IN-DEPTH SURVEY REPORT

CONTROL TECHNOLOGY FOR SMALL BUSINESS

EVALUATION OF A FLEXIBLE DUCT VENTILATION SYSTEM FOR RADIATOR REPAIR

AT

A-1 Radiator
Reno, Nevada

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PLANT SURVEYED	A-1 Radiator 875 East 2nd Street Reno, Nevada 89502
SIC CODE	7539
SURVEY DATE	June 26-28, 1989
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I INTRODUCTION

The National Institute for Occupational Safety and Health (NIOSH) was established by the Occupational Safety and Health Act of 1970 Among the numerous responsibilities assigned to the Institute by this Act are the identification of occupational safety and health hazards, evaluation of these hazards, and recommendation of standards to regulatory agencies to control the hazards Located in the Department of Health and Human Services (formerly Department of Health, Education, and Welfare), NIOSH conducts research separate from the standard setting and enforcement functions conducted by the Occupational Safety and Health Administration (OSHA) in the Department of Labor An important area of NIOSH research deals with methods for controlling occupational exposure to potential chemical and physical hazards The Engineering Control Technology Branch (ECTB) of the Division of Physical Sciences and Engineering has been given the lead within NIOSH to study the engineering aspects relevant to the control of these hazards in the workplace

NIOSH has been instrumental in the development of recommendations for safeguarding workers' safety and health from exposure to occupational hazards Since 1976, ECTB has conducted assessments of health hazard control technology on the basis of industry, common industrial process, or specific control techniques The objective of each of these studies has been to document and evaluate control techniques and to determine their effectiveness in reducing potential health hazards in an industry or at specific processes These data will create a greater awareness of the need for or availability of an effective system of hazard control measures

A research study of control technology for radiator repair shops by ECTB was prompted by the dangers of potential lead contamination in the workplace and by the need to provide control technology information concerning the prevention of occupational disease to small businesses that may not have access to current technology State occupational health programs have identified radiator repair shops as a high-risk small business, several states have reported a high incidence of violations for overexposure to lead in these shops Practical and proven engineering control solutions in this industry do not appear in the literature This research study has as its goal to provide control technology information for the prevention of disease from exposure to lead during radiator repair

This report presents the results of an engineering control evaluation by NIOSH researchers and a Nevada Occupational Safety and Health compliance inspector of a radiator repair shop which operated at a very high level of production The shop has the potential for high exposures to lead because of the high volume of work, the number of radiator repair stations, and repairs to huge radiators for mining equipment, which generate a large amount of lead fume Local exhaust ventilation (LEV) which utilized adjustable-arm "elephant trunk" exhaust hoods (10-inch diameter flexible ducts) had been installed 18 months prior to this investigation, as a result of a compliance inspection by Nevada OSHA which documented worker lead exposures that were twice the OSHA permissible exposure limit (PEL)

The objective of this plant study was to evaluate and document the effectiveness of the A-1 Radiator LEV system to control exposure to lead during radiator repair operations This was accomplished by determining the exposure of radiator repair mechanics to airborne concentrations of lead while using the control system and comparing these levels to the OSHA PEL for lead A Nevada Occupational Safety and Health compliance inspector had conducted personal sampling for lead prior to the installation of the LEV system at this shop The availability of these records permitted us to additionally evaluate the effectiveness of the engineering controls by determining the reduction in lead exposure based on "before" and "after" results

Secondary objectives in this plant evaluation were to assess the effectiveness of the LEV system during the busiest season for radiator repair (June, July, and August), to determine factors which account for two- to three-fold differences in lead exposures among radiator repair mechanics, and to assess the relative effectiveness of the elephant trunk LEV system for the repair of industrial radiators as compared to automobile/small truck radiators

The report from this in-depth survey will be used as a basis for making control recommendations in Institute policy documents and for preparing technical reports and journal articles on the effectiveness of designs and techniques for controlling hazards This information is part of a data base available to health professionals, equipment manufacturers, and others to assist in the development of effective control measures in the workplace

II PLANT AND PROCESS DESCRIPTION

FACILITY DESCRIPTION

This shop repairs both automotive and industrial radiators It services radiators from 80 percent of the mines in Nevada [1] The present site was opened in January 1985 The floor plan of this 14,000-square foot building is shown in Figure 1 The drive-in bays can handle up to 21 automobiles and small trucks plus several large trucks The shop is open 6 days a week for car and light truck radiator repair and the staff is on call 24 hours a day for industrial radiator repairs At the time of our study, approximately 30 workers were employed at this facility

The shop has eight radiator repair stations (Figure 2) Each station includes a water tank, two acetylene torches for burning and soldering, and a lift device for securing the radiator Industrial radiators are repaired at workstations 7 and 8, when these radiators are too large to be repaired over the water tank, they are held by a hoist located in the aisle next to the workstation The very large industrial radiators are not soldered, but are rebuilt using new parts This is done in the room adjacent to the radiator repair area The shop also has an enclosed sand blaster for cleaning parts

During the summer months, A-1 Radiator operates at a very high level of production due in part to radiator failure of the many vehicles driving cross country during hot weather During our survey, the shop repaired 30 to 50 automobile and light truck radiators each day, in addition to the industrial radiators

