NIOSH HEALTH HAZARD EVALUATION REPORT

HETA #2003-0246-3013
Joint Pacific Marine Safety Code Committee
San Francisco, California

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DEPARTMENT OF HEALTH AND HUMAN SERVICES
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

PREFACE

The Hazard Evaluation and Technical Assistance Branch (HETAB) of the National Institute for Occupational Safety and Health (NIOSH) conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employers or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

HETAB also provides, upon request, technical and consultative assistance to federal, state, and local agencies; labor; industry; and other groups or individuals to control occupational health hazards and to prevent related trauma and disease. Mention of company names or products does not constitute endorsement by NIOSH.

ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by Mark M. Methner and A. Yvonne Boudreau HETAB, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS). Field assistance was provided by Chandran Achutan, Chad Dowell, Donald Booher, and Kevin Dunn. Statistical analyses were performed by Chuck Mueller. Analytical support was provided by DataChem Laboratories. Desktop publishing was performed by Robin Smith. Editorial assistance was provided by Ellen Galloway.

For the purpose of informing affected employees, copies of this report shall be posted by the employer in a prominent place accessible to the employees for a period of 30 calendar days.

Highlights of the NIOSH Health Hazard Evaluation

In April 2003, the National Institute for Occupational Safety and Health (NIOSH) received a health hazard evaluation (HHE) request from the Joint Pacific Marine Safety Code Committee to evaluate worker exposure to diesel exhaust during marine container handling operations. From September 2003 to July 2005, field surveys were conducted at the Long Beach, California; Oakland, California; and Tacoma, Washington marine terminals to measure diesel exhaust, carbon monoxide (CO), and airborne particulate concentrations, and to conduct medical interviews with concerned workers.

What NIOSH Did

- We took 168 personal breathing zone (PBZ) samples for diesel exhaust across 15 job titles.
- We took 21 area air samples for diesel exhaust.
- We took 60 PBZ samples for CO across 13 job titles.
- We took area air samples for particles.
- We checked weather conditions.
- We conducted medical interviews with workers.

What NIOSH Found

- Average diesel exhaust exposure did not exceed the California Department of Health Services recommended exposure limit of 20 micrograms per cubic meter of air (µg/m^3) across all terminals.
- On six occasions, PBZ air samples for diesel exhaust exceeded 20 µg/m^3.
- CO exposures, on average, were low but some jobs had peak exposures above the NIOSH Recommended Exposure Limit Ceiling of 200 parts per million (ppm).
- Most airborne particle concentrations were similar to background levels. Higher concentrations were measured during some tasks such as welding and working on running diesel engines.
- Medical interviews indicated a possible link between exposure to diesel exhaust and reported health symptoms.

What Marine Terminal Managers Can Do

- Move the exhaust stack on Side Picker equipment to reduce the chances of diesel exhaust entering the cab.
- Improve ventilation in repair shops if diesel engines will be operated indoors.
- Use flexible hoses connected to diesel engine exhaust pipes to direct combustion products outside the Shop work area.

What Marine Terminal Employees Can Do

- Side Picker operators should keep cab windows closed, if possible, to prevent diesel exhaust from entering the cab.
- Shop Men should be aware of where the diesel engine's exhaust pipe is and try to minimize their time near running engines.
- Report illnesses you believe are related to your work to your physician or company doctor.

What To Do For More Information:
We encourage you to read the full report. If you would like a copy, either ask your health and safety representative to make you a copy or call 1-513-841-4252 and ask for HETA Report #2003-0246-3013

Health Hazard Evaluation Report 2003-0246-3013
Joint Pacific Marine Safety Code Committee
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SUMMARY

On April 30, 2003, the National Institute for Occupational Safety and Health (NIOSH) received a request from the Joint Pacific Marine Safety Code Committee (JPMSCC) in San Francisco, California, to conduct a health hazard evaluation (HHE). The JPMSCC comprises members from the International Longshore and Warehouse Union (ILWU) and the Pacific Maritime Association (PMA). They were concerned about worker exposure to equipment-generated diesel exhaust during move/load/unload operations at marine terminals along the Pacific Coast. This report summarizes the evaluations at terminals in Long Beach and Oakland, California and Tacoma, Washington.

NIOSH collected full-shift personal breathing zone (PBZ) and ambient area air samples for diesel exhaust (using elemental carbon [C_e] as a surrogate for exposure) and carbon monoxide (CO). Additionally, ambient airborne particulate matter concentrations and meteorological conditions were monitored. Voluntary confidential medical interviews with a physician were also conducted. Results from 168 air samples for C_e collected across 15 job titles ranged from 1.0 micrograms per cubic meter of air (µg/m^3) to 42 µg/m^3, and only six (4%) exceeded the California Department of Health Services, Hazard Evaluation System and Information Service (HESIS) recommended exposure limit of 20 µg/m^3. When the data for PBZ samples were pooled and a mean exposure value calculated for each job title across all terminals, none of the job titles or ambient area air samples collected for C_e exceeded the HESIS exposure limit. However, the mean exposure for the Side Picker job title at Oakland did exceed the HESIS limit. While none of the 60 PBZ time-weighted average CO exposures exceeded occupational exposure criteria, some peak exposures did momentarily exceed the NIOSH ceiling limit of 200 parts per million (ppm). Results for the airborne particulate matter measurements indicate that some tasks, such as electric arc welding, street cleaning operations, and working near idling diesel engines increase particle concentrations above background levels. Interviewed workers reported symptoms consistent with exposure to diesel exhaust. Tasks such as working near idling diesel engines and installing/testing generator sets are associated with higher levels of diesel exhaust exposure and reported symptoms.

NIOSH investigators conclude that a potential health hazard existed at the time of these surveys for workers in certain job titles. CO peak exposures occasionally exceeded the NIOSH REL of 200 ppm (Shop Men, Transtainer Mechanic, Side Picker). These peaks, however, mostly occurred during lunch and/or breaks and could be related to exposure to cigarette smoke. Symptoms reported by workers were consistent with exposure to diesel exhaust and tasks performed by workers in specific job titles (Shop Men working on running diesel engines) put them at risk of overexposure. Most diesel exhaust exposures, however, did not exceed the HESIS recommended exposure limit of 20 $\mu g/m^3$. The exhaust system on Side Picker equipment should be directed away from the cab to reduce operator exposure to diesel exhaust, and Side Picker operators should keep the cab windows closed. If diesel engines are to be operated in the repair shop, exhaust ventilation should be improved to prevent the buildup of diesel exhaust within the shop. Shop Men should avoid exhaust pipes when working on running diesel engines, and use a flexible hose attached to the engine's exhaust pipe, routing the hose outdoors.

Keywords: NAICS 488320, Diesel exhaust, carbon monoxide, airborne particulate, meteorological conditions, longshoring, stevedoring, marine terminal, cargo container handling

Table of Contents

INTRODUCTION

On April 30, 2003, the National Institute for Occupational Safety and Health (NIOSH) received a request from the Joint Pacific Marine Safety Code Committee (JPMSCC) located in San Francisco, California, to conduct a health hazard evaluation (HHE). The JPMSCC comprises members from the International Longshore and Warehouse Union (ILWU) and the Pacific Maritime Association (PMA). The principal business of the PMA is to negotiate and administer maritime labor agreements with the ILWU. The JPMSCC was concerned about worker exposure to equipment-generated diesel exhaust during move/load/unload operations at marine terminals along the Pacific Coast (Long Beach, California; Oakland, California; Tacoma, Washington; and Portland, Oregon).

Members of the ILWU who work at the marine terminals expressed concern related to short- and long-term exposure to diesel exhaust. Some workers claimed that exposure to diesel exhaust resulted in a variety of health effects including eye, nose, and throat irritation; shortness of breath; chronic coughing; nausea; and asthma. In response to the request, a NIOSH investigator met with ILWU and PMA representatives on July 14, 2003, in Long Beach, California, to obtain background information on job categories and work practices, discuss health concerns, and devise an exposure assessment strategy. Over a period of 2 years, NIOSH investigators evaluated exposure to diesel exhaust at the following terminals: Yusen Terminals, Incorporated (YTI), at the Port of Long Beach from September 8–11, 2003; American Presidents Line (APL) at the Port of Oakland from August 16–19, 2004; and Washington United Terminals (WUT) at the Port of Tacoma from July 12–14, 2005. The marine terminal at the Port of Portland was not evaluated because data collected from the previous three terminals provided enough exposure information to estimate the magnitude of worker exposure and make recommendations to reduce exposures. Full-shift personal breathing zone (PBZ) air samples for diesel exhaust were collected across 13 to 15 different job categories at each marine terminal. Additionally, full-shift ambient area air samples for diesel exhaust were collected at various fixed locations at each marine terminal. In addition, carbon monoxide (CO), ambient airborne particle size data, and on-site meteorological data were collected. NIOSH investigators also interviewed employees and reviewed health and safety records. An interim report was issued for each of the terminals surveyed: Long Beach, December 2003; Oakland, January 2005; and Tacoma, November 2005. Each interim report included the exposure monitoring results for the specific terminal.

METHODS

Environmental Sampling

To characterize airborne exposures for each job title, PBZ samples and ambient area air samples were collected and analyzed for elemental carbon [C_e], a surrogate measure of diesel exhaust. Volunteers wore PBZ air sampling devices while engaged in normal work practices. Air samples were collected and analyzed in accordance with NIOSH Manual of Analytical Methods (NMAM) Method 5040.[1] The samples were collected on 37-mm quartz-fiber filters enclosed in cassettes connected via a length of Tygon® tubing to battery-powered air sampling pumps (AirCheck 2000: SKC Inc., Eighty Four, Pennsylvania) operated at a nominal flow rate of 2.5 liters per minute (Lpm).

