HETA 95-0200-2579
Jim Dixon Lincoln-Mercury, Inc.
Fairfield, Ohio

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PREFACE

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ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by Alan S. Echt, of the Hazard Evaluations and Technical Assistance Branch, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS), and Charles S. Hayden II, of the Engineering Control Technology Branch, Division of Physical Sciences and Engineering. Field assistance was provided by Ova E. Johnson and Deborah Friedman. Desktop publishing by Ellen E. Blythe.

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Health Hazard Evaluation Report 95-0200-2579
Jim Dixon Lincoln-Mercury, Inc.
Fairfield, Ohio
May 1996

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SUMMARY

On March 27, 1995, the National Institute for Occupational Safety and Health (NIOSH) received a confidential request from three employees of Jim Dixon Lincoln-Mercury, in Fairfield, Ohio, concerning possible health hazards associated with applying automobile undercoating, carbon monoxide from car exhaust, and fumes from a kerosene-fired steam cleaner. Subsequent evaluations by NIOSH investigators revealed that airborne solvents measured during automobile undercoating do not exceed applicable occupational exposure criteria. However, some deficiencies were noted in respiratory protection practices during undercoating. The steam cleaner is a source of carbon monoxide, and should be vented to the exterior of the building. Carbon monoxide sampling performed on a winter day revealed concentrations ranging from 19-25 parts per million (ppm), as an 8-hour time-weighted average (TWA). These results are less than the NIOSH recommended exposure limit of 35 ppm for an exposure up to 10-hr TWA and the Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) of 50 parts per million (ppm), 8-hour TWA. In three of seven samples, the results were equal to the American Conference of Governmental Industrial Hygienists' (ACGIH®) Threshold Limit Value of 25 ppm, 8-hr TWA. An engineering evaluation revealed deficiencies in the tail-pipe exhaust ventilation system.

NIOSH investigators did not identify any overexposures to compounds associated with automobile undercoating. The steam cleaner was identified as a source of carbon monoxide, and should be vented to the exterior of the building. Deficiencies were noted in the performance of the tail-pipe exhaust ventilation system, which may contribute to the carbon monoxide exposures. Recommendations to correct deficiencies in respiratory protection practices associated with undercoating and to correct problems with the tail-pipe exhaust ventilation system are noted in the Recommendations section of this report.

Keywords: SIC 5511 (Motor Vehicle Dealers [New and Used]), carbon monoxide, undercoating, tail-pipe exhaust ventilation, garages, local exhaust ventilation

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INTRODUCTION

On March 27, 1995, the National Institute for Occupational Safety and Health (NIOSH) received a confidential request for a health hazard evaluation (HHE) from three employees of Jim Dixon Lincoln-Mercury, in Fairfield, Ohio. 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. The employees reported symptoms of headaches, nausea, vomiting, and dizziness. On June 9, 1995, an industrial hygienist and a mechanical engineer from NIOSH visited Jim-Dixon Lincoln Mercury to evaluate the performance of the tail-pipe exhaust ventilation system, measure exhaust emissions from the steam cleaner, and gather information about the undercoating process. A NIOSH letter dated July 7, 1995, reported the results of that initial site visit, provided preliminary recommendations based upon those results, and discussed future plans to evaluate the undercoating process. NIOSH investigators returned to Jim Dixon Lincoln-Mercury on August 8, 1995, to further evaluate the tail-pipe exhaust ventilation system. On August 29, 1995, NIOSH investigators performed air sampling to evaluate exposures during undercoating and collected bulk samples of undercoating compounds for qualitative analysis. The NIOSH investigators visited Jim Dixon Lincoln-Mercury again on November 9, 1995, to complete their evaluation of the tail-pipe exhaust ventilation system. Finally, a NIOSH industrial hygienist conducted air sampling for carbon monoxide in the service department on January 25, 1996.

BACKGROUND

Undercoating is performed in an area enclosed on three sides by curtains in the service bay area. One wall of the shop is the fourth side of this enclosure. Two products are used for undercoating; one is for undercoating the vehicle, and the other is used for rustproofing inside doors and in similar applications. Rustproofing is performed infrequently. Company records reviewed during the June 9, 1995, site visit indicated that a total of nine rustproofing jobs had been performed in April and May. The technician who performs rustproofing uses a NIOSH-approved Survivair® half-mask, continuous-flow supplied air respirator connected to a breathing air pump located on a bench in the enclosed undercoating area.

The steam cleaner is used to clean the floors, to steam clean engines, and to clean the underside of the body of used cars. According to the technician who uses the steam cleaner, steaming an engine takes about 10 - 15 minutes, while cleaning the floor takes up to half an hour. Cleaning engines or vehicles is performed once a week or less, while the floors are cleaned once every two to three weeks.

As shown in the line diagram of Figure 1, there were 16 steel-framed engine exhaust ports in the garage floor. Two (#7 and #8) were bolted closed. The remaining 14 exhaust ports, 1 at each service bay area of the garage, direct vehicle tail-pipe exhaust gases from a flexible exhaust hose into a common duct under the service area garage floor. Tail-pipe exhaust gases pass through the under-floor duct to a sump, where any liquids in the ventilation system are trapped and pumped to waste. The exhaust gases are then directed out the side of the building through an exhaust fan. Hinged steel cover plates, flush to the garage floor, cap the individual exhaust ports when they are not in use.

