# DRAFT For Discussion Purposes Only

Attached is the draft "Air Resources Board Emission Estimation Methodology for Cargo Handling Equipment Operating at Ports and Intermodal Rail Yards in California." This document provides a description of the methodology developed to estimate emissions from cargo handling equipment and the estimated emissions for that equipment.

This draft is being released so comments can be made on the methodology. Please do not cite or quote from this draft document, as it is possible that the methodology and the estimated emissions may change based on the comments we receive.

**DRAFT For Discussion Purposes Only**

# Emission Estimation Methodology for Cargo Handling Equipment Operating at Ports and Intermodal Rail Yards in California

For 10/04/05 Workgroup

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## EXECUTIVE SUMMARY

The California Air Resources Board (ARB) staff developed a statewide emission estimation methodology for cargo handling equipment at ports and intermodal rail yards. This effort was undertaken to support the development of a statewide emission control strategy addressing emissions from cargo handling equipment at ports and intermodal rail yards. The methodology reflects updated population and activity data for cargo handling equipment statewide by equipment type based on a survey conducted by ARB in early 2004 and recent emission inventories prepared for the ports of Los Angeles and Long Beach. Emissions estimates were developed for nine equipment types associated with California's ports and intermodal rail yards including aerial lifts, cranes, excavators, forklifts, container handling equipment, other general industrial equipment, sweeper/scrubbers, tractor/loader/backhoes, and yard trucks. A total of 16 ports and 14 intermodal rail yards are included in this estimation.

The ARB staff estimates that in 2004, cargo handling equipment diesel-fueled engines operating at ports and intermodal rail yards in California emitted approximately 0.66 tons per day of diesel PM. In addition, those engines are estimated to have emitted approximately 19 tons per day of oxides of nitrogen (NOx), and 1.6 tons per day of hydrocarbons. As shown in Table ES-1, yard trucks, container handling equipment (top picks, sides picks, etc.), and cranes are responsible for the majority of the emissions representing approximately 90 percent of the emissions for all pollutants.

**Table ES-1: Estimated Statewide 2004 Cargo Handling Equipment Emissions**

| Equipment Types | Numbers of Equipment | 2004 Pollutant Emissions, Tons Per Day | | |
|---|---|---|---|---|
| | | NOx | HC | Diesel PM |
| **Cranes** | **321** | 1.93 | 0.15 | 0.07 |
| **Excavators** | **28** | 0.24 | 0.02 | 0.01 |
| **Forklifts** | **464** | 0.54 | 0.06 | 0.03 |
| **Container Handling Equipment** | **487** | 3.24 | 0.22 | 0.11 |
| **Other, General Industrial Equipment** | **40** | 0.08 | <0.01 | <0.01 |
| **Sweeper/Scrubbers** | **28** | 0.04 | <0.01 | <0.01 |
| **Tractor/Loader/ Backhoe** | **93** | 0.18 | 0.02 | 0.01 |
| **Yard Trucks** | **2,277** | 12.78 | 1.14 | 0.43 |
| **Totals** | **3,738** | 19.03 | 1.61 | 0.66 |

Emissions were also allocated to the districts based on the location of a port or intermodal rail yard. Only 8 of the 35 air pollution control (APCD) or air quality management districts (AQMD) (districts) in California had emissions associated with ports or intermodal rail yards. A summary of the emission estimates for the five districts with the highest estimates of emissions is provided in Table ES-2. As is shown, the districts with the ports or intermodal rail yards responsible for the largest contributions of emissions are in the South Coast AQMD and the Bay Area AQMD. Those two districts account for approximately 90 percent of the statewide numbers of cargo handling equipment and 85 percent of the emissions of all pollutants from cargo handling equipment.

**Table ES-2: Estimated District Allocations of Statewide 2004 Cargo Handling Equipment Emissions**

| District | NOx | HC | Diesel PM |
|---|---|---|---|
| Bay Area | 3.34 | 0.26 | 0.11 |
| Mojave | 0.08 | 0.01 | <0.01 |
| North Coast | 0.06 | 0.01 | <0.01 |
| San Diego | 0.75 | 0.06 | 0.03 |
| San Joaquin | 0.55 | 0.04 | 0.01 |
| South Coast | 13.38 | 1.13 | 0.45 |
| Ventura | 0.66 | 0.06 | 0.02 |
| Yolo-Solano | 0.08 | 0.01 | <0.01 |

Note 1: The following districts had no cargo handling equipment emissions allocated to them: Amador, Antelope Valley, Butte, Calaveras, Colusa, El Dorado, Feather River, Glenn, Great Basin Unified, Imperial, Kern, Lake, Lassen, Mariposa, Mendocino, Modoc, Monterey Bay, Unified, Northern Sierra, Northern Sonoma, Placer, Sacramento, San Luis Obispo, Santa Barbara, Shasta, Siskiyou, Tehama, and Tuolumne.
Note 2: The total emissions may vary slightly from the values shown in Table ES-1 due to rounding.

