IN DEPTH SURVEY REPORT
OF
Yellow Freight System, Inc.
St. Louis, Missouri

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16. Abstract (Limit: 200 words) This survey was part of an industrywide study to investigate mortality and industrial hygiene among truck drivers, dock workers and mechanics presumably exposed to diesel exhaust aerosol. During each of the surveys conducted at seven truck terminals, personal and area sampling was performed to evaluate exposures to submicrometer elemental carbon, submicrometer organic carbon, and several other particulate and gaseous components of diesel exhaust including respirable dust, nitrogen oxides, polynuclear aromatic hydrocarbons, and nitro substituted organics. The major source of exposures to diesel aerosol in the dock workers appeared to be the operation of diesel powered fork lift trucks on the dock. The major source of exposure for mechanics was during ingress and egress of diesel tractors to and from the shop areas. Exposures to nitrogen oxides and respirable dust were very low. The authors recommend that exposures to diesel exhaust should be reduced to the lowest feasible limits using source controls, work practices, substitution, and engineering controls.

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PURPOSE:	To conduct an in-depth survey of workers' exposures to diesel exhaust. The survey was conducted as part of the Industrywide Studies Branch case control mortality and industrial hygiene study of truck drivers, dock workers and mechanics presumably exposed to diesel exhaust aerosol.
DATE OF SURVEY:	February 13-16, 1989
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SIC CODE:	4231 - Freight Trucking Terminals, with or without maintenance facilities

DISCLAIMER

Mention of facility names or products in this report does not constitute endorsement by the National Institute for Occupational Safety and Health.

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Abstract

The Industrywide Studies Branch of NIOSH is currently conducting a combined case-control mortality and industrial hygiene study of members of the International Brotherhood of Teamsters. The purposes of the study are: 1) to determine whether persons exposed to diesel aerosol as a part of their job continue to have an elevated risk of contracting lung cancer after controlling for tobacco smoking, and 2) to determine relative exposures to diesel aerosol among the four major presumably exposed job groups (road drivers, local drivers, dock workers, and mechanics) identifiable from Teamsters Union records. The second objective was accomplished by conducting a series of industrial hygiene surveys at seven U.S. truck terminals. During each of these surveys, personal and area sampling were conducted to evaluate exposures to submicrometer elemental carbon (used as the principal surrogate marker of exposure), submicrometer organic carbon, and several other particulate and gaseous components of diesel exhaust, including gravimetrically determined respirable dust, polynuclear aromatic hydrocarbons (PAHs), nitro-substituted PAHs, nitrogen dioxide, and nitric oxide.

Elemental carbon sampling results at the Yellow Freight System, Inc. break bulk terminal in St. Louis, Missouri during cold weather indicate low-level exposures indistinguishable from geometric mean ambient residential and highway background concentrations (1.76 ug/m^3 and 1.35 ug/m^3, respectively) in road drivers (1.08 ug/m^3) and local drivers (2.44 ug/m^3), and exposures substantially above background highway concentrations in dock workers (25.8 ug/m^3), and in mechanics (16.1 ug/m^3). Dock workers and mechanics were found to have the highest mean exposures to elemental carbon, organic carbon, and nitrogen dioxide. Area concentrations of airborne respirable particulate indicated the lowest exposures in road tractor cabs (10.4 ug/m^3), and the highest concentrations in the shop areas (50.7 ug/m^3). Area concentrations of polynuclear aromatic hydrocarbons (PAHs) and two nitro-PAHs were either not detectable or at trace levels. Exposures to NO, NO_2, and respirable particulate were far below OSHA PELs or NIOSH RELs for these contaminants. The major source of exposures in dock workers appeared to be the operation of diesel-powered fork lift trucks on the dock. The principal source in mechanics was during the entry and egress of diesel tractors to and from the shop areas, but the more enclosed environment in which they were working exacerbated concentrations of diesel aerosol. In view of the potential human carcinogenicity of whole diesel exhaust, recommendations are made to further reduce exposures, particularly of dock workers and mechanics.

INTRODUCTION

NIOSH researchers are conducting a study to characterize the current and historical diesel exhaust exposures of trucking industry employees, with the objective of ranking jobs by exposure within the industry. The rankings will be used subsequently in a case-control mortality study to help interpret the results of the study in terms of dose-response, and to correctly classify the study participants by the level of their diesel exhaust exposure. The purpose of the mortality study is to determine if workers in certain jobs in the trucking industry have experienced an increased risk of developing lung cancer compared to those in presumably non-exposed jobs, after controlling for smoking. The study includes men who died in 1982-83, and applied for a Teamsters Union pension. Thus all persons in the study are long term Teamsters Union members.

One of the difficulties in determining relative exposures to diesel exhaust is deciding what substance or substances to measure. Whole diesel exhaust cannot be measured directly since it is a complex mixture of chemical substances. In addition, many other combustion or pyrolysis products, such as tobacco smoke, industrial aerosols, and wood smoke, contain many of the same components. Several components or fractions of diesel exhaust for which measurement methods have been established include respirable particulate, total airborne particulate, and oxides of nitrogen, sulfur, and carbon (1). In this study, measurement of the elemental carbon content of airborne submicrometer particulate was used as the primary marker of exposure to diesel exhaust.

This report describes the results of an in-depth industrial hygiene survey conducted at the Yellow Freight System, Inc. break bulk terminal in St. Louis, MO during the period February 13-16, 1989. During the survey, 60 personal and area samples were obtained for evaluation of workers' exposures to elemental and organic carbon in airborne "submicrometer" aerosol (particles generally smaller than one micrometer in aerodynamic diameter), and 30 personal samples each were obtained for evaluation of workers' exposures to nitrogen dioxide and nitric oxide. Additional area samples were obtained for evaluation of concentrations of airborne respirable dust, elemental and organic carbon content of total airborne particulate, fourteen polynuclear aromatic hydrocarbons (PAHs), and two nitro-substituted PAHs, 1-nitropyrene, and 2-nitrofluorene. This report describes the terminal and its workforce, the toxicity of diesel exhaust and applicable exposure criteria, the methods used during the survey to evaluate diesel exhaust exposures, the results of the sampling, and conclusions and recommendations based on the results.

TRUCK TERMINAL DESCRIPTION

Yellow Freight System, Inc. is one of the nation's largest over-land freight haulers. The system includes 24 "hub" or "break bulk" terminals located throughout the continental U.S. and Alaska. The company has in excess of 27,000 employees nationwide. Yellow Freight's St. Louis terminal is a large break bulk terminal consisting of line-haul (long distance) and city (local area) freight transport, dock, and tractor/trailer repair operations. The facility, opened in 1965, is situated on an 18 acre site at 400 Barton Street (about 6 miles from downtown St. Louis), and employs over 740 people. There are two main buildings - the terminal and the garage (repair shop), in addition to a fuel check lane. The truck yard surrounding the dock and offices is asphalt paved. The site currently includes the company's regional and terminal offices, including a truck/driver dispatching area, and one of the company's largest tractor/trailer maintenance facilities.

Dock Operations

The St. Louis dock (Appendix A) is typical of break bulk truck docks. The floor of the dock (loading platform) is a concrete slab elevated approximately 3 feet off the ground to allow easy loading and off- loading of truck trailers parked at the doors. The total loading platform floor space is approximately 90,000 square feet. The floor of the dock is mostly open space, but most floor space, except for the tow- motor (forklift) driving lanes, is normally taken up with materials, hand carts and other moving equipment, and other stock being transferred from one trailer to another within the dock. In general, inbound freight is received at the west end of the dock, and is distributed from this terminal to satellite terminals via the line-haul (long distance or "road") operation, and to local points via the city transport operation. Outbound freight (from local pickups and satellite terminals) is consolidated and shipped from the east end of the dock.

The terminal offices are located approximately in the center and on one side of the dock. There are also four supervisor workstations (elevated but not enclosed platforms) situated at even intervals, two at each end of the dock, and a dock control office (enclosed) in the center. The dock building itself consists of a prefabricated steel structure with a total of 189 open doors along both sides and one end. Each door is sized larger than the open end of most truck trailers (approximately 10 feet square), again to allow easy access to the interior of the trailer. The doors do not have closures, but during normal dock operations, trailers are parked at many of the door openings.

Ventilation conditions on the dock are essentially the same during both warm or cool weather; i.e., dock doors remain open to the same degree during all weather, and the dock is not heated nor mechanically ventilated. The dock currently operates twenty-four hours per day on three eight-hour shifts.

The terminal currently owns approximately 34-36 Toyota Co. tow-motor trucks, all less than 2 years old. However, only 13 to 15 of these are operated on a given shift. All of the tow-motors are diesel-engine powered. These receive complete engine tune-ups every 6 months, and oil and filters are changed every 16,000 miles. Yellow Freight System, Inc. bought Datsun Co. gasoline-engine tow-motors through 1978. Beginning in 1979, all purchases of new tow-motors have been Toyota Co. diesel-engine powered vehicles. Nationwide, the company owns approximately 1800 of the Toyota diesel tow-motors (used mainly at the 24 break bulk terminals). The company also owns about 250 gasoline-powered tow-motors, and about 200 older gasoline-powered tow-motors converted to use propane fuel, all of which are used at the satellite terminals.

Repair Shop Operations

The terminal's maintenance garage is in a separate building across the street from the main terminal. Maintenance facilities at this site consist of a tractor shop, a safety lane/service area, parts room, lunchroom, shower and locker facilities, and shop offices. The shop offices are located on the second floor of the repair shop building. The fuel check area, located on the main lot between the dock and the repair shop, consists of an open-sided covered structure divided into several open-ended parallel lanes. Almost all of the road and city tractors undergo this routine service upon arrival at the terminal.

The tractor shop, consisting of a single large room, has two overhead doors (16' x 18'), at one end, two center driving lanes, eighteen repair bays 18-20 feet long located at oblique angles to the driving lanes, and a single service/safety lane at the opposite end of the shop from the overhead doors. The tractor shop does most tuneups, and mechanical, brake, tire, wheel, engine, transmission, and electrical repairs, as well as metal cutting with acetylene torches, and welding.

Mechanically assisted, rectangular (approximately 3' x 3'), canopy exhaust hoods are suspended at ceiling level above each repair bay. Strips of flexible plastic film are suspended from the bottom of each hood around the entire periphery of the hood, and extend downwards approximately 3 feet. Tractors requiring service in this shop are driven into the shop through one of the overhead doors, and are driven into the repair bays such that the tractor's exhaust stack is located underneath the canopy hood, and inside the plastic strips. In addition, the shop has an exhaust fan (4' diameter radial blade) located on the wall near the southeast corner of the tractor shop. This fan was not used during the survey, and is generally not used in colder weather. Finally, 15 ceiling fans were located in a grid pattern throughout the shop. These fans only recirculated air and did not exhaust air to the outside.

The mechanic in charge of the service/safety lane runs through a checklist of service/safety items (oil, brakes, grease, tires, lights, wipers, etc.) to determine the operating condition of the vehicle. This lane has two overhead doors located at each end of the bay, but no mechanically assisted, local exhaust to the outside for tractors parked in this area. In the winter, the overhead doors are left closed due to the cold weather (which was the case during this survey in February), except during tractor entry and exit.

Truck Fleet Description

Yellow Freight's line-haul (road) tractors are not assigned to any one terminal for dispatch or maintenance, but are maintained in a pool for dispatch or maintenance from any one of the region's line-haul terminals. Approximately 2500 of 4000 (about 63%) of Yellow Freight's road tractors are GMC Brigadier models. The fleet also includes about 500 White, 500 International Navistar, and 500 Ford tractors. All of the road tractors are conventional design (in which the engine is situated in front of the cab, also referred to as "long-nose"), single and double axle tractors, which can haul up to approximately 20,000 or 40,000 lbs. weight, respectively. All except the Ford tractors are powered by F-300 855 $in.^3$ Cummins Co. diesel engines. The Ford tractors are powered by Cummins Co. L10, 633 $in.^3$ diesel engines. There are also a small number (about 25 each) of Kenworth and Freightliner tractors in the fleet. The average age of the fleet is about 20-30 months, with a maximum age of 5 years (1984 model year and newer). All of the road tractors are currently fitted with vertical ("stack") exhaust systems located on the right side (opposite the driver), over-cab fairings, and air conditioning.

