



## Case Studies: Hazards at your Auto Dealership (Including Everything you Ever Wanted to Know about a Tail-Pipe Exhaust Ventilation System)

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# Hazards At Your Auto Dealership (Including Everything You Ever Wanted to Know About a Tail- Pipe Exhaust Ventilation System)

## Case Studies

Dawn Tharr, Column Editor

Reported by Alan Echt, Charles Hayden, II, and Ova Johnston

### Introduction

The National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation from employees of an automobile dealership. The requestors were concerned about possible health hazards associated with automobile undercoating, carbon monoxide from car exhaust, and fumes from a kerosene-fired steam cleaner. Employees reported symptoms of headache, nausea, vomiting, and dizziness.

### Background

Workers undercoated new cars in an area enclosed on three sides by curtains in a service bay area. One wall of the shop was the fourth side of this enclosure. Two products were used for undercoating; one was used for undercoating the vehicle and the other was used for rustproofing inside doors and similar applications. Rustproofing was performed infrequently. Company records reviewed during the initial site visit indicated that a total of nine rustproofing jobs had been done in the previous two months.

A steam cleaner was used to clean floors, engines, and undersides of the bodies of used cars. According to the service advisor who used the steam cleaner, steaming an engine took about 10 to 15 minutes while cleaning the floor took up to 30 minutes. Cleaning engines or vehicles was performed once a week or less, and the floor was cleaned once every 2 to 3 weeks.

As shown in Figure 1, there were 16 steel-framed engine exhaust ports in the garage floor. Two ports (7 and 8) were bolted closed. The remaining 14 exhaust ports, 1 at each service bay area of the garage, directed vehicle tail-pipe exhaust gases from a flexible exhaust hose into a

common duct under the service area floor. Tail-pipe exhaust passed through the under-floor duct to a sump where any liquids in the ventilation system were trapped and pumped to waste. Exhaust gases were then directed outside the building through an exhaust fan. Hinged steel cover plates, flush to the garage floor, capped the individual exhaust ports when not in use.

The 3½-inch outside diameter flexible garage exhaust hose varied in length from 6 to 10 feet. One end of the hose fit over the vehicle's tail-pipe (an average tail-pipe diameter is about 2 inches). The other end was placed into the 7-inch square exhaust port. When the hose was connected between a vehicle tail-pipe and the exhaust port, approximately 4 square inches (in<sup>2</sup>) of leakage area existed between the tail-pipe and the flexible hose. Forty square inches of leakage area existed between the exhaust port and flexible hose (Figure 2). In addition, a total of 12 in<sup>2</sup> of leakage area existed through two ¾-inch diameter finger holes, in each of the 14 functional cover plates. The finger holes provided access to lift the cover plate during exhaust port use. A loose fit between closed cover plates and exhaust ports provided leakage area into the exhaust system. Warped or bent exhaust port frames and cover plates exacerbated the loose fit.

Engineering drawings of the service area garage provided no design specifications for the vehicle exhaust removal system. The building architect and construction contractor for the 20-year-old facility were unable to provide original design specifications. Consequently, a comparison of design and current operating characteristics was not possible. The exhaust fan, a 20-foot length of exhaust fan inlet piping, the sump, and the exhaust ports were the only accessible portions of the ventilation system. A 3-horsepower motor was used to belt drive the exhaust fan. No nameplate data

were found on the exhaust fan to indicate its type or capacity.

### Methods

#### Industrial Hygiene Methods

During the first site visit, exhaust emissions (carbon monoxide, nitrogen dioxide, sulfur dioxide) from the steam cleaner were measured above its exhaust pipe while the steam cleaner was running, using the length-of-stain detector tubes.<sup>(1)</sup> Two methods were used to collect air samples during a subsequent site visit to evaluate exposures during undercoating. Because the undercoating operation was expected to be brief, thermal desorption tubes were used to collect qualitative samples to identify the volatile organic compounds (VOCs) associated with the process. Three samples for VOCs were collected and analyzed using thermal desorption-gas chromatography-mass spectroscopy (TD-GC-MS).

Samples were collected in the breathing zone of a service advisor during undercoating and at the workstations of two master technicians on the north side of the service department. Aliquots of bulk samples of undercoating compounds were injected onto thermal desorption tubes and analyzed for VOCs using TD-GC-MS analysis.

