Cost-Effective Radiator Repair Ventilation Control

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Radiator repair shops in the United States employ an estimated 40,000 workers. The shops are generally small, employing an average of four workers each. Airborne lead levels as high as 500 μg/m³, ten times the OSHA PEL of 50 μg/m³, have been reported in some of these shops, and blood lead levels in workers of over 60 μg/dl are not uncommon. Although numerous publications deal with the exposure problem, few describe methods to reduce lead levels.

Typically, engineering controls in these radiator repair shops consist of propeller fans in the building walls or roof for general ventilation or electrostatic precipitators suspended from the ceiling to remove particulate from the air. Both methods are ineffective in reducing worker lead exposures to below the Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL).

This article describes a cost-effective ventilation enclosure made of a flexible silicone sheet reinforced by fibrous glass that forms a tent-like structure over the water bath that is used to leak test radiators. An opening in the front of the enclosure permits the mechanic to repair the radiator inside the enclosure. A propeller fan mounted in the rear (outside wall) of the enclosure exhausts air at a rate of 3400 m³/hr (2000 cfm), producing an air flow of 1 m/sec (200 fpm) through the enclosure opening. The authors are not aware of any ventilation hood of this type that has previously been designed or installed in radiator repair shops.

The effectiveness of this enclosure was evaluated by collecting short-term and time-weighted average personal breathing zone samples for lead at a "controlled" work station that used the enclosure. In addition, similar personal breathing zone samples for lead were collected at a work station in the same facility without the enclosure (uncontrolled).

Lead exposures during radiator repair at the controlled work station averaged 9.9 μg/m³, 20 percent of the OSHA PEL. Personal breathing zone samples taken at an uncontrolled work station averaged 453 μg/m³—45 times higher than that at the controlled station. These results demonstrate excellent control of lead fumes using this enclosure. Goldfield, J.; Sheehy, J.W.; Gunter,

Introduction

There are an estimated 10,000 radiator repair shops in the United States. The shops are generally small, employing an average of four persons each.[1]

Worker overexposure to lead during radiator repair activity is amply demonstrated in the literature. Table I presents airborne lead concentrations and blood lead levels reported for a number of studies. Personal lead concentrations up to 590 μg/m³ show that radiator repair mechanics may be exposed to lead levels more than ten times the Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL). Furthermore, OSHA requires that a worker with a blood lead level higher than 60 μg/dl of whole blood be removed from exposure to lead until the level drops back to 40 μg/dl.[12] As shown in Table I, workers have been monitored with blood lead levels greater than 60 μg/dl. Results from the Second National Health and Nutrition Evaluation Survey[3] show that only 6 percent of male workers with potential occupational lead exposure had blood lead concentrations above 30 μg/dl, and Lussenhop et al.[4] report that blood lead levels in the general population average 13–15 μg/dl. Therefore, it is evident that radiator repair mechanics do have elevated blood lead levels—a manifestation of excess lead exposures.

Garretson[13] cites cases where young children of radiator repair mechanics have developed lead poisoning through exposure to lead dust brought home by their fathers.

Although many references describe hazardous lead exposures for radiator repair mechanics and refer to the need for effective ventilation, there is a paucity of references describing effective exhaust systems. General ventilation by roof and wall fans is common, but of doubtful effectiveness. Goldman et al.[3] report that six shops in the

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TABLE I. Airborne Lead Exposures and Blood Lead Levels Among Radiator Repair Mechanics[2-11]

	Air Lead Levels (μg/m³)			Blood Lead (μg/dl)		
Reference	No. of Samples	Arithmetic Mean	Range	No. of Samples	Arithmetic Mean	Range
2	8	160	10–290	—	—	—
3	5	79	8–160	56	35	16–73
4	16	113	0–590	53	32	5–58
5	—	—	—	58	38	17–83
6	—	—	10–570	—	—	20–66
7	5	—	10–100	8	—	11–57
8	2	—	50–100	—	—	29–65
9	3	—	50–70	3	—	44–62
10	—	—	>50	4	41	32–51
11	8	120	20–380	2	—	>40

Boston area (22 percent of the total visited) had electrostatic precipitators to clean the air; however, the precipitators were poorly maintained and positioned and often went unused. Lussenhop and co-workers,[4] in a study of radiator repair shops in the Minneapolis–St. Paul area, report that few shops had local ventilation and most ventilation systems were not used. They articulate the need for improved ventilation in the radiator repair industry.