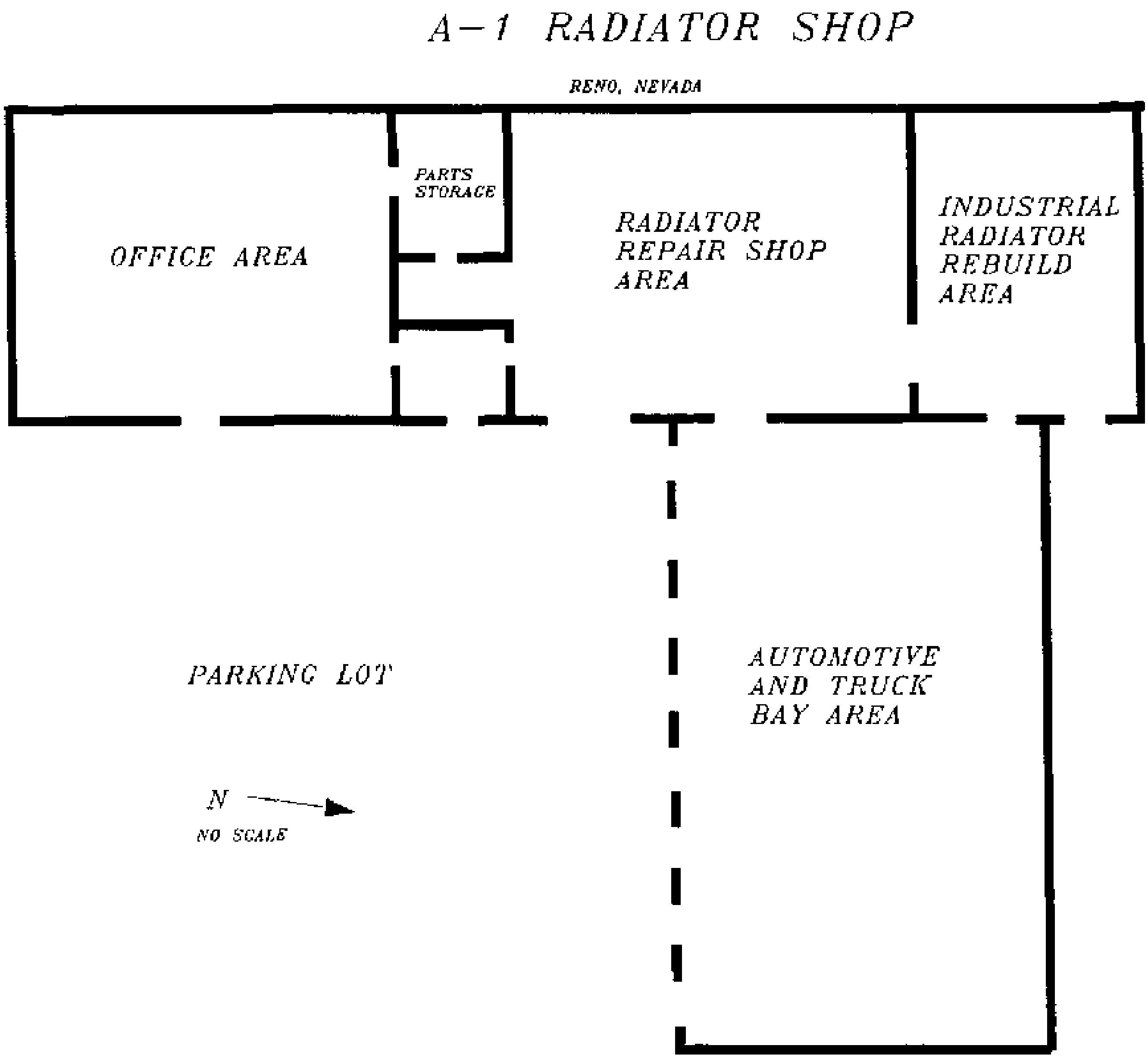


Figure 1

Building Layout

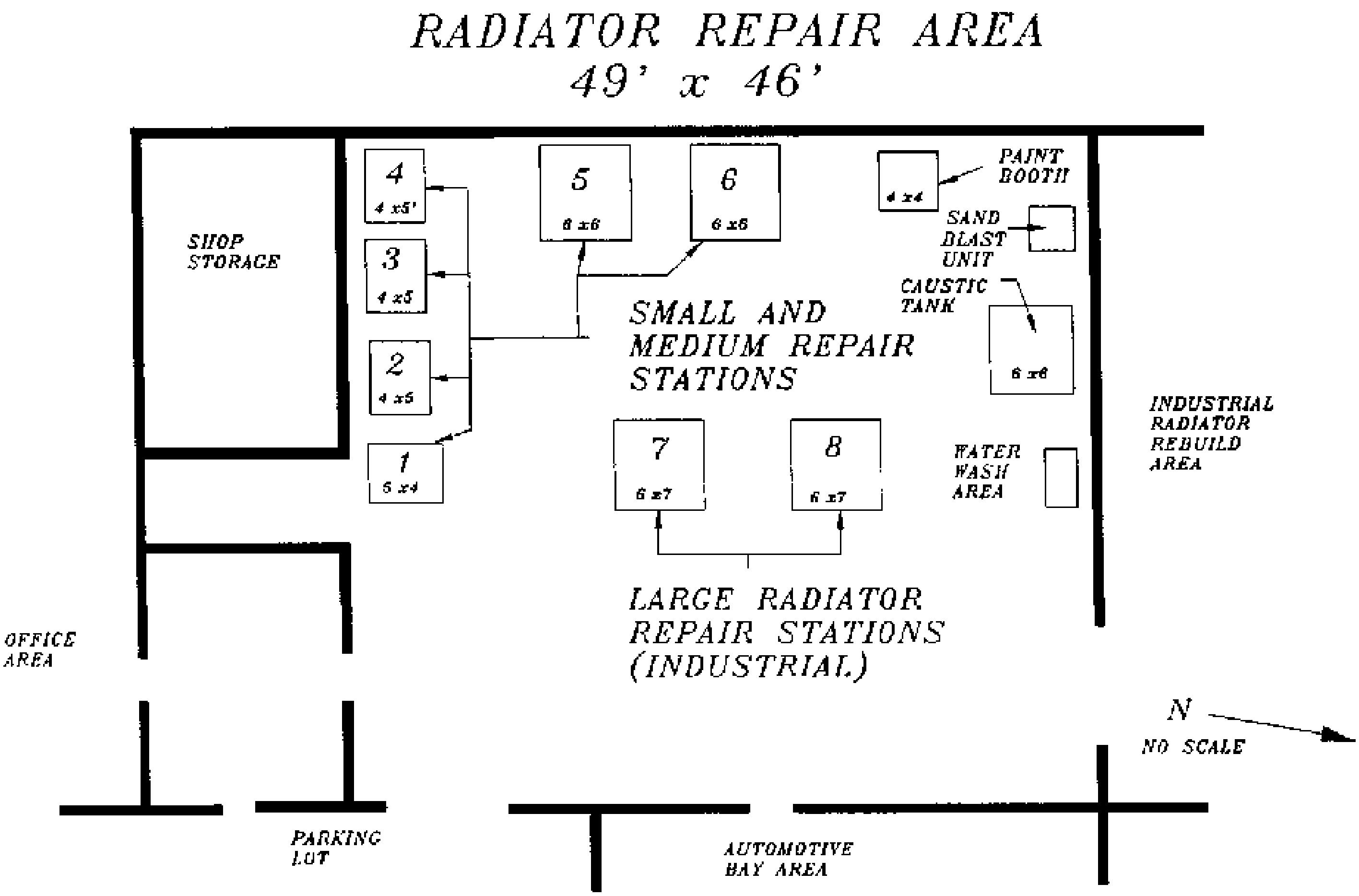


Figure 2

Layout - Radiator Repair

PROCESS DESCRIPTION

Radiators are pulled from the car or truck or brought to the shop The radiator is cleaned of surface grime and dirt, if needed, and then checked for leaks, flow restrictions, and overall integrity For minor repairs, radiators are patched with solder For big jobs, radiators are cleaned in a caustic bath (sodium hydroxide), rinsed with either a water hose or high pressure water, and the top and bottom sections of a radiator are separated from the core by melting the lead-based solder with a torch Leaks are marked and patched with 60-40 lead-tin solder heated with an acetylene torch All soldering is done at the front of the tank or workstation with one of two torches The radiator is placed in the water tank and checked for leaks, if it passes the final leak test, it is painted black in a ventilated paint spray booth

VENTILATION SYSTEM

Each of the eight radiator repair stations is equipped with local exhaust ventilation (LEV) consisting of an adjustable-arm elephant trunk exhaust hood shown in Figure 3 Because the ducts are made of flexible material, the mechanic can position the exhaust hood close to the soldering operation The hood opening is 10 inches in diameter Air exhausts through the hood, into the flexible duct to a rigid plenum, and through the roof fan Each of the four exhaust fans serve two exhaust hoods There are no air cleaning devices in the exhaust system An 8-inch diameter hole was cut into each of the four plenums, just below the ceiling to exhaust any fumes that accumulate near the ceiling Before these holes were made, fumes collected near the ceiling of the shop and migrated into second floor offices, however, these holes reduce the exhaust air volume at the hoods The four fans were designed to pull a total of 16,000 cubic feet per minute (cfm) During April 1988, the flexible duct LEV system was installed at Tanks 3 and 4 and at the industrial radiator Tanks 7 and 8 The installation was completed at Tanks 1 and 2 and Tanks 5 and 6 during the summer of 1988 Since then, several of the flexible ducts have partially collapsed, reducing the air flow in the ducts

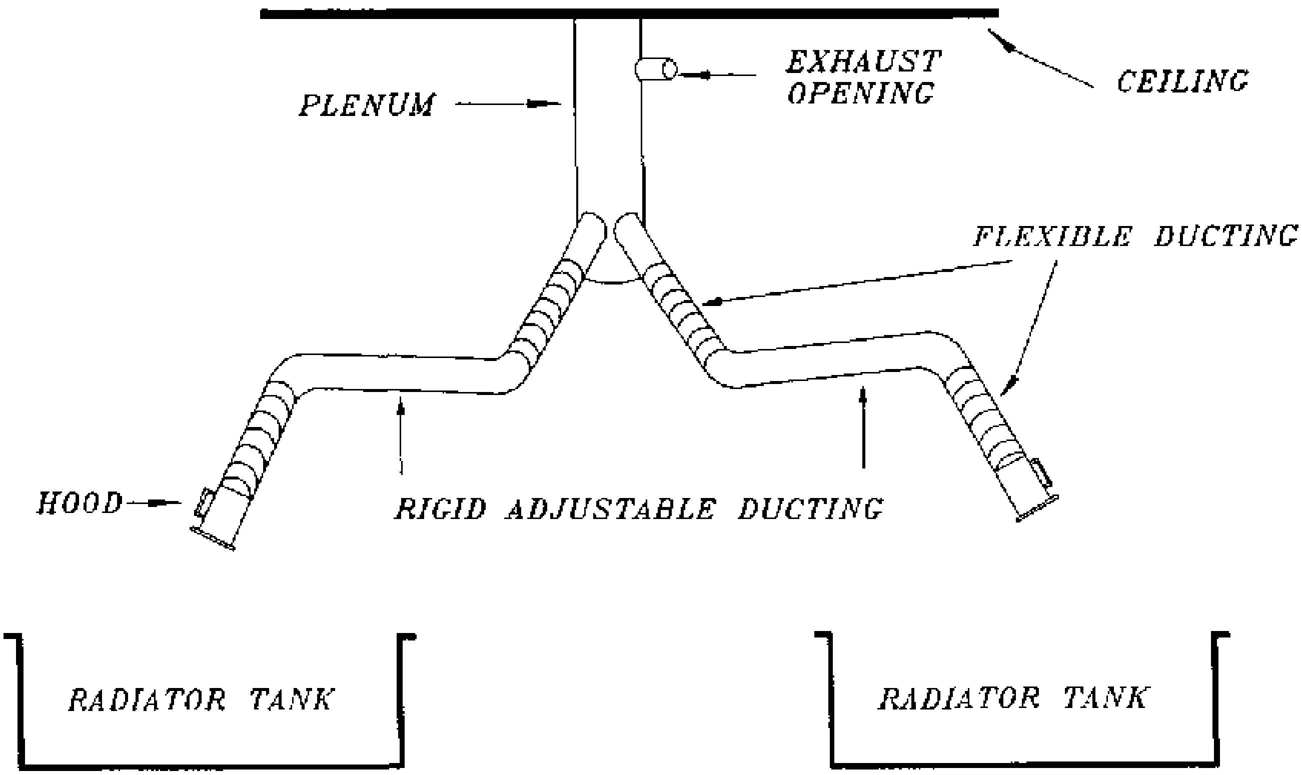
A-1 Radiator also installed a makeup air unit with filters and heater as part of the ventilation system The cost of the entire ventilation system was $35,000, $20,000 for the LEV and $15,000 for the makeup air unit [1]

III POTENTIAL HEALTH HAZARDS AND EVALUATION CRITERIA

The important routes of lead adsorption by man are inhalation and ingestion Man absorbs small amounts of lead in his food and from the air which normally does not cause poisoning Lead absorbed from occupational sources, such as soldering operations in radiator repair shops, are in addition to this "normal" body burden of lead [2]

HEALTH EFFECTS OF LEAD

Lead adversely affects a number of organs and systems The four major target organs and systems are the central nervous system, the peripheral nervous system, kidney, and hematopoietic (blood-forming) system [3] Inhalation or ingestion of inorganic lead has caused loss of appetite, metallic taste in the



ADJUSTABLE-ARM ELEPHANT TRUNK EXHAUST VENTILATION SYSTEM

Figure 3

Schematic of LEV System

mouth, constipation, nausea, pallor, blue line on the gum, malaise, weakness, insomnia, headache, muscle and joint pains, nervous irritability, fine tremors, encephalopathy, and colic Lead exposure can result in a weakness in the muscles known as "wrist drop," anemia (due to lower red blood cell life and interference with the heme synthesis), proximal kidney tubule damage, and chronic kidney disease [2,4] A recent study shows high blood pressure is also related to blood lead levels [5] Lead can concentrate in the soft tissue and bones, particularly in the liver and kidney, and elimination is slow Finally, exposure is associated with fetal damage in pregnant women [3,4]

EVALUATION CRITERIA

The occupational exposure criterion for inorganic lead is the current OSHA permissible exposure limit (PEL) of 50 $\mu g/m^3$, the OSHA action level for lead is 30 $\mu g/m^3$ [6] The occupational exposure criteria for other metals, minerals, solvents, sodium hydroxide, and carbon monoxide are the OSHA PELs, NIOSH RELs, and Threshold Limit Values (TLVs®) (see Table B-1) [7,8,9]

IV METHODOLOGY

AIR SAMPLING AND ANALYSIS

Personal and area samples for lead and other metals were collected on 37 mm diameter cellulose ester, 0 8 μm pore size filters using SKC pumps at 2 0 liters per minute (Lpm) Samples for lead and other metals were analyzed by inductively coupled plasma-atomic emission spectrometry (ICP) in accordance with NIOSH Method 7300 [10] The limit of detection (LOD) for lead was 2 0 μg/filter Both full-shift sampling and short-term sampling for the duration of a single radiator repair operation (less than 1 to 2 hours) were performed

Area samples for solvent vapors were collected on charcoal tubes at a flow rate of 0 05 Lpm using DuPont Model P-200 pumps and were analyzed by gas chromatography/mass spectrometry (GC/MS) The LOD for the charcoal tube samples varied with the identity of the solvent

Area samples for sodium hydroxide were taken on 37 mm diameter, 1 μm pore size PTFE membrane filters using SKC pumps at 2 0 Lpm and analyzed for sodium hydroxide in accordance with NIOSH Method 7401 [10] The limit of detection was 40 μg/filter Area samples for carbon monoxide were also taken using Draeger tubes

OBSERVATIONS

During the sampling survey, work practices and use of personal protective equipment were documented Ventilation measurements were taken using Kurz digital and analog hot-wire anemometers The capacity and dimensions of the local exhaust ventilation system were also obtained

Each radiator repair mechanic was videotaped during the repair of a single radiator, and a short-term personal sample was collected during the repair activity The videotape was reviewed by the authors and the relative effectiveness of the mechanic's work practices were estimated and compared with the mechanic's exposure to lead