Three and one half-inch (in) outside diameter flexible garage exhaust hoses vary in length from six to ten feet. One end of the flexible hose fits over the vehicle's tail pipe (an average tail-pipe diameter is about 2 in). The other end of the flexible hose is placed into the 7 in square exhaust port. When a flexible hose is connected between a vehicle tail-pipe and exhaust port, approximately 4 square inches (in^2) of leakage area exist between the tail pipe and the flexible hose. Forty in^2 of leakage area exist between the exhaust port and flexible hose (see Figure 2). In addition, a total of 12 in^2 of leakage area exists through two 3/4-in diameter finger holes, in each of the 14 functional cover plates. The finger holes provide access to lift the cover plate during exhaust port use. A loose-fit between closed cover plates and exhaust ports also provide leakage areas into the exhaust system. Warped or bent exhaust port frames and cover plates exacerbate 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 likewise unable to provide original design specifications. As a result, a comparison of design and current operating characteristics was not possible. The exhaust fan, a 20 foot (ft) length of exhaust fan inlet piping, the sump, and the exhaust ports were the only accessible portions of the ventilation system. A three horsepower motor was used to belt-drive the exhaust fan. No nameplate data were found on the exhaust fan to indicate type and capacity.

METHODS

Industrial Hygiene Methods

Two methods were used to collect air samples on August 29, 1995. Because the undercoating operation was expected to be of short duration, thermal desorption tubes were used to collect qualitative samples to identify the volatile organic compounds (VOCs) associated with the process. This method is an extremely sensitive and a very specific screening technique; it will identify the VOCs present on the sample in the parts per billion range. Three samples for VOCs were collected using thermal desorption tubes, which were then analyzed using thermal desorption-gas chromatography-mass spectroscopy (TD-GC-MS). The thermal desorption tubes were connected via Tygon tubing to battery-powered sampling pumps operating at a calibrated flow rate of 50 milliliters per minute (mL/min). The thermal desorption tubes contain three sorbent beds in consecutive layers from front to back (Carbopack Y, Carbopack B, and Carboxen 1003) which are used to capture organic compounds over a wide range of volatility. Substances such as acetone, toluene, pentane, hexane, etc., will be trapped with this sorbent tube. Samples were collected in the breathing zone of the 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 the 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 some of the VOCs identified during the analysis of the thermal desorption tube samples. Two charcoal tube samples were collected in the breathing zone of the service advisor while he undercoated a small car. One of the charcoal tube samples was collected for the duration of the entire undercoating job. The other charcoal tube sample was collected during the exterior portion of the undercoating job. The remaining three charcoal tube samples were collected in the breathing zones of two master technicians and a mechanic working at the north side of the service department. The garage doors were closed during sampling to simulate winter conditions. Samples were collected using charcoal tubes in plastic holders connected via Tygon tubing to air sampling pumps operating at a flow rate of 100 mL/min. Based upon the results of the analyses of the thermal desorption tubes, the charcoal tubes were quantitatively analyzed for toluene, Stoddard Solvent, and hydrocarbons which eluted in the range between C_6 hydrocarbons and toluene. The charcoal tube samples were analyzed according to NIOSH Methods 1500 and 1550, with modifications to the desorption process, the GC column, and the GC oven conditions.[1] Media standards were used in the analysis. The minimum detectable concentration (MDC) of toluene and C_6-toluene hydrocarbons was 0.5 milligrams per cubic meter (mg/m^3), based on an analytical limit of detection (LOD) of 0.001 mg/sample for both analytes and a maximum sample volume of 2.1 liters (L). The minimum quantifiable concentration (MQC) for these analytes was 1.6 mg/m^3, based on an analytical limit of quantitation of 0.0033 mg/sample and a maximum sample volume of 2.1 L. The MDC for Stoddard Solvent was 3.8 mg/m^3, based upon an LOD of 0.008 mg/sample and a maximum sample volume of

2.1 L. The MQC for Stoddard Solvent was 12.3 mg/m^3, based upon the 2.1 L sample volume and an LOQ of 0.026 mg/sample.

During the June 9, 1995, 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 length-of-stain colorimetric detector tubes.[2] These tubes contain an indicator which changes color when it reacts with the air contaminant being measured. A known volume of air is drawn through the tube using a hand pump. The length of stain is in proportion to the concentration of the contaminant in the air, which is then measured using a scale marked on the side of the tube.

On January 25, 1996, seven personal breathing zone samples for carbon monoxide were collected in the service department using colorimetric length-of-stain diffusion tubes (National Drager, Pittsburgh, PA). In these diffusion tubes, the atmospheric contaminant diffuses into the tube and reacts with a chemical reagent on an inert carrier to produce a colored reaction product. The length of the stain thus produced is a product of the concentration of the contaminant and the sampling time. The range of measurement for these tubes is 50 to 600 parts per million hours (ppm hrs), or 6 to 75 ppm for an eight hour measurement.

Ventilation Evaluation Methods

The tail-pipe exhaust ventilation system was evaluated during the June 9, 1995, site visit by measuring flow rates at 14 of the 16 exhaust ports (two of the ports were bolted closed and were out of service). The exhaust rate at each port was obtained by averaging the results of five measurements made at each square port — one measurement at the midpoint of each of the four sides, and a 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 rate was obtained by averaging the results of a 15-point traverse of the main exhaust duct upstream of the fan. All of the exhaust port covers were closed when the total exhaust rate was measured, therefore, this measurement is an indication of system leakage only. 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 the 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 uses an Accu-mass™ model 730-N7-1 (Sierra Instruments Inc., Monterey, CA) thermal anemometer flowmeter. The flowmeter outputs to the FloBox™ model 904M signal conditioner/digital readout device which indicates 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 eliminate unnecessary leakage.