In addition to the thermal desorption tube samples, five air samples were collected on charcoal tubes for quantitative analysis of selected compounds found on the thermal desorption tube samples. Two charcoal tube samples were collected in the breathing zones of the service advisor while he undercoated a small car. One was collected for the duration of the entire undercoating job and a second was collected while undercoating was applied to the car's underside. The remaining three charcoal tube samples were collected in the breathing zones of two master technicians and a mechanic working on the north side of the service de-

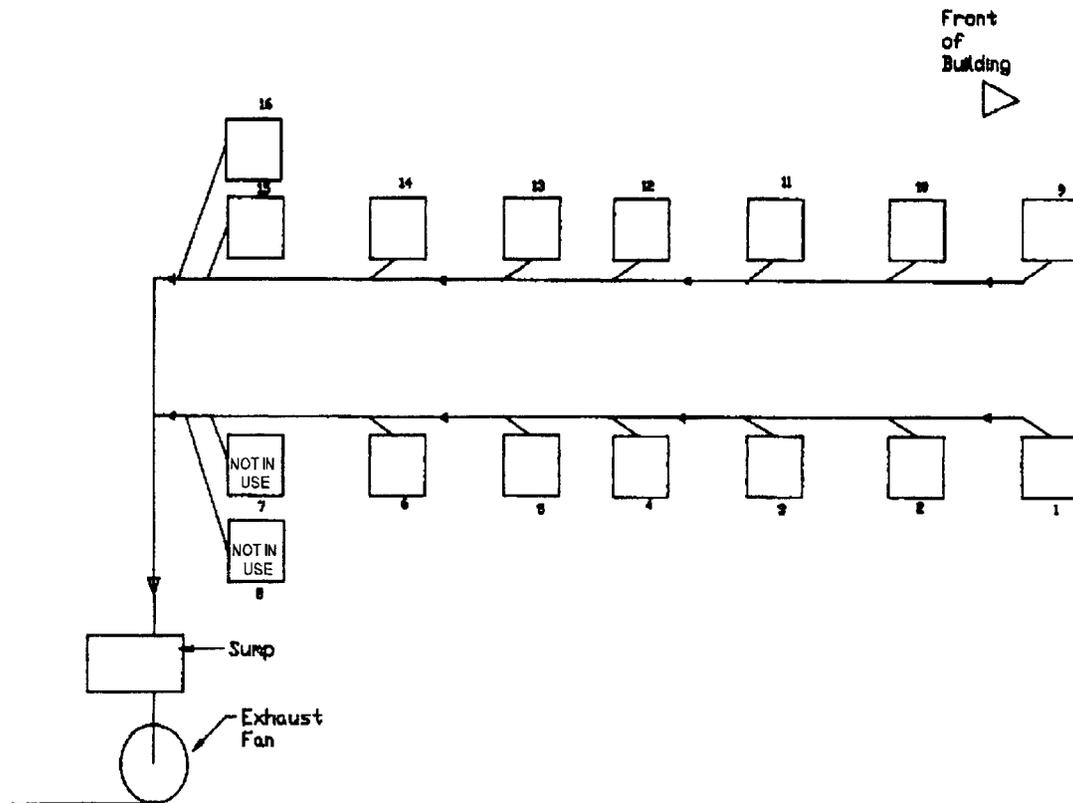


FIGURE 1. Line diagram of carbon monoxide removal system.

partment. The garage doors were closed during sampling to simulate winter conditions. Based on the results of the thermal desorption tubes analysis, the charcoal tubes were quantitatively analyzed for toluene, Stoddard solvent, and hydrocarbons that eluted in the range between  $C_6$  hydrocarbons and toluene.

During a final site visit the following winter, personal breathing zone samples for carbon monoxide were collected in the same service department using colorimetric length-of-stain diffusion tubes.

#### Ventilation Evaluation Methods

The tail-pipe exhaust ventilation system was evaluated during the initial site visit by measuring flow rates at 14 of 16 exhaust ports (two of the ports were bolted closed and were out of service). The exhaust rate at each port was calculated by averaging the results of five measurements made at each square port—one measurement at the midpoint of each of the four sides, and one measurement in the center of the port. All flow rates were obtained with all other exhaust port cover plates closed except the one being measured. The total exhaust flow rate

was obtained by averaging the results of a 20-point traverse of the main exhaust duct upstream of the fan. All of the exhaust port covers were closed when the total exhaust flow rate was measured. Therefore, this measurement was only an indication of system leakage. Air flow measurements were made using a TSI VelociCalc Plus model 8360 air velocity meter. This instrument measures air velocity and converts the readings to air flow measurements when the user enters information about the size and shape of the duct or opening being measured.