# I. BACKGROUND

In this chapter, ARB staff provides background on the cargo handling equipment emissions inventory, our purpose and goals in preparing an emissions inventory update, and a general overview of the methodology developed to estimate the emissions from cargo handling equipment.

Cargo handling equipment is used for commercial purposes to move consumer goods through California's ports and intermodal facilities. There are a number of types of cargo handling equipment including container handling equipment such as top picks and rubber tire gantry cranes and bulk handling equipment which includes tractors, sweepers, fork lifts, and excavators.

A list of the different types of cargo handling equipment and a brief description of the work done by that equipment type is found in Table I-1. This equipment is generally operated at a port or intermodal facility, although it can be used at other facilities such as distribution centers.[1]

**Table I-1: Categories of Cargo Handling Equipment Included in the Emissions Inventory**

| Equipment Type | Description |
|---|---|
| Cranes | Cranes include rubber tire gantry cranes and other mobile cranes used to move containers from vessels to dockside, used to stack and unstack containers, used to move containers to and from yard trucks |
| Excavators | Used to pick up heavy bulk materials and other dry bulk materials |
| Forklifts | Used to move cargo, truck chassis, or other equipment short distances for placement on or removal from stacks |
| Container Handling Equipment | Includes side picks, top picks, reach stackers. Used to stack containers, move containers from one area of the terminal to another, or move containers on and off yard trucks |
| Other, General Industrial Equipment | Includes a variety of equipment types including aerial lifts, euclids, rail-car movers, and heavy duty off-highway trucks |
| Sweeper/Scrubbers | Used to clean up after bulk goods movement |
| Tractor/Loader/ Backhoe | Used to load and unload bulk materials |
| Yard Truck | Used to move containers to and from ships/trains, move containers within or off the terminal, and move containers to and from RTG cranes for placement on or removal from stacks |

Cargo handling equipment can be a significant source of diesel particulate matter (PM) emissions in communities near ports and intermodal rail facilities. To reduce diesel particulate matter (PM) emissions in communities near ports and intermodal rail yards, ARB staff are undertaking a rule-making effort to require reductions in emissions from

[1] Cargo handling equipment used at other types of facilities associated with the movement of goods in California, such as distribution centers, are not included in this emissions inventory.

cargo handling equipment. To support that rule-making and to assist in understanding the impacts from any proposed rule, it is necessary to develop a detailed emissions inventory for the specific types of equipment used in these facilities.

Our goals in undertaking this emissions inventory update were to:

- Update the inventory to reflect the most current cargo handling equipment fleets;
- Develop a consistent methodology that could be used statewide to estimate emissions from cargo handling equipment at ports and intermodal rail yards;
- Establish a structure that would allow allocation of the statewide emissions to individual ports and/or intermodal rail facilities; and
- Accurately reflect adopted regulations and other regulatory programs in the baseline inventory and in any future year forecasts.

## II. EMISSION CALCULATION METHODOLOGY

In this section, we provide a discussion of the methodology used to develop the cargo handling equipment emission estimation methodology.

Briefly, the approach used to develop the cargo handling equipment emissions inventory estimates entailed determining the average annual emissions per engine for each equipment type and then multiplying that value by the total number of engines in that grouping. The majority of the inputs that went into developing the average annual emissions came from individual engine profiles developed using the information from a Cargo Handling Equipment Survey conducted by the ARB in 2004 and cargo handling equipment population information provided by the ports of Los Angeles and Long Beach. These inputs were then processed using a template based on the ARB's OFFROAD model to estimate annual emissions per engine for each equipment type. This data was then expanded to include the estimated statewide population of cargo handling equipment fitting a specific age and horsepower range. To estimate port-specific emissions, the populations of cargo handling equipment were allocated based on the ARB Survey and the port-specific data. Emission estimates were developed for the eight types of equipment described in Table I-1. Estimates for oxides of nitrogen (NOx), hydrocarbons (HC), and particulate matter (PM) were made.

Below, we provide a more detailed discussion of the methodology used to estimate the cargo handling equipment emission inventory, including the assumptions and data inputs used.