Total tail-pipe exhaust ventilation system flow rates were obtained at the exhaust fan inlet by averaging the results of a 21-point pitot tube traverse. The pitot tube readings were obtained using a Neotronics (Gainesville, GA) Model MP20 electronic digital micromanometer. The micromanometer was also used to obtain a static pressure measurement at exhaust port #9, before the exhaust hose, with temporary modifications in place during the August 8, 1995. The static pressure measurement taken at this location indicates the tail-pipe exhaust removal system's capacity to provide a particular flow rate in the most limiting case with known leakage areas sealed (Port #9 being the furthest away 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 (Figure 4) designed and fabricated by engineers at NIOSH in exhaust ports in use. The adapters are 6 ¾ in square x ¾ in thick plywood pieces with 3 ½ in diameter round holes cut into the center. The outer perimeter of the wood piece is fitted with C in x ¾ in weather strip seal (foam tape). The weather strip seals the contact point between the exhaust port adapter and the exhaust port. 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 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 common duct, blocking off upstream exhaust ports. Two aluminum brackets were attached to opposite sides of the adapters. The brackets held the adapter in the exhaust port.

Flexible garage exhaust hoses of varying lengths, as described below, were employed during testing. The static pressure drop associated with the flexible hoses is rated by the manufacturer at 0.344 inches of water (″H_2O) per foot of hose at 100 cfm and 0.09 ″H_2O 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 August 8, 1995, site visit, a 3 ft long 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, respectively. The order 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 exhaust port(s) previously examined during a particular run (see Tables 3 and 4). 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 examination of the effects on flow rate of having a number of exhaust ports open simultaneously to the tail-pipe exhaust ventilation system.

During the November 9, 1995, site visit, a 10 ft long 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 hoses 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 the flow rate data during this visit, chemical smoke was used to check for vehicle exhaust gases escaping from around the tail-pipe/flexible hose loose fit connection by releasing smoke near the vehicle's tailpipe 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 which can start and idle at particular service bays simultaneously would require the service work 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 5). 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 August 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 long hoses for use during the November 9th visit. This type of hose is usually purchased in 10 ft lengths, the shorter lengths used earlier were probably modified by the mechanics. The use of hoses of different lengths enabled the NIOSH investigators to examine the lower flow rate in the longer hoses due to higher static pressure losses.

A vehicle having a 3-liter engine was being serviced in the respective service bays during the first, fourth, fifth, and sixth test runs on November 9, 1995. An approximate exhaust gas flow rate of 50 cfm would be expected from a 3-liter engine idling at 1000 revolutions per minute (rpm).[3] A vehicle having a 4-liter engine was being serviced during the second and third test runs. An approximate exhaust gas flow rate of 70 cfm would be expected from a 4-liter engine idling at 1000 rpm.[3]

EVALUATION CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for the assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects even though their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity (allergy). In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the criterion. These combined effects are often not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus potentially increase the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria for the workplace are: (1) NIOSH recommended exposure limits (RELs)[4], (2) the American Conference of Governmental Industrial Hygienists' (ACGIH®) Threshold Limit Values (TLVs®)[5], and (3) the U.S. Department of Labor, the Occupational Safety and Health Administration (OSHA) permissible exposure limits (PELs).[6] In July 1992, the 11th Circuit Court of Appeals vacated the 1989 OSHA PEL Air Contaminants Standard. OSHA is currently enforcing the 1971 standards which are listed as transitional values in the current Code of Federal Regulations; however, some states operating their own OSHA approved job safety and health programs continue to enforce the 1989 limits. NIOSH encourages employers to follow the 1989 OSHA limits, the NIOSH RELs, the ACGIH® TLVs®, or whichever are the more protective criterion. The OSHA PELs reflect the feasibility of controlling exposures in various industries where the agents are used, whereas NIOSH RELs are based primarily on concerns relating to the prevention of occupational disease. It should be noted when reviewing this report that employers are legally required to meet those levels specified by an OSHA standard and that the OSHA PELs included in this report reflect the 1971 values.

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8- to 10-hour workday. Some substances have recommended short-term exposure limits (STEL) or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from higher exposures over the short-term.

Carbon Monoxide

Carbon monoxide, a component of vehicle exhaust, in an insidious poison that is a naturally occurring byproduct of the incomplete combustion of carbon-based fuels. Because carbon monoxide is colorless, tasteless, odorless, and nonirritating, its presence is usually not detected. The early symptoms of carbon monoxide poisoning are nonspecific (e.g., headache, dizziness, weakness, nausea, visual disturbances, and confusion). Consequently, carbon monoxide poisoning may be misdiagnosed as the flu or other acute illnesses. Each year in the United States, approximately 500 deaths are attributed to carbon monoxide poisoning. Carbon monoxide poisonings in the United States increase during the winter months, particularly because of the risks for exposure to the exhaust from vehicles and combustion appliances during periods when heating systems are in use and ventilation is more likely to be inadequate.[7]

The NIOSH REL for carbon monoxide is 35 ppm as TWA concentration for up to a 10-hour day, with a ceiling limit of 200 ppm.[4] The ACGIH® TLV® for carbon monoxide is 25 ppm as an 8-hour TWA.[5] The OSHA PEL for carbon monoxide is 50 ppm as an 8-hour TWA.[6]

Service Garage Ventilation Systems

ACGIH® recommends the tail-pipe exhaust system be capable of providing 100 cfm per vehicle (for cars and trucks up to 200 horsepower).[8] Further, ACGIH® recommends that 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. American Society for 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 the building dimensions, prevailing winds, etc. and is designed to prevent reentrainment of exhaust air back into the building.