Sheehy et al.[14] describe an adjustable-arm, elephant-trunk exhaust system that reduced lead exposures by about 50 percent at a large, high-volume, radiator repair shop. This system exhausts air at an average of 1800 m³/hr (1050 cfm) per station. The effectiveness of this ventilation system is closely related to the attentiveness of the mechanic and the careful placement and frequent repositioning of the hood. The ventilation system for eight radiator repair stations cost $20,000 plus an additional $15,000 for a make-up air unit. This article describes a novel, cost-effective method for controlling airborne lead exposures resulting from radiator repair activities.

Methodology

In September 1988, the owners of three radiator repair shops in the Denver, Colorado, metropolitan area requested a health hazard evaluation to investigate occupational exposures to lead during radiator repair activity.[2] The shops were small, employing up to three workers, with three to four work stations per location.

In response to this request, researchers from the National Institute for Occupational Safety and Health (NIOSH) and Colorado State Health Department personnel conducted environmental and medical evaluations at the three shops. The report[2] on these evaluations stated that workers at all three locations had lead levels in their breathing zones exceeding the OSHA PEL (50 μg/m³ of lead). Six of eight breathing zone samples for lead exceeded 50 μg/
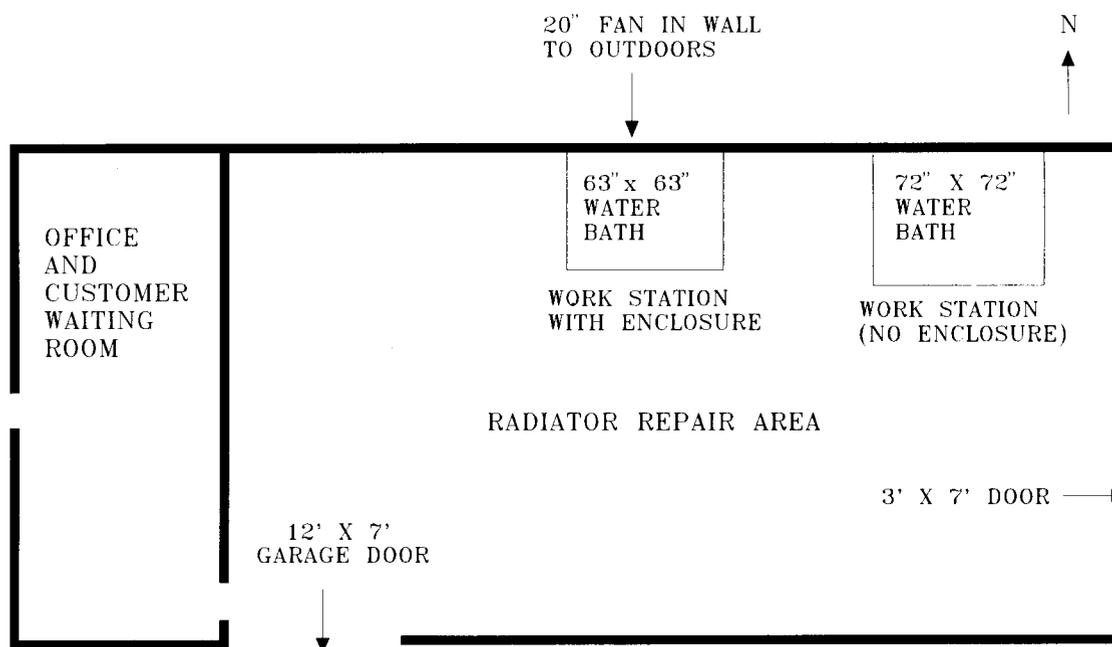

FIGURE 1. Layout of radiator repair work stations (not to scale).

m³; the highest concentration was 290 µg/m³. The medical evaluation found elevated blood lead levels among the mechanics. Three of the ten mechanics tested had blood lead levels above 40 µg/dl, and four had zinc protoporphyrin (ZPP) levels above 60 µg/dl, the upper limit of normal.

Following the above evaluation, NIOSH researchers and a consultant visited these radiator repair shops for the purpose of observing operations and recommending ventilation systems for reducing airborne lead concentrations. After examining these operations, the survey team proposed that a new ventilation system, designed to control lead exposures to below the OSHA PEL, be installed and tested in one of the three Denver radiator shops.

