IN DEPTH SURVEY REPORT
OF
CAROLINA FREIGHT CARRIERS
Carlisle, Pennsylvania, and
York, Pennsylvania

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16. Abstract (Limit: 200 words) An in depth study was made of worker exposures to diesel exhaust as part of a case/control mortality and industrial hygiene study of truck drivers, dock workers and mechanics presumably exposed to this aerosol in the course of their jobs. Samplings were taken at the Carolina Freight Carriers Terminal (SIC-4231) located in Carlisle and York, Pennsylvania. Measurements of elemental carbon (7440440) taken during mild weather conditions indicated exposures only slightly above ambient highway concentrations of 3.8 micrograms/cubic meter (microg/m3) in most jobs. Geometric mean exposures to submicrometer elemental carbon ranged from 5.5microg/m3 in dock workers using gas powered tow motors to 8.9microg/m3 in road drivers driving road tractors equipped with horizontal exhaust systems. The geometric mean exposures to elemental carbon in all jobs were significantly higher than the geometric mean ambient concentration of 0.75microg/m3 measured in a residential area of Harrisburg. Only very low or non detectable levels of other components such as nitrogen oxides, respirable particulates, polycyclic aromatic hydrocarbons or nitro substituted polycyclic aromatic hydrocarbons were reported from this sampling. Those which were detectable were far below allowable levels.

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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.
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SIC CODE:	4231 - Freight Trucking Terminals, with or without maintenance facilities

DISCLAIMER

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Abstract

The Industrywide Studies Branch of NIOSH is currently conducting a combined case-control 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 Carolina Freight Carriers terminal in Carlisle, Pennsylvania, and York, Pennsylvania, during mild weather indicate low-level exposures only slightly above ambient highway concentrations (3.8 ug/m^3) in most jobs. Geometric mean exposures to submicrometer elemental carbon ranged from 5.5 ug/m^3 in dock workers using gas-powered tow-motors to 8.9 ug/m^3 in road drivers driving road tractors equipped with horizontal exhaust systems. Other job exposure means were intermediate. However, geometric mean exposures to elemental carbon in all jobs were significantly elevated above the geometric mean ambient concentration (0.75 ug/m^3) measured in a residential area in Harrisburg. Exposures to other components measured (oxides of nitrogen, 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 others, 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 two in-depth industrial hygiene surveys conducted at Carolina Freight Carriers' terminals in Carlisle and York, Pennsylvania during the period September 12-16, 1988. During the surveys, 60 personal 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 28 personal samples each for evaluation of workers' exposures to nitrogen dioxide and nitric oxide. Additional area samples were obtained for evaluation of concentrations of airborne respirable dust, 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

Carolina Freight Corporation, the parent company of Carolina Freight Carriers, is located in Cherryville, North Carolina. The company was founded in Cherryville, North Carolina in 1932. Other trucking companies operated by Carolina Freight Corporation include G.I. Trucking Company, Red Arrow Freight Lines, and Cardinal Freight Carriers, Inc.

Two Carolina Freight Carriers terminals were included in this survey. The larger of the two, at Carlisle, is a break bulk terminal consisting of line-haul (long distance road transport), dock, and tractor/trailer repair shop operations. The smaller terminal, at York (about 35 miles south of Harrisburg), includes only a small dock and a local area transport (city) operation.

The Carlisle terminal is Carolina Freight's second largest break bulk terminal, employing over 600 people. The site currently includes some of Carolina Freight's district (regional) offices, and the break-bulk (or hub) terminal, which includes terminal offices and truck/driver dispatching area, a 159-door dock, a wash rack, and a large tractor/trailer maintenance facility. The facility, opened in 1975, is situated on a 24 acre site in Carlisle (near Harrisburg). Three dock additions have been constructed since 1975, the last one in 1987. The terminal is currently in the process of expanding both the dock and the maintenance facilities.

The York terminal is a small, local area-only terminal consisting of a small dock of about 6500 square feet and 30 doors. The total employment is 29 including supervisory and clerical personnel. The terminal is located on a site of approximately five acres including the dock, lot, and offices.

Dock Operations

The Carlisle 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 72,000 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 an open-sided covered structure with 159 open doors along both sides and both ends. Approximately one half of the dock extends outward from each end of the main terminal office building (located approximately in the middle and on one side of the dock). Each door is sized larger than the open end of most truck trailers, 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 19 tow-motor trucks. However, only six or seven of these are operated on a given shift. All of the tow-motors are gasoline-engine powered vehicles. Currently, almost all tow-motors owned nationwide by this company are gasoline powered.

The York dock is similar in structure, but is much smaller. Only two tow-motors are operated on the dock, one gasoline and one propane powered vehicle. The site consists of only one building, which includes the terminal offices (at one end) and the dock. The dock is operated on three shifts, 24 hours per day.

Repair Shop Operations (Carlisle Terminal)

The shop area at Carlisle totals approximately 27,000 square feet, and is in a separate building from the main terminal. The maintenance facilities at this site consist of a tractor repair shop, a trailer repair shop, a tire shop, a tow-motor repair shop, a body shop, a drive- through wash bay, and eight service lanes (seven lanes were being used at the time of the survey). Each of the service lanes is approximately 200 feet long and about 18-20 feet wide, with large overhead bay doors at each end.

Minor and medium level repairs are done in the four repair areas, 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 service/safety check bay, parked, and the engine turned off. If the engine must remain running while in the service bay area, and/or bay doors are closed, an overhead general exhaust system is turned on. 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.

The repair shops do most tuneups, and mechanical, brake, tire, wheel, and electrical repairs, but do 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. Other than the overhead exhaust systems in the tractor shop and service lanes, which are run any time the doors are closed or an engine analyzer is used, no ventilation systems were in place in the shop area.

During the 1970's and earlier, mechanics used compressed air to blow out wheel drums during brake repairs. According to company personnel, most mechanics had heavy, almost daily exposure to brake dust (and consequently potential exposure to any asbestos used in the linings). Since the late 1970's, however, all drum cleaning is done by washing with a petroleum distillate solvent. The solvent is sprayed into the wheel drum using a small, portable, compressed air spray gun, and the drum is then wet-wiped with rags.

Truck Fleet Description

At the Carlisle break bulk terminal, 165 road tractors are available in the tractor pool. These include tractors manufactured by Ford (90%), International (5%), and White (5%) companies. 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 axle tractors, which can haul up to 20,000

lbs. weight. No cabover tractors (where the cab is situated directly over the engine compartment) are owned by Carolina Freight Carriers.

All road tractors used by Carolina Freight Carriers are configured with horizontal exhaust systems located on the undercarriage of the tractor. Almost all of the road tractors are currently powered by one of four Cummins Co. diesel engines, including NTC290 BigCam III (855 in^3), Fleet 270 (855 in^3), L10-270 and L10-300 models (600 - 650 in^3). The L10 engines are increasing in use because they are smaller (thus consuming less fuel) and have the same horsepower as the larger engines. Currently, approximately 25% of the road tractors are powered by L10 engines.

At the York Terminal, a pool of 17 city tractors (GMC and Ford) are available, all of which have been bought new since 1978. Six of these have vertical stack exhaust systems, and the remaining 11 have horizontal exhaust systems similar to the road tractors. These use the same Cummins Co. engines as do the road tractors.

During the warmer months, the tractor fleet runs on Mobil No. 2 diesel fuel. In winter, a mixture of mobil diesel No. 1 and No. 2 grade fuel is used. Since 1958, all of the road tractor cabs (but none of the city cabs) have been either bought or retrofitted with air-conditioning units.

Nationwide, the Carolina Freight Carrier Corporation's road and city tractor fleets were converted from gasoline engines to diesel engines in 1950. Reliable non-asbestos composition brake linings became available in 1986, and since that time, all tractor wheels have been relined with the non-asbestos linings. None of the tractors have been equipped with air deflectors.

WORKFORCE DESCRIPTION

At Carlisle, approximately 610 persons were, as of the date of the survey, employed at the terminal. These included about 170 regular dockmen, 251 line drivers, 13 dispatchers, and about 80 "casuals" (temporary or part-time dock employees). The terminal also employed 9 office clerks, 1 secretary, and 31 management personnel. The management personnel included one district manager, one office manager, 4 operations managers, 16 supervisors, 2 management trainees, 2 "O.S.& D." (Overage, Shortages, and Damages) personnel, 3 weight inspection supervisors, 1 loss prevention supervisor, and 1 Division loss control and safety manager. With the exception of the clerks and secretaries, and one line driver, all were male. The repair shop employed 55 personnel: 44 mechanics, 5 shop supervisors, 1 parts manager, 2 parts helpers, 1 administrative secretary, 1 garage manager, and 1 area manager.

The dock and repair shop operate on three eight-hour shifts, 24 hours per day. Line drivers originating at the Carlisle 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 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.

At the York terminal, 23 of the 29 employees were combination city drivers and dockmen (performing either job as needed). The workforce also included 1 manager, 2 supervisors, 1 mechanic, all of whom were male, and 2 clerical personnel, both female. The dock operates 24 hours per day on three shifts. 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 Carolina Freight has a well developed safety program, with a safety supervisor located in Cherryville, N.C, as well as a loss control and safety manager located at the Carlisle break bulk terminal. The program includes extensive new-employee and periodic training programs in safety and hazardous materials, and a corporate quality improvement incentive awards program. For terminal personnel, pre-shift meetings are held regularly on every shift covering both safety and hazardous materials handling, and road drivers participate in quarterly safety and hazardous materials training seminars. A self-contained training van (owned by Carolina Freight Carriers Corp.) and audio-visual training aids (such as video tapes) are used extensively during these meetings.

