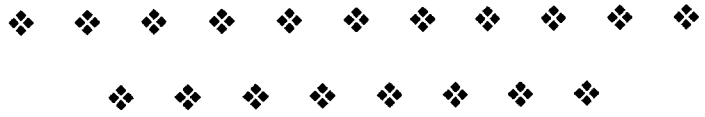
PERC

# USAGE OF CHEMICAL BRAKE CLEANERS IN AUTOMOTIVE REPAIR FACILITIES



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## ABSTRACT

A survey was conducted to determine the usage patterns of aerosol brake cleaner products. A survey questionnaire was sent to 5,000 brake cleaner repair shops within the United States. The questionnaire consisted of 18 questions which addressed physical parameters of the shops, numbers of people working in the shops as well as the numbers that perform brake repair service, weekly rates of brake jobs and aerosol can usage. A total of 569 questionnaires were returned for an overall response rate of 12% of which 436 reported using aerosol chemical brake cleaners. The average garage size was over 66,172 cubic feet and an average of 3.2 bays were used to perform brake repair services. The majority of garages reported using open doors as one means of ventilation. The average shop conducts 7.8 brake jobs each week and uses 0.85 aerosol cans per job. About half of the respondents reported using the aerosol brake cleaner for other uses.

The information obtained in the survey was also used to estimate workplace concentration levels from aerosol cans containing 100% perchloroethylene. Worst case and average case assumptions concerning shop air turnover rates, and daily number of aerosol cans used per day were used in the calculation in order to determine if the threshold limit value (TLV) of 25 ppm (8-hour time-weighted average, or TWA) for perchloroethylene recommended by the American Conference of Governmental Industrial Hygienists (ACGIH) would be exceeded. Under average case assumptions (daily shop air volume turnover rate of 36 and the midpoint of the range of the number of cans used per day), 0.7% of shops exceeded the TLV, and none exceeded the current permissible exposure limit (PEL) of 100 ppm 8-hour TWA established by the Occupational Safety and Health Administration. Under worst case assumptions (daily shop air volume turnover rate of nine and using the high endpoint of the range of cans used per day) less than 9% exceeded the TLV.

The survey was not designed to address the potential to exceed the recent ACGIH 15-minute short-term exposure limit (STEL) recommendation of 100 ppm. Collection of relevant data is now underway, and decisions concerning formulation of aerosol brake cleaner products should take into account the information being developed and any other information that may be available concerning the possibility of exceeding the ACGIH STEL recommendation.

Two field studies were available in which actual perchloroethylene concentrations were measured in brake repair shops. Estimates of perchloroethylene in these shops were made using the reported quantities of aerosol used per work period. The estimates were similar to the actual measured values.

# Usage of Chemical Brake Cleaners in Automotive Repair Facilities

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## 1.0 Introduction

Firms that formulate and manufacture halogenated solvents are concerned with determining potential human exposure to those chemicals in their various applications. This report deals with one application of interest to formulators and manufacturers: the use of aerosol chemical brake cleaners in commercial automotive repair facilities.

In support of the product stewardship programs of its member firms, the Halogenated Solvents Industry Alliance, Inc. (HSIA) conducted a survey of automotive repair facilities. The goal of the survey was to provide a description of the level of usage of chemical brake cleaners in commercial settings. This paper details the results of the survey and contains a summary description of characteristics of the respondent firms and of their usage of chemical brake cleaners.

This paper also attempts to link the levels of usage observed in the brake repair facilities surveyed to theoretical and empirical levels of potential concentrations of perchloroethylene in the workplace and includes detailed descriptions of the alternative assumptions underlying the two usage scenarios employed in calculations.

The model yields distributions of theoretical workplace concentrations that interested parties may use as aids in making judgments as to the workplace concentration of perchloroethylene under different usage scenarios. The general model may also be used to generate distributions of theoretical exposure to other chemical compounds that might also be used in chemical brake cleaners.

The principal finding of the study is that, under proposed assumptions, the incidence of workplace concentrations of perchloroethylene in excess of the threshold limit value (TLV) of 25 ppm (8-hour time-weighted average, or TWA) recommended by the American Conference of Governmental Industrial Hygienists (ACGIH) is low, even in the case of formulations using 100% perchloroethylene. After the survey was circulated, the ACGIH 15-minute short-term exposure limit (STEL) was lowered to 100 ppm. This report does not address whether short-term concentrations above the ACGIH STEL are likely to occur, nor does it address possible use of aerosol brake cleaners in residential garages.

## 2.0 Survey and Methodology

The survey attached as Exhibit 1 was developed by HSIA staff, in consultation with the author and with representatives of member firms of HSIA. Initial drafts were circulated and pretested, and the final questionnaire represents a balancing of efforts at completeness and parsimony.

On March 12, 1993, HSIA mailed copies of the survey along with prepaid return envelopes to 2,000 automotive repair facilities across the United States. On April 13, 1993, a second mailing of questionnaires went to an additional 3,000 facilities. The mailing labels were provided by the Alvin Zeller Company of New York, which maintains a list of 39,311 automotive repair shops in all states (excluding the District of Columbia). Approximately 185 surveys were returned by the post office because of incorrect addresses, incorrect names, expired forwarding addresses, or similar reasons. No follow-up letters were sent to either set of recipients of the surveys.

HSIA stopped processing returned questionnaires on April 26, 1993. As of that date, 594 total surveys had been returned for an overall response rate of 12%. Of those, 569 (96%) indicated that automotive brake repairs were performed at their facilities and were thus usable in the study. Of the 569 shops performing brake repair work, 436 respondents (77%) indicated that they used aerosol chemical brake cleaners. Those 436 respondents provided the data for the analyses of greatest interest to HSIA representatives studying aerosol brake cleaners. Analysis of the postmarks on the return envelopes indicated that surveys were received in numbers roughly proportional to the populations of the 45 states from which they were returned.

## 3.0 Results

Tables 1–8 contain descriptive univariate statistics, which give an overview of the kinds of information received from the surveyed facilities.