At the Long Beach, California marine terminal, some workers completed their normal duties before their 8-hour shift was over. In these instances, NIOSH investigators transferred the sampling pump to the “relief” worker (a person who continues performing the same job after the original worker completes their shift) to obtain a full 8-hour time-weighted average (TWA) sample for that particular job title. Ambient area air samples for C_e were collected at various locations within the terminal boundaries (see Figures 1–3 for sampling locations at each marine terminal). These samples provide an indication of background levels of diesel exhaust. All calculations and statistical manipulations were performed using SAS for Windows, version 8, (SAS Institute, Cary, North Carolina).

Because CO can be a substantial component of diesel exhaust and can cause adverse health effects, it was also measured. A randomly selected subset of workers within various job titles were asked if they would wear the CO sampling devices (ToxiUltra Atmospheric Monitors, Biosystems Inc., Middletown, Connecticut). The samplers log the CO levels, which can be downloaded to a laptop computer. Once again, samplers were transferred to a relief worker if the original worker was not scheduled to complete an 8-hour shift.

Because airborne particle size can affect respiratory exposure, concentrations of particles in specific size ranges were measured using a light-scattering automatic particle counter (Model HHPC-6, ART Instruments Inc., Grants Pass, Oregon). This instrument measures the total number of particles, regardless of origin, in six size ranges (0.3 micrometers [µm]–0.5 µm, 0.6–1.0 µm, 1.1–3.0 µm, 3.1–5.0 µm, and 5.1–10 µm). This instrument was used to identify potential sources of particulate and measure airborne particle concentrations during work tasks to compare to background levels.

Because of the potential effect of weather on exposures in this outside work environment, meteorological information was collected daily using a portable weather station (Qualimetrics Inc., Sacramento, California). Weather variables, such as wind speed, wind direction, temperature, relative humidity, and barometric pressure, were recorded.

Medical Evaluation

Prior to each NIOSH site visit, ILWU representatives informed their members of the dates that NIOSH investigators would be on-site and encouraged their participation in our confidential interviews. Through self-selection, 69 employees volunteered to participate. NIOSH investigators also reviewed available medical records, and reviewed the Occupational Safety and Health Administration (OSHA) Log and Summary of Occupational Injuries and Illnesses (forms 200 and 300) for Southern and Northern California, and the Washington Longshore registrants for the years 1998–2005.

EVALUATION CRITERIA

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

The primary sources of environmental evaluation criteria for the workplace are: (1) NIOSH Recommended Exposure Limits (RELs),[2] (2) the American Conference of Governmental Industrial Hygienists' (ACGIH®) Threshold Limit Values (TLVs®),[3] and (3) the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs).[4] Employers are encouraged to follow the OSHA limits, the

NIOSH RELs, the ACGIH TLVs, or whichever are the more protective criteria.

OSHA requires an employer to furnish employees a place of employment that is free from recognized hazards that are causing or are likely to cause death or serious physical harm [Occupational Safety and Health Act of 1970, Public Law 91–596, sec. 5(a)(1)]. Thus, employers should understand that not all hazardous chemicals have specific OSHA exposure limits such as permissible exposure limits (PELs) and short-term exposure limits (STELs). An employer is still required by OSHA to protect their employees from hazards, even in the absence of a specific OSHA PEL.

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

Health Effects of Diesel Exhaust

The emissions from diesel engines consist of a complex mixture that includes gaseous and particulate fractions. The composition of the mixture varies greatly with fuel and engine type, load cycle, maintenance, tuning, and exhaust gas treatment. The gaseous constituents include carbon dioxide (CO_2), CO, nitric oxide (NO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and volatile organic compounds (VOCs) (e.g., ethylene, formaldehyde, methane, benzene, phenol, acrolein, and polynuclear aromatic hydrocarbons).[5,6,7,8] The particulate fraction (soot) is composed of solid carbon cores produced during the combustion process, which tend to combine to form chains of particles or aggregates, the largest of which are in the respirable range (more than 95% are less than 1 micron in size).[9] Estimates indicate that as many as 18,000 substances resulting from the combustion process may be adsorbed onto these particulates.[10] The adsorbed material contains 15%–65% of the total particulate mass and includes compounds such as polynuclear aromatic hydrocarbons, a number of which are known mutagens and carcinogens.[11,12]

Many of the individual components of diesel exhaust are known to have toxic effects. The following health effects have been associated with some of the components of diesel exhaust: (1) pulmonary irritation from oxides of nitrogen; (2) irritation of the eyes and mucous membranes from SO_2, phenol, sulfuric acid, sulfate aerosols, and acrolein; and (3) cancer in animals from polynuclear aromatic hydrocarbons.[10] Several studies confirm an association between exposure to whole diesel exhaust and lung cancer in rats and mice. Limited epidemiological evidence suggests an association between occupational exposure to diesel exhaust emissions and lung cancer.[13] The agreement of current toxicological and epidemiological evidence led NIOSH in 1988 to recommend that whole diesel exhaust be regarded as a "potential occupational carcinogen," as defined in the OSHA Cancer Policy ("Identification, Classification, and Regulation of Potential Occupational Carcinogens," 29 CFR 1990).[2,4] Accordingly, NIOSH recommends controlling exposures to the lowest feasible concentration. Although OSHA and ACGIH have exposure limits for some of the individual components of diesel exhaust (i.e., NO_2, xylene, and CO), neither a PEL nor a TLV has been established for whole diesel exhaust.[3,4] The California Department of Health Services, Hazard Evaluation System and Information Service (HESIS) has published an 8-hour TWA recommended exposure limit of 20 $\mu g/m^3$ measured as C_e.[14]

Carbon Monoxide

CO is a colorless, odorless, tasteless gas produced by incomplete burning of carbon-containing materials (e.g., diesel fuel, gasoline, natural gas). The initial symptoms of CO poisoning may include headache, dizziness, drowsiness, and nausea. If prolonged or high exposures occur, these initial symptoms may advance to vomiting, loss of consciousness, collapse, coma, or death.

The NIOSH REL for CO is 35 parts per million (ppm) for up to an 8-hour TWA exposure, with a ceiling limit of 200 ppm which should not be exceeded.[2] The ACGIH has established an 8-hour TWA-TLV of 25 ppm, with a ceiling level of 400 ppm.[3] The OSHA PEL for CO is 50 ppm for an 8-hour TWA exposure.[4]

RESULTS

Diesel Exhaust

A total of 189 air samples (168 PBZ and 21 ambient area air samples) for C_e were collected across three marine terminals (See Tables 1–5). For the 54 samples collected at Long Beach, 29 (54%) were below the minimum quantifiable concentration (MQC) and were considered "trace" concentrations (< 3.4 µg/m^3). Only two samples were found to be less than the minimum detectable concentration (MDC) of approximately 1 µg/m^3. The percentage of trace concentrations was 35% at Oakland and 56% at Tacoma. To be included in statistical analyses, samples found to contain trace amounts were assigned values equal to the MDC. At Long Beach, some filters appeared "disturbed," that is, the surface of the filter had visual evidence of a fingerprint or contact with some object that resulted in a heavy deposit or tearing of the filter. In such cases, the laboratory analyst visually selected an "undisturbed" area of the filter to analyze for C_e, if such an area was available. If no such area was available for analysis, the data generated from that particular sample were not used in the statistical analysis. In order to prevent incidental contact with the air sampling filter media, all filter cassettes were operated in closed-face mode at Oakland and Tacoma.

A statistical summary of all PBZ C_e samples, stratified by job category, is presented in Table 1. Not all job titles were present at all marine terminals (e.g., no Lane Clerks, Transtainer Operators, Transtainer Mechanics were present in Tacoma). Additionally, not all job titles were sampled equally in number because they were not equally distributed at each marine terminal. The 168 PBZ samples across 15 job titles were analyzed by the Tukey-Kramer Multiple Comparison Test to determine whether significant differences across mean exposure values existed. The mean exposure values for the pooled data ranged from 2.5 µg/m^3 (Crane Operators) to 12 µg/m^3 (Shop Men). The mean exposure value for Shop Men (12 µg/m^3) was significantly higher than nearly all other job titles ($p < 0.05$). Maximum exposure values ranged from 5.2 µg/m^3 (Crane Operator) to 42 µg/m^3 (Shop Man). However, no mean exposure value for any job title exceeded the HESIS recommended exposure limit of 20 µg/m^3.

A total of 21 ambient area air samples for C_e (Table 2) were collected at various locations at each of the three marine terminals (Long Beach – 6; Oakland – 10; Tacoma – 5). Mean concentrations ranged from 1.9 µg/m^3 (Tacoma) to 5.0 µg/m^3 (Oakland) with Oakland significantly higher than the other two ports ($p < 0.05$). Maximum concentrations ranged from 2.6 µg/m^3 (Tacoma) to 10 µg/m^3 (Oakland). The location of the ambient area air samples is noted in Figures 1–3.

Summary statistics of the PBZ C_e data stratified by marine terminal appear in Tables 3–5. All individual PBZ and ambient area air sample data used in the statistical analysis appear in Appendix A.