### A. Methodology

The basic equation used for estimating emissions from cargo handling equipment is:

$$E_{y,t} = S\ Pop_{t,v,x} * HP * \%Load_{t} * EF_{v,x} * Hrs_{t}$$

where

| | | |
|---|---|---|
| E | = | pollutant specific emissions (tons per year of NOx, HC, and diesel PM) |
| Pop | = | cargo handling equipment type-specific population |
| HP | = | engine average rated brake horsepower in a given horsepower range |
| % Load | = | average engine load |
| EF | = | emission factor |
| Hrs | = | average annual use in hours |
| y | = | inventory year |
| t | = | equipment type (cranes, yard trucks, etc) |
| v | = | engine age (based on model year) |
| x | = | horsepower range of the engine |

Each of these elements, and how they were incorporated into the cargo handling equipment emission estimates, are discussed below. The base year for the cargo handling equipment emissions inventory is 2004.

## B. Emission Inventory Inputs

### 1. Population

The cargo handling equipment populations were developed using information from the ARB 2004 Cargo Handling Equipment Survey, the 2001 Port of Los Angeles emissions inventory, and the 2002 Port of Long Beach emissions inventory. These sources of information are described below. In addition, the steps taken to develop port-specific and intermodal facility-specific estimates of the numbers of cargo handling equipment for 2004 are described.

*ARB's Cargo Handling Equipment Survey (December 2004)*

The ARB conducted a survey of cargo handling equipment owner/operators to collect information about the different types of cargo handling equipment (ARB's Statewide Cargo Handling Equipment Survey, or ARB Survey). Owners/operators of cargo handling equipment were sent a copy of the ARB's survey in 2004. The survey requested, for the year 2004, information about the numbers of different types of cargo handling equipment at port terminals, annual use, information about the general equipment operating conditions, and engine information (make and model of the engine, horsepower, annual hours of use, any control equipment associated with it, etc.). The ARB Survey also requested information on projected estimated growth in equipment and hours of operation in 2010 and 2020.

The survey was sent to more than 120 owner/operators statewide and the ARB received 69 responses representing approximately 2,000 pieces of equipment. A copy of the ARB Survey is provided in Appendix A. Because the Ports of Los Angeles and Long Beach had recently conducted a similar survey, the terminal operators at those two ports were only requested to respond to the survey questions on anticipated growth and the types of installed controls.

*Port of Los Angeles and Port of Long Beach Cargo Handling Equipment Data*

To develop port-wide emissions inventories, the Ports of Los Angeles and Long Beach (the Ports) authorized Starcrest Consulting Group to collect information about the cargo handling equipment that operate on their respective properties. The Port of Los Angeles collected information for 2001 and the Port of Long Beach collected data for 2002. The information collected by Starcrest was provided to the ARB and included information about the equipment type, owner/operator contact information, engine-specific information (make, model, load factor, etc.), and annual activity.

*Estimating 2004 Cargo Handling Equipment Populations*

To make the cargo handling equipment emission estimates compatible with the ARB's OFFROAD model, the different equipment types at ports and intermodal rail yards collected through the ARB Survey and the Ports of Los Angeles (POLA) and Long Beach (POLB) were allocated to the eight equipment categories described previously in Table I-1. Because the cargo handling equipment populations for the ports of Los Angeles and Long Beach were associated with 2001 and 2002, respectively, these populations were grown to 2004 estimates using a 3% annual growth factor for both the equipment populations and the equipment activity. This growth factor is based on the projected growth data collected as a part of the ARB Survey. The populations of cargo handling equipment, by type, were assigned to a port or intermodal facility based on ARB Survey data.[2]

In addition, adjustments to the cargo handling equipment populations at several ports were made due to partial, or no, reporting of the cargo handling equipment at a number of ports. Using information gathered by contacting the ports directly or from published information regarding cargo throughputs, the ARB staff developed estimates of the populations for cargo handling equipment for each port where information was not complete.

Based on this approach, we estimate that there are approximately 3,700 pieces of cargo handling equipment statewide.

**Table II-1: Estimated Statewide Cargo Handling Equipment Populations[3]**

| Equipment Type | Estimated 2004 Population |
|---|---|
| Cranes | 321 |
| Excavators | 28 |
| Forklifts | 464 |
| Container Handling Equipment | 487 |
| Other, General Industrial Equipment | 40 |
| Sweeper/Scrubbers | 28 |
| Tractor/Loader/Backhoe | 93 |
| Yard Truck | 2,277 |
| Total | 3,738 |

[2] There were no additional adjustments to cargo handling equipment populations associated with intermodal rail yards because 100 percent of the intermodal facilities reported their equipment populations.
[3] The population values only include diesel-fueled engines. While there are gasoline and alternate fuel-powered cargo handling equipment, this inventory only focuses on diesel-fueled equipment.

