IN-DEPTH SURVEY REPORT:

CONTROL OF AIRBORNE SOLVENTS IN A SMALL OFFSET PRINT SHOP

at

Express Service Printing
Indianapolis, Indiana

REPORT WRITTEN BY
Keith G Crouch
Michael G Gressel

REPORT DATE
February 12, 1997

REPORT NO
ECTB 205-13a

U S DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health
Division of Physical Sciences and Engineering
4676 Columbia Parkway, R5
Cincinnati, Ohio 45226

PLANT SURVEYED	Express Service Printing 1365 East 86th Street Indianapolis, Indiana 46240
SIC CODE	2752
SURVEY DATES	August 9-11 & September 13-15, 1995
SURVEY CONDUCTED BY	Keith G Crouch Michael G Gressel Kenneth R Mead Daniel R Farwick
EMPLOYER REPRESENTATIVE CONTACTED	Stuart Goldner Express Service Printing
EMPLOYEE REPRESENTATIVE CONTACTED	No Union
ANALYTICAL WORK PERFORMED BY	Data Chem
MANUSCRIPT PREPARED BY	Robin Smith Bernice Clark

DISCLAIMER

Mention of company names or products does not constitute endorsement by the Centers for Disease Control and Prevention (CDC)

INTRODUCTION

This report contains the results of personal exposure and area sampling for airborne solvent vapors conducted at a small printing establishment during two periods, in August and in September of 1995 Also included are the sampling methods, the exposure standards, ventilation flow measurements, and some recommendations for follow-up work Between the sampling periods, a local exhaust system was installed on two of the three operating presses The system supplied fresh make-up air to the press room through ceiling inlets added exclusively for use by the fresh air system An air-to-air heat exchanger (Raydot, Incorporated, Cokato, MN) was included to improve the energy efficiency of the system In addition, a second fresh air system was installed between sampling periods in the office/reception area The sampling data provided a basis for evaluating the effectiveness of the fresh air systems in reducing personal exposure levels to the airborne solvent vapors

PROCESS DESCRIPTION

For small presses, necessary press cleaning operations are carried out by hand by the press operators periodically during a printing run, and between runs The cleaning solvents are typically a volatile mixture of several compounds, having potential adverse health effects Although substitution of solvents having lower toxicity has been helpful in reducing over-exposures to the airborne solvent vapors, a need for improved control remains Also, the usual anti-offset powder was used at this facility The powder was automatically sprayed on to the back of each printed sheet as it ejected from the final roller in the press to prevent wet ink from the previously printed sheet from contacting the back of the ejected sheet This dust is very fine, non-toxic, and escapes from the presses to settle on top of all exposed surfaces in the press room

CONTROL PRINCIPLES

Occupational exposure can be controlled by the application of a number of well-known principles, including engineering measures, work practices, personal protection, and monitoring These principles may be applied at or near the hazard source or at the point of occupational exposure to individuals Controls applied at the source of the hazard, including material substitution, process or equipment modification, isolation or automation, local ventilation, and work practices are generally the preferred and most effective in terms of both occupational and environmental concerns Controls which may be applied to airborne hazards that have escaped into the workplace environment include dilution ventilation, dust suppression, and housekeeping Control measures can also be applied near individual workers

VENTILATION SYSTEMS

The facility had two HVAC systems in operation during our visits One supplied only the reception/copy area and the offices The other supplied the press room and the storage area There was a very slight negative relative pressure in the press room, resulting in a slight flow of air into the press room from the reception/copy area through the two connecting swinging doors

Also, between our visits, two fresh air supply systems were installed in the printing facility to control airborne cleaning solvent vapors and anti-offset powder One was installed to supply the reception/copy and office areas, and the other was installed in the press room and storage areas Two of the three presses in the single press room (Figure 1) were provided with local exhaust inlets, shown in the attached photo An air-to-air heat exchanger was installed in the fresh air system (Figure 2) for energy economy Figure 2 is a diagram of the air flow for the press room fresh air system Fresh make-up air was provided through four ceiling outlets, as shown in the diagram (Figure 3) This fresh air system exhausted a total of 870 cfm from the two local exhaust inlets and supplied 940 cfm to four ceiling outlets

Observations of air flow patterns were made with the local exhaust system in operation, using a smoke release method Air from the roller train and from the paper delivery area flowed to the exhaust inlet, indicating that both solvents applied to the press and the anti-offset powder should be captured by the local exhaust system

SOLVENT EXPOSURE RESULTS: AIRBORNE AND SKIN CONTACT

Charcoal Tube Data --

Full-shift, time-weighted-average personal and area sampling on charcoal tubes was carried out for airborne solvent vapors for two days each before and after the fresh air systems were installed Analysis for isopropanol, methylene chloride, acetone, and total hydrocarbons was conducted, based on preliminary qualitative sample analysis by gas chromatography-mass spectrometry and the listings of solvent composition found on MSD sheets The results are given in Tables 1 and 2 Definition of the exposure standards is given in Attachment 1 The sampling methods are described in Attachment 2 The concentrations for acetone were below the limit of detection (< 0 2 ppm), so it was not included in the Tables or Figures

Employees are exposed to several solvent vapors simultaneously, and these vapors have some adverse health effects in common Therefore, cumulative exposure levels were calculated by the method given in Appendix 2, and are shown in bar charts (Figures 4-11), as well as levels for the individual species For purposes of estimating cumulative exposures only, the PEL for narcotic effects for methylene chloride was approximated as 200 ppm, based upon statements found in the toxicological literature [Federal Register, 29 CFR Parts 1910, 1915 and 1926, Occupational Exposure to Methylene Chloride, Proposed Rule, 56 (216) 57080-57081, 1991] The horizontal bar charts of cumulative exposures (Figures 4-11) show that before the fresh air supply was added, all three of the personal exposure samples for the press operators were about 35-45% of the Permissible Exposure Limit (PEL) After the addition of a fresh air supply, exposures were 18-37% of the PEL The average percent reduction in cumulative concentration for the press operators was 47 +/- 10 (95% confidence limit) Using the two sampling points in the area of the presses, the cumulative solvent concentration decreased by 67 +/- 5 %

However, after installation of the fresh air system, the average concentration of methylene chloride for the press operators increased by 43 +/- 28 % For the press area samples, the average methylene chloride concentration decreased by 37 +/- 10 % as a result of the addition of fresh air The NIOSH action level for methylene chloride is 12 5 ppm Tables 1 and 2 show that before installation of the fresh air system, no samples were at or above the Action Level After installation of the fresh air system, 2 samples for the press operators were at the 12 5 ppm Action Level, and one sample was between the Action Level and the PEL In view of the substantial reductions in the concentration of all other solvent vapors as a result of the addition of the fresh air system, it is surprising that the methylene chloride concentration for the press operators increased It may be that the unexpectedly high concentrations of methylene chloride occurred when the blanket wash squeeze bottles were being refilled The solvent containing methylene chloride (blanket wash) was dispensed into one-quart squeeze bottles from a 55-gallon drum, which was located away from a local exhaust inlet A blanket wash squeeze bottle was refilled at least once each day on September 14-15, possibly a second time at the end of the day on the 15th Differences in air flow patterns where the bottles were filled, or variations in work practices or work load could account for the additional exposures, in spite of the generally lower concentrations of solvent vapor after the addition of the fresh air system

Real-Time Vapor and Dust Concentrations --

Figures 12 and 13 show the time dependence of the concentration of total organic compounds (TOC's) and carbon dioxide (CO_2) in the press room This data was collected with a Bruel & Kjær Multi-gas Monitor Type 1302 (Bruel & Kjær, Gas Products Division, Nærum, Denmark) Both the CO_2 and TOC concentrations are relatively high during the day, when people are in the building and printing is in progress, and relatively low at night The data show an 83% decrease in the level of TOC's, and a reduction of above-background CO_2 of 82% in the press room as a result of the installation of the fresh air system

The quantity of TOC indicated by the Multi-gas Monitor is related to the sum of the concentrations of organic compounds The instrument does not distinguish between two or more compounds which might have very different health effects Therefore, the indicated TOC levels reflect the combined concentration of organic compounds in unknown proportions, and they cannot be compared to any health standards

The CO_2 levels indicated by the Multi-gas Monitor are well below 5000 ppm, the hazardous level established by OSHA, NIOSH and ACGIH The background level in the atmosphere is 350-400 ppm, and the American Society of Heating, Refrigeration and Air-conditioning Engineers recommends maintaining the CO_2 concentration below 1000 ppm in occupied spaces The indicated CO_2 concentrations are thus acceptable according to known standards

Cleaning solvents were applied from one quart capacity squeeze bottles Solvent usage was determined by measurement of the level of the liquid in the bottles However, these usage measurements were taken only on the two days after control installation On September 14, the total solvent usage volume was 1 42 liters, and on September 15, it was 1 12 liters, 79% of the previous day's usage The average cumulative concentration of the airborne solvent vapors determined by personal sampling of the press operators on the 15th was 127 +/- 21 % of the concentration on the 14th, just the opposite of the expected result This surprising disagreement could possibly be explained by variations in work practices

Skin Contact with Solvents --

Skin contact with solvents can cause dermatitis, and some solvents can be absorbed through the skin Press operators should wear impermeable gloves when performing cleaning operations Solvent manufacturers can suggest appropriate glove materials (on the Material Safety Data Sheets) Methylene chloride and some of the other hydrocarbons can be absorbed through the skin to a significant extent, in addition to the airborne route of exposure Therefore, press operators may have higher solvent exposures than indicated by the results of our airborne sampling In order to evaluate the total absorbed from these multiple exposure routes, biological sampling of the employee's blood, urine or expired air is necessary The primary concern in this study was the airborne exposure route, since the skin absorption route can be controlled through the use of gloves, so biological sampling was not conducted If glove wearing cannot be assured, it would be necessary to carry out biological sampling of the press operators to see if the additional absorption through skin contact resulted in a health hazard