Medical Programs

There is no on-site medical clinic or nurse's station, but supervisors on-site have been trained in first aid. The company has no specific arrangement for medical or emergency care, but the city emergency response system is reportedly excellent.

For 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, urine tests including tests for drugs, specific gravity, albumin, and sugar. Drug screening was begun about four years ago. The examination also includes an EKG and a chest X-ray. Appendix A is a blank form used for the examination. Similar pre-employment and periodic screening is also provided to terminal personnel.

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 comprise 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. 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 10 personal samples for submicrometer Ce and organic carbon (Co) were obtained on each of the two shifts sampled each day. Generally, 3 to 5 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 (both tow-motor drivers and non-driver dock workers), and local drivers during the day shift. The sampling was conducted for three days (six shifts).

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 Zeflour^{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, including the results of the highway and residential area samples obtained for reference. Figures 3, 4, and 5 are similar charts illustrating exposures to NO_2, 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 7 is a statistical summary of respirable dust concentrations in four areas. Tables 1- 5 in appendix C contain the individual personal, eight-hour, time weighted average exposures to elemental and organic carbon, NO_2, NO, and respirable dust samples. 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 a low of 5.9 ug/m^3 in dock workers (labelled "Dock" in Figure 1) to a high of 8.9 ug/m^3 in road drivers (Road). The other job means were (from low to high - refer to Figure 1): local drivers (Local: 7.1 ug/m^3), switchers (Swit: 7.1 ug/m^3), and mechanics (Mech: 7.8 ug/m^3). Area concentrations in four areas averaged 5.2 ug/m^3 in road tractor cabs (Rcab), 6.3 ug/m^3 on the dock (Darea), 7.6 ug/m^3 in local cabs (Lcab), and 7.7 ug/m^3 in the repair shop.

By contrast, concentrations measured on a local freeway near Harrisburg averaged 3.8 ug/m^3 (range: 2.3 to 5.2 ug/m^3 in three samples), and in a residential area (at least one mile from the nearest highway or freeway) averaged 0.75 ug/m^3 (range: 0.46 to 1.7 ug/m^3 in three samples).

Inspection of Figure 1 indicates that exposures to elemental carbon in all jobs were generally of the same order of magnitude as highway background concentrations. In fact, the 95% upper confidence limit (UCL) of the highway concentrations (Table III) was higher than the 95% lower confidence limit (LCL) of any of the other job means, suggesting that none of the 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. 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.

However, three job means appear to be significantly greater than background residential concentrations, as indicated by non-overlapping 95% lower confidence intervals. These jobs are local drivers, mechanics, and road drivers.

Table IV contains 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 41 ug/m^3 in Local drivers to a high of 68 ug/m^3 in dock workers. Other job means (Table IV and Figure 2) were intermediate to these. Geometric mean area concentrations of organic carbon ranged from 28 ug/m^3 in the repair shop to 31 ug/m^3 in road tractor cabs.

Highway area concentrations of submicrometer organic carbon averaged 20 ug/m^3, and residential area concentrations averaged 18 ug/m^3. The 95% LCL of personal samples from all five jobs was greater than the 95% UCL for the highway samples (27.5 ug/m^3), suggesting that their exposure to submicrometer organic carbon was significantly greater than background highway concentrations of organic carbon. The most obvious explanation for this is that non-diesel aerosol may have been contributing to the level of total carbon exposure. This may have included tobacco (cigarette, pipe, and cigar) smoke as well as other airborne aerosols such as industrial emissions.

Oxides of Nitrogen

Nitrogen dioxide (NO_2) exposure means obtained in personal samples from 5 jobs (Figure 3 and Table V) ranged from a low of 0.036 ppm in local drivers to a high of 0.056 ppm in road drivers. Geometric mean exposures in dock workers were 0.036 ppm, in mechanics 0.041 ppm, and in switcher operators, 0.044 ppm. All of these 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) (22).

Similarly, nitric oxide (NO) exposure means from the same persons (Figure 4 and Table VI; NO_2 and NO samples were obtained as duplicate samples on the same workers) ranged from a low of 0.028 ppm in Mechanics to 0.278 ppm in dock workers. These exposures are again far below applicable OSHA PELs or NIOSH RELs (Table I).

In general, inspection of Figures 3 and 4 indicates that the same relative levels of exposures between jobs is not apparent when comparing NO_2 and NO exposure means. Dock workers had the second lowest NO_2 mean among the five jobs, but by far the highest NO exposure mean. However, road drivers appeared to consistently rank toward the high end of the range. However, conclusions regarding relative ranking of jobs cannot be very firm, since all exposure levels were very low, and were generally near the limit of quantitation.

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, and Table 5 in Appendix B.

Respirable Dust

Figure 5 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 35 ug/m^3, 42 ug/m^3 on the dock, 46 ug/m^3 in local tractor cabs, and 47 ug/m^3 in road tractor cabs. In general, concentrations of respirable dust were of the same order of magnitude in all areas sampled, approximately 40 - 50 ug/m^3.

CONCLUSIONS

Based on the data obtained and subjective observations made during the survey, the following conclusions have been made:

1. Based on measurements of personal, breathing zone concentrations of elemental carbon at this terminal, it appears that no exposures to diesel aerosol were elevated significantly above background highway concentrations found in the Harrisburg area. However, this conclusion is not a rigorous one, since the small sample sizes generated necessarily wide confidence limits around the geometric means. Firmer conclusions must await analysis of this data in conjunction with data collected during the remainder of the surveys at other terminals. It appears that the low exposures of dock workers (near highway background levels) were due to the fact that only gasoline-powered tow-motors, and not diesel-powered tow-motors, were operated on the dock.

2. Geometric mean highway concentrations of submicrometer elemental carbon were, in this survey, approximately five times the geometric mean residential concentrations (3.8 ug/m^3 vs. 0.75 ug/m^3). In addition, road and local drivers' mean exposures 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 substantially higher than elemental carbon concentrations in all jobs and areas sampled at this terminal, indicating the presence of some non-diesel aerosol, including tobacco smoke, in the samples (most of the individual samples indicating very high organic carbon concentrations were obtained on smokers). 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. 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.

5. 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 horizontal (under- carriage) exhaust systems, and conventional (not cabover) 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 all jobs (during the warm weather prevalent at the time of the survey) were only slightly above local ambient highway concentrations. However, 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.

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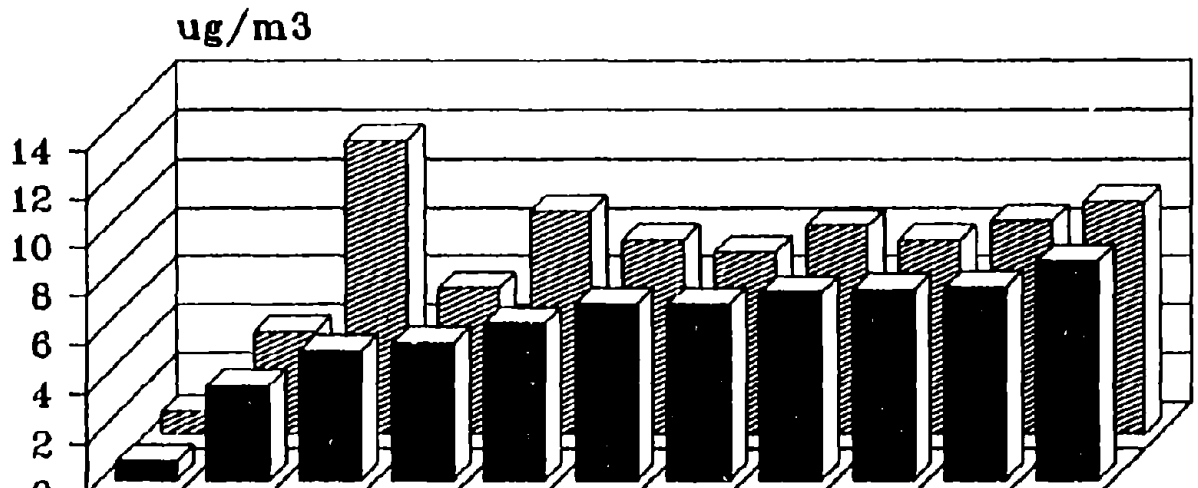
Figure 1. Elemental Carbon Exposure
Carolina Freight Carriers