Facility Description

The radiator repair shop, chosen for the evaluation of the new ventilation system, employs two radiator repair mechanics. Figure 1 shows a layout of the shop and the two work stations. Each work station consists of a water bath, two natural gas torches, and a hydraulic lift device that allows the mechanic to raise, lower, and rotate the radiator being repaired.

The principal radiator repair operations in use at this shop are as follows:

1. The radiator is placed in a water bath and checked for leaks and overall integrity.
2. The top and bottom (or side) tanks are separated from the radiator core by melting the lead-based solder with a torch.
3. The leaks are patched with 40–60 tin–lead solder using a torch.
4. The tanks are reattached to the core by soldering

FIGURE 3. Ventilated enclosure above water bath.

with 40–60 tin–lead solder which generates additional lead fumes.

A natural gas–oxygen flame is used to heat the assembly to melt the solder to remove the tanks and other pieces attached to the core. This operation generates a great deal of the lead fume. (A natural gas–oxygen flame has a temperature of close to 5000°F, well above the temperatures needed to vaporize lead.[15]

It was observed that metal equipment in the shop was quite corroded. The operators indicated that exhaust ducts or fans made of steel or aluminum had a limited life. (The corrosion is possibly caused by the chloride fluxes used for soldering.)

The shop propeller fans, mounted in the wall at the rear of each water bath, exhausted air to the outdoors. The effectiveness of these fans, as shown by breathing zone sample lead concentrations,[2] was quite poor. During cold weather, the building is closed up, and the air-moving capability of the fans is reduced further because of the lack of make-up air. In the other two radiator shops that were surveyed, a ceiling exhaust fan, located almost directly above the fume source, was also ineffective in capturing contaminants as shown by the breathing zone lead concentrations.[2]

Description of Ventilation Control

The effectiveness of exhaust ventilation decreases rapidly with distance. Where the exhaust is several feet away from the source of fume generation, the effect becomes almost negligible. In order to control contaminants, an adequate control velocity must be maintained near the point of fume generation. The new ventilation control was designed to enclose the area of fume generation and to maintain a control velocity at points where fumes could escape into the room.

Figures 2 and 3 show the enclosure over the work station. The walls of the enclosure consist of a curtain of silicone-coated fiber glass cloth about 1.5 mm (1/16 in.) thick. The curtain has a temperature rating of 1000°F, will
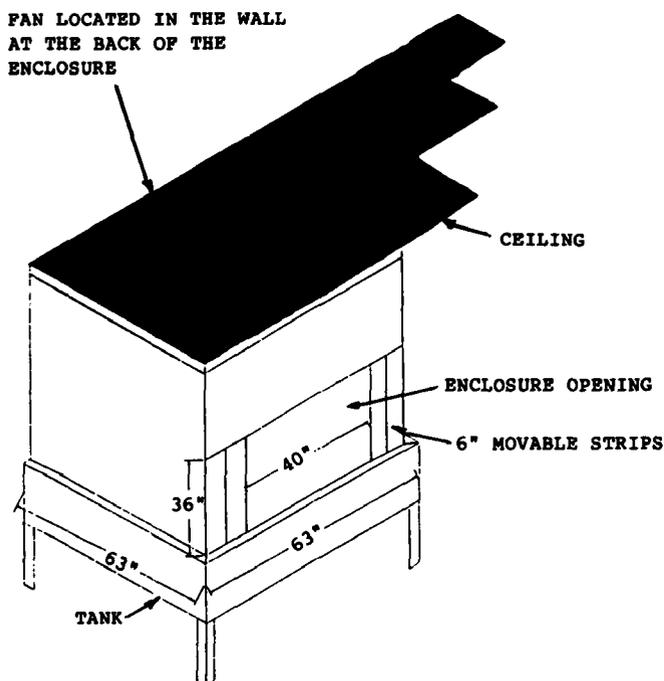
FAN LOCATED IN THE WALL
AT THE BACK OF THE
ENCLOSURE

CEILING

ENCLOSURE OPENING

6" MOVABLE STRIPS

40"

36"

63"

63"

TANK

FIGURE 2. Schematic of ventilated enclosure.

not support combustion, and cannot be set on fire by the mechanic's torches. Significantly, the curtain will not corrode.

