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IN DEPTH SURVEY REPORT
OF
TRANSCON LINES INC.
Camp Hill, Pennsylvania

SURVEY CONDUCTED BY:
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NIOSH
Industrial Hygiene Section
Industrywide Studies Branch

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An in depth survey report was conducted at Transcon Lines, Inc. (SIC-4231), Camp Hill, Pennsylvania to determine relative exposures to diesel aerosol among the four major presumably exposed job groups of road drivers, local drivers, dock workers, and mechanics. Elemental carbon (7440440) sampling results at the Transcon Lines terminal during mild weather indicated low level exposures below geometric mean ambient highway concentrations in mechanics and local drivers, exposures slightly above highway concentrations in road drivers and switchers, and exposures significantly above highway concentrations in dock workers. Geometric mean exposures to submicrometer elemental carbon in all jobs were significantly elevated above the geometric mean ambient concentration measured in a residential area in Harrisburg. Relative job rankings suggested by personal exposures to elemental carbon, oxides of nitrogen and respirable dust were similar: lowest for mechanics, highest for dock workers, and intermediate for local and road drivers. Area concentrations of other airborne diesel exhaust components measured were very low or not detected and far below any established limits.

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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:	September 19-23, 1988
PLANT CONTACTS:	John Wiley, Terminal Manager Thomas H. Flannery, Supt. Maintenance Lane Flick, Supv. Terminal Operations
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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 Transcon Lines terminal in Camp Hill Pennsylvania during mild weather indicate low-level exposures below geometric mean ambient highway concentrations (5.6 ug/m^3) in mechanics (3.7 ug/m^3) and local drivers (4.9 ug/m^3), exposures slightly above highway concentrations in road drivers (7.6 ug/m^3) and switchers (9.8 ug/m^3), and exposures significantly above highway concentrations in dock workers (22 ug/m^3). Geometric mean exposures to submicrometer elemental carbon in all jobs were significantly elevated above the geometric mean ambient concentration (0.78 ug/m^3) measured in a residential area in Harrisburg. Relative job rankings suggested by personal exposures to elemental carbon, nitric oxide, and respirable dust were similar - lowest for mechanics, highest for dock workers, and intermediate for local and road drivers. Area concentrations of other airborne diesel exhaust components measured (nitrogen dioxide, respirable particulate, PAHs and nitro-substituted PAHs) were very low or not detected, and in the cases of NO, NO_2, and respirable particulate, were far below OSHA PELs or NIOSH RELs for these contaminants.

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 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 Transcon Lines terminal in Camp Hill, Pennsylvania during the period September 19-23, 1988. During the survey, 66 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 26 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, sixteen specific 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 preliminary conclusions and recommendations.

TRUCK TERMINAL DESCRIPTION

The corporate offices of Transcon Incorporated, the parent company of Transcon Lines, are located in Oklahoma City. The company was formed in 1981. Transcon Lines, a large motor freight common carrier, is a wholly owned subsidiary of Transcon Inc., and began operations in 1946 as a general commodities carrier. Transcon Lines currently has over 200 truck terminals and relay stations located in the United States and Canada. In 1986, the company had approximately 4,000 employees (Transcon Incorporated Annual Report 1986).

Transcon Lines' Camp Hill terminal is a medium sized terminal consisting of line-haul (long distance) freight transport, local area (city) freight transport, dock, and tractor/trailer repair shop operations, and employs over 250 people. The site currently includes the terminal offices and a truck driver dispatching area (both located at one end of the dock), an 88-door dock, a wash rack, and a tractor/trailer maintenance facility. The facility, opened in 1973, is situated on a 16 acre site on St. John's Road in Camp Hill (near Harrisburg). The original 44 open doors on the dock were expanded to 88 open doors in 1984. The truck yard surrounding the dock and offices is paved with asphalt.

Dock Operations

The Camp Hill dock is typical of break bulk truck docks. The floor of the dock 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 dock floor space is approximately 140,000 square feet. The floor of the dock is essentially an 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.

The dock building itself consists of a prefabricated steel structure with 88 open doors along both sides and one end (offices are located at 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 most 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. The dock currently operates twenty-four hours per day on three shifts.

The terminal currently owns 17 tow-motor trucks. However, only five or six of these are operated on a given shift. Fifteen of the tow-motors are diesel-engine powered, and 2 are gasoline-engine powered vehicles. Currently, almost all tow-motors owned nationwide are diesel powered.

Repair Shop Operations (Camp Hill Terminal)

The repair shop floor area totals approximately 13,000 square feet, and is in a separate building from the main terminal. The repair shop at this site is located on the first floor of a two-story building, and consists of a tractor/trailer repair shop, a lunchroom, a parts room, a superintendent's office, and two service/safety lanes (one inbound and one outbound). Each of the service lanes and repair bays is approximately 90 feet long and about 18-20 feet wide, with large overhead bay doors (16' x 18') at each end. The road truck (line-haul) dispatch area, a shower facility, and a lunchroom are located on the second floor of this building above the shop.

Minor and medium level repairs are done in the repair shop while routine safety checks and services are done in the service lanes. All arriving trucks are routed through the service lane. These trucks are driven into the inbound service/safety check bay, parked, and the engine turned off. The mechanics in charge of these lanes run through a checklist of service/safety items (oil, brakes, grease, tires, lights, wipers, etc.) to determine the operating condition of the vehicle. If the engine must remain running while in the service bay area, and bay doors are closed, an overhead general exhaust system, consisting of six ceiling exhaust fans, is turned on. There are no local exhaust ducts in place which can be connected to the trucks' exhaust stacks.

The repair shop does most tuneups, and mechanical, brake, tire, wheel, engine, transmission, and electrical repairs, but does not do major jobs such as major engine overhauls or transmission overhauls. During the survey, the large bay doors on all service bays were kept open at both ends due to the warm (greater than 65-70 degree daytime highs) ambient temperatures. During cold weather, however, the bay doors are closed and the overhead exhaust systems are frequently turned off, according to company personnel. Other than the overhead exhaust systems in the tractor shop and service lanes, no mechanically assisted ventilation systems were in place in the shop area.

The brakes on all local and road tractors are replaced once each year. Non-asbestos composition brake linings have been exclusively used since 1985. According to company personnel, mechanics at this facility have never used compressed air to remove brake dust during brake repairs. Since the late 1970s, all drum cleaning has been done by washing with a petroleum distillate solvent and rags.

Truck Fleet Description

At the Camp Hill terminal, 65 road tractors are available in the tractor pool, with approximately 50-90 arrivals/departures each day. These include tractors manufactured by International (60%), and Freightliner (40%) companies. A few Mack Co. tractors are still in use company wide (about 100 company wide) but are being phased out. Almost 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. Only a small number (2 at this terminal) of cab-over tractors are used by Transcon Lines. All of the road tractors are currently fitted with air conditioning.

All road tractors used by Transcon Lines are configured with vertical (stack) exhaust systems located on the right hand side (opposite the driver) of the tractor. Almost all of the road tractors are currently powered by one of two Cummins Co. diesel engines, including BigCam III and BigCam IV engines, both 855 in^3. The BigCam IVs are increasing in use since they have more horsepower and have better fuel economy. According to the Transcon Lines 1986 annual report, the average age of the road tractor fleet is approximately 3.2 years. Company personnel indicated that the tractors currently used are typically 1985 to 1988 models. The date of conversion of the road tractor fleet from gasoline engines to diesel was not precisely known, but was estimated to be more than 25 years ago, and was probably complete by approximately 1960.

City tractors (International, GMC, and Freightliner) do not (and have never) had air conditioning installed. Approximately 80% of these tractors are fitted with vertical exhaust systems and about 20% are fitted with horizontal (undercarriage) exhaust systems. Until about 12 years ago (ca 1976) city tractors were gasoline-engine powered. Conversion of the city fleet to diesel engines was complete in the late 1970s.

The tractor fleet runs on Gulf, Mobil, or Exxon No. 2 diesel fuel. Most of the refueling is done at the terminal and is bought in bulk for this purpose. Most of the tractors (road and city) have been equipped with over-cab air deflectors.

WORKFORCE DESCRIPTION

Approximately 259 persons were, as of the date of the survey, employed at the terminal. These included about 85 dockmen/yard jockeys, 101 road (line) drivers, and 9 local (city) drivers. The terminal also employed 8 office employees, 1 person in sales, and 28 management personnel. The repair shop employed 17 mechanics and 1 superintendent. With the exception of the clerks and secretaries, and two "casual" (part-time) line drivers, all were male.

The dock and repair shop operate on three eight-hour shifts, 24 hours per day. Line drivers originating at the Camp Hill terminal are "on-call", but most start their shift in the late afternoon or early evening. The terminal has no "sleeper" runs (in which the driver returns the next day), but is a single relay, line haul operation, 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 4:00 p.m.).