Table 1 summarizes the results from survey questions 2 and 3 and shows that respondent facilities (hereinafter referred to as "shops") averaged over four service bays, with just over three of them used in performing brake service. The most frequently given shop size was three bays, and the most frequent response to "How many bays perform brake service work?" was two.

Table 2 (results from survey questions 4 and 5) indicates that an average bay was about 26 feet long and about 15 feet wide; it also indicates that the service area of the shops averaged almost 70 feet by about 53 feet, with an average ceiling height of 15.6 feet.

One variable of considerable interest is shop ventilation. It was assumed that respondents were unlikely to be able to indicate the flow of air through the facilities in cubic feet per minute. Therefore, an alternative measure (question 6) addressed the different types of ventilation used. Table 3 details the response categories and frequencies. The Building Officials and Code Administrators (BOCA) standard for air flow in an automotive repair facility is 1.5 cubic feet per minute per square foot of floor area. In the case of an average-sized shop, with a ceiling height of 20 feet, there would be 4.5 complete shop air volume turnovers per hour, or 36 turnovers

during an 8-hour working period.

Questions 7 and 8 on the survey asked about the number of people in the service area and the number of people performing brake service work. The results presented in Table 4 indicate that the modal response was "1–3 for both questions, and that it was unusual to find more than six persons in a shop who normally performed brake service work. The averages reported in the right-hand column were calculated by assuming that each response in a category represented the midpoint of that interval.

The results of question 18 regarding use of aerosols in the presence of open flames are presented in Table 5. About 50% of the shops reported using open flames and/or welding equipment. Therefore, flammability of compounds used in aerosol brake cleaners may be an issue of concern. Furthermore, an Occupational Safety and Health Administration (OSHA) regulation sets forth precautions that should be taken to prevent vapors of chlorinated hydrocarbons from reaching the atmosphere surrounding welding operations (29 C.F.R. 1910.252).

Table 6 (questions 9 and 12) reveals that the average incidence of brake repair was about eight brake jobs per week. Most respondents indicated they used less than one can of chemical brake cleaner per brake job. On the issue of what constituted a "brake job," a follow-up telephone survey of respondents revealed that a single

"brake job" was considered the repair of a single car, regardless of the number of brakes being repaired. Respondents indicated that about half of the brake jobs were performed on two brakes, either front or rear, and about half were brake jobs involving all four brakes.

Over 75% of the respondents reported using less than one aerosol can per brake job, and none used over two cans. Assuming that "less than one can" means 0.75 of one can, the average amount of brake cleaner used per brake job is 0.85 aerosol cans (Table 6). Multiplying average usage per job (0.85 cans) by average number of brake jobs performed each week (7.8, Table 6) demonstrates that less than seven cans (6.6 cans) are used per week.

Table 7 contains the responses to question 17, "What is the total number of cans used at the entire facility each week?" The modal response was "1-3," and a usage rate of more than 36 cans occurred only twice in the sample of respondents.

Although the survey included a possible response of "73 and above," no one chose this category. Therefore, using the midpoints of the intervals as average responses in each category, an average usage of less than six cans (5.6 cans) of product per week was calculated.

This result is in agreement with the calculated value of 6.6 cans using the responses from questions 9 and 12 as demonstrated above. It is possible that the

assumption that "less than one can" equals 0.75 of one can is too conservative. In addition, the responses in Table 8 show that chemical brake cleaners were used (on the average) for a multitude of degreasing applications. About half of respondents claimed to employ the product for some use other than cleaning brakes. These results would indicate that the actual amount used for cleaning brakes would be less than the total amount reported in the questionnaire.

In an effort to understand how intensely the facilities were used (and therefore, how high the concentrations might be in the most active shops), questions 3 (number of bays performing brake service work) and 9 (brake jobs performed per week), questions 8 (number of people performing brake service work) and 9, and questions 9 and 17 (number of aerosol cans used per week) were cross tabulated (Tables 9-11). The category was defined as either low intensity (10 or fewer brake jobs performed each week) or high intensity (more than 10 brake jobs performed each week). Results in Table 9 show that the number of brake jobs done per week was conditional on the number of bays performing brake service work. There appeared to be some potential for higher exposure in small shops: 55 shops with 1–3 bays were performing 11 or more brake jobs per week. Table 10 demonstrates that when fewer people (1–3) perform brake service work, fewer brake jobs per week (1–10) are performed. Furthermore, the number of cans used was conditional on the number of brake jobs

performed (Table 11). These findings demonstrate that the information obtained from the questionnaire is both reasonable and reliable.

Table 12 estimates the mean aerosol can weekly usage levels using interval midpoints (question 17) to be 5.57 cans per week. By assuming that there are 544 g of perchloroethylene per aerosol can and that the work week represents 5.25 days (see assumptions below), a daily average of 576.87 g was calculated. Under worst case assumptions, the top of the interval of each category in question 17 was used to estimate a mean weekly aerosol can usage of 7.49. This represents a daily average use of 814.88 g of perchloroethylene, assuming that the work week is five days (see assumptions below).

### 3.1 Further analyses

A number of assumptions were made in order to estimate time-weighted average (TWA) concentrations of perchloroethylene that could result under various usage patterns of brake cleaner aerosols in repair shops. The assumptions are as follows:

1. Each aerosol can contained only 544 g of perchloroethylene (a 100% perchloroethylene formulation) and 16 g of carbon dioxide as a propellant.

2. When a can of perchloroethylene was used, the entire 544 g were released and volatilized into the air.

3. The air turnover rate was taken as 1.5 $ft^3/min * ft^2$ (the BOCA standard

recommended for "brake repair shops"). There are 36 volume changes during an 8-hour work period:

$$\frac{[1.5\ ft^3/\text{min}{\cdot}ft^2][60\ \text{min}/hr][8\ hr/work\ period]}{[20\ ft\ ceiling\ height]} = 36$$

Although the average ceiling height reported in the survey was 15.6 ft (Table 2), a ceiling height of 20 ft was used in the above calculation, resulting in a more conservative estimate of volume changes during the work period. Under a worst case scenario, the number of volume changes during an 8-hour work period was arbitrarily taken as nine.