RESULTS AND DISCUSSION

Industrial Hygiene

During the June 9, 1995, site visit, NIOSH investigators noted that the supplied-air respirator available for use by the technician who applied undercoating was dirty and was stored in the tool cabinet above the bench. The breathing air pump was located on the bench. The technician had a full beard at the time of the survey. These observations indicate that there are several deficiencies involved in the use of this respirator. First, the breathing air pump must either be moved to a location where clean, breathable air can be assured at all times, or equipped with an air intake extension hose, the inlet of which is placed in a suitable location (for instance, outdoors, away from vehicle exhaust and other contaminant sources). The respirator manufacturer's literature states that the air intake filter for the breathing air pump is not an air-purifying filter. Second, respirators must be cleaned and stored in a clean location which protects them from damage to ensure that proper protection is provided for the wearer.[9,10] After cleaning, some employers choose to use plastic bags for respirator storage. Respirators should not be stored in lockers or tool boxes unless they are in carrying cases or cartons.[10] Third, facial hair interferes with the fit and function of tight-fitting respirators which rely upon an adequate face-to-facepiece seal to protect the wearer.[9,10] Finally, while fit testing is not currently required for air-supplied respirators, it is recommended for all tight-fitting facepieces.[9,10] Fit testing permits the selection of the properly sized respirator necessary to provide an adequate face-to-facepiece seal.

Most of the components detected in the bulk samples of the undercoating compounds and on the thermal desorption tube air samples collected on August 29, 1995, were C_9 — C_{12} aliphatic hydrocarbons. This is consistent with the material safety data sheets for the undercoating compounds, which indicate that they contain mostly hydrotreated kerosene and/or mineral spirits. In addition, toluene and C_7 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 Ford Non Chlorinated Metal 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 tube samples are provided in Table 1. These results indicate that, on the day of the survey, the exposures were less than the relevant occupational exposure criteria for these compounds. It should be noted that automobile undercoating spray operations in garages, conducted in areas having adequate natural or mechanical ventilation, are exempt from the OSHA requirements pertaining to spray finishing operations, when using undercoating materials not more hazardous than kerosene or undercoating materials using only solvents listed as having a flashpoint in excess of 100°F.[11]

Air sampling for carbon monoxide while the steam cleaner operated during the June 9, 1995, site visit 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 ppm and 3 ppm, respectively. While these values cannot be directly compared to occupational health exposure criteria, which are based upon personal exposures, they indicate that 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 are vented to the outside, the kerosene-powered steam cleaner (which was not used on the day of the January 25, 1996 survey), and cigarette smoke. The results of carbon monoxide sampling conducted on January 25, 1996, are presented in Table 2. The diffusion tubes used to measure carbon monoxide in this evaluation are marked in graduations of 50, 100, 200, 400, and 600 ppm hrs. Results in Table 2 are based upon an estimate of the length of stain if the result was between two of the graduations. The results in Table 2 indicate that none of the exposures were in excess of the evaluation criteria for carbon monoxide, although three of the seven samples were equal to the ACGIH® TLV®.[5] When reviewing these results, it is important to note that 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 19-20 of those cars completed. Included among these were five or six minor services, one transmission repair, three or four tune-ups, one partial engine repair, one lower engine repair, and two or three 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 exit the vehicle's tail pipe through the flexible duct to an exhaust duct under the service area floor, and flow into a common duct which is connected to a fan located inside the service area. Exhaust from the fan is directed out the side of the building. During the initial site visit in June 1995, 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 cubic feet/minute (cfm) was obtained. After the flexible ducts were removed from the two upstream exhaust ports, 210 cfm was being provided at port #9.

Table 3 shows exhaust port flow rates measured on August 8, 1995, with no modifications in place. Since 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.[8] A 700 cfm flow rate was indicated at the exhaust fan inlet during runs 1A and 1B.

Flow rate measurements made on August 8, 1995, with modifications in place are shown in Table 4. The modifications produced significant increases in the 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_2O 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 the November 1995 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 November 9, 1995, with modifications in place are shown in Table 5. Since only one exhaust port with an operating vehicle could be measured at a time without disrupting the operation of the service garage, and since flow rates did not change substantially within each run (Table 4), it was decided to measure the flow rate at succeeding ports. Table 5 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, there were vehicles being moved into and out of the service area or otherwise momentarily idling in the service area which were not connected to the tail-pipe exhaust removal system. No dilution ventilation system was provided to the service area garage.

CONCLUSIONS

Air sampling performed during undercoating of a small car indicated that exposures to the components of the undercoating compounds did not exceed applicable exposure criteria. However, review of the use of the supplied-air respirator in this operation revealed some deficiencies which should be corrected.

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 REL and the OSHA PEL 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 tail-pipe exhaust ventilation 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 effects an exhaust port's flow rate. The static pressure losses associated with flexible hoses is very high and the tail-pipe exhaust ventilation system should be designed to accommodate this pressure loss. Comparing the results presented in Table 4 (3 ft flexible hose) and Table 5 (12 ft total flexible hose length) shows 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 feet long.

RECOMMENDATIONS

The following recommendations may improve the working environment in the service department of Jim Dixon Lincoln-Mercury.

Undercoating

1. The breathing air pump should be moved to a location where clean, breathable air can be assured at all times, or equipped with an air intake extension hose. The inlet of the air intake extension hose should be placed in a suitable location (for instance, outdoors, away from vehicle exhaust and other contaminant sources).