Nationwide, Yellow Freight has a pool of 6500 city tractors, of which 5,000 are GMC Brigadier tractors, 500 are Fords (both powered by Cummins Co. F-240 diesel engines), 500 International Navistar tractors (powered by Detroit Diesel DT466 engines), 300 Mercedes tractors (OM 352 engines), and 200 GMC-JJ (Detroit Diesel DT671 engines). The GMC-JJ tractors are fitted with horizontal (undercarriage) exhaust systems, and the remainder of the tractors are fitted with vertical exhaust systems. City tractors do not (and have never) had air conditioning installed. Approximately 80 city tractors are domiciled at this terminal.

The date of conversion of the road tractor fleet from gasoline engines to diesel was not precisely known, but was estimated to have begun in the mid-1960s, and was complete by about 1970. Conversion of the city tractor fleet began in approximately 1972, and was complete about 1980.

The tractor fleet runs entirely on grade #1 diesel fuel in both summer and winter. Most of the refueling is done at the terminal and is bought in bulk for this purpose. The terminal has a 60000 gallon fuel storage facility on site.

WORKFORCE DESCRIPTION

Approximately 744 persons were, as of the date of the survey, employed at the St. Louis terminal. Of these, 651 are Teamsters Union positions, and 93 are non-union, administrative (salaried) positions. The Administrative positions include the terminal manager and secretary, 47 dock supervisors, 6 city operation supervisors, 6 office employees, 9 sales personnel, 16 line-haul supervisors, and 7 repair shop supervisors. The union positions include 189 dock workers, 143 in the city operation (of which 57 are city drivers, 56 are "yard" employees driving spotting or switching tractors, and 30 are office employees), 1 sales secretary, 267 line-haul (road) drivers, 44 mechanics, and 7 terminal janitors.

The dock and repair shop operate on three eight-hour shifts, 24 hours per day. Road drivers originating at the Toledo terminal are "on-call", but most start their shift in the late afternoon or early evening, which typically lasts 10-12 hours. The terminal is a break bulk or "hub" terminal, in which incoming freight from satellite terminals in the district is consolidated and transferred to another break bulk terminal or to its final destination terminal. Almost all of the local area deliveries and pickups by city drivers are done during daytime hours (8:00 a.m. to about 6:00 p.m.).

MEDICAL, SAFETY, AND INDUSTRIAL HYGIENE PROGRAMS

Safety and Hygiene Programs

The company has no formal in-house industrial hygiene program, but uses consultants when necessary. Air sampling was conducted in 1987, at four of the company's terminals, for carbon monoxide, oxides of nitrogen, total aldehydes, and "nuisance" dust. All results were reportedly very low or not detected.

Yellow Freight has well developed centralized safety and hazardous material training programs, and has a Regional Safety Supervisor located at the terminal. Safety is considered a distributed primary responsibility of all managers and supervisors, but the company has a centralized emergency and spill response capability through its corporate offices in Overland Park, Kansas, and has arrangements with both local and non-local licensed, hazardous materials response contractors. The program includes extensive new-employee and periodic training in safety and hazardous materials, focusing on spill prevention, freight handling, packing, and moving. There are driver safety and safe worker programs for dock workers and repair shop employees.

Although no personal protective equipment is required for routine work at the terminal, the terminal does maintain supplies of ear plugs, impervious suits and gloves, protective boots, goggles, and respirators. The respirators available on site include Scott Airpaks^{tm} (self- contained, supplied air), and a variety of cartridge and canister respirators. This equipment is maintained primarily should it be needed for spills or releases of hazardous materials. The company also has an arrangement with a local contractor for respirator maintenance.

Medical Programs

There is no on-site medical clinic or nurse's station, but the company has an arrangement for medical or emergency care with two nearby clinics. In the case of road drivers, the Department of Transportation requires a pre-employment physical and periodic physicals every two years. The physical is a limited one and includes a medical history, vision tests, hearing and audiometry, and urine tests including a drug screen, specific gravity, albumin, and sugar. All employees are given a similar pre-employment physical. However, except in the case of a return from an injury and periodic audiometry, no periodic physicals are provided for non-drivers. Appendix B is a blank form used for the examination.

DIESEL AEROSOL TOXICOLOGY AND EXPOSURE CRITERIA

Toxic and Carcinogenic Effects

Three characteristics of diesel exhaust particles (DEP) are important in considering the toxicity of diesel exhaust. First, the particles are small and readily inhalable and therefore can reach the lower respiratory system, where they are retained (2). Second, at least several thousand organic compounds can be adsorbed on the surface of the carbon particle aggregates, many of which are cytotoxic, carcinogenic or mutagenic (3). These adsorbed compounds can include polynuclear aromatic hydrocarbons (PAHs), and nitro-substituted PAHs such as 1-nitropyrene and 2-nitrofluorene (4). Third, diesel particles consist largely of carbonaceous material which is relatively stable in biological media. Thus, inhaled diesel particles tend to be retained for long periods in the lower respiratory tract and can accumulate, favoring induction of chronic pulmonary effects such as respiratory impairment and carcinogenesis (4).

Whole diesel exhaust also includes a number of toxic gases or vapors (i.e., various oxides of nitrogen and sulfur, aldehydes, etc.), which appear to play a major role in effects such as acute respiratory irritation. However, it is conceivable that these gases or the organic material adsorbed on deposited particles may play an additive or synergistic role in reducing ciliary clearance as well, perhaps through direct chemical cell toxicity (2).

In a major chronic inhalation study conducted by the Lovelace Institute, rats exposed at a concentration of 350 ug/m^3 DEP for 7 hr/day, 5 days/wk for up to 2 years did not have clearance rates that were significantly different from controls (5). However, rats similarly exposed at a concentration of 7000 ug/m^3 did show clear evidence of pulmonary accumulation of DEP after only 12 months, indicating impaired particle clearance. Rats exposed at concentrations of 3500 ug/m^3 did not demonstrate impaired clearance until after 18 months of exposure. These data suggest that (at least in rats) impairment of pulmonary clearance is a function of both concentration and duration of exposure, and that significant impairment of pulmonary clearance and subsequent accumulation of DEP begins somewhere between a concentration of 350 and 7000 ug/m^3 (0.35 and 7 mg/m^3). However, substantial differences in lung clearance rates between test animals and humans make these data difficult to interpret in terms of human risk assessment (2).

NIOSH recently published a current intelligence bulletin (1) which concluded that "...whole diesel exhaust be regarded as a potential occupational carcinogen in conformance with the OSHA Cancer Policy (29 CFR 1990)". This conclusion was based on the results of recent animal and human epidemiology studies. The studies in rats and mice confirmed the association between induction of lung tumors and exposure to whole diesel exhaust, and especially the particulate phase (5-9). Several recent human epidemiology studies also consistently suggested an association between occupational exposure to whole diesel exhaust and lung cancer (10-12).

The most recent and thorough epidemiological studies were done by Garshick et al. (11,12) in railroad workers. In both of those case control studies, significant excesses of lung cancer were identified in certain age groups of exposed railroad workers, after controlling for tobacco smoking and asbestos exposures. Classification of the workers into exposed and unexposed groups was confirmed using adjusted respirable particulate (ARP) exposure measurements in 39 representative jobs from four U.S. railroads over a 3-year period. The measurements were adjusted by analyses for nicotine from composited filters obtained from each job group (13). Geometric mean exposures to ARP ranged from 17 ug/m^3 for clerks to 134 ug/m^3 for locomotive shop workers. Differences in climate, facilities, equipment, and work practices were found to affect exposures to diesel exhaust (14).

Exposure Criteria

Permissible exposure limits (PELs) promulgated by the Occupational Safety and Health Administration (OSHA) and the Mine Safety and Health Administration (MSHA), and NIOSH recommended exposure limits (RELs), exist for a number of gas/vapor species present in whole diesel exhaust (Table I, reproduced from NIOSH's Current Intelligence Bulletin No. 50 (1). There are essentially no exposure limits (either promulgated as standards or recommended) directly applicable to evaluation of diesel aerosol (particulate phase) exposures. Both OSHA and MSHA have promulgated exposure limits for respirable nuisance (inert or non-toxic) dust for general occupational (5 mg/m^3) and coal-mine environments (2 mg/m^3). However, neither of these standards were intended to apply to diesel exhaust particulate. These standards are roughly comparable to the medium (3.5 mg/m^3) and high (7 mg/m^3) exposure concentrations used in the animal studies reported by Mauderly et al. (5). Thus, it is unlikely that these concentrations represent reasonable exposure limits for human exposure to diesel aerosol. There are also no existing exposure limits for specific PAHs or N-substituted PAHs. Similarly, the OSHA PEL for coal tar pitch volatiles (measured by solvent extraction of collected particulate) is not considered relevant to diesel emissions.

Measurements of the specific compounds mentioned above (and relating the results to published standards and recommendations) will not serve as adequate surrogates for diesel exhaust, nor do they allow an accurate assessment to be made of the effects of factors such as climate, facility design, work practices, and tractor/tow-motor configuration, type, or age. The measurement of submicrometer elemental carbon, which was used in this survey, appears to be a more sensitive and specific surrogate for diesel exhaust than other previously used surrogates. Currently there are no promulgated standards or recommended limits for exposure to submicrometer elemental carbon in whole diesel exhaust.

METHODS

Background

Characterizing worker exposures to diesel exhaust is difficult because of the complex nature of diesel engine emissions. One of the chief difficulties is determining which of the thousands of compounds best serves as an index of diesel exhaust exposure and as an indicator for the expression of adverse health effects. Since measuring each of the compounds in diesel exhaust is obviously impossible, it is necessary to identify a component of whole exhaust which is thought to be related to the health effect of interest. In this study the health effect of interest is lung cancer.

One of the many problems associated with choosing an appropriate air sampling method is the uncertainty about which specific agent or agents are responsible for the mutagenic and carcinogenic properties of diesel aerosol. It has been established in previous research that whole diesel exhaust has low in-vitro mutagenic potency and low in-vivo carcinogenic potency in rats and mice (15). At present, the role of individual diesel components in the etiology of human lung cancer is unknown. However, it has been established that 90% of the mutagenic potency of diesel exhaust appears to be limited to the particulate phase (16). In addition, although a few animal studies indicate that filtered diesel exhaust (i.e. the gaseous phase) may also be carcinogenic, lung tumor induction in animals has been primarily associated with exposure to the particulate fraction (1). Therefore, it is reasonable to use an index directly related to the particulate, and not gaseous phase, of diesel aerosol.

Several methods have previously been used to measure worker exposures to diesel exhaust. Measurement of ARP (respirable particulate adjusted for the contribution of tobacco smoke by quantitation of nicotine extracted from the same filters) was used in a recently completed exposure study in railroad workers (14). MSHA, the Bureau of Mines (BOM), and NIOSH have measured exposures to diesel aerosol in dieselized coal mines by gravimetric determination of submicrometer particulate, using a custom- designed "dichotomous" sampling cassette (17).

The major problems associated with the use of these methods in the trucking industry include: 1) the relative insensitivity of the gravimetric method (as high as 200 ug/filter), and 2) lack of specificity, since tobacco smoke produces an unknown and potentially large positive bias.

In this study, exposure to submicrometer elemental carbon (Ce) was chosen as the principal marker of exposure to whole diesel exhaust because: 1) it has 100-fold greater sensitivity over the gravimetric method (the limit of detection is on the order of 2 ug/filter); 2) diesel particulate is typically 60-80% elemental carbon (thus the major component of diesel exhaust is measured); and 3) tobacco smoke is almost entirely organic carbon, and should not produce a significant positive bias.

Sampling Strategy

Approximately 8 personal samples for submicrometer Ce and organic carbon (Co) were obtained on each of the two shifts sampled each day. Generally, 3 to 4 personal samples were obtained from both dock workers and road drivers during one shift per day, and an equivalent number of personal samples were obtained from mechanics and local drivers during the other shift. The sampling was conducted for three days (six shifts) beginning with the second shift on February 13, and ending on the first shift on February 16, 1989.

Passive monitors (Palmes tubes) were also placed on most (not all) of the people from each of the four job groups on whom carbon samplers were placed. Both NO_2 and total oxides of nitrogen samplers were placed (side-by-side) in order to measure the workers' exposures to both nitrogen dioxide (NO_2) and nitric oxide (NO).

Additional area sampling was conducted during the survey to measure concentrations of 1) respirable airborne particulate, 2) submicrometer elemental and organic carbon, 3) elemental and organic carbon content in total (not size selected) airborne particulate, and 4) PAHs and nitro- PAHs (see Table II). Two area samples of each of the four types were obtained on each shift, one in each of the two areas sampled; e.g., in the garage and dock areas during both shifts, in city tractor cabs during the day shift, and in road tractor cabs during the second shift. In the case of the tractor cabs, the sampling pumps were placed on the floor of the cab driven by the person (road or city driver) on whom personal samples were obtained for submicrometer elemental carbon. The sampling cassettes were attached to an appropriate location near the dashboard. In the case of the dock and repair shop, the samplers were placed at one strategic location in each area.