During two subsequent engineering evaluations, exhaust port flow rate measurements were made using a flow measuring stand constructed as shown in Figure 3. The flow measuring stand used an Accu-mass™ model 730-N7-1 thermal anemometer flowmeter. The flowmeter output to a FloBox™ model 904M signal conditioner/digital readout device that indicated flow rate in cubic feet per minute (cfm). On both of these occasions, flow rate measurements were obtained with and without temporary modifications (described below) in place which eliminated unnecessary leakage.

A Neotronics Model MP20 electronic digital micromanometer was used to obtain a static pressure measurement at exhaust port 9. The static pressure measurement taken at this location indicated the tail-pipe exhaust removal system's capacity to provide a particular flow rate in the most limiting case with the known leakage area sealed (port 9 being the farthest from the exhaust fan).

Temporary modifications to eliminate unnecessary leakage included taping 3-mil plastic sheets over exhaust ports not in use and installing exhaust port/flexible hose adapters (designed and fabricated by engineers at NIOSH) in exhaust ports in use (Figure 4). The adapters are  $6\frac{3}{4}$ -inch square  $\times$   $\frac{3}{4}$ -inch thick plywood pieces with  $3\frac{1}{2}$ -inch diameter round holes cut into the center. The outer perimeter of the wood piece was fitted with  $\frac{1}{8}$ - $\times$   $\frac{3}{4}$ -inch weather strip seal (foam tape). The weather strip sealed the contact point between the exhaust port adapter and the exhaust ports. Weather stripping is also provided on the inside diameter of the adapter's round hole to reduce leakage between the exhaust hose/adapter contact point. The