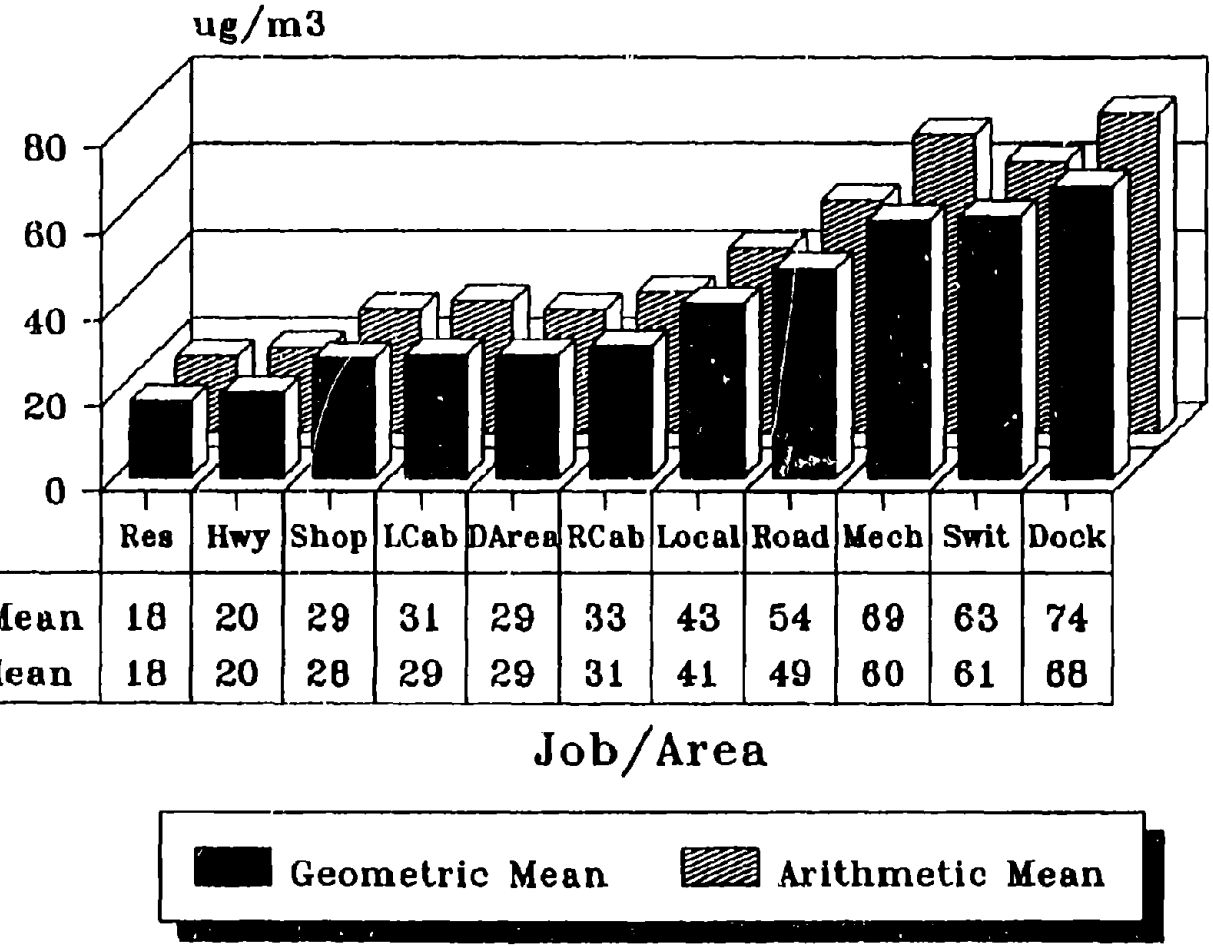
	Res	Hwy	Rcab	Dock	DArea	Local	Swit	Lcab	Shop	Mech	Road
Arithmetic Mean	0.89	4.1	12	5.9	9.1	7.9	7.4	8.5	7.9	8.7	9.5
Geometric Mean	0.75	3.8	5.2	5.5	6.3	7.1	7.1	7.6	7.7	7.8	8.9

Job/Area

Geometric Mean Arithmetic Mean

September 1988

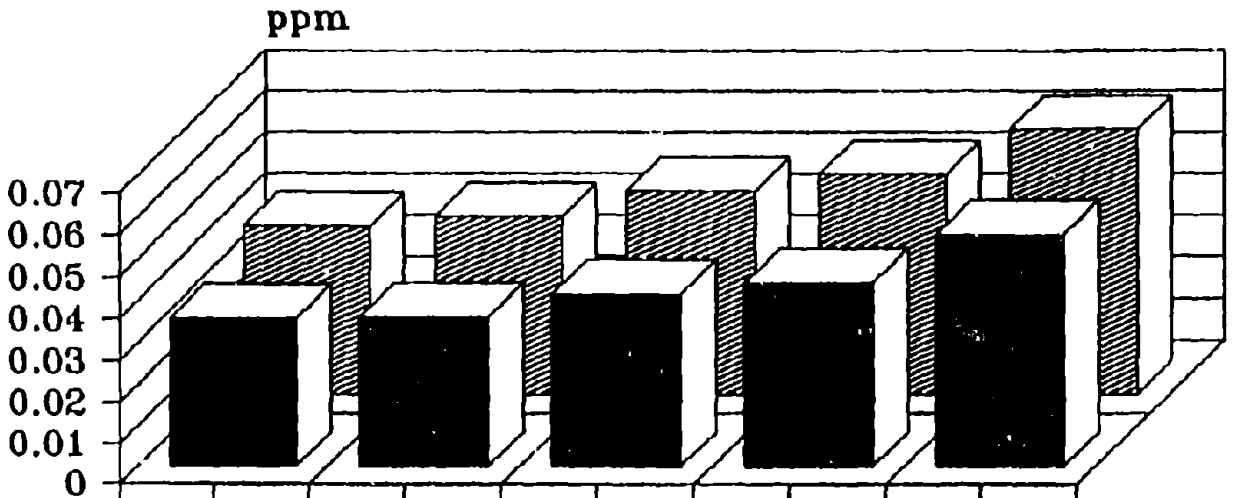
Figure 2. Organic Carbon Exposures
Carolina Freight Carriers



	Res	Hwy	Shop	LCab	DArea	RCab	Local	Road	Mech	Swit	Dock
Arithmetic Mean	18	20	29	31	29	33	43	54	69	63	74
Geometric Mean	18	20	28	29	29	31	41	49	60	61	68

September 1988

Figure 3. Nitrogen Dioxide Exposures
Carolina Freight Carriers



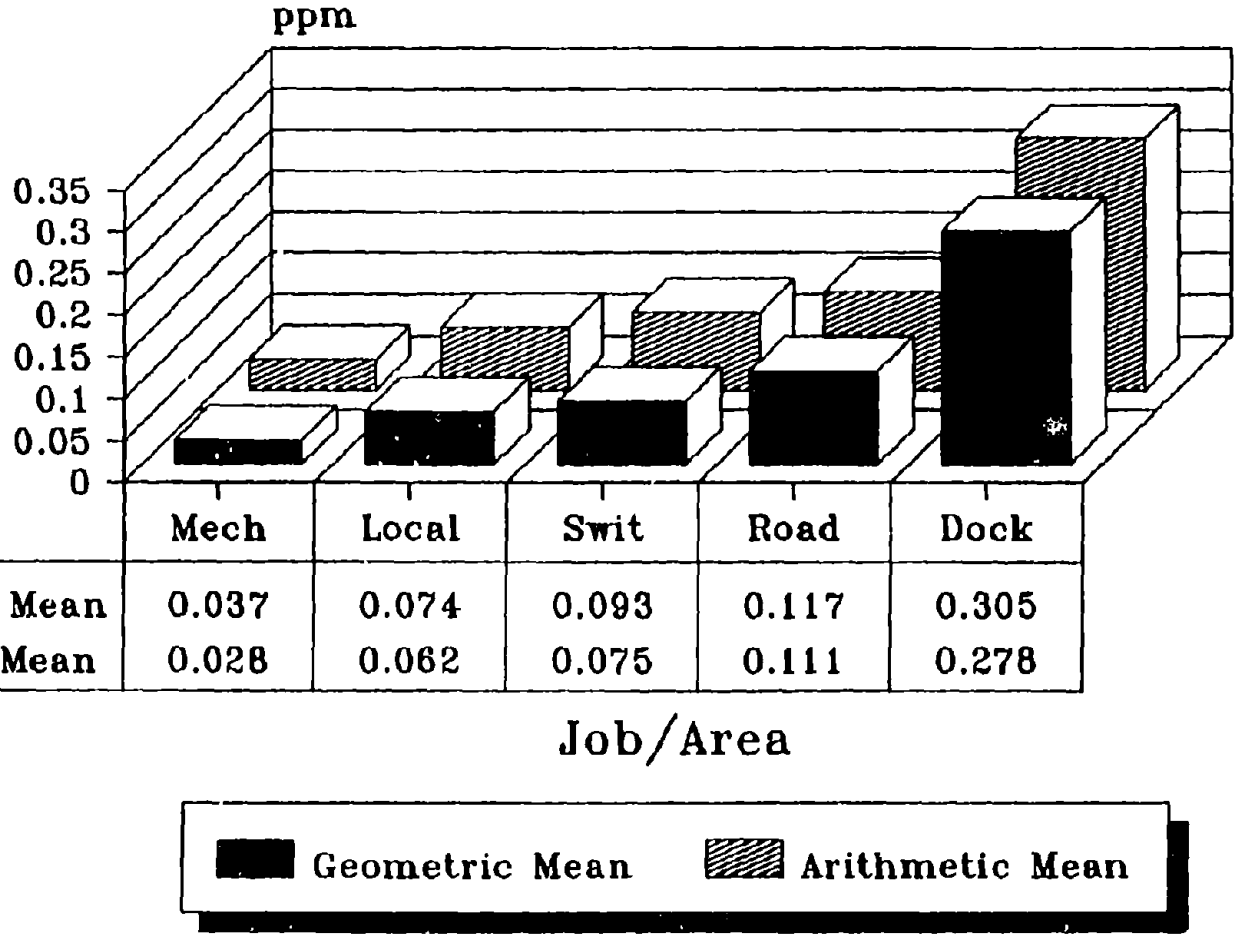
	Local	Dock	Mech	Swit	Road
Arithmetic Mean	0.04	0.042	0.049	0.053	0.064
Geometric Mean	0.036	0.036	0.041	0.044	0.056