MEDICAL, SAFETY, AND INDUSTRIAL HYGIENE PROGRAMS

Safety and Hygiene Programs

The company has no formal in-house industrial hygiene program, but Transcon Lines has a well developed safety program, with a safety supervisor located in Oklahoma City, as well as a safety committee which meets at least once per month located at the Camp Hill terminal. The committee is composed of six employees from all areas at the terminal. The program includes extensive new employee and periodic training programs in safety and hazardous materials, and a corporate quality improvement incentive awards program.

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 a clinic approximately one-half mile away. A pre-employment physical is required for all new employees, but no periodic physicals are provided, except for road drivers.

For road drivers only, 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 specific gravity, albumin, and sugar. The examination also includes an EKG and a chest X- ray. Appendix A 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. However, NIOSH, in its Current Intelligence Bulletin No. 50, has indicated that "As prudent public health policy, employers should reduce exposure (to whole diesel exhaust) to the lowest feasible limits" (1).

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 mechanics and road drivers during the second shift, and an equivalent number of personal samples were obtained from dock workers (including yard jockeys, or "switchers" who drove the trailer switching vehicles in the yard), and local drivers during the day shift. The sampling was conducted for three days (six shifts) during September 19-23, 1988.

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) fourteen specific PAHs (refer to Table II), 1-nitropyrene, and 2-nitrofluorene, and 3) submicrometer elemental and organic carbon. Two samples of each of the three types were obtained on each shift, one in each of the two areas sampled; i.e., on the dock and in city tractor cabs during the day shift, and in the repair shop and 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 (>1 um aerodynamic diameter) when operating the sampler at 4 Lpm instead of 2 Lpm.

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.

Area 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 are collected on the PTFE membrane filters, and volatile/semivolatile PAHs are 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 reference. Figures 3 and 4 are similar charts illustrating exposures to nitric oxide (NO), 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 statistical summaries of NO_2 and NO concentrations by job or area. Table VII is a statistical summary of respirable dust concentrations in four areas. Tables 1- 5 in appendix B contain the individual personal, eight-hour, time weighted average exposures to elemental and organic carbon, NO_2, NO, and respirable dust. No tables of PAH or nitro-PAH concentrations are included in this report because the results were all below the limit of quantitation. 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 3.7 ug/m^3 in mechanics (labelled "Mech" in Figure 1) to 22.5 ug/m^3 in Dock Workers (Dock). The other job means were (from low to high - refer to Figure 1): local drivers (Local: 4.9 ug/m^3), road drivers (Road: 7.6 ug/m^3), and switchers (Swit: 9.8 ug/m^3). Area concentrations in four areas averaged 2.7 ug/m^3 in the repair shop (Shop), 2.9 ug/m^3 in local tractor cabs (LCab), 7.9 ug/m^3 in road cabs (Rcab), and 17 ug/m^3 on the dock (DArea).

By contrast, concentrations of Ce measured on the Carlisle Pike in Harrisburg, a heavily travelled (by both cars and trucks) four-lane road located within the city, averaged 5.6 ug/m^3 (range: 3.8 to 8.7 ug/m^3 in three samples), and in a residential area (at least one mile from the nearest highway or freeway) averaged 0.78 ug/m^3 (range: 0.52 to 2.9 ug/m^3 in three samples).

Inspection of Figure 1 indicates that mean exposures to elemental carbon in two jobs, mechanics and local drivers, were slightly below highway background concentrations, and in road drivers, switchers, and dock workers, were slightly above highway concentrations. However, the 95% upper confidence limit (UCL) of the highway concentrations (Table III) was higher than the 95% lower confidence limit (LCL) of all of the other job means except dock workers, suggesting that only dock workers' true job means were significantly higher than local highway concentrations of submicrometer elemental carbon. However, it may be that the sample sizes within individual jobs (N ranging from 3 to 12) were too small to detect a true significant difference. Also, multiple comparisons errors make these comparisons 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.

Four of the job means appear to be significantly greater than background residential concentrations, as indicated by non-overlapping 95% lower confidence intervals. These jobs are mechanics, local drivers, road drivers, and dock workers. Only switchers' exposures appear not to be higher, but again, the small sample size (only 2 samples were obtained in this job) precludes a firm conclusion.

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 12.6 ug/m^3 in switchers to a high of 23 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 8 ug/m^3 in local cabs to 12.9 ug/m^3 in road tractor cabs.

Highway area concentrations of submicrometer organic carbon averaged 2.4 ug/m^3, and residential area concentrations averaged 1.1 ug/m^3. The 95% LCL of personal samples from all five jobs overlapped the 95% UCL for the highway samples (59.5 ug/m^3), suggesting that their exposures to submicrometer organic carbon were not significantly greater than background highway concentrations of organic carbon. However, the very high variation in concentrations from samples obtained on the highway (reflected in a very high geometric standard deviation for these samples of 3.65) suggests that the lack of significance is due more to wide confidence limits (a function of the small sample size) than to the lack of a real difference.

The relative rankings of jobs suggested by comparison of mean concentrations of elemental carbon and organic carbon in personal samples are not the same. The most obvious explanation for this is that, in some jobs, notably mechanics, the presence of non-diesel aerosol may have been contributing to the level of total carbon (Ce and Co) exposure. This may have included tobacco (cigarette, pipe, and cigar) smoke as well as other airborne contaminants such as paint aerosol and vapors, grease, fuel vapors, and degreasing solvents used in the repair shop, as well as industrial emissions.

Oxides of Nitrogen

Nitrogen dioxide (NO_2) concentrations determined in personal samples from 5 jobs (Figure 3 and Table V) ranged from not detected (<0.04 ppm) to 0.1 ppm. No descriptive statistics were calculated for this contaminant since the great majority of individual sample results were below the limit of detection. All of the detectable 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 3 and Table VI; NO_2 and NO samples were obtained as duplicate samples on the same workers) ranged from 0.04 ppm in mechanics to 0.16 ppm in dock workers. These exposures are again far below applicable OSHA PELs or NIOSH RELs (Table I).

Polynuclear Aromatic Hydrocarbons

Concentrations of fourteen PAHs, 1-nitropyrene, and 2-nitrofluorene were all below the limits of quantitation for these compounds (Table II). Traces of acenaphthene and phenanthrene were found on the backup sorbent tubes, but detectable quantities of other PAHs and the two N-PAHs were not found. Similarly, detectable amounts of the sixteen PAH compounds were not found on the filters. All of these samples were taken side-by- side (as replicates) with the respirable dust samples shown in Table VII.

Respirable Dust

Figure 4 and Table VII summarize concentrations of respirable dust obtained in specific areas of the repair shop, dock, and in local and road truck tractors. Respirable dust concentrations in the repair shop averaged 29.3 ug/m^3, 51.9 ug/m^3 in local cabs, 59.4 ug/m^3 in road cabs, and 66 ug/m^3 in the dock area.

CONCLUSIONS

1. Based on measurements of personal, breathing zone concentrations of elemental carbon at this terminal, it appears that only dock workers' exposures to diesel aerosol were elevated significantly above background highway concentrations found in the Harrisburg area. The high exposures of dock workers (relative to other jobs) were very likely due to the use of diesel-powered tow-motors on the dock, since switchers' (operating switching vehicles in the yard) mean exposures to elemental carbon were much lower than those of dock workers. However, this conclusion is not a rigorous one, since the small sample sizes generated necessarily wide confidence limits. 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 highway concentrations of submicrometer elemental carbon were, in this survey, approximately seven times the geometric mean residential concentrations (5.6 ug/m^3 vs. 0.78 ug/m^3). 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 not substantially higher than elemental carbon concentrations in most jobs and areas sampled at this terminal, with the notable exception of the mechanics, possibly indicating the presence of some non-diesel air contaminants, including paint, degreasing solvent vapors, or tobacco smoke, in the samples. In general, the relative ranking of the five jobs evaluated, based on organic carbon sampling results, did not completely correspond with the ranking suggested by the elemental carbon results. Again, however, the small overall sample sizes would preclude firm conclusions until additional data is collected and analyzed.

4. The relative rankings of jobs suggested by personal exposures to submicrometer elemental carbon and nitric oxide, and area concentrations of respirable dust, were not conspicuously different. Mean exposures to all three contaminants suggested that the lowest exposures were in mechanics, the highest were in dock workers, and that local and road drivers' exposures were intermediate.

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. 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 mild conditions (approximately 70 degrees F. daytime highs), and represent tractors with mostly vertical (stack) exhaust systems, and mostly conventional (not cab-over) tractor designs.

RECOMMENDATIONS

In general, exposures to submicrometer elemental carbon were relatively low during the survey. The data indicate that overall exposures to whole diesel exhaust in most jobs (during the warm weather prevalent at the time of the survey) were only slightly above local ambient highway concentrations. The lone exception, dock workers, experienced exposures substantially higher, by a factor of approximately four, due mainly to the operation of diesel powered tow-motors on the dock. In view of the potential carcinogenicity of whole diesel exhaust to humans as documented by NIOSH in its 1988 Current Intelligence Bulletin, the following 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 or propane powered vehicles for diesel powered vehicles.