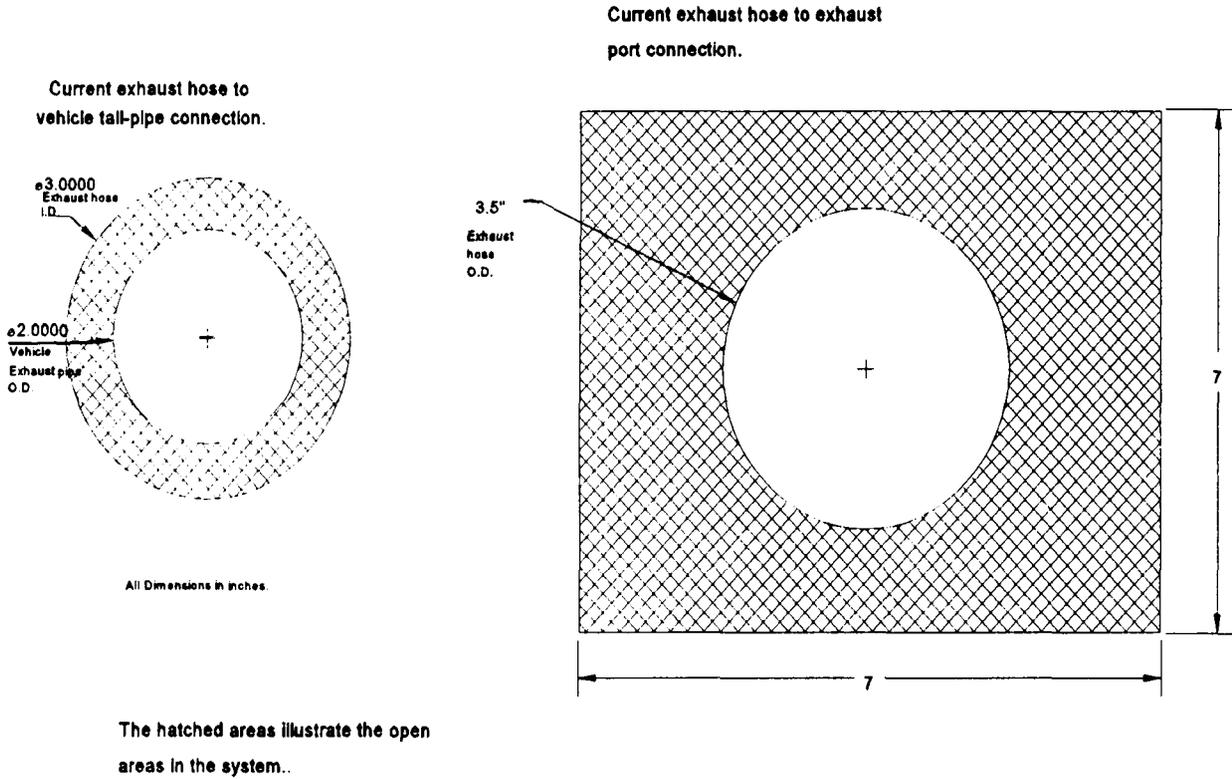


FIGURE 2. Existing flexible garage exhaust hose to tailpipe and export port leak areas.

semi-tight fit between the exhaust hose and the round passage through the adapter ensured the duct would not drop through the exhaust port into the com-

mon duct, blocking off upstream exhaust ports. Two aluminum brackets were attached to opposite sides of the adapter to hold the adapter in the exhaust port.

Flexible garage exhaust hoses of varying lengths, as described below, were used during testing. The static pressure drop associated with the flexible hoses

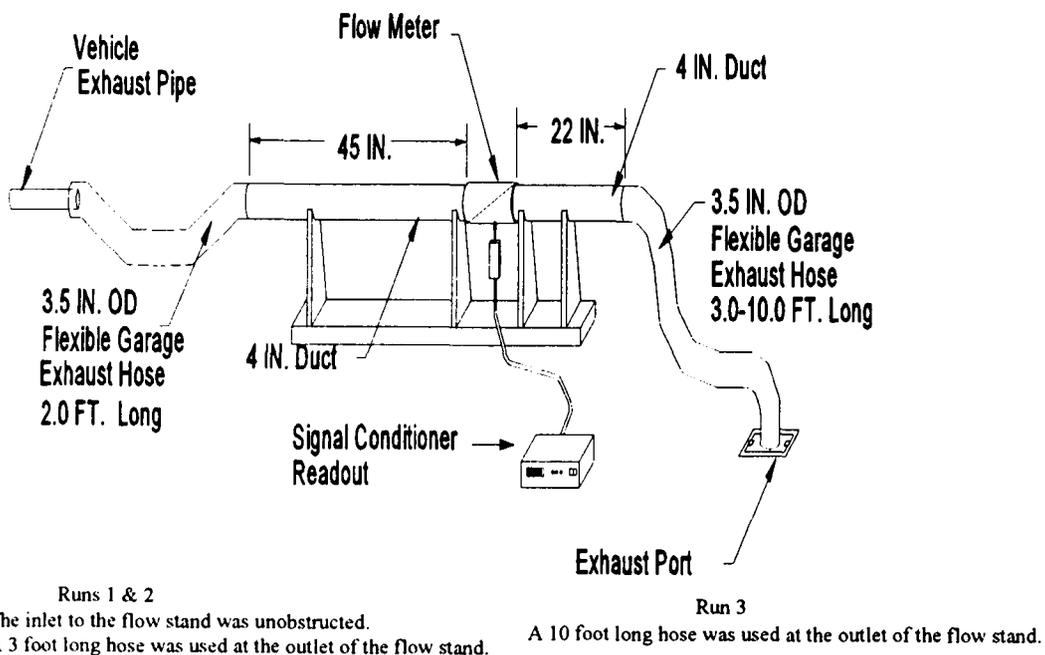


FIGURE 3. Flowstand used in taking tail-pipe exhaust removal system flow rate measurements at the exhaust ports.

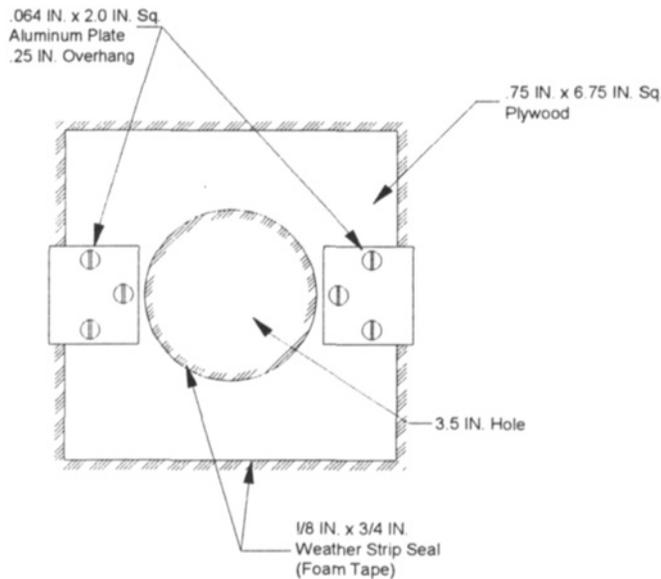


FIGURE 4. Flexible garage exhaust hose to exhaust port adapter.