Job (Personal Exposures)

Geometric Mean Arithmetic Mean

September 1988

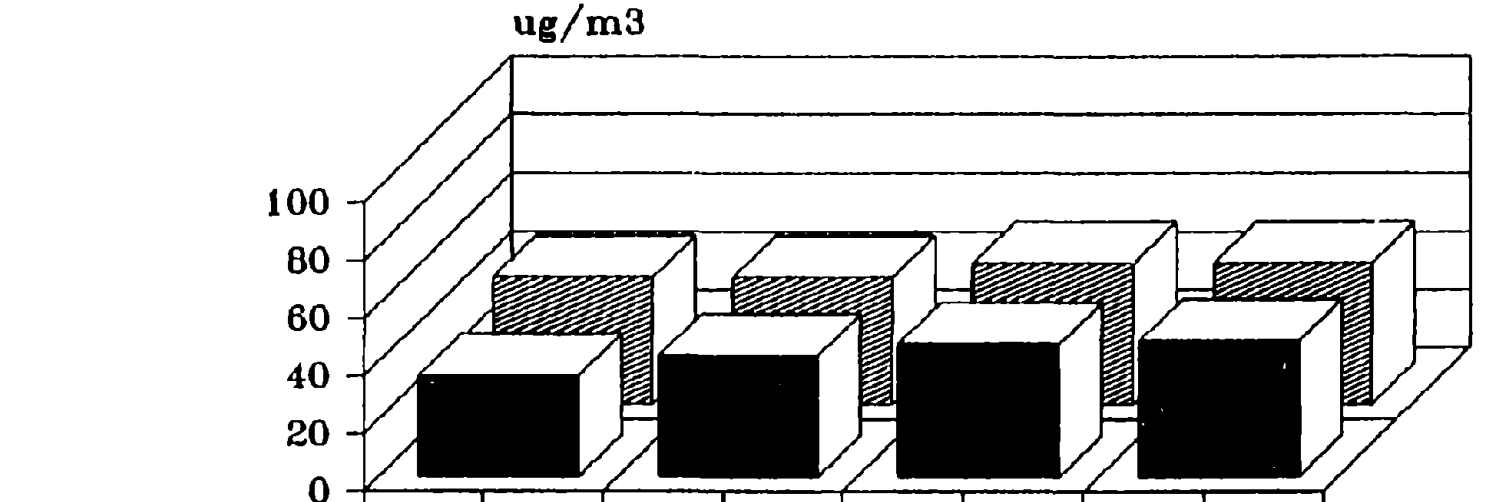
Figure 4. Nitric Oxide Exposures
Carolina Freight Carriers



	Mech	Local	Swit	Road	Dock
Arithmetic Mean	0.037	0.074	0.093	0.117	0.305
Geometric Mean	0.028	0.062	0.075	0.111	0.278

September 1988

Figure 5. Respirable Dust Exposures Carolina Freight Carriers; by Area



	Shop	Dock	LCab	RCab
Arithmetic Mean	44	44	49	49
Geometric Mean	35	42	46	47

September 1988

Table 1.--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 and Nitro–substituted PAHs Determined in Four Areas Carolina Freight Carriers; 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
Carolina 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
Resident	3	0.46	1.67	0.90	0.39	**0.75**	2.00	0.13	4.23
Hwy.	3	2.25	5.21	4.06	0.92	**3.81**	1.58	1.22	11.93
Road Cab	3	0.49	20.45	11.65	5.88	**5.19**	7.83	0.03	861.18
Dock	9	2.94	9.17	5.93	0.79	**5.46**	1.56	3.87	7.70
Dock Area	3	2.72	19.83	9.09	5.40	**6.33**	2.79	0.49	81.03
Local	7	2.53	13.19	7.91	1.35	**7.08**	1.73	4.26	11.76
Switch	3	4.96	8.81	7.37	1.21	**7.14**	1.37	3.26	15.66
Local Cab	2	4.63	12.46	8.54	3.92	**7.59**	2.02	0.01	4125.52
Shop Area	3	6.70	10.19	7.88	1.15	**7.73**	1.27	4.27	14.01
Mechanic	12	1.96	14.42	8.65	1.01	**7.78**	1.72	5.51	10.97
Road	11	4.09	14.12	9.45	1.00	**8.85**	1.49	6.77	11.57

Table IV. Organic Carbon Summary Statistics
By Job or Specific Location
Carolina 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
Resident	3	16.2	21.1	18.1	1.5	**18.0**	1.15	12.6	25.6
Hwy.	3	17.5	22.5	20.2	1.5	**20.1**	1.14	14.6	27.5
Shop Area	3	21.8	41.4	29.3	6.1	**28.1**	1.41	12.1	65.6
Local Cab	2	19.5	41.7	30.6	11.1	**28.5**	1.71	0.2	3620
Dock Area	3	27.9	29.5	28.6	0.5	**28.6**	1.03	26.5	30.8
Road Cab	3	18.2	41.5	33.3	7.6	**31.2**	1.60	9.7	100
Local	7	26.6	68.3	43.4	5.7	**41.3**	1.40	30.3	56.3
Road	11	21.8	103.2	53.8	7.8	**48.9**	1.58	35.9	66.4
Mechanic	12	32.5	183.3	68.5	12.1	**60.5**	1.63	44.4	82.4
Switch	3	42.4	77.0	63.3	10.6	**61.3**	1.38	27.5	137
Dock	9	37.4	137.9	74.0	11.2	**67.7**	1.56	48.0	95.5

Table V. Nitrogen Dioxide Summary Statistics
By Job or Specific Location
Carolina Freight Carriers
(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
Local	4	0.02	0.06	0.04	0.01	**0.04**	1.83	0.01	0.09
Dock	7	0.02	0.07	0.04	0.01	**0.04**	1.92	0.02	0.07
Mechanic	6	0.02	0.09	0.05	0.01	**0.04**	1.92	0.02	0.08
Switch	3	0.02	0.08	0.05	0.02	**0.04**	2.21	0.01	0.32
Road	8	0.02	0.12	0.06	0.01	**0.06**	1.77	0.03	0.09

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

Job or Area	N	Min	Max	Arithmetic Mean	S.E.	Geometric Mean	Geometric Std. Dev.	95% Confidence Limit Lower	95% Confidence Limit Upper
Mechanic	6	0.01	0.09	0.04	0.01	**0.03**	2.21	0.01	0.06
Local	4	0.02	0.13	0.07	0.02	**0.06**	2.08	0.02	0.20
Switch	3	0.03	0.13	0.09	0.03	**0.07**	2.44	0.01	0.69
Road	7	0.05	0.16	0.12	0.01	**0.11**	1.47	0.08	0.16
Dock	7	0.12	0.54	0.30	0.05	**0.28**	1.62	0.18	0.43

Table VII. Respirable Particulate Summary Statistics
By Job or Location
Carolina Freight Carriers
September 1988; (ug/m3)

				Arithmetic		Geometric		95% Confidence Limit	
Area	N	Min	Max	Mean	S.E.	Mean	Std. Dev.	Lower	Upper
Shop	3	12	72	44	18	35	2.56	3.4	360
Dock	3	26	55	44	9	42	1.51	15	120
Local Cab	2	32	67	49	18	46	1.69	0.4	5130
Road Cab	2	37	61	49	12	47	1.44	1.8	1220

Appendix A
Medical Exam Form
Carolina Freight Carriers
Harrisburg, PA

PHYSICAL EXAMINATION

FORM LE 47 (FORMERLY NOS. 428 & 458)

9/77

Name			Job Applied For
Address			Job Physical Requirements
Social Security No.	Date of Birth	Sex	
☐ New Certification ☐ Recertification	Personal Physician		

HAVE YOU EVER:	Yes or No	MEDICAL HISTORY QUESTIONNAIRE				IF ANY ANSWER IS YES, EXPLAIN BELOW.	
Been seriously injured		Been refused employment for health reasons		Had any other nervous disorder		Received a pension for disability	
Been Operated on		Been forced to give up a job because of health reasons		Received Workmen's Compensation		Been refused Life Insurance	
Been advised to have an operation		Had extensive confinement by illness or injury		Been rejected for military service for health reasons		Been made ill by your work	
Been a patient in a sanitarium or institution		Had Psychiatric disorder		Been discharged from military service for health reasons		Been refused a driver's license for health reasons	
EXPLANATION OF "YES" ANSWERS ABOVE:							
HAVE YOU EVER: Injured your back		Had a hernia or rupture		Had seizures, fits, convulsions or fainting		Do you need glasses for distance	
Worn a back brace		Been treated with X-rays		Had head or spinal injuries		Do you ever use a hearing aid	
Worn a knee brace		Worked with Radio-active material		Do you have a permanent defect from illness, disease, or injury		Had nerve trouble	
Do you ever wear a truss		Worked in a dusty trade		Do you need glasses to read		Do you take medicine regularly	
EXPLANATION OF "YES" ANSWERS ABOVE:							
HAVE YOU EVER HAD: Arthritis		Emphysema: Lung disease		High Blood Pressure		Nervous Breakdown	
Cancer		Epilepsy		Kidney Disease		Tuberculosis	
Diabetes		Heart trouble		Muscular Disease		Suffering from any other Disease	
EXPLANATION OF "YES" ANSWERS ABOVE:							
HAVE YOU EVER HAD: Asthma		Hay fever		Rheumatic fever		Urination Difficulties	
Allergies, or reactions to drugs		Headaches (frequent)		Shortness of Breath		Varicose veins	
Blood in Urine		Jaundice		Skin Rashes or Eczema		Veneral Disease	
Cough (frequent or chronic)		Joint Pains		Gastrointestinal or stomach ulcer or nervous stomach		Cardiovascular disease	
Fainting spells or dizziness		Paralysis		Swelling of legs or ankles		Alcoholism	
EXPLANATION OF "YES" ANSWERS ABOVE:							
IMMUNIZATIONS: Tetanus (Lock Jaw)		Date of Last Shot		Polio		How many Shots	
FOR FEMALES: Do you have any female or menstrual problems						Date of last period	