ANTI-OFFSET DUST RESULTS

The anti-offset dust used by the presses is a nuisance in the printing facility, because it is carried in the air and settles on surfaces throughout The dust has a vegetable composition with no known health hazards Real-time monitoring of the dust concentration was conducted before and after installation of the fresh air system using a DataRAM (MIE, Inc , Billerica, Massachusetts) with an omnidirectional sampling inlet located 1 5 m (60 inches) above the floor adjacent to the presses The data are shown in Figures 14 and 15 The DataRAM responds to particles having a diameter between 0 1 and 10μm Peak dust concentrations before installation were near 0 8 mg/m^3, average concentration around 0 22 mg/m^3 during working hours After installation of the fresh air system, the dust concentration peaked at 0 4 mg/m^3 with an average of about 0 07 mg/m^3 The percent reduction in dust concentration was about 67% These dust concentrations are well below the OSHA PEL of 5 mg/m^3 for respirable nuisance dusts

RECOMMENDATIONS

If effective substitutes can be found, replace solvents that contain methylene chloride with ones that are free of it Be sure that the replacement solvents contain no potentially carcinogenic or otherwise highly toxic components (avoid benzene, for example)

Since press operator C tended to have higher exposure levels than the other operators, and operator C's press was the one without a local exhaust inlet, it would likely be good practice to add an exhaust takeoff to C's press

The following suggestions affect the maintenance and efficiency of the ventilation control systems discussed above The duct work should be smooth on the inside and have a circular cross-section This minimizes dust accumulation in the ductwork, and resistance to air flow Also, round, smooth duct withstands larger negative pressures, will support a larger buildup of dirt inside the duct, and can be cleaned, in contrast to most flexible, corrugated, or rectangular duct The duct should be sized to maintain at least 3000 feet per minute air velocity in the duct to prevent settling and accumulation of the anti-offset powder inside horizontal duct runs Assuming a 420 cfm exhaust flow as measured on Press 2, the associated branch of the duct work should be 4 inches by 5 inches if rectangular, and 5 inches in diameter if round, in order to maintain the above mentioned minimum air velocity There should be a dust filter at the inlet to the fresh air system to protect the air-to-air heat exchanger from degradation caused by dust accumulation The use of an electrostatic precipitator at this point might be an effective substitute, and would have less air resistance than a filter If not removed before it enters the fresh air system, the anti-offset powder can build up quickly in the fine passages of the heat exchanger, resulting in a recurrent maintenance problem

CONCLUSIONS

The installation of a local exhaust system on two of three presses, with fresh make-up air, has reduced solvent vapor exposures to the press operators by 47 % Originally, all of the press operator's cumulative exposures were between the Action Level and half of the Action Level After installation of the controls, all but one of the cumulative exposures were less than half of the Action level It is not clear why the press operator exposures to methylene chloride were greater after control installation than they were before, especially since the area concentrations of methylene chloride in the press room were lower after control installation Squirt bottle refilling may be the source of the increased methylene chloride exposures The anti-offset dust concentration has also been reduced by 50-67% The long-term effectiveness of the system depends in part on maintenance considerations covered in the recommendations

Finally, the application of local exhaust controls to offset lithographic presses is a promising approach to reducing airborne cleaning solvent and anti-offset powder emissions, and should lead to acceptable worker exposures when used with complimentary control measures, such as impermeable gloves and avoidance of potentially carcinogenic solvents

Table 1 Charcoal Tube Sampling Results, Concentration in ppm, Express Service Printing.

	Isopropyl Alcohol				Methylene Chloride				Other Hydrocarbons			
Date WORKER/*AREA*	10-Aug	11-Aug	14-Sep	15-Sep	10-Aug	11-Aug	14-Sep	15-Sep	10-Aug	11-Aug	14-Sep	15-Sep
Customer Service A	8	35	1	1	2	2	0	0	9	8	2	2
Press Op A	35	116	19	24	9	8	9	7	29	24	9	8
Press Op B	30	101	29	18	6	7	12	12	25	22	12	9
Press Op C	36	108	49	25	11	9	16	9	27	24	17	11
Customer Service B	8	39	2	1	2	1	0	0	10	8	2	2
Photocopy	7	27	1	1	2	1	0	0	7	7	2	1
Reception	6	25	1	1	2	1	0	0	6	7	2	2
Office	7	23	1	0	2	1	0	0	6	7	2	2
Press, central	31	77	16	14	7	5	4	5	19	23	7	8
Press, edge	24	76	10	6	6	5	3	2	19	22	5	3
Outdoors	0	10	0	0	0	0	0	0	2	3	2	1
PEL	400				500				100			
TLV	400				50				100			
REL	400				25				100			

Table 2 Summary of area and personal sampling data, Express Service Printing.

Date	Before				After			
	10-Aug		11-Aug		14-Sep		15-Sep	
Worker/*Area*	Cum *	MeCl**	Cum *	MeCl**	Cum.*	MeCl**	Cum.*	MeCl**
Customer Service A	0 11	0 07	0 11	0 06	0 02	0 00	0 02	0 01
Press Op A	0 42	0 34	0 37	0 30	0 18	0 34	0 17	0 27
Press Op B	0 35	0 22	0 35	0 28	0 25	0 46	0 19	0 49
Press Op C	0 41	0 43	0 40	0 38	0 37	0 65	0 22	0 38
Customer Service B	0 13	0 06	0 11	0 04	0 03	0 01	0 02	0 01
Photocopy	0 09	0 07	0 09	0 03	0 02	0 00	0 02	0 01
Reception	0 08	0 06	0 09	0 03	0 02	0 00	0 02	0 00
Office	0 08	0 08	0 08	0 03	0 03	0 00	0 02	0 00
Press, central	0 30	0 26	0 36	0 22	0 13	0 16	0 14	0 20
Press, edge	0 28	0 22	0 35	0 21	0 09	0 12	0 06	0 09
Outdoors	0 02	0 00	0 03	0 00	0 02	0 00	0 01	0 00
Indoors Average	0 23	0 18	0 23	0 16	0 11	0 17	0 09	0 15

	Overall	Press Operators
Cumulative Average Before	0 23	0 38
Cumulative Average After	0 10	0 23
MeCl Average Before	0 17	0 33
MeCl Average After	0 16	0 43

* Cum , Cumulative = Cumulative concentration relative to the PEL, using an estimated narcotic limit of 200 ppm for methylene chloride

** MeCl = Concentration of methylene chloride relative to its carcinogenic limit of 25 ppm

% Reduction in the Overall cumulative concentration, 65 +/- 6 (95% confidence limit)

% Reduction in the cumulative concentration for the Press Operators, 47 +/- 10

% Reduction in the Overall methylene chloride concentration, 42 +/- 20

% Increase in the methylene chloride concentration for the Press Operators, 43 +/- 28

ATTACHMENT 1 - EXPOSURE STANDARDS

The term *time-weighted average* (TWA) is applied to an exposure which is averaged over the duration of the sampling, typically for a full shift

TLVs - The American Conference of Governmental Industrial Hygienists (ACGIH) recommends exposure limits for chemical and physical agents These limits are called Threshold Limit Values or TLVs and are widely recognized in the field of industrial hygiene They are updated yearly as new information becomes available

(American Conference of Governmental Industrial Hygienists *1993-1994 Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices* Cincinnati ACGIH, 1993)

(American Conference of Governmental Industrial Hygienists *Annual Reports of the Committees on Threshold Limit Values and Biological Exposure Indices* Cincinnati ACGIH, 1994)

PELs - The Occupational Safety and Health Administration (OSHA) is the federal regulatory agency which promulgates and enforces the legal limits for exposures to chemical and physical agents They are called PELs, or Permissible Exposure Limits Few changes have been made in the PELs since OSHA was originated in 1971, and they are not generally considered to be the most protective limits

(*Air Contaminants*, Code of Federal Regulations Title 29, Part 1910 1000 1993)

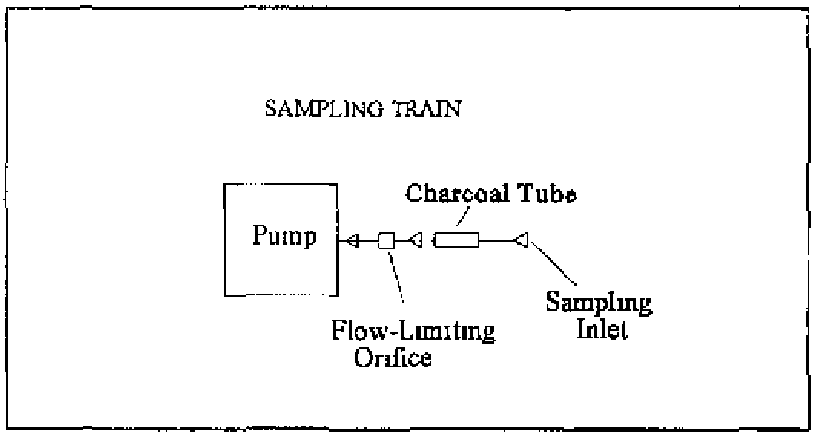
RELs - The National Institute for Occupational Safety and Health (NIOSH) is a federal research organization which recommends limits for chemical and physical agents They are called Recommended Exposure Limits, or RELs, and are widely recognized in the field of industrial hygiene NIOSH's criteria for establishing standards are based on health effects and the most sensitive method available for measuring contaminants, so RELs are often lower than other limits