Methods and Materials

Worker exposures to submicrometer Ce and Co were determined by obtaining full shift personal samples using a modified dichotomous sampling cassette developed by NIOSH's Division of Respiratory Disease Studies (DRDS) (17), but containing 37 mm Pallflex Corporation QAOT quartz fiber filters instead of 37 mm PVC filters. Battery-operated personal sampling pumps were used to draw air through these cassettes at a flowrate of 4 Lpm. The modification to the DRDS design entailed resizing the inlet diameter to approximately 0.0520" in order to preserve the impaction characteristics (reject particles greater than 1 um aerodynamic diameter) when operating the sampler at a flow rate of 4 Lpm instead of 2 Lpm. "Total" elemental and organic carbon were measured in the same way, but using a standard, 37 mm open-face polystyrene cassette instead of the dichotomous sampler.

The dichotomous cassette is essentially a single-stage personal cascade impactor, designed to collect submicrometer particles, and to reject supermicrometer (those larger than 1 um) particles. The dichotomous cassette was used in order to exclude, to the extent possible, non- diesel particulate, since almost all diesel particles (about 95%) are smaller than one micrometer (18). All of these samples were obtained for a full shift, since the main problem is sensitivity, not overloading. The limit of detection is about 2 ug/filter, which translates to a concentration of about 1 ug/m^3, assuming a 2 cubic meter air volume.

Subsequent to the survey, the sample filters were submitted to a laboratory for thermal-optical quantitation of elemental and organic carbon (19-20). In the thermal-optical analysis, a 1 x 1.5 cm rectangular portion of the filter (i.e., a "punch") is removed and placed in a furnace. During each of the two major phases of the analysis, the furnace temperature is increased (stepped) several times to drive off the various carbon species in stages, resulting in a carbon species profile, or thermogram. The method is capable of accurate speciation of elemental and organic carbon fractions in deposits on the filter.

Defining the nature of Ce is not a simple matter. Most researchers define it entirely in terms of the method of analysis. However, elemental (as opposed to "organic") carbon has certain fundamental properties which allow its separation and quantitation, including:

- non-volatility in the absence of oxygen, even at high temperatures,
- in small particles, absorbs light of any wavelength,
- chemical inertness to most acids at room temperature,
- insolubility in all solvents, and
- electrical conductivity.

The thermal-optical determination makes good use of the first two of the above properties. In the first major phase of the analysis, the temperature in the furnace is stepped (250 to 680 degrees C.) in the absence of oxygen to drive off the volatile (essentially organic) species of carbon compounds. During this phase, the transmission of a helium-neon laser beam through the filter is monitored to correct for inadvertent pyrolysis (charring) of organic carbon species to elemental carbon. In the second major phase, the furnace temperature is reduced slightly, and then is again stepped (525 to 750 degrees C.), but in a 2% oxygen atmosphere, to oxidize elemental carbon to carbon dioxide. Quantitation is accomplished during both phases by catalytic reduction of carbon dioxide to methane, and detection using flame ionization.

Respirable dust samples were obtained using NIOSH method 0600 (21). This method measures the mass concentration in air of any non-volatile respirable dust, as specified by the American Conference of Governmental Hygienists (22). The samples were collected using a preweighed 37 mm Millipore 5 um pore-size polyvinyl chloride filter held in a polystyrene cassette. The cassette was placed in a 10 mm nylon cyclone, which separates the particles into respirable and non-respirable fractions. Air was drawn through the cyclone/filter at a flowrate of 1.7 Lpm. The filter was post weighed, after reconditioning in the laboratory, to determine the net weight of particulate collected on the filter.

Nitrogen dioxide was determined by NIOSH method 6700 (21), and total oxides of nitrogen by the method of Palmes et al. (23). Both methods employ a passive diffusion monitor generally referred to as a "Palmes tube". In this technique, the NO_2 reacts with triethanolamine (TEA) coated onto three 40x40 per inch mesh stainless steel screens inserted at the closed end of a 2.8 in. long acrylic tube. The NO_2 reacts with the TEA in a diazotization reaction, quantitatively converting the gas to nitrite. The total oxides of nitrogen sampler is similar, but the NO_x species are first oxidized to NO_2 using a chromic acid impregnated glass fiber disc, also inserted at the closed end of the sampler.

In practice, two Palmes tubes were used side-by-side, only one containing the chromic acid disc. The sampler without the chromic acid disc was used to quantitate NO_2, and the other to quantitate NO_x (essentially NO_2 + NO). In use, the monitors were placed side-by-side in the worker's breathing zone, and the bottom end of each monitor was uncapped. At the end of the worker's shift, the bottom end of each tube was recapped. The trapped NO_2 in all cases was determined by colorimetric determination of nitrite. NO was determined as the difference between the NO_x and NO_2 values. The effective sampling range is between 0.13 and 8.5 ug NO_2 per sample (21). The estimated limit of quantitation (LOQ) for this set of samples was reported to be on the order of 0.085 ug per sample.

Concentrations of polynuclear aromatic hydrocarbons (PAHs) and nitro-substituted PAHs (N-PAHs) were determined using NIOSH method 5506 (21). The sampling train consisted of a 37 mm Zefluor^tm PTFE filter housed in a polystyrene sampling cassette, followed in line by a glass tube containing washed XAD-2 resin (Orbo-43^tm tube). In this method, particulate-phase PAHs were collected on the PTFE membrane filters, and volatile/semivolatile PAHs were collected by the washed XAD-2 resin.

During sampling, air was drawn through the sampling train at a rate of 2 Lpm for approximately eight to ten hours. Prior to sampling, the filter cassette and Orbo-43 tube assembly were wrapped with aluminum foil to prevent ultraviolet (UV) degradation of collected PAHs. After sampling, the filter was transferred to a glass scintillation vial, and both the vial and the recapped Orbo-43 tube were again wrapped in aluminum foil. Samples were kept frozen until analysis by the laboratory. In the laboratory, both filters and resin were desorbed with acetonitrile. Fourteen PAHs and two N-PAHs (2-nitrofluorene and 1-nitropyrene) were determined by high-performance liquid chromatography and quantitated using fluorescence/UV detection.

RESULTS

Figures 1 and 2 are bar charts of the geometric mean concentrations of elemental and organic carbon, by job or area, including the results of the highway and residential area samples obtained for comparison. Figures 3 to 5 are similar charts illustrating exposures to nitrogen dioxide (NO_2), nitric oxide, and respirable particulate, respectively. Tables III and IV present statistical summaries, by job categories, of those personal samples obtained to evaluate time weighted average exposures to elemental and organic carbon, respectively. Tables V and VI contain similar statistical summaries of NO_2 and nitric oxide (NO) concentrations by job or area. Table VII is a statistical summary of respirable dust concentrations in four areas. Table VIII is a summary of concentrations of five PAHs found in sorbent tube samples in the repair shop, road tractors, and local tractors. Tables 1- 6 in appendix B contain the individual personal, eight-hour, time weighted average exposures to elemental and organic carbon, NO_2, NO, respirable dust, and five PAHs. Concentrations of nine of the fourteen PAHs and the two nitro-PAHs for which sampling was conducted (Table II) are not included in this report because all of the sampling results were below the limit of detection of the analytical method. In the following discussion, the terms "average" and "mean" denote geometric means (not arithmetic), unless indicated otherwise.

Submicrometer Elemental and Organic Carbon

As indicated in Figure 1 and Table III, the geometric mean submicrometer elemental carbon exposures of personnel sampled at this facility ranged from 1.08 ug/m^3 in road drivers to 25.8 ug/m^3 in dock workers. The intermediate job means were (from low to high - refer to Figure 1): local drivers (2.44 ug/m^3), and mechanics (16.1 ug/m^3). Area concentrations in four areas averaged 1.89 ug/m^3 in road cabs, 2.17 ug/m^3 in local tractor cabs, 17.7 ug/m^3 on the dock, and 26.5 ug/m^3 in the shop area.

By contrast, concentrations measured on a major interstate freeway within St. Louis (at the intersection of Broadway and I-55) averaged 1.35 ug/m^3 (range: 1.0 to 3.05 ug/m^3 in three samples), and in a residential area (at least 1 mile from the nearest major highway) averaged 1.76 ug/m^3 (range: 1.0 to 5.66 ug/m^3 in three samples).

Inspection of Figure 1 indicates that mean exposures to elemental carbon in two jobs, road drivers and local drivers, were essentially indistinguishable from either residential or highway background concentrations. However, exposures of both dock workers and mechanics appeared to be substantially above background concentrations (both residential and highway). In dock workers, the 95% lower confidence limit (LCL) of the exposures in this job (21.1 ug/m^3) was greater than the 95% upper confidence limit (UCL) of highway concentrations (Table III), suggesting that dock workers' exposures were significantly higher. Although this was not true in mechanics, it may be that the sample sizes within this job and those from the highway area (10 and 3, respectively) were too small to determine a true significant difference. Also, multiple comparisons make inferences based on individual significance tests only approximate. Thus, final judgement on this conclusion (using factorial analysis of variance) will be reserved until the data from all seven surveys have been pooled and analyzed together.

Concentrations of elemental carbon in total airborne particulate (Table III) measured in road and local tractor cabs, on the dock, and in the repair shop were essentially indistinguishable from concentrations of submicrometer elemental carbon measured simultaneously in the same areas. Assuming that the source of most or all of the airborne elemental carbon is diesel engine exhaust, this result is not surprising, since almost all (approximately 95%) diesel particles are smaller than 1 um in aerodynamic diameter (1). Mean concentrations of total elemental carbon in these samples ranged from 1.48 ug/m^3 in local cabs to 31.4 ug/m^3 in the shop area.

Figure 2 and Table IV contain comparable summary statistics for the same samples analyzed for organic carbon. As indicated, geometric mean exposures to submicrometer organic carbon ranged from a low of 16.3 ug/m^3 in road drivers to a high of 61.4 ug/m^3 in mechanics. Other job means (Table IV and Figure 2) were intermediate to these. Geometric mean area concentrations of organic carbon ranged from 10 ug/m^3 on the dock to 52.7 ug/m^3 in the shop area.

Residential area concentrations of submicrometer organic carbon averaged 0.6 ug/m^3, and highway ambient area concentrations averaged 1.51 ug/m^3. Only the 95% LCL of personal samples from mechanics (37.5 ug/m^3) was higher than the 95% UCL for the highway samples (26.0 ug/m^3), suggesting that only mechanics' exposures to submicrometer organic carbon were significantly greater than background highway concentrations of organic carbon. Although substantial quantities of organic carbon species can be present in diesel exhaust, this result more likely reflects exposures to other sources of organic carbon, such as tobacco smoke, paint aerosol and solvents, degreasing vapors, and fuel vapors from vehicles (during refueling operations for example). Exposures of road drivers, local drivers, and dock workers could not be similarly distinguished from background highway concentrations. However, the small number of samples from the highway (3) generated very wide confidence limits around the mean, suggesting that the lack of a significant difference could be due either to too small a sample size, or the lack of a real difference.

Oxides of Nitrogen

Nitrogen dioxide (NO_2) concentrations determined in personal samples from 4 jobs (Figure 3 and Table V) ranged from 0.04 ppm (road drivers) to 0.11 ppm (mechanics). All of the results were far below the OSHA PEL of 5 ppm (ceiling), the NIOSH REL of 1 ppm (15 minute ceiling), or the American Conference of Governmental Industrial Hygienists' Threshold Limit Value (TLV) of 3 ppm (8-hour time-weighted average).

Nitric oxide (NO) exposure means (Figure 4 and Table VI; NO_2 and NO samples were obtained as duplicate samples on the same workers) ranged from 0.02 ppm in local drivers to 0.03 ppm in mechanics. No exposure means or other statistics (other than ranges) were calculated for road drivers since the majority of concentrations (6 of 9) were below the limit of detection. These exposures are again far below applicable OSHA PELs or NIOSH RELs (Table I).

Respirable Dust

Figure 5 and Table VII summarize concentrations of non-volatile respirable dust obtained in specific areas of the repair shop, dock, and in local and road tractors. Respirable dust concentrations in road cabs averaged 10.4 ug/m^3, 24.5 ug/m^3 on the dock, 37.7 ug/m^3 in local cabs, and 50.7 ug/m^3 in the shop area.