REFERENCES

1. Current Intelligence Bulletin No. 50. Carcinogenic Effects of Exposure to Diesel Exhaust. National Institute for Occupational Safety and Health, Cincinnati, OH, July 1988.

2. McClellan, R.O., D.E. Bice, R.G. Cuddihy, N.A. Gillett, R.F. Henderson, R.K. Jones, J.L. Mauderly, J.A. Pickrell, S.G. Shami, and R.K. Wolff. Health Effects of Diesel Exhaust. To be published in the Proceedings of the U.S. - Dutch International Symposium on Aerosols held in Williamsburg, VA, May 19-24, 1985.

3. Pierson, W.R., R.A. Gorse Jr., A.C. Szkariat, W.W. Brachaczek, S.M. Japar, and F.S.-C. Lee. Mutagenicity and Chemical Characteristics of Carbonaceous Particulate Matter from Vehicles on the Road. Environmental Science and Technology 17:31, 1983.

4. Wolff, R.K., R.F. Henderson, M.B. Snipes, J.D. Sun, J.A. Bond, C.E. Mitchell, L.L. Mauderly and R.O. McClellan. Lung Retention of Diesel Soot and Associated Organic Compounds. To be published in Carcinogenicity and Mutagenicity Effects of Diesel Engine Exhaust, Proceedings of the Symposium on Toxicological Effects of Emissions from Diesel Engines held in Tsukuba City, Japan, July 26-28, 1986.

5. Mauderly, J.L., R.K. Jones, W.C. Griffith, R.F. Henderson, R.O. McClellan. Diesel Exhaust is a Pulmonary Carcinogen in Rats Exposed Chronically by Inhalation. Fund. Appl. Toxicol. 9:208-221.

6. Heinrich, U., H. Muhle, S. Takenaka, H. Ernst, R. Fuhst, U. Mohr, F. Pott, W. Stober. Chronic Effects on the Respiratory Tract of Hamsters, Mice, and Rats after Long-term Inhalation of high concentrations of filtered and unfiltered diesel engine emissions. J. Appl. Toxicol. 6(6):383-395, 1986.

7. Brightwell, J., X. Fouillet, A-L Cassano-Zopi, R. Gatz, F. Duchosal. Neoplastic and Functional Changes in Rodents After Chronic Inhalation of Engine Exhaust Emissions. In: Ishinishi, N., A. Koizumi, R.O. McClellan, W. Stober eds. Carcinogenic and Mutagenic Effects of Diesel Engine Exhaust. Proceedings of the Symposium on Toxicological Effects of Emissions from Diesel Engines, Tsukuba City, Japan, July 26-28, 1986. New York, NY: Elsevier Science Publishers, pp. 471-487, 1986.

8. Ishinishi, N., Duwabara, N., Nagase, S., Suzuki, T., Ishiwata, S., Kohno, T. Long-term Inhalation studies on Effects of Exhaust from Heavy and Light Duty Diesel Engines on F344 Rats. In: Ishinishi, N., A. Koizumi, R.O. McClellan, W. Stober eds. Carcinogenic and Mutagenic Effects of Diesel Engine Exhaust. Proceedings of the Symposium on Toxicological Effects of Emissions from Diesel Engines, Tsukuba City, Japan, July 26-28, 1986. New York, NY: Elsevier Science Publishers, pp. 329-348, 1986.

9. Iwai, K., Udagawa, T., Yamagishi, M., Yamada, H. Long-term Inhalation Studies of Diesel Exhaust on F344 SPF rats. Incidence of Lung Cancer and Lymphoma. In: Ishinishi, N., A. Koizumi, R.O. McClellan, W. Stober eds. Carcinogenic and Mutagenic Effects of Diesel Engine Exhaust. Proceedings of the Symposium on Toxicological Effects of Emissions from Diesel Engines, Tsukuba City, Japan, July 26-28, 1986. New York, NY: Elsevier Science Publishers, pp. 349-360, 1986.

10. Edling, C., C-G Anjou, O. Axelson, H. Kling. Mortality Among Personnel Exposed to Diesel Exhaust. Int. Arch Occup. Environ. Health 59:559-565, 1987.

11. Garshick, E., M.B. Schenker, A. Munoz, M. Segal, T.J. Smith, S.R. Woskie, S.K. Hammond, F.E. Speizer. A Case-control Study of Lung Cancer and Diesel Exhaust Exposure in Railroad Workers. Am. Rev. Respir. Dis. 135(6):1242-1248, 1987.

12. Garshick, E., M.B. Schenker, A. Munoz, M. Segal, T.J. Smith, S.R. Woskie, S.K. Hammond, F.E. Speizer. A Retrospective Cohort Study of Lung Cancer and Diesel Exhaust Exposure in Railroad Workers. Am. Rev. Respir. Dis. 137:820-825, 1988.

13. Hammond, S.K., B.P. Leaderer, A.C. Roche, and M. Schenker. Collection and Analysis of Nicotine as a Marker for Environmental Tobacco Smoke. Atmos. Env. 21:457-462, 1987.

14. Woskie, S.R., T.J. Smith, S.K. Hammond, M.B. Schenker, E. Garshick, and F.E. Speizer. Estimation of the Diesel Exhaust Exposures of Railroad Workers: I. Current Exposures. Am. J. Ind. Med. 13:381-394, 1988.

15. McClellan, R.O. Health Effects of Diesel Exhaust: A Case Study in Risk Assessment. Am. Ind. Hyg. Assoc. J. 47(1):1-13, 1986.

16. Schuetzle, D. Sampling of Vehicle Emissions for Chemical Analysis and Biological Testing. Env. Health Perspectives 47:65-80, 1983.

17. McCawley, M., J. Cocalis, J. Burkhart, and G. Piacitelli. Identification and Measurement of Diesel Particulates. Interim Final Report, Contract No. J0145006. Prepared for the U.S. Dept. of Interior, Bureau of Mines. Division of Respiratory Disease Studies, Environmental Investigations Branch, NIOSH, 1988.

18. McCawley M., J. Cocalis. Diesel Particulate Measurement Techniques for Use With Ventilation Control Strategies in Underground Coal Mines. In: Wheeler, R.W., ed. International Conference on the Health of Miners. Annals of the American Conference of Governmental Industrial Hygienists 14:271-281, 1986.

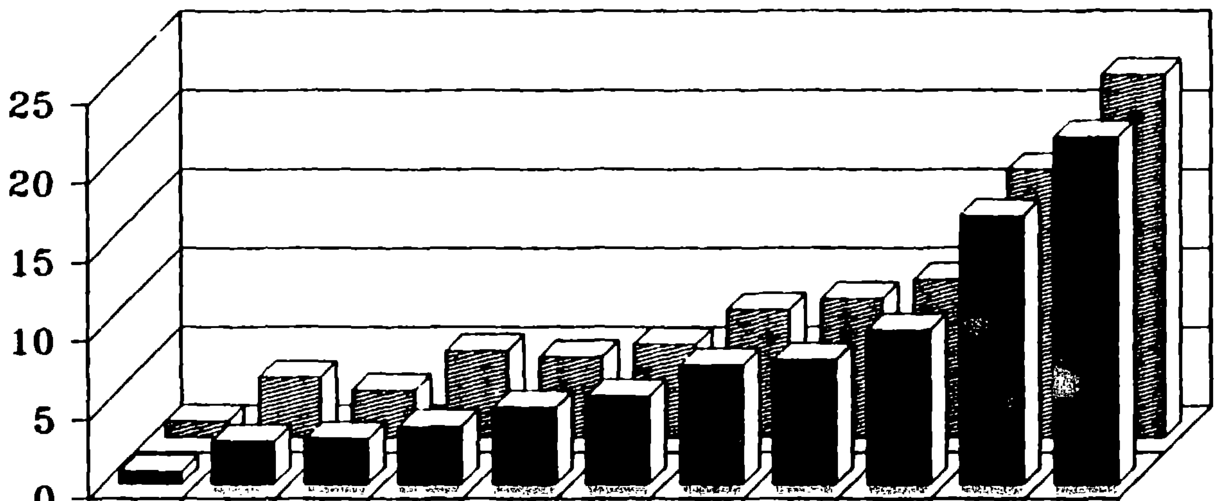
19. Cadle, S.H., P.J. Groblicki, and D.P. Stroup. Automated Carbon Analyzer for Particulate Samples. Analytical Chemistry 52:2201-2206, 1980.

20. Johnson, R.I., J.S. Jitendra, R.A. Cary, and J.J. Huntzicker. An Automated Thermal-Optical Method for the Analysis of Carbonaceous Aerosol. In: ACS Symposium Series, No. 167, Atmospheric Aerosol: Source/Air Quality Relationships, E.S. Macias and P.K. Hopke, Eds., American Chemical Society, 1981.