2. The respirator should be maintained in a clean condition and stored in a manner that will protect it from damage. The manufacturer's instructions should be followed for cleaning and sanitizing respirators, especially in regard to maximum temperatures.[9] OSHA requires that respirators be stored to protect against dust, sunlight, heat, excessive moisture, and damaging chemicals.[10] Respirators should not be stored in lockers or tool boxes unless they are in carrying cases or cartons, or left unprotected on workbenches.[9]

3. Air sampling conducted during an undercoating job indicated that the use of a respirator is not required. However, if a respirator is used, the user should be trained in the use and maintenance of the respirator. Since the respirator user has a beard, that individual must either shave, or be provided with a respirator which does not require a face-to-facepiece seal to provide protection to the wearer. Loose-fitting hoods are one type of respirator which does not rely on a face-to-facepiece seal. Another advantage of this type of respirator is that it does not need to be fit-tested.

4. The manufacturer of the air-supplied respirator used in the service department provided a variety of literature to the NIOSH industrial hygienist, including catalogs, a fit-test form, information about a turn-key hazard communication program, and a copy of the current OSHA respiratory protection standard. While NIOSH does not endorse any product or service, this information was forwarded to the management at Jim Dixon with the NIOSH letter dated July 7, 1995. You should contact the equipment manufacturer to determine what services, such as training or fit-testing, they may provide.

5. OSHA requires, and NIOSH recommends, that a respiratory protection program, including written standard operating procedures, be developed and implemented in workplaces where respirators are used.[9,10] Paragraphs (b)(1) through (b)(11) of the enclosed OSHA respiratory protection standard outline the basic elements of an acceptable program.[10] The written document need not be extensive (an outline or example may be available from the respirator manufacturer). It should, for example, spell out in the simplest terms who is responsible for cleaning and maintaining the respirator, and how this will be accomplished.

Kerosene-Fired Steam Cleaner

1. The exhaust emissions from the steam cleaner should be vented to the exterior of the building. One way this might be accomplished would be to fabricate a device to allow the steam cleaner to be connected to the tailpipe exhaust ventilation system.

Tail-pipe Exhaust Ventilation System

1. The exhaust port covers should be replaced with covers having self-closing caps. The exhaust port 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 (see Appendix A). 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 discharged at the ASHRAE-recommended stack height.[13] 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 area garage. This should be accomplished with a ventilation system separate from the tail-pipe exhaust ventilation system.[8]

The management at Jim Dixon may wish to contact a qualified engineering firm for assistance in implementing the ventilation system recommendations.

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Table 1 - Results of Air Sampling During Undercoating
Jim Dixon Lincoln-Mercury, Inc., Fairfield, Ohio
HETA 95-0200
August 29, 1995

Job Title	Location/ Activity	Sample Time (minutes)	Sample Volume (liters)	Results (milligrams of analyte/cubic meter of sampled air)					
				Toluene		C_6 - Toluene (as n-heptane)		Stoddard Solvent	
				actual	8-hr TWA	actual	8-hr TWA	actual	8-hr TWA
Service Advisor	Undercoating	18	1.8	4.3	0.16	6.1	0.23	150	5.6
Service Advisor	Undercoating*	12	1.2	5.5	0.14	8.3	0.21	200	5.0
Master Technician	North Side, Near Carwash	18	1.8	7.8	0.29	4.4	0.17	Trace	---
Master Technician	North Side Center	20	2.0	145	6.0	230	9.6	42	1.8
Mechanic	North Side, Near Front	21	2.1	9.0	0.39	11	0.48	Trace	---
NIOSH Recommended Exposure Limit				375 mg/m^3, 10-hr TWA 560 mg/m^3, STEL		350 mg/m^3, 10-hr TWA 1800 mg/m^3, Ceiling		350 mg/m^3, 10-hr TWA 1800 mg/m^3, Ceiling	
OSHA Permissible Exposure Limit				753 mg/m^3, 8-hr TWA 1130 mg/m^3, Ceiling 1883 mg/m^3, 10 minute maximum peak		2000 mg/m^3, 8-hr TWA		2900 mg/m^3, 8-hr TWA	
ACGIH® Threshold Limit Value				188 mg/m^3, 8-hr TWA		1640 mg/m^3, 8-hr TWA 2050 mg/m^3, STEL		525 mg/m^3, 8-hr TWA	

*this sample was collected during the exterior portion of the undercoating job. The other undercoating sample was collected over the duration of the interior and exterior portions of the undercoating job. The eight hour time–weighted average (8-hr TWA) exposure was calculated assuming that no further exposure occurred during the day of sampling, because the undercoating job was arranged for the purpose of evaluating these exposures. A trace value is a result between the minimum detectable concentration and the minimum quantifiable concentration, with limited confidence in its accuracy. The minimum detectable concentration (MDC) of toluene and C6 - toluene hydrocarbons was 0.5 milligrams per cubic meter (mg/m^3), based on a maximum sample volume of 2.1 liters (L). The minimum quantifiable concentration (MQC) for these analytes was 1.6 mg/m^3, based on a maximum sample volume of 2.1 L. The MDC for Stoddard Solvent was 3.8 mg/m^3, based upon of 2.1 L. The MQC for Stoddard Solvent was 12.3 mg/m^3, based upon the 2.1 L sample volume.