Polynuclear Aromatic Hydrocarbons

Table VIII is a summary of concentrations of five PAH compounds found on the five XAD-2 sorbent tube samples obtained in the repair shop, road tractors, and local tractors. Only these five compounds were detectable on any of the samples obtained during the survey on either the filters or the backup sorbent tubes. Detectable concentrations of the remainder of the fourteen PAHs and two nitro-PAHs analyzed (Table II) were not found in these samples. As indicated, the geometric mean concentrations of the five PAHs ranged from 0.04 ug/m^3 (anthracene) to 0.4 ug/m^3 (phenanthrene). Obvious potential sources of these PAHs include either or both diesel exhaust and tobacco smoke.

CONCLUSIONS

1. Based on measurements of personal, breathing zone concentrations of elemental carbon at this terminal, it appears that dock workers' exposures to diesel aerosol were elevated significantly above background highway concentrations found in the St. Louis area. In addition, the relatively high exposures of mechanics were very likely due to the more enclosed environment in which they were working. Dock workers' high exposures were undoubtedly due to the operation of diesel-powered forklift trucks on the dock, since this was the major source of their exposure. With regard to the other jobs sampled, the lack of demonstrably higher exposures compared with background highway concentrations may be due to a small sample size (and necessarily wide confidence limits), or may be due to the lack of a true difference. Firmer conclusions must await analysis of this data in conjunction with data collected during the remainder of the surveys at other terminals.

2. Geometric mean ambient highway concentrations of submicrometer elemental carbon were, in this survey, essentially of the same order of magnitude as geometric mean ambient residential concentrations. In addition, road and local drivers' mean exposures to elemental carbon were generally of the same order of magnitude as ambient highway concentrations. Thus, a substantial portion of truck drivers' exposures may have stemmed from ambient (highway) concentrations, rather than from the truck they were driving.

3. Geometric mean organic carbon concentrations were higher than elemental carbon concentrations in most jobs and areas sampled at this terminal, particularly mechanics, very likely indicating the presence of some non-diesel air contaminants, including paint solvents, degreasing solvent vapors, or tobacco smoke, in the samples. In fact, the generally very low concentrations of submicrometer elemental carbon in most samples, except in samples from dock workers and mechanics, suggest that very little if any diesel aerosol was being sampled in these jobs or areas.

4. The mean personal exposures to submicrometer elemental carbon, organic carbon, and NO_2, and area concentrations of respirable dust, suggested that the lowest exposures to diesel aerosol were in road and local drivers, and higher exposures to diesel exhaust were in dock workers and in mechanics.

5. Geometric mean exposures to oxides of nitrogen (NO_2 and NO), and respirable dust were very low, and were far below OSHA PELs and NIOSH RELs for these airborne contaminants.

6. Only five PAHs were detectable (and those only in trace amounts) in area samples obtained in the repair shop, road tractors, and local tractors. No other PAHs or nitro-PAHs were detected in these samples in either the filters or backup sorbent tubes. Those PAHs detected could have come from either the presence of diesel aerosol or to the presence of tobacco smoke in those areas monitored.

7. Additional data collected during this survey regarding environmental factors (e.g. ambient temperatures), tractor configurations, tractor age, engine size and type, trailer weight, miles driven per shift, presence or absence of air conditioning, and other factors will be consolidated with similar data collected at other terminals and used to help determine the significance of these factors in exposure to diesel exhaust. The data reported here were collected in relatively cold conditions (approximately 40-45 degrees F. daytime highs), and represent tractors with vertical (stack) exhaust systems, and mostly conventional (not cab-over) tractor designs.

RECOMMENDATIONS

In general, exposures of road and local drivers to submicrometer elemental carbon were quite low during the survey. The data indicate that overall exposures to whole diesel exhaust in these jobs were only slightly above local ambient highway concentrations. The mechanics working in the shop experienced exposures substantially higher, by a factor of approximately twelve, due mainly to the more enclosed space in which they were working, compared to other jobs. The dock workers experienced higher exposures (by a factor of about 20 compared with highway concentrations), due mainly to their direct work in areas frequented by diesel-powered tow-motors trucks. In view of the potential carcinogenicity of whole diesel exhaust to humans as documented by NIOSH in its 1988 Current Intelligence Bulletin, the following general recommendations are prudent.

Exposures to diesel exhaust should be reduced to the lowest feasible limits using one or more of the following techniques: source controls, changes in work practices, substitution, and engineering controls such as local and general exhaust ventilation techniques. Source controls would include careful, continued engine maintenance and tune-ups in tow- motors, tractors, and switching vehicles, as well as use of direct exhaust controls such as ceramic filters. Changes in work practices could include planned rotation of workers between jobs to minimize exposures (between work on the dock and driving tractor cabs, for instance). Local exhaust techniques include use of flexible duct vehicle exhaust removal systems in buildings or other enclosed or semi- enclosed spaces such as the repair shop. General (dilution) exhaust and tempered air makeup systems can be useful in controlling exposures in enclosed spaces such as the repair shop, particularly in cold weather, or where it is not possible to effectively control exposure using only local exhaust systems. Substitution would include replacement of older or malfunctioning equipment with newer, more efficient models, or substituting gasoline, electric, or propane powered vehicles for diesel powered vehicles.

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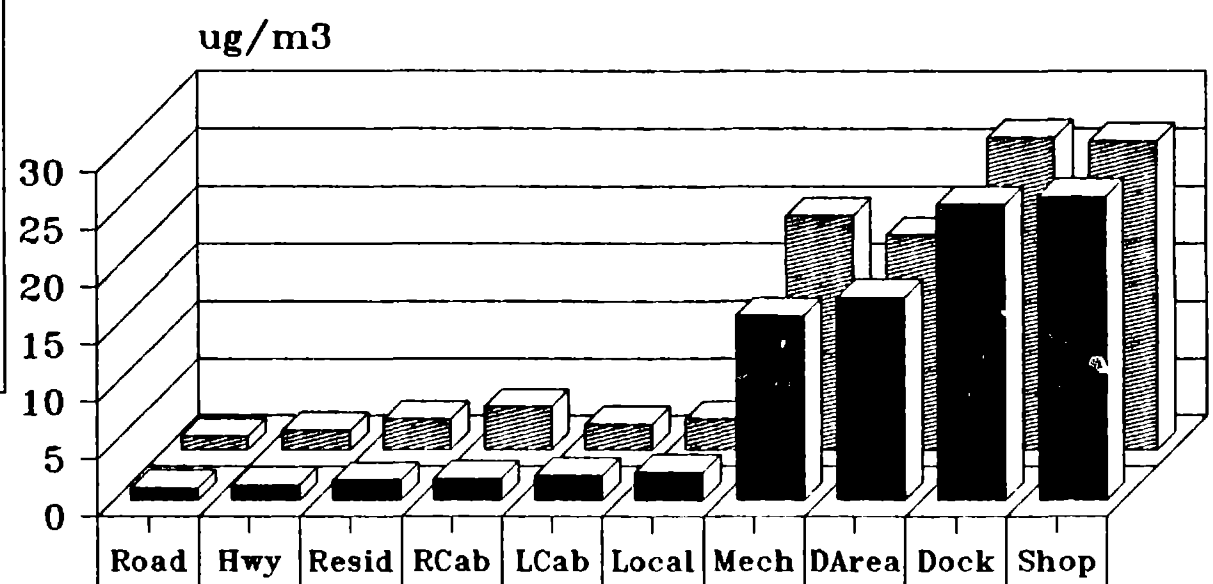
Figure 1. Elemental Carbon Exposure
Yellow Freight System, Inc.

Road = Road driver
Hwy = Highway
Resid = Residential
RCab = Road Cab
LCab = Local Cab
Local = Local driver
Mech = Mechanic
DArea = Dock Area
Dock = Dock Worker
Shop = Shop Area



	Road	Hwy	Resid	RCab	LCab	Local	Mech	DArea	Dock	Shop
Arithmetic Mean	1.18	1.71	2.67	3.75	2.23	2.68	20.4	18.7	27.2	26.9
Geometric Mean	1.08	1.35	1.76	1.89	2.17	2.44	16.1	17.7	25.8	26.5

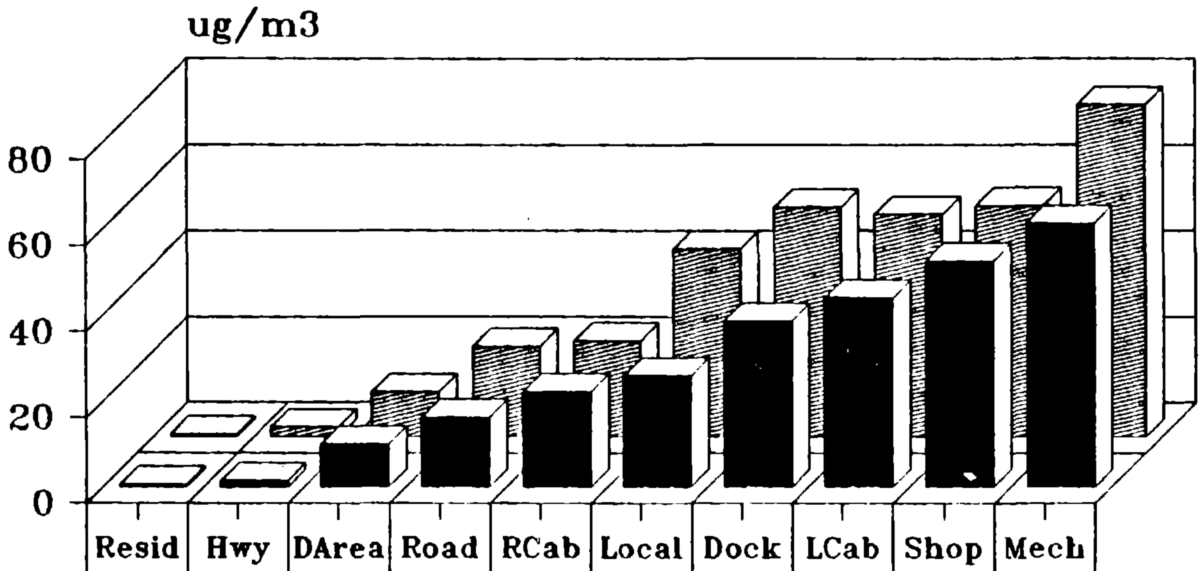
Job/Area

Geometric Mean   Arithmetic Mean

February 1989

Figure 2. Organic Carbon Exposure
Yellow Freight System, Inc.

Road = Road driver
Hwy = Highway
Resid = Residential
RCab = Road Cab
LCab = Local Cab
Local = Local driver
Mech = Mechanic
DArea = Dock Area
Dock = Dock Worker
Shop = Shop Area



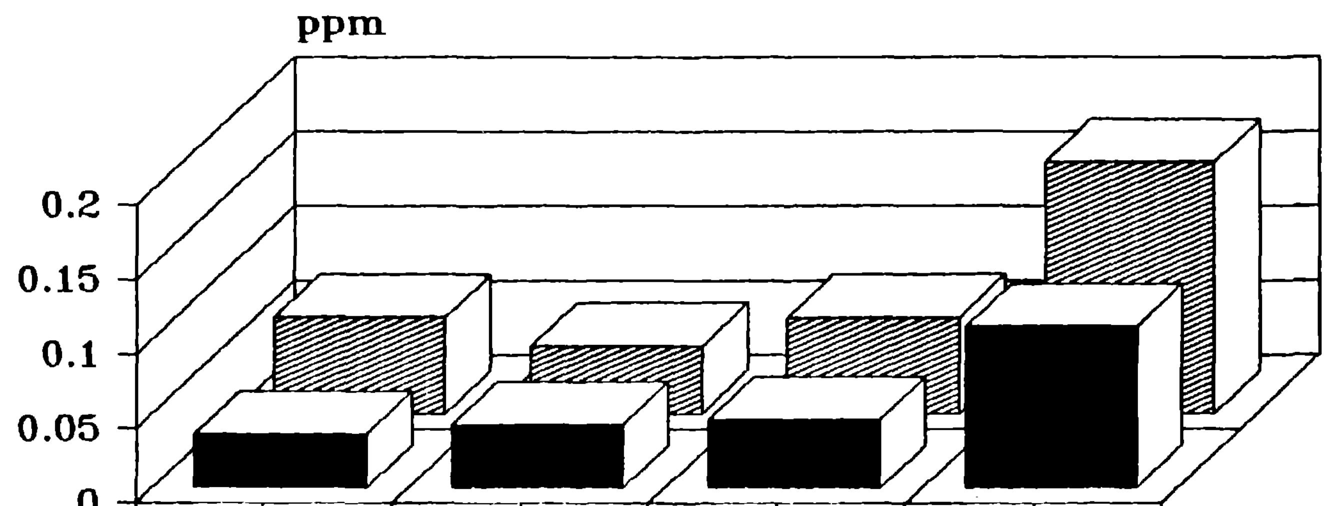
	Resid	Hwy	DArea	Road	RCab	Local	Dock	LCab	Shop	Mech
Arithmetic Mean	0.59	2.3	10.4	21	22.4	43.7	53.4	51.7	53.8	77.3
Geometric Mean	0.6	1.51	10	16.3	22.3	25.9	38.7	44.1	52.7	61.4