(National Institute for Occupational Safety and Health Pocket Guide to Chemical Hazards, DHHS(NIOSH) Publication No 94-116 Cincinnati NIOSH, 1994)

ATTACHMENT 2 - PRINTING PROCESSES AND AIRBORNE SAMPLING METHODS

Employees are involved in sales, layout, duplication, bindery and press operations The primary airborne contaminants are generated by press clean up operations of the plate, rollers and other press components of the three offset lithographic presses Also, normal press operation involves some evaporation of ink solvents and fountain solutions Because of their proximity, the press operators could be expected to have the highest exposures to these airborne emissions

Full-shift personal sampling for the cleaning solvents was conducted on 5 employees for all or part of four days Also, area sampling was conducted at 5 locations inside the building and one outside The results are shown in Tables 1 & 2 and in Figures 4 - 11 The personal sampling was discontinued during the employees' lunch break, and at other times when they left the building, and resumed when they returned The area sampling proceeded continuously throughout the day



Both the personal and the area sampling made use of the sampling train shown in the adjacent diagram The sampling inlets for the personal sampling were located in the breathing zone of the individuals, clipped to their collars The collection medium was coconut shell charcoal tubes (100 mg/50 mg) The sampling rate was about 10 cm^3/min on August 10 & 11 and about 25 cm^3/min on September 14 & 15 The charcoal tubes were analyzed using gas chromatography for the following species according to the NIOSH Manual of Analytical Methods 1300, 1400, 1550 and 1005 with modifications Isopropanol, methylene chloride, acetone, and total hydrocarbons, respectively

Additive exposures were calculated using the formula

$$C_1/L_1 + C_2/L_2 + \quad = \text{Additive Exposure,}$$

where C is the measured exposure for a species and L is the corresponding exposure limit Additive exposures greater than 1 0 are considered overexposures

Tables 1 & 2 show the personal sampling results for the charcoal tube measurements The additive exposures for both personal and area sampling are shown again in the bar charts, Figures 4 - 11 Note that the current exposure standards are given in the Tables Also, the exposure standards used for Total Hydrocarbons have not been defined, since it consists of an indefinite mixture of various compounds The standards appropriate for Stoddard Solvent were used as an approximation, since Stoddard Solvent is also a mixture of compounds The additive exposures can therefore be considered as only an approximate indicator of potential narcotic effects

Figure 1. ESP Facility Layout.

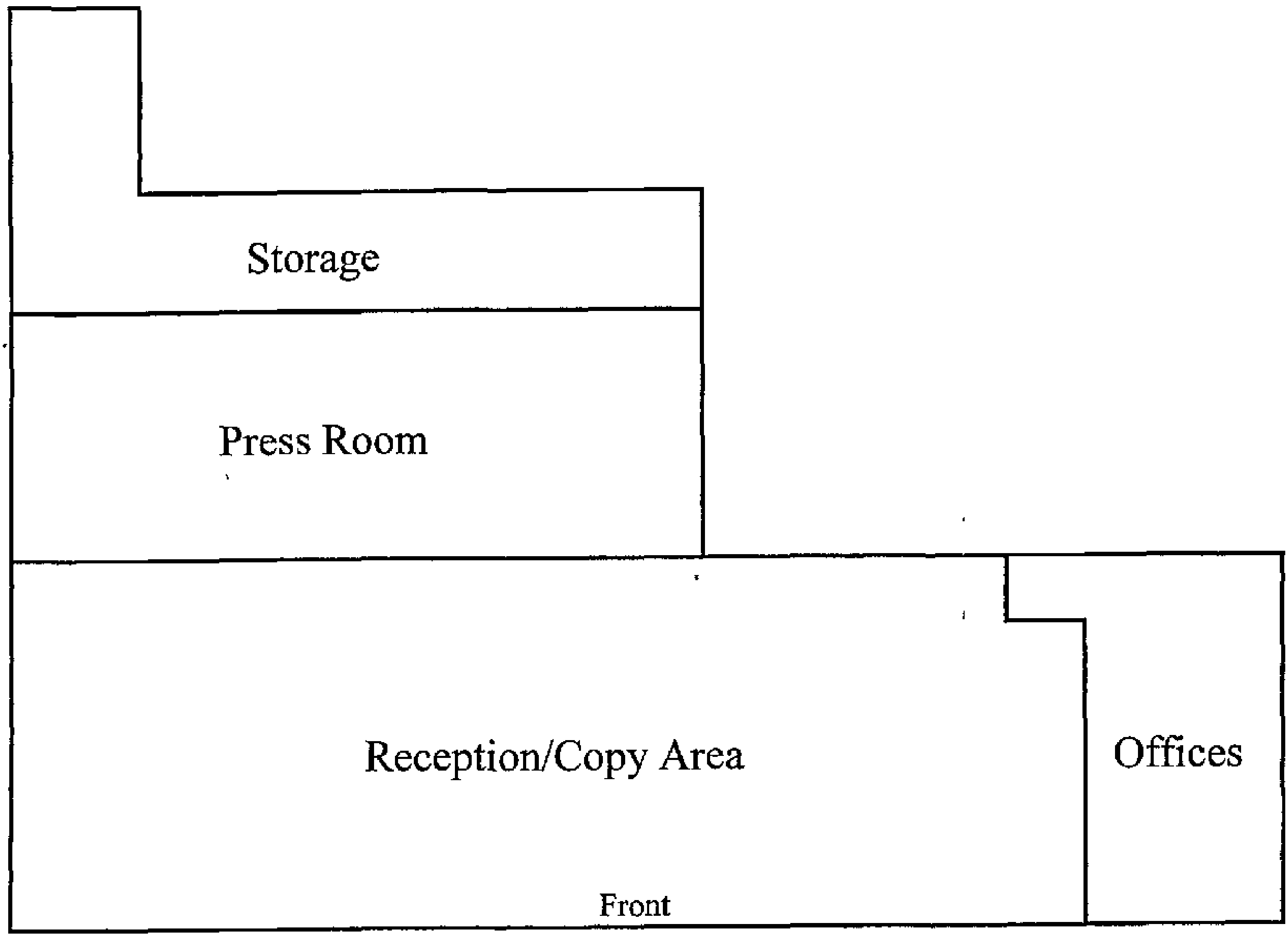


Figure 2. ESP fresh air supply system flow diagram.