The curtain is suspended from the ceiling to the top outer edge of the water bath to form the side walls. The ceiling forms the top of the enclosure, and the back wall of the building (containing an exhaust fan) forms the back of the enclosure. The front wall of the enclosure consists of a sheet that drops 90 cm (36 in.) from the ceiling with an opening 160 cm wide by 90 cm high (63 in. by 36 in.). To further reduce the amount of exhaust air needed to control the fumes that are generated, four 15-cm (6-in.) wide strips of flexible, but sturdy plastic material are suspended from the curtain above the opening to the top of the water bath as shown in Figure 2. These flexible strips reduce the width of the opening to 100 cm (40 in.). A face velocity of 1 m/sec (200 fpm) through the 100-cm by 90-cm (40-in. by 36-in.) opening yields an exhaust volume of 3400 m³/hr (2000 cfm).

The existing 50-cm (20-in.) diameter propeller fan mounted in the outside wall above the rear of the 1.6-m (63-in.) square water bath (Figure 1) was incorporated into the design and construction of the enclosure. The fan, purchased from W.W. Grainger, is equipped with a ¼ hp, 1725 rpm motor and a 61-cm (24-in.) square shutter. The rated exhaust capacity of the fan is about 5000 m³/hr (2900 cfm) of free air delivery and 4200 m³/hr (2500 cfm) at 3 mm (⅛ in.) of water static pressure.

For the enclosure to be effective, the radiator must be repaired within the enclosure. The enclosure is designed so that the radiator can be clamped in the hydraulic lift and manipulated within the enclosure; this enables the mechanic to always direct the torch flame into the enclosure.

The enclosure control (see Figures 2 and 3) was installed over the water bath by a carpenter in 2 hours using a prefabricated curtain. The cost of the prefabricated curtain and installation was $600. [If the radiator shop did not have an existing fan, a suitable propeller fan could have been purchased for $220 to $280 (1990 dollars) excluding fan installation.]

Evaluation of the Effectiveness of Ventilation Control

Personal and area samples for lead were collected on 37-mm diameter, cellulose ester, 0.8-µm pore size filters using SKC and Gilian pumps at 2.0–3.5 L/min. Samples were analyzed for lead by atomic absorption spectroscopy using NIOSH Method 7082.[16] The limit of detection (LOD) for lead was 0.4 µg/filter.

Both full-shift sampling and short-term sampling for the duration of a single radiator repair operation (< 1–2 hours) were performed. Personal breathing zone samples were taken on both the mechanic at the work station equipped with the enclosure (controlled) and the mechanic at the work station without the enclosure (uncontrolled). These samples were collected during four modes of radiator repair activity: 1) both work stations in use; 2) only the uncontrolled work station in use; 3) only the controlled work station in use; and 4) no repair activity. The arithmetic mean personal lead concentrations during each mode of radiator repair activity were then compared; with the key comparison being between the mechanic's lead exposure at the controlled work station and the mechanic's lead exposure at the uncontrolled work station. Indoor background samples for lead were taken in the shop at locations away from radiator repair operations and in the shop office; outdoor ambient samples were collected at two locations on opposite sides of the building approximately 5–10 feet from the building.

Ventilation measurements were made using Kurz digital and analog hot-wire anemometers. A smoke tube was used to qualitatively evaluate air movement in front of and in the enclosure. The capacity and dimensions of the building, enclosure, and fans also were obtained.

Results and Discussion

Lead Exposure Results

Table II and Figure 4 show the results of personal breathing zone samples for lead collected on the mechanics working at the controlled and the uncontrolled work stations.