### 2. Average Horsepower

Using the ARB's 2004 Cargo Handling Equipment Survey and the cargo handling equipment emissions inventory data for the ports of Los Angeles and Long Beach, average horsepower for various engine horsepower ranges were estimated by equipment type. Below, the horsepower range of the equipment, the average horsepower, and the average annual hours of operation for each equipment type at ports (Table II-2) and at intermodal rail yards (Table II-3) are presented below.

**Table II-2: 2004 Cargo Handling Equipment Profiles at Ports**

| Equipment Type | HP Range | Average HP | Average Annual Use (hrs – 2004) |
|---|---|---|---|
| Cranes | < 50 | 43 | 1371 |
| | 51 - 120 | 112 | |
| | 121 - 175 | 150 | |
| | 176 - 250 | 210 | |
| | 251 - 500 | 412 | |
| | 501 - 750 | 657 | |
| | 751 - 1000 | 966 | |
| Excavators | 176 - 250 | 245 | 2222 |
| | 251 - 500 | 387 | |
| Forklifts | < 50 | 45 | 1098 |
| | 51 - 120 | 103 | |
| | 121 - 175 | 154 | |
| | 176 - 250 | 208 | |
| | 251 - 500 | 278 | |
| Container Handling Equipment | 51 - 120 | 111 | 2388 |
| | 121 - 175 | 164 | |
| | 176 - 250 | 236 | |
| | 251 - 500 | 310 | |
| | 751 - 1000 | 930 | |
| Other General Equipment | <50 | 50 | 693 |
| | 51 – 120 | 99 | |
| | 121 – 175 | 157 | |
| | 176 – 250 | 225 | |
| | 251 - 500 | 387 | |
| Sweeper/Scrubber | < 50 | 48 | 872 |
| | 51 - 120 | 106 | |
| | 121 - 175 | 148 | |
| | 176 - 250 | 180 | |
| Tractor/Loader/Backhoe | <50 | 40 | 755 |
| | 51 – 120 | 88 | |
| | 121 – 175 | 148 | |
| | 176 – 250 | 203 | |
| | 251 – 500 | 356 | |
| | 501 – 750 | 750 | |
| Yard Trucks | 51 – 120 | 85 | 2536 |
| | 121 – 175 | 172 | |
| | 176 – 250 | 212 | |
| | 251 – 500 | 434 | |
| | 501 - 750 | 635 | |

**Table II-3: 2004 Cargo Handling Equipment Profiles at Intermodal Rail Yards**

| Equipment Type | HP Range | Average HP | Average Annual Use (hrs – 2004) |
|---|---|---|---|
| Cranes | 176 – 250 | 236 | 1632 |
| | 251 – 500 | 309 | |
| Forklifts | 51 – 120 | 93 | 803 |
| | 121 – 175 | 153 | |
| | 176 – 250 | 200 | |
| Container Handling Equipment | 121 – 175 | 160 | 2388 |
| | 176 – 250 | 208 | |
| | 251 – 500 | 299 | |
| Other General Equipment | 126 – 175 | 150 | 1632 |
| | 176 – 250 | 250 | |
| | 251 - 500 | 344 | |
| Sweeper/Scrubber | 176 – 250 | 200 | 872 |
| Tractor/Loader/Backhoe | 51 – 120 | 70 | 755 |
| Yard Truck | 126 – 175 | 150 | 1289 |
| | 176 – 250 | 203 | |

Note: If there is not a specific horsepower range listed for a specific type of equipment, then there were no engines in that size range used by that type of equipment.

### 3. Activity

The ARB Survey and the information provided by the ports of Los Angeles and Long Beach provided engine-specific annual use values (hours of operation). It was assumed that all of an engine's hours of operation occurred within the borders of California. The equipment type-specific annual average use, in hours, can be found in Tables II-2 and II-3 above. The annual use values were used to estimate cumulative engine use. Cumulative engine use is estimated by multiplying the annual use by the age of the engine. The estimate of cumulative engine use is the basis for estimating the impacts of engine deterioration on emissions from individual engines. A discussion of how emission factor deterioration rates were developed is provided in subsection 6 "Emission Factor Deterioration."