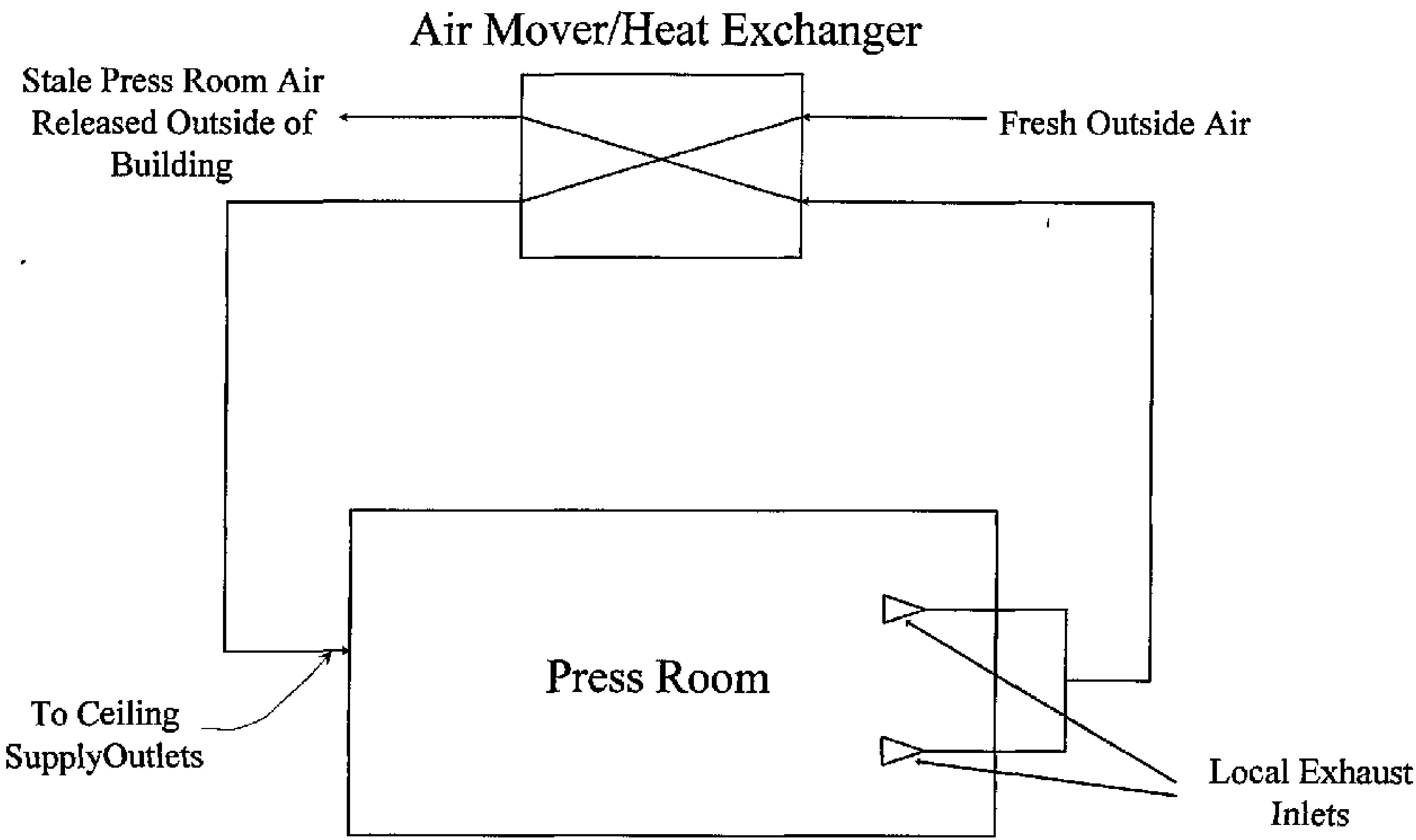
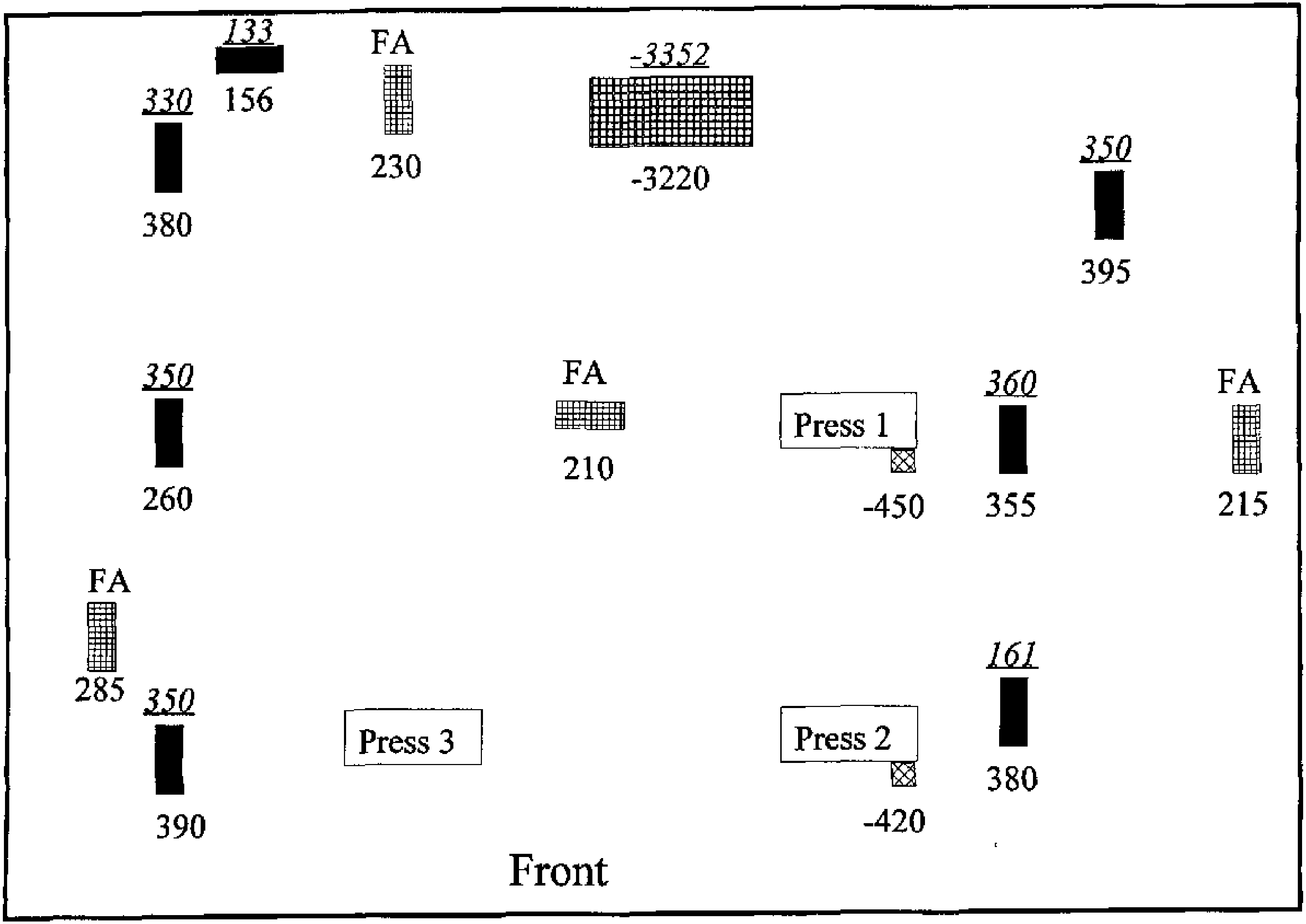


Figure 3. ESP Press Area: Ventilation Rates, CFM ***BEFORE***/AFTER.



FA = Fresh Air Supply

Negative Numbers are Exhaust Flow Rates.

Figure 4. Concentrations Relative to the PEL, Express Service Printing, August 10, 1995. Personal Samples.

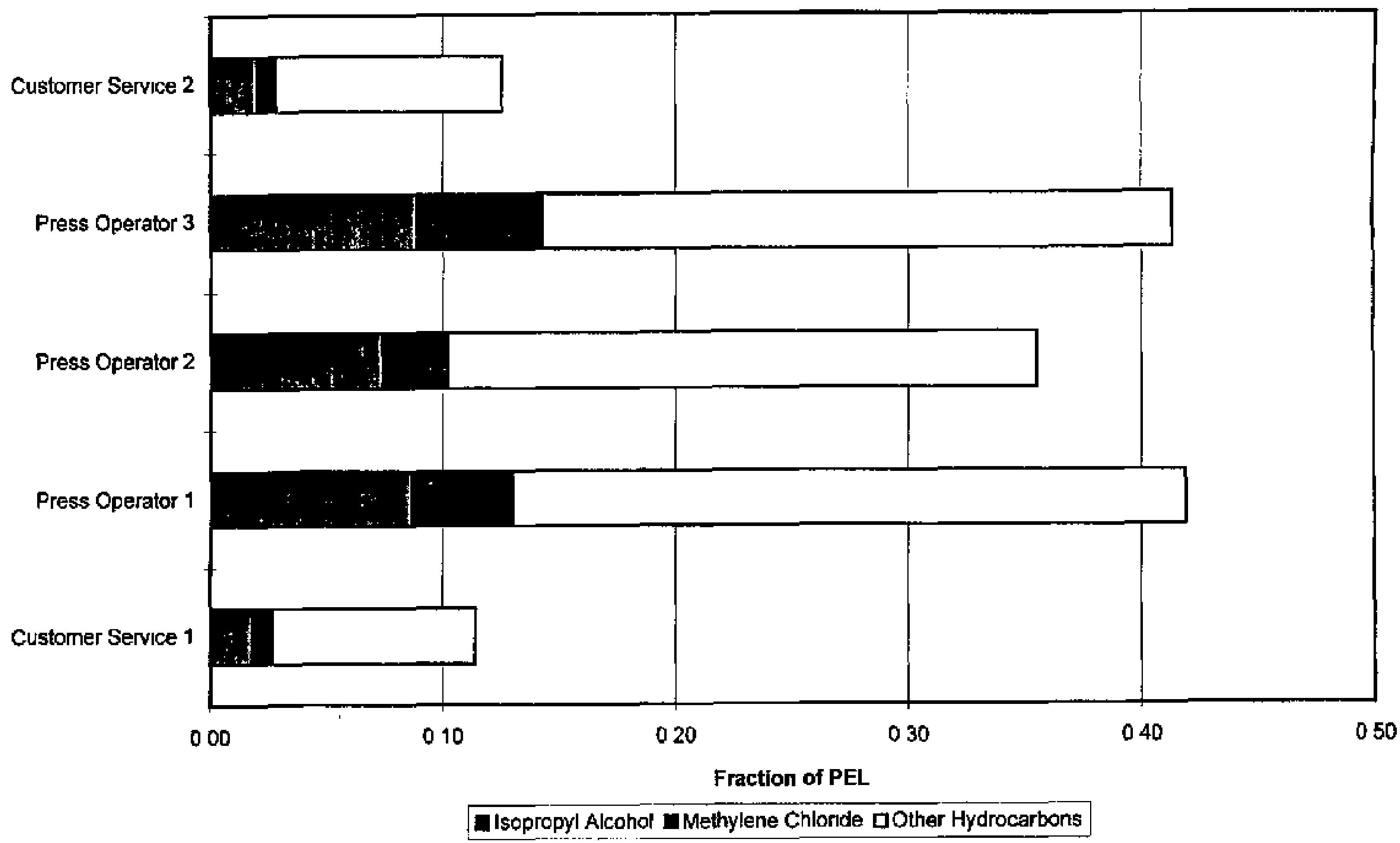


Figure 5. Concentration Relative to the PEL, Express Service Printing, August 10, 1995. Area Samples.