Carbon Monoxide

A total of 60 full-shift PBZ samples across 16 job titles were collected at the three marine terminals. Most mean TWA exposure values ranged from 0.0 ppm to 1.0 ppm, regardless of marine terminal or job title. Peak values for all job titles ranged from 1.0 ppm to 1515 ppm. At Oakland, a Transtainer Operator's CO measurement averaged 39 ppm with a peak value of 1515 ppm. Upon reviewing this worker's time-series data, it became evident that the sampling instrument may have been placed by the worker very near a strong source of CO (i.e., an exhaust tailpipe). This conclusion is supported by the fact that the data exhibited a defined "ramping effect" for a few minutes and then returned to values in the 1 ppm to 2 ppm range. This exposure pattern was repeated a few times throughout the shift. With these questionable data removed from the analysis, this worker's average exposure decreased to 2 ppm, a value very similar to other Transtainer Operators. Peak values ranged from 2.0 ppm to 228 ppm (excluding the suspect value of 1515 ppm). For comparison, the ACGIH TLV is 25 ppm for an 8-hour TWA.[3] The NIOSH REL is 35 ppm for up to an 8-hour TWA, with a Ceiling Limit of 200 ppm.[2] The OSHA PEL for CO is 50 ppm for an 8-hour TWA exposure.[4] A summary of CO data is presented in Table 6, and all original data appear in Appendix B.

Airborne Particulate and Meteorological Data

A total of 56 measurements were taken across the three marine terminals. In general, ambient air particle concentrations at the three marine terminals were similar (Appendix C–E). However, specific events did tend to increase particle concentrations. At Oakland, one sample collected during "street cleaning" operations showed a 14-fold increase in airborne particle concentration in the 3.1–5.0 µm range while a 16-fold increase was noted for particles in the 5.1–10 µm range. During electric arc welding inside the chassis shop, a similar but smaller trend was measured (5-fold increase for 3.1–5.0 µm particles; 6-fold increase for 5.1–10 µm particles). At Tacoma, three events lead to increases in particle concentrations in the 5.1–10 µm range relative to ambient background. One sample collected near an idling outbound truck under the Power Shop canopy ("Roadability" check station) showed a 21-fold increase in airborne particle concentration in the 3.1–5.0 µm range when compared to an identical measurement taken when the truck's engine was not running. For the 5.1–10 µm particle size range, a 108-fold increase was observed during this operation. During electric arc welding outside the Power Shop, a similar trend was observed (52-fold increase for the 3.1–5.0 µm particle size range; 772-fold increase for 5.1–10 µm particle size range when compared to measurements collected outside the Power Shop with no trucks running or welding operations in the immediate vicinity). Finally, measurements collected in the breathing zone of a Shop Man during diesel generator start-up showed an increase of 31-fold in the 3.1–5.0–µm particle size range and 257-fold in the 5.1–10 µm particle size range.

At each of the three marine terminals, meteorological data were collected throughout the day (Appendix F). While wind speed varied from 0.0 to 16 miles per hour, wind direction was predominantly from the west. Temperatures ranged from 19 degrees Celsius (^{o}C) in the morning to 28^{o}C in the afternoon while relative humidity ranged from 40% to 76%. Barometric pressure was similar across all marine terminals and sampling days and ranged from 29.72 millimeters of mercury (mmHg) to 30.24 mmHg. No rain occurred during any sampling event.

Medical Evaluation

At Long Beach, out of a possible 280 employees present during industrial hygiene sampling, 13 (4.6%) volunteered to participate in private interviews with NIOSH medical personnel. The self-described job titles included Crane Operators, Tractor Drivers, Gate Employees, Gear Men, General Yard and Swing Workers, Signal Men, and Lashers. One medical record was provided to the NIOSH investigators. The most frequently reported health concerns thought to be caused by diesel exhaust by those interviewed included eye, nose and throat irritation (in 5 of the interviewed workers), bronchitis (2 workers), allergies (2), nausea (2), sinus infections (2), shortness of breath (2), headaches (1), emphysema (1), chronic coughing (1), and asthma (1). The single medical record documented sinusitis and bronchitis, but did not address work-relatedness.

Other issues reported by the interviewed employees included inadequate maintenance of filters in vehicle cabs, lack of filters in "Transtainer" cabs, inadequate or unavailable respiratory protection at cement and sulfur docks, lack of clean drinking water at some terminals, personal protection suits being too large for some employees, and poor ergonomic design of entry area into trucks resulting in difficulty when repeatedly climbing into and out of truck cabs. One worker suggested installing showers somewhere on terminal property so employees could shower before leaving the site.

Review of the OSHA 300 logs showed that, among the approximately 4700 registered Southern California longshoremen, there were 7105 entries for injuries or illnesses during the period from January 1998, through August 2003. Of these, 30 (0.4%) were reported as exposures to fumes. The occupations listed for the workers who reported these exposures included eight Truck Drivers, six Clerks, five Crane Operators, three Dock Men, three Top Pickers, two Shop Men, one Lasher, one Sweeper, and one Manager. Symptoms from these exposures included headaches in 7 of the 30 (23%), nausea in 6 (20%), dizziness in 5 (17%), and difficulty breathing in 2 (7%).

At Oakland, out of 60 employees present during industrial hygiene sampling, 16 (27%) volunteered to participate and were privately interviewed by NIOSH medical personnel. The interviewed employees consisted solely of Shop Men who worked in the power, chassis, tire, and container shops. The health concerns thought to be caused by diesel exhaust reported by those interviewed included chronic coughing (in 4 of the interviewed workers), eye/nose/throat irritation (3 workers), headaches (3), sinus infections (2), shortness of breath (1), nausea (1) and wheezing (1).

Other issues that were reported by the interviewed employees included possible asbestos exposure from removal of ceiling material in the Chassis Shop, discomfort of respirators, possible CO exposure from equipment, and high noise levels. Recommendations suggested by those interviewed included more detailed respirator training, provision of welding hoods that can accommodate respirators, training in cardiopulmonary resuscitation (CPR) for Lead Men and Supervisors, improved ventilation, emission controls on vehicles, air monitoring for CO, better cleaning of shops, and enforcement of rules to keep trucks from idling.

Review of the OSHA 300 logs showed 3434 entries for injuries or illnesses from January 1998 through July 2004 among the approximately 1430 registered Northern California longshoremen. Of these, 18 (0.6%) were reported as exposures to fumes or chemicals from diesel exhaust. The occupations listed for the people who reported these exposures included six Crane Operators, four Lashers, three Truck Drivers, three Hold Men, one Top Picker and one Foreman. Symptoms from these exposures included nausea in six of the 18 (33%), headache in five (27%), dizziness in two (11%), throat irritation in one (5%) and eye irritation in one (5%).

At Tacoma, out of a possible 205 employees present during industrial hygiene sampling, 40 (20%) volunteered to participate in private interviews with NIOSH medical personnel. These included Yard and Ship Tractor Drivers, Crane Operators, Supervisors, Dock Men, and Shop Men. The health concerns interviewees thought were related to exposure to diesel emissions included headaches (in 9 of the interviewed workers), sneezing (4 workers), coughing (4), nausea (3), allergies (2), asthma (2), nose bleeds (2), bad taste in mouth (2), sinus infections (2), drowsiness (1), heartburn (1), frequent colds (1), sore throat (1), chest tightness (1), and nasal congestion (1).

Interviewed employees also reported their observations relating to diesel exhaust exposure at the work site. These observations included the following: “T-trucks” seem to be worse than other trucks with regard to diesel exhaust output; heavy output occurs upon startup of trucks, especially in the morning when they are all started at one time and allowed to warm up; the fans in the trucks are often broken so they do not provide cab ventilation; maintenance and emission testing are not performed on the trucks regularly; and respirators or dust masks are not readily available for most jobs for people who would like to wear them. The interviewed workers also provided suggestions for improving the work environment. These included making sure the fans work in all trucks; adding a second fan to the trucks; reconfiguring the exhaust pipes on the trucks so they exhaust to the outside of the breathing zones of the drivers of adjacent trucks; adding filters to the exhaust pipes on the trucks; configuring the fuel system to re-trap the fuel or to a system similar to a turbo system; using different fuel such as propane, lower emission diesel, biodiesel or emulsified fuel; requiring regular emissions testing and compliance with vehicle emission standards; replacing old equipment; making respirators/dust masks available in break rooms; sweeping out the decks of the vessels prior to working on them to decrease particulate matter; and maintaining the road surfaces at the terminals so the trucks do not experience excess wear and tear due to poor road conditions.

Review of the OSHA 200 and 300 logs showed that, among the approximately 976 individuals registered with the Tacoma Longshoreman local unions, there were 793 entries for injuries or illnesses during the period from January 1998 through July 2005. Of these, 25 (3.2%) were reported as exposures to fumes or chemicals. The occupations listed for the people who reported these exposures included nine Crane Operators, seven Lashers, four Tractor Drivers, three Lift Drivers, one Foreman, one Holdman and one unknown. Symptoms from these exposures included nausea in 6 (24%) of the 25, dizziness in 5 (20%) and fainting in 5 (20%).

DISCUSSION

Diesel Exhaust

The goal of this evaluation was to measure airborne levels of diesel exhaust for different job titles at Pacific coast marine terminals and to compare the levels to the California Department of Health Services HESIS-recommended exposure limit of 20 µg/m^3. Of the Pacific coast marine terminals, the Port of Long Beach YTI terminal was deemed, *a priori* by the ILWU to have the greatest potential diesel exhaust exposure. However, PBZ and ambient area air sampling indicated that most exposures at the YTI terminal were very low relative to the other marine terminals surveyed, and some job categories (Crane Operators and Rail Men) had no detectable exposures.