### 4. Engine Load Factor

The engine load under normal operating conditions is another key activity input. Information about the operating load factors for cargo handling equipment was taken from the engine load factors specified in the ARB's OFFROAD model for the specific type of cargo handling equipment or similar equipment. Table II-4 below provides the engine load factors, by equipment type, used to estimate emissions.

**Table II-4: Engine Load Factors**

| Equipment Type | Engine Load Factor |
|---|---|
| Cranes | 43% |
| Excavators | 57% |
| Forklifts | 30% |
| Container Handling Equipment | 59% |
| Other, General Industrial Equipment | 51% |
| Sweeper/Scrubbers | 68% |
| Tractors/Loaders/Backhoes | 55% |
| Yard Trucks | 65% |

Staff considered using an alternative load factor for yard tractors to better represent the engine load yard trucks operate under in their day-to-day activities. However, after additional investigation, ARB staff decided not to revise the engine load factor at this time. This decision is based on a lack of adequate test data to support the use of a revised yard truck engine load factor. There is a study underway by the ARB and the Port of Los Angeles to investigate cargo handling equipment load factors. As the results of those studies become available, the cargo handling equipment emission inventory will be revised.

### 5. Emission Factors

In 2004, the cargo handling equipment populations at California's ports and intermodal rail yards were comprised of a mix of cargo handling equipment units with different engines types (off-road and on-road) and units employing voluntary emission control strategies (controlled). In an effort to take this equipment mix into account, the ARB staff developed a composite emission factor based on the relative percentage off-road, on-road, and retrofitted engines. The emission factors for off-road engines are taken from the ARB's OFFROAD model. Emission factors for on-road engines were taken from the ARB's on-road engine certification standards. The emission factors for retrofitted equipment were developed using OFFROAD emission factors with the control device-specific control efficiencies applied.

### 6. Emission Factor Deterioration

As an engine ages, the pollutant-specific emission factors slowly increase. This phenomenon is described as "deterioration" and is primarily due to the wear on the various parts of an engine with use. Deterioration occurs at different rates for each pollutant. When developing emission estimates, it is essential that deterioration be taken into account and factored in the emissions estimation methodology. The deterioration rates used in the OFFROAD model are expressed as the percent increase in emissions over the percent of an engine's useful life consumed (see Appendix B). The methodology used for cargo handling equipment relies on the deterioration functions developed for the ARB's OFFROAD model. However, modifications were made to better reflect the operation of cargo handling equipment.

The deteriorated emission factors were developed using the same methodology found in the ARB's OFFROAD model.

Deteriorated Emission Factor

$$EF = ZH + DR * Hrs$$

And

Deterioration Rate

$$DR = (ZH * DF) / UL$$

Where: EF = emission factor, in grams per horsepower-hour (g/hp-hr)
ZH = zero-hour emission rate, or when the equipment is new (g/hp-hr)
Hrs = cumulative hours, or total number of hours accumulated on the equipment (equipment age x average annual activity, from survey data)
DR = deterioration rate, or the increase in ZH emissions as the equipment is used (g/hp-hr)
DF = deterioration factor (% increase per % useful life consumed)
UL= useful life of engine (in hours) (cargo handling equipment survey maximum useful life * average annual activity)

Two of the components, zero hour emission factors (ZH) and useful life values (UL), were revised based on the data gathered by the ARB's cargo handling equipment survey and the cargo handling equipment emissions inventory done by the ports of Los Angeles and Long Beach. A discussion of these two adjustments is provided below.

Zero Hour Emission Rates

As discussed above, revised zero hour emission factors were developed using a weighted average based on the product of the numbers of off-road, on-road, and retrofitted engines in the statewide cargo handling equipment population and the emission factors associated with those engines. The numbers of off-road, on-road, and controlled engines were based on engine model information collected from the ARB's survey and the emission inventories at the ports. Table II-5 below provides a summary of the percentage breakdown for the different engine configurations (on-road, off-road or controlled) estimated for each model year.