was rated by the manufacturer at 0.344 inches of water ( $"\text{H}_2\text{O}$ ) per foot of hose at 100 cfm, and 0.09  $"\text{H}_2\text{O}$  per foot of hose at 50 cfm.

Exhaust port flow rates were examined during two separate visits to the study site. On both occasions, flow rate measurements were obtained with and without modifications being made to the tail-pipe exhaust ventilation system.

During the first site visit, a 3-ft flexible garage exhaust hose connected the outlet of the flow stand to the exhaust port. The inlet to the flow stand was unobstructed and open to the garage area. Flow rate measurements were taken first at exhaust port 9, followed by exhaust ports 10, 1, 11, 2, and 3. The order in which the exhaust ports were examined was determined by the respective exhaust port's distance from the exhaust fan (i.e., due to system pressure losses, the farther from the exhaust fan an exhaust port was, the lower the exhaust port's flow rate). All exhaust ports were either closed or sealed except the exhaust port being examined and the exhaust port(s) previously examined during a particular run (see Tables 1

and 2). After the flow rate measurement was made in one exhaust port, a 6-ft length of hose was left in that exhaust port and the flow stand was moved to the succeeding exhaust port. This allowed for examination of the effects on flow rate of having a number of exhaust ports open simultaneously to the tail-pipe exhaust ventilation system.

On the second site visit, a 10-ft flexible garage exhaust hose connected the outlet of the flow stand to the exhaust port. A 2-ft length of flexible hose connected the inlet of the flow stand to a vehicle tail-pipe. Using the longer hose afforded the opportunity to observe the effect that higher static pressure losses had on exhaust port flow rate. Separate flow rate measurements were obtained with the vehicle off and with the vehicle idling to determine if an idling vehicle would provide a booster effect on the tail-pipe exhaust ventilation system. Tail-pipe exhaust ventilation system flow rate measurements were taken in the order described earlier. In addition to gathering flow rate data during this visit, chemical smoke was used to check for vehicle exhaust

gases escaping from around the tail-pipe/flexible hose fit connection by releasing smoke near the vehicle's tail-pipe and observing its movement. To prevent a disruption in workplace productivity, researchers did not examine the tail-pipe exhaust ventilation system while more than one idling vehicle at a time was connected to the system. Having six cars that can start and idle at particular services bays simultaneously would require the service work to be stopped while operating vehicles were specially brought into the particular bays. When the flow rate measurement was finished in one port, a 10-ft length of hose was left in that port and a new hose was used for the next flow rate measurement (see Table 3). This allowed NIOSH researchers to determine the maximum number of exhaust ports that could be simultaneously connected to the tail-pipe exhaust ventilation system and still have the system work effectively.

During the first visit, the hose lengths used in obtaining flow rate measurements were based primarily on what the service garage had on hand. NIOSH researchers provided 10-ft hoses for use during the second visit. This type of hose is purchased in 10-ft lengths; the shorter lengths used earlier were probably modified by the mechanics. The use of different lengths of hoses enabled NIOSH investigators to examine the lower flow rate in the longer hoses due to higher static pressure losses.

A vehicle with a 3-liter engine was being serviced in the respective service bays during the first, fourth, fifth, and sixth test runs. An approximate exhaust gas flow rate of 50 cfm was expected from a 3-liter engine idling at 1000 revolutions per minute (rpm).<sup>(2)</sup> A vehicle with a 4-liter engine was being serviced during the second and third test runs. An approximate exhaust gas flow rate of 70 cfm was expected from a 4-liter engine idling at 1000 rpm.<sup>(2)</sup>

TABLE 1. Flow Rates With No Modifications

RUN	Exhaust Port 9	Exhaust Port 10	Exhaust Port 1	Exhaust Port 2	Exhaust Port 11	Exhaust Port 12	All Other Exhaust Ports
1A	24	Closed	Closed	Closed	Closed	Closed	Closed
1B	6	10	Closed	Closed	Closed	Closed	Closed

Flow rates are in cubic feet per minute.

