrial hygiene section, and give number of units as appropriate on a separate sheet of paper.
See Page 11

17. On a separate sheet of paper please list the noise and heat stress measuring instruments available for use by the industrial hygiene section.
See Page 11

18. How are calibrations of direct reading instruments for airborne contaminants maintained?
(Check each applicable term or statement)

a. Use manufacturer's calibrations
(b) Use only NIOSH certified indicating tubes
(c) Calibrate periodically in known concentrations of gas or vapor

19. How frequently are all noise survey equipment calibrated?

Specify Before and after each use

20. How are employees specifically informed about the industrial hygiene hazards of their jobs?
Through supervision
Through training programs

21. Are employees oriented to potential health hazards and preventive measures:
(Check each applicable term or statement)

(a) By supervisors?
(b) By orientation sessions?
(c) By printed material (give example) VCM standard, Appendix to lead standard
d. No orientation of employees

22. Are supervisors informed of potential health hazards, necessary monitoring, and proper operation and maintenance of control devices?

a. Routinely
b. Occasionally
c. Seldom
d. Never
(e) As the need arises

23. Is this information given in
(Check each applicable term or statement)

(a) Formal training sessions?
(b) Written instructions and memoranda?
c. No formal procedure

24. Is there a health and safety committee in this facility?

(a) Yes
b. No

25. How often does this committee meet?

Monthly

26. List job titles of current members.

Manager, Safety - Chairman
Manager of Maintenance (Resins)
Plant Engineer (Fab Prod)
Safety Supervisor (Resins)
Two clock card representatives for location

27. Does the industrial hygiene section maintain a current file on materials in the facility which may pose a health hazard potential?

(a) Yes
b. No
c. Not as such

28. Have all processes been reviewed for all potential health hazards?

(a) Yes
b. No
c. Don't know

29. Are all new chemicals or processes cleared for potential health hazard introduction?

(a) Always
b. Usually
c. Seldom
d. Never

30. Do purchase specifications for equipment routinely include limits on noise production?

(a) Yes State Criteria Not to exceed 85 dBA .
b. No

31. Are special handling procedures required for specific toxic materials? (For example, carbon tetrachloride, carbon disulfide, toluene diisocyanate, beryllium, tetrachloroethane, etc)

(a) Yes
b. No
c. If yes, attach procedure. Used only in lab area (R&D or Analytical) & kept under lock and key. Quarterly reminder.

32. Are regular walk-through surveys performed to note the presence of potential health hazards?

(a) Yes
b. No

How frequently? (e.g., annually, etc.) Monthly

By whom? Safety Committee and G. D. Lloyd

33. How are walk-through survey results transmitted to production management?

Verbally unless a condition warrants a written report - then verbally with follow-up report

34. How frequently are all SOP's revised for health hazard control?
Annually or as needed

By whom? G. D. Lloyd and/or Production

35. Attach summaries of air contaminant studies conducted in the last two years including:

a. Substances sample
b. Types of samples
c. Number of samples and range of results

36. At what concentration is a regular monitoring program for air contaminants set up? State criteria.

When initial determination indicates the need

37. Average exposures of workers to air contaminants are determined by: (Check each applicable term or statement)

(a) Personal sampling of all affected workers
(b) Personal sampling of representative affected workers
c. Area sampling
d. Average exposures are not determined

38. How is area monitoring data used to evaluate occupational exposures?

It is not used to evaluate exposure dose. It is used only as an alarm system. The production areas do average out reading on occasions, however, they useless for determining exposure unless backed by job-time-motion studies

39. What is the procedure for responding to employee health hazard complaints? What guidelines are established for the timeliness of this response?

Employee reports to supervisor. If not resolved it goes to Safety Committee member and Plant Production Manager or Plant Manager. At this point it becomes a committee item. Potentially serious problems are reported directly and correction dates established.

40. How often is worker noise exposure monitored?

Specify Annually, or as needed or requested

41. What do you consider to be your problem materials and/or physical hazards? List in order of decreasing importance and indicate estimated number of people at risk to each material or hazard.

Material or Hazard	Number of People at Risk
Vinyl Chloride	250

42. What is the procedure for review and establishment of CEL's for materials without AEL's?

Literature Review
MSDS
Corporate Industrial Hygiene and Medical Procedure

43. To whom are reports of worker exposure determinations routinely sent? (Check each applicable term or statement)

a. Worker's department
b. Medical department
(c) Plant engineering
(d) Establishment superintendent
(e) Labor - Management Health & Safety Committee
(f) Corporate medical or industrial hygiene office EASE
g. Other _____

44. Are lunch rooms or areas provided for all personnel?

(a) Yes
b. No

45. Is there a system for transmitting industrial hygiene recommendations on new or revised processes to the engineering designers?