21. NIOSH Manual of Analytical Methods, Third Ed., Vols. 1-3. DHHS (NIOSH) Publication No. 84-100. National Institute for Occupational Safety and Health, Cincinnati, OH. 45226, 1984.

22. Threshold Limit Values and Biological Exposure Indices for 1988-1989. American Conference of Governmental Industrial Hygienists, 6500 Glenway Ave., Bldg. D7, Cincinnati, OH. 45211-4438, 1987.

Figure 1. Elemental Carbon Exposure
Transcon Freight Company

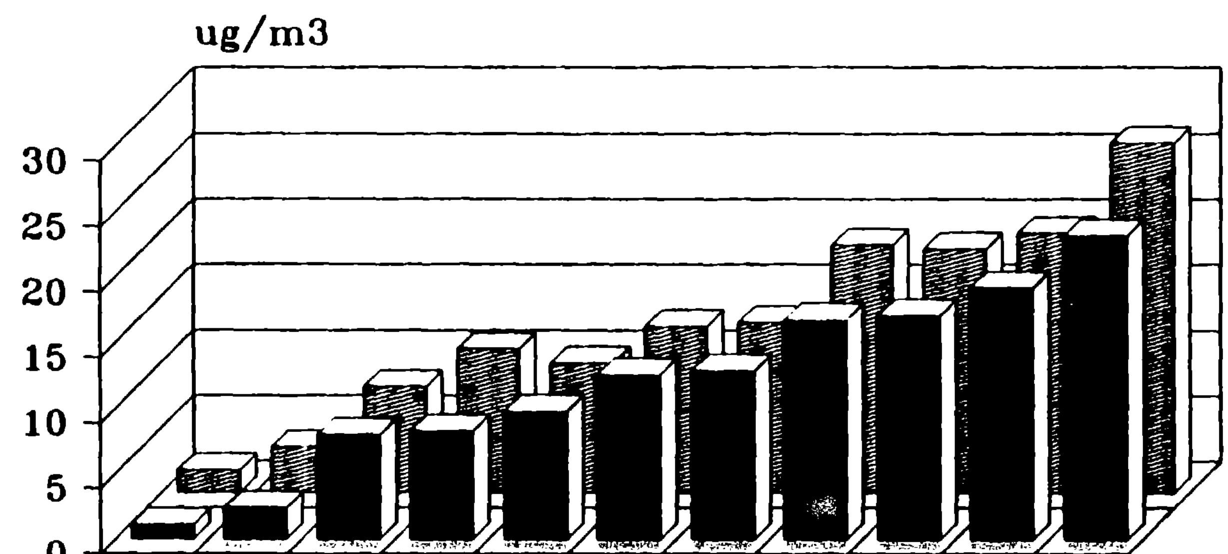


	Resid	Shop	LCab	Mech	Local	Hwy	Road	RCab	Swit	DArea	Dock
Arithmetic Mean	1	3.8	3	5.5	5.1	5.9	8.1	8.8	10	17	23
Geometric Mean	0.8	2.7	2.9	3.7	4.9	5.6	7.6	7.9	9.8	17	22

Job/Area

September 1988

Figure 2. Organic Carbon Exposure
Transcon Freight Company



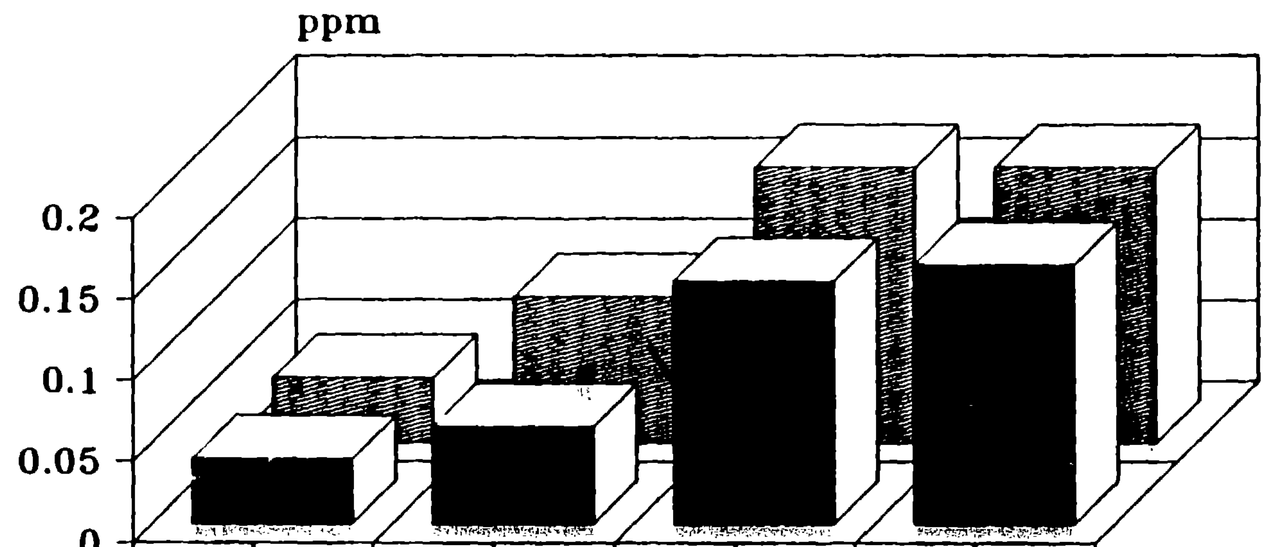
	Resid	Hwy	LCab	Shop	DArea	Swit	RCab	Road	Local	Dock	Mech
Arithmetic Mean	1.7	3.5	8.1	11	9.9	12.7	13	18.9	18.6	19.8	26.7
Geometric Mean	1.1	2.4	8	8.3	9.8	12.6	12.9	16.8	17.1	19.2	23.2

Job/Area

Geometric Mean   Arithmetic Mean

September 1988

Figure 3. Nitric Oxide Exposures
Transcon Freight Company



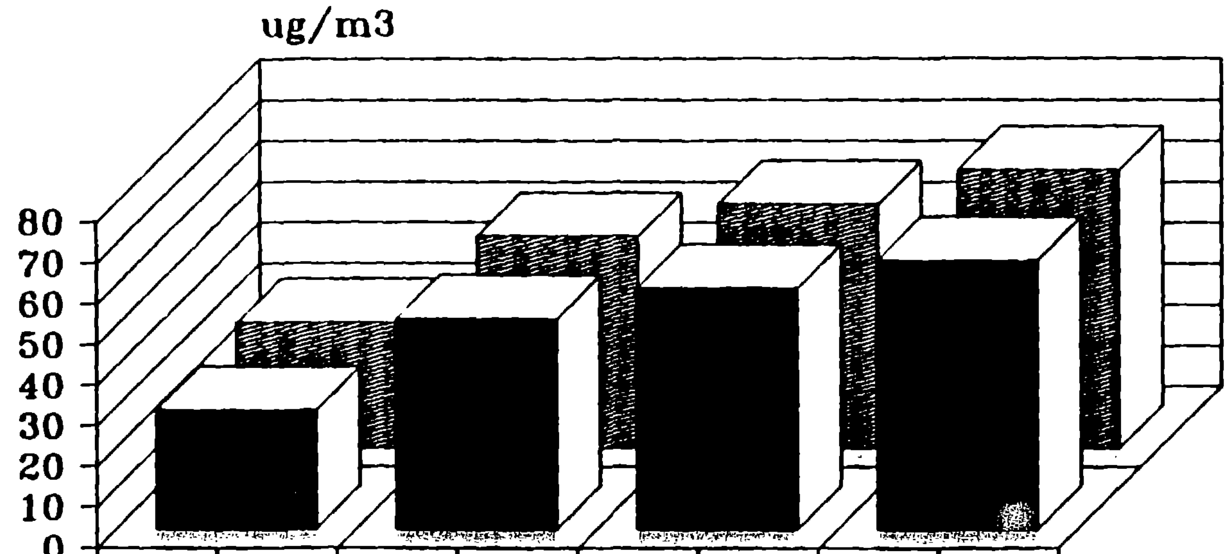
	Mech	Road	Local	Dock
Arithmetic Mean	0.04	0.09	0.17	0.17
Geometric Mean	0.04	0.06	0.15	0.16

Job/Area

■ Geometric Mean ▨ Arithmetic Mean

September 1988

Figure 4. Respirable Dust Exposure
Transcon Freight Company



	Shop Area	Local Cab	Road Cab	Dock Area
Arithmetic Mean	30.9	52	59.8	68.2
Geometric Mean	29.3	51.9	59.4	66.1

Job/Area

Geometric Mean   Arithmetic Mean

September 1988

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*: Underground coal mines	MSHA PELs*: Metal and nonmetal mines	NIOSH REL
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 and
Nitro-substituted PAHs Determined in Four Areas
Transcon Lines; September 1988