At the Port of Oakland APL terminal, only the Side Picker (mean = 21 µg/m^3) exceeded the HESIS exposure limit. The next highest mean exposure was measured on the Shop Man (12 µg/m^3). In the case of the Side Picker, the exhaust outlet was positioned slightly above and closer to the cab. This position, coupled with the cab door and/or window of the Side Picker remaining open for most of the workday, could contribute to higher PBZ levels of diesel exhaust. Additionally, the height of the Side Picker cab was approximately the same height as the exhaust outlets of idling semi-trucks awaiting container loading/unloading. The fact that semi-trucks idled while being loaded/unloaded could also contribute to elevated airborne levels of diesel exhaust inside the cab of the Side Picker. With regard to the airborne levels of diesel exhaust encountered by the Shop Men, it appears that working underneath the outbound canopy adjacent to the shop (while trucks idled) could account for their somewhat higher exposures (approximately 2.5 times higher than ambient). The remaining five job titles (Crane Operators, Guards, Hatch Bosses, Ship Tractor Drivers, and Walking Bosses) had "trace" exposures (between the MDC and the MQC).

At the Port of Tacoma WUT terminal, of the 70 samples collected for diesel exhaust (PBZ and ambient area), 39 were found to contain "trace" amounts (<4.3 µg/m^3). However, one Ship Tractor Driver had an exposure of 33 µg/m^3 although data from all other samples collected during identical work ranged from 5 µg/m^3 to 13 µg/m^3. Therefore, this single high value skewed the average exposure for this category. Overall, the highest mean exposure value across all job titles was 10 µg/m^3 (Ship Tractor Driver) while the lowest was 2 µg/m^3 (Hatch Boss).

Two factors likely played a role in keeping exposure levels low for most of the job titles evaluated. First, concentrations were measured outdoors. This factor can exert a substantial dilution effect on any airborne contaminant. The second factor involves the location of the exhaust outlet relative to the operator. Most of the powered equipment had exhaust outlets on the side of the vehicle opposite the operator. This would, in effect, direct the engine exhaust away from the operator, thereby reducing and/or eliminating exposure. However, if the windows on the equipment were rolled down, and wind currents directed diesel exhaust back toward the cab, higher PBZ exposures could result.

Mean exposure values for some job titles were substantially different than other job titles; however, due to the relatively small sample size, the difference was not statistically significant (e.g., only two samples collected for Transtainer Mechanic and Transtainer Operator). Of the 168 PBZ samples collected for diesel exhaust, six exceeded the HESIS recommended exposure limit (Appendix A).

Carbon Monoxide

Most CO exposures at all three marine terminals were very low. A few workers (Ship Tractor Driver, Transtainer Clerk) had average exposures higher than the majority of the other job titles sampled (12 ppm and 19 ppm vs. 0 ppm to 4 ppm). Other workers (Guards and Lane Clerks) had occasional, short-term increases in CO exposure. However, these excursions in CO concentration may not reflect occupational exposure caused by work tasks or equipment if the workers smoked, or were in the vicinity of smokers while wearing the measurement device, because cigarette smoke contains CO. Also, such short-duration increases had very little effect on the full-shift TWA exposure.

With respect to CO exposures at Tacoma, one worker (Shop Man) had a peak exposure of 443 ppm that may be due to installing/testing generator sets while near the exhaust pipe of a running diesel engine. Also, one worker's peak exposure value (Top Picker) occurred during breaks and lunch and was not associated with the operation of diesel powered equipment. This worker may have been a cigarette smoker or have been around smokers.

Airborne Particulate and Meteorological Data

Of particular interest is the concentration of particles in the 5–10 µm range, which are important physiologically because they penetrate deepest into the lungs. Most particles smaller than 5 µm remain suspended in air and are expired upon exhalation. Because we did not determine the chemical composition of these particles, it is impossible to use the data to isolate the diesel particulate component. However, some work practices at Oakland and Tacoma did result in increased airborne particulates in the 5–10 µm range (See Appendix C–E for comparisons). At Oakland, one worker operating a Street Sweeper and another operating an electric arc welder caused an increase in particle concentrations. At Tacoma, Shop Men who welded, worked on operating generator sets, or worked near idling trucks under the outbound "Roadability" canopy were more likely to be exposed to higher than background concentrations of particles. However, once these tasks ended, or the truck departed, particle concentrations returned to ambient background levels.

Meteorological conditions (wind speed, temperature, relative humidity, and barometric pressure) did not vary widely at the three marine terminals (Appendix F). Wind direction did vary slightly. Exposure levels may be different under meteorologic conditions different from those at the time of the NIOSH evaluation.

Medical

Neither the symptoms reported by the interviewed worker's nor those on the OSHA 200 and 300 forms are readily associated with a specific causative agent. While some of the symptoms, such as eye, nose, and throat irritation, coughing, nausea, dizziness, allergies and asthma are consistent with exposure to diesel exhaust, they are common in the general population and can be caused by a variety of substances both inside and outside the workplace. However, they could be caused or exacerbated by diesel exhaust exposure, even if measured exposures are not above accepted levels.[15] The low level of participation in medical interviews (5% in Long Beach, 27% in Oakland, and 20% in Tacoma) makes confirming any association between exposure to diesel exhaust and symptoms difficult.

Suggestions for improving work conditions were provided by many of the interviewed employees. These are detailed in the Results section of this report. Many of these suggestions were brought up by more than one employee, indicating that these are issues that employees would like to see addressed.

CONCLUSIONS

In general, the low concentrations of diesel exhaust particulate and CO are consistent with the findings of previous NIOSH evaluations that examined worker exposure to diesel exhaust.[16,17] Occasional excursions above the HESIS recommended exposure limit for diesel exhaust of 20 µg/m^3, indicate that a potential health hazard exists for workers in certain job titles. In the case of the Side Picker operators at Oakland, the location of the exhaust stack appeared to play a major role in increasing exposure to diesel exhaust, along with the fact that trucks idled while being loaded/unloaded, and the operator often kept the windows of the cab open. Shop Men also received higher exposure to diesel exhaust relative to other job titles, and this is most likely due to working closely with running diesel engines in somewhat confined spaces (e.g., under a canopy, inside a repair shop, or installing and testing a generator set).

The CO data do not indicate exposures that would consistently exceed occupational exposure limits and that, on average, workforce exposures are similar across the three marine terminals. However, Shop Men who install/test generator sets may experience peak exposures that could exceed the NIOSH ceiling of 200 ppm.

The airborne particle size data suggest that particle concentrations in the 5 to 10 µm range were similar across the three marine terminals, except when short duration, particle-generating tasks such as electric arc welding or starting a diesel generator were conducted. However, once the tasks were completed, particle concentrations decreased to ambient concentrations.

RECOMMENDATIONS

The following recommendations should be considered for implementation at the three marine terminals evaluated. These recommendations may also be useful at other marine terminals.

1. Redirect the exhaust stack away from the Side Picker operator cab.

2. When air-conditioning is turned on, the Side Picker operator should keep the windows closed to reduce infiltration of diesel exhaust into the cab.

3. Have trucks awaiting loading/unloading shut down their engines to prevent their exhaust from infiltrating the cab of the Side Picker.

4. Repair shops should use mechanical ventilation (e.g., fans that move air from ground level out through the roof) to remove diesel exhaust.

5. Flexible hoses should be attached to the exhaust pipes of operating diesel engines within the repair shops and routed outdoors to prevent buildup of diesel exhaust.

6. Install diesel engine exhaust filters.

7. When working on diesel generator sets, care should be taken not to position one’s body close to the exhaust, especially during startup when more diesel soot is produced.

8. Report all exposures and potentially work-related health problems to a health care provider. Because the work-relatedness of certain health concerns may be difficult to prove, each person with possible work-related health problems needs to be fully evaluated by a physician familiar with occupational conditions.

9. Meetings between employee and union representatives and management should be convened on a regular basis to address issues

that concern employees. Issues, observations and suggestions that were reported by employees during the NIOSH interviews (detailed in the Results section of this report) should be discussed with employees and addressed.

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Table 1 **Summary Statistics for Diesel Particulate Personal Breathing Zone Air Samples - All Terminals Combined** **Joint Pacific Marine Safety Code Committee, San Francisco, California (HETA 2003-0246-3013)** **Concentrations shown in micrograms/cubic meter (μg/m^3)**						
Job Title ID	**Job Title**	**Number of Samples**	**Mean**	**Std Dev**	**Range**	**Mean Value Was Significantly Different* Than Other Job Title ID Numbers**
1	Shop Man	18	12	9.0	2.1-42	6-9, 11-15
2	Side Picker	8	12	8.7	12-22	12-15
3	Ship Tractor Driver	17	7.3	7.3	1.7-33	14-15
4	Transtainer Mechanic	2	6.4	3.0	4.3-8.5	
5	Yard Tractor Driver	13	6.2	3.1	1.6-14	14-15
6	Dockman	14	5.1	2.6	1.6-11	1
7	Top Picker	17	5.0	2.2	2.4-9.0	1
8	Hatch Clerk	12	4.6	2.9	1.8-12	1
9	Lane Clerk	9	4.5	2.2	1.5-7.6	1
10	Transtainer Operator	5	4.4	2.7	2.5-9.0	
11	Walking Boss/Yard Supervisor	7	3.7	0.9	2.4-5.1	1
12	Guard	14	3.2	1.3	1.3-5.4	1,2
13	Rail Man	8	3.0	1.7	1.0-5.0	1,2
14	Hatch Boss	10	2.6	2.2	0.8-8.1	1-3,5
15	Crane Operator	14	2.5	1.2	1.0-5.2	1-3,5
* indicates mean concentration for a specific job title was compared to the mean for each other job title using the Tukey-Kramer Multiple Comparison Test at a significance level of $p<0.05$.						