(a) Yes, please specify. Fund
b. No

46. Do you use your industrial hygiene data to recommend specific control measures?

(a) Always
b. Usually
c. Occasionally
d. Never

47. Are new and/or modified processes inspected after design and after evaluation by industrial hygiene to assure that work conditions are healthful and meet all applicable standards?

(a) Always
b. Usually
c. Special situations only
d. Seldom or never

Specify_____

48. Are noise control devices inspected periodically for integrity and effectiveness?

(a) Yes
b. No
c. There are no noise control enclosures

If yes, how frequently and by whom? (specify)

Annually or sooner if needed

49. Are local exhaust (1) ventilation hoods and (2) area ventilation inspected periodically for integrity and/or need for maintenance?

(a) Yes
b. No
c. There are no local exhaust hoods

If yes, how often and by whom?

(1) Occasionally
(2) Seldom Done

50. Are maintenance employee environmental exposures being routinely evaluated?

(a) Yes
b. No

Specify Part of VCM Monitoring Program

51. Is there a written respirator program?

(a) Yes - attach copy
b. No

52. Are respirators checked for suitability and approved for intended use?

(a) Yes By whom Safety Dept. and Production
b. No

53. Are users instructed and trained?

(a) Yes By whom G. D. Lloyd and Production
b. No

54. What action is taken to insure that respirators are worn?

Specify Monthly checks, job observations, monthly inspections, disciplinary action program

55. Are earmuffs and/or plugs provided when noise exposures are above OSHA requirements?

(a.) Yes
b. No
c. Other actions taken

Employees with hearing loss are medically restricted to wearing protection

56. Is the wearing of hearing protection enforced?

(a.) Yes By whom Supervision
b. No

57. Are face shields or goggles provided where necessary?

(a.) Yes
b. No
c. There are no areas where their use would be necessary

58. Is protective clothing provided?

(a.) Yes, where necessary
b. No
c. There are no areas where it would be desirable

59. Are processes where chemicals have been substituted checked periodically to assure that lower hazard materials are still being used?

(a.) Yes By whom? G. D. Lloyd

b. No

60. Are work practices observed periodically to assure that proper methods are being used?

(a.) Yes (Give approximate interval) Monthly Job Observation Program
b. No
c. Not applicable

61. Are records of significant worker exposure to toxic materials kept so that each worker's exposure can be estimated?

(a.) Yes
b. No

62. Are records of air contamination kept by area so that changes can be readily identified?

(a) Yes
b. No

63. Are records of inspection of control devices, e.g., ventilation systems kept?

(a) Yes
b. No

64. Are records of ventilation quantities for each exhaust hood kept and associated with static suction or other simple inspection measure?

(a) Yes
b. No

65. Does the industrial hygiene section participate in employee orientation for potential emergency and safety hazards in the facility?

(a) Yes
b. No

RLC:2430E
1/24/83

15. Air Sampling Equipment

1. SIPIN SP-1 (3)
2. Bendix Super Sampler (3)

16. Direct Reading Air Sampling

1. Bendix Gastec, 100 ML (1)
2. Century - Several
3. HNU - Several

17. Noise

1. Gen Rad, 1954 Indicator (2)
2. Gen Rad, 1982 Sound Level Meter (1)
3. Gen Rad, 1954-9710 Exposure Monitor (3)

Heat Stress

1. Wet Bulb, Black Globe, Dry Bulb Arrangement. Full location summer and winter profiles completed.

APPENDIX II

1. Testing of Ventilation Systems

Air flow measurements and test data are often needed in connection with the proper functioning and design of industrial exhaust systems. The importance and value of obtaining test data can be noted in the following applications.

a. To determine whether a new exhaust system is functioning in accordance with design data.

b. To obtain air flow data necessary for proper setting of blast gates on systems designed for blast-gate balancing.

c. To determine, by periodic checks, if further maintenance or repairs of a system are necessary to assure efficient operation.

d. To obtain measurements necessary to determine whether the system has sufficient capacity for additional hoods or future exhaust equipment.

e. To obtain design data from existing satisfactorily controlled operations for future installations of similar character.

f. To obtain air flow data necessary to determine the degree of compliance with state codes, regulations or trade association standards.