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 Summary Statistics
By Job or Specific Location
Transcon Freight Company
(ug/m3)

Job or Area	N	Min	Max	Arithmetic Mean	Arithmetic S.E.	Geometric Mean	Geometric Std. Dev.	95% Confidence Limit Lower	95% Confidence Limit Upper
Residential	5	0.52	2.87	1.03	0.46	**0.78**	2.10	0.31	1.95
Shop Area	4	0.52	6.08	3.75	1.23	**2.70**	3.08	0.45	16.2
Local Cab	2	2.56	3.51	3.04	0.47	**3.00**	1.25	0.41	21.9
Mechanic	15	0.79	31.0	5.51	1.87	**3.68**	2.34	2.30	5.90
Local	8	3.11	7.24	5.06	0.51	**4.88**	1.33	3.84	6.20
Highway	3	3.80	8.67	5.92	1.44	**5.59**	1.51	1.99	15.7
Road	12	4.12	14.9	8.13	0.90	**7.61**	1.47	5.96	9.72
Road Cab	3	5.46	15.0	8.79	3.11	**7.85**	1.75	1.94	31.7
Switch	2	7.00	13.7	10.3	3.34	**9.78**	1.61	0.14	693
Dock Area	3	11.7	22.8	17.4	3.22	**16.8**	1.40	7.22	38.9
Dock	9	15.7	31.2	22.9	1.50	**22.5**	1.22	19.2	26.3
Elemental Carbon in Total Airborne Particulate:									
Local Cab (Total)	1	1.79	1.79	1.79	--	**1.79**	--	--	--
Shop Area (Total)	3	3.58	4.96	4.20	0.40	**4.17**	1.18	2.77	6.26
Road Cab (Total)	3	5.80	20.6	12.6	4.33	**11.1**	1.89	2.28	53.7
Dock Area (Total)	3	14.3	23.9	19.6	2.84	**19.2**	1.31	9.89	37.2

Table IV. Organic Carbon Summary Statistics
By Job or Specific Location
Transcon Freight Company
(ug/m3)

Job or Area	N	Min	Max	Arithmetic Mean	S.E.	Geometric Mean	Std. Dev.	95% Confidence Limit Lower	Upper
Residential	5	0.52	4.41	1.69	0.76	**1.14**	2.66	0.34	3.82
Highway	3	0.53	5.10	3.53	1.50	**2.38**	3.65	0.10	59.5
Local Cab	2	6.91	9.34	8.13	1.21	**8.03**	1.24	1.19	54.4
Shop Area	4	4.95	28.5	11.3	5.77	**8.27**	2.30	2.20	31.1
Dock Area	3	9.03	10.8	9.86	0.53	**9.83**	1.10	7.82	12.3
Switch	2	11.3	14.2	12.7	1.43	**12.6**	1.17	3.01	53.1
Road Cab	3	10.8	14.9	13.0	1.21	**12.9**	1.18	8.54	19.4
Road	12	9.58	44.3	18.9	3.09	**16.8**	1.62	12.4	22.8
Local	8	10.3	41.9	18.6	3.48	**17.1**	1.52	12.0	24.2
Dock	9	11.5	26.9	19.8	1.66	**19.2**	1.31	15.6	23.6
Mechanic	15	11.0	67.2	26.7	4.36	**23.2**	1.68	17.4	31.0
Organic Carbon in Total Airborne Particulate:									
Shop Area (Total)	3	12.7	15.7	14.4	0.88	**14.3**	1.11	10.9	18.73
Road Cab (Total)	3	15.1	31.6	23.2	4.75	**22.2**	1.45	8.88	55.35
Dock Area (Total)	3	31.8	38.3	35.2	1.89	**35.1**	1.10	27.8	44.25
Local Cab (Total)	1	35.3	35.3	35.3	--	**35.3**	--	--	--

Table V. Nitrogen Dioxide Summary Statistics
By Job or Specific Location
Transcon Freight Company
(ppm)

Job or Area	N	Min	Max	Arithmetic Mean	Arithmetic S.E.	Geometric Mean	Geometric Std. Dev.	95% Confidence Limit Lower	95% Confidence Limit Upper
Dock	5	<0.04	0.08	--	--	—	--	--	--
Local	6	<0.03	0.10	--	--	—	--	--	--
Mechanic	7	<0.04	0.09	--	--	—	--	--	--
Road	8	<0.03	0.07	--	--	—	--	--	--

Table VI. Nitric Oxide Summary Statistics
By Job or Specific Location
Transcon Freight Company
(ppm)

Job or Area	N	Min	Max	Arithmetic Mean	Arithmetic S.E.	Geometric Mean	Geometric Std. Dev.	95% Confidence Limit Lower	95% Confidence Limit Upper
Mechanic	7	0.02	0.06	0.04	0.005	**0.04**	1.38	0.03	0.05
Road	8	0.00	0.14	0.09	0.02	**0.06**	3.77	0.02	0.18
Local	6	0.08	0.36	0.17	0.05	**0.15**	1.83	0.08	0.28
Dock	5	0.11	0.22	0.17	0.02	**0.16**	1.32	0.12	0.23

Table VII. Respirable Dust Summary Statistics
By Job or Specific Location
Transcon Freight Company
(ug/m3)

Job or Area	N	Min	Max	Arithmetic Mean	S.E.	Geometric Mean	Std. Dev.	95% Confidence Limit Lower	Upper
Shop Area	3	19.0	43.3	30.9	7.04	**29.3**	1.51	10.5	82.0
Local Cab	2	48.9	55.1	52.0	3.11	**51.9**	1.09	24.3	111
Road Cab	3	53.9	70.4	59.8	5.30	**59.4**	1.16	41.1	85.7
Dock Area	3	46.8	86.1	68.1	11.5	**66.1**	1.37	30.4	144

Appendix A
Medical Exam Form
Transcon Lines
Camp Hill, PA

REV. 5/73

transcon LINES PHYSICAL EXAMINATION FORM

LAST NAME (PRINT)	FIRST	MIDDLE	SOCIAL SECURITY NUMBER	☐ NEW CERTIFICATION ☐ RECERTIFICATION

ADDRESS NUMBER	STREET	CITY	STATE–ZIP CODE	AGE	BIRTHDATE (MO.,DAY,YR.)

HEALTH HISTORY

TERMINAL	JOB TITLE

YES NO

- ☐ ☐ Head or spinal injuries
- ☐ ☐ Seizures, fits, convulsions, or fainting
- ☐ ☐ Extensive confinement by illness or injury
- ☐ ☐ Cardiovascular disease
- ☐ ☐ Tuberculosis
- ☐ ☐ Syphilis
- ☐ ☐ Gonorrhea
- ☐ ☐ Diabetes
- ☐ ☐ Gastrointestinal ulcer
- ☐ ☐ Nervous Stomach
- ☐ ☐ Rheumatic Fever
- ☐ ☐ Asthma
- ☐ ☐ Kidney disease
- ☐ ☐ Muscular disease
- ☐ ☐ Suffering from any other disease or injury
- ☐ ☐ Permanent defect from illness, disease or injury
- ☐ ☐ Psychiatric disorder
- ☐ ☐ Any other nervous disorder
- ☐ ☐ Any surgery

If answer to any of the above is yes, explain: ______

PHYSICAL EXAMINATION

GENERAL APPEARANCE AND DEVELOPMENT ☐ GOOD ☐ FAIR ☐ POOR

HEIGHT | COLOR HAIR | WEIGHT | COLOR EYES

ABDOMEN SCARS

VISION FOR DISTANCE — RIGHT EYE 20/ LEFT EYE 20/

☐ WITHOUT CORRECTIVE LENSES
☐ WITH CORRECTIVE LENSES – IF WORN
☐ WITH CONTACT LENSES

ABNORMAL MASSES | TENDERNESS

EVIDENCE OF DISEASE OF INJURY — RIGHT EYE LEFT EYE

HORIZONTAL FIELD OF VISION — RIGHT EYE ° LEFT EYE °

HERNIA ☐ YES ☐ NO IF SO, WHERE? IS TRUSS WORN ☐ YES ☐ NO

COLOR VISION TEST

HEARING 20 FT — RIGHT EAR /20 LEFT EAR /20

GENITO-URINARY SCARS | URETHRAL DISCHARGE

EAR DISEASE OR INJURY

Gastrointestinal: Ulceration or other disease Yes ______ No ______

REFLEXES ROMBERG PUPILLARY

Audiometric test. (If audiometer is used to test hearing)

______ Decibel loss at 500 Hz ______ at 1,000 Hz ______ at 2,000 Hz

LIGHT — RIGHT LEFT | ACCOMMODATION — RIGHT LEFT

MOUTH

KNEE JERKS NOTE ABNORMAL ENDINGS UNDER COMMENTS
RIGHT — NORMAL | INCREASED | ABSENT

THROAT

LEFT — NORMAL | INCREASED | ABSENT

THORAX HEART

EXTREMITIES

SPINE ______

IF ORGANIC DISEASE IS PRESENT, IS IT FULLY COMPENSATED?