Job/Area

Geometric Mean — Arithmetic Mean

February 1989

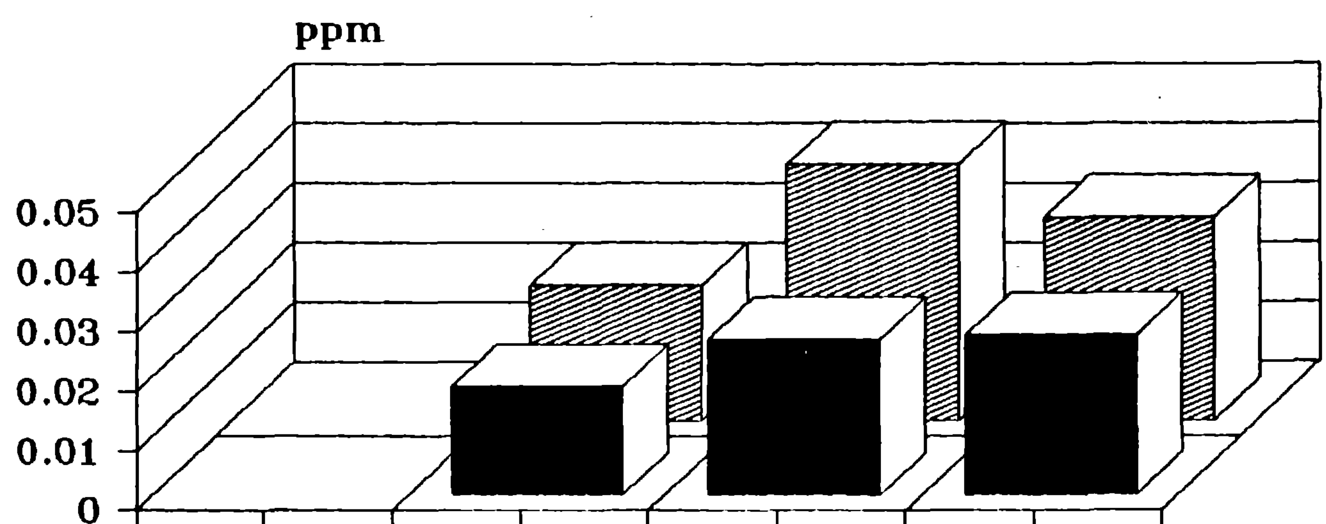
Figure 3. Nitrogen Dioxide Exposure
Yellow Freight System, Inc.



	Road Dr	Local Dr	Dock Wrk	Mechanic
Arithmetic Mean	0.065	0.046	0.064	0.169
Geometric Mean	0.036	0.043	0.046	0.108

February 1989

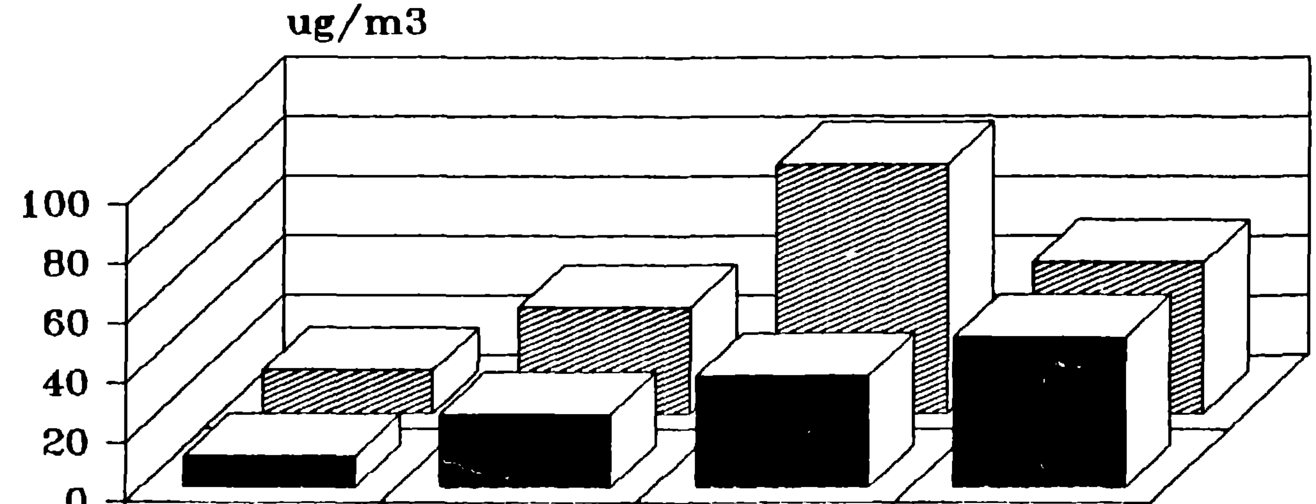
Figure 4. Nitric Oxide Exposure Yellow Freight System, Inc., 02/89



	Road Dr**	Local Dr	Mechanic	Dock Wrk
Arithmetic Mean		0.023	0.043	0.034
Geometric Mean		0.018	0.026	0.027

** More than 50% of values below L.O.D.

Figure 5. Respirable Dust Exposure
Yellow Freight System, Inc.



	Road Cab	Dock Area	Local Cab	Shop Area
Arithmetic Mean	14.5	35.6	83.5	50.8
Geometric Mean	10.4	24.5	37.7	50.7

Job/Area

February 1989

Table I—Limits for occupational exposure to selected components of the gaseous fraction of diesel exhaust; OSHA, MSHA, NIOSH compared

Component	OSHA PEL	MSHA PELs*		NIOSH REL
		Underground coal mines	Metal and nonmetal mines	
Carbon dioxide (CO_2)	5,000 ppm (9,000 mg/m^3), 8-hr TWA†	5,000 ppm (9,000 mg/m^3), 8-hr TWA; 30,000 ppm (54,000 mg/m^3), STEL§	5,000 ppm (9,000 mg/m^3), 8-hr TWA; 15,000 ppm (27,000 mg/m^3), STEL	10,000 ppm (18,000 mg/m^3), 8-hr TWA; 30,000 ppm (54,000 mg/m^3), 10-min ceiling
Carbon monoxide (CO)	50 ppm (55 mg/m^3), 8-hr TWA	50 ppm (55 mg/m^3), 8-hr TWA; 400 ppm (440 mg/m^3), STEL	50 ppm (55 mg/m^3), 8-hr TWA; 400 ppm (440 mg/m^3), STEL	35 ppm (40 mg/m^3), 8-hr TWA; 200 ppm (230 mg/m^3), ceiling (no minimum time)
Formaldehyde	1 ppm, 8-hr TWA; 2 ppm, 15-minute STEL	1 ppm (1.5 mg/m^3), 8-hr TWA; 2 ppm (3 mg/m^3), STEL	2 ppm (3 mg/m^3), ceiling	0.016 ppm (0.020 mg/m^3), 8-hr TWA; 0.1 ppm (0.12 mg/m^3), 15-min ceiling
Nitrogen dioxide (NO_2)	5 ppm (9 mg/m^3), ceiling	3 ppm (6 mg/m^3), 8-hr TWA; 5 ppm (10 mg/m^3), STEL	5 ppm (9 mg/m^3), ceiling	1 ppm (1.8 mg/m^3), 15-min ceiling
Nitric oxide (NO)	25 ppm (30 mg/m^3), 8-hr TWA	25 ppm (30 mg/m^3), 8-hr TWA	25 ppm (30 mg/m^3), 8-hr TWA; 37.5 ppm (46 mg/m^3), STEL	25 ppm (30 mg/m^3), 10-hr TWA
Sulfur dioxide (SO_2)	5 ppm (13 mg/m^3), 8-hr TWA	2 ppm (5 mg/m^3), 8-hr TWA; 5 ppm (10 mg/m^3), STEL	5 ppm (13 mg/m^3), 8-hr TWA; 20 ppm (52 mg/m^3), STEL (5 min)	0.5 ppm (1.3 mg/m^3), 10-hr TWA

*MSHA limits are based on threshold limit values (TLVs®) of the American Conference of Governmental Industrial Hygienists (ACGIH). 1973 TLVs® are used for metal and nonmetal mines. Current TLVs® are used for underground coal mines.
†Time-weighted average.
§Short-term exposure limit.

Table II
Polycyclic Aromatic Hydrocarbons (PAHs) and Nitro–substituted PAHs ; Detection and Quantitation Limits Yellow Freight System, Inc.; February 1989

Name	LOD (ng/tube)	LOD (ng/filter)	LOQ (ng/tube)	LOQ (ng/filter)
Acenaphthene	100	100	300	-
Phenanthrene	50	50	200	-
Anthracene	30	30	100	-
Fluoranthrene	30	30	-	-
Pyrene	30	30	100	80
Benz(a)anthracene	30	30	-	-
Chrysene	30	30	-	-
Benzo(b)fluoranthene	30	30	-	-
Benzo(k)fluoranthene	30	30	-	-
Benzo(e)pyrene	30	30	-	-
Benzo(a)pyrene	30	30	100	100
Indeno(1,2,3–cd)pyrene	30	30	-	-
Dibenz(a,h)anthracene	30	30	-	-
Benzo(ghi)perylene	30	30	-	-
1–nitropyrene	100	100	-	-
2–nitrofluorene	600	200	2000	-

LOD = Limit of Detection
LOQ = Limit of Quantitation

Table III. Elemental Carbon Exposures By Job or Specific Location Yellow Freight System, Inc. (ug/m3)

Job or Area	N	Min	Max	Arithmetic Mean	Error	Geometric Mean	Std. Dev.	95% Confidence Limit Lower	Upper
Road	10	<1.0	1.95	1.18	0.16	**1.08**	1.59	0.77	1.50
Highway	3	<1.0	3.05	1.71	0.73	**1.35**	2.44	0.15	12.4
Residential	3	<1.0	5.66	2.67	1.54	**1.76**	3.27	0.09	33.4
Road Cab	2	<1.0	7.00	3.75	3.24	**1.89**	6.36	0.00	3.15E+07
Local Cab	3	1.67	2.94	2.23	0.37	**2.17**	1.33	1.07	4.41
Local	12	0.84	4.50	2.68	0.30	**2.44**	1.63	1.79	3.33
Mechanic	10	4.28	34.0	20.4	3.75	**16.1**	2.25	9.01	28.7
Dock Area	3	11.8	26.2	18.7	4.16	**17.7**	1.49	6.59	47.7
Dock	12	16.8	54.2	27.2	2.89	**25.8**	1.37	21.1	31.5
Shop Area	2	21.9	32.0	26.9	5.01	**26.5**	1.30	2.43	288
Elemental Carbon Content of Total Airborne Particulate:									
Local Cab (total)	3	<1.0	2.90	1.85	0.70	**1.48**	2.50	0.15	14.4
Road Cab (total)	3	1.17	7.19	3.38	1.91	**2.47**	2.58	0.23	26.1
Dock Area (total)	3	15.4	24.1	19.4	2.54	**19.0**	1.25	10.9	33.3
Shop Area (total)	3	29.0	35.7	31.5	2.10	**31.4**	1.12	23.7	41.4

Table IV. Organic Carbon Exposures By Job or Specific Location Yellow Freight System, Inc. (ug/m3)

Job or Area	N	Min	Max	Arithmetic Mean	S.E.	Geometric Mean	Std. Dev.	95% Confidence Limit Lower	95% Confidence Limit Upper
Residential	2	<1.1	<1.3	--	--	--	--	--	--
Highway	3	<1.0	5.07	2.30	1.41	**1.51**	3.14	0.09	26.0
Dock Area	3	6.86	13.6	10.4	1.95	**10.0**	1.42	4.23	23.8
Road	10	<2.5	47.1	21.0	3.63	**16.3**	2.63	8.17	32.7
Road Cab	2	20.0	24.8	22.4	2.41	**22.3**	1.16	5.65	87.9
Local	12	<1.1	105	43.7	9.20	**25.9**	4.40	10.1	66.5
Dock	12	18.9	216	53.4	16.5	**38.7**	2.11	24.0	62.3
Local Cab	3	26.6	94.1	51.7	21.3	**44.1**	1.95	8.40	232
Shop Area	2	43.1	64.5	53.8	10.7	**52.7**	1.33	4.05	685
Mechanic	10	27.0	200	77.3	18.9	**61.4**	1.99	37.5	101
<u>Organic Carbon Content of Total Airborne Particulate:</u>									
Dock Area (total)	3	17.6	29.0	23.4	3.29	**23.0**	1.29	12.3	42.9
Road Cab (total)	3	26.4	29.8	27.7	1.10	**27.6**	1.07	23.4	32.7
Shop Area (total)	3	57.1	77.6	68.1	5.95	**67.6**	1.17	45.9	99.3
Local Cab (total)	3	32.2	432	167	132	**80.8**	4.28	2.18	2995