4. A workday was considered to be eight hours. About one half of the shops were open for an average of 0.5 days on Saturday (follow-up telephone survey). It was therefore assumed that a work week was 5.25 days, under average conditions. Under the worst case scenario, it was assumed that no operations occurred on Saturday or Sunday, and that the work week was five days. Table 13 summarizes the assumptions that were made in estimating workplace concentrations under different conditions.

The following equation was used to determine TWA concentrations of perchloroethylene under different usage practices:

$$C_s = \frac{(24.45 \times 10^3 m^3/mol)(A)(B)(10^6)}{(M)(V)(1 + D)}$$

$C_s$ = ppm
$A$ = 544 g perchloroethylene/aerosol can
$B$ = number of cans used per work period
***midpoint of interval/5.25 days (average case conditions)
***maximum of interval/5.0 days (worst case conditions)
$M$ = 165.8; molecular weight of perchloroethylene
$V$ = shop volume ($m^3$)
$D$ = volume changes/work period
***36 volume changes (average case conditions)
***9 volume changes (worst case conditions)

Table 14A summarizes the calculations of estimated 8-hour TWA concentrations of perchloroethylene in the workplace under different conditions of aerosol brake cleaner usage. Under average case conditions, the maximum and minimum TWA was determined to be 35.75 ppm in the 4–6 cans per week category and 0.05 ppm in the 1–3 cans per week category, respectively. Under worst case conditions, the maximum TWA was calculated to be 166.65 ppm in the 4–6 cans per week category, and the minimum was determined to be 0.29 ppm in the 1–3 cans per week category. The highest average TWA concentrations were 4.99 in the 13–36 cans per week category and 28.49 in the 13-36 cans per week category under the average and worst case conditions, respectively. The overall average (all categories) under average case

assumptions was 2.18 ppm and under worst case assumptions was 11.34 ppm (Table 14B).

Table 15 lists the frequencies of TWA workplace concentrations of up to 1, 5, 10, 15, 20, 25, and over-25 ppm (the results are also presented in Figure 1). Under the "normal" case assumptions, three incidents of theoretical workplace concentrations in excess of the ACGIH TLV of 25 ppm were found. Under the "conservative" assumptions, 38 such incidents were found.

Differences between "high workplace perchloroethylene concentration" (greater than or equal to 25 ppm) and "low workplace perchloroethylene concentration" (less than 25 ppm) shops were evaluated. The hypotheses that the means from the groups were equal were tested using two-tailed t-tests under the worst case conditions in order to calculate a number of theoretical air concentrations in excess of 25 ppm. As displayed in Table 16, the results indicate that for the group with "high" theoretical air concentrations, the number of bays doing brake work was no different from that of the "low" level category group, but the number of bays in total was smaller. That is, smaller shops doing the same amount of work were more likely to have high air concentrations. Significant differences in the shop dimensions were also found, but not in the bay dimensions: Smaller shops had a greater incidence of high air concentrations. Not surprisingly, high air concentrations were also related to product

usage rates, to the number of brake jobs done per day, and to the number of brake jobs done per bay each day; a measure of the intensity of the facility's usage for brake repair work. In Table 17, theoretical workplace concentrations were found to depend on shop size, with people in larger shops being less likely to experience perchloroethylene levels above the ACGIH TLV.

Table 18 demonstrates the differences in the means of three calculated variables—brake jobs per bay per day, concentrations under "average" assumptions, and concentrations under "conservative" assumptions—in small and large shops. Small shops have higher means for all three variables.

## 3.2 Predictability of the Model

In order to verify the ability of the model to estimate the air concentration of solvent in the workplace, calculated air concentrations were compared to empirical results obtained in industrial hygiene monitoring studies that previously had been conducted in automotive repair shops. These field studies used aerosol brake cleaner products containing different formulations of perchloroethylene, 1,1,1-trichloroethane, and other components.

In one study, workers wore personal monitors while working with a brake cleaner formulation containing 60% perchloroethylene (Olberding and Mainz, 1992). The three workers were monitored for 4-hour periods on ten different occasions. The

average amount of product used was 1.4 cans per daily work period, which is slightly more than the average daily usage rate of 1.06 cans found in the survey. The monitoring results showed that the average measured workday perchloroethylene TWA in air was 3.8 ppm. A theoretical perchloroethylene TWA concentration in air of 1.4 ppm was calculated by using the reported amounts of perchloroethylene released from the aerosol cans each work period, the shop volume of 59,109 cubic ft (1,674 cubic meters) and the average case assumption that there were 36 air changes during the workday. The study report indicated that no ventilation equipment was used during the trials, therefore the average case assumption of 36 air turnovers may be too high for this facility. In the worst case assumption where nine air changes during the workday is used, the estimated TWA perchloroethylene concentration in air was 5.2 ppm.

In another study conducted in a 19-bay repair shop, eleven workers wore personal monitors for about seven hours while working with a brake cleaner formulation containing 75% perchloroethylene (Jurgiel, 1992). The reported amount of brake cleaner used was 27.5 cans on the day the monitoring study was conducted. This daily usage rate is much higher than the average daily usage rate of 1.06 cans found in the survey, and none of the shops responding to the survey report using over 72 cans per week. The monitoring results showed that the average measured workday perchloroethylene TWA in air was 20.7 ppm. By using an average bay size of 407.6

sq ft and an average height of 15.6 ft (as reported in Table 2 of the survey), a shop volume of 120,813 cubic ft (3421 cubic meters) was calculated. A theoretical perchloroethylene TWA concentration in air of 13.1 ppm was calculated by using the estimated shop volume, the reported amount of perchloroethylene released from the aerosol cans and the average case assumption that there were 36 air changes during the workday. In the worst case assumption where nine air changes during the workday is used, the estimated TWA perchloroethylene concentration in air was 48.4 ppm.