Table 2 -Results of Air Sampling for Carbon Monoxide
Jim Dixon Lincoln-Mercury, Inc., Fairfield, Ohio
HETA 95-0200
January 25, 1996

Title	Location	Smoker	Sample Time (hours)	Carbon Monoxide (ppm)	
				Actual TWA	8-hour TWA
Technician/Service Advisor	South Side, Next to Counter	Yes	7.1	21	19
Technician	South Side, Next to Counter	Yes	7.8	19	19
Technician	North Side, 2nd From East Door	Yes	7.0	29	25
Technician	North Side, Next to Car Wash	No	8.0	25	25
Assistant Manager	Counter	No	6.9	29	25
Service Advisor	Counter	No	8.1	19	19
Technician	North Side, Center	Yes	4.6	33	19

ppm means parts per million of carbon monoxide in sampled air by volume. TWA means time-weighted average. The first, third, and fifth individuals in the table left the building at lunch for an hour. Accordingly, 1 hour was subtracted from their sampling times. The seventh individual in the table arrived for work later in the day. His sampling time began at 11:54 a.m. The NIOSH Recommended Exposure Limit for carbon monoxide is 35 ppm as an 8-hour TWA, with a ceiling limit of 200 ppm. The ACGIH® Threshold Limit Value for carbon monoxide is 25 ppm as an 8-hour TWA. The OSHA Permissible Exposure Limit for carbon monoxide is 50 ppm as an 8-hour TWA.

Table 3 - Flow Rates With No Modifications
Jim Dixon Lincoln-Mercury, Inc., Fairfield, Ohio
HETA 95–0200
August 8, 1995

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 4 - Flow Rates After Modifications
Jim Dixon Lincoln-Mercury, Inc., Fairfield, Ohio
HETA 95–0200
August 8, 1995

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

Table 5 - Flow Rates After Modifications With *Vehicle Off/Vehicle Idling*
Jim Dixon Lincoln-Mercury, Inc., Fairfield, Ohio
HETA 95–0200
November 9, 1995

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

Figure 1
Line Diagram of Carbon Monoxide Removal System
Jim Dixon Lincoln-Mercury, Inc.
Fairfield, Ohio
HETA 95-0200

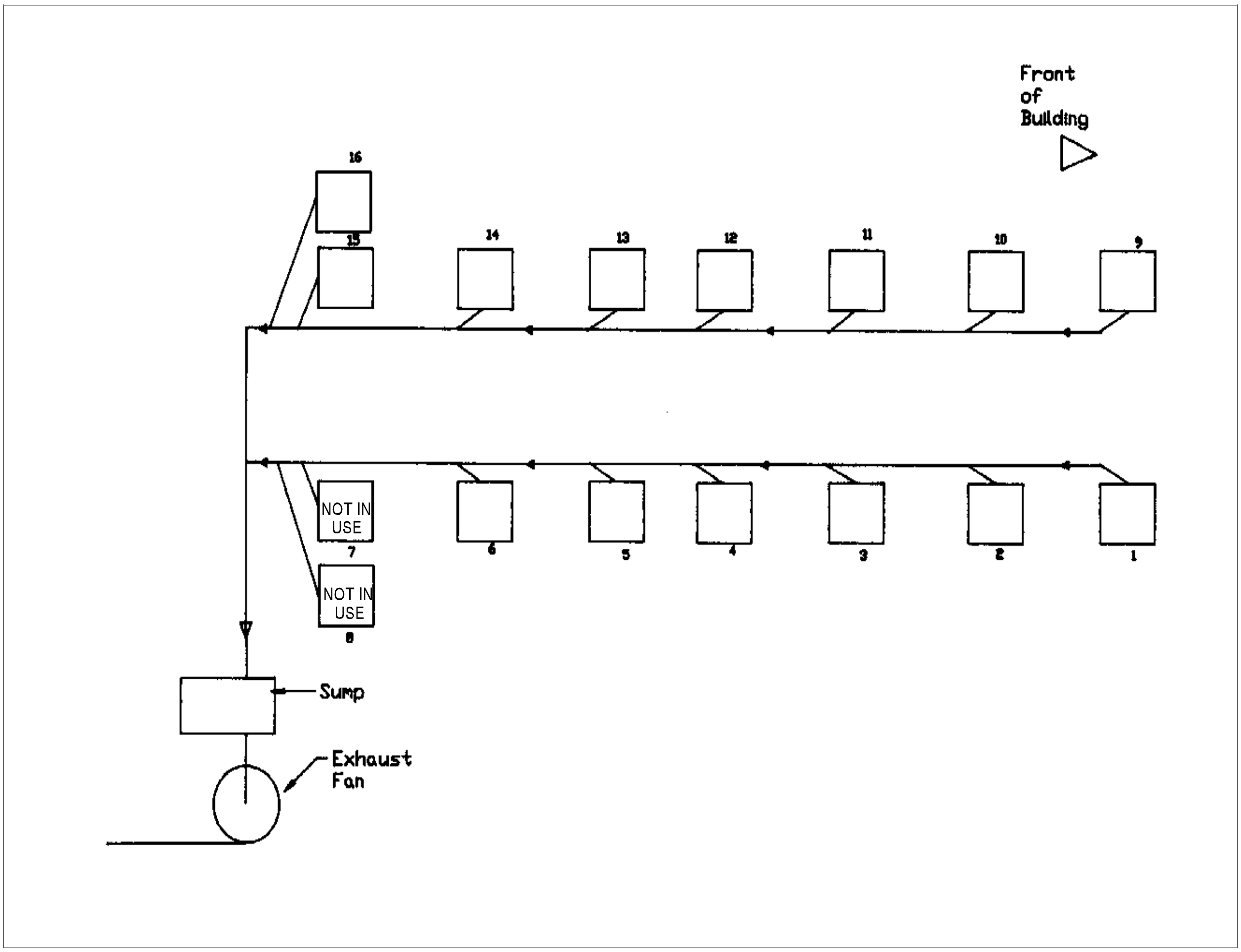


Figure 2
Existing Flexible Garage Exhaust Hose to Tailpipe and Export Port Leak Areas
Jim Dixon Lincoln-Mercury, Inc.
Fairfield, Ohio
HETA 95-0200