UPPER LOWER

BLOOD PRESSURE (SITTING) — SYSTOLIC | DIASTOLIC

LABORATORY FINDINGS URINE — SPEC. GR. | ALB. | SUGAR

PULSE — BEFORE EXERCISE | IMMEDIATELY AFTER EXERCISE

OTHER LABORATORY DATA — BLOOD SEROLOGY | ELECTROCARDIOGRAPH

LUNGS

RADIOLOGICAL DATA

GENERAL COMMENTS

PHYSICIAN'S CERTIFICATE

THIS IS TO CERTIFY THAT I HAVE THIS DAY EXAMINED THE ABOVE NAMED DRIVER IN ACCORDANCE WITH: THE MOTOR CARRIER SAFETY REGULATIONS (49 CFR 391.41 - 391.49) AND WITH KNOWLEDGE OF HIS DUTIES, I FIND HIM:

☐ QUALIFIED & PHYSICALLY FIT ☐ QUALIFIED & PHYSICALLY FIT ONLY WHEN WEARING CORRECTIVE LENSES ☐ QUALIFIED & PHYSICALLY FIT ONLY WHEN WEARING HEARING AID ☐ PHYSICALLY UNFIT (DISQUALIFYING CONDITION HAS BEEN DISCUSSED WITH APPLICANT)

TO PERFORM THE USUAL DUTIES INCIDENT TO EMPLOYMENT AS A DRIVER OF COMMERCIAL VEHICLES.

NOTE: This section to be completed ONLY when visual test is conducted by a licensed Optometrist.

Date ______ Address of Optometrist ______

Name of Optometrist (Print) ______

Signature of Optometrist ______

I have kept on file, in my office a complete examination form for this person.

Date ______ Address of Examining Physician ______

Name of Examining Physician (Print) ______

Signature of Examining Physician ______

Signature of Driver ______

TO SAFETY & COMPLIANCE - OKC

Appendix B
Tables 1-5
Individual Sample Results
Transcon Lines
Camp Hill, PA

Table 1. Concentrations of Elemental Carbon
Transcon Freight Lines
September 1988

Date	Sample Number	Job/Area	Time Start		Time Stop		Flow (L/min)	Weight (ug)	Time (min)	Volume (L)	Concentration (ug/m3)
9-20	TCC.12	Dock	7	24	14	50	3.9	42.2	446	1739	**24.3**
9-20	TCC.14	Dock	7	10	14	50	4.0	41.8	460	1840	**22.7**
9-20	TCC.15	Dock	7	8	14	54	3.9	56.5	466	1813	**31.2**
9-21	TCC.43	Dock	7	7	14	59	4.0	41.4	472	1888	**21.9**
9-21	TCC.45	Dock	7	9	14	52	3.8	38.2	463	1755	**21.8**
9-21	TCC.38	Dock	7	6	15	3	3.9	32.9	477	1856	**17.7**
9-22	TCC.61	Dock	7	20	14	4	4.0	41.4	404	1616	**25.6**
9-22	TCC.63	Dock	7	20	14	17	3.9	25.5	417	1622	**15.7**
9-22	TCC.62	Dock	7	20	14	5	3.9	39.6	405	1584	**25.0**
9-20	TCC.17	Dock Area	7	35	13	35	3.9	16.5	360	1415	**11.7**
9-21	TCC.44	Dock Area	7	25	15	7	4.0	32.6	462	1834	**17.8**
9-22	TCC.65	Dock Area	7	43	14	11	4.0	35.4	388	1552	**22.8**
9-21	TCT.07	Dock Area (Total)*	7	24	15	12	4.2	40.8	468	1970	**20.7**
9-22	TCT.11	Dock Area (Total)*	7	43	14	11	4.2	39.1	388	1633	**23.9**
9-20	TCT.03	Dock Area (Total)*	7	35	14	52	4.3	26.7	437	1875	**14.3**
9-19	TCC.13	Highway	17	2	1	2	4.2	7.6	480	1997	**3.8**
9-20	TCC.25	Highway	9	2	16	42	4.0	15.9	460	1840	**8.7**
9-20	TCC.39	Highway	18	0	1	31	4.2	10.0	451	1876	**5.3**
9-20	TCC.21	Local	9	0	17	0	3.9	7.8	480	1882	**4.1**
9-20	TCC.18	Local	7	50	15	50	4.0	13.9	480	1915	**7.2**
9-20	TCC.20	Local	7	43	17	5	4.0	10.8	562	2265	**4.8**
9-20	TCC.19	Local	7	45	17	45	4.0	7.4	600	2382	**3.1**
9-21	TCC.37	Local	8	53	16	53	3.9	9.5	480	1872	**5.1**
9-21	TCC.42	Local	12	58	20	58	3.9	10.2	480	1882	**5.4**
9-21	TCC.36	Local	9	5	17	5	4.0	7.3	480	1920	**3.8**
9-21	TCC.41	Local	8	14	16	14	4.0	13.3	480	1934	**6.9**
9-20	TCC.22	Local Cab	8	11	16	11	4.0	4.9	480	1920	**2.6**
9-21	TCC.35	Local Cab	9	17	17	17	3.9	6.6	480	1877	**3.5**
9-21	TCT.08	Local Cab (Total)*	9	17	18	14	4.3	4.1	537	2304	**1.8**
9-19	TCC.01	Mechanic	15	38	23	22	4.0	10.3	464	1837	**5.6**
9-19	TCC.04	Mechanic	15	42	23	23	3.9	8.6	461	1803	**4.8**
9-19	TCC.02	Mechanic	15	40	23	26	4.1	12.0	466	1887	**6.3**
9-19	TCC.03	Mechanic	15	41	23	26	3.9	4.3	465	1818	**2.4**
9-20	TCC.24	Mechanic	15	23	23	15	3.9	7.0	472	1846	**3.8**
9-20	TCC.27	Mechanic	15	28	23	21	4.2	2.6	473	1963	**1.3**

Table 1 (Continued)

Date	Sample Number	Job/Area	Time Start		Time Stop		Flow (L/min)	Weight (ug)	Time (min)	Volume (L)	Concentration (ug/m3)
9-20	TCC.26	Mechanic	15	25	23	20	3.9	2.8	475	1857	**1.5**
9-20	TCC.28	Mechanic	15	55	22	44	4.1	52.4	409	1693	**31.0**
9-21	TCC.54	Mechanic	15	31	23	15	3.9	9.3	464	1800	**5.2**
9-21	TCC.58	Mechanic	15	30	20	43	4.0	<2.0	313	1265	**<1.6**
9-21	TCC.56	Mechanic	15	28	23	11	4.0	10.0	463	1857	**5.4**
9-22	TCC.64	Mechanic	7	2	13	21	4.0	3.4	379	1516	**2.2**
9-22	TCC.67	Mechanic	7	16	14	27	3.9	5.4	431	1681	**3.2**
9-22	TCC.68	Mechanic	7	4	14	21	4.0	6.9	437	1735	**4.0**
9-22	TCC.66	Mechanic	7	10	14	27	3.8	8.6	437	1656	**5.2**
9-19	TCC.11	Residential	16	50	0	50	4.0	<2.0	480	1920	**<1.0**
9-20	TCC.40	Residential	17	50	1	50	4.0	<2.0	480	1920	**<1.0**
9-20	TCC.23	Residential	9	5	17	5	4.0	5.6	480	1934	**2.9**
9-21	TCC.47	Residential	8	40	16	40	4.0	<2.0	480	1930	**<1.0**
9-22	TCC.72	Residential	7	48	13	35	4.2	<2.0	347	1444	**<1.4**
9-19	TCC.08	Road	17	19	3	19	4.1	25.0	600	2484	**10.1**
9-19	TCC.09	Road	18	55	4	55	4.0	15.4	600	2424	**6.4**
9-19	TCC.07	Road	17	13	3	13	3.9	27.6	600	2364	**11.7**
9-19	TCC.06	Road	18	45	4	45	4.0	35.9	600	2406	**14.9**
9-20	TCC.33	Road	18	38	23	59	4.0	9.7	321	1297	**7.5**
9-20	TCC.31	Road	17	52	23	7	3.9	12.1	315	1238	**9.8**
9-20	TCC.32	Road	21	32	2	25	3.9	8.2	293	1137	**7.2**
9-20	TCC.30	Road	18	2	4	2	4.0	20.4	600	2400	**8.5**
9-21	TCC.50	Road	17	24	3	24	4.2	10.3	600	2490	**4.1**
9-21	TCC.51	Road	17	53	3	53	3.9	9.7	600	2346	**4.1**
9-21	TCC.52	Road	17	57	3	57	3.9	14.3	600	2346	**6.1**
9-21	TCC.53	Road	17	59	3	59	3.9	17.0	600	2358	**7.2**
9-19	TCC.10	Road Cab	17	22	23	37	3.9	22.0	375	1466	**15.0**
9-20	TCC.34	Road Cab	18	8	5	46	4.0	16.5	698	2792	**5.9**
9-21	TCC.49	Road Cab	16	55	2	55	4.0	13.0	600	2376	**5.5**
9-19	TCT.01	Road Cab (Total)*	17	22	23	34	3.1	23.7	372	1146	**20.6**
9-20	TCT.06	Road Cab (Total)*	18	8	3	15	3.2	19.6	547	1729	**11.4**
9-21	TCT.09	Road Cab (Total)*	16	55	2	55	4.1	14.4	600	2484	**5.8**
9-19	TCC.05	Shop Area	15	45	23	30	4.2	10.0	465	1930	**5.2**
9-20	TCC.29	Shop Area	15	20	23	22	4.0	<2.0	482	1909	**<1.0**
9-21	TCC.57	Shop Area	15	34	23	11	4.0	5.9	457	1828	**3.2**
9-21	TCC.55	Shop Area	15	15	23	10	3.9	11.4	475	1867	**6.1**