2. Ventilation System Surveys

A. System Start-up vs Design Basis

Any ventilation system, be it local exhaust for contaminant control or general for comfort, is designed in terms of removing or distributing a specified quantity of air at a specified velocity at a total system pressure which is the sum of the parts. An initial survey of the system is the only time a valid comparison can be made between the design basis and optimum system performance.

B. Survey Procedures

1. Sketch of the system. A sketch, not necessarily to scale but representative of dimensions, should be drawn noting such items as hoods, elbows, branchings, air cleaner, fan and stack. Supply ducts, plenums, and diffusers should be shown for general systems.

   The sketch should be considered as part of the permanent record on which future changes in the systems may be recorded.

2. Specific air flow measurements. Measurements in terms of air flow, velocity, and static pressure must be made to determine that the system is adequately balanced and performing according to the design basis. These measurements include:

   a. Statis pressure measurements at:

      - o hoods
      - o up and downstream of the air cleaner
      - o up and downstream of the fan

   b. Air flow in cfm at:

      - o hoods (throat suction method)
      - o branches and mains (Pitot tube)
      - o up and downstreams of fan (Pitot tube)

   c. Supply, capture, and conveying velocities at:

      - o diffuser outlets (supply velocity)
      - o face or opening of hood (capture velocity)
      - o branches and mains (conveying velocity)

d. Fan performance

- o fan speed in rpm
- o horsepower (BHP) calculated using cfm (Q), total pressure (TP), and mechanical efficiency (ME) of fan.

$$BHP = \frac{(Q)\ \ (TP)}{6356 \times ME}$$

The locations of the measurements must be identified on the sketch and a record kept for future comparisons.

The measurements obtained should agree within 10% of the design basis. If not, system modification should be made until such agreement is obtained.

3. Other checks. Local exhaust systems are installed for the singular purpose of removing some contaminant from the work environment. Visualization techniques using smoke tubes or candles can be most helpful in verifying that the system exerts a sphere of control over a sufficient area to prevent excessive exposures to operating personnel. Air evaluation, for specific contaminants, is also recommended to verify the system will control contaminants to levels known to be safe. Air samples taken in the breathing zone of operating personnel will be most helpful in assessing the adequacy of contaminant control.

C. System Operating vs System Start-up

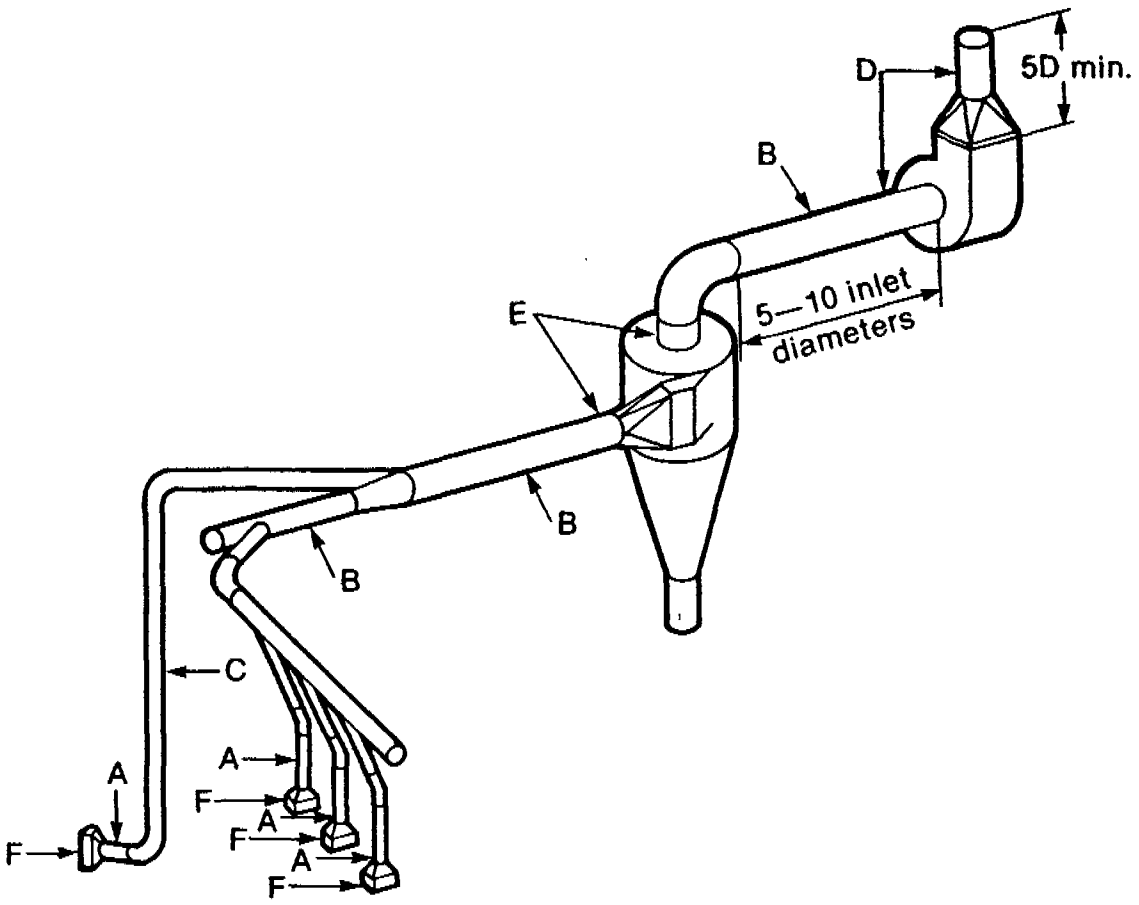
Once systems are started up and determined to perform satisfactorily, the degree of evaluation can be reduced as long as good records of start-up or initial conditions have been made. Experience with air flow systems clearly indicates periodic surveys are required to assure system performance is adequate. Operating personnel cannot be relied upon as an "indicator" of system performance. Also, ventilation systems are rarely an integral part of the operation in terms of quality and production and all too often receive inadequate maintenance.