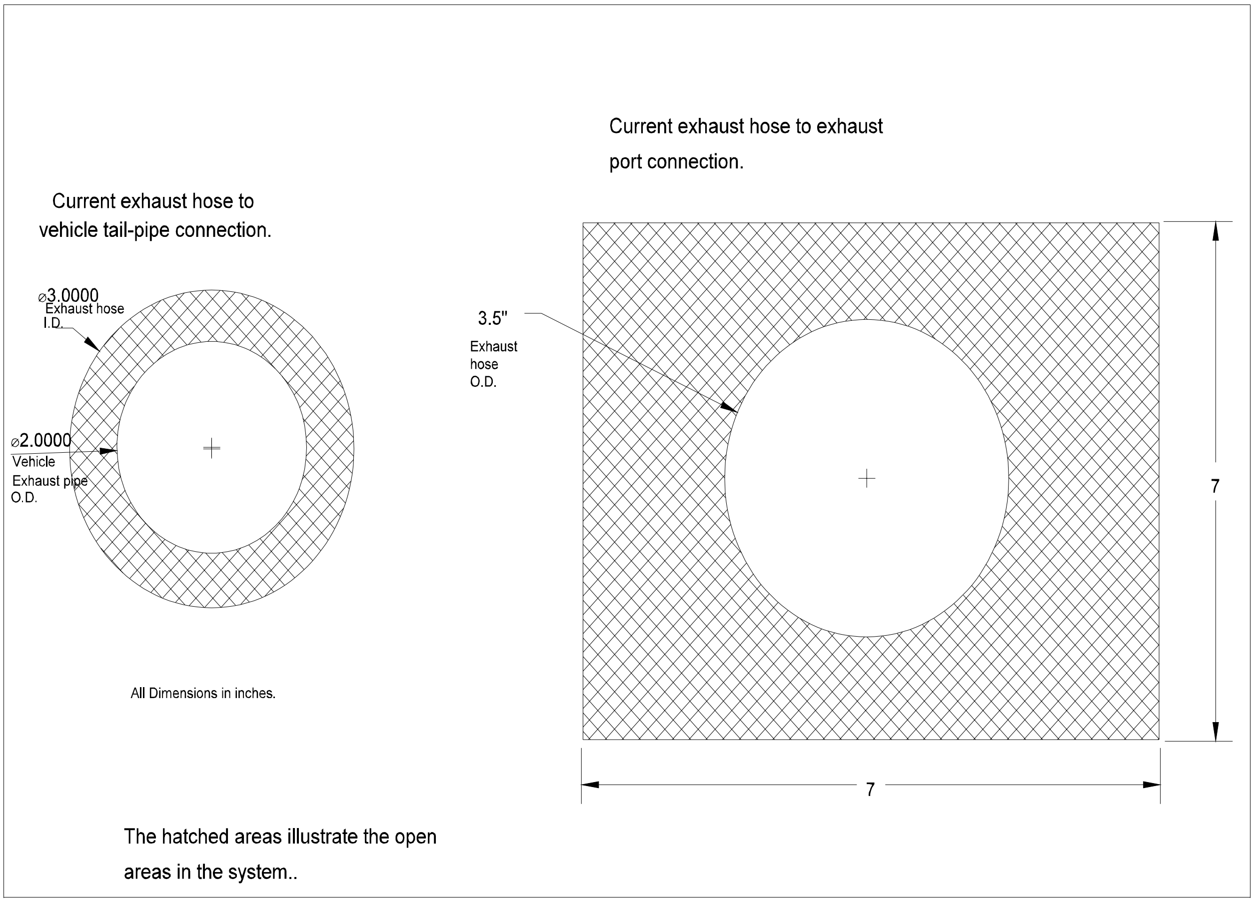
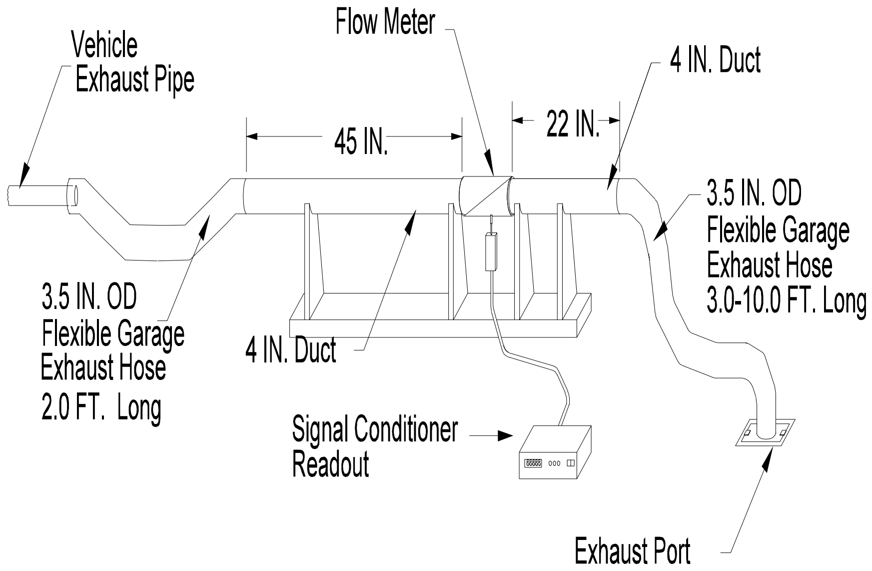


Figure 3
Flowstand used in taking tail-pipe exhaust removal system flow rate measurements at the exhaust ports.