Table V. Nitrogen Dioxide Summary Statistics
By Job or Specific Location
Yellow Freight System, Inc.
(ppm)

Job or Area	N	Min	Max	Arithmetic Mean	S.E.	Geometric Mean	Std. Dev.	95% Confidence Limit Lower	Upper
Road	9	0.01	0.30	0.06	0.03	**0.04**	2.92	0.02	0.08
Local	7	0.02	0.07	0.05	0.01	**0.04**	1.50	0.03	0.06
Dock	4	0.01	0.12	0.06	0.02	**0.05**	2.87	0.01	0.25
Mechanic	10	<0.02	0.64	0.17	0.06	**0.11**	3.05	0.05	0.24

Table VI. Nitric Oxide Exposures
By Job or Specific Location
Yellow Freight System, Inc.
(ppm)

Job or Area	N	Min	Max	Arithmetic Mean	Error	Geometric Mean	Std. Dev.	95% Confidence Limit Lower	Upper
Road*	9	<0.02	0.05	*	*	*	*	*	*
Local	7	<0.02	0.05	0.02	0.01	**0.02**	2.07	0.01	0.04
Mechanic	10	<0.02	0.14	0.04	0.01	**0.03**	2.87	0.01	0.06
Dock	4	<0.02	0.06	0.03	0.01	**0.03**	2.32	0.01	0.10

* No Statistics calculated since greater than 50% of concentrations were below the limit of detection of 0.02 ppm

Table VII. Respirable Dust Exposures By Job or Specific Location Yellow Freight System, Inc. (ug/m3)

Job or Area	N	Min	Max	Arithmetic Mean	Error	Geometric Mean	Std. Dev.	95% Confidence Limit Lower	Upper
Road Cab	3	<11.8	31.7	14.5	8.60	**10.4**	2.63	0.94	115
Dock Area	3	<11.8	55.9	35.5	15.1	**24.5**	3.44	1.14	530
Local Cab	3	<12.0	200	83.5	59.1	**37.7**	5.81	0.48	2990
Shop Area	3	48.3	54.1	50.8	1.73	**50.7**	1.06	43.9	58.7

Table VIII. Summary of Concentrations of *Polynuclear Aromatic Hydrocarbons* Yellow Freight System, Inc. February 1989

Date	Area	Concentration (ug/m3) Acenapthene	Phenanthrene	Anthracene	Fluoranthrene	Pyrene
2-14	Shop Area	<0.15	0.09	<0.06	<0.04	<0.06
2-15	Shop Area	0.22	1.32	0.07	0.29	0.19
2-16	Local Cab	0.1	0.1	<0.04	0.03	<0.04
2-14	Road Cab	0.2	0.08	0.09	0.24	0.1
2-15	Road Cab	<0.10	0.08	<0.04	<0.04	<0.04
Geometric Mean:		--	0.18	--	0.08	--
Arithmetic Mean:		0.13	0.40	0.04	0.14	0.07

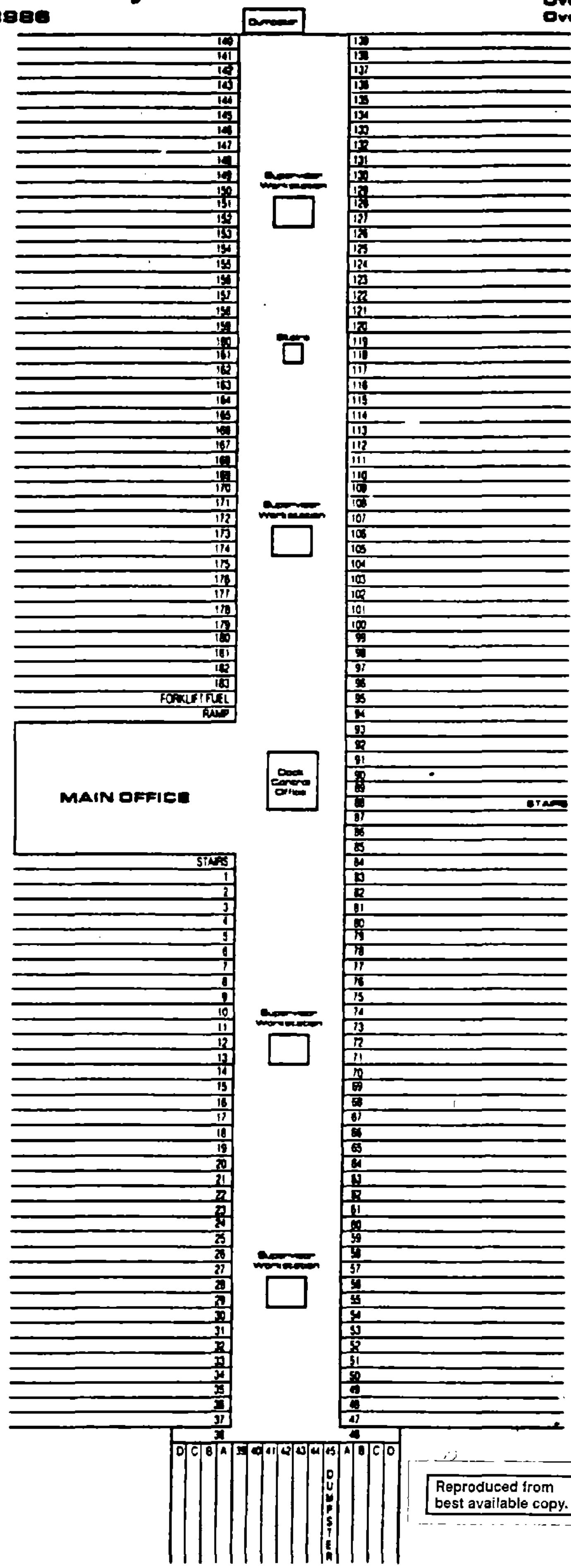
Analysis of these samples for eight other of the 14 PAHs, and 2 nitro-PAHs, (Table II) indicated concentrations below the limit of detection, which ranged from 0.03 to 0.10 ug/m3, assuming a sampled air volume of one cubic meter. Only the five PAHs indicated in this table were detected in these area samples.

Appendix A
St. Louis Dock Layout
Yellow Freight System, Inc.
St. Louis, Missouri

STL Dock Layout

October 31, 1986

Overall Length - 898'
Overall Width - 90'



Appendix B
Medical Exam Form
Yellow Freight System, Inc.
St. Louis, Missouri

OD 121
Rev. 1/74

YELLOW FREIGHT SYSTEM

PHYSICAL EXAMINATION REPORT

☐ New Certification
☐ Recertification

Date ______________

Terminal ______________

Name (Print or Type) ______ (Last) ______ (First) ______ (Middle)

Present Address ______ (Number) ______ (Street) ______ (City) ______ (State) ______ (Zip)

______ (Soc. Sec. Acct. No.) Birth ______ (Month, Day, Year) Age ______

HEALTH HISTORY

Yes	No		Yes	No		Yes	No		Check One
☐	☐	Head or spinal injuries (severe)	☐	☐	Syphillis	☐	☐	History of back injury	☐ Road Driver
☐	☐	Convulsions (fits, epilepsy, fainting)	☐	☐	Gonorrhea	☐	☐	Gastrointestinal ulcer	☐ P & D Driver
			☐	☐	Diabetes	☐	☐	Suffering from any other disease.	☐ Dock
☐	☐	Encephalitis (sleeping sickness)	☐	☐	Rheumatic fever	☐	☐	Permanent defect from illness, disease or injury	☐ Mechanic
☐	☐	Extensive confinement by illness or injury.	☐	☐	Asthma				☐ Other
			☐	☐	Nervous stomach	☐	☐	Psychiatric disorder	
☐	☐	Cardiovascular disease	☐	☐	Muscular disease	☐	☐	Any other nervous disorder.	
☐	☐	Tuberculosis	☐	☐	Kidney disease	☐	☐	Have you ever filed W.C.C. or V.A. claim	

If answer to any of the above is yes, explain. ______________

PHYSICAL EXAMINATION

General Appearance. Slender ______ Average ______ Obese ______

General Appearance Development. Good ______ Fair ______ Poor ______ Height ______ Weight ______

Head: Eyes: (Without glasses) (With glasses if worn) For distance: Right 20/ ______ Left 20/ ______

Evidence of disease or injury. Right ______ Left ______

Color Vision ______ Horizontal field of vision: Right ______ ° Left ______

Ears: Hearing, 20 ft. Right ear ______ /20 Left ear ______ /20 Disease or injury ______

Audiometric Test (complete only if audiometer is used to test hearing decibel loss at 500 Hz ______, at 1,000 Hz ______, at 2,000 Hz ______

Mouth ______ Throat ______

Thorax Heart ______

If organic disease is present, is it fully compensated? ______ Blood pressure (sitting): Systolic ______ Diastolic ______

Pulse: Before exercise ______ Two minute's rest after excercise ______ Lungs ______

Abdomen: Scars ______ Abnormal masses ______ Tenderness ______

Hernia. Yes ______ No ______ If so, where? ______ Is truss worn? ______

Gastrointestinal: Ulceration or other disease: Yes ______ No ______

Genito-Urinary: Scars ______ Urethral discharge ______ Prostatitis ______

Reflexes: Rhomberg ______

Pupillary ______ Light: R ______ L ______ Accommodation: R ______ L ______

Knee jerks: Right: Normal ______ Increased ______ Absent ______ Left: Normal ______ Increased ______ Absent ______

Remarks ______

Extremeties: Upper ______ Lower ______ Spine ______

Laboratory findings: Urine: Spec. Gr. ______ Alb. ______ Sugar ______

Blood serology ______ Chest X-ray ______

____

____

General Comments ______________

MEDICAL EXAMINER'S CERTIFICATE

I certify that I have examined ______ (Driver's name (Print)) in accordance with the Motor Carrier Safety Regulations (49 CFR 391.41–391.49) and with knowledge of his duties, I find him qualified under the regulations.

☐ Qualified only when wearing corrective spectacles.
☐ Qualified only when wearing hearing aid.