V RESULTS/DISCUSSION

PRINCIPLES OF CONTROL

Occupational exposures can be controlled by the application of a number of well-known principles including engineering measures, work practices, and personal protection These principles may be applied proximate to the hazard source, to the general workplace environment, or at the point of occupational exposure to individuals Controls applied at the source of the hazard, including engineering measures (material substitution, process and equipment modification, isolation or automation, local ventilation) and work practices, are generally the preferred and most effective means of control, both in terms of occupational and environmental concerns Controls which may be applied to hazardous substances that have escaped into the workplace environment include dilution ventilation, dust suppression, and housekeeping Control measures may also be applied near individual workers, including the use of remote control rooms, isolation booths, supplied-air cabs or operator stations, work practices, and personal protective equipment

These principles of control apply to all situations This paper discusses an application of the principles of local ventilation and work practices to the control of lead exposure during radiator repair operations

LEAD AIR SAMPLING RESULTS

The parameters and analytical results of individual samples are shown in the appendices to this report

Personal Samples

Lead concentrations obtained in the breathing zone of the radiator repair mechanics are summarized in Table 1 for each of the repair tanks (workstation/benches) Arithmetic mean personal sample concentrations for lead ranged from 17 to 71 $\mu g/m^3$ A single 2-hour sample for lead taken on a worker at the industrial radiator repair benches was 8 $\mu g/m^3$ Geometric mean personal sample concentrations for lead were similar, ranging from 17 to 67 $\mu g/m^3$ Four observations can be drawn from the lead exposure data shown in Table 1 First, mean lead exposures at the automobile/small truck radiator repair benches, except for bench 4, were at or near the OSHA PEL for lead of 50 $\mu g/m^3$, second, lead exposures were, on average, three times higher while performing automobile/small truck radiator repairs than for industrial radiator repairs, third, lead exposures for the worker at bench 4 were substantially higher than for the other workers, and fourth, arithmetic and geometric mean concentrations for lead give similar results

Table 1. Personal Exposures to Inorganic Lead at Tanks

Worker	Tank #	Number of Samples	Average Sample Duration (min)	Concentration* (μg/m³) Arithmetic Mean	Geometric Mean	Range
A	2	5	196	55	55	40 - 66
B	3	5	200	48	44	18 - 74
C	4	5	204	71	67	32 - 91
D	5	5	205	48	44	29 - 89
E	6**	2	167	42	42	40 - 44
E	Industrial	3	173	17	17	17 - 18
F	Industrial	1	118	8	8	-
OSHA PEL			50 μg/m³			
OSHA Action Level			30 μg/m³			

* Excludes short-term personal samples
** Worked short time at industrial radiator

Area and Background Samples

Area lead concentrations for each radiator repair tank studied are shown in Table 2 In Figure 4, the average personal lead concentrations are compared with the average area concentrations for each of the radiator repair tanks and also background lead concentrations taken in the center of the shop, away from the process The average area lead concentrations taken at the automobile/small truck radiator repair tanks ranged from 21 to 40 $\mu g/m^3$ and all were less than the personal concentrations for lead at the corresponding tanks There was neither a statistically significant nor a practical correlation between the personal and the area sample lead concentrations measured at the same tank The average lead concentration at the sand blaster (28 $\mu g/m^3$) showed that it was an additional source for lead exposure in the shop

Area lead concentrations at the radiator repair tanks were two to three times higher than the average ambient lead concentration in the center of the shop The indoor ambient lead concentration of 12 $\mu g/m^3$ represents approximately 25 percent of the radiator mechanics' allowable exposure, thus, a worker standing in the center of the shop and doing no soldering could be exposed to one-fourth of the PEL for lead

Lead concentrations in the office area (which also included the retail sales counter and customer waiting area) were very low, averaging 3 $\mu g/m^3$ This level is well below the ambient lead concentration in the shop and indicates no cross-contamination between the shop and the office Outdoor ambient lead concentrations were all less than the limit of detection which averaged 3 $\mu g/m^3$ These data indicate outdoor lead levels contributed little or nothing to lead levels in the shop and that lead emissions through the roof vents and other shop openings did not have a material effect on the immediate environment

Field Blank Results

The results of field blanks (Table A-4, Appendix A) analyzed for lead were below the limit of detection (LOD) Therefore, no blank corrections were made to the analytical results of the lead samples

COMPARISON TO OSHA PEL

The OSHA PEL for inorganic lead is 50 $\mu g/m^3$ and the OSHA action level (requiring medical surveillance and environmental monitoring to be instituted) is 30 $\mu g/m^3$ Personal sampling results from our survey showed that 10 of the 15 TWA exposures for inorganic lead were at or below the OSHA PEL (Table 3) Three of the five high lead exposures were measured on the mechanic working at Tank 4 The other two high lead exposures (60 $\mu g/m^3$) occurred to the mechanics at Tanks 2 and 5 With the present LEV system at A-1 Radiator, workers at the automobile radiator repair stations, except at Tank 4, should normally be in compliance with the lead standard To ensure that TWA lead exposures are below the OSHA PEL during very high levels of production (as was the case during our survey), improved work practices such as optimal positioning of the LEV hood near the soldering should be emphasized

Table 2. Area and Background Inorganic Lead Concentrations

Sample Location	Number of Samples	Lead Concentration ($\mu g/m^3$)		
		Arithmetic Mean	Geometric Mean	Range
Tank 2	3	27	19	<5 - 40
Tank 3	3	40	25	<5 - 66
Tank 4	2	22	21	17 - 27
Tank 5	3	36	33	20 - 61
Tank 7	2	21	19	13 - 29
Tank 8	2	27	25	16 - 38
Sand Blaster	3	28	27	18 - 36
Indoor Ambient	3	12	12	9 - 16
Office	3	3	3	2 - <5
Outdoor Ambient	3	<3	<3	<4

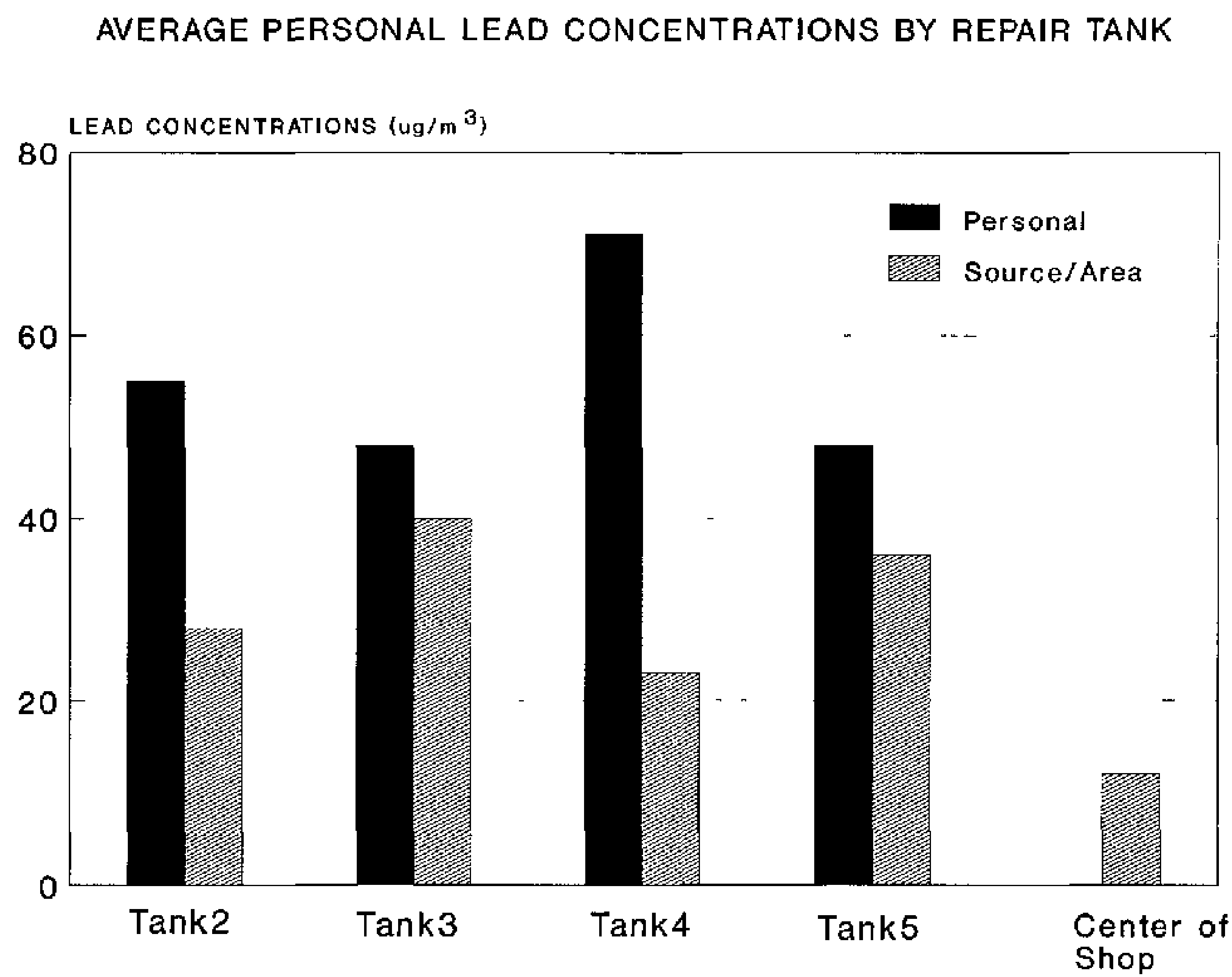

AVERAGE PERSONAL LEAD CONCENTRATIONS BY REPAIR TANK
LEAD CONCENTRATIONS (ug/m 3)
80
60
40
20
0
Personal
Source/Area
Tank2
Tank3
Tank4
Tank5
Center of Shop

Figure 4

Table 3. Time-Weighted-Average Exposures to Inorganic Lead

Worker	Tank #	Concentration ($\mu g/m^3$) 6/26/89	6/27/89	6/28/89[a]
A	2	49	60	50
B	3	51	49	50
C	4	73	62	79
D	5	42	60	43
E	Industrial	35	17	--
E	6		--	44
OSHA PEL		50 $\mu g/m^3$		
OSHA Action Level		30 $\mu g/m^3$		

(a) Half-day samples taken in morning—TWA exposures assume same exposure in the afternoon

The TWA lead exposures for the mechanic at Tank 4 were consistently above the OSHA PEL Some possible origins of these high lead levels are (1) Tank 4 is located in the corner of the shop with radiator repair benches on both open sides (See Figure 2), (2) it is farthest from the open garage doors and excluded from the dilution air currents in the shop, (3) the mechanic was observed to be working very close to the soldering fume in an effort to better observe the work, and (4) inadequate LEV air volume to capture the fumes The mechanic's work practices were generally good and the LEV air volume was adequate, thus, improved work practices and/or ventilation may not be sufficient to bring exposure at this tank into compliance with the lead standard Either not using Tank 4 during moderate or heavy production or moving it out of the corner to another location may also reduce the lead exposure of workers at the two adjacent automobile radiator repair tanks