Table 1 (Continued)

Date	Sample Number	Job/Area	Time Start		Time Stop		Flow (L/min)	Weight (ug)	Time (min)	Volume (L)	Concentration (ug/m3)
9-19	TCT.02	Shop Area (Total)*	15	45	23	30	3.1	7.1	465	1432	5.0
9-20	TCT.05	Shop Area (Total)*	15	20	23	22	4.6	7.9	482	2217	3.6
9-21	TCT.10	Shop Area (Total)*	15	15	23	10	4.6	8.9	475	2185	4.1
9-21	TCC.46	Switch	7	10	14	29	3.3	19.9	439	1457	13.7
9-22	TCC.48	Switch	6	53	14	17	3.3	10.3	444	1474	7.0

* Elemental carbon content in total airborne particulate

Table 2. Concentrations of Organic Carbon
Transcon Freight Company
September 1988

Date	Sample Number	Job/Area	Time Start		Time Stop		Flow (L/min)	Weight (ug)	Time (min)	Volume (L)	Concentration (ug/m3)
9-20	TCC.12	Dock	7	24	14	50	3.9	28.7	446	1739	**16.5**
9-20	TCC.14	Dock	7	10	14	50	4.0	21.1	460	1840	**11.5**
9-20	TCC.15	Dock	7	8	14	54	3.9	44.4	466	1813	**24.5**
9-21	TCC.43	Dock	7	7	14	59	4.0	50.8	472	1888	**26.9**
9-21	TCC.45	Dock	7	9	14	52	3.8	29.9	463	1755	**17.0**
9-21	TCC.38	Dock	7	6	15	3	3.9	39.2	477	1856	**21.2**
9-22	TCC.61	Dock	7	20	14	4	4.0	39.5	404	1616	**24.5**
9-22	TCC.63	Dock	7	20	14	17	3.9	26.1	417	1622	**16.1**
9-22	TCC.62	Dock	7	20	14	5	3.9	32.0	405	1584	**20.2**
9-20	TCC.17	Dock Area	7	35	13	35	3.9	15.3	360	1415	**10.8**
9-21	TCC.44	Dock Area	7	25	15	7	4.0	16.6	462	1834	**9.0**
9-22	TCC.65	Dock Area	7	43	14	11	4.0	15.1	388	1552	**9.7**
9-21	TCT.07	Dock Area (Total)*	7	24	15	12	4.2	69.6	468	1970	**35.3**
9-22	TCT.11	Dock Area (Total)*	7	43	14	11	4.2	62.6	388	1633	**38.3**
9-20	TCT.03	Dock Area (Total)*	7	35	14	52	4.3	59.6	437	1875	**31.8**
9-19	TCC.13	Highway	17	2	1	2	4.2	10.2	480	1997	**5.1**
9-20	TCC.25	Highway	9	2	16	42	4.0	9.1	460	1840	**5.0**
9-20	TCC.39	Highway	18	0	1	31	4.2	<2.0	451	1876	**<1.1**
9-20	TCC.21	Local	9	0	17	0	3.9	34.3	480	1882	**18.3**
9-20	TCC.18	Local	7	50	15	50	4.0	24.5	480	1915	**12.8**
9-20	TCC.20	Local	7	43	17	5	4.0	40.1	562	2265	**17.7**
9-20	TCC.19	Local	7	45	17	45	4.0	99.7	600	2382	**41.9**
9-21	TCC.37	Local	8	53	16	53	3.9	32.7	480	1872	**17.5**
9-21	TCC.42	Local	12	58	20	58	3.9	33.5	480	1882	**17.8**
9-21	TCC.36	Local	9	5	17	5	4.0	19.7	480	1920	**10.3**
9-21	TCC.41	Local	8	14	16	14	4.0	25.2	480	1934	**13.0**
9-20	TCC.22	Local Cab	8	11	16	11	4.0	17.9	480	1920	**9.3**
9-21	TCC.35	Local Cab	9	17	17	17	3.9	13.0	480	1877	**6.9**
9-21	TCT.08	Local Cab (Total)*	9	17	18	14	4.3	81.2	537	2304	**35.3**
9-19	TCC.01	Mechanic	15	38	23	22	4.0	45.3	464	1837	**24.7**
9-19	TCC.04	Mechanic	15	42	23	23	3.9	27.3	461	1803	**15.1**
9-19	TCC.02	Mechanic	15	40	23	26	4.1	20.8	466	1887	**11.0**
9-19	TCC.03	Mechanic	15	41	23	26	3.9	26.4	465	1818	**14.5**
9-20	TCC.24	Mechanic	15	23	23	15	3.9	43.7	472	1846	**23.7**
9-20	TCC.27	Mechanic	15	28	23	21	4.2	24.2	473	1963	**12.3**

Table 2 (Continued)

Date	Sample Number	Job/Area	Time Start		Time Stop		Flow (L/min)	Weight (ug)	Time (min)	Volume (L)	Concentration (ug/m3)
9-20	TCC.26	Mechanic	15	25	23	20	3.9	119.3	475	1857	**64.2**
9-20	TCC.28	Mechanic	15	55	22	44	4.1	33.0	409	1693	**19.5**
9-21	TCC.54	Mechanic	15	31	23	15	3.9	121.0	464	1800	**67.2**
9-21	TCC.58	Mechanic	15	30	20	43	4.0	29.3	313	1265	**23.1**
9-21	TCC.56	Mechanic	15	28	23	11	4.0	36.3	463	1857	**19.6**
9-22	TCC.64	Mechanic	7	2	13	21	4.0	44.6	379	1516	**29.4**
9-22	TCC.67	Mechanic	7	16	14	27	3.9	52.1	431	1681	**31.0**
9-22	TCC.68	Mechanic	7	4	14	21	4.0	45.3	437	1735	**26.1**
9-22	TCC.66	Mechanic	7	10	14	27	3.8	32.4	437	1656	**19.6**
9-19	TCC.11	Residential	16	50	0	50	4.0	4.4	480	1920	**2.3**
9-20	TCC.40	Residential	17	50	1	50	4.0	<2.0	480	1920	**<1.0**
9-20	TCC.23	Residential	9	5	17	5	4.0	<2.0	480	1934	**<1.0**
9-21	TCC.47	Residential	8	40	16	40	4.0	8.5	480	1930	**4.4**
9-22	TCC.72	Residential	7	48	13	35	4.2	<2.0	347	1444	**<1.4**
9-19	TCC.08	Road	17	19	3	19	4.1	23.8	600	2484	**9.6**
9-19	TCC.09	Road	18	55	4	55	4.0	83.0	600	2424	**34.3**
9-19	TCC.07	Road	17	13	3	13	3.9	42.8	600	2364	**18.1**
9-19	TCC.06	Road	18	45	4	45	4.0	60.5	600	2406	**25.1**
9-20	TCC.33	Road	18	38	23	59	4.0	18.6	321	1297	**14.4**
9-20	TCC.31	Road	17	52	23	7	3.9	14.0	315	1238	**11.3**
9-20	TCC.32	Road	21	32	2	25	3.9	50.4	293	1137	**44.3**
9-20	TCC.30	Road	18	2	4	2	4.0	28.6	600	2400	**11.9**
9-21	TCC.50	Road	17	24	3	24	4.2	35.9	600	2490	**14.4**
9-21	TCC.51	Road	17	53	3	53	3.9	46.7	600	2346	**19.9**
9-21	TCC.52	Road	17	57	3	57	3.9	28.3	600	2346	**12.1**
9-21	TCC.53	Road	17	59	3	59	3.9	27.2	600	2358	**11.5**
9-19	TCC.10	Road Cab	17	22	23	37	3.9	19.4	375	1466	**13.2**
9-20	TCC.34	Road Cab	18	8	5	46	4.0	30.1	698	2792	**10.8**
9-21	TCC.49	Road Cab	16	55	2	55	4.0	35.5	600	2376	**14.9**
9-19	TCT.01	Road Cab (Total)*	17	22	23	34	3.1	36.2	372	1146	**31.6**
9-20	TCT.06	Road Cab (Total)*	18	8	3	15	3.2	26.2	547	1729	**15.1**
9-21	TCT.09	Road Cab (Total)*	16	55	2	55	4.1	56.7	600	2484	**22.8**
9-19	TCC.05	Shop Area	15	45	23	30	4.2	9.5	465	1930	**4.9**
9-20	TCC.29	Shop Area	15	20	23	22	4.0	12.1	482	1909	**6.3**
9-21	TCC.57	Shop Area	15	34	23	11	4.0	52.2	457	1828	**28.5**
9-21	TCC.55	Shop Area	15	15	23	10	3.9	9.8	475	1867	**5.2**