A completed examination form for this person is on file in my office at ______ (Address)

______ (Date of examination) ______ (Name of examining doctor (Print)) ______ (Signature of examining doctor)

______ (Signature of driver) ______ (Address of driver)

NOTE: This section to be completed only when visual test is conducted by a licensed optometrist. Date of examination ______

Appendix C
Tables 1-6
Individual Sample Results
Yellow Freight System, Inc.
St. Louis, Missouri

Table 1. Concentrations of Elemental Carbon
Yellow Freight System, Inc.
February 1989

Date	Sample Number	Job/Area	Time Start		Time Stop		Flow (L/min)	Weight (ug)	Time (min)	Volume (L)	Concentration (ug/m3)
2-14	YF.17	Dock	9	12	17	17	4.0	32.8	485	1955	16.8
2-14	YF.18	Dock	9	14	17	17	4.0	105.5	483	1946	54.2
2-14	YF.15	Dock	9	14	17	14	3.9	37.0	480	1872	19.8
2-14	YF.16	Dock	9	11	17	11	4.0	60.9	480	1939	31.4
2-15	YF.33	Dock	9	27	17	10	3.9	56.1	463	1815	30.9
2-15	YF.35	Dock	9	3	17	3	4.0	43.1	480	1896	22.7
2-15	YF.36	Dock	9	4	13	46	4.1	26.7	282	1145	23.3
2-15	YF.34	Dock	9	24	17	8	4.0	41.3	464	1875	22.0
2-16	YF.56	Dock	8	38	16	24	4.1	41.7	466	1897	22.0
2-16	YF.53	Dock	9	11	16	23	4.0	35.3	432	1724	20.5
2-16	YF.54	Dock	8	39	16	24	4.0	62.3	465	1855	33.6
2-16	YF.57	Dock	8	36	16	21	4.0	53.8	465	1874	28.7
2-14	YF.19	Dock Area	9	30	17	30	3.9	34.0	480	1886	18.0
2-15	YF.39	Dock Area	10	6	18	1	4.0	49.9	475	1905	26.2
2-16	YF.60	Dock Area	8	57	17	0	4.0	22.9	483	1937	11.8
2-14	YF.28	Highway	16	59	0	59	4.0	5.9	480	1920	3.0
2-15	YF.40	Highway	11	10	19	10	4.1	3.0	480	1963	1.6
2-16	YF.63	Highway	9	40	17	40	4.0	<2.0	480	1920	<1.0
2-14	YF.11	Local	8	46	16	46	4.0	5.0	480	1896	2.6
2-14	YF.12	Local	8	50	16	47	4.0	8.6	477	1903	4.5
2-14	YF.14	Local	8	50	16	50	4.1	6.2	480	1949	3.2
2-14	YF.13	Local	8	48	16	48	4.1	5.1	480	1954	2.6
2-15	YF.30	Local	8	47	16	47	4.1	6.3	480	1954	3.2
2-15	YF.31	Local	8	48	19	14	4.0	2.1	626	2523	0.8
2-15	YF.37	Local	8	49	16	49	4.0	6.5	480	1915	3.4
2-15	YF.32	Local	8	49	16	49	4.0	6.2	480	1934	3.2
2-16	YF.52	Local	8	31	16	31	3.9	6.1	480	1872	3.3
2-16	YF.55	Local	8	31	16	31	4.0	2.2	480	1939	1.1
2-16	YF.59	Local	8	28	16	28	4.0	3.6	480	1939	1.9
2-16	YF.58	Local	8	32	16	32	4.0	4.2	480	1896	2.2
2-14	YF.20	Local Cab	9	5	17	5	4.1	4.1	480	1958	2.1
2-15	YF.38	Local Cab	9	14	18	12	4.0	6.3	538	2147	2.9
2-16	YF.61	Local Cab	8	45	16	45	4.0	3.2	480	1934	1.7
2-13	YF.03	Mechanic	15	43	23	43	4.1	8.4	480	1958	4.3
2-13	YF.04	Mechanic	15	45	23	45	3.9	56.5	480	1848	30.6
2-13	YF.01	Mechanic	15	41	23	41	3.9	63.1	480	1853	34.0
2-13	YF.02	Mechanic	15	45	23	45	3.9	62.4	480	1872	33.3
2-14	YF.23	Mechanic	15	38	23	38	3.9	37.2	480	1872	19.9

Table 1. Concentrations of Elemental Carbon (Cont'd)
Yellow Freight System, Inc.
February 1989

Date	Sample Number	Job/Area	Time Start		Time Stop		Flow (L/min)	Weight (ug)	Time (min)	Volume (L)	Concentration (ug/m3)
2-14	YF.24	Mechanic	15	38	23	38	3.9	28.5	480	1853	15.4
2-15	YF.42	Mechanic	15	38	23	38	3.9	52.0	480	1853	28.1
2-15	YF.45	Mechanic	15	42	23	42	4.2	11.6	480	2002	5.8
2-15	YF.44	Mechanic	15	40	23	40	4.1	52.1	480	1954	26.7
2-15	YF.43	Mechanic	15	39	22	49	3.9	10.0	430	1677	5.9
2-14	YF.29	Residential	16	46	23	14	3.9	2.8	388	1529	1.8
2-15	YF.41	Residential	10	55	14	23	4.0	4.7	208	836	5.7
2-16	YF.62	Residential	9	30	17	30	3.9	<2.0	480	1891	<1.1
2-13	YF.07	Road	0	44	8	44	4.1	2.1	480	1949	1.1
2-13	YF.06	Road	19	45	3	41	4.0	3.7	476	1899	1.9
2-13	YF.08	Road	18	42	2	42	4.0	2.2	480	1915	1.2
2-13	YF.05	Road	16	56	0	6	4.0	3.0	430	1737	1.7
2-14	YF.27	Road	19	0	3	0	3.9	3.4	480	1848	1.9
2-14	YF.26	Road	19	1	3	1	3.9	1.8	480	1872	1.0
2-14	YF.25	Road	18	58	22	17	4.1	<2.0	199	812	<2.5
2-15	YF.47	Road	20	13	1	29	4.0	<2.0	316	1255	<1.6
2-15	YF.49	Road	20	15	4	15	3.9	<2.0	480	1872	<1.1
2-15	YF.50	Road	18	2	2	2	3.9	<2.0	480	1848	<1.1
2-13	YF.10	Road Cab	17	40	1	40	4.0	13.3	480	1906	7.0
2-15	YF.51	Road Cab	19	17	3	17	4.1	<2.0	480	1958	<1.0
2-13	YF.09	Shop Area	17	30	23	53	3.9	47.7	383	1494	32.0
2-15	YF.46	Shop Area	16	40	23	51	3.9	37.2	431	1694	21.9
2-14	YFT.3	Dock Area (total)	9	30	17	30	4.0	35.8	480	1920	18.6
2-15	YFT.08	Dock Area (total)	10	5	18	5	4.0	46.2	480	1920	24.1
2-16	YFT.11	Dock Area (total)	8	57	16	57	4.0	29.5	480	1920	15.4
2-14	YFT.4	Local Cab (total)	9	5	16	58	4.0	4.1	473	1906	2.1
2-15	YFT.07	Local Cab (total)	9	14	12	24	4.0	2.2	190	762	2.9
2-16	YFT.12	Local Cab (total)	8	45	16	45	4.0	<2.0	480	1925	<1.0
2-13	YFT.02	Road Cab (total)	17	40	1	40	4.1	14.1	480	1958	7.2
2-14	YFT.06	Road Cab (total)	19	29	3	29	4.0	3.4	480	1920	1.8
2-15	YFT.10	Road Cab (total)	19	17	3	17	4.1	2.3	480	1958	1.2
2-13	YFT.1	Shop Area (total)	17	31	23	53	4.0	45.7	382	1528	29.9
2-14	YFT.05	Shop Area (total)	18	26	23	51	4.0	37.6	325	1300	29.0
2-15	YFT.09	Shop Area (total)	16	40	23	51	4.0	61.5	431	1724	35.7

Table 2. Concentrations of Organic Carbon
Yellow Freight System, Inc.
February 1989

Date	Sample Number	Job/Area	Time Start		Time Stop		Flow (L/min)	Weight (ug)	Time (min)	Volume (L)	Concentration (ug/m3)
2-14	YF.17	Dock	9	12	17	17	4.0	423	485	1955	216
2-14	YF.18	Dock	9	14	17	17	4.0	211	483	1946	109
2-14	YF.15	Dock	9	14	17	14	3.9	47.5	480	1872	25.4
2-14	YF.16	Dock	9	11	17	11	4.0	39.1	480	1939	20.2
2-15	YF.33	Dock	9	27	17	10	3.9	87.4	463	1815	48.2
2-15	YF.35	Dock	9	3	17	3	4.0	44.8	480	1896	23.6
2-15	YF.36	Dock	9	4	13	46	4.1	39.9	282	1145	34.9
2-15	YF.34	Dock	9	24	17	8	4.0	35.4	464	1875	18.9
2-16	YF.56	Dock	8	38	16	24	4.1	77.6	466	1897	40.9
2-16	YF.53	Dock	9	11	16	23	4.0	101	432	1724	58.3
2-16	YF.54	Dock	8	39	16	24	4.0	40.6	465	1855	21.9
2-16	YF.57	Dock	8	36	16	21	4.0	45.0	465	1874	24.0
2-14	YF.19	Dock Area	9	30	17	30	3.9	25.6	480	1886	13.6
2-15	YF.39	Dock Area	10	6	18	1	4.0	20.6	475	1905	10.8
2-16	YF.60	Dock Area	8	57	17	0	4.0	13.3	483	1937	6.9
2-14	YF.28	Highway	16	59	0	59	4.0	9.7	480	1920	5.1
2-15	YF.40	Highway	11	10	19	10	4.1	2.5	480	1963	1.3
2-16	YF.63	Highway	9	40	17	40	4.0	<2.0	480	1920	<1.0
2-14	YF.11	Local	8	46	16	46	4.0	82.5	480	1896	43.5
2-14	YF.12	Local	8	50	16	47	4.0	181	477	1903	95.1
2-14	YF.14	Local	8	50	16	50	4.1	115	480	1949	59.1
2-14	YF.13	Local	8	48	16	48	4.1	81.4	480	1954	41.7
2-15	YF.30	Local	8	47	16	47	4.1	108	480	1954	55.3
2-15	YF.31	Local	8	48	19	14	4.0	10.4	626	2523	4.1
2-15	YF.37	Local	8	49	16	49	4.0	66.7	480	1915	34.8
2-15	YF.32	Local	8	49	16	49	4.0	37.3	480	1934	19.3
2-16	YF.52	Local	8	31	16	31	3.9	<2.0	480	1872	<1.1
2-16	YF.55	Local	8	31	16	31	4.0	54.9	480	1939	28.3
2-16	YF.59	Local	8	28	16	28	4.0	72.0	480	1939	37.1
2-16	YF.58	Local	8	32	16	32	4.0	199	480	1896	105
2-14	YF.20	Local Cab	9	5	17	5	4.1	52.2	480	1958	26.6
2-15	YF.38	Local Cab	9	14	18	12	4.0	202	538	2147	94.1
2-16	YF.61	Local Cab	8	45	16	45	4.0	66.3	480	1934	34.3
2-13	YF.03	Mechanic	15	43	23	43	4.1	56.4	480	1958	28.8

Table 2. Concentrations of Organic Carbon (Cont'd)
Yellow Freight System, Inc.
February 1989

	Sample		Time				Flow	Weight	Time	Volume	Concentration
Date	Number	Job/Area	Start		Stop		(L/min)	(ug)	(min)	(L)	(ug/m3)
2-13	YF.04	Mechanic	15	45	23	45	3.9	160	480	1848	86.5
2-13	YF.01	Mechanic	15	41	23	41	3.9	122	480	1853	66.1
2-13	YF.02	Mechanic	15	45	23	45	3.9	117	480	1872	62.3
2-14	YF.23	Mechanic	15	38	23	38	3.9	65.5	480	1872	35.0
2-14	YF.24	Mechanic	15	38	23	38	3.9	73.3	480	1853	39.6
2-15	YF.42	Mechanic	15	38	23	38	3.9	311	480	1853	168
2-15	YF.45	Mechanic	15	42	23	42	4.2	54.0	480	2002	27.0
2-15	YF.44	Mechanic	15	40	23	40	4.1	390	480	1954	200
2-15	YF.43	Mechanic	15	39	22	49	3.9	100	430	1677	59.7
2-14	YF.29	Residential	16	46	23	14	3.9	<2.0	388	1529	<1.3
2-16	YF.62	Residential	9	30	17	30	3.9	<2.0	480	1891	<1.1
2-13	YF.07	Road	0	44	8	44	4.1	43.2	480	1949	22.2
2-13	YF.06	Road	19	45	3	41	4.0	44.6	476	1899	23.5
2-13	YF.08	Road	18	42	2	42	4.0	39.0	480	1915	20.4
2-13	YF.05	Road	16	56	0	6	4.0	33.7	430	1737	19.4
2-14	YF.27	Road	19	0	3	0	3.9	87.0	480	1848	47.1
2-14	YF.26	Road	19	1	3	1	3.9	33.1	480	1872	17.7
2-14	YF.25	Road	18	58	22	17	4.1	<2.0	199	812	<2.5
2-15	YF.47	Road	20	13	1	29	4.0	25.7	316	1255	20.5
2-15	YF.49	Road	20	15	4	15	3.9	47.5	480	1872	25.4
2-15	YF.50	Road	18	2	2	2	3.9	22.8	480	1848	12.4
2-13	YF.10	Road Cab	17	40	1	40	4.0	47.3	480	1906	24.8
2-15	YF.51	Road Cab	19	17	3	17	4.1	39.2	480	1958	20.0
2-13	YF.09	Shop Area	17	30	23	53	3.9	96.3	383	1494	64.5
2-15	YF.46	Shop Area	16	40	23	51	3.9	72.9	431	1694	43.1
2-14	YFT.3	Dock Area (total)	9	30	17	30	4.0	55.6	480	1920	29.0
2-15	YFT.08	Dock Area (total)	10	5	18	5	4.0	45.5	480	1920	23.7
2-16	YFT.11	Dock Area (total)	8	57	16	57	4.0	33.8	480	1920	17.6
2-14	YFT.4	Local Cab (total)	9	5	16	58	4.0	61.3	473	1906	32.2
2-15	YFT.07	Local Cab (total)	9	14	12	24	4.0	329	190	762	432
2-16	YFT.12	Local Cab (total)	8	45	16	45	4.0	72.9	480	1925	37.9
2-13	YFT.02	Road Cab (total)	17	40	1	40	4.1	51.6	480	1958	26.4
2-14	YFT.06	Road Cab (total)	19	29	3	29	4.0	51.4	480	1920	26.8
2-15	YFT.10	Road Cab (total)	19	17	3	17	4.1	58.4	480	1958	29.8