Lead exposures while repairing the industrial radiators were well below the OSHA PEL. Mechanic "E" experienced the lowest TWA lead exposure (17 $\mu g/m^3$) of the survey on the day he worked only at the industrial radiator bench, however, his exposure was 2 6 times higher on the next day when he worked at Tank 6 (an automobile/small truck radiator repair bench) The TWA results indicate much lower lead exposures occur when working at the industrial radiator benches than at the automotive radiator repair tanks

COMPARISON TO LEAD EXPOSURES FROM EARLIER SAMPLING SURVEYS

Prior to our survey, personal samples for lead were collected on three separate occasions at A-1 Radiator by the State of Nevada The sampling results for lead from these surveys are presented in Table 4. In December 1987, lead exposures for three mechanics ranged from 74 $\mu g/m^3$ to 110 $\mu g/m^3$ and were, on average, nearly twice the OSHA PEL of 50 $\mu g/m^3$ These high lead exposures were recorded even though work activity on that date was light and only three of the eight radiator repair tanks (benches) were used (Radiator repair activity is generally much slower in the winter than in the summer months) At that time, the only mechanical ventilation in the A-1 Radiator shop was the 5,000 cfm roof exhaust fan There was no mechanical makeup air unit, and in December, the shop doors were presumably closed which may have increased the lead levels

A second set of samples for lead were collected in May 1988 During April 1988, adjustable-arm elephant trunk exhaust hoods had been installed at radiator repair Tanks 3 and 4 and the industrial radiator tanks (7 and 8) The lead exposures of the radiator repair mechanics' at Tanks 3 and 4 were approximately one-third of those measured before installation of the LEV system However, the mechanic at the industrial radiator repair tank sampled in May 1988 still experienced lead levels above the OSHA PEL

In September 1988, sampling for airborne lead was conducted by the State of Nevada after elephant trunk exhaust hoods had been installed at radiator repair Tanks 1, 2, 5, and 6 and the size of the fan motor serving the exhaust hoods for the two industrial radiator repair tanks had been increased These results showed the mechanics' exposure averaged 32 $\mu g/m^3$ and ranged from 20 to 55 $\mu g/m^3$ at the automotive repair tanks Radiator repair activity was steady at the automobile radiator repair benches The production level was

Table 4. Lead Exposure Results from Previous Sampling Surveys

Sample Date	Worker Location	Lead Concentration ($\mu g/m^3$)	Work Load	Local Exhaust Ventilation (cfm)*
12/17/87	n.a.	74	light	roof fan only
	n.a.	79	"	
	n.a.	110	"	
5/21/88	Tank 3	19	light	2000
	Tank 4	32	steady	1400
	Industrial	67	steady	1400
9/22/89	Tank 1	55	steady	1800
	Tank 5	22	"	1500
	Tank 6	20	"	1700
	Tank 8 (Industrial)	51	heavy	1900

* Exhaust volume is an estimate calculated from center line velocity at hood

heavy at the industrial radiator repair bench, and the mechanic's exposure was 51 $\mu g/m^3$ of lead

The arithmetic mean and geometric mean personal sample lead concentrations are compared between our survey (June 1989) and the earliest sampling survey (December 1987) in Figure 5 The lead exposures experienced by the radiator repair mechanics were consistently lower after installation of the elephant trunk LEV system except for the mechanic at Tank 4 Moreover, because the workload or production level was considerably higher during the June 1989 survey than during the December 1987 survey, the reduction in lead exposures by use of the LEV system is greater than indicated by the numbers shown here

VENTILATION

Local Exhaust Ventilation

The exhaust air volumes and capture velocities at a distance of 6 and 12 inches from the face of each of the eight adjustable-arm elephant trunk exhaust hoods are presented in Table 5 The capture velocity results are the average of two or three individual readings for each exhaust hood The exhaust volumes ranged from 670 to 1,350 cfm for the hoods used at the automobile/small truck radiator repair Tanks (1 to 6) The 6-inch capture velocities for these hoods ranged from 240 to 440 feet per minute (fpm) and were generally proportional to the exhaust air volume except for the hood at Tank 3 The ratio of capture velocity to exhaust volume (fpm/cfm) was 0 25 to 0 38, but at Tank 3 the ratio of capture velocity to exhaust volume was much higher at 0 63 There is no apparent reason for this proportionately higher capture velocity

In theory, a 6-inch capture velocity of 400 fpm would be required to provide for reasonable fume capture 10 to 12 inches from the hood For our survey, when the 6-inch capture velocity was over 400 fpm, the 12-inch capture velocity ranged from 100 to 150 fpm When the 6-inch capture velocity was 200 to 260 fpm, the corresponding 12-inch capture velocity ranged from less than 50 to 100 fpm, indicating inadequate capture velocity for lead fumes The measurements at 12 inches are only approximate since room cross-currents were strong relative to the capture velocity readings at 12 inches Nevertheless, except at Tank 5 (when the damper was not fully open) and Tank 6, the capture velocity was 100 fpm or more at a distance of 12 inches from all the hoods

Table 5 also shows the exhaust air volume and capture velocities for the exhaust hoods at the industrial radiator Tanks 7 and 8 Most industrial radiators were too large to be repaired at one tank and as a result they were generally positioned between the two exhaust hoods During our survey, the damper to exhaust hood 8 was mostly or totally closed, which resulted in more exhaust air volume being drawn through hood 7 than 8 The exhaust volume through Tank 7 hood ranged from 1,120 to 1,320 cfm, depending on whether the damper to Tank 8 hood was open The exhaust air volume to hood 8 was 170 cfm with the damper closed and 990 cfm with the damper open

In the 6 months preceding our survey, A-1 Radiator added an 8-inch diameter exhaust opening to each of the four LEV plenums a foot or so below the ceiling to remove fumes that were accumulating near the ceiling and migrating into the

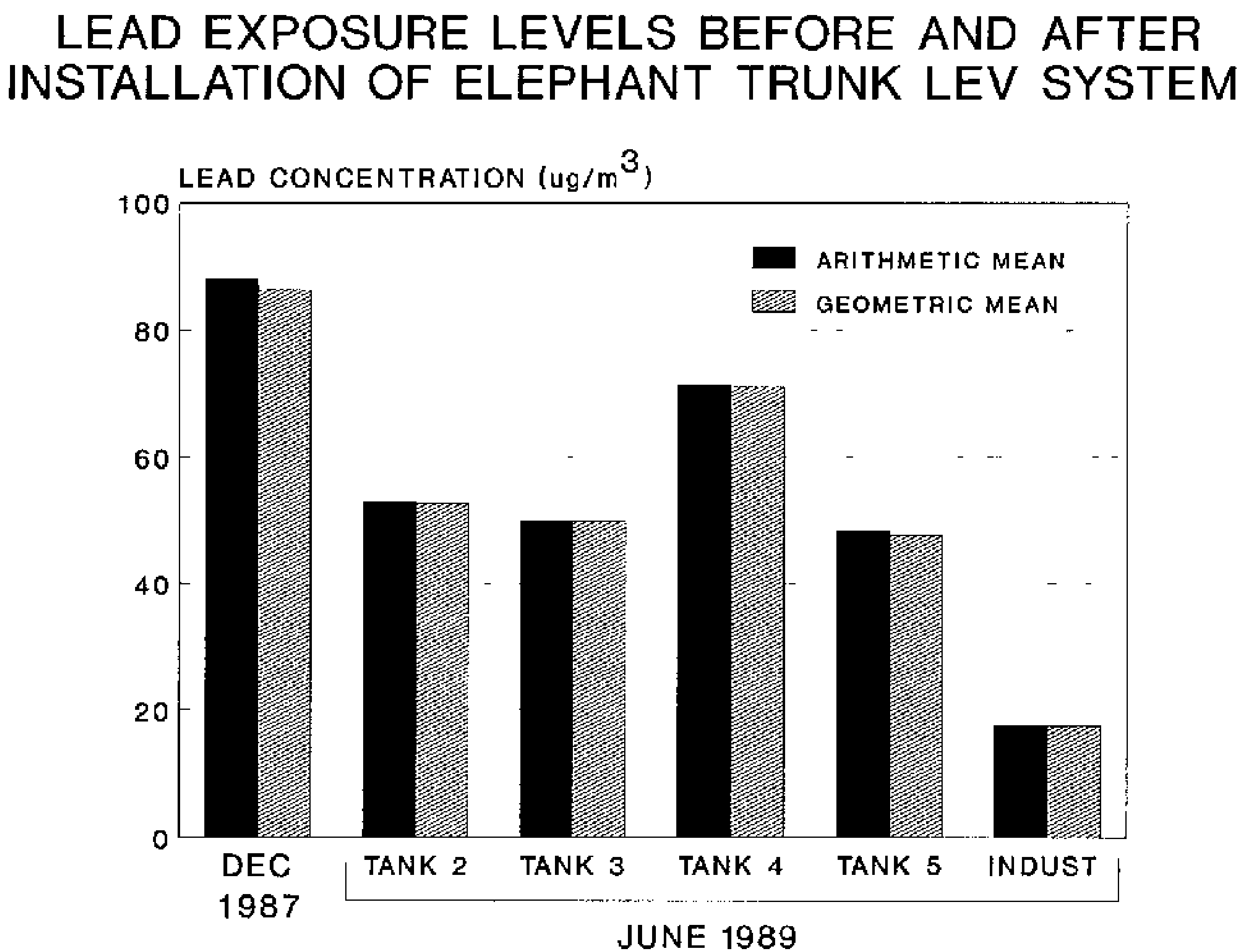

LEAD EXPOSURE LEVELS BEFORE AND AFTER INSTALLATION OF ELEPHANT TRUNK LEV SYSTEM
LEAD CONCENTRATION (ug/m3)
100
80
60
40
20
0
ARITHMETIC MEAN
GEOMETRIC MEAN
DEC 1987
TANK 2
TANK 3
TANK 4
TANK 5
INDUST
JUNE 1989

Figure 5

Table 5. Ventilation Measurements for June 26-28, 1989

Tank #	Exhaust Volume (cfm)	Capture Velocity (fpm)	
		@6 inches	@12 inches
1	1350	430	100
2	740	240	100
3	670	420	130
4	1160	440	120
5[a]	1030	-	50
5[b]	1200	440	130
6	1030	260	50
7	1320	420	150
7[c]	1120	-	-
8[c]	170	200	<50
8[b]	990	400	100

a - damper to #5 exhaust hood not fully open
b - damper to hood fully open
c - damper to #8 exhaust hood closed

mezzanine office areas The exhaust ports appeared to be working because no visible fumes were observed at ceiling level However, these ports reduced the exhaust volume (suction) at the radiator repair tanks The exhaust volume was measured at each of the hoods of Tanks 1 to 4 with the plenum exhaust openings blocked off These measurements showed the exhaust volume increased by 800 cfm or 40% for Tanks 1 and 2, but by less than 5% for Tanks 3 and 4 A primary reason for the additional 800 cfm for Tanks 1 and 2 is likely fan size the ventilation system at Tanks 1 and 2 is equipped with a 3 horsepower fan, while the system for Tanks 3 and 4 has a 2 HP fan (see Table 6) Except at Tank 6, satisfactory capture velocities remain with the plenum exhaust opening in place