Table 2 (Continued)

Date	Sample Number	Job/Area	Time Start		Time Stop		Flow (L/min)	Weight (ug)	Time (min)	Volume (L)	Concentration (ug/m3)
9-19	TCT.02	Shop Area (Total)*	15	45	23	30	3.1	21.1	465	1432	**14.8**
9-20	TCT.05	Shop Area (Total)*	15	20	23	22	4.6	28.1	482	2217	**12.7**
9-21	TCT.10	Shop Area (Total)*	15	15	23	10	4.6	34.2	475	2185	**15.7**
9-21	TCC.46	Switch	7	10	14	29	3.3	16.5	439	1457	**11.3**
9-22	TCC.48	Switch	6	53	14	17	3.3	20.9	444	1474	**14.2**

* Organic carbon content of total airborne particulate

Table 3. Concentrations of Nitrogen Dioxide
Transcon Freight Company
September 1988

Date	Sample Number	Job/Area	Time Start		Time Stop		Weight (ug NO2	Weight (nmoles)	Time (hr)	Concentration (ppm NO2)
9-20	TC2-9	Dock	7	8	14	52	<0.03	<0.65	7.73	**<0.04**
9-20	TC2-7	Dock	7	24	14	50	<0.03	<0.65	7.43	**<0.04**
9-21	TC2-21	Dock	7	9	14	54	<0.03	<0.65	7.75	**<0.04**
9-21	TC2-19	Dock	7	6	15	3	<0.03	<0.65	7.95	**<0.04**
9-21	TC2-20	Dock	7	7	15	2	0.07	1.52	7.92	**0.08**
9-20	TC2-10	Local	7	50	19	5	<0.03	<0.65	11.25	**<0.03**
9-20	TC2-12	Local	7	43	17	20	<0.03	<0.65	9.62	**<0.03**
9-20	TC2-11	Local	7	45	18	15	<0.03	<0.65	10.50	**<0.03**
9-21	TC2-23	Local	12	58	21	40	<0.03	<0.65	8.70	**<0.03**
9-21	Tc2-22	Local	9	5	18	18	0.03	0.65	9.22	**0.03**
9-21	TC2-24	Local	8	52	18	41	0.1	2.17	9.82	**0.10**
9-19	TC2-2	Mechanic	15	40	23	26	0.07	1.52	7.77	**0.09**
9-19	TC2-1	Mechanic	15	38	23	22	0.05	1.09	7.73	**0.06**
9-19	TC2-3	Mechanic	15	41	23	26	<0.03	<0.65	7.75	**<0.04**
9-20	TC2-15	Mechanic	15	28	23	21	<0.03	<0.65	7.88	**<0.04**
9-20	TC2-14	Mechanic	15	25	23	20	<0.03	<0.65	7.92	**<0.04**
9-20	TC2-13	Mechanic	15	23	23	20	<0.03	<0.65	7.95	**<0.04**
9-21	TC2-27	Mechanic	15	25	23	11	<0.03	<0.65	7.77	**<0.04**
9-19	TC2-4	Road	17	13	3	0	<0.03	<0.65	9.78	**<0.04**
9-19	TC2-6	Road	18	55	3	45	0.07	1.52	8.83	**0.07**
9-19	TC2-5	Road	18	45	1	36	<0.03	<0.65	6.85	**<0.04**
9-20	TC2-17	Road	18	2	3	15	0.04	0.87	9.22	**0.04**
9-20	TC2-16	Road	21	23	8	30	<0.03	<0.65	11.12	**<0.03**
9-20	TC2-18	Road	17	52	5	15	<0.03	<0.65	11.38	**<0.02**
9-21	TC2-25	Road	17	53	8	0	0.05	1.09	14.12	**0.03**
9-21	TC2-26	Road	17	57	3	30	<0.03	<0.65	9.55	**<0.03**

Table 4. Concentrations of Nitric Oxide
Transcon Freight Company
September 1988

Date	Sample Number	Job/Area	Time Start		Time Stop		Mass (ug NOx)	Mass (nmoles)	Time (hr)	Concentration (ppm NO)
9-20	TC2-9	Dock	7	8	14	52	0.25	5.43	7.73	**0.22**
9-20	TC2-7	Dock	7	24	14	50	0.15	3.26	7.43	**0.13**
9-21	TC2-21	Dock	7	9	14	54	0.21	4.57	7.75	**0.18**
9-21	TC2-19	Dock	7	6	15	3	0.14	3.04	7.95	**0.11**
9-21	TC2-20	Dock	7	7	15	2	0.28	6.09	7.92	**0.19**
9-20	TC2-10	Local	7	50	19	5	0.17	3.70	11.25	**0.10**
9-20	TC2-12	Local	7	43	17	20	0.19	4.13	9.62	**0.13**
9-20	TC2-11	Local	7	45	18	15	0.41	8.91	10.50	**0.27**
9-21	TC2-23	Local	12	58	21	40	0.14	3.04	8.70	**0.10**
9-21	TC2-22	Local	9	5	18	18	0.13	2.83	9.22	**0.08**
9-21	TC2-24	Local	8	52	18	41	0.58	12.61	9.82	**0.36**
9-19	TC2-2	Mechanic	15	40	23	26	0.13	2.83	7.77	**0.06**
9-19	TC2-1	Mechanic	15	38	23	22	0.08	1.74	7.73	**0.03**
9-19	TC2-3	Mechanic	15	41	23	26	0.04	0.87	7.75	**0.02**
9-20	TC2-15	Mechanic	15	28	23	21	0.05	1.09	7.88	**0.03**
9-20	TC2-14	Mechanic	15	25	23	20	0.05	1.09	7.92	**0.03**
9-20	TC2-13	Mechanic	15	23	23	20	0.06	1.30	7.95	**0.04**
9-21	TC2-27	Mechanic	15	25	23	11	0.07	1.52	7.77	**0.05**
9-19	TC2-4	Road	17	13	3	0	0.11	2.39	9.78	**0.07**
9-19	TC2-6	Road	18	55	3	45	0.12	2.61	8.83	**0.04**
9-19	TC2-5	Road	18	45	1	36	0.01	0.22	6.85	**<0.03**
9-20	TC2-17	Road	18	2	3	15	0.22	4.78	9.22	**0.14**
9-20	TC2-16	Road	21	23	8	30	0.15	3.26	11.12	**0.09**
9-20	TC2-18	Road	17	52	5	15	0.13	2.83	11.38	**0.07**
9-21	TC2-25	Road	17	53	8	0	0.33	7.17	14.12	**0.14**
9-21	TC2-26	Road	17	57	3	30	0.2	4.35	9.55	**0.14**

Table 5. Concentrations of Respirable Dust
Transcon Freight Company
September 1988

Date	Sample Number	Job/Area	Time Start		Time Stop		Flow (L/min)	Weight (ug)	Time (min)	Volume (L)	Concentration (ug/m3)
9-20	FW4215	Dock Area	7	35	14	55	1.7	35	440	748	46.8
9-21	FW4373	Dock Area	7	24	14	48	1.7	65	444	755	86.1
9-22	FW4372	Dock Area	7	43	13	53	1.7	45	370	629	71.5
9-20	FW4225	Local Cab	8	11	16	11	1.7	45	480	816	55.1
9-21	FW4361	Local Cab	9	17	18	18	1.7	45	541	920	48.9
9-19	FW4209	Road Cab	17	22	23	38	1.7	45	376	639	70.4
9-20	FW4230	Road Cab	18	8	2	8	1.7	45	480	816	55.1
9-21	FW4367	Road Cab	16	55	2	55	1.7	55	600	1020	53.9
9-19	FW4208	Shop Area	15	45	23	30	1.7	15	465	791	19.0
9-20	FW4224	Shop Area	15	20	23	22	1.7	25	482	819	30.5
9-21	FW4368	Shop Area	15	15	23	10	1.7	35	475	808	43.3