TABLE II. Summary of Lead Exposures

|	Controlled Booth			Uncontrolled Tank		
	Concentration (µg/m³)	Sample Time (min)	Date	Concentration (µg/m³)	Sample Time (min)	Date
Both tanks in use	52	173	11/14	433	150	11/14
Only uncontrolled tank in use				247	83	11/15
				680	42	11/15
Only controlled tank in use	7.1	106	11/14			
	6.8	37	11/14			
	11	26	11/14			
	5.6	72	11/14			
	3.9	73	11/14			
	22.5	68	11/15			
	10.4	163	11/15			
	12.3	46	11/15			
	10.1	46	11/15			
No work being done	10.7	107	11/14	9.5	184	11/14
	20.8	156	11/15			
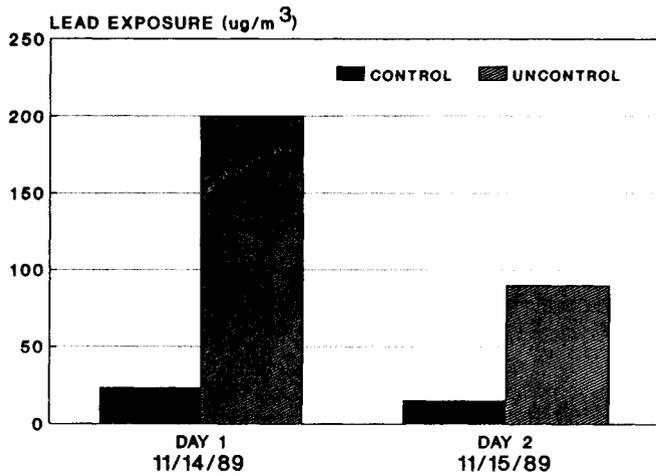
FIGURE 4. Comparison of TWA airborne lead exposures between controlled and uncontrolled work stations (OSHA PEL 50 μg/m³).

Nine personal breathing zone samples for lead (averaging 71 minutes each) were taken on the mechanic at the controlled work station while radiator repair work was being performed at the controlled station, but not at the uncontrolled station. The average lead exposure was 9.9 μg/m³, or 20 percent of the OSHA PEL of 50 μg/m³.

Three personal breathing zone samples (averaging 92 minutes each) were taken at the uncontrolled radiator repair station. The average lead exposure was 453 μg/m³. This is 45 times greater than the lead exposure for the mechanic at the controlled work station. (During the sampling survey, the wall fan near the uncontrolled work station was inoperative.)

A single, personal breathing zone sample for lead, taken on the mechanic at the controlled work station when both the controlled and the uncontrolled work benches were being used, was 52 μg/m³. This was probably caused by contaminated air being drawn from the uncontrolled work station across the breathing zone of the mechanic working at the controlled work station and into the enclosure.

Three personal breathing zone samples for lead, ob-

tained when no radiator repair work was being done, averaged 14 μg/m³ which is similar to the average indoor background lead concentration (15 μg/m³) measured at locations away from radiator repair operations. It is interesting to note that the average lead exposure for the mechanic working at the controlled work station was actually less than the background lead level inside the shop and less than lead exposures when no radiator repair work was being done. Background samples taken in the shop office averaged 12 μg/m³.

Background lead concentrations in the shop (samples taken at locations away from the process) indicate a build-up of lead indoors and cross-contamination of the office area. If both work stations were controlled and the inside of the shop carefully cleaned and painted, background lead levels in the shop probably would decrease to considerably less than 15 μg/m³.

Full-shift, outdoor, ambient area samples for lead averaged 0.6 μg/m³. Four outdoor area samples were collected, two northwest and two south of the building. These data indicate that outdoor lead levels contributed little or nothing to lead levels in the shop and that lead emissions exhausted by the propeller fans did not have a tangible effect on the immediate environment.

Ventilation Data

Table III shows the results of ventilation measurements taken with a thermal anemometer at the face of the opening of the ventilated enclosure being evaluated. In addition, ventilation measurements were taken in a vertical plane 30 cm (12 in.) in front of the opening.

With either the large garage door (shown in Figure 1) opened 18 cm (7 in.) or a smaller, 90-cm by 210-cm (3-ft by 7-ft) door opened to the outside, the average face velocity at the enclosure opening was close to the design flow of 1 m/sec (200 fpm). The average capture velocity 30 cm (12 in.) in front of the enclosure opening was 0.56 m/sec (110 fpm)—half of the velocity at the face of the opening.