TABLE 2. Flow Rates After Modifications

RUN	Exhaust Port 9	Exhaust Port 10	Exhaust Port 1	Exhaust Port 2	Exhaust Port 11	Exhaust Port 12	All Other Exhaust Ports
2A	110	Sealed	Sealed	Sealed	Sealed	Sealed	Sealed
2B	102	102	Sealed	Sealed	Sealed	Sealed	Sealed
2C	99	96	104	Sealed	Sealed	Sealed	Sealed
2D	92	94	94	94	Sealed	Sealed	Sealed
2E	84	84	90	92	86	Sealed	Sealed
2F	82	78	84	84	82	80	Sealed

Flow rates are in cubic feet per minute.

**Evaluation Criteria**

ACGIH®'s Industrial Ventilation Committee recommends tail-pipe exhaust systems be capable of providing 100 cfm per vehicle (for cars and trucks up to 200 horsepower).<sup>(3)</sup> Further, they recommend a minimum of 5000 cfm per operating vehicle (not connected to a tail-pipe exhaust system) be provided as general dilution ventilation to the service garage. The American Society of Heating, Ventilating and Air-Conditioning Engineers (ASHRAE®) recommends the exhaust from buildings be directed from the building via a stack through the roof. The stack height is to be determined based on criteria such as building dimensions and prevailing wind, and is designed to prevent reentrainment of exhaust air back into the building.<sup>(4)</sup>

**Results and Discussion**

Most of the components detected in the bulk samples of the undercoating compounds and on the thermal desorption were C<sub>9</sub>-C<sub>12</sub> aliphatic hydrocarbons. This is consistent with the material safety data sheets for the undercoating compounds, which indicate that they contain mostly hydro-treated kerosene and/or mineral spirits. In addition, toluene and C<sub>7</sub> alkanes were major peaks also identified on the air samples. Some methanol

and dichlorodifluoromethane were also present on the tube samples. Toluene is not a component of the undercoating compounds but is an ingredient in the brake parts cleaner. Methanol is an ingredient in windshield washer fluid. Dichlorodifluoromethane is Freon 12, a refrigerant used in automobile air conditioners (although it is no longer used in new cars).

Results of the quantitative analyses of the charcoal tubes indicated only low concentrations of all compounds (<10 mg/m<sup>3</sup>). These results indicate that, on the day of the survey, the exposures were less than relevant occupational exposure criteria for these compounds. It should be noted that automobile undercoating spray operations in garages, conducted in an area having adequate natural or mechanical ventilation, are exempt from the Occupational Safety and Health Administration (OSHA)'s requirements pertaining to spray finishings operation when using undercoating materials less hazardous than kerosene or those containing only solvents having a flashpoint in excess of 100°F.<sup>(7)</sup>

Air sampling for carbon monoxide while the steam cleaner operated resulted in a measurement of 300 ppm directly above the exhaust of the machine. The results of sampling for nitrogen dioxide

and sulfur dioxide were 1 and 3 ppm, respectively. While these values cannot be directly compared to occupational health exposure criteria, which are based on personal exposure, they indicate the steam cleaner is a source of these combustion gases. The manufacturer of the steam cleaner recommended that the device be used with adequate general ventilation (open doors and windows) or vented directly outside.

In addition to vehicle exhaust, other potential sources of carbon monoxide in the garage included eight gas-fired cabinet heaters, which were vented to the outside, the kerosene-powered steam cleaner, and cigarette smoke. The results of carbon monoxide sampling conducted on a winter day indicated 8-hour time-weighted average concentrations ranging from 19 to 25 ppm. The results indicate that none of the exposures were in excess of the evaluation criteria for carbon monoxide, although 3 of the 7 samples were equal to the ACGIH Threshold Limit Value (TLV®).<sup>(8)</sup> When reviewing these results, it is important to note test sampling was performed on a day when an average of 11 vehicles were in the garage at any given time (based upon an hourly count of the number of vehicles in the garage) and when a total of 30 cars were serviced, with 19 to 20 of those cars