1. For most systems simple velocity measurements at exhaust hoods and supply ducts will provide a crude indication of system performance when compared with start-up evaluations. For local exhaust systems, the throat suction method applied to exhaust hoods and static pressure differentials for air cleaners and fans will suffice in confirming the system is performing satisfactorily.

The throat suction method will provide valid information unless:

- o The hood entry has been modified/damaged;

FIGURE 5.1 Information Needed for a Detailed Ventilation Summary



OCC 8269

Point	Measurement	Location of measurement	Measurement use
A	Hood static pressure	Distance from hood— 3 pipe diameters-flanged or plain hood 1 pipe diameter-tapered hood	1. estimate flow: Q = 4005 CeA SPh 2. check point for hood and system performance.
B	Velocity and static pressure	Branch and mains-preferably 7.5 diameters straight run downstream from nearest air disturbance (el, entry, etc.)	1. transport velocity 2. exhaust volume: Q = VA 3. SP as system check point
C	Centerline VP	Small ducts location as above. Centerline velocity reading only.	Round duct only. Use on small ducts where traverse impractical or where approximate volume wanted.
D	Static, velocity and total pressures	Inlet and outlet of fan-any two of three readings at each location	1. Fan static and total pressures FSP = SPo + SPi – VPi TP = SPo + SPi + VPo – VPi 2.Motor size or CFM estimate $BHP = \frac{CFM \times TP}{6356 \times ME \text{ of fan}}$ 3.SP as system check point
E	Static pressure	Inlet and outlet of collector Differential pressure	1.Compare pressure drop with normal operating range 2.Checkpoints for maintenance. Readings above or below normal indicate plugging, wear or damage to collector elements, need of cleaning
F	Face velocity	Hood face-measure at center of hood face cross-sectional areas	1.Estimate capture velocity Average face velocity measurements 2.Determine hood performance.*

‡ Adapted from Industrial Ventilation, 16th ed. ACGIH, 1980.

*Observation of air flows surrounding exhaust openings may be visually augmented by use of smoke generators, trails and streamers.

- o There are obstructions ahead of the point of measurement; or

- o The system has been modified.

However, a reduction in throat suction can provide valuable information, such as an indication that there has been:

- o Accumulations of materials in an elbow, branch, or main, thus clogging or restricting air flow. Accumulation in the elbows result from impaction, while build-ups in straight runs result from insufficient conveying velocity or overloading the system.

- o A change in blast gate setting if the system is balanced using blast gates.

- o Additional branches and hoods added to the system. "Adding on" to a system is a real temptation. It is not sound economics when it renders the entire system deficient.

- o Excessive build-up on the filter. It is best to monitor filter build-up by attaching a static pressure measuring device across the filter (manometer).

- o Reduced fan output resulting from belt slippage, damaged or worn rotor, or build-up on the fan blades.