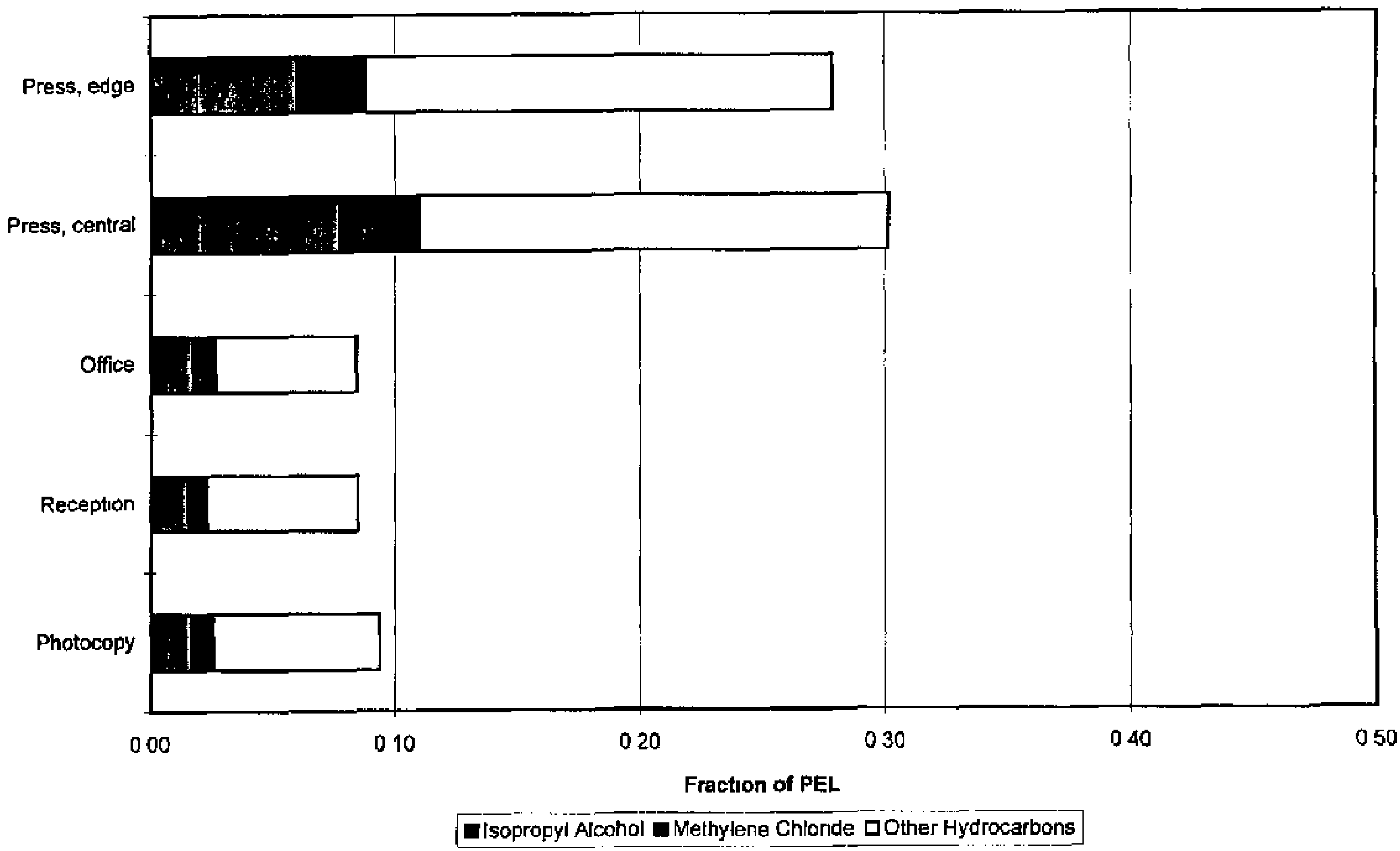


Figure 6. Concentration Relative to the PEL, Express Service Printing, August 11, 1995. Personal Samples.

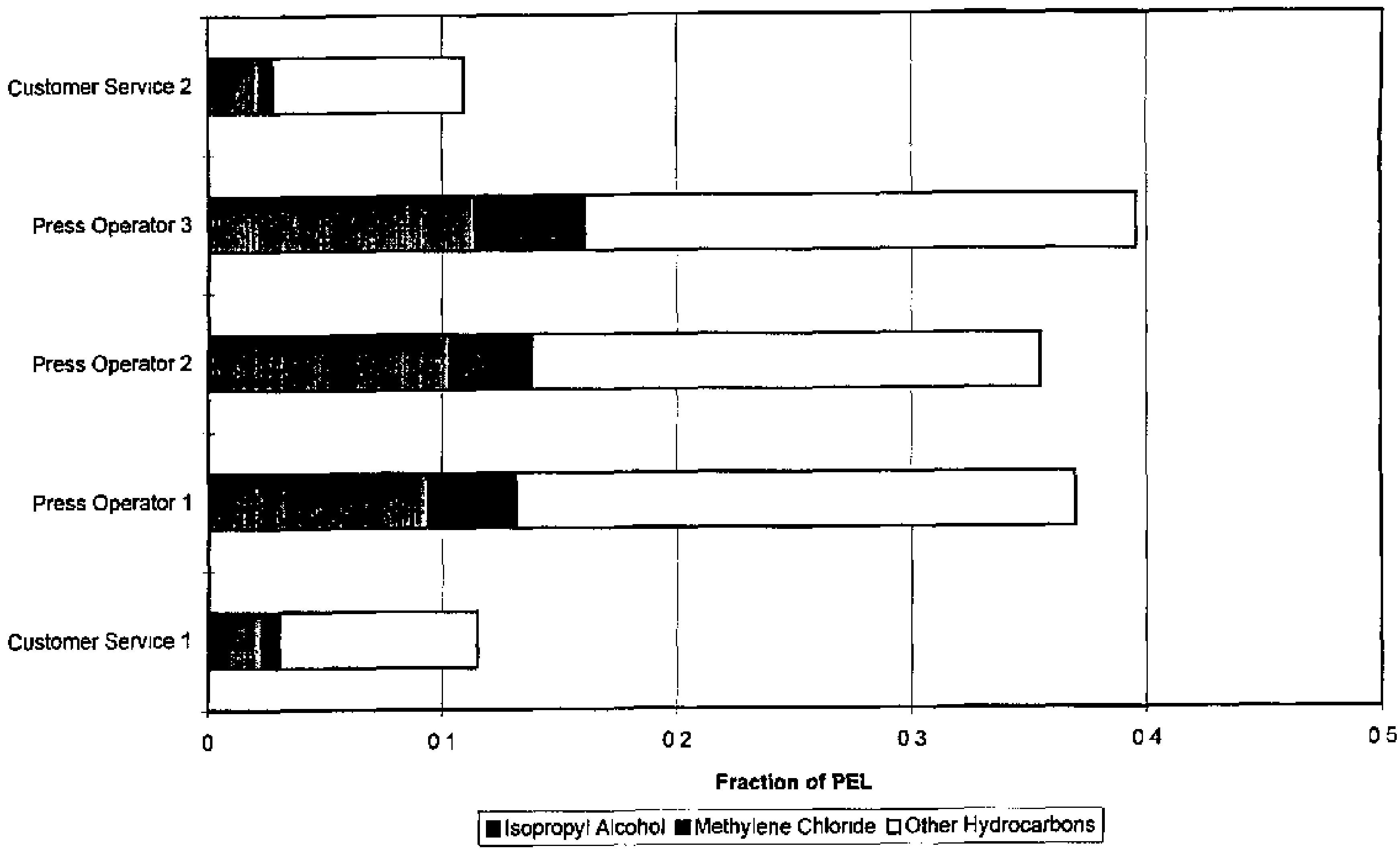


Figure 7. Concentration Relative to the PEL, Express Service Printing, August 11, 1995 Area Samples.

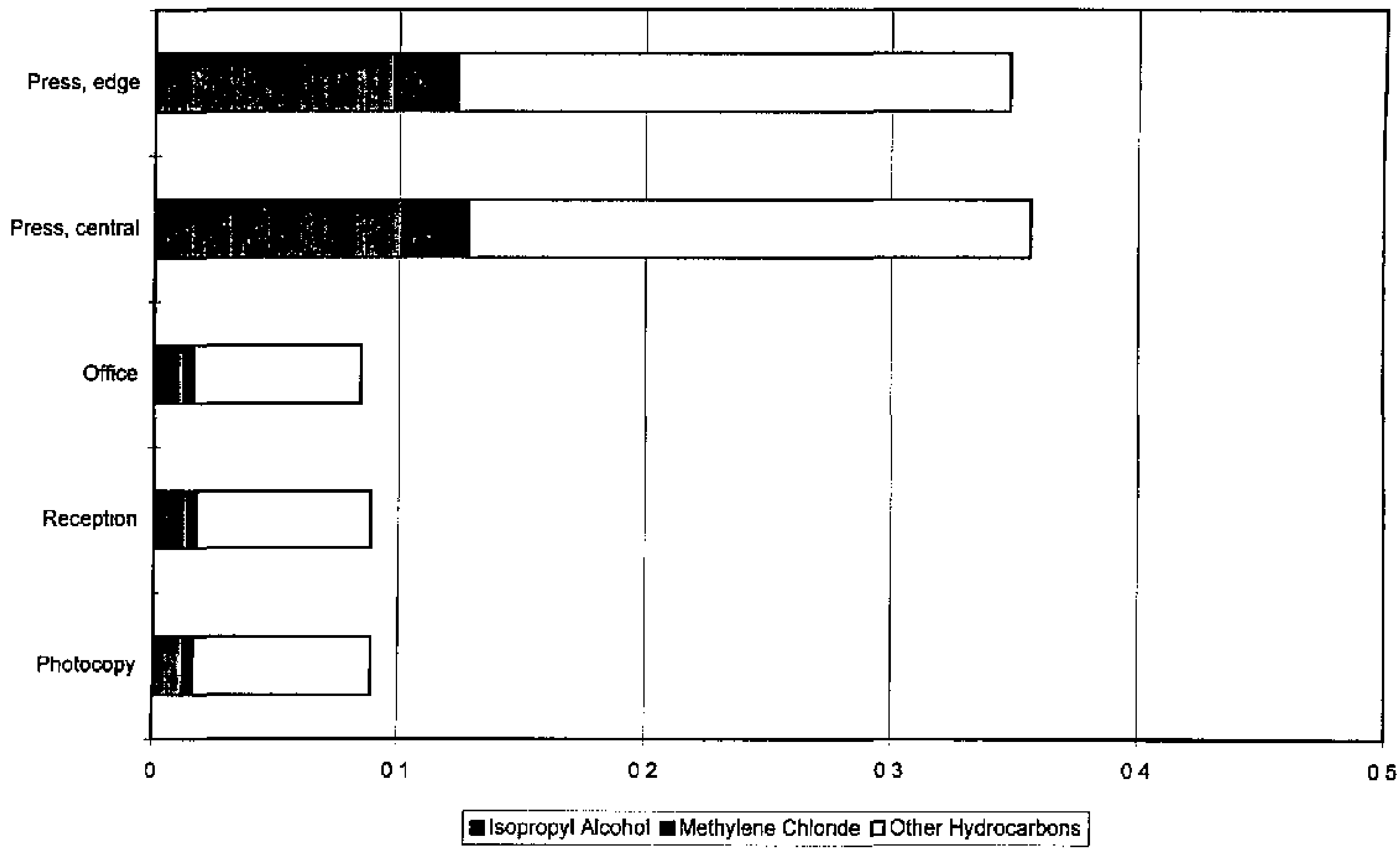


Figure 8. Concentrations Relative to the PEL, Express Service Printing, September 14, 1995. Personal Samples.