Table 2. Concentrations of Organic Carbon (Cont'd)
Yellow Freight System, Inc.
February 1989

Date	Sample Number	Job/Area	Time Start		Time Stop		Flow (L/min)	Weight (ug)	Time (min)	Volume (L)	Concentration (ug/m3)
2-13	YFT.1	Shop Area (total)	17	31	23	53	4.0	106	382	1528	69.6
2-14	YFT.05	Shop Area (total)	18	26	23	51	4.0	74.2	325	1300	57.1
2-15	YFT.09	Shop Area (total)	16	40	23	51	4.0	134	431	1724	77.6

Table 3. Concentrations of Nitrogen Dioxide
Yellow Freight System, Inc.
February 1989

Date	Sample Number	Job/Area	Time Start		Time Stop		Mass (ug NO2)	Mass (nmoles)	Time (hr)	Concentration (ppm NO2)
2-14	YFNO2.15	Dock	9	14	17	15	0.18	3.91	8.0	0.04
2-14	YFNO2.16	Dock	9	11	17	15	0.23	5.00	8.1	0.09
2-14	YFNO2.17	Dock	9	12	17	17	0.16	3.48	8.1	0.01
2-14	YFNO2.18	Dock	9	14	17	18	0.25	5.43	8.1	0.12
2-14	YFNO2.12	Local	8	50	16	47	0.18	3.91	8.0	0.04
2-14	YFNO2.13	Local	8	48	17	45	0.18	3.91	9.0	0.03
2-14	YFNO2.14	Local	8	50	17	0	0.21	4.57	8.2	0.07
2-14	YFNO2.11	Local	8	46	16	45	0.17	3.70	8.0	0.02
2-15	YFNO2.24	Local	8	47	18	10	0.21	4.57	9.4	0.06
2-15	YFNO2.23	Local	8	48	19	16	0.19	4.13	10.5	0.04
2-15	YFNO2.26	Local	8	49	18	0	0.21	4.57	9.2	0.06
2-13	YFNO2.01	Mechanic	15	41	23	41	0.27	5.87	8.0	0.14
2-13	YFNO2.03	Mechanic	15	43	23	43	0.14	3.04	8.0	<0.02
2-13	YFNO2.04	Mechanic	15	45	23	45	0.28	6.09	8.0	0.15
2-13	YFNO2.02	Mechanic	15	45	23	45	0.26	5.65	8.0	0.13
2-14	YFNO2.20	Mechanic	15	38	23	38	0.28	6.09	8.0	0.15
2-14	YFNO2.19	Mechanic	15	38	23	38	0.24	5.22	8.0	0.11
2-15	YFNO2.28	Mechanic	15	38	23	38	0.3	6.52	8.0	0.18
2-15	YFNO2.30	Mechanic	15	42	23	42	0.69	15.00	8.0	0.64
2-15	YFNO2.29	Mechanic	15	40	23	40	0.28	6.09	8.0	0.15
2-15	YFNO2.27	Mechanic	15	39	23	51	0.17	3.70	8.2	0.02
2-13	YFNO2.06	Road	19	45	3	10	0.18	3.91	7.4	0.04
2-13	YFNO2.08	Road	18	42	2	42	0.16	3.48	8.0	0.01
2-13	YFNO2.07	Road	0	44	8	44	0.19	4.13	8.0	0.05
2-13	YFNO2.05	Road	16	56	0	56	0.14	3.04	8.0	<0.02
2-14	YFNO2.21	Road	18	58	2	58	0.18	3.91	8.0	0.04
2-14	YFNO2.25	Road	19	0	3	0	0.23	5.00	8.0	0.09
2-14	YFNO2.22	Road	19	1	3	1	0.4	8.70	8.0	0.30
2-15	YFNO2.33	Road	18	2	2	2	0.18	3.91	8.0	0.04
2-15	YFNO2.31	Road	20	15	4	15	0.16	3.48	8.0	0.01

Table 4. Concentrations of Nitric Oxide
Yellow Freight System, Inc.
February 1989

Date	Sample Number	Job/Area	Time Start		Time Stop		Weight (ug NOx	Conc NO2 (ppm)	Weight (nmoles)	Time (hr)	Conc. NO (ppm)
2-14	YFNO2.15	Dock	9	14	17	15	0.2	0.04	4.35	8.02	0.02
2-14	YFNO2.16	Dock	9	11	17	15	0.19	0.09	4.13	8.07	<0.02
2-14	YFNO2.17	Dock	9	12	17	17	0.21	0.01	4.57	8.08	0.04
2-14	YFNO2.18	Dock	9	14	17	18	0.32	0.12	6.96	8.07	0.06
2-14	YFNO2.12	Local	8	50	16	47	0.19	0.04	4.13	7.95	0.01
2-14	YFNO2.13	Local	8	48	17	45	0.24	0.03	5.22	8.95	0.05
2-14	YFNO2.14	Local	8	50	17	0	0.22	0.07	4.78	8.17	0.01
2-14	YFNO2.11	Local	8	46	16	45	0.21	0.02	4.57	7.98	0.04
2-15	YFNO2.24	Local	8	47	18	10	0.21	0.06	4.57	9.38	<0.02
2-15	YFNO2.23	Local	8	48	19	16	0.21	0.04	4.57	10.47	0.01
2-15	YFNO2.26	Local	8	49	18	0	0.25	0.06	5.43	9.18	0.03
2-13	YFNO2.01	Mechanic	15	41	23	41	0.37	0.14	8.04	8.00	0.09
2-13	YFNO2.03	Mechanic	15	43	23	43	0.24	0.01	5.22	8.00	0.07
2-13	YFNO2.04	Mechanic	15	45	23	45	0.29	0.15	6.30	8.00	0.01
2-13	YFNO2.02	Mechanic	15	45	23	45	0.28	0.13	6.09	8.00	0.02
2-14	YFNO2.20	Mechanic	15	38	23	38	0.26	0.15	5.65	8.00	<0.02
2-14	YFNO2.19	Mechanic	15	38	23	38	0.26	0.11	5.65	8.00	0.02
2-15	YFNO2.28	Mechanic	15	38	23	38	0.36	0.18	7.83	8.00	0.05
2-15	YFNO2.30	Mechanic	15	42	23	42	0.24	0.64	5.22	8.00	<0.02
2-15	YFNO2.29	Mechanic	15	40	23	40	0.43	0.15	9.35	8.00	0.14
2-15	YFNO2.27	Mechanic	15	39	23	51	0.17	0.02	3.70	8.20	<0.02
2-13	YFNO2.06	Road	19	45	3	10	0.16	0.04	3.48	7.42	<0.02
2-13	YFNO2.08	Road	18	42	2	42	0.16	0.01	3.48	8.00	<0.02
2-13	YFNO2.07	Road	0	44	8	44	0.22	0.05	4.78	8.00	0.03
2-13	YFNO2.05	Road	16	56	0	56	0.22	0.01	4.78	8.00	0.05
2-14	YFNO2.21	Road	18	58	2	58	0.16	0.04	3.48	8.00	<0.02
2-14	YFNO2.25	Road	19	0	3	0	0.19	0.09	4.13	8.00	<0.02
2-14	YFNO2.22	Road	19	1	3	1	0.17	0.30	3.70	8.00	<0.02
2-15	YFNO2.33	Road	18	2	2	2	0.17	0.04	3.70	8.00	<0.02
2-15	YFNO2.31	Road	20	15	4	15	0.2	0.01	4.35	8.00	0.04

Table 5. Concentrations of Respirable Dust
Yellow Freight System, Inc.
February 1989

Date	Sample Number	Job/Area	Time Start		Time Stop		Flow (L/min)	Weight (ug)	Time (min)	Volume (L)	Concentration (ug/m3)
2-14	FW4714	Local Cab	9	5	17	5	1.7	30	480	816.0	**44.9**
2-15	FW1713	Local Cab	9	16	17	16	1.7	160	480	835.2	**200**
2-16	FW1717	Local Cab	8	45	16	45	1.7	<10	480	835.2	**<12.0**
2-14	FW4712	Dock Area	9	30	17	30	1.7	40	480	835.2	**55.9**
2-15	FW1714	Dock Area	10	9	18	9	1.7	30	480	820.8	**44.7**
2-16	FW1325	Dock Area	8	51	16	51	1.8	<10	480	844.8	**<11.8**
2-13	FW1732	Road Cab	17	39	1	39	1.8	20	480	840.0	**31.7**
2-14	FW1333	Road Cab	19	29	3	29	1.8	<10	480	844.8	**<11.8**
2-15	FW1719	Road Cab	19	17	3	17	1.8	<10	480	840.0	**<11.9**
2-13	FW4705	Shop Area	17	34	23	59	1.8	30	385	677.6	**54.1**
2-14	FW1329	Shop Area	18	26	23	51	1.7	20	325	552.5	**48.3**
2-15	FW1715	Shop Area	16	40	23	51	1.7	30	431	732.7	**50.0**

Table 6. Concentrations of Polynuclear Aromatic Hydrocarbons Yellow Freight System, Inc. February 1989

Date	Sample Number	Job/Area	Time Start	Time Stop	Flow (L/min)	Weight (ug)	Time (min)	Volume (L)	Concentration (ug/m3)
Acenaphthene:									
2-14	YFP-1	Shop Area	18 26	23 51	2.1	<0.1	325	685.8	**<0.15**
2-15	YFP-3	Shop Area	16 40	23 51	2.1	0.2	431	909.4	**0.22**
2-16	YFP-5	Local Cab	8 45	16 45	2.0	0.1	480	974.4	**0.10**
2-14	YFP-2	Road Cab	19 29	3 29	2.1	0.2	480	1003.2	**0.20**
2-15	YFP-4	Road Cab	19 17	3 17	2.1	<0.1	480	1003.2	**<0.10**
Phenanthrene:									
2-14	YFP-1	Shop Area	18 26	23 51	2.1	0.06	325	685.8	**0.09**
2-15	YFP-3	Shop Area	16 40	23 51	2.1	1.2	431	909.4	**1.32**
2-16	YFP-5	Local Cab	8 45	16 45	2.0	0.1	480	974.4	**0.10**
2-14	YFP-2	Road Cab	19 29	3 29	2.1	1.1	480	1003.2	**1.10**
2-15	YFP-4	Road Cab	19 17	3 17	2.1	0.08	480	1003.2	**0.08**
Anthracene:									
2-14	YFP-1	Shop Area	18 26	23 51	2.1	<0.04	325	685.8	**<0.06**
2-15	YFP-3	Shop Area	16 40	23 51	2.1	0.06	431	909.4	**0.07**
2-16	YFP-5	Local Cab	8 45	16 45	2.0	<0.04	480	974.4	**<0.04**
2-14	YFP-2	Road Cab	19 29	3 29	2.1	0.09	480	1003.2	**0.09**
2-15	YFP-4	Road Cab	19 17	3 17	2.1	<0.04	480	1003.2	**<0.04**
Fluoranthene:									
2-14	YFP-1	Shop Area	18 26	23 51	2.1	<0.03	325	685.8	**<0.04**
2-15	YFP-3	Shop Area	16 40	23 51	2.1	0.26	431	909.4	**0.29**
2-16	YFP-5	Local Cab	8 45	16 45	2.0	0.03	480	974.4	**0.03**
2-14	YFP-2	Road Cab	19 29	3 29	2.1	0.24	480	1003.2	**0.24**
2-15	YFP-4	Road Cab	19 17	3 17	2.1	<0.03	480	1003.2	**<0.04**
Pyrene:									
2-14	YFP-1	Shop Area	18 26	23 51	2.1	<0.04	325	685.8	**<0.06**
2-15	YFP-3	Shop Area	16 40	23 51	2.1	0.17	431	909.4	**0.19**
2-16	YFP-5	Local Cab	8 45	16 45	2.0	<0.04	480	974.4	**<0.04**
2-14	YFP-2	Road Cab	19 29	3 29	2.1	0.1	480	1003.2	**0.10**
2-15	YFP-4	Road Cab	19 17	3 17	2.1	<0.04	480	1003.2	**<0.04**