THE ABOVE STATEMENTS ARE TRUE TO THE BEST OF MY KNOWLEDGE. I UNDERSTAND THAT ANY MISSTATEMENT OF FACT IS GROUNDS FOR RELEASE

Signature of Applicant	Date

HEIGHT	WEIGHT	BODY FRAME ☐ Slender ☐ Medium ☐ Large	GENERAL APPEARANCE ☐ Good ☐ Fair ☐ Poor

VISION WITHOUT GLASSES	WITH GLASSES		HEARING R ____ L ____
Far ____	Far ____	Color Vision ____	Disease ____
Near ____	Near ____	Peripheral Vision ____	Injury ____
		Depth Perception ____	

EVIDENCE OF DISEASE OR INJURY TO EYES:
Right – Left –

EVIDENCE OF DISEASE OR INJURY TO EARS:
Right – Left –

AUDIOMETRIC TEST
Decibel Loss at: 500 HZ – 1000 HZ – 2000 HZ –

THORAX
Heart –

IF ORGANIC DISEASE IS PRESENT, IS IT FULLY COMPENSATED?

ANY HISTORY OF MYOCARDIAL INFRACTION, ANGINA CORONARY, INSUFFICIENCY OR CONGESTIVE HEART FAILURE? YES ☐ NO ☐

BLOOD PRESSURE	Pulse before Exercise	Pulse 2 min. after Exercise	Lungs
Systolic – Diastolic –			

REFLEXES: Rhomberg	Pupillary	Light R – L –	Accomodation Right – Left –

KNEE JERKS:
RIGHT: Normal ____ Increased ____ Absent ____ LEFT: Normal ____ Increased ____ Absent ____

REMARKS:

CHECK (✓) IF NORMAL. MARK (O) IF DEVIATION FROM NORMAL AND GIVE DETAILS BELOW.

SKIN – SCARS ☐	GLANDS ☐	LUNGS ☐	EXTREMITIES ☐	SPINE:	SPECIAL EXAMS:	
HEAD – NECK ☐	THYROID ☐	HEART ☐	NEUROLOGICAL ☐	MOTION ☐	FUNDI ☐	PELVIC ☐
NOSE – SINUSES ☐	EYES ☐	VESSELS ☐	HERNIA ☐	PALPATIONS ☐	INTRACULAR TENSION ☐	BREASTS ☐
TEETH – GUMS ☐	EARS ☐	ABDOMEN ☐	VARICOSITIES ☐			
MOUTH–THROAT ☐	CHEST ☐	JOINTS ☐	GENITO–URINARY ☐ GASTROINTESTINAL ☐	DEFORMITIES ☑	RECTAL ☐	OTHER ☐

DETAILS OF ABNORMAL FINDINGS ABOVE:

PSYCHOLOGICAL STATUS:

LABORATORY FINDINGS:
URINALYSIS: Albumin– H.B. – Sugar Serology (if indicated) –

RADIOLOGICAL DATA: ELECTROCARDIOGRAPH

SPECIAL PROCEDURES:
Chest X-Ray Back X-Ray – Other X-Ray – CBC –

REMARKS:

BLOOD SAMPLE HAS ☐ HAS NOT ☐ BEEN FORWARDED TO A LABORATORY FOR SMAC PROFILE.

MEDICAL EXAMINER'S CERTIFICATE (FOR NON-DRIVER APPLICANTS)

THIS IS TO CERTIFY THAT I HAVE THIS DAY EXAMINED — NAME (Please Print)

AND WITH KNOWLEDGE OF HIS DUTIES TO BE PERFORMED, I FIND HIM/HER ☐ QUALIFIED ☐ UNQUALIFIED FOR EMPLOYMENT.

EXPLANATION OF DISQUALIFICATION

SIGNATURE OF EXAMINING DOCTOR	SIGNATURE OF APPLICANT	DATE OF EXAMINATION

MEDICAL EXAMINER'S CERTIFICATE (FOR DRIVER APPLICANTS)

THIS IS TO CERTIFY THAT I HAVE THIS DAY EXAMINED – NAME (Please Print)

AND THAT I FIND HIM/HER ☐ QUALIFIED ☐ UNQUALIFIED FOR EMPLOYMENT IN ACCORDANCE WITH THE MOTOR CARRIER SAFETY REGULATIONS (49 CFR 391.41 – 391.49) AND WITH THE KNOWLEDGE OF HIS DUTIES TO BE PERFORMED.

☐ QUALIFIED ONLY WHEN WEARING CORRECTIVE LENSES. ☐ QUALIFIED ONLY WHEN WEARING A HEARING AID.

EXPLANATION OF DISQUALIFICATION

A COMPLETED EXAMINATION FORM FOR THIS PERSON IS ON FILE IN MY OFFICE AT:

NAME OF DOCTOR (Print)	ADDRESS

SIGNATURE OF EXAMINING DOCTOR	DATE OF EXAMINATION

SIGNATURE OF DRIVER	ADDRESS OF DRIVER

THE FOLLOWING TO BE COMPLETED ONLY WHEN THE VISUAL TEST IS CONDUCTED BY A LICENSED OPTOMETRIST.

NAME OF OPTOMETRIST (Print)	ADDRESS OF OPTOMETRIST

SIGNATURE OF OPTOMETRIST	DATE OF EXAMINATION

PURCHASE ORDER NUMBER	ATTENDING PHYSICIAN – THIS NUMBER MUST SHOW ON YOUR INVOICE

DO NOT WRITE BELOW THIS LINE (FOR PERSONNEL DEPARTMENT REVIEW OF THIS FORM)

EXPLANATION OF POSITIVE ANSWERS:

REMARKS:

SIGNATURE OF PERSON AUTHORIZED TO REVIEW THIS FORM:	DATE

ALL APPLICANTS FOR EMPLOYMENT WHO ARE UNDER DEFINITE JOB CONSIDERATION MUST HAVE RESULTS OF THEIR PHYSICAL EXAMINATIO

SMAC BLOOD TEST PROFILE APPROVED BY THE PERSONNEL DEPARTMENT PRIOR TO FINAL EMPLOYMENT APPROVAL.

INSTRUCTIONS FOR PERFORMING AND RECORDING PHYSICAL EXAMINATIONS

The examining physician should review these instructions before performing the physical examination. Answer each question yes or no where appropriate.

THE EXAMINING PHYSICIAN SHOULD BE AWARE OF THE RIGOROUS PHYSICAL DEMANDS AND MENTAL AND EMOTIONAL RESPONSIBILITIES PLACED ON THE DRIVER OF A COMMERCIAL MOTOR VEHICLE. IN THE INTEREST OF PUBLIC SAFETY THE EXAMINING PHYSICIAN IS REQUIRED TO CERTIFY THAT THE DRIVER DOES NOT HAVE ANY PHYSICAL, MENTAL, OR ORGANIC DEFECT OF SUCH A NATURE AS TO AFFECT THE DRIVER'S ABILITY TO OPERATE SAFELY A COMMERCIAL MOTOR VEHICLE.

GENERAL INFORMATION: The purpose of the history and physical examination is to detect the presence of physical, mental or organic defects of such a character and extent as to affect the applicant's ability to operate a motor vehicle safely. The examination should be made carefully and at least as complete as indicated by the attached form. History of certain defects may be cause for rejection or indicate the need for making certain laboratory tests or a further, and more stringent, examination. Defects may be recorded which do not, because of their character or degree, indicate that certification of physical fitness should be denied. However, these defects should be discussed with the applicant and he should be advised to take the necessary steps to insure correction, particularly of those which, if neglected, might lead to a condition likely to affect his ability to drive safely.

GENERAL APPEARANCE AND DEVELOPMENT. Note marked overweight. Note any posture defect, perceptible limp, tremor, or other defects that might be caused by alcoholism, thyroid intoxication, or other illnesses. The Motor Carrier Safety Regulations provide that no driver shall use a narcotic or other habit-forming drug.

HEAD-EYES: When other than the Snellen chart is used, the results of such test must be expressed in values comparable to the standard Snellen test. If the applicant wears corrective lenses, these should be worn while applicant's visual acuity is being tested. If appropriate, indicate on the Medical Examiner's Certificate by checking the box, "Qualified only when wearing corrective spectacles." In recording distance vision use 20 feet as normal. Report all vision as a fraction with 20 as numerator and the smallest type read at 20 feet as denominator. Note ptosis, discharge, visual fields, ocular muscle imbalance, color blindness, corneal scar, exophthalmos or strabismus, uncorrected by corrective lenses. Monocular or aphakic drivers are not qualified to operate commercial motor vehicles under existing Motor Carrier Safety Regulations.