The partial collapse of the flexible portion of the ducts was identified at several of the radiator repair tanks Further collapse of any of the ducts could greatly reduce the exhaust volume and it is recommended that the air flow to each hood be tested every 2 months by the shop to identify severely restricted ducts Related to this is the tendency for the damper in the exhaust hood to automatically close It would be prudent to lock the damper open Testing the hood exhaust volume bimonthly would also identify the event of a closed damper

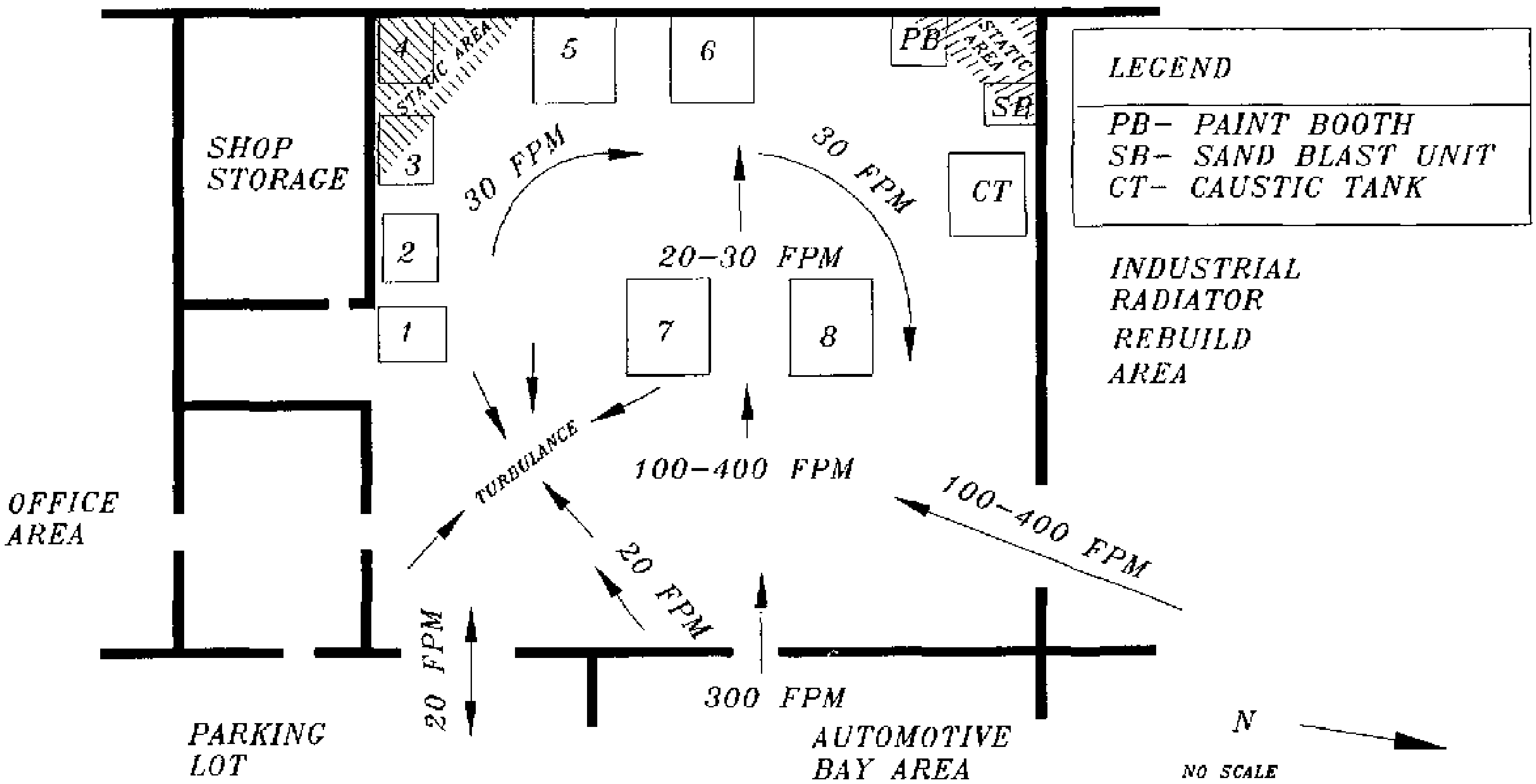
Dilution Ventilation

The movement and direction of air flow in the shop depends on how many doors are open, and on the outside wind direction and speed During our survey, the air temperature inside the shop ranged from 72 to about 80°F and the relative humidity ranged from 48 to 56% At that time, and presumably during the warm weather months (which encompasses the busy season at A-1 Radiator), all shop doors were open There is a 10- by 12-foot door (120 square feet opening) directly across from the industrial radiator repair tanks, a 3- by 8-foot door (24 square feet) between the automotive bay area and the shop, and a door approximately 8 by 8 feet (64 square feet opening) to the industrial radiator assembly room in the northeast corner of the shop Shop airflow patterns and air velocities on the afternoon of June 27 are shown in Figure 6 Air currents in the shop were in a circular pattern with the doors open, with static or dead spots in the two back corners of the shop near station 4 and the paint booth The airflow pattern shown in Figure 6 was valid for all three days of our survey as long as the wind was blowing, however, during occasional calm periods a different airflow configuration is liable

Airflow measurements showed wind speeds through the door to the industrial radiator assembly room were typically 100 to 400 fpm (12,000 to 48,000 cfm) on June 27 and up to 300 to 400 fpm on June 26 The wind was blowing into the shop through this door on June 28 although the velocity was not measured An additional 300 fpm (7200 cfm) of air enters through the 3- by 8-foot door Roughly 10,000 cfm of air are exhausted from the shop area by the LEV system, thus, a major portion of outside air entering the shop is pulled toward the south and west walls of the shop where the exhaust hoods for the automobile/small truck radiator repair tanks are located This also means that lead fumes in the shop air and from the industrial radiator repair soldering operations are conducted toward the mechanics at the automobile radiator repair workstations Lead fumes can further accumulate as the air crosses Tanks 1, 2,

Table 6. Exhaust Ventilation Design Data

Tank #	Fan Horsepower	Exhaust Volume (cfm)	Static Pressure (inches)
1 & 2	3	3,200	3-1/2
3 & 4	2	4,000	1-1/2
5 & 6	3	3,200	3-1/2
7 & 8	5	5,000	3-1/2



AIR FLOW PATTERNS ON 6/27/89

Figure 6

and 3 and culminates with the highest concentration at Tank 4 Additionally, the static air conditions tend to concentrate airborne lead at Tank 4

Dilution ventilation in the shop appeared to greatly assist in reducing the lead exposures of the industrial radiator repair workers A large quantity of outside air flows by these two stations, and rapidly dilutes the lead soldering fumes In our survey, the three personal sample concentrations for lead for the industrial radiator repair mechanics were all less than 20 $\mu g/m^3$ and demonstrate the importance of general dilution ventilation in controlling the lead exposure of these workers

Paint Spray Booth

The total exhaust air volume for the paint spray booth, which was 4 feet high and 3 to 10 feet across, was 1,290 cfm and the face velocity averaged 85 fpm The booth is operated only intermittently for a few minutes at a time

WORK PRACTICES

The normal procedure for radiator repair consisted of mounting and securing the radiator on a lift device above the tank, and burning off the old solder to remove the top and bottom reservoirs of the radiator If required, the old solder around the ends of the tubes in the radiator core was heated and removed The reservoirs were cleaned in an enclosed sand blaster, new solder was applied to the core, the core ends around each tube, and reservoirs as needed, and the reservoirs were reattached and soldered to the core The radiator was leak tested, removed from the lift, dried, and painted

The main source of lead exposure for the radiator repair mechanics is the removal of the old solder and application of new solder that holds the top and bottom parts to the radiator Lead exposures can also result while soldering to seal leaks in tubes in the core and to attach new tubes to the core ends Heating the solder to very high temperatures produces a continuous stream of lead fumes Excess liquid flux and melted solder are blown from the radiator with air hoses, creating a potential source of lead particulate emissions

The major work procedures that minimize the radiator repair mechanics' exposure to lead are The exhaust ventilation hood must be located within 12 to 18 inches from the radiator surface being heated When this was done, virtually all the smoke generated was captured by the hood If the hood was more than 18 inches from the area being heated, smoke was observed to escape Second, the hood should be positioned above and behind the lead emission source so that fumes are drawn away from the breathing zone Generally, the radiator was positioned over the tank, the exhaust hood behind the radiator, and the operator worked in front of the radiator One mechanic, however, placed the radiator forward of the tank, set the exhaust hood over the tank, and worked between the hood and the radiator, as a result, lead fumes and smoke were drawn into his breathing zone Third, for repair work that requires inspection to within a few inches of the source, the mechanic should allow the exhaust hood to dissipate the smoke before making the inspection (In one radiator shop, a mechanic was fitted with corrective lenses so he could see his work better and thus reduced his exposure to lead) The mechanic should aim air hoses toward the back of the workstation and not toward himself or other employees

At the two industrial radiator repair stations (in the center of the shop), the radiators are often set in the aisle a few feet from the repair tanks so that the mechanic can solder the radiator from either side Again, to minimize the mechanics' lead exposure, the exhaust hood must be within 18 inches of work area to capture the smoke and lead fumes Because the industrial radiator repair stations were located in the path of strong air currents, failure to capture smoke and lead fumes resulted in increased lead exposure to the other employees in the shop, especially those downwind of this station At the industrial radiator repair stations, the mechanic should work with the torch on the upwind side of the radiator to reduce his exposure Finally, the industrial radiators are very large, smoke can travel through tubes in the core and escape from radiator hose connections and other holes more than 2 feet from the exhaust hood and not be captured by the hood Again, working upwind of the torch should further reduce exposure to lead

Workers at this shop made good use of the radiator lifts to move and position the radiator during repairs The mechanic could manually carry the small and medium size radiators without strain Hoists and fork lifts were used to move the larger industrial radiators

The sand blasting booth used to clean the reservoir of the radiators was totally enclosed Mechanics were observed to wait for all the dust to be exhausted before opening the sand blasting booth and removing the part cleaned

Small and medium size radiators were painted in a ventilated spray booth The ventilation was turned on before painting was started