Table 2 **Summary Statistics for Diesel Particulate Ambient Air Samples -By Terminal** **Joint Pacific Marine Safety Code Committee, San Francisco, California (HETA 2003-0246-3013)** **Concentrations shown in micrograms/cubic meter (μg/m^3)**						
Terminal ID	**Terminal Name**	**Number of Samples**	**Mean**	**Std Dev**	**Range**	**Mean Value Was Significantly Different* Than Other Terminal ID Numbers**
1	Long Beach	6	2.9	2.8	0.7-7.4	
2	Oakland	10	5.0	2.5	1.8-10	1,3
3	Tacoma	5	1.9	0.6	1.1-2.6	
* indicates mean concentration for a specific terminal was compared to the mean for each other terminal using the Tukey-Kramer Multiple Comparison Test at a significance level of $p<0.05$.						

Table 3 **Summary Statistics for Diesel Particulate Personal Breathing-Zone Air Samples** **Yusen Terminals, Inc. (YTI) – Port of Long Beach** **Joint Pacific Marine Safety Code Committee, San Francisco, California (HETA 2003-0246-3013)** **Concentrations shown in micrograms/cubic meter (µg/m³)**				
Job Title	**Number of Samples**	**Mean**	**Standard Deviation**	**Range**
Shop Man – Repair *	3	23	17	11–42
Dockman/Signalman **	5	5.6	4.1	1.6–11
Side Picker	3	5.0	6.0	1.6–12
Yard Tractor Driver **	4	4.7	2.6	2.1–7.0
Top Picker - Rail Yard	5	3.5	0.7	2.9–4.7
Ship Tractor Driver **	5	3.5	1.1	1.7–4.6
Lane Clerk **	4	3.0	1.4	1.5–4.8
Hatch Boss **	4	3.0	3.5	0.8–8.1
Hatch Clerk **	4	2.8	1.1	1.8–3.8
Guard **	4	2.5	1.1	1.3–3.7
Crane Operator ***	4	1.9	0.9	1.3–3.2
Rail Man - Dock Aloft ***	3	1.1	0.0	1.0–1.1

MDC = Minimum Detectable Concentration = 0.86 µg/m³
MQC = Minimum Quantifiable Concentration = 3.42 µg/m³
* indicates one sample was disturbed. If that value (42 µg/m³) is omitted from the statistical analysis, the mean value for the remaining two samples would be 13 µg/m³
** indicates some samples fell between the MDC and the MQC. In such cases, imputed values were used based on either the MDC (for the not detected values) or the reported laboratory value (for the "trace" concentrations).
*** indicates all samples were below the limit of detection, but the MDC was used for calculation purposes.

Table 4 **Summary Statistics for Diesel Particulate Personal Breathing-Zone Air Samples** **American Presidents Line (APL) – Port of Oakland** **Joint Pacific Marine Safety Code Committee, San Francisco, California (HETA 2003-0246-3013)** **Concentrations shown in micrograms/cubic meter (µg/m^3)**				
Job Title	**Number of Samples**	**Mean**	**Standard Deviation**	**Range**
Side Picker	3	21**	1.1	20–22
Shop Man	9	12	5.2	6.9–21
Yard Tractor Driver *	4	7.7	5.1	1.6–14
Hatch Clerk *	4	7.4	3.4	5.0–12
Transtainer Mechanic	2	6.4	3.0	4.3–8.5
Ship Tractor Driver *	4	5.9	4.3	3.0–12
Top Picker *	5	5.7	2.8	2.4–9.0
Lane Clerk *	5	5.7	2.1	2.3–7.6
Transtainer Operator	5	4.4	2.7	2.5–9.0
Guard *	5	4.1	1.4	1.7–5.3
Crane Operator *	4	3.3	0.4	3.1–3.9
Walking Boss *	2	3.2	1.1	2.4–4.0
Hatch Boss *	3	2.8	0.6	2.3–3.5

MDC = Minimum Detectable Concentration: Crane Operators, Hatch Bosses, Hatch Clerks = 1.0 µg/m^3
MQC = Minimum Quantifiable Concentration: Crane Operators, Hatch Bosses, Hatch Clerks = 4.2 µg/m^3

MDC = Ship Tractor Drivers, Walking Bosses, Yard Tractor Drivers, Guards = 2.1 µg/m^3
MQC = Ship Tractor Drivers, Walking Bosses, Yard Tractor Drivers, Guards = 7.3 µg/m^3

MDC = Ambient air samples, Lane Clerks, Shop Men, Side Picker, Top Picker, Transtainer Mechanic Transtainer Operator = 0.9 µg/m^3
MQC = Ambient air samples, Lane Clerks, Shop Men, Side Picker, Top Picker, Transtainer Mechanic Transtainer Operator = 3.1 µg/m^3

* indicates some samples fell between the MDC and the MQC. In such cases, imputed values were used for calculating statistics based on the MDC for that particular job category.

** Value exceeds the California Department of Health Services Recommended Exposure Limit of 20µg/m^3.

Table 5 Summary Statistics for Diesel Particulate Personal Breathing-Zone Air Samples Washington United Terminals (WUT) - Port of Tacoma Joint Pacific Marine Safety Code Committee, San Francisco, California (HETA 2003-0246-3013) Concentrations shown in micrograms/cubic meter (µg/m^3)				
Job Title	**Number of Samples**	**Mean**	**Standard Deviation**	**Range**
Ship Tractor Driver	8	10	9.5	3.1–33**
Shop Man – Repair	6	7.7	5.0	2.1–14
Side Picker	2	7.6	4.9	4.1–11
Yard Tractor Driver	5	6.3	1.0	5.3–7.7
Top Picker - Rail Yard	7	5.5	2.2	2.9–8.2
Dockman/Signalman	9	4.8	1.5	2.9–7.8
Rail Man *	5	4.2	0.5	3.7–5.0
Yard Supervisor *	5	3.9	0.9	2.7–5.1
Guard *	5	3.0	0.8	1.7–3.9
Hatch Clerk *	4	3.7	1.6	2.0–5.7
Crane Operator *	6	2.4	1.6	1.0–5.2
Hatch Boss *	3	2.0	1.3	1.1–3.5

MDC = Minimum Detectable Concentration = 0.2 µg/m^3
MQC = Minimum Quantifiable Concentration = 4.3 µg/m^3
* Mean value is considered "trace" because it fell between the MDC and the MQC. In such cases, imputed values were used for calculating statistics based on the MDC for that particular job category.
** Value exceeds the California Department of Health Services Recommended Exposure Limit of 20 µg/m^3.

Table 6 **Summary of Carbon Monoxide PBZ Samples (By Terminal)** **Joint Pacific Marine Safety Code Committee, San Francisco, California (HETA 2003-0246-3013)** **Concentrations shown in parts per million (ppm)**					
Terminal I.D.	**Job Title**	**# of Samples**	**Range of Mean Values**	**Range of Peak Values**	**Comments**
Long Beach	Lane Clerk	4	0	1–57	
	Guard	4	<1	2–155	
	Crane Operator	1	0	38	
	Hatch Clerk	2	0	4–9	
	Hatch Boss	1	0	1	
	Ship Tractor Driver	1	0	1	
Oakland	Shop Man	3	<1	2–42	
	Ship Tractor Driver	5	0–4	4–128	Most exposure occurred during lunch period (smoker?)
	Guard	2	1–2	11–84	
	Yard Tractor Driver	1	2	23	
	Side Picker	1	0	5	
	Top Picker	2	0–12	5–69	
	Transtainer Operator	3	2–39	24–1515	Suspect sample (1515)
	Transtainer Clerk	1	19	71	Smoker
	Transtainer Mechanic	2	2–4	86–228	Working near running diesel engine exhaust pipe
	Hatch Boss	2	1–2	6–19	
	Hatch Clerk	1	0	6	
	Lane Clerk	1	1	4	
Tacoma	Shop Man	4	1–4	4–443	Working near running diesel engine exhaust pipe
	Dockman	3	1–2	2–24	
	Yard Tractor Driver	2	2–3	9–109	One worker is a smoker
	Ship Tractor Driver	2	1–2	7–16	
	Side Picker	1	1	75	
	Top Picker	2	2–4	14–250	All peak exposures occurred during lunch (smoker?)
	Hatch Clerk	2	3	17–19	
	Guard	1	1	3	
	Crane Operator	2	1–2	3–4	
	Yard Supervisor	1	2	13	Worker is a smoker
	Hatch Boss	1	2	62	
	Railman	2	2–5	14–47	

Appendix A
Original Data: Diesel Particulate Air Samples
Joint Pacific Marine Safety Code Committee, San Francisco, California (HETA 2003-0246-3013)
Concentrations shown in micrograms/cubic meter (μg/m^3)