**Table II-5: Estimated Percentages of Existing Cargo Handling Equipment with Onroad, Offroad, or Controlled Engines**

| Model Yr | Yard Trucks | | Cranes | Forklift | Other, General Equip |
|---|---|---|---|---|---|
| | Onroad | Offroad w/controls | Offroad w/controls | Offroad w/controls | Offroad w/controls |
| 1980 | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 1981 | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 1982 | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 1983 | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 1984 | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 1985 | 27.3% | 0.0% | 0.0% | 0.0% | 0.0% |
| 1986 | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 1987 | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 1988 | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 1989 | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 1990 | 13.8% | 0.0% | 0.0% | 0.0% | 0.0% |
| 1991 | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 1992 | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 1993 | 7.9% | 0.0% | 0.0% | 0.0% | 0.0% |
| 1994 | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 1995 | 24.9% | 0.0% | 0.0% | 0.0% | 0.0% |
| 1996 | 24.9% | 65.0% | 13.1% | 8.0% | 42.9% |
| 1997 | 24.9% | 65.0% | 13.1% | 8.0% | 42.9% |
| 1998 | 24.9% | 65.0% | 13.1% | 8.0% | 42.9% |
| 1999 | 24.9% | 65.0% | 13.1% | 8.0% | 42.9% |
| 2000 | 24.9% | 65.0% | 13.1% | 8.0% | 42.9% |
| 2001 | 24.9% | 65.0% | 13.1% | 8.0% | 42.9% |
| 2002 | 24.9% | 65.0% | 13.1% | 8.0% | 42.9% |
| 2003 | 24.9% | 65.0% | 13.1% | 8.0% | 42.9% |
| 2004 | 24.9% | 65.0% | 13.1% | 8.0% | 42.9% |

## Useful Life

The average useful life for each type of cargo handling equipment was based on operators responses to the ARB Cargo Handling Equipment Survey. Table II-6 provides the average useful life by equipment type based upon where the equipment is used, at a port or at a rail yard. Table II-6 also includes the average annual usage (from Tables II-2 and II-3) and the engine load factor (from Table II-4).

**Table II-6: Cargo Handling Equipment Useful Life Inputs**

| Equipment Type | Average Annual Usage (hrs/yr) | Average Annual Usage (hrs/yr) | Engine Load Factors | Average Useful Life (yrs) | Average Useful Life (yrs) |
|---|---|---|---|---|---|
| | Port | Rail | Port/Rail | Port | Rail |
| Cranes | 1371 | 1632 | 0.43 | 24 | 18 |
| Excavators | 2222 | NA | 0.57 | 16 | NA |
| Forklifts | 1098 | 803 | 0.30 | 16 | 20 |
| Container Handling Equipment | 2388 | 2388 | 0.59 | 16 | 18 |
| Other, General Industrial Equipment | 693 | 1632 | 0.51 | 16 | 16 |
| Sweeper/Scrubbers | 872 | 872 | 0.68 | 16 | 16 |
| Tractors/ Loaders/ Backhoes | 755 | 755 | 0.55 | 16 | 16 |
| Yard Trucks | 2536 | 1289 | 0.65 | 12 | 8 |

The percent useful life (%UL) was estimated by dividing the engine age by the useful life for a specific equipment type. The final deteriorated emission factors are developed using the following equation:

$$EF = ZH + DR * Hrs$$

$$= ZH + \frac{ZH * DF}{UL} * Hrs$$

$$= ZH + ZH(DF) * \frac{Hrs}{UL}$$

## 7. Fuel Correction Factors

California implemented diesel fuel regulations in 1993, which lowered the limits of aromatic compounds and the sulfur content of fuel marketed in California. The fuel correction factors used in the development of a statewide cargo handling equipment emission inventory are contained in the ARB's OFFROAD model. The fuel correction factors are dimensionless multipliers applied to the basic exhaust emission rates. These fuel correction factors account for the differences in the properties of CARB diesel fuels compared to those of commercially dispensed fuels. Specifics about the fuel correction factors are found in Appendix B.

## 8. Add-on Controls and Other Emission Reduction Strategies

A number of the state's deep-water ports have encouraged voluntary implementation of cargo handling equipment emission reduction strategies using state funding, such as the Carl Moyer Program, or through port funding mechanisms. Many operators have taken advantage of these programs by implementing various control options including installation of diesel oxidation catalysts (DOCs), using emulsified fuels alone or in conjunction with a DOC, or installation of diesel particulate filters.

As a result of these voluntary programs, approximately 1,400 cargo handling equipment vehicles, primarily yard trucks, have been retrofitted with DOCs or replaced with new, cleaner engines in the last three years. As stated previously, the impacts from these voluntary strategies are included in the inventory methodology by adjusting the zero-hour emission rates.

## C. Emission Projections

Emission projections for the years 2010 and 2020 were developed. These projections reflect expected growth rates in equipment populations and activity; the turnover or attrition of the fleet; and the change in emission factors over time as the new engine standards are implemented. Below, ARB staff describes the assumptions used to generate the emission projections for future years.