Analysis of Individual Work Practices

Most of the mechanics kept the hood within 18 inches of the radiator repair surface and their breathing zone out of the path of the visible fumes between the radiator and the exhaust hood However, one mechanic worked with his head close to the fume source which may have increased his lead exposure Another worker placed his breathing zone between the fume source and the capture hood when performing repairs that required intricate work with the torch to solder in tight places, such as sealing individual tubes in the core Work practices observed while repairing the industrial radiators ranged from good to poor The exhaust hood(s) at the industrial radiator repair tanks were positioned anywhere from within 18 inches to over 4 feet from the source of the soldering fumes In addition, some mechanics stood downwind of the smoke and fumes

Because of the size of these radiators, a lot of extra maneuvering was required to position the exhaust hoods to capture the smoke and fumes Even though the exhaust hoods were not always utilized, the strong air currents in the shop tended to carry away almost all the lead emissions, thus protecting the industrial radiator repair mechanics Unfortunately, these fumes were carried to other areas of the shop and were a potential source of lead exposure for the other employees When heat was applied to the bottom of a large industrial radiator, fumes and smoke escaped through the radiator tubes as much as 4 feet from the exhaust hood A second exhaust hood located near the bottom of the radiator would improve capture of the lead fumes

The mechanics' work practices were sometimes dramatically different during videotaping than at other times While being videotaped, one worker pulled the hood within 18 inches of the fume source, and positioned it so that the smoke and fumes were drawn away from his breathing zone His lead exposure during videotaping was very low When not being videotaped, we observed this worker to use comparatively poor work practices, such as leaving the exhaust hood over 3 feet from the radiator and placing his head between the radiator (fume source) and the exhaust hood During the rest of our survey (when not being videotaped), this worker's lead exposure averaged about triple that during videotaping It is likely that the three-fold reduction in lead exposure during the videotaping was the result of much better work practices

Although in most situations work practices affect workers' exposure, our data indicate little correlation between poor work practices and high lead exposures Other factors such as workstation location and the effect of general air currents predominate at A-1 Radiator In one case, however, the lead exposure of a mechanic was reduced three-fold by improved work practices such as appropriate use of the exhaust hood

OTHER AIR SAMPLING RESULTS

Solvents

Area samples for solvents were collected on charcoal tubes near the paint spray booth on all three days of the survey, and in the industrial radiator assembly room while industrial radiators were being painted These samples were analyzed for benzene, toluene, xylenes, and trimethyl benzene, the results are presented in Table A-2 of the Appendix Area concentrations were well below their respective OSHA PELs and TLVs® for all four materials [7,8] Based on the the results for these four chemicals, there appears to be little potential for excessive solvent exposure at this shop

Hydroxides

Table A-3 of the Appendix shows the results for area samples taken each day at the caustic tank and analyzed for alkaline dust All three sample concentrations were below the LOD (0 05 to 0 11 mg/m^3) The ceiling TLV is 2 mg/m^3 for sodium hydroxide [8]

Carbon Monoxide

Four samples for carbon monoxide collected with Draeger tubes in the radiator shop area were all below the LOD of 20 parts per million (ppm) The OSHA PEL for carbon monoxide is 50 ppm and the NIOSH REL is 35 ppm [11]

Results for Other Metals and Minerals

Limited amounts of copper and zinc were found on the sample filters, one filter contained chromium These metals were below their respective PELs Assuming that all zinc emissions were zinc chloride, personal sample concentrations ranged up to 350 $\mu g/m^3$ or about one-third the OSHA PEL for zinc chloride The highest copper concentration (of 59 samples collected) was 24% of the OSHA PEL for copper fume (100 $\mu g/m^3$), there is no NIOSH REL for copper The single chromium exposure was 5 $\mu g/m^3$ The results for the following metals and minerals were all below the LOD aluminum, arsenic, barium, beryllium, calcium, cadmium, cobalt, lithium, magnesium, manganese, molybdenum, nickel, phosphorus, platinum, selenium, silver, sodium, tin, tellurium, thallium, titanium, tungsten, vanadium, yttrium, and zirconium

PERSONAL PROTECTIVE EQUIPMENT, HYGIENE, AND MONITORING

All mechanics wore safety glasses, rubber gloves, and steel-toed rubber boots when working on radiators Coveralls were provided through a cleaning service, the employees and the company each pay half the cost The shop has a locker room for changing clothes and cleaning up No smoking or eating was allowed in the shop and all radiator repair mechanics were enjoined from purchasing food from the lunch wagon without first washing their hands

VI CONCLUSIONS AND RECOMMENDATIONS

1 Ten of the 15 mechanics' time-weighted-average personal exposures for lead were at or below the OSHA PEL while the shop operated at a high level of production The three highest TWA lead exposures were found on the same worker located at a radiator repair tank in the corner of the shop The other two TWA exposures were both 60 $\mu g/m^3$, slightly above the OSHA PEL Personal exposures for lead while using the adjustable-arm elephant trunk LEV system were, on average, half the personal exposures reported as a result of a compliance inspection 18 months earlier prior to installation of the LEV system During our survey, production at the shop operated near its peak rate, this was also a high volume for radiator repair shops in general The radiator repair mechanics' exposures (half-day samples) for lead ranged from 17 to 91 $\mu g/m^3$ TWA lead exposures ranged from 17 to 79 $\mu g/m^3$

2 Our results indicate that the adjustable-arm elephant trunk ventilation system (Figure 3) would normally control lead fumes at this shop to the OSHA PEL during very high production levels with the following caveats (1) the existing elephant-trunk ventilation system is not capable of controlling lead fumes at Tank 4 even if higher exhaust volumes were used, and (2) the shop doors are kept open The likelihood of overexposure to lead when doors are closed is small, since radiator repair activity is generally slower in the winter months The LEV system may work well with doors closed and the 15,000 cfm makeup-air system functioning, however, because it was not in operation at the time of this survey, no definitive conclusions can be drawn Confirmation that the LEV system can adequately control lead exposures with doors closed should be documented by additional sampling for lead in the winter months

3 Work practices appeared to be a source for excess lead exposures at this shop One worker, using good work practices while being videotaped, achieved a lead exposure equal to about a third of that measured when he

was not being videotaped It was noted that this worker stood between the exhaust hood and the soldering torch when not being videotaped, but that he was careful to correctly position the exhaust hood during videotaping Training and reinforcement in good work practices would undoubtedly result in the reduction and maintenance of lead exposures below the OSHA PEL for these workers

4 The lead exposure of mechanics at A-1 Radiator is due to emissions from their own soldering and also from other soldering activity upwind of their station For some, lead exposure is dependant more upon the production level and work practices at the adjacent radiator repair tanks than on their own activity From our survey results, the most vulnerable position was at Tank 4 This is an automobile radiator repair station squeezed into a corner between Tanks 2, 3, and 5 Because of the prevailing air currents in the shop, the mechanic at Tank 4 is exposed to lead emissions generated at Tanks 2 and 3 and possibly at Tanks 1 and 5, in addition to lead fumes from his own soldering The air also stagnates in that corner of the shop (see Figure 6) Even though the mechanic at Tank 4 correctly positioned the LEV hood to obtain satisfactory capture velocity and followed good work practices, he had the highest lead exposure and was consistently above the OSHA PEL Because of this, it is strongly recommended that this radiator repair station not be used during moderate or heavy production activity Tank 1, which was generally not used during our survey, is better located to take advantage of the general dilution ventilation pattern Tanks 7 and 8 may be used in the future because the management at A-1 Radiator opened a new shop that will probably handle most of the industrial radiator repair

5 Sampling results for 29 metals and minerals, carbon monoxide, solvents, and sodium hydroxide were well within their respective OSHA PELs If lead exposures are adequately controlled, exposure to other potentially hazardous substances should not be a concern

6 The exhaust openings in the plenums at the ceiling prevented the accumulation of visible fumes near the ceiling but reduced the exhaust volume at the hoods Even with this loss of exhaust volume, the capture velocities were generally acceptable at the exhaust hoods

7 The partial collapse of the flexible portion of the ducts was identified at several of the radiator repair tanks Further collapse of any of the ducts could greatly reduce the exhaust volume and it is recommended that the airflow to each hood be tested every 2 months by the shop to identify severely restricted ducts Related to this is the tendency for the damper in the exhaust hood to automatically close It would be prudent to lock the damper open Testing the hood exhaust volume bimonthly would also identify the event of a closed damper

8 The handle attached to the hood is difficult for the mechanics to reach and discourages them from always positioning the hood correctly To facilitate the mechanics ability to always move the hood to the fume source, a 3-inch flange should be added to the hood This will also increase the efficiency of the hood by improving the capture velocity

9 The enforcement of good personal hygiene by the management is commended

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9 Occupational Health Guidelines for Chemical Hazards DHHS (NIOSH)/DOL (OSHA) Pub 81-123, Cincinnati, Ohio, 1978, 1988

10 NIOSH Method 7300 NIOSH Manual of Analytical Methods Third Ed , Vol 2 Cincinnati, OH U S Dept Health and Human Services DHHS (NIOSH) Publication No 84-100 February 15, 1984

11 Occupational Health Guidelines for Chemical Hazards Occupational Safety and Health Guideline for Carbon Monoxide DHHS (NIOSH)/DOL (OSHA) Pub 81-123, Cincinnati, Ohio, 1978