EARS: Note evidence of mastoid or middle ear disease, discharge, symptoms of aural vertigo or Meniere's Syndrome. When recording hearing, record distance from patient at which a forced whispered voice can first be heard. If audiometer is used to test hearing, record decibel loss at 500 Hz, 1,000 Hz, and 2,000 Hz.

THROAT: Note evidence of disease, irremediable deformities of the throat likely to interfere with eating or breathing, or any laryngeal condition which could interfere with the safe operation of a motor vehicle.

THORAX-HEART: Stethoscopic examination is required. Note murmurs and arrhythmias, and any past or present history of cardiovascular disease, of a variety known to be accompanied by syncope, dyspnea, collapse, enlarged heart, or congestive heart failure. Electrocardiogram is required when findings so indicate.

BLOOD PRESSURE: Record with either spring or mercury column type of sphygmomanometer. If the blood pressure is consistently above 160/90 mm. Hg., further tests may be necessary to determine whether the driver is qualified to operate a motor vehicle.

LUNGS: If any lung disease is detected, state whether active or arrested; if arrested, your opinion as to how long it has been quiescent.

GASTROINTESTINAL SYSTEM: Note any diseases of the gastrointestinal system.

ABDOMEN: Note wounds, injuries, scars, or weakness of muscles of abdominal walls sufficient to interfere with normal function. Any hernia should be noted if present. State how long and if adequately contained by truss.

ABNORMAL MASSES: If present, note location, if tender, and whether or not applicant knows how long they have been present. If the diagnosis suggests that the condition might interfere with the control and safe operation of a motor vehicle, more stringent tests must be made before the applicant can be certified.

TENDERNESS: When noted, state where most pronounced, and suspected cause. If the diagnosis suggests that the condition might interfere with the control and safe operation of a motor vehicle, more stringent tests must be made before the applicant can be certified.

GENITO-URINARY: Urinalysis is required. Acute infections of the genitourinary tract, as defined by local and State public health laws, indications from urinalysis of uncontrolled diabetes, symptomatic albumin-urea in the urine, or other findings indicative of health conditions likely to interfere with the control and safe operation of a motor vehicle, will disqualify an applicant from operating a motor vehicle.

NEUROLOGICAL: If positive Romberg is reported, indicate degrees of impairment. Pupillary reflexes should be reported for both light and accommodation. Knee jerks are to be reported absent only when not obtainable upon reinforcement, and as increased when foot is actually lifted from the floor following a light blow on the patella. Sensory vibratory and positional abnormalities should be noted.

EXTREMITIES: Carefully examine upper and lower extremities. Record the loss or impairment of a leg, foot, toe, arm, hand, or fingers. Note any and all deformities, the presence of atrophy, hemiparalysis or paralysis, or varicose veins. If a hand or finger deformity exists, determine whether sufficient grip is present to enable the driver to secure and maintain a grip on the steering wheel. If a leg deformity exists determine whether sufficient mobility and strength exist to enable the driver to operate pedals properly. Particular attention should be given to and a record should be made of any impairment or structural defect which may interfere with the driver's ability to operate a motor vehicle safely.

SPINE: Note deformities, limitation of motion, or any history of pain, injuries, or disease, past or presently experienced in the cervical or lumbar spine region. If findings so dictate, radiologic and other examinations should be made to diagnose congenital or acquired defects; or spondylolisthesis and scoliosis.

RECTO-GENITAL STUDIES: Diseases or conditions causing discomfort should be evaluated carefully to determine the extent to which the condition might be handicapping while lifting, pulling, or during periods of prolonged driving that might be necessary as part of the driver's duties.

LABORATORY AND OTHER SPECIAL FINDINGS: Urinalysis is required, as well as such other tests as the medical history or findings upon physical examination may indicate are necessary. A serological test is required if the applicant has a history of luetic infection or present physical findings indicate the possibility of latent syphilis. Other studies deemed advisable may be ordered by the examining physician.

DIABETES: If insulin is necessary to control a diabetic condition, the driver is not qualified to operate a motor vehicle. If mild diabetes is noted at the time of examination and it is stabilized by use of a hypoglycemic drug and a diet that can be obtained while the driver is on duty, it should not be considered disqualifying. However, the driver must remain under adequate medical supervision.

The physician must date and sign his findings upon completion of the examination.

SUBPART E
PHYSICAL QUALIFICATIONS AND EXAMINATIONS

SECTION 391.4. PHYSICAL QUALIFICATIONS FOR DRIVERS.

(a) A person shall not drive a motor vehicle unless he is physically qualified to do so and has on his person the original, or a photographic copy, of a medical examiner's certificate that he is physically qualified to drive a motor vehicle.

(b) A person is physically qualified to drive a motor vehicle if he—

(1) has no loss of a foot, a leg, a hand, or an arm, or has been granted a waiver pursuant to Section 391.49;

(2) has no impairment of the use of a foot, a leg, a hand, fingers, or an arm, and no other structural defect or limitation, which is likely to interfere with his ability to control and safely drive a motor vehicle, or has been granted a waiver pursuant to Section 391.49 upon a determination that the impairment will not interfere with his ability to control and safely drive a motor vehicle;

(3) has no established medical history or clinical diagnosis of diabetes mellitus currently requiring insulin for control;

(4) has no clinical diagnosis of myocardial infarction, angina pectoris, coronary insufficiency, thrombosis, or any other cardiovascular disease of a variety known to be accompanied by syncope, dyspnea, collapse, or congestive cardiac failure;

(5) has no established medical history or clinical diagnosis of a respiratory dysfunction likely to interfere with his ability to control and drive a motor vehicle safely;

(6) has no clinical diagnosis of high blood pressure likely to interfere with his ability to operate a motor vehicle safely;

(7) has no established medical history or clinical diagnosis of rheumatism, arthritic, orthopedic, muscular, neuromuscular, or vascular disease which interferes with his ability to control and operate a motor vehicle safely;

(8) has no established medical history or clinical diagnosis of epilepsy or any other condition which is likely to cause loss of consciousness or any loss of ability to control a motor vehicle;

(9) has, no mental, nervous, organic, or functional disease or psychiatric disorder likely to interfere with his ability to drive a motor vehicle safely;

(10) has distant visual acuity of at least 20/40 (Snellen) in each eye with or without corrective lenses or visual acuity separately corrected to 20/40 (Snellen) or better with corrective lenses, distant binocular acuity of at least 20/40 (Snellen) in both eyes with or without corrective lenses, field of vision of at least 70° in the horizontal meridian in each eye, and the ability to recognize the colors of traffic signals and devices showing standard red, green, and amber;

(11) first perceives a forced whispered voice at not less than 5 feet with better ear without use of a hearing aid, or, if tested by use of an audiometric device, does not have a loss greater than 25-30 decibels at 500 Hz, 1,000 Hz, and 2,000 Hz in the better ear without a hearing aid.

(12) does not use an amphetamine, narcotic, or any habit-forming drugs;

(13) has no current clinical diagnosis of alcoholism.

SECTION 391.43 MEDICAL EXAMINATION; CERTIFICATE OF PHYSICAL EXAMINATION.

(a) Except as provided in paragraph (b) of this section, the medical examination shall be performed by a licensed doctor of medicine or osteopathy.

(b) A licensed optometrist may perform so much of the medical examination as pertains to visual acuity, field of vision, and the ability to recognize colors as specified in subparagraph (10) of Section 391.41(b).

(c) The medical examination shall be performed, and its results shall be recorded, substantially in accordance with the following instructions and examination form:

SMAC PROFILE: (Sequential Multiple Analysis-Computer) consists of the following tests:

1. CL - Chloride
2. CO_2 - Carbon Dioxide
3. K - Potassium
4. NA - Sodium
5. BUN - Blood Urea Nitrogen
6. Glu - Glucose (Blood Sugar)
7. Total Protein
8. Albumin
9. Globulin
   A/G - not a test - a ratio of 8 & 9 (Albumin & Globulin)
10. CA - Calcium
11. Inor. Phos. - Inorganic Phosphorus
12. Chol. - Cholesterol
13. Uric Acid
14. Creat. - Creatinine
15. T. Bili. - Total Bilirubin
16. Alk. Phos. - Alkaline Phosphatase
17. CPK - Enzyme test
18. LDH - Enzyme test
19. SGOT - Enzyme test
20. MCG/DL - Total serum iron
21. MG/DL - Triglycerides

Appendix B
Tables 1-5
Individual Sample Results
Carolina Freight Carriers
Harrisburg, PA