TABLE 3. Flow Rates After Modifications With Vehicle Off/Vehicle Idling

RUN	Exhaust Port 9	Exhaust Port 10	Exhaust Port 1	Exhaust Port 2	Exhaust Port 11	Exhaust Port 12	All Other Exhaust Ports
3A	48/50	Sealed	Sealed	Sealed	Sealed	Sealed	Sealed
3B	*	52/70	Sealed	Sealed	Sealed	Sealed	Sealed
3C	*	*	62/65	Sealed	Sealed	Sealed	Sealed
3D	*	*	*	48/44	Sealed	Sealed	Sealed
3E	*	*	*	*	48/50	Sealed	Sealed
3F	*	*	*	*	*	50/45	Sealed

\*A garage hose, 10 feet in length, was connected to exhaust port through the adapter. Smoke tube checks indicated flow into the open hose end in all cases. Flow rates are in cubic feet per minute.

completed. Included among these were 5 or 6 minor services, 1 transmission repair, 3 or 4 tune-ups, 1 partial engine repair, 1 lower engine repair, and 2 or 3 minor warranty adjustments. In addition, two technicians were absent on the day of the survey. Employees described this workload as "slow" to "medium." Thus, a different mix of jobs or a busier day might result in a higher level of exposure.

### Ventilation Evaluation

Exhaust gases exited the vehicle's tail-pipe through the flexible duct to an exhaust duct under the service area floor. Gases then flowed into a common duct connected to a fan located inside the service area. Exhaust from the fan was directed outside of the building. During the initial site visit, a total exhaust flow rate of 560 cfm was measured in the main duct upstream of the fan. This measurement was made with all ports closed and no temporary modifications installed. Flexible duct was being stored inside exhaust ports 10 and 11. When initial flow rates were measured at exhaust port 9, a value of 160 cfm was obtained. After the flexible ducts were removed from the two upstream exhaust ports, 210 cfm was being provided at port 9.

Table 1 shows exhaust port flow rates measured on the second survey, with no modifications in place. Because the flow rates were extremely low, only two ports at most were measured simultaneously. After run 1B, further evaluation of the system was unnecessary as the lower limit of ACGIH-recommended flow rates (100 cfm per vehicle for automobiles and trucks up to 200 hp, and 200 cfm per vehicle for automobiles and trucks over 200 hp) was unattainable from even one exhaust port.<sup>(3)</sup> A 700-cfm flow rate was indicated at the exhaust fan inlet during runs 1A and 1B.

Flow rate measurements made during the second survey, with modifications in place, are shown in Table 2. The modifications produced significant increases in exhaust port flow rates. Flow rates near ACGIH-recommended values were observed while using up to six exhaust ports simultaneously. While the exhaust port flow rates generally declined as more exhaust ports were added, the flow rates within each individual run remained relatively equal. A total tail-pipe exhaust ventilation system flow rate of 280 cfm

was measured at the exhaust fan inlet during run 2A.

A static pressure of 2.0 "H<sub>2</sub>O was measured at exhaust port 9, downstream of the exhaust hose during run 2A. Static pressure measurements were not obtained during subsequent runs since the static pressure measurement at port 9, during run 2A, demonstrated the tail-pipe exhaust ventilation system's optimum capacity.

During a third evaluation, no measurable flow was observed at port 9 without modifications in place. Chemical smoke indicated that tail-pipe exhaust gases were escaping from around the garage hose/tail-pipe connection into the service area. Further evaluation of the system without applying modifications was unnecessary.

Flow rate measurements made on the third visit, with modifications in place, are shown in Table 3. Because only one exhaust port with an operating vehicle could be measured at a time without disrupting the operation of the service garage, and because flow rates did not change substantially within each run (Table 2), it was decided to measure the flow rate at succeeding ports. Table 3 shows flow rates with a vehicle turned off followed by the flow rate with the vehicle idling (i.e., vehicle off/vehicle idling). A total tail-pipe exhaust ventilation system flow rate of 500 cfm was measured at the exhaust fan inlet during run 3A. Chemical smoke checks indicated no vehicle exhaust gases were escaping from the flexible hose/tail-pipe loose fit connection.

During all visits, vehicles were moved in and out of the service area or were otherwise idling in the service area and were not connected to a tail-pipe exhaust hose. There was no dilution ventilation system in the service area garage.

### Conclusions

Air sampling measurements made during undercoating of a small car indicated that exposures to the components of the undercoating compounds did not exceed applicable exposure criteria.