Comparison of the estimated TWA air concentrations with the empirical data from the two field studies shows that the model produces reasonable estimates of the air concentrations using the normal case assumptions, and that the worst case assumptions are adequately conservative to provide reasonable estimates of air concentrations even under conditions of low ventilation or high usage rates that are clearly outside the normal use patterns as determined by the survey responses.

## 4.0 Discussion and Conclusions

Results from the survey revealed that most shops use less than one can of product per brake job, and that on average facilities reported using about one can per day. The estimations of concentrations in the workplace based on survey data indicate that exposure in excess of the ACGIH TLV is unlikely to result in the absence of very

intense usage of the product in a small facility.

The theoretical incidence of workplace air concentrations exceeding 25 ppm over the workday (using aerosol cans containing 100% perchloroethylene and normal case assumptions) was determined to be 0.7%; these concentrations were 27, 32, and 38 ppm. If the formulation used was decreased to 50% perchloroethylene, the actual air levels would be decreased proportionally and all shops in the survey would be below the TWA of 25 ppm. It should also be noted that under normal case assumptions, none of the estimates calculated exceeded the

current permissible exposure limit (PEL) of 100 ppm 8-hour TWA adopted by the Occupational Safety and Health Administration (OSHA)[1].

An egregious overuse of the product (worst case assumptions) resulted in shop[1] air concentrations exceeding the TLV in less than 9% of cases. Even under this worst case scenario, only 3 out of 428 shops theoretically exceeded the OSHA PEL of 100 ppm TWA.

Because some of the variables were incompletely defined in the survey, or respondents omitted information that could have a material consequence, clarification was obtained in follow-up telephone surveys to eliminate as much ambiguity as

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[1]The previous OSHA PEL of 25 ppm 8-hour TWA, which was in effect at the time the brake cleaner survey was designed, was vacated by a federal court.

possible.

No attempt was made to quantify nonresponsive bias, nor is it likely to be a problem. However, if nonresponding firms are materially different from those that responded (e.g., if they practiced poor industrial hygiene and unsafe product usage), that fact is necessarily unknown.

Furthermore, some of the variables had a category "greater than" or "less than" some number. Where there were responses in those categories, averages are technically unavailable; assumptions were made about the meaning of "greater than" or "less than" in order to use the responses in calculations, and a note of the direction of the bias was made. Readers should consider the frequencies of the responses as well as the reported average responses. The distribution of responses is, after all, discrete in most cases.

This study did not address possible use of the product in residential garages (e.g., the do-it-yourself user) and is silent on issues dealing with this market. If there is significant household use, additional study would be required to address issues of product packaging (for example, designs that would prevent accidental spraying toward the user's face) and adequate labeling.

Although the likelihood of ordinary brake cleaner usage resulting in concentrations exceeding the current OSHA acceptable ceiling concentration of 200

ppm and acceptable maximum peak above the ceiling of 300 ppm (for 5 minutes in any 3 hours) seems low, the potential to exceed the 15-minute ACGIH short-term exposure limit (STEL) of 100 ppm was not addressed in this study as additional information on individual worker usage behavior would be required. Collection of such data is being considered by HSIA. Decisions concerning formulation of aerosol brake cleaner products should take into account such information as may be available concerning the possibility of exceeding the ACGIH STEL recommendation.

The most important contribution of this study is for industrial hygienists to understand better how aerosol brake cleaner products are used in the workplace and to use these findings to determine whether practices need to be altered in order to maintain acceptable perchloroethylene concentrations in workplace air. The use of the data to estimate workplace air concentrations has been demonstrated.

Estimates of concentrations in the workplace were made in this paper using conservative assumptions; others who may wish to utilize these data may wish to make and use other assumptions that would better reflect more specific workplace conditions and product usages.

## References

Jurgiel, J. P. (1992), *Results of the Industrial Hygiene Investigation of Various Solvents for Potential Aerosol Degreasing Applications, January-February, 1991* (mimeo).

Nyberg, J. M. and E. L. Mainz (1993), *Applications Research Group Task Report: Industrial Hygiene Study of Methylene Chloride/Perchloroethylene/Methylchloroform Blended Aerosol Brake Cleaners* (mimeo).

Exhibit 1
Survey Instrument

# Questionnaire on Aerosol Brake Cleaner Use Patterns

1. Do you perform brake repair service?
   Yes ☐ No ☐
   If yes, please answer the following questions.
   If no, please stop here and return questionnaire.

2. How many service bays are in your garage?
   1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 or more ☐

3. How many bays perform brake service work?
   1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 or more ☐

4. What is the average size of each bay?
   Length in feet _____ Width in feet _____

5. What are the approximate dimensions of the entire shop area (including storage and other areas not partitioned off as separate rooms)?
   Length in feet _____ Width in feet _____ Height in feet _____

6. What types of ventilation are present?
   Wall fan ☐ Ceiling or exhaust fan ☐ Non-powered roof ☐ Ventilator ☐ Open doors ☐ Other _____

7. What is the total number of people working in the service area?
   1 to 3 ☐ 4 to 6 ☐ 7 to 10 ☐ 11 to 15 ☐ 16 or more ☐

8. How many of the people in the service area perform brake service?
   1 to 3 ☐ 4 to 6 ☐ 7 to 10 ☐ 11 to 15 ☐ 16 or more ☐

9. How many brake jobs are done each week?
   1 to 5 ☐ 6 to 10 ☐ 11 to 15 ☐ 16 to 30 ☐ 30 or more ☐

10. Do you use a chemical brake cleaner?
    Yes ☐ No ☐
    If yes, please answer the following questions.
    If no, please stop here and return questionnaire.