### 1. Growth Factors

The growth factors used to estimate cargo handling equipment emissions in future years was based on an analysis done by ARB staff using growth estimates provided by terminal owner/operators as a part of the ARB's 2004 Cargo Handling Equipment Survey. The terminal owner/operators provide estimates of the numbers of pieces of equipment, by equipment type, they anticipated having in 2010 and 2020. In addition, the terminal owner/operators were asked to provide estimates of the percent of growth in activity of their equipment in 2010 and 2020.

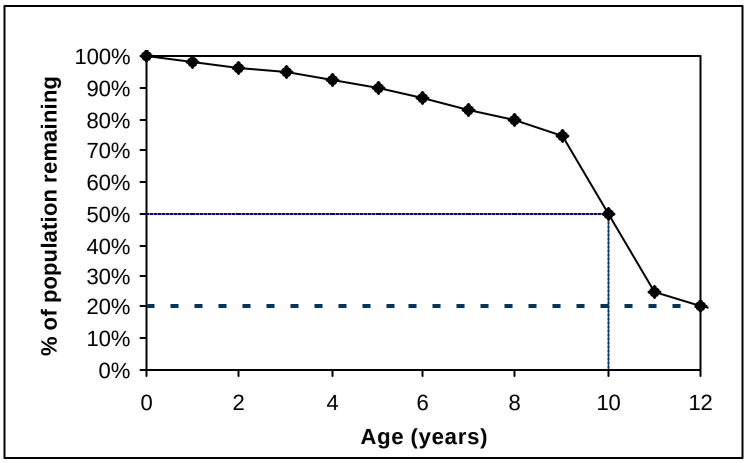
ARB staff used these estimates to develop statewide growth estimates for both equipment populations and equipment activity using a weighted average of the estimated growth over two time intervals, 2004 – 2010 and 2010 – 2020. The estimated growth rate was approximately six percent annually (three percent annually for cargo handling equipment populations and three percent annually for cargo handling equipment activity). This translates to about a tripling in activity due to growth over the period from 2004 to 2020.

### 2. Equipment Attrition or Scrappage

Scrappage is a function that describes the relationship between equipment age and the proportion of equipment that has been removed from service. This function is expressed in terms of a fraction of the average lifetime of the equipment. The average lifetime varies by the type of cargo handling equipment. For this cargo handling equipment emission estimation methodology, the scrappage function in the ARB's OFFROAD model was used. However, the application of the scrappage function was tailored to align with our understanding of the useful life information gathered in the ARB Survey. It was assumed that, at the average useful life determined from the ARB Survey, 20 percent of the engines for a given model year would remain.

For example, the average useful life reported in the ARB Survey for port yard trucks is 12 years. This means that on average, a yard truck is kept 12 years, however there are some yard trucks that are removed from service more quickly and others that remain beyond 12 years. In the scrappage curve developed for the current cargo handling emission estimation methodology, approximately 50 percent of the original population remains at 80 percent of the average useful life, in this case approximately 10 years. Approximately 20 percent of the original population remains at 12 years. The entire population of engines were accounted for in the inventory, however in the model, the engines were distributed over 12 model years. An example of the port yard truck attrition curve is presented in Figure II-1.[4] Similar attrition curves were developed for container handling equipment, general cargo handling equipment and cranes.

**Figure II-1: Attrition Curve, 12-year Useful Life**




Additional discussion of the role the scrappage function plays in the development of off-road equipment and a tabular representation of the ARB scrappage rate function is presented in the ARB's OFFROAD model.

### 3. New Engine Standards

Emission factors for future years were basd on the OFFROAD model which incorporates the impacts of new engine standards (Tier 3 and 4) for each year and horsepower range. The emission factors reflect any phase-in of emission standards allowed by the regulations establishing the new engine standards.

[4] The model developed for cargo handling equipment did not deteriorate emissions past the average useful life. Rather it assumed any engine past the average useful life would have the same emissions as an engine at the average useful life.

## III. EMISSION ESTIMATES

### A. Statewide Emission Estimates

The emission inventory for cargo handling equipment includes total emissions for the entire state, subtotals for each of the air basins and subtotals for each county, or a portion of a county, in each air basin. The data in Table III-1 summarizes the statewide inventory of oxides of nitrogen (NOx), hydrocarbons (HC), and diesel particulate matter (PM) for 2004 by equipment type.