Table 1
Concentrations of Elemental Carbon
Carolina 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)
9-12	CFC2	Dock	15	36	23	30	4.0	9.5	474	1896	5.0
9-13	CFC23	Dock	15	36	23	41	4.0	5.7	485	1940	2.9
9-13	CFC24	Dock	15	39	23	34	4.0	6.1	475	1900	3.2
9-12	CFC25	Dock	15	42	23	33	4.0	6.2	471	1884	3.3
9-12	CFC3	Dock	15	37	22	30	4.0	15.1	413	1652	9.2
9-12	CFC4	Dock	15	39	23	29	4.0	13.4	470	1880	7.1
9-14	CFC44	Dock	15	38	23	38	4.0	13.2	480	1920	6.9
9-14	CFC46	Dock	15	38	23	38	4.0	14.3	480	1920	7.4
9-14	CFC48	Dock	15	38	23	33	4.0	15.8	475	1900	8.3
9-12	CFC10	Dock Area	16	32	23	34	4.0	7.9	422	1688	4.7
9-13	CFC32	Dock Area	16	0	23	44	4.0	5.0	464	1856	2.7
9-14	CFC55	Dock Area	15	53	23	29	4.0	36.2	456	1824	19.8
9-14	CFC21	Highway	23	4	7	29	4.0	9.5	505	2020	4.7
9-13	CFC34	Highway	16	11	0	11	4.0	10.0	480	1920	5.2
9-15	CFC64	Highway	8	0	14	4	4.0	3.3	364	1456	2.2
9-13	CFC11	Local	8	3	16	3	4.0	9.7	480	1920	5.1
9-13	CFC12	Local	8	7	16	7	4.0	25.3	480	1920	13.2
9-13	CFC13	Local	8	12	16	12	4.0	4.9	480	1920	2.5
9-13	CFC14	Local	8	15	16	15	4.0	17.6	480	1920	9.2
9-14	CFC40	Local	8	35	16	3	4.0	19.4	448	1792	10.9
9-14	CFC41	Local	8	40	16	40	4.0	13.3	480	1920	6.9
9-14	CFC42	Local	8	42	16	42	4.0	14.7	480	1920	7.6
9-13	CFC15	Local Cab	8	30	16	30	4.0	23.9	480	1920	12.5
9-14	CFC47	Local Cab	8	50	16	50	4.0	8.9	480	1920	4.6
9-13	CFC16	Mechanic	7	34	15	5	4.0	24.3	451	1804	13.5
9-13	CFC17	Mechanic	7	13	13	44	4.0	13.5	391	1564	8.6
9-13	CFC18	Mechanic	7	21	15	21	4.0	14.9	480	1920	7.7
9-13	CFC20	Mechanic	7	28	14	53	4.0	17.5	445	1780	9.8
9-14	CFC35	Mechanic	7	18	15	13	4.0	12.8	475	1900	6.7
9-14	CFC36	Mechanic	7	23	14	40	4.0	17.4	437	1748	9.9
9-14	CFC37	Mechanic	7	30	15	10	4.0	15.2	460	1840	8.3
9-14	CFC38	Mechanic	7	34	12	42	4.0	17.8	308	1232	14.4
9-15	CFC59	Mechanic	7	18	14	0	4.0	12.4	402	1608	7.7
9-15	CFC60	Mechanic	7	22	14	10	4.0	6.8	408	1632	4.2
9-15	CFC62	Mechanic	7	30	14	5	4.0	17.3	395	1580	10.9

Table 1 (Continued)

Date	Sample Number	Job/Area	Time Start		Stop		Flow (L/min)	Weight (ug)	Time (min)	Volume (L)	Concentration (ug/m3)
9-15	CFC63	Mechanic	7	36	14	9	4.0	3.1	393	1572	2.0
9-13	CFC19	Residential	5	48	15	8	4.0	3.7	560	2240	1.7
9-13	CFC33	Residential	16	35	23	39	4.0	<1.9	424	1696	<1.1
9-14	CFCS6	Residential	23	48	8	11	4.0	<1.9	503	2012	<0.9
9-13	CFC28	Road	18	8	2	8	4.0	7.9	480	1920	4.1
9-13	CFC29	Road	18	4	2	4	4.0	10.4	480	1920	5.4
9-13	CFC30	Road	19	7	3	7	4.0	12.0	480	1920	6.2
9-13	CFC31	Road	19	12	3	12	4.0	15.2	480	1920	7.9
9-12	CFCS	Road	17	59	1	59	4.0	24.7	480	1920	12.9
9-14	CFCS0	Road	19	38	3	38	4.0	24.4	480	1920	12.7
9-14	CFCS1	Road	19	43	3	43	4.0	20.0	480	1920	10.4
9-14	CFCS2	Road	19	45	3	45	4.0	19.9	480	1920	10.4
9-14	CFCS3	Road	20	10	4	10	4.0	27.1	480	1920	14.1
9-12	CFC6	Road	18	5	0	26	4.0	12.7	381	1524	8.3
9-12	CFC7	Road	19	2	3	2	4.0	22.1	480	1920	11.5
9-13	CFC27	Road Cab	18	20	2	20	4.0	<1.9	480	1920	<1.0
9-14	CFCS4	Road Cab	19	53	3	53	4.0	26.9	480	1920	14.0
9-12	CFC9	Road Cab	18	24	2	24	4.0	39.3	480	1920	20.4
9-13	CFC22	Shop Area	7	3	15	15	4.0	13.2	492	1968	6.7
9-14	CFC39	Shop Area	7	7	15	7	4.0	13.0	480	1920	6.8
9-15	CFCS7	Shop Area	7	11	13	57	4.0	16.5	406	1624	10.2
9-12	CFC1	Switch	15	34	23	34	4.0	16.0	480	1920	8.3
9-13	CFC26	Switch	15	46	23	32	4.0	9.3	466	1864	5.0
9-14	CFC45	Switch	15	34	23	34	4.0	16.9	480	1920	8.8

Table 2. Concentrations of Organic Carbon
Carolina 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)
9-12	CFC04	Dock	15	39	23	29	4.0	168.4	470	1880	**89.6**
9-12	CFC02	Dock	15	36	23	30	4.0	96.9	474	1896	**51.1**
9-12	CFC03	Dock	15	37	22	30	4.0	170.6	413	1652	**103.3**
9-13	CFC23	Dock	15	36	23	41	4.0	101.7	485	1940	**52.4**
9-13	CFC25	Dock	15	42	23	33	4.0	172.8	471	1884	**91.7**
9-13	CFC24	Dock	15	39	23	34	4.0	78.7	475	1900	**41.4**
9-14	CFC48	Dock	15	38	23	33	4.0	71.2	475	1900	**37.4**
9-14	CFC46	Dock	15	38	23	38	4.0	118.2	480	1920	**61.5**
9-14	CFC44	Dock	15	38	23	38	4.0	264.7	480	1920	**137.9**
9-12	CFC10	Dock Area	16	32	23	34	4.0	47.7	422	1688	**28.3**
9-13	CFC32	Dock Area	16	0	23	44	4.0	51.7	464	1856	**27.9**
9-14	CFC55	Dock Area	15	53	23	29	4.0	53.9	456	1824	**29.5**
9-13	CFC34	Hwy.	16	11	0	11	4.0	43.2	480	1920	**22.5**
9-14	CFC21	Hwy.	23	4	7	29	4.0	35.3	505	2020	**17.5**
9-15	CFC64	Hwy.	8	0	14	4	4.0	29.9	364	1456	**20.6**
9-13	CFC12	Local	8	7	16	7	4.0	131.2	480	1920	**68.3**
9-13	CFC11	Local	8	3	16	3	4.0	65.8	480	1920	**34.3**
9-13	CFC14	Local	8	15	16	15	4.0	90.0	480	1920	**46.9**
9-13	CFC13	Local	8	12	16	12	4.0	69.2	480	1920	**36.0**
9-14	CFC40	Local	8	35	16	3	4.0	47.7	448	1792	**26.6**
9-14	CFC42	Local	8	42	16	42	4.0	110.9	480	1920	**57.8**
9-14	CFC41	Local	8	40	16	40	4.0	64.6	480	1920	**33.7**
9-13	CFC15	Local Cab	8	30	16	30	4.0	80.1	480	1920	**41.7**
9-14	CFC47	Local Cab	8	50	16	50	4.0	37.4	480	1920	**19.5**
9-13	CFC20	Mechanic	7	28	14	53	4.0	81.3	445	1780	**45.7**
9-13	CFC17	Mechanic	7	13	13	44	4.0	135.3	391	1564	**86.5**
9-13	CFC16	Mechanic	7	34	15	5	4.0	188.0	451	1804	**104.2**
9-13	CFC18	Mechanic	7	21	15	21	4.0	79.3	480	1920	**41.3**
9-14	CFC37	Mechanic	7	30	15	10	4.0	144.7	460	1840	**78.7**
9-14	CFC36	Mechanic	7	23	14	40	4.0	320.4	437	1748	**183.3**
9-14	CFC38	Mechanic	7	34	12	42	4.0	50.8	308	1232	**41.3**
9-14	CFC35	Mechanic	7	18	15	13	4.0	105.9	475	1900	**55.7**
9-15	CFC62	Mechanic	7	30	14	5	4.0	75.5	395	1580	**47.8**
9-15	CFC60	Mechanic	7	22	14	10	4.0	53.0	408	1632	**32.5**
9-15	CFC63	Mechanic	7	36	14	9	4.0	74.1	393	1572	**47.1**
9-15	CFC59	Mechanic	7	18	14	0	4.0	93.5	402	1608	**58.2**

Table 2 (Continued)