TABLE A-1 INDIVIDUAL INORGANIC LEAD SAMPLE RESULTS FOR A-1 RADIATOR

DATE	SAMPLE NUMBER	TYPE	PERSON CODE	TANK NUMBER/ LOCATION	SAMPLE TIME (min)	VOLUME (liters)	LEAD DETECTION LIMIT	LEAD MASS (ug)	LEAD CONC (ug/m3)
6/26/89	2	PERS	KB	2	143	286		19	66
6/26/89	86	PERS	KB	2	263	526		21	40
6/26/89	3	PERS	JA	3	140	280		13	46
6/26/89	95	PERS	JA	3	279	558		30	54
6/26/89	73	PERS	DG	4	137	274		24	88
6/26/89	57	PERS	DG	4	272	544		36	66
6/26/89	56	PERS	TT	5	138	276		8	29
6/26/89	74	PERS	TT	5	276	552		27	49
6/26/89	64	PERS	JE	INDUS	84	168		3	18
6/26/89	91	PERS	JE	INDUS/6	289	578		23	40
6/26/89	62	PERS ST	DG	4	89	178		12	67
6/26/89	54	PERS ST	TT	5	26	52	ND	<2	<38
6/26/89	85	PERS ST	JE	INDUS	32	64	ND	<2	<31
6/26/89	92	AREA		2	431	862		30	35
6/26/89	70	AREA		3	196	392		26	66
6/26/89	63	AREA		5	440	880		18	20
6/26/89	58	AREA		8	26	52	NQ	2	38
6/26/89	76	AREA		8	440	880		14	16
6/26/89	71	AREA		SANDBL	451	902		26	29
6/26/89	82	AREA		OUTSIDE	419	838	ND	<2	<2
6/26/89	52	AREA		OFFICE	471	942	NQ	2	2
6/26/89	72	AREA		BCKSHOP	371	742		8	11
6/27/89	83	PERS	KB	2	193	386		25	65
6/27/89	9	PERS	KB	2	171	342		19	56
6/27/89	84	PERS	JA	3	168	336		6	18
6/27/89	31	PERS	JA	3	203	406		30	74
6/27/89	53	PERS	DG	4	201	402		13	32
6/27/89	11	PERS	DG	4	203	406		37	91
6/27/89	99	PERS	TT	5	195	390		12	31
6/27/89	27	PERS	TT	5	203	406		36	89
6/27/89	94	PERS	JE	INDUS	237	474		8	17
6/27/89	35	PERS	JE	INDUS	198	396		7	18
6/27/89	81	PERS ST	JA	3	83	166		3	18
6/27/89	32	PERS ST	JE	INDUS	281	562		11	20
6/27/89	66	AREA		2	447	894		36	40
6/27/89	100	AREA		3	461	922		45	49
6/27/89	97	AREA		4	451	902		24	27
6/27/89	51	AREA		5	420	840		51	61
6/27/89	69	AREA		7	436	872		11	13
6/27/89	44	AREA		SANDBL	362	724		13	18
6/27/89	98	AREA		OUTSIDE	423	846	ND	<2	<2
6/27/89	60	AREA		OFFICE	402	804	NQ	2	2
6/27/89	80	AREA		BCKSHOP	432	864		14	16
6/28/89	89	PERS	KB	2	208	416		21	50
6/28/89	67	PERS	JA	3	208	416		21	50
6/28/89	68	PERS	DG	4	208	416		33	79
6/28/89	78	PERS	TT	5	211	422		18	43
6/28/89	77	PERS	JE	6	160	320		14	44
6/28/89	21	PERS ST	TY	8	118	236	ND	<2	<8
6/28/89	87	PERS ST	TT	5	87	174		9	52
6/28/89	90	AREA		2	209	418	ND	<2	<5
6/28/89	13	AREA		3	205	410	ND	<2	<5
6/28/89	55	AREA		4	208	416		7	17
6/28/89	38	AREA		5	213	426		12	28
6/28/89	96	AREA		7	223	446		13	29
6/28/89	75	AREA		SANDBL	209	418		15	36
6/28/89	12	AREA		OUTSIDE	222	444	ND	<2	<5
6/28/89	59	AREA		OFFICE	220	440	ND	<2	<5
6/28/89	22	AREA		BCKSHOP	220	440		4	9

TABLE A-2 SOLVENT RESULTS FOR A-1 RADIATOR

DATE	SAMPLE NUMBER	MEDIA	LOCATION	SAMPLE TIME (min)	VOLUME (liters)	BENZENE MASS (ug)	BENZENE CONC (mg/m3)	TOLUENE MASS (ug)	TOLUENE CONC (mg/m3)	XYLENES MASS (ug)	XYLENES CONC (mg/m3)	TRIMETHYL BENZENE MASS (ug)	TRIMETHYL BENZENE CONC (mg/m3)
6/26/89	005	CT	PAINT BOOTH	385	19 3	1	0 05	9	0 47	15 6	0 81	48	2 5
6/27/89	002	CT	PAINT BOOTH	151	7 8	0 3	0 04	1 3	0 17	3 4	0 45	14	1 8
6/27/89	003	CT	PAINT BOOTH	138	6 9	0 3	0 04	0 9	0 13	1 6	0 23	7	1 1
6/27/89	007	CT	PAINT BOOTH	121	6 1	0 1	0 02	1	0 17	2 3	0 38	8	1 3
6/28/89	010	CT	PAINT BOOTH	209	10 5	0 1	0 01	1 2	0 11	3 2	0 31	12	1 1
6/28/89	004	CT	INDUST REBUILD	70	3 5	0 2	0 06	1 3	0 37	2 2	0 63	8	2 1
6/26/89	006	BLANK		0	0	0 1		< 1		< 3		< 5	
6/28/89	001	BLANK		0	0	0 3		< 1		< 3		< 5	
6/28/89	017	BLANK		0	0	0 1		< 1		< 3		< 5	

TABLE A-3 SODIUM HYDROXIDE RESULTS FOR A-1 RADIATOR

DATE	SAMPLE NUMBER	MEDIA	LOCATION	SAMPLE TIME (min)	VOLUME (liters)	ALKALINE DUST MASS (ug)	ALKALINE DUST CONC (mg/m3)
6/26/89	100	PTFE	CAUSTIC TANK	378	756	<40	0 05
6/27/89	102	PTFE	CAUSTIC TANK	402	804	<40	0 05
6/28/89	103	PTFE	CAUSTIC TANK	190	380	<40	0 11
6/28/89	105	BLANK		0	0	<40	

TABLE A-4 BLANK RESULTS FOR LEAD A-1 RADIATOR

DATE	SAMPLE NUMBER	TYPE	VOLUME (liters)	LEAD DETECTION LIMIT	LEAD MASS (ug)
6/26/89	65	BLANK	0	ND	<2
6/26/89	88	BLANK	0	ND	<2
6/27/89	79	BLANK	0	ND	<2
6/27/89	29	BLANK	0	ND	<2
6/27/89	20	BLANK	0	ND	<2
6/28/89	10	BLANK	0	ND	<2
6/28/89	25	BLANK	0	ND	<2
6/28/89	30	BLANK	0	ND	<2
6/28/89	81	BLANK	0	ND	<2
6/28/89	93	BLANK	0	ND	<2

TABLE B-1

CHEMICAL NAME	OSHA PEL (mg/m3)	NIOSH REL (mg/m3)	TWA (mg/m3)
Aluminum	---	---	0 2
Arsenic	0 01	0 002	0 2
Barium	0 5	---	0 5
Benzene	32	3 2	32
Beryllium	0 002	0 0005	0 002
Cadmium	0 1	0 04	0 01
Carbon Monoxide	55	40	57
Chromium	0 5	0 025	0 5
Cobalt	0 1	---	0 05
Copper	0 1	---	0 2
Lithium, hydride	0 025	---	0 025
Magnesium oxide fume (total)	15	---	10
Manganese	5 (C)	---	1
Molybdenum	5	---	5
Nickel	1	0 015	1
Platinum	---	---	1
Selenium	0 2	---	0 2
Silver	0 01	---	0 01
Sodium Hydroxide	2	2 (C)	2 (C)
Tellurium	0 1	---	0 1
Thallium	0 1	---	0 1
Toluene	750	375	375
Trimethyl Benzene	---	---	125
Tungsten (soluble)	---	1	1
Vanadium	0 1	1	0 05
Xylene	435	435	435
Yttrium	1	---	1
Zinc Chloride	1	---	1
Zirconium	5	---	5