11. What type of brake cleaner package do you use?
    ☐ Aerosol can ☐ One gallon can ☐ Five gallon can

12. If aerosol cans are used, how many are used per brake job?
    Less than 1 ☐ 1 ☐ 2 ☐ 3 ☐

13. Where are the brake parts cleaned?
    On the vehicle ☐ Off the vehicle ☐ On and off the vehicle ☐

14. When the brake parts are cleaned with aerosol, are the parts at:
    Floor level ☐ Eye level ☐ Bench level ☐

15. Are brake cleaners used for other jobs besides cleaning brakes?
    Yes ☐ No ☐

16. If answer to 15 above is Yes, check other uses below.
    ☐ Engine degreasing
    ☐ Cleaning tools
    ☐ Cleaning cloths/Removing spots
    ☐ General cleaning
    ☐ Other

17. What is the total number of aerosol cans used at the entire facility each week?
    1 to 3 cans ☐ 4 to 6 cans ☐ 7 to 12 cans ☐ 13 to 36 cans ☐ 37 to 72 cans ☐ 73 and above ☐

18. Are cutting/welding torches employed or are other open flames or sparks present in the work area?
    Yes ☐ No ☐

To register for the FREE Trip Drawing:
Name _____
Company _____
Bus. Address _____
_____ ZIP _____

*Please return your completed questionnaires to the HSIA, 2001 L Street, N.W., Suite 506, Washington, D.C. 20036, in the enclosed postage-paid envelope.*

TABLE 1

| | Survey Question | Service Bays * | 1 | 2 | 3 | 4 | 5 | 6 | 7+ | Avg |
|---|---|---|---|---|---|---|---|---|---|---|
| Total Sample N=569 | 2: How many service bays are in your garage? | 2 | 12 | 80 | 118 | 102 | 79 | 64 | 112 | 4.4 |
| | 3: How many bays perform brake service work? | 6 | 75 | 170 | 119 | 80 | 52 | 33 | 34 | 3.2 |
| Aerosol Users N=436 | 2: How many service bays are in your garage? | 1 | 7 | 57 | 97 | 83 | 54 | 47 | 90 | 4.4 |
| | 3: How many bays perform brake service work? | 3 | 51 | 136 | 94 | 63 | 39 | 24 | 26 | 3.2 |

Notes:
- Average value is biased downward because the value "7" represents the response "7 or more."

*Response left blank

TABLE 2

| | Shop Sizes | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Survey Question | Bay dimensions (feet) | | | Service Area Dimensions (feet) | | | |
| | | Length | Width | Square Feet | Length | Width | Height | Cubic Feet |
| Total Sample N=547 | 4: What is the average size of each bay? | 26.2 (7.9) | 14.6 (6.2) | 397.8 (270.0) | | | | |
| | 5: What are the dimensions of the service area? | | | | 68.9 (46.2) | 53.3 (29.6) | 15.6 (4.4) | 73288* (183487) |
| Aerosol Users N=425 | 4: What is the average size of each bay? | 26.4 (8.1) | 14.8 (6.6) | 407.6 (290.7) | | | | |
| | 5: What are the dimensions of the service area? | | | | 69.1 (44.7) | 52.5 (26.3) | 15.6 (4.2) | 66172* (100967) |

Notes:
o Cell entries are averages; standard deviations in parentheses

* Some of the shops surveyed only provided total volume and not dimensions. These shops were included in the average shop volume calculations.

TABLE 3

| Ventilation methods in use | | | | |
|---|---|---|---|---|
| Survey Question 6<br>What types of ventilation are present? | Total Sample | | Aerosol Users | |
| | No | Yes | No | Yes |
| a. Wall Fan | 421 | 147 | 321 | 115 |
| b. Ceiling or exhaust fan | 344 | 224 | 261 | 175 |
| c. Non-powered roof | 507 | 61 | 390 | 46 |
| d. Ventilator | 508 | 60 | 390 | 46 |
| e. Open doors | 76 | 492 | 60 | 376 |

TABLE 4

| | Personnel | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Survey Question | * | 1–3 | 4–6 | 7–10 | 11–15 | 16+ | Avg |
| Total Sample N=566 | 7: What is the total number of people in the service area? | 3 | 309 | 214 | 37 | 4 | 2 | 3.7 |
| | 8: How many of the people in the service area perform brake service? | 1 | 438 | 121 | 8 | 0 | 1 | 2.8 |
| Aerosol Users N=436 | 7: What is the total number of people in the service area? | 2 | 230 | 171 | 28 | 4 | 1 | 3.7 |
| | 8: How many of the people in the service area perform brake service? | 0 | 333 | 96 | 6 | 0 | 1 | 2.8 |

Notes:
- Average value is calculated based on the midpoint of each interval times its frequency, except for the entry 16+, which was assumed to represent a value of 20.

*Response left blank

TABLE 5

| Use of Open Flames | | | | |
|---|---|---|---|---|
| Survey Question 18 | Total Sample (N= 498) | | Aerosol Users (N= 434) | |
| | No | Yes | No | Yes |
| 18: Are cutting/welding torches or are other open flames or sparks present in the work area? | 168 | 330 | 144 | 290 |

TABLE 6

Brake Work and Aerosol Usage

| Survey Question | 9: How many brake jobs are done each week? | | | | | | | 12: How many aerosol cans are used per brake job? | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | * | 1–5 | 6–10 | 11–15 | 16–30 | 31+ | Avg | * | <1 | 1 | 2 | 3+ | Avg |
| Total Sample | 3 | 270 | 174 | 64 | 45 | 13 | 8.1 | | | | | | |
| Aerosol Users | 2 | 205 | 140 | 52 | 31 | 6 | 7.8 | 13 | 318 | 88 | 17 | 0 | .85 |

Notes:

- Average value of 9 is calculated based on the midpoint of each interval times its frequency, except for the entry 31+, which was assumed to represent a value of 40.
- Average value of 12 is calculated based on the frequency of each value, except for the cases using "<1" can; that response was assumed to represent a value of 0.75 cans per job. No respondents indicated usage exceeding 2 cans per brake job.