Port I.D.	Crane Operator	Dock Man	Guard	Hatch Boss	Hatch Clerk	Lane Clerk	Rail Man	Shop Man	Side Picker	Ship Tractor Driver	Top Picker	Yard Tractor Driver	Transtainer Mechanic	Transtainer Operator	Walking Boss/ Yard Supervisor	Ambient Area Air
Long Beach	3.2*	2.9*	3.7	1.9*	1.9*†	1.5*	1.1*†	15	1.6*	3.4	2.9*	2.1*	NS	NS	NS	7.4
	1.5*	3.4	1.3*†	0.8**	3.8	4.8†	1.0*	42***†	1.6*	3.8	3.0*†	6.7	NS	NS	NS	5.4
	1.5*	11†	3.2*	8.1	3.6	3.2*	1.1*	11	12	3.9	4.7	2.9*	NS	NS	NS	1.2*
	1.3*	1.6*	1.9	0.9*	1.8*	2.3*	NS	NS	NS	1.7*	3.8	7.0	NS	NS	NS	1.2*
	NS	9.4	NS	NS	NS	NS	NS	NS	NS	4.6	3.3*†	NS	NS	NS	NS	1.3*
	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.7**
MDC	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
MQC	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4
Oakland	3.1*	NS	4.9*	2.5*	7.5	2.3*	NS	6.9	22***	3.2*	4.7	14	8.5	3.0*	4.0*	4.8
	3.2*	NS	5.4*	3.5*	5.0	6.9	NS	16	20***	3.0*	2.4*	8.9	4.3	2.5*	2.4*	3.0*
	3.9*	NS	3.7*	2.3*	12	6.1	NS	9.4	22***	12	9.0	6.4*	NS	4.6	NS	6.3
	3.2*	NS	4.6*	NS	5.0	5.6	NS	13	NS	5.2*	8.3	1.9**	NS	3.1	NS	7.0
	NS	NS	1.7**	NS	NS	7.6	NS	15	NS	NS	4.1	NS	NS	9.0	NS	1.8*
	NS	NS	NS	NS	NS	NS	NS	21***	NS	NS	NS	NS	NS	NS	NS	3.6
	NS	NS	NS	NS	NS	NS	NS	6.9	NS	NS	NS	NS	NS	NS	NS	6.7
	NS	NS	NS	NS	NS	NS	NS	7.2	NS	NS	NS	NS	NS	NS	NS	10
	NS	NS	NS	NS	NS	NS	NS	7.2	NS	NS	NS	NS	NS	NS	NS	4.8
MDC	1.0	NS	2.1	1.0	1.0	0.9	NS	0.9	0.9	2.1	0.9	2.1	0.9	0.9	2.1	0.9
MQC	4.2	NS	7.3	4.2	4.2	3.1	NS	3.1	3.1	7.3	3.1	7.3	3.1	3.1	7.3	3.1
Tacoma	1.0*	2.9*	3.9*	3.5*	2.0*	NS	3.9*	14	11	5.3	8.2	5.3	NS	NS	4.1*	2.5*
	1.2*	4.1*	2.6*	1.4*	3.0*	NS	4.3	2.1*	4.1*	7.6	8.0	7.7	NS	NS	5.1	1.8*
	1.5*	3.9*	3.4*	1.1*	4.0*	NS	3.7*	5.5	NS	5.6	3.7*	6.9	NS	NS	4.0*	1.1*
	3.2*	4.5	3.3*	NS	5.7	NS	5.0	11	NS	33***	6.6	5.5	NS	NS	2.7*	1.7*
	2.2*	4.7	1.7*	NS	NS	NS	4.1*	2.6*	NS	7.3	2.9*	6.0	NS	NS	3.7*	2.6*
	5.2	3.8*	NS	NS	NS	NS	NS	10	NS	3.1*	5.8	NS	NS	NS	NS	NS
	NS	4.8	NS	NS	NS	NS	NS	NS	NS	8.4	3.5*	NS	NS	NS	NS	NS
	NS	7.8	NS	NS	NS	NS	NS	NS	NS	13	NS	NS	NS	NS	NS	NS
	NS	6.3	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
MDC	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
MQC	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3

MDC = Minimum Detectable Concentration. MQC = Minimum Quantifiable Concentration. NS = No sample.
* indicates “trace” quantity (analytical result was between the MDC and the MQC).
** indicates sample was found to be below the MDC. In such cases, an imputed value (the MDC) was used for statistical calculations.
*** indicates sample met or exceeded the California Department of Health Services Recommended Exposure Limit of 20 μg/m^3.
† indicates a “fingerprint” was noticed on the filter prior to analysis, therefore results may not accurately reflect air concentration.

Appendix B Original Data: Carbon Monoxide PBZ Samples (All Terminals) Joint Pacific Marine Safety Code Committee, San Francisco, California (HETA 2003-0246-3013) Concentrations shown in parts per million (ppm)					
Terminal ID	**Job Title**	**Run Time (Mins)**	**Mean**	**Peak**	**Comments**
Long Beach	Lane Clerk	471	0	57	
Long Beach	Lane Clerk	471	0	4	
Long Beach	Lane Clerk	446	0	2	
Long Beach	Lane Clerk	444	0	1	
Long Beach	Guard	500	0	13	
Long Beach	Guard	548	1	35	
Long Beach	Guard	544	1	155	
Long Beach	Guard	538	0	2	
Long Beach	Crane Operator	515	0	38	
Long Beach	Hatch Clerk	497	0	4	
Long Beach	Hatch Clerk	502	0	9	
Long Beach	Hatch Boss	504	0	1	
Long Beach	Ship Tractor Driver	495	0	1	
Oakland	Shop Man	323	0	2	
Oakland	Shop Man	257	0	14	
Oakland	Shop Man	506	1	42	
Oakland	Ship Tractor Driver	394	1	14	
Oakland	Ship Tractor Driver	462	0	6	
Oakland	Ship Tractor Driver	423	4	128	Most of exposure occurred at lunchtime (smoker?)
Oakland	Ship Tractor Driver	445	0	6	
Oakland	Ship Tractor Driver	464	1	4	
Oakland	Guard	311	2	84	
Oakland	Guard	486	1	11	
Oakland	Yard Tractor Driver	574	2	23	
Oakland	Side Picker	192	0	5	Smoker
Oakland	Top Picker	181	0	5	
Oakland	Top Picker	569	12	69	
Oakland	Transtainer Operator	549	2	24	
Oakland	Transtainer Operator	541	39	1515	Suspect sample
Oakland	Transtainer Operator	569	2	45	
Oakland	Transtainer Clerk	556	19	71	Smoker
Oakland	Transtainer Mechanic	486	2	228	Working on running diesel engine
Oakland	Transtainer Mechanic	491	4	86	
Oakland	Hatch Boss	591	2	19	
Oakland	Hatch Boss	495	1	6	
Oakland	Hatch Clerk	443	0	6	
Oakland	Lane Clerk	491	1	4	
Tacoma	Shop Man	519	2	4	
Tacoma	Shop Man	533	1	24	Working on reefer containers
Tacoma	Shop Man	515	4	143	Installing generator sets and working roadability

Appendix B
Original Data: Carbon Monoxide PBZ Samples (All Terminals)
Joint Pacific Marine Safety Code Committee, San Francisco, California (HETA 2003-0246-3013)
Concentrations shown in parts per million (ppm)

Tacoma	Shop Man	549	4	443	Installing/testing generator sets on reefer containers
Tacoma	Dock Man	431	2	4	
Tacoma	Dock Man	434	1	2	
Tacoma	Dock Man	445	2	24	
Tacoma	Yard Tractor Driver	565	2	9	
Tacoma	Yard Tractor Driver	543	3	109	Smoker
Tacoma	Ship Tractor Driver	447	1	7	
Tacoma	Ship Tractor Driver	561	2	16	
Tacoma	Side Picker	526	1	75	
Tacoma	Top Picker	530	4	250	All peaks occurred during breaks/lunch (smoker?)
Tacoma	Top Picker	569	2	14	
Tacoma	Hatch Clerk	441	3	19	
Tacoma	Hatch Clerk	557	3	17	
Tacoma	Guard	389	1	3	
Tacoma	Crane Operator	443	2	3	
Tacoma	Crane Operator	558	1	4	
Tacoma	Yard Supervisor	527	2	13	Smoker
Tacoma	Hatch Boss	550	2	62	
Tacoma	Rail Man	529	5	47	
Tacoma	Rail Man	519	2	14	