Closing all doors to the outside reduced the air flow

TABLE III. Ventilation Measurements at the Face of the Enclosure

Date 1989	Velocity Range m/sec (fpm)	Average Velocity m/sec (fpm)	No. of Readings	Remarks
11/14	0.9–1.2 (170–240)	1.0 (190)	12	12-ft garage door open 7 in. All other doors closed.
11/14	0.9–1.2 (170–240)	1.0 (190)	12	12-ft garage door open 7 in. Office (inside) door open.
11/14	0.8–1.2 (150–240)	0.9 (180)	12	All doors closed.
11/14	0.6–1.2 (120–240)	1.1 (210)	9	12-ft garage door closed (3-ft by 7-ft door probably open).
11/15	0.8–1.3 (160–250)	1.1 (210)	16	12-ft garage door fully open. All other doors closed.
11/15	0.5–1.1 (90–210)	0.9 (170)	12	All doors closed. Worker at station. Radiator in booth.

into the enclosure by 10 percent to 0.9 m/sec (180 fpm) indicating a considerable amount of air leakage into the building. When a mechanic stood in front of the enclosure and a radiator was set up inside the enclosure, face velocities at the opening decreased by about 5 percent. Air velocity measurements and smoke tube tests indicated that the radiator profile only marginally interferes with air flow through the enclosure opening.

Ventilation results also reveal that the exhaust air volume of the fan may be less than the rated exhaust air volume. The existing 50-cm (20-in.) diameter propeller fan was rated at 4200 m³/hr (2500 cfm) of air at 3 mm (⅛ in.) water gauge; however, the total air flow exhausted into the enclosure was only 3400 m³/hr (2000 cfm). This 20 percent reduction can be explained by the added pressure drop due to the automatic shutters and the possible discrepancy between catalog and field data.

Make-Up Air

A further consideration in designing a ventilation control is that had this shop been relatively tight, the exhaust system would not have operated as efficiently when drawing air from the closed work space. However, since it is a leaky building, the exhaust fan capacity was not greatly reduced with all the doors closed. If an additional fan is installed to exhaust lead fumes from the uncontrolled work station, the resultant total exhaust volume of 6800 m³/hr (4000 cfm) may cause a significant negative pressure in the shop; therefore, a make-up air unit, equal to the exhaust capacity of the ventilating fans, would be required.

In addition, the make-up air must be heated to maintain acceptable temperatures in the winter months. In Denver, that design must have the capacity to heat air from −5°F to +65°F, a total of 70°F. The units can be direct fired, i.e., the gas can burn directly in the air stream because any products of combustion are diluted by the large amounts of make-up air. The heating unit should be modulating so that a thermostat in the supply air can adjust the amount of gas required as a function of outside temperature. The make-up air supply should be distributed to avoid adversely affecting the control and the mechanics' comfort. Exhaust air discharged from radiator repairs shops contains lead and should never be recirculated or mixed with the make-up air supply to conserve heat.

The installation and operation of a make-up air system may cost more than the enclosures and fans; therefore, it would be well to minimize make-up air requirements. The two parameters that can reduce make-up air requirements are the size of the opening into the enclosure and the design velocity of exhaust air through the opening. Experiments should be performed to reduce the width of this opening. If it could be decreased by 25 percent, the required exhaust air volume could be reduced by 25 percent. (However, if the front opening of the enclosure must be enlarged to accommodate larger water baths or larger radiators, the quantity of exhaust air would need to be increased proportionately.) Secondly, experiments should be conducted to determine if the face velocity can be

significantly decreased from 1 m/sec (200 fpm) and still effectively control lead exposures. If this is feasible, the quantity of exhaust air (and consequently the make-up air volume) could be reduced further.

Multiple Repair Stations

A ventilation system can easily be designed that will handle multiple radiator repair stations. A fiber glass–reinforced plastic duct system may be used to connect the enclosures to a single centrifugal fan. Blast gates could be used to close off the air flow to nonoperating stations in order to reduce the quantity of make-up air during the heating season.

Conclusions and Recommendations

The ventilated enclosure evaluated in this study provided very good control of lead fumes. Personal lead concentrations averaged one-fifth the OSHA PEL when using this control. In addition, the enclosure reduced lead exposures by greater than an order of magnitude compared to lead exposures before the enclosure was installed. Finally, the worker's lead exposure at the adjacent uncontrolled work station was more than 40 times higher than at the controlled work station. The authors are not aware of any ventilation hood of this type that has previously been designed or installed in radiator repair shops.

This cost-effective ventilation control system could be utilized by most small- and medium-sized radiator repair shops. A description of this exhaust control system and data showing the effectiveness of this control should be widely disseminated to radiator repair shop owners and operators.

Experiments should be conducted to further reduce control air volumes and make-up air requirements when using the enclosure.

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