*Response left blank

TABLE 7

| Cans Used per Week | | | | | | | |
|---|---|---|---|---|---|---|---|
| Survey Question | Aerosol Users | | | | | | |
| | * | 1–3 | 4–6 | 7–12 | 13–36 | 36–72 | Avg |
| 17: How many cans per week are used in your facility? | 2 | 219 | 117 | 71 | 25 | 2 | 5.6 |

Notes:

o Average usage is calculated based on the midpoint of each frequency multiplied by its frequency. No respondents indicated usage exceeding 72 cans per week.

* Response left blank

TABLE 8

| Alternative Uses of Brake Cleaner | | | | |
|---|---|---|---|---|
| Survey Question | Total Sample | | Aerosol Users | |
| | No | Yes | No | Yes |
| 15: Do you use aerosol brake cleaner for other purposes? | 247 | 238 | 211 | 221 |
| 16: Specific uses -- | | | | |
| a: Degreasing | 135 | 107 | 129 | 95 |
| b: Cleaning tools | 149 | 94 | 136 | 88 |
| c: Spot Removal | 168 | 75 | 152 | 72 |
| d: General cleaning | 129 | 114 | 117 | 107 |
| e: Other uses | 185 | 58 | 167 | 57 |

# TABLES 9, 10, 11

Table 9
Intensity of facility usage for brake work

| | | Bays performing service work | | Row total |
|---|---|---|---|---|
| | | 1-3 | 4 or more | |
| Brake jobs per week | 1-10 | 308 | 134 | 442 |
| | 11 or more | 55 | 64 | 119 |
| Column total | | 363 | 198 | 561 |

Notes
Reference Questions 3 and 9 on survey.
$\chi 2$ value of 22.5 with 1 df significant at .01.

Table 10
Intensity of personnel usage for brake work

| | | People performing brake service work | | Row total |
|---|---|---|---|---|
| | | 1-3 | 4 or more | |
| Brake jobs per week | 1-10 | 376 | 68 | 444 |
| | 11 or more | 61 | 61 | 122 |
| Column total | | 437 | 129 | 566 |

Notes
Reference Questions 8 and 9 on survey.
$\chi 2$ value of 65.4 with 1 df significant at .01.

Table 11
Intensity of aerosol brake cleaner usage for brake work

| | | Number of cans used per week | | Row total |
|---|---|---|---|---|
| | | 1-3 | 4 or more | |
| Brake jobs per week | 1-10 | 192 | 151 | 343 |
| | 11 or more | 26 | 63 | 89 |
| Column total | | 218 | 214 | 432 |

Notes
Reference Questions 9 and 17 on survey.
Aerosol users only.
$\chi 2$ value of 20.2 with 1 df significant at .01.

TABLE 12

| Mean Usage Levels | | | |
|---|---|---|---|
| Survey Question 17 | Cans Used per week | Cans Used per day | Grams used per day |
| Average case assumptions | 5.57 (6.36) | 1.06 (1.21) | 576.87 (659.48) |
| Worst case assumptions | 7.49 (8.92) | 1.50 (1.78) | 814.88 (970.69) |

Notes
- o Cell entries are means for aerosol users.
- o Standard deviations appear in parentheses.
- o All cases assume 100% perc formulation, 544 grams/can.
- o Average case assumptions assumes a 5.25 day work week.
- o Worst case assumptions assumes a 5.0 day work week.

TABLE 13

| Assumptions | | | |
|---|---|---|---|
| Variable | Realistic (Plausible Case) | Conservative (Worst Case) | Notes |
| Solvent concentration | 100% | 100% | |
| Size of can used | 20 oz | 20 oz | |
| Amount of PERC per can | 544 grams (19oz) | 544 grams(19 oz) | |
| Air turnover rate | 36/day | 9/day | BOCA national code for auto repair facilities is 1.5 cfm/ft2; ceiling height 20 ft; working day 8 hours |
| Number of days in work week | 5.25 | 5 | About 1/2 the facilities are open for about 1/2 day on Saturday |
| Usage in cans/week | Interval midpoint | Interval Maximum | |
| Air mixing | Uniform | Uniform | |

TABLE 14A*

ESTIMATION OF SHOP CONCENTRATION LEVELS

| CANS USED PER WEEK | | PPM (TWA) AVERAGE CASE ASSUMPTIONS[1] | PPM (TWA) WORST CASE ASSUMPTIONS[2] |
|---|---|---|---|
| 37–72 category | average value | 2.65 | 13.60 |
| | maximum value | 2.65 | 13.60 |
| | minimum value | 2.65 | 13.60 |
| | sample size | 1.00 | 1.00 |
| 13–36 category | average value | 4.99 | 28.49 |
| | maximum value | 18.23 | 104.07 |
| | minimum value | 0.53 | 3.04 |
| | sample size | 24.00 | 24.00 |
| 7–12 category | average value | 4.05 | 18.89 |
| | maximum value | 30.79 | 151.09 |
| | minimum value | 0.10 | 0.47 |
| | sample size | 72.00 | 72.00 |
| 4–6 category | average value | 2.26 | 10.53 |
| | maximum value | 35.75 | 166.65 |
| | minimum value | 0.16 | 0.76 |
| | sample size | 112.00 | 112.00 |
| 1–3 category | average value | 1.21 | 7.05 |
| | maximum value | 9.82 | 57.23 |
| | minimum value | 0.05 | 0.29 |
| | sample size | 219.00 | 219.00 |

[1]PPM ESTIMATED UNDER AVERAGE CASE ASSUMPTIONS
A. THE INTERVAL MIDPOINT WAS TAKEN FOR NUMBER OF CANS USED PER WEEK
B. ONE CAN CONTAINED 544 GRAMS (19.2 OUNCES) OF PERCHLOROETHYLENE
C. THE DAILY SHOP AIR VOLUME TURNOVER RATE WAS 36
D. THE WORK WEEK CONTAINED 5.25 DAYS
E. THE PERCHLOROETHYLENE WAS COMPLETELY VOLITILIZED AND UNIFORMLY MIXED

[2]PPM ESTIMATED UNDER WORST CASE CONDITIONS
A. THE INTERVAL MAXIMUM WAS TAKEN FOR NUMBER OF CANS USED PER WEEK
B. ONE CAN CONTAINED 544 GRAMS (19.2 OUNCES) OF PERCHLOROETHYLENE
C. THE DAILY SHOP AIR VOLUME TURNOVER RATE WAS 9
D. THE WORK WEEK CONTAINED 5 DAYS
E. THE PERCHLOROETHYLENE WAS COMPLETELY VOLITILIZED AND UNIFORMLY MIXED

*The values in this table are slightly different than an earlier version because the number of work days under average case assumptions (5.25) was incorrectly used for worst case assumptions and the number of work days under worst case assumptions (5) was used for average case assumptions.