Appendix C Airborne Particle Size Distribution: Summary statistics – Port of Long Beach Joint Pacific Marine Safety Code Committee, San Francisco, California (HETA 2003-0246-3013) Concentrations shown in number of particles/liter of air						
	Particle size in micrometers (µm)					
Location	**0.3 µm**	**0.5 µm**	**1 µm**	**3 µm**	**5 µm**	**10 µm**
West end of terminal yard between rows 702 and 704	52,583	5,641	1,842	153	18	1
Dockside knuckle between ships	48,163	5,329	1,770	111	7	0
Inside repair shop - Bay #5	55,351	6,900	2,138	113	9	0
Center of rail yard	46,112	4,971	1,598	99	10	0
Ambient readings at choke point	52,546	10,974	4,574	465	74	1
On dock, shipside, when engines first started	66,424	11,671	4,807	495	72	0
As ship was leaving	53,249	10,980	4,709	451	70	1
Indies Gate	53,200	9,700	3,873	356	48	0
Main Gate	74,437	11,997	4,642	614	135	3
Base of marine tower - pre-shift	180,089	22,407	5,545	732	124	5
Dockside knuckle between ships (morning)	187,588	24,786	5,984	846	146	6
Dockside knuckle between ships (afternoon)	186,861	25,306	6,065	929	168	6
Worker assembly area	156,620	21,435	5,298	668	100	4
Base of marine tower -during day shift (1:15 pm)	141,008	20,785	5,748	736	111	6
Beneath Crane # 4. One truck idling, 3 more in line	163,974	25,015	5,988	595	64	12
Beneath Crane # 3.	165,779	23,637	5,797	614	119	48
Crane # 2. Between lanes 3 and 4	136,694	16,765	4,311	312	17	1
Crane # 8. Between lanes 1 and 2	137,623	17,299	4,281	242	12	1
Crane # 3	151,485	18,835	4,688	353	19	1
Base of marine tower	144,629	15,599	3,567	351	33	1
Base of marine tower	143,611	14,418	3,104	290	19	1
Beneath Crane # 7	129,835	13,162	3,280	347	26	1
Beneath Crane # 3	121,274	14,853	3,863	276	16	1
Mean	115,180	15,325	4,238	441	62	4
Standard Deviation	51,579	6,603	1,417	240	51	10
Minimum	46,112	4,971	1,598	99	7	0
Maximum	187,588	25,306	6,065	929	168	48

Appendix D
Airborne Particle Size Distribution: Summary statistics – Port of Oakland
Joint Pacific Marine Safety Code Committee, San Francisco, California (HETA 2003-0246-3013)
Concentrations shown in number of particles/liter of air

Location	Particle size in micrometers (µm)					
	0.3 µm	**0.5 µm**	**1 µm**	**3 µm**	**5 µm**	**10 µm**
Main Gate	34,735	5,269	1,509	147	26	0
Main Gate	28,062	3,771	1,103	100	11	3
Beneath Crane #134 (no ship present)	18,684	3,338	1,316	194	23	0
Top Picker drop-off point	19,744	3,629	1,141	115	18	0
Next to truck idling	55,050	5,630	1,798	136	17	1
Main gate between lanes 1 and 2	85,725	9,368	1,803	163	13	0
Outbound canopy next to Power Shop (truck idling)	128,189	22,034	5,903	303	40	3
Behind Power Shop next to idling trucks	80,735	26,780	6,470	436	52	7
Outbound canopy (Roadability with truck idling)	30,372	5,299	1,620	87	6	0
Street cleaner (no water spray for dust suppression)	42,579	14,297	8,834	3,480	2,346	874
Center of row 18 (no activity)	31,381	3,087	819	68	4	0
Chassis shop during MIG welding	372,891	211,869	52,333	1,510	842	332
Behind Power Shop next to idling trucks	287,564	37,007	2,681	143	39	1
Inbound Gate area	86,005	9,197	1,678	118	14	0
Beneath Crane #135	40,506	3,707	704	65	11	0
Beneath Crane #134	40,848	3,850	761	82	9	0
Beneath Crane #135	35,718	3,404	718	52	4	0
Beneath Crane #134	35,145	3,361	735	85	21	0
Beneath Crane #133	55,297	6,722	1,150	266	78	5
Beneath Crane #134	60,744	6,552	695	64	11	0
Beneath Crane #135	58,065	6,335	734	75	11	1
Center of Row 39 (next to Operating Top Picker)	80,535	8,780	1,299	125	19	0
Mean	77,501	17,921	4,278	358	163	54
Standard Deviation	84,924	43,129	10,685	744	506	192
Minimum	18,684	3,087	695	52	4	0
Maximum	372,891	211,869	52,333	3,480	2,346	874

Appendix E Airborne Particle Size Distribution: Summary statistics – Port of Tacoma Joint Pacific Marine Safety Code Committee, San Francisco, California (HETA 2003-0246-3013) Concentrations shown in number of particles/liter of air						
	Particle size in micrometers (µm)					
Location	**0.3 µm**	**0.5 µm**	**1 µm**	**3 µm**	**5 µm**	**10 µm**
Under Crane #2-Center of truck lanes	19,569	909	263	19	0	0
Next to Top Picker during unloading of idling semi-truck	38,837	3,908	1,546	129	35	2
Next to idling semi-truck waiting for Top Picker	37,005	3,893	1,378	123	46	1
Rail Yard next to Top Picker	55,162	6,360	2,431	221	76	13
Power Shop – Under Roadability canopy (Truck engine off)	55,607	10,003	2,995	148	31	0
Power Shop – Under Roadability canopy (Truck engine running)	53,093	23,700	11,666	788	660	108
Shop Man – Breathing Zone during diesel generator startup	59,233	11,429	6,297	703	947	257
Ground level next to Top Picker during loading of container	55,598	2,077	493	25	10	0
Electric arc welding on chassis outside of Power Shop	199,353	186,882	89,255	1,615	1,607	772
Mean	63,717	27,685	12,925	419	379	128
Standard Deviation	52,460	60,099	28,849	530	574	256
Minimum	19,569	909	263	19	0	0
Maximum	199,353	186,882	89,255	1,615	1,607	772

Appendix F Meteorological data – All Terminals Joint Pacific Marine Safety Code Committee, San Francisco, California (HETA 2003-0246-3013)							
Port I.D.	**Date**	**Time**	**Wind Speed (MPH)**	**Wind Direction**	**Temperature (ºCelsius)**	**Relative Humidity (%)**	**Barometric Pressure (mmHg)**
Long Beach	9/8/2003	3:15 pm	6	SW	27	43	29.83
	9/9/2003	8:15 am	4	SE	19	73	30.23
	9/10/2003	11:05 am	4	SE	23	68	29.80
	9/11/2003	7:55 am	0	-	19	66	29.88
	9/11/2003	9:45 am	0	-	24	55	29.87
	9/11/2003	1:25 pm	13	NW	24	60	29.83
	9/11/2003	4:04 pm	16	N-NW	23	66	29.78
Oakland	8/16/2004	1:30 pm	8	SW	24	56	29.93
	8/16/2004	3:45 pm	9	W	32	40	29.94
	8/17/2004	7:35 am	5	W-SW	20	76	30.10
	8/17/2004	3:20 pm	9	S	28	41	29.82
	8/18/2004	10:10 am	6	SW	20	50	29.72
	8/18/2004	12:50 pm	12	S	27	46	29.87
	8/19/2004	1:50 pm	15	W	25	55	29.83
Tacoma	7/12/2005	8 am–5 pm*	6	W	21	55	30.12
	7/12/2005	6 pm–2 am*	5	SW	21	60	30.13
	7/13/2005	8 am–5 pm*	5	NW	19	51	30.24
	7/14/2005	8 am–5 pm*	8	N	20	64	30.12

* indicates meteorological data were automatically logged every minute during the entire workshift. Values are presented as averages.

Figure 1: Location of Ambient Air and Meteorological Sampling Equipment – YTI, Long Beach, CA