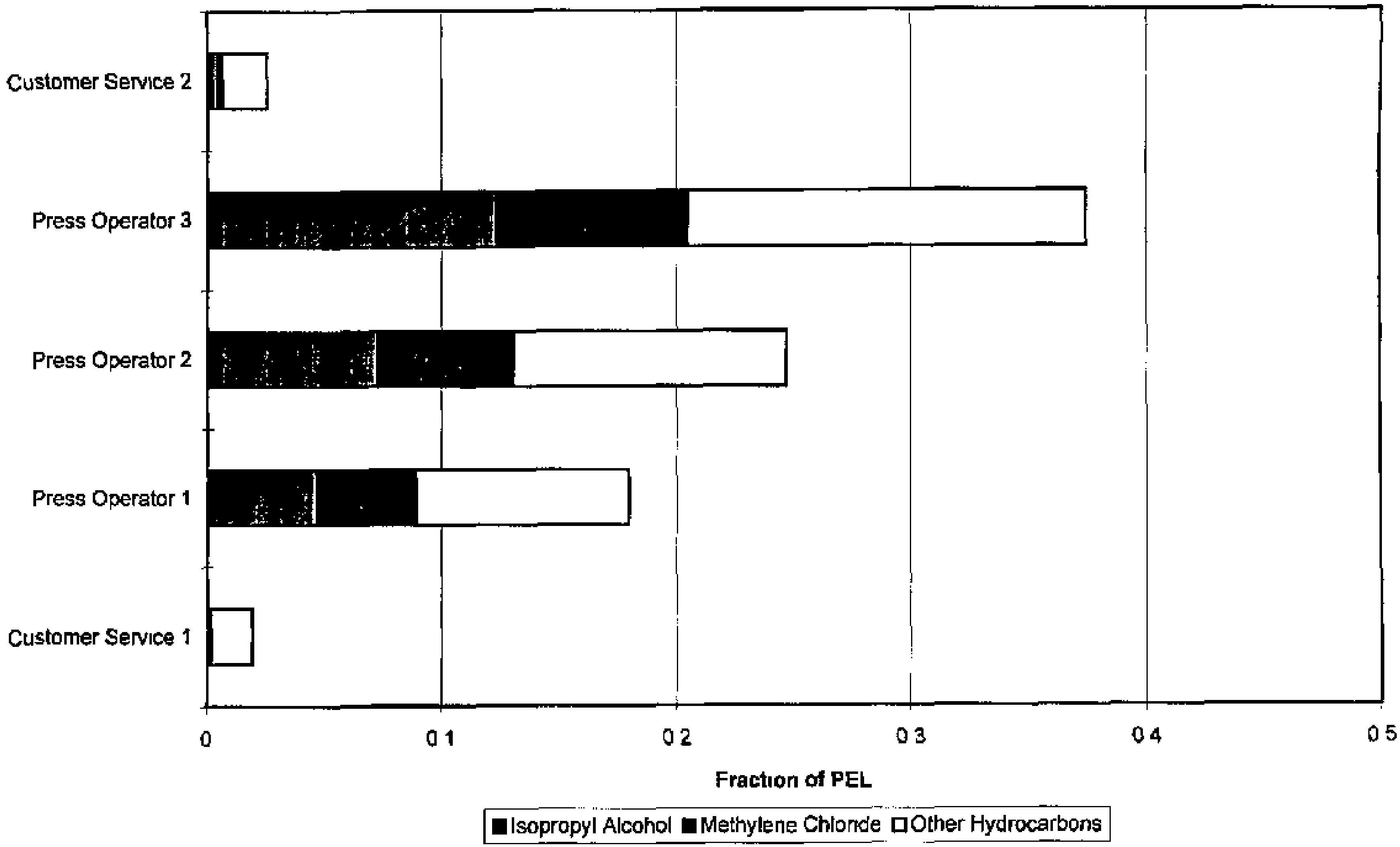


Figure 9. Concentrations Relative the PEL, Express Service Printing, September 14, 1995. Area Samples.

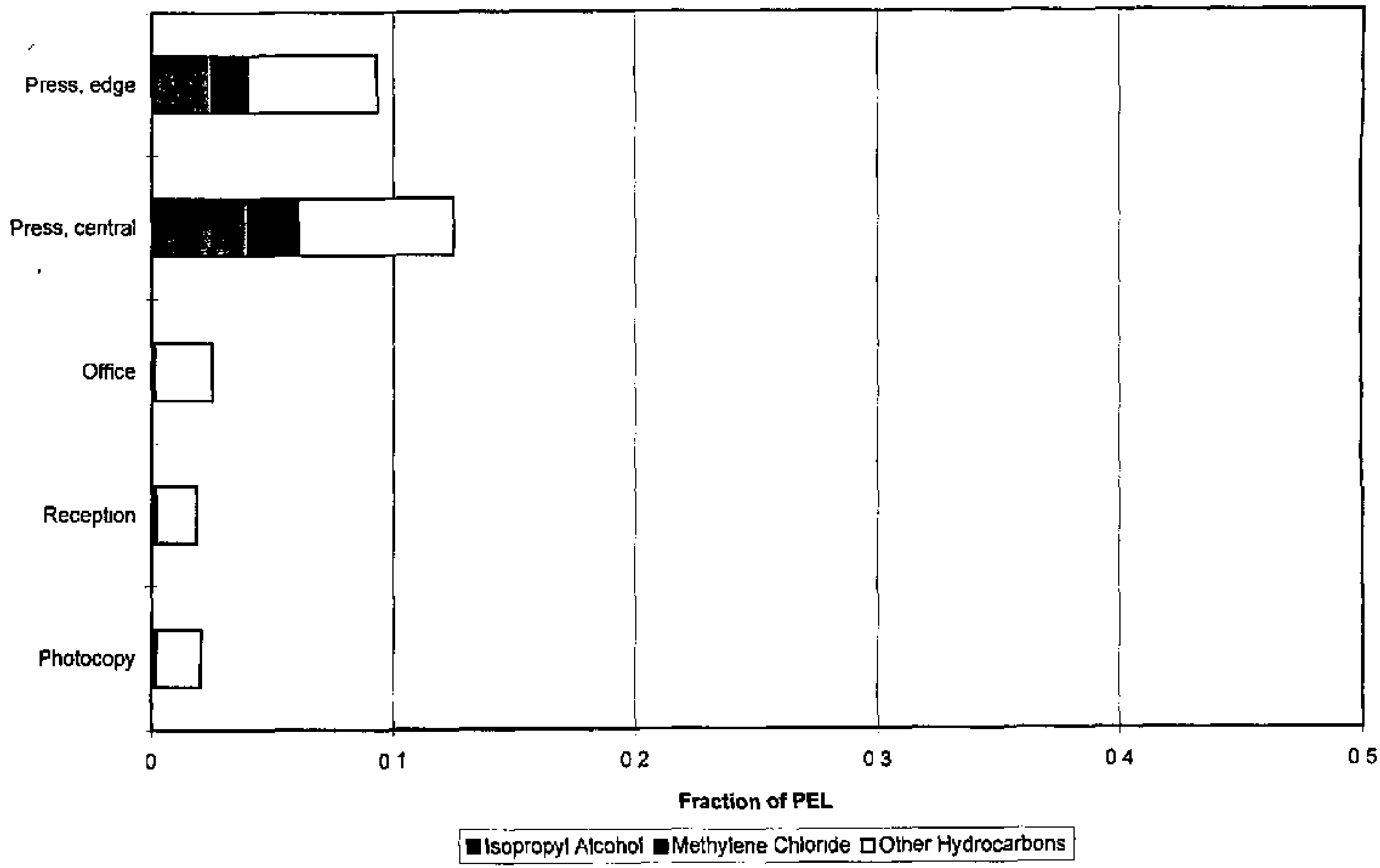


Figure 10. Concentrations Relative to the PEL, Express Service Printing, September 15, 1995. Personal Samples.