TABLE 14B*

OVERALL AVERAGE (TOTAL SAMPLE)

| CANS USED PER WEEK | SAMPLE SIZE | PPM (TWA) AVERAGE CASE ASSUMPTIONS[1] | PPM (TWA) WORST CASE ASSUMPTIONS[2] | COUNT X PPM AVERAGE CASE | COUNT X PPM WORST CASE |
|---|---|---|---|---|---|
| 37–72 | 1 | 2.65 | 13.60 | 2.65 | 13.60 |
| 13–36 | 24 | 4.99 | 28.49 | 119.76 | 683.76 |
| 7–12 | 72 | 4.05 | 19.89 | 291.60 | 1432.08 |
| 4–6 | 112 | 2.26 | 10.53 | 253.12 | 1179.36 |
| 1–3 | 219 | 1.21 | 7.05 | 264.99 | 1543.95 |
| TOTAL | 428 | | | 932.12 | 4852.75 |
| SAMPLE AVERAGE | | | | 2.18 | 11.34 |

[1]PPM ESTIMATED UNDER AVERAGE CASE ASSUMPTIONS
A. THE INTERVAL MIDPOINT WAS TAKEN FOR NUMBER OF CANS USED PER WEEK
B. ONE CAN CONTAINED 544 GRAMS (19.2 OUNCES) OF PERCHLOROETHYLENE
C. THE DAILY SHOP AIR VOLUME TURNOVER RATE WAS 36
D. THE WORK WEEK CONTAINED 5.25 DAYS
E. THE PERCHLOROETHYLENE WAS COMPLETELY VOLITILIZED AND UNIFORMLY MIXED

[2]PPM ESTIMATED UNDER WORST CASE CONDITIONS
A. THE INTERVAL MAXIMUM WAS TAKEN FOR NUMBER OF CANS USED PER WEEK
B. ONE CAN CONTAINED 544 GRAMS (19.2 OUNCES) OF PERCHLOROETHYLENE
C. THE DAILY SHOP AIR VOLUME TURNOVER RATE WAS 9
D. THE WORK WEEK CONTAINED 5 DAYS
E. THE PERCHLOROETHYLENE WAS COMPLETELY VOLITILIZED AND UNIFORMLY MIXED

*The values in this table are slightly different than an earlier version because the number of work days under average case assumptions (5.25) was incorrectly used for worst case assumptions and the number of work days under worst case assumptions (5) was used for average case assumptions.

TABLE 15

Frequency of Concentrations under Alternative Assumptions

| | TWA Exposure Levels (ppm) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 5 | 10 | 15 | 20 | 25 | >25 | Total |
| Normal Case Assumptions | 168 | 217 | 34 | 4 | 2 | 0 | 3 | 428 |
| Worst Case Assumptions | 11 | 161 | 118 | 62 | 24 | 14 | 38 | 428 |

Notes

- Cell entries are numbers of firms whose theoretical exposure levels include value up to and including the value listed in the column heading.
- "Normal Assumptions" include using the midpoints of intervals and BOCA standards for air circulation.
- "Worst case" assumptions include using the endpoints of intervals and 1/4 BOCA standards for air circulation.
- All cases assume 100% perc formulation, 544 grams/can.