Air sampling for carbon monoxide at the exhaust of the steam cleaner indicated that the steam cleaner is a source of carbon monoxide, and should only be used with the doors to the garage open or when the exhaust can be vented directly outside the building. Seven personal

breathing zone air samples for carbon monoxide during a winter day showed concentrations less than the NIOSH Recommended Exposure Limits and the OSHA Permissible Exposure Limits in all cases, but equal to the ACGIH TLV in three cases. Exposures may be somewhat higher or lower on other days, depending upon the number and type of repairs performed in the garage.

Prior to installing temporary modifications, the tail-pipe exhaust ventilation system did not effectively remove vehicle exhaust gases from the service area garage space. After installing temporary modifications to block leakage areas in the tail-pipe exhaust ventilation system, the system was still unable to provide the minimum ACGIH-recommended flow rates which can ensure capture of vehicle exhaust. Nevertheless, smoke tube checks indicated no escape of vehicle exhaust gases into the service area environment when modifications were in place.

Abundant leakage areas into the tail-pipe exhaust ventilation system are the "path of choice" for air pulled into the system. Leakage areas diminish the capacity of the system to pull air through the flexible duct since static pressure losses through leakage areas are lower than the static pressure losses through the flexible duct.

The cause of the disparity between measured system flow rates during the site visits was not determined. However, the difference between the total flow rates and the individual exhaust port flow rates indicate that there is leakage into the tail-pipe exhaust ventilation system not identified in this study.

When engine exhaust gas flow rate exceeds the flow rate measured at a particular exhaust port with the engine off, a slight "booster fan" effect of the idling engine is observed in some cases by the higher exhaust port flow rate. Exhaust port flow rates during runs 3B and 3C (4-liter engines) demonstrate this effect. A typical 4-liter engine, idling at 1000 rpm, could be expected to exhaust a flow rate of approximately 70 cfm (2-liter engine at 1000 rpm would exhaust approximately 35 cfm). Thus, when measuring exhaust port flow rates there will be differences associated with vehicle engine size and operating speed as compared to flow rates when no vehicle is operating.

The length of the flexible garage exhaust hose radically affects an exhaust

port's flow rate. The static pressure losses associated with flexible hoses are very high and the tail-pipe exhaust ventilation system should be designed to accommodate this pressure loss. Comparing the results presented in Table 2 (3-ft flexible hose) and Table 3 (12-ft total flexible hose length) shows that the shorter the flexible hose, the higher the exhaust port flow rate. However, considering the variety of vehicle tail-pipe to exhaust port distances found in the service area, it would be unreasonable to use flexible hoses less than 6 ft long.

### Recommendations

#### *Tail-pipe Exhaust Ventilation Systems*

1. The exhaust port covers should be replaced with covers having self-closing caps. The exhaust ports covers and caps should provide an airtight seal when not in use.
2. The exhaust fan should be replaced with a unit capable of providing approximately 5 inches of water column static pressure at the fan inlet with a 600-cfm flow rate. This would enable the tail-pipe exhaust ventilation system to provide sufficient flow rates for up to six vehicles simultaneously.
3. Exhaust fan discharge should be relocated to the roof of the building and discharge at the ASHRAE-recommended stack height.<sup>(4)</sup> This will prevent reentrainment of the exhaust fan discharge air and subsequent return of the contaminants into the building.
4. Five thousand cubic feet per minute of dilution ventilation should be provided to the service bay area garage. This should be accomplished with a ventilation system separate from the tail-pipe exhaust ventilation system.<sup>(3)</sup>

#### *Kerosene-Fired Steam Cleaner*

1. The exhaust emissions from the steam cleaner should be vented to the exterior of the building. One way to accomplish this would be to fabricate a device allowing the steam cleaner to be connected to the tail-pipe exhaust ventilation system.

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sure Indices. ACGIH, Cincinnati, OH (1995).

**EDITORIAL NOTE:** Alan Echt is with the Hazard Evaluation and Technical Assistance Branch and Charles Hayden II and Ova Johnston are with the Engineering Control Technology Branch of NIOSH. More detailed information on this evaluation is contained in the Health Hazard Evaluation Report No. 95-0200-2579, available through NIOSH, Health Hazard Evaluation and Technical Assistance Branch, 4676 Columbia Parkway, Cincinnati, Ohio 45226; telephone (800) 35-NIOSH; fax (513) 533-8573.