Date	Sample Number	Job/Area	Time Start		Time Stop		Flow (L/min)	Weight (ug)	Time (min)	Volume (L)	Concentration (ug/m3)
9-13	CFC19	Resident	5	48	15	8	4.0	37.8	560	2240	**16.9**
9-13	CFC33	Resident	16	35	23	39	4.0	35.9	424	1696	**21.1**
9-14	CFCS6	Resident	23	48	8	11	4.0	32.7	503	2012	**16.2**
9-12	CFC05	Road	17	59	1	59	4.0	184.1	480	1920	**95.9**
9-12	CFC06	Road	18	5	0	26	4.0	93.6	381	1524	**61.4**
9-12	CFC07	Road	19	2	3	2	4.0	128.9	480	1920	**67.1**
9-13	CFC31	Road	19	12	3	12	4.0	198.2	480	1920	**103.2**
9-13	CFC30	Road	19	7	3	7	4.0	80.6	480	1920	**42.0**
9-13	CFC28	Road	18	8	2	8	4.0	74.2	480	1920	**38.7**
9-13	CFC29	Road	18	4	2	4	4.0	85.4	480	1920	**44.5**
9-14	CFCS3	Road	20	10	4	10	4.0	64.9	480	1920	**33.8**
9-14	CFCS1	Road	19	43	3	43	4.0	77.5	480	1920	**40.4**
9-14	CFCS2	Road	19	45	3	45	4.0	82.9	480	1920	**43.2**
9-14	CFCS0	Road	19	38	3	38	4.0	41.8	480	1920	**21.8**
9-12	CFC09	Road Cab	18	24	2	24	4.0	77.5	480	1920	**40.4**
9-13	CFC27	Road Cab	18	20	2	20	4.0	34.9	480	1920	**18.2**
9-14	CFCS4	Road Cab	19	53	3	53	4.0	79.7	480	1920	**41.5**
9-13	CFC22	Shop Area	7	3	15	15	4.0	42.9	492	1968	**21.8**
9-14	CFC39	Shop Area	7	7	15	7	4.0	47.4	480	1920	**24.7**
9-15	CFCS7	Shop Area	7	11	13	57	4.0	67.3	406	1624	**41.4**
9-12	CFC01	Switch	15	34	23	34	4.0	147.8	480	1920	**77.0**
9-13	CFC26	Switch	15	46	23	32	4.0	78.9	466	1864	**42.4**
9-14	CFC45	Switch	15	34	23	34	4.0	135.5	480	1920	**70.6**

Table 3. Concentrations of Nitrogen Dioxide
Carolina Freight Carriers
September 1988

Date	Sample Number	Job/Area	Time Start		Time Stop		Mass (ug NO2)	Mass (nmoles)	Time (hr)	Concentration (ppm NO2)
9-12	CF2-3	Dock	15	37	22	40	0.04	0.87	7.05	**0.05**
9-12	CF2-2	Dock	15	36	23	32	<0.03	<0.65	7.93	**<0.04**
9-12	CF2-4	Dock	15	39	23	29	0.05	1.09	7.83	**0.06**
9-13	CF2-19	Dock	15	42	23	32	<0.03	<0.65	7.83	**<0.04**
9-13	CF2-17	Dock	15	36	23	41	0.05	1.09	8.08	**0.06**
9-13	CF2-18	Dock	15	39	23	35	<0.03	<0.65	7.93	**<0.04**
9-14	CF2-29	Dock	15	38	23	40	0.06	1.30	8.03	**0.07**
9-13	CF2-10	Local	8	7	17	17	0.06	1.30	9.17	**0.06**
9-13	CF2-9	Local	8	3	18	19	0.05	1.09	10.27	**0.05**
9-14	CF2-28	Local	8	45	18	3	<0.03	<0.03	9.30	**<0.03**
9-14	CF2-27	Local	8	40	18	55	0.04	0.87	10.25	**0.04**
9-13	CF2-14	Mechanic	7	21	15	10	0.04	0.87	7.82	**0.05**
9-13	CF2-13	Mechanic	7	13	13	44	0.04	0.87	6.52	**0.06**
9-13	CF2-16	Mechanic	7	34	15	6	<0.03	<0.65	7.53	**<0.04**
9-13	CF2-15	Mechanic	7	28	15	7	0.07	1.52	7.65	**0.09**
9-14	CF2-26	Mechanic	7	30	15	12	0.05	1.09	7.70	**0.06**
9-14	CF2-25	Mechanic	7	18	15	5	<0.03	<0.65	7.78	**<0.04**
9-12	CF2-7	Road	19	2	6	11	0.085	1.85	11.15	**0.07**
9-12	CF2-8	Road	19	5	4	42	0.06	1.30	9.62	**0.06**
9-12	CF2-5	Road	17	59	9	39	0.04	0.87	15.67	**0.02**
9-12	CF2-6	Road	18	5	5	30	0.13	2.83	11.42	**0.11**
9-13	CF2-21	Road	18	8	8	17	0.05	1.09	14.15	**0.03**
9-13	CF2-22	Road	18	4	2	58	0.11	2.39	8.90	**0.12**
9-13	CF2-24	Road	19	12	9	5	0.05	1.09	13.88	**0.03**
9-13	CF2-23	Road	19	7	8	29	0.088	1.91	13.37	**0.06**
9-12	CF2-1	Switch	15	34	23	41	0.05	1.09	8.12	**0.06**
9-13	CF2-20	Switch	15	46	23	37	<0.03	<0.65	7.85	**<0.04**
9-14	CF2-30	Switch	15	34	23	40	0.07	1.52	8.10	**0.08**

Table 4. Concentrations of Nitric Oxide
Carolina Freight Carriers
September 1988

Date	Sample Number	Job/Area	Time Start		Time Stop		Mass (ug NOx)	Mass (nmoles)	Time (hr)	Concentration (ppm NO)
9-12	CFX-3	Dock	15	37	22	40	0.23	5.00	7.05	**0.20**
9-12	CFX-2	Dock	15	36	23	32	0.4	8.70	7.93	**0.35**
9-12	CFX-4	Dock	15	39	23	29	0.18	3.91	7.83	**0.12**
9-13	CFX-17	Dock	15	36	23	41	0.44	9.57	8.08	**0.35**
9-13	CFX-19	Dock	15	42	23	32	0.3	6.52	7.83	**0.26**
9-13	CFX-18	Dock	15	39	23	35	0.35	7.61	7.93	**0.31**
9-14	CFX-29	Dock	15	38	23	40	0.66	14.35	8.03	**0.54**
9-13	CFX-9	Local	8	3	18	19	0.13	2.83	10.27	**0.06**
9-13	CFX-10	Local	8	7	17	17	0.09	1.96	9.17	**0.02**
9-14	CFX-28	Local	8	45	18	3	0.12	2.61	9.30	**0.08**
9-14	CFX-27	Local	8	40	18	55	0.23	5.00	10.25	**0.13**
9-13	CFX-16	Mechanic	7	34	15	6	0.07	1.52	7.53	**0.05**
9-13	CFX-13	Mechanic	7	13	13	44	0.04	0.87	6.52	**<0.04**
9-13	CFX-15	Mechanic	7	28	15	7	0.07	1.52	7.65	**<0.04**
9-13	CFX-14	Mechanic	7	21	15	10	0.07	1.52	7.82	**0.03**
9-14	CFX-26	Mechanic	7	30	15	12	0.06	1.30	7.70	**0.01**
9-14	CFX-25	Mechanic	7	18	15	5	0.11	2.39	7.78	**0.09**
9-12	CFX-5	Road	17	59	9	39	0.34	7.39	15.67	**0.14**
9-12	CFX-7	Road	19	2	6	11	0.25	5.43	11.15	**0.11**
9-12	CFX-8	Road	19	5	4	42	0.25	5.43	9.62	**0.14**
9-12	CFX-6	Road	18	5	5	30	0.21	4.57	11.42	**0.05**
9-13	CFX-24	Road	19	12	9	5	0.29	6.30	13.88	**0.13**
9-13	CFX-23	Road	19	7	8	29	0.38	8.26	13.37	**0.16**
9-13	CFX-21	Road	18	8	8	17	0.23	5.00	14.15	**0.09**
9-12	CFX-1	Switch	15	34	23	41	0.08	1.74	8.12	**0.03**
9-13	CFX-20	Switch	15	46	23	37	0.16	3.48	7.85	**0.13**
9-14	CFX-30	Switch	15	34	23	40	0.2	4.35	8.10	**0.12**

Table 5. Concentrations of Respirable Particulate
Carolina Freight Carriers
September 1988

Date	Sample Number	Area	Time Start		Time Stop		Flow (L/min)	Weight (ug)	Time (min)	Volume (L)	Concentration (ug/m3)
9-12	FW4214	Dock	16	30	23	37	1.7	40	427	726	**55**
9-13	FW4218	Dock	16	0	23	45	1.7	40	465	791	**51**
9-14	FW4227	Dock	15	55	23	30	1.7	20	455	774	**26**
9-13	FW4226	Local	8	30	17	17	1.7	60	527	896	**67**
9-14	FW4231	Local	8	50	18	3	1.7	30	553	940	**32**
9-13	FW4217	Road	18	24	2	24	1.7	30	480	816	**37**
9-14	FW4229	Road	19	55	3	55	1.7	50	480	816	**61**
9-13	FW4219	Shop	7	3	15	15	1.7	40	492	836	**48**
9-14	FW4210	Shop	7	7	15	15	1.7	10	488	830	**12**
9-15	FW4221	Shop	7	11	13	57	1.7	50	406	690	**72**

* Note: PAH and Nitro-PAH samples were obtained in the same locations as the above samples: i.e. in replicate with those samples.