# FIGURE 1

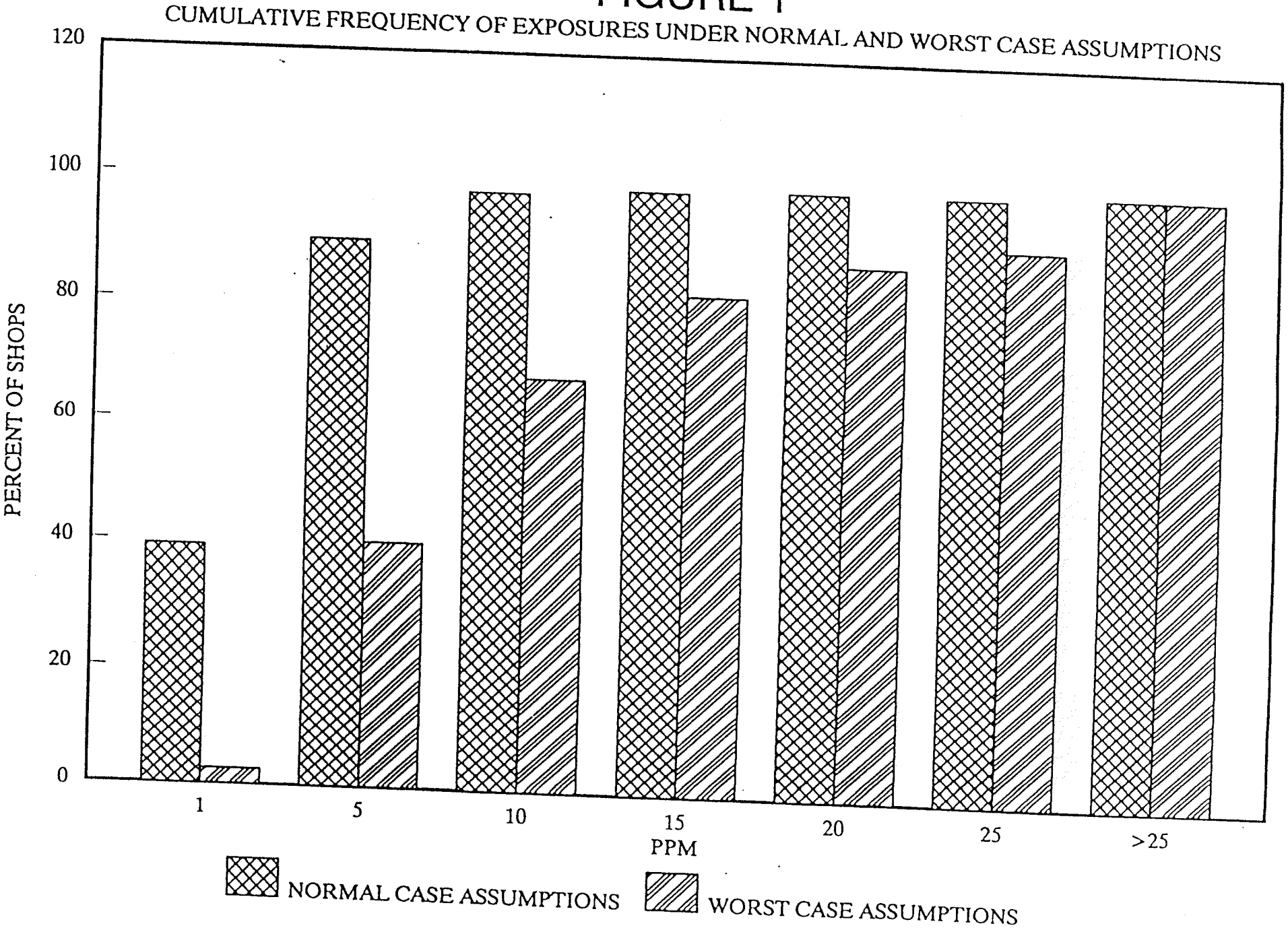
CUMULATIVE FREQUENCY OF EXPOSURES UNDER NORMAL AND WORST CASE ASSUMPTIONS
120
100
80
60
40
20
0
PERCENT OF SHOPS
1
5
10
15
20
25
>25
PPM
NORMAL CASE ASSUMPTIONS
WORST CASE ASSUMPTIONS

Table 16

| Differences Between Concentration Groups | | | | |
|---|---|---|---|---|
| | Means | | Test Results | |
| Variable<br><br>Survey Question | Group O: Theoretical Exposure Less than 25 ppm | Group 1: Theoretical Exposure Greater than or equal to 25 ppm | T | Prob > [T] |
| 2: Number of bays | 4.5 | 3.8 | 2.47 | .01 |
| 3: Bays doing brake work | 3.2 | 3.0 | .74 | .46 |
| 4a: Bay length | 26.53 | 25.58 | 0.71 | .48 |
| 4b: Bay width | 14.85 | 14.65 | .18 | .86 |
| 4c: Bay square feet | 410.82 | 276.75 | 1.1 | .27 |
| 5a: Shop length | 71.56 | 46.02 | 4.88 | .0001 |
| 5b: Shop width | 53.82 | 40.29 | 3.17 | .0016 |
| 5c: Shop height | 15.81 | 13.71 | 3.05 | .0024 |
| 5d: Shop cubic feet | 70.179 | 28.546 | 2.52 | .0119 |
| Cans used per week | 4.78 | 13.12 | −8.59 | .0001 |
| Cans used per day | .91 | 2.49 | −8.59 | .0001 |
| People in the shop area | 3.77 | 3.50 | .81 | .42 |
| People performing brake work | 2.78 | 2.87 | −.355 | .72 |
| Grams discharged per day | 495.74 | 1359.63 | −8.59 | .0001 |
| Grams discharged per day | 691.83 | 2006.17 | −8.93 | .0001 |
| Brake jobs per day | 1.43 | 2.24 | −3.43 | .0007 |
| Brake jobs per bay per day | .51 | .77 | −3.68 | .0003 |
| Exposure ppm: Average case" assumptions: | 1.43 | 9.22 | −7.27 | .0001 |
| Exposure ppm Worst case" assumptions: | 7.50 | 47.84 | −7.89 | .0001 |

Notes

o In each case, the test is a two−tailed t−test of Ho: the means are equal. The appropriate test statistic in each case was determined by the outcome of an F test of the equality of the sample variances.

TABLE 17

Relationship Between Shop Size and Concentrations

| Survey Question 2 | | Concentrations | | Row Total |
|---|---|---|---|---|
| | | Low | High | |
| Shop Size | 1–2 bays | 54 | 11 | 65 |
| | 3–4 bays | 163 | 17 | 180 |
| | 5 bays or more | 178 | 13 | 191 |
| Column total | | 395 | 41 | 436 |

Notes
- o Aerosol users only.
- o $chi^2$ value of 5.83 with 2 df significant at .10(p=.054).

# TABLE 18

Table 18
Differences Between Size Groups

| | Means | | Test Results | |
|---|---|---|---|---|
| Variable | Large Shops (More than 4 bays) | Small Shops (4 Bays or less) | T | Prob > \|T\| |
| brake jobs per bay per day | .49 | .57 | -1.92 | .0003 |
| Exposure ppm: "Average case" assumptions | 1.59 | 2.65 | -3.63 | .0001 |
| Exposure ppm: "Worst case" assumptions | 8.19 | 13.89 | -3.91 | .0001 |

Notes
In each case, the test is a two-tailed t-test of Ho: the means are equal. The appropriate test statistic in each case was determined by the outcome of an F test of the equality of the sample variances.

## References

Jurgiel, J.P. (1992), "Results of the Industrial Hygiene Investigation of Various Solvents for Potential Aerosol Degreasing Applications, January-February, 1991" (mimeo).

Nyberg, J. M. and E. L. Mainz (1993), "Applications Research Group Task Report: Industrial Hygiene Study of Methylene Chloride/Perchloroethylene/Methylchloroform Blended Aerosol Brake Cleaners" (mimeo).