2. Smoke tubes are also helpful in identifying uneven air flow patterns near hood entry areas and the effect of room air currents on the performance of hoods.

D. Data Handling and Recording

The sketch of the system made at start-up or for the initial air evaluation survey and the results of the ensuing air flow survey must be recorded and filed in such a manner that future air flow surveys can be conducted in a similar manner. The frequency of air flow surveys can only be determined by such conditions as:

- o Nature of the materials being controlled. The more hazardous the materials, the more frequently the system should be checked.

- o Nature of the system. Blast gate systems and laboratory hoods will require more frequent checks than other systems.

- o The degree of maintenance. Air flow surveys can be used to indicate the need for more frequent and improved maintenance.

APPENDIX III

Organization Chart

R. F. Gervais

S. P. Dominick, Jr.
Vice President & General Manager
Resins

Open
Vice President & General Manager
Fabricated Products

F. F. Hoy
Director-Manufacturing

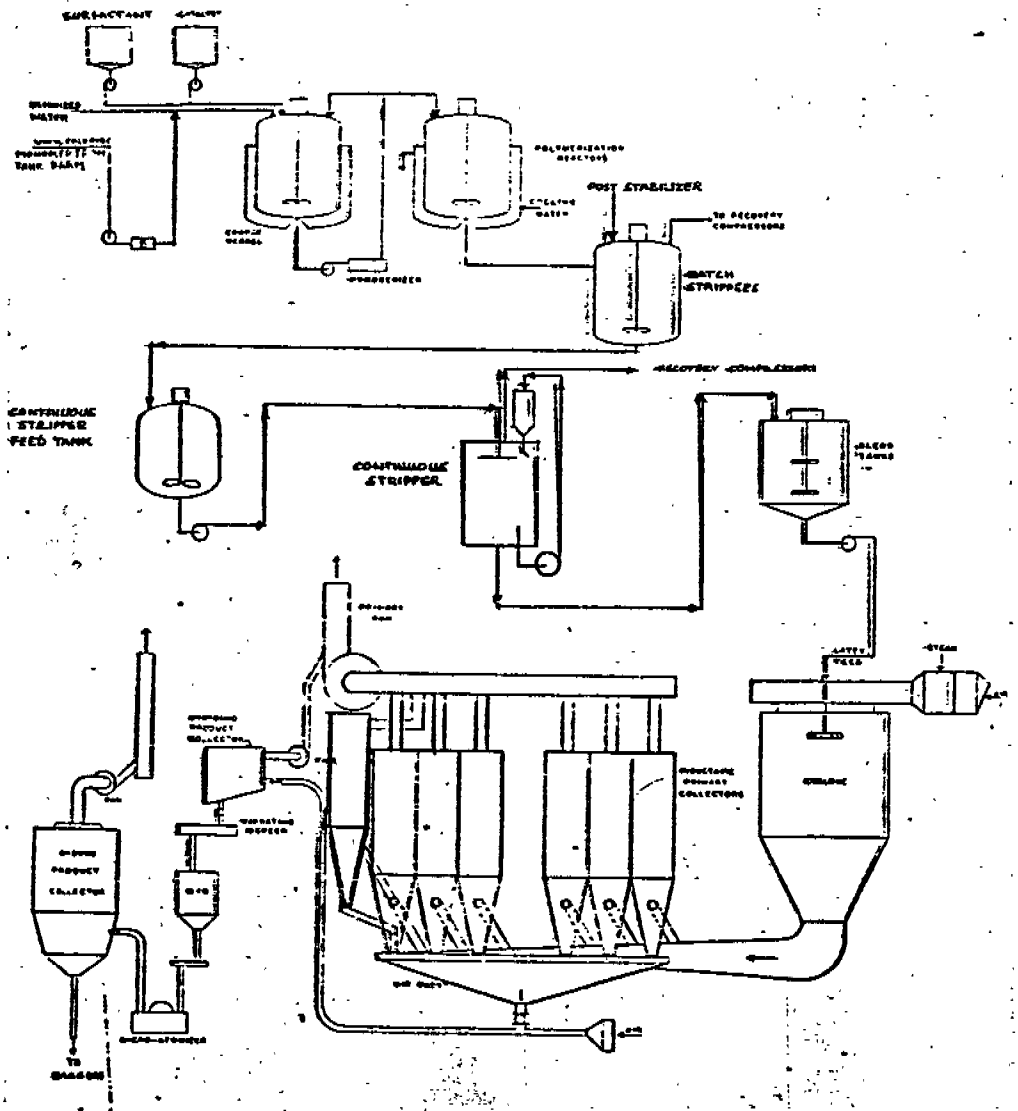
J. T. Wolfsperger
Director-Manufacturing