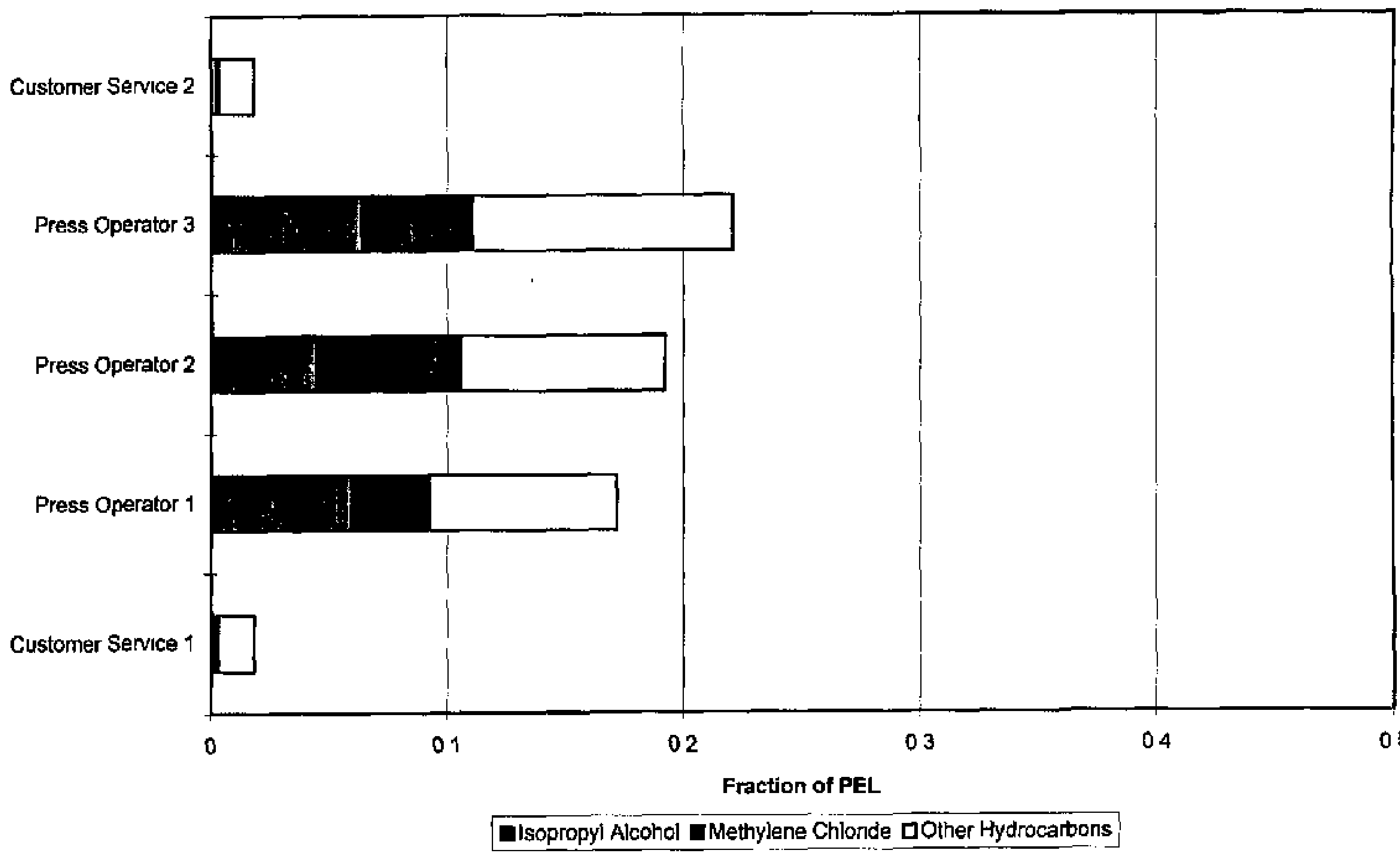


Figure 11. Concentrations Relative to the PEL, Express Service Printing, September 15, 1995. Area Samples.

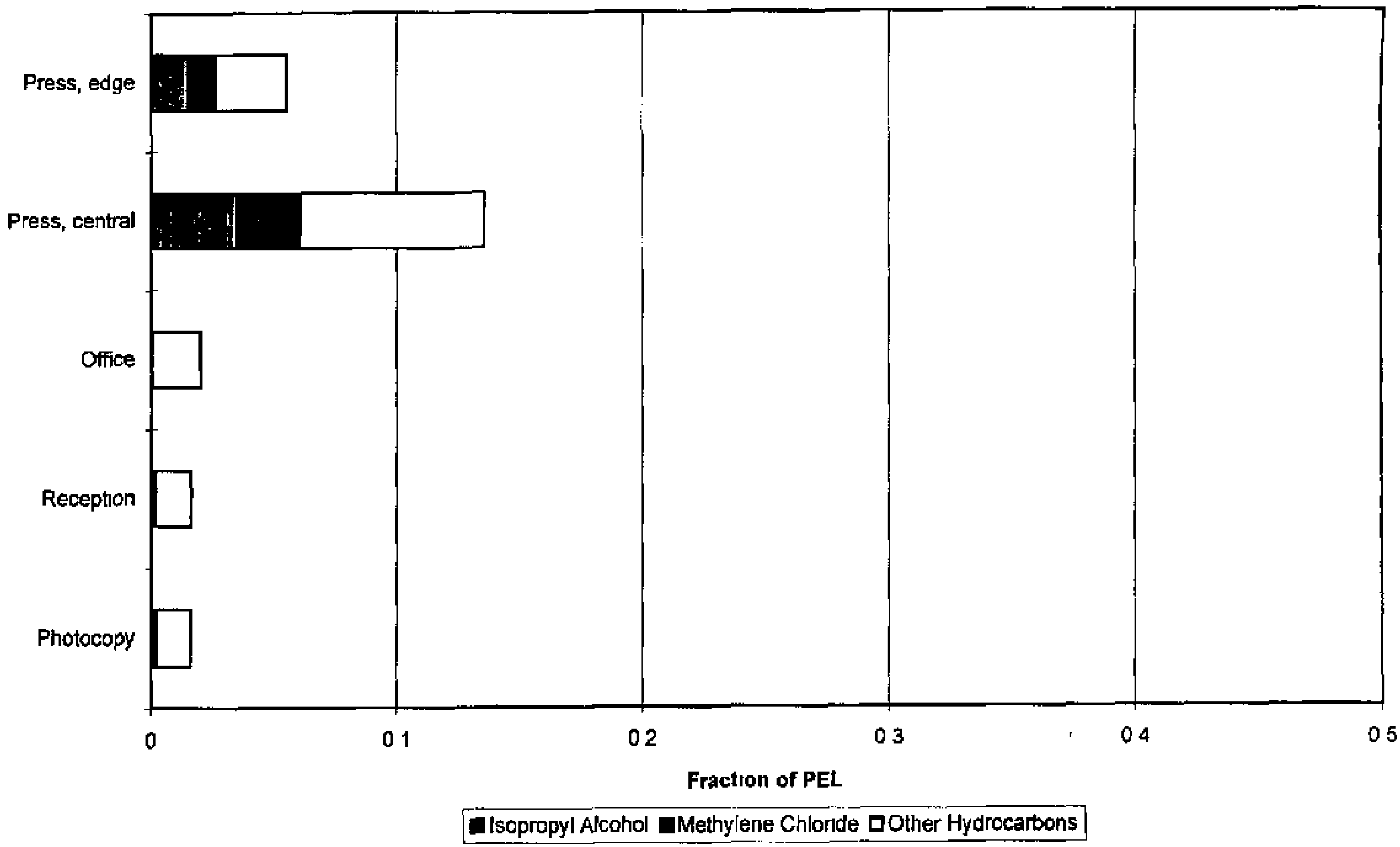


Figure 12. ESP, Concentration vs Time, B & K Data, August 10 & 11, 1995.