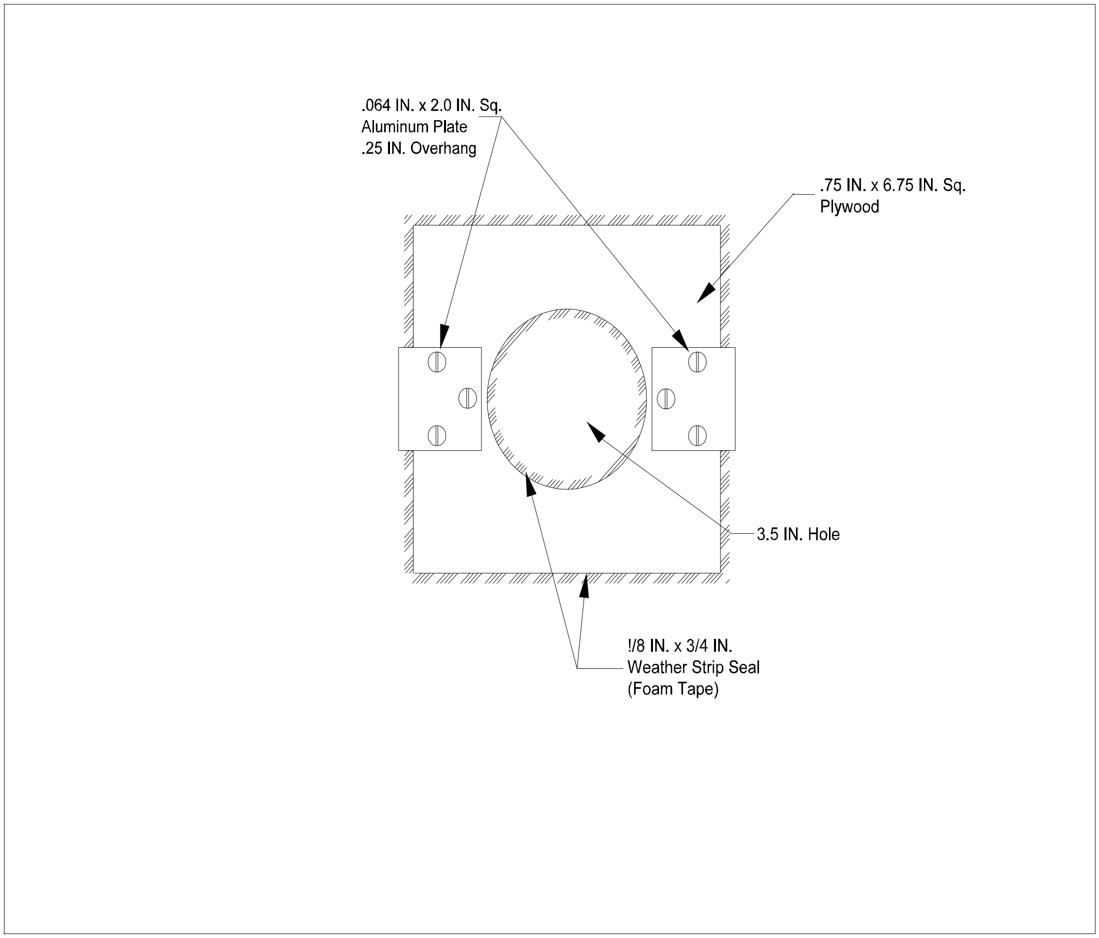
Jim Dixon Lincoln-Mercury, Inc.
Fairfield, Ohio
HETA 95-0200



Runs 1 & 2
The inlet to the flow stand was unobstructed.
A 3 foot long hose was used at the outlet of the flow stand.

Run 3
A 10 foot long hose was used at the outlet of the flow stand.

Figure 4
Flexible Garage Exhaust Hose to Exhaust Port Adapter
Jim Dixon Lincoln-Mercury, Inc.
Fairfield, Ohio
HETA 95-0200



Appendix A

A preliminary design was accomplished to determine the approximate capacity needs of the tail-pipe exhaust removal system. Meeting the following static pressure and flow rate level could maintain sufficient flow rates for up to six exhaust ports in the service area garage. The limiting exhaust port is port #9. If sufficient static pressure is provided at exhaust port #9, it follows that sufficient static pressure will be provided at all other exhaust ports. The design results show that at least 5 ″H_2O static pressure must be available at the exhaust fan inlet (assuming leak areas are sealed) to provide the minimum recommended flow rate of 100 cfm at the end of a 10 ft long flexible garage exhaust hose attached to exhaust port #9.

Assumptions	Static pressure losses (″H_2O)
8 inch square pipe, 300 feet long with 3-long radius elbows. @600 cfm.	1.12
Flexible duct entry loss @100 cfm.	0.12
10 feet of 3.5 inch diameter flexible garage exhaust hose @ 100 cfm.	3.44
Misc. losses	0.3
Total losses	**5.0**

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