G. D. Lloyd
Manager-Safety
(Hygiene)

H. F. Dubec
Manager-Safety & Environment
(Hygiene)

Calender Plant

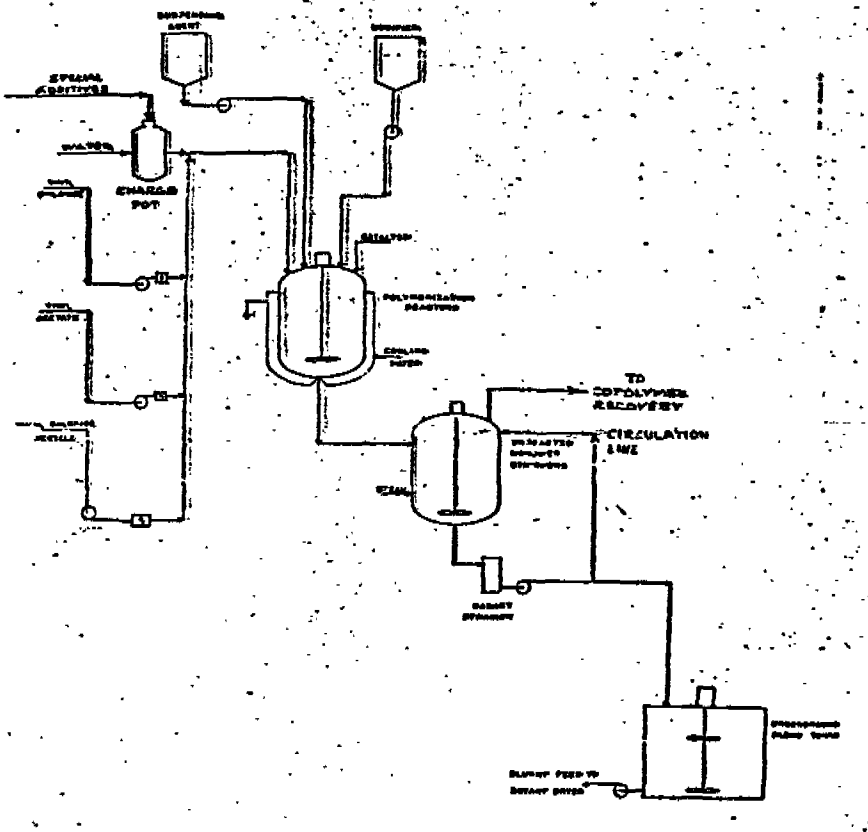
The Film and Sheeting Division takes the above resin(s) and compounds them with other ingredients such as plasticizers, stabilizers, lubricants, fillers, and colorants. The blended material is then Banburyed, milled and calendered into film along four calendering lines. The film is shipped in roll form either to the Salisbury printing plant or to trade customers for further processing.



POLYVINYLCHLORIDE DISPERSION RESINS MANUFACTURE
FLOW DIAGRAM

OCC 8273

PLASTISOL



COPOLYMER SUSPENSION RESIN MANUFACTURE
FLOW DIAGRAM

COPOLYMER

OCC 8274

#1

Occidental Chemical Corporation

Environment, Health & Safety

MEMO

No. 236

To K. Garner
E. Lapreziosa

Date March 8, 1983

From M. R. Zavon, M.D.

Subject Industrial Hygiene Assessment - Pottstown

cc: F. F. Hoy
J. T. Wolfsperger
R. J. Schuttler
G. D. Lloyd
H. F. Dubec

Attached please find the correct Page 4 and 11 for this assessment. Please remove any Page 4's and 11's in the original copy sent to you and replace it with the attached.

My apoligies for any inconvenience.

2709E-1

Attachment

CT ~~JDL~~

Occidental Chemical Corporation

Environment, Health & Safety

MEMO

T J. Wilkenfeld **Date** April 25, 1983

From M. R. Zavon

Subject Pottstown Industrial Hygiene Assessment

cc: S. P. Dominick
R. L. Comboy

Enclosed is a copy of the Pottstown Industrial Hygiene Assessment. The facility response to the recommendations will be found following our recommendations. If you have any questions regarding this report, please call me.

2990E-1

Enclosure