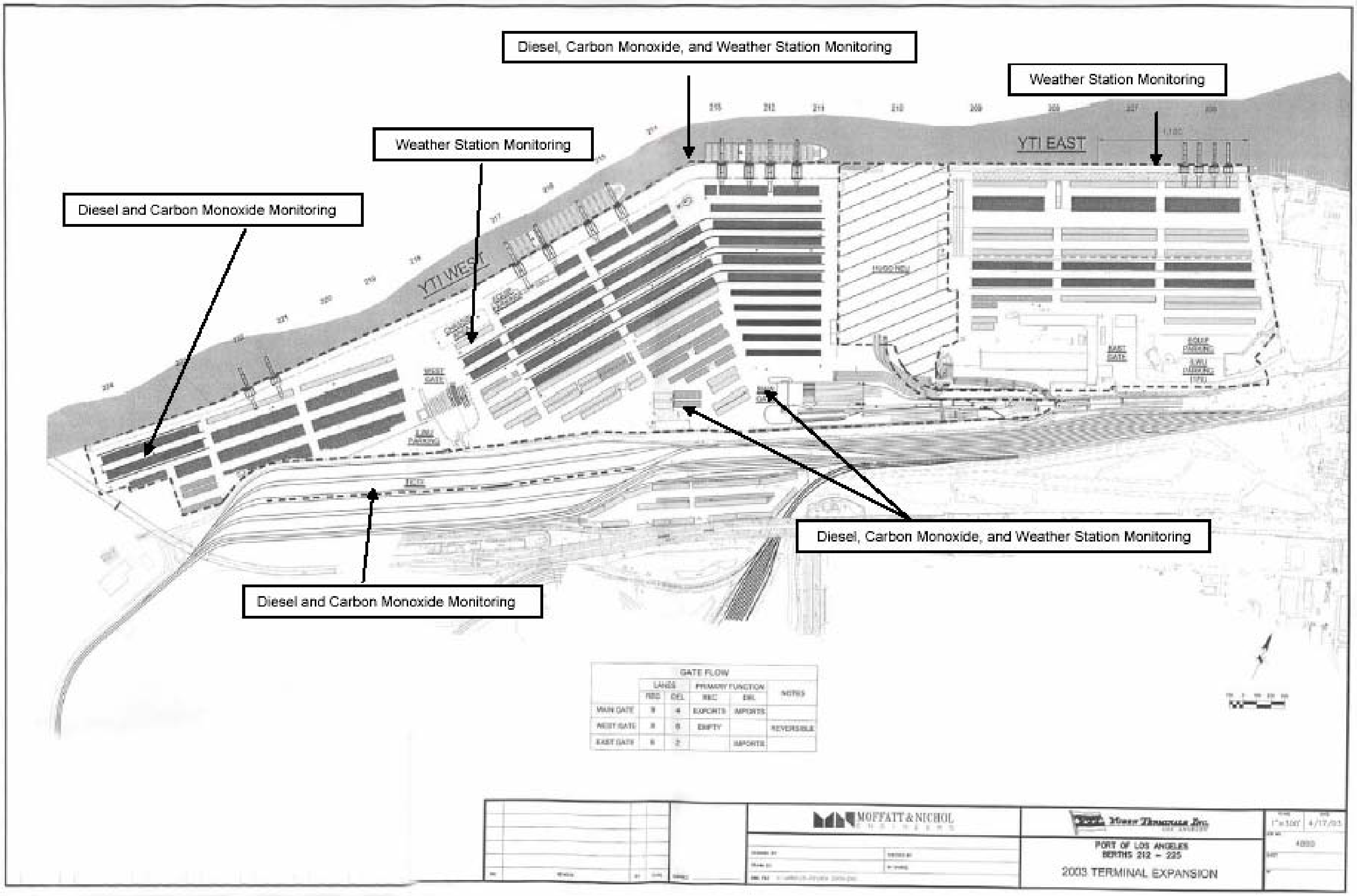


Figure 2: Location of diesel exhaust and CO ambient air samples – APL, Port of Oakland, CA

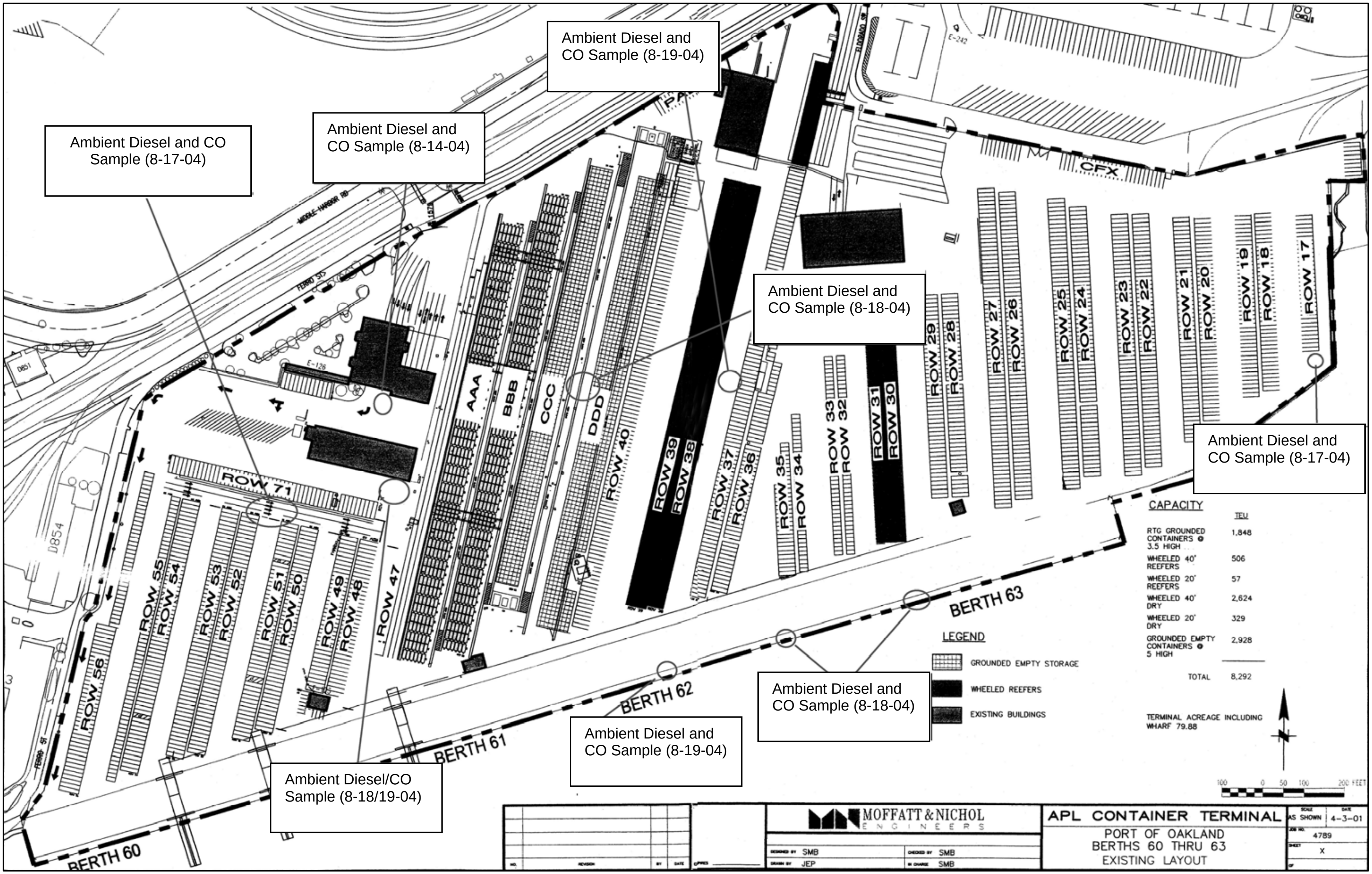
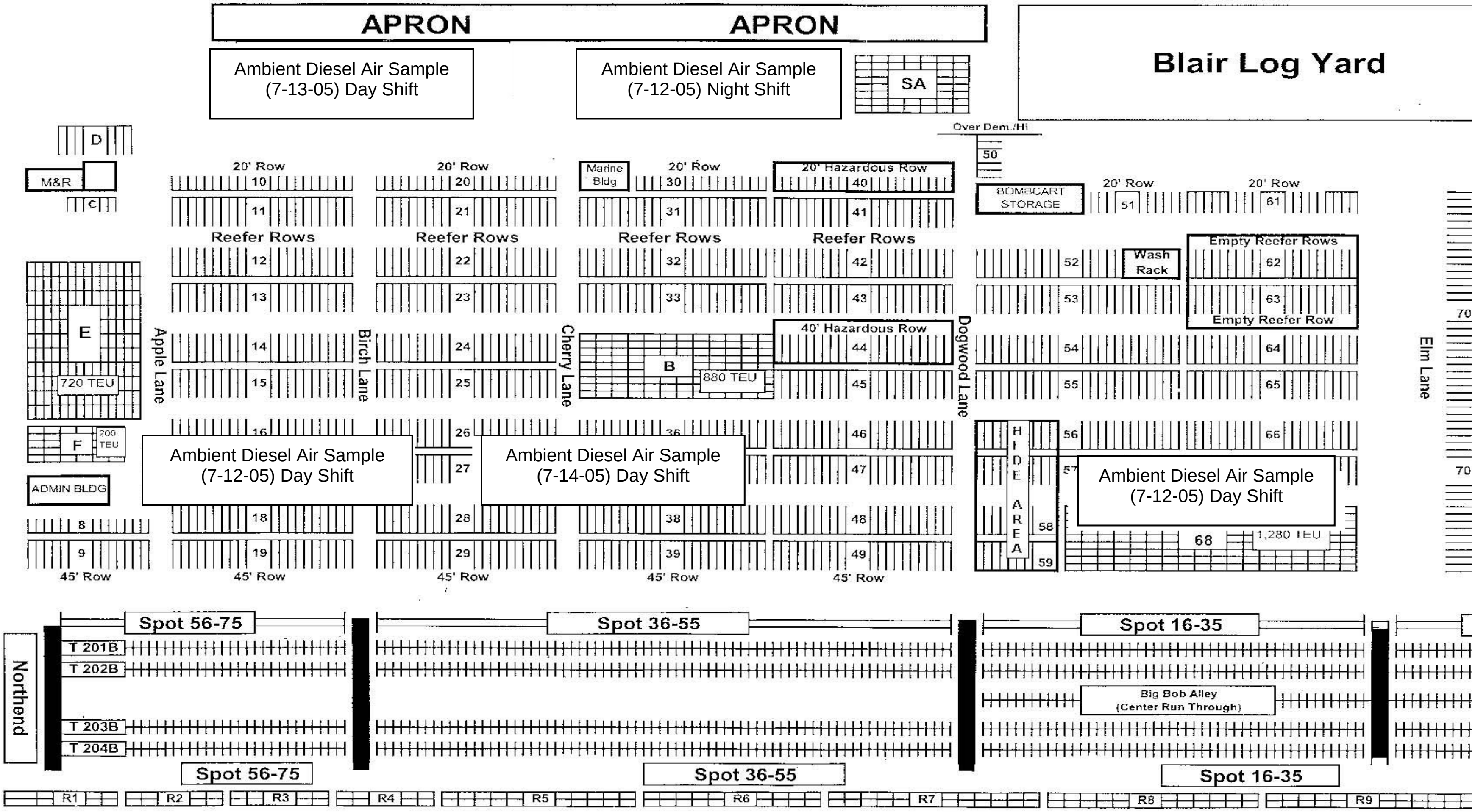


Figure 3: Location of diesel exhaust ambient air samples – WUT, Port of Tacoma, WA



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