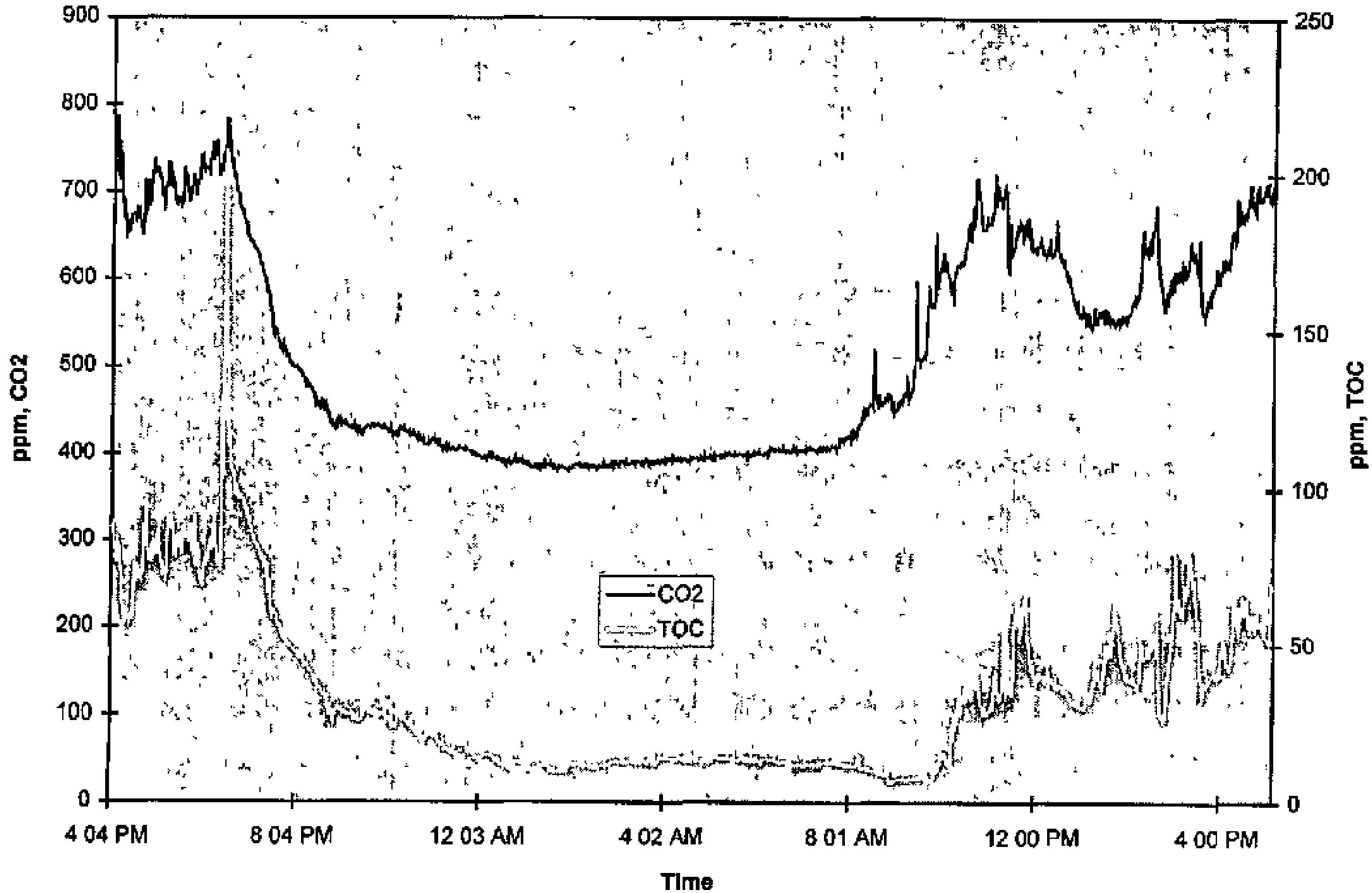


Figure 13. ESP, Concentration vs Time, B & K Data, September 14 & 15, 1995.

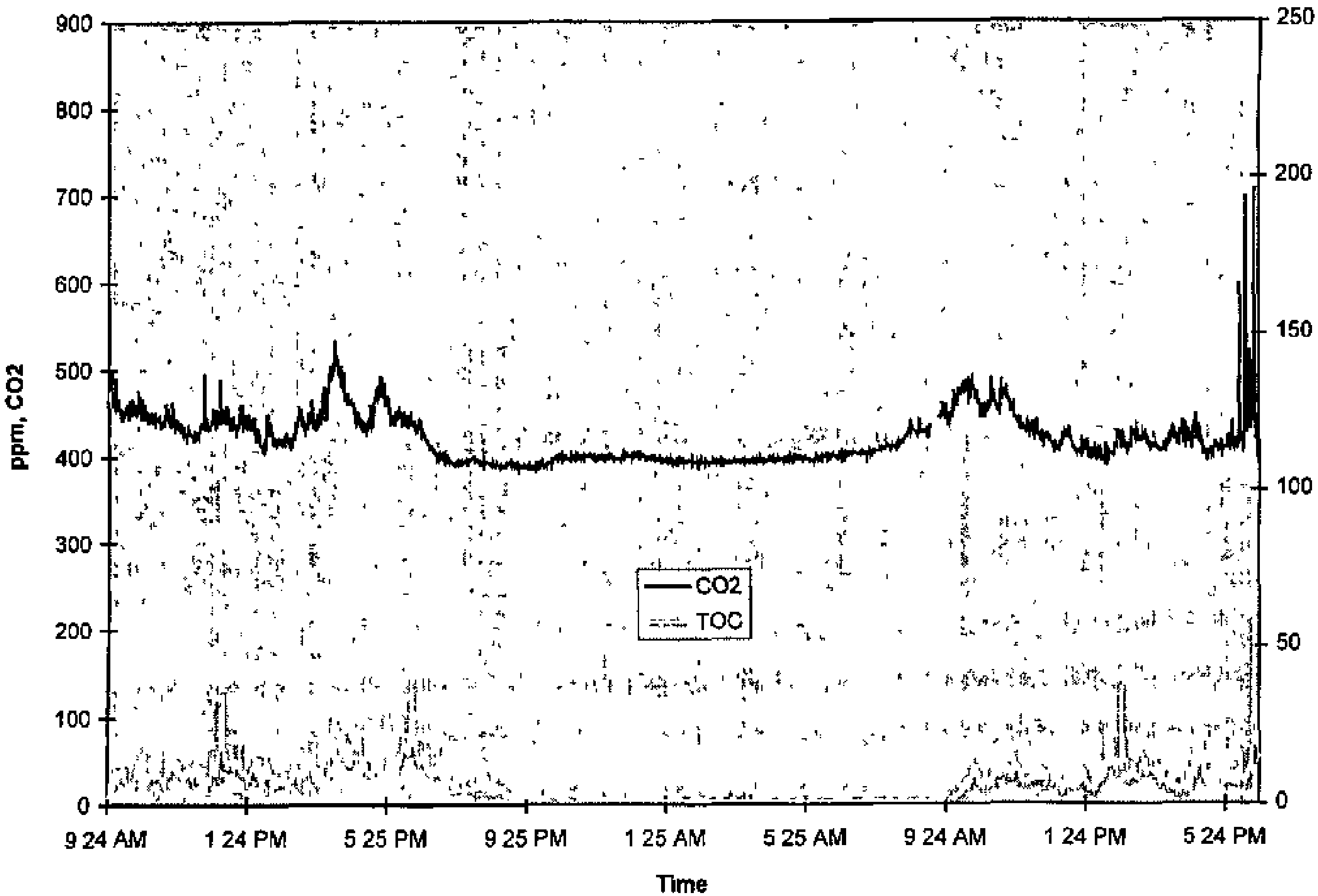


Figure 14. ESP, Dust Concentration vs Time, DataRAM, August 9-11, 1995.

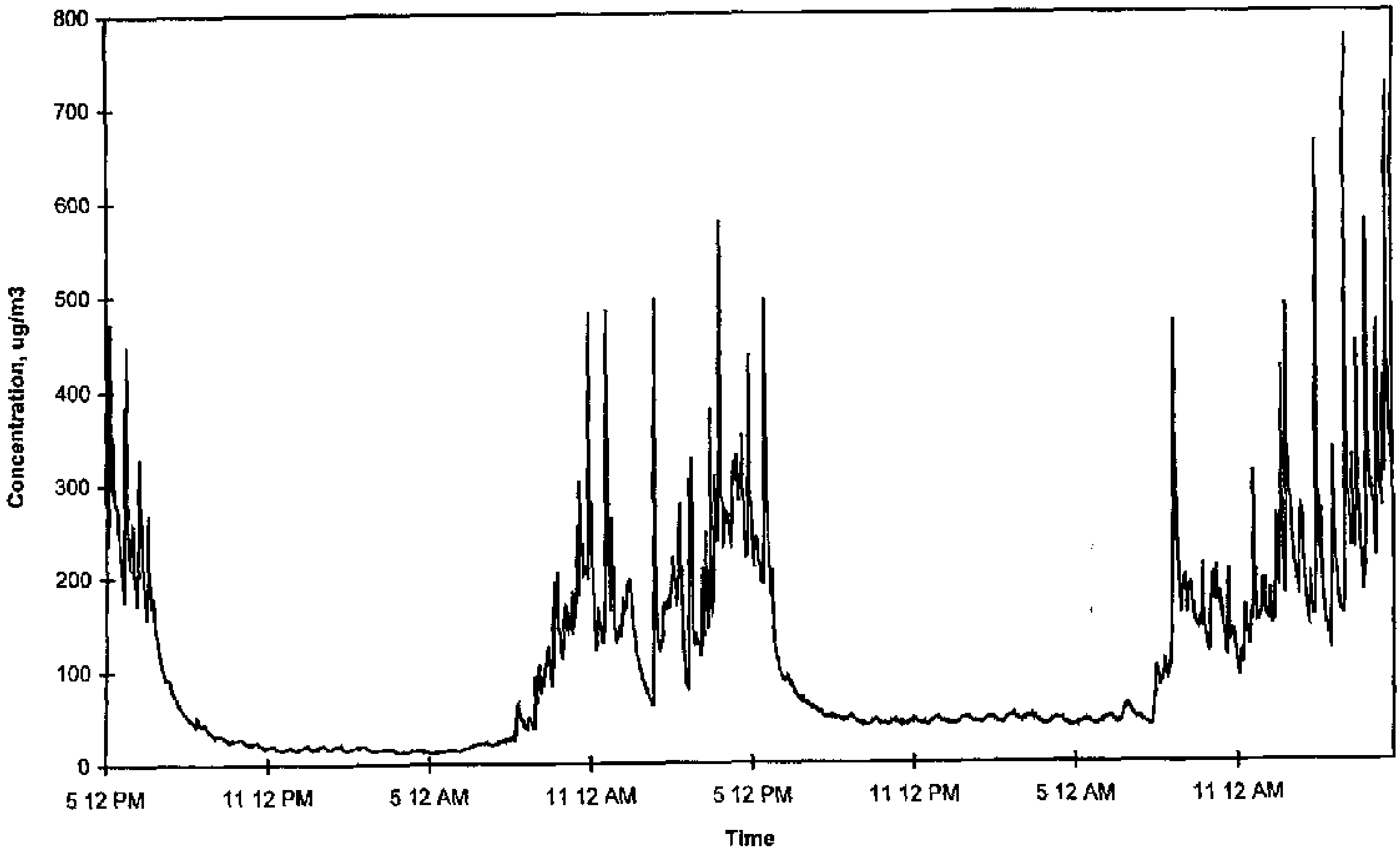


Figure 15. ESP, Dust Concentration vs Time, DataRAM, September 14 & 15, 1995.