(C) Ceiling

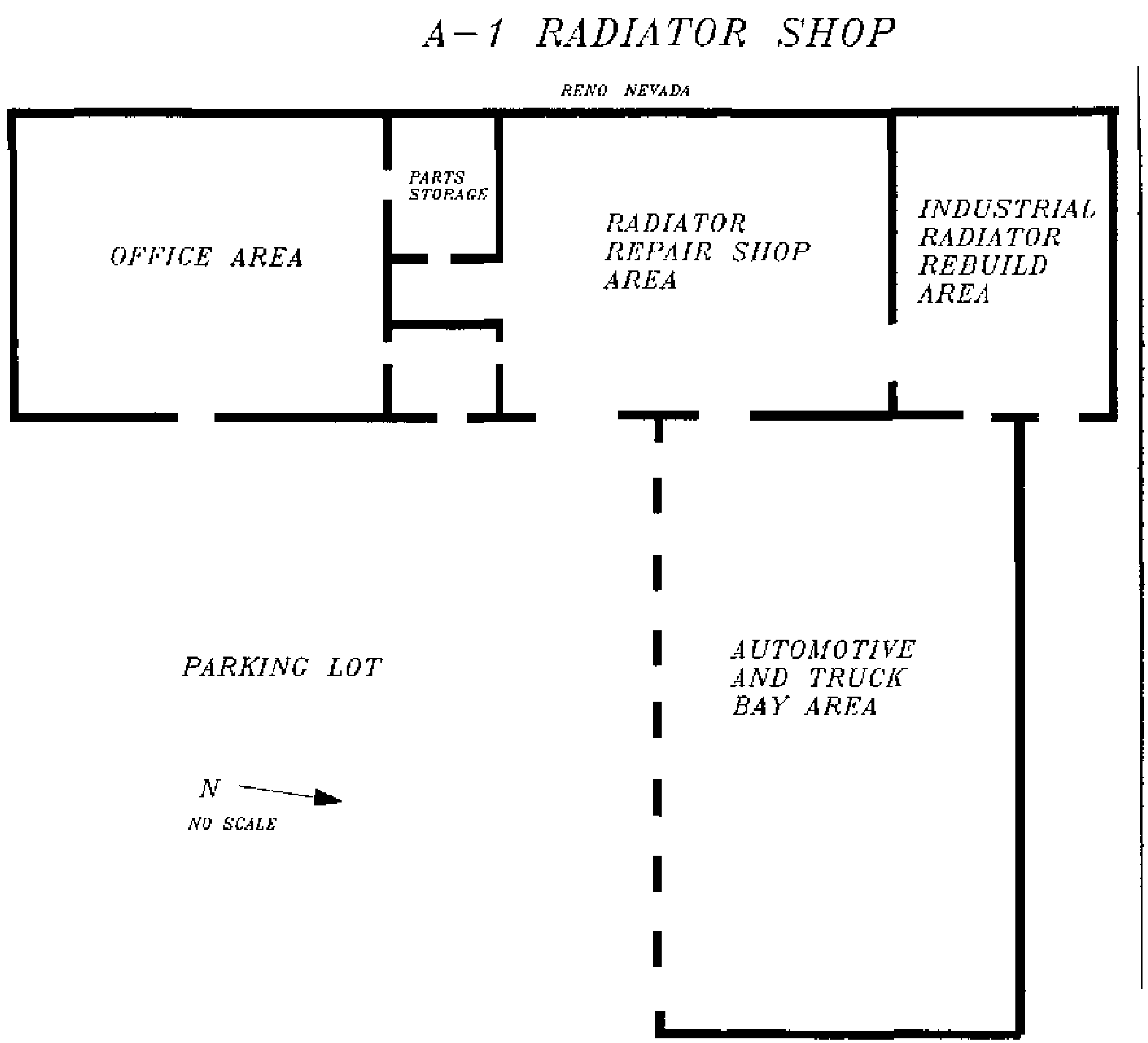


Figure 1

Building Layout

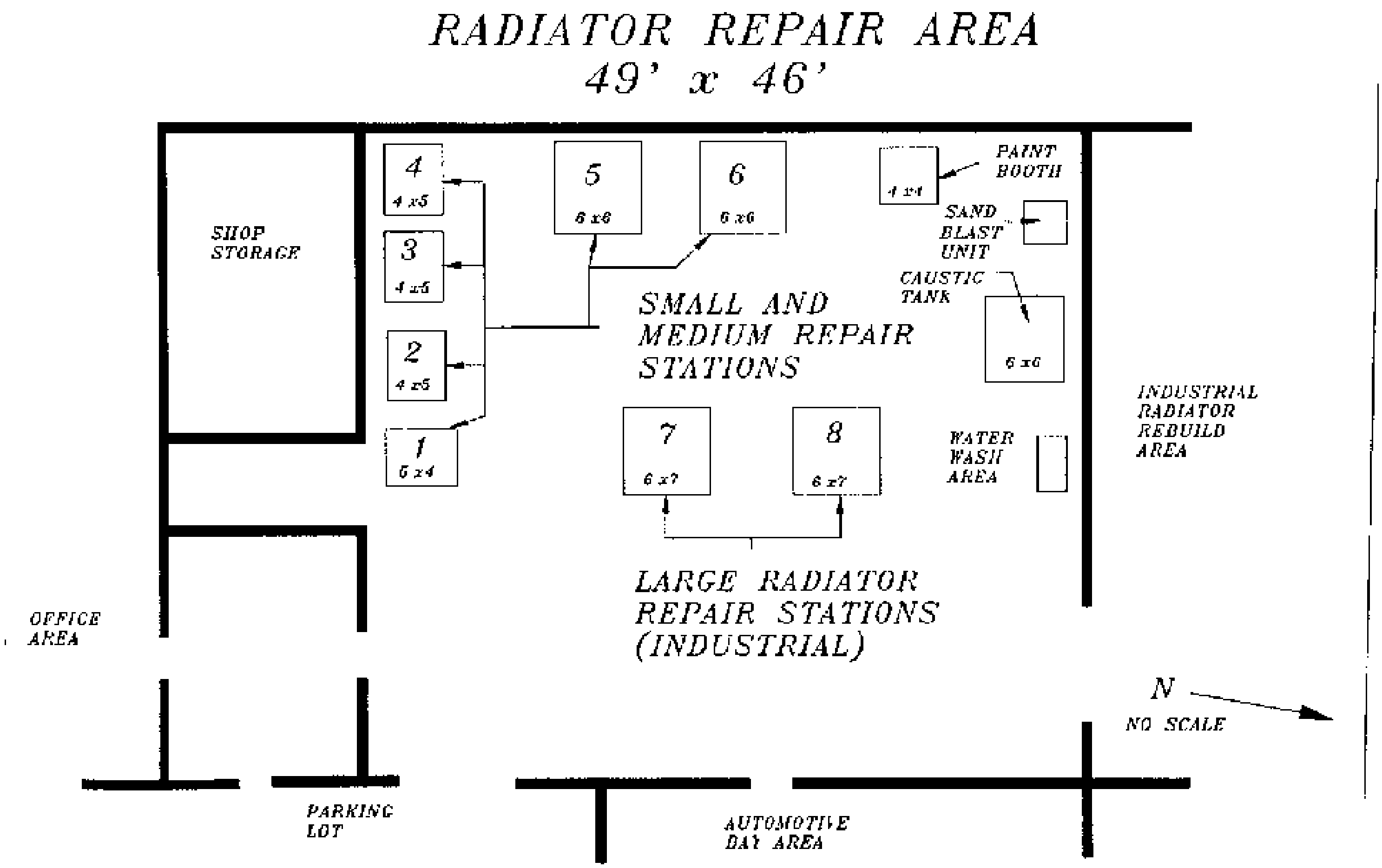
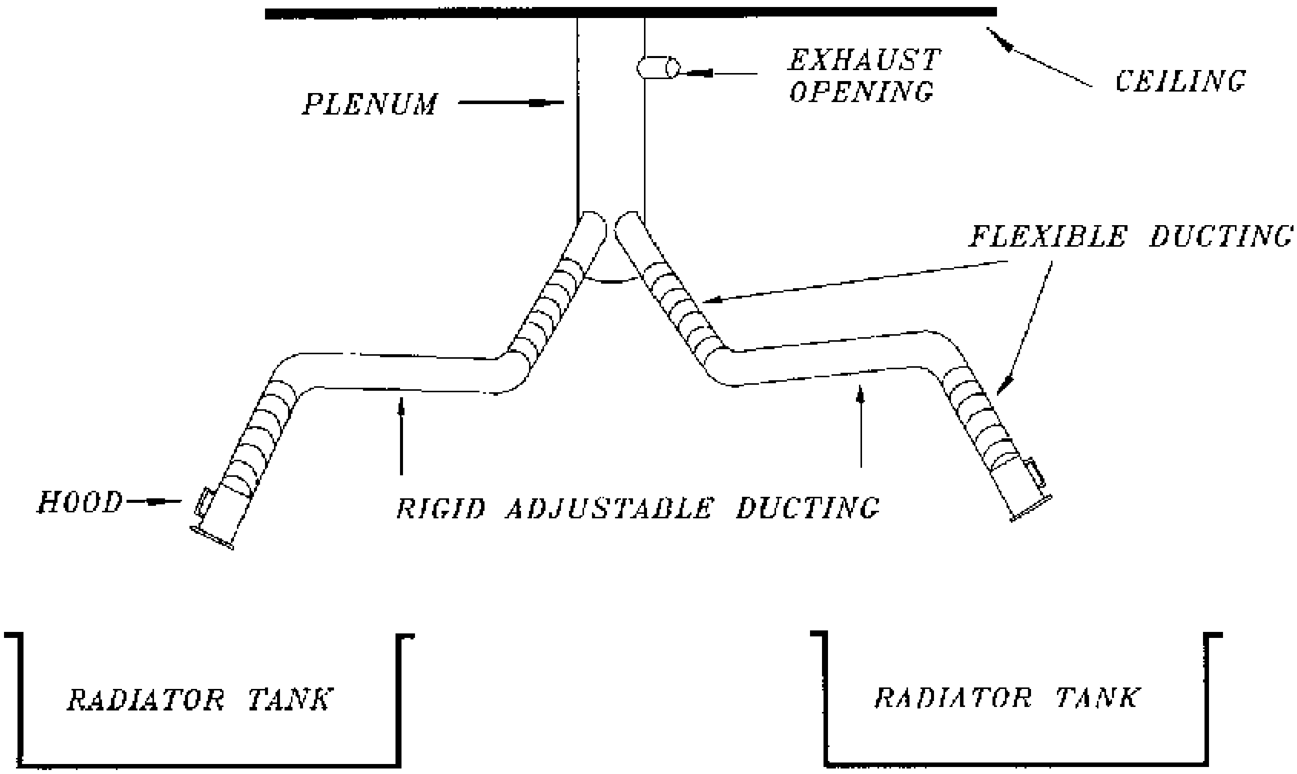


Figure 2

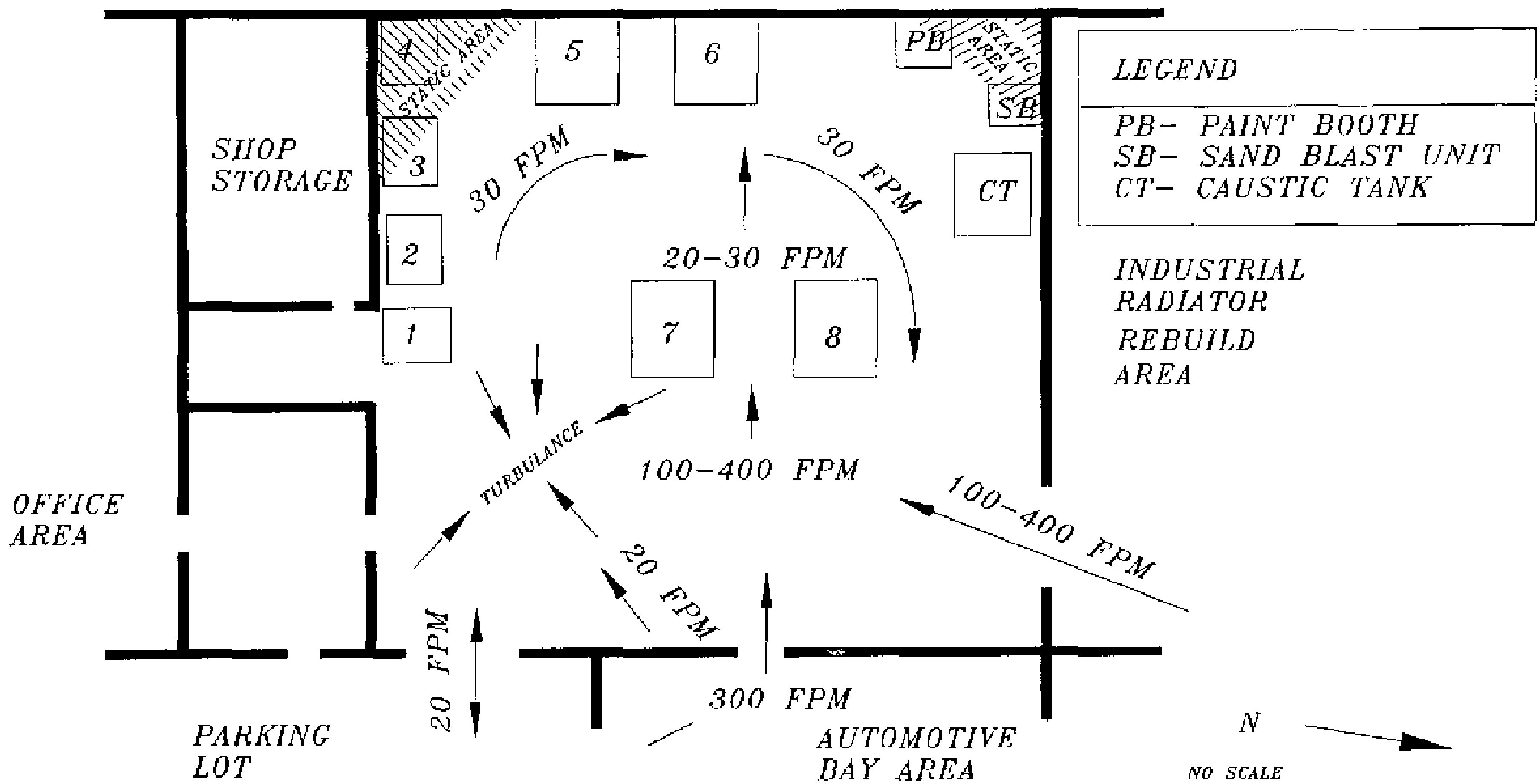
Layout - Radiator Repair



ADJUSTABLE-ARM ELEPHANT TRUNK EXHAUST
VENTILATION SYSTEM

Figure 3

Schematic of LEV System



AIR FLOW PATTERNS ON 6/27/89

Figure 6