**Table III-1: Estimated Statewide 2004 Cargo Handling Equipment Emissions (tons per day)**

| Equipment Types | Numbers of Equipment | 2004 Pollutant Emissions, Tons Per Day | | |
|---|---|---|---|---|
| | | NOx | HC | Diesel PM |
| **Cranes** | **321** | 1.93 | 0.15 | 0.07 |
| **Excavators** | **28** | 0.24 | 0.02 | 0.01 |
| **Forklifts** | **464** | 0.54 | 0.06 | 0.03 |
| **Container Handling Equipment** | **487** | 3.24 | 0.22 | 0.11 |
| **Other, General Industrial Equipment** | **40** | 0.08 | <0.01 | <0.01 |
| **Sweeper/Scrubbers** | **28** | 0.04 | <0.01 | <0.01 |
| **Tractor/Loader/ Backhoe** | **93** | 0.18 | 0.02 | 0.01 |
| **Yard Trucks** | **2,277** | 12.78 | 1.14 | 0.43 |
| **Total** | **3,738** | 19.03 | 1.61 | 0.66 |

As can be determined from the information presented in Table III-1, yard trucks, container handling equipment (top picks, sides picks, etc.), and cranes are the responsible for approximately 90 percent of the emissions for all pollutants.

### B. District-specific Emission Estimates

Estimates of emissions from cargo handling equipment were made on a port-by-port and intermodal facility-specific basis using the numbers of specific equipment types located at each facility. These emissions were then allocated to the appropriate air pollution control and air quality management districts based on the location of the ports and intermodal facilities. A summary of district-specific emissions for NOx, HC, and PM is provided in Table III-2.

**Table III- 2: Estimated 2004 Cargo Handling Equipment Emissions By District (tons per day)[5]**

| District | NOx | HC | Diesel PM |
|---|---|---|---|
| Bay Area | 3.34 | 0.26 | 0.11 |
| Mojave | 0.08 | 0.01 | <0.01 |
| North Coast | 0.06 | 0.01 | <0.01 |
| San Diego | 0.75 | 0.06 | 0.03 |
| San Joaquin | 0.55 | 0.04 | 0.01 |
| South Coast | 13.38 | 1.13 | 0.45 |
| Ventura | 0.66 | 0.06 | 0.02 |
| Yolo-Solano | 0.08 | 0.01 | <0.01 |

These emission estimates vary slightly from the statewide emission estimates as a result of rounding issues associated with the software package used to develop the emission estimates.

### C. Cargo Handling Equipment-specific Emission Estimates

Appendix C contains emission estimates by equipment type for 2004. The estimates are presented by equipment type, by model year, and by horsepower category.

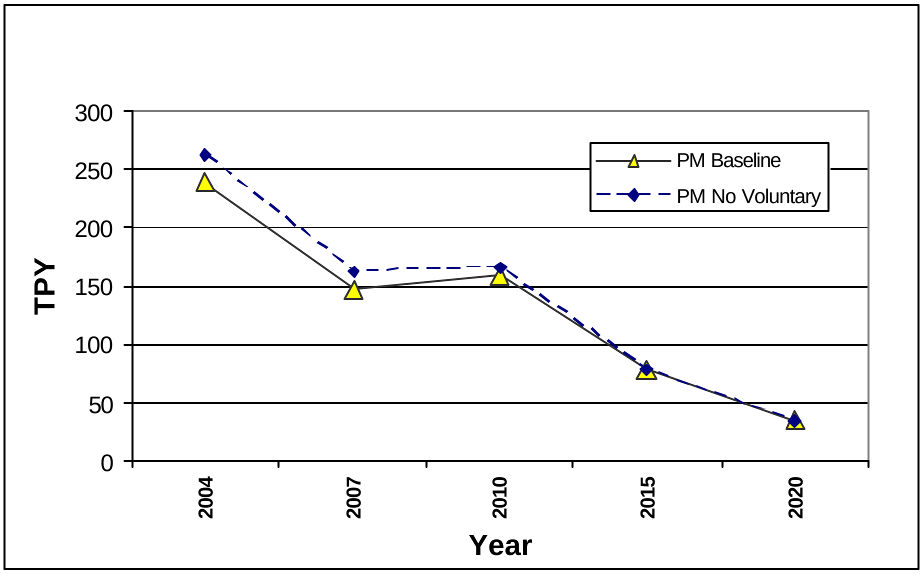
### D. Benefits of Voluntary Programs and Future Emission Projections

The emission reductions attributable to the voluntary emission reduction strategies (retrofits) implemented at California's ports have been incorporated in the baseline emission estimates. The ARB estimates that the installation of aftertreatment control technologies will result in an estimated 13 percent reduction in diesel PM emissions from 2004 through 2020. The ARB staff is unable to project any future emission reductions associated with voluntary emission reduction strategies because information about the continued implementation of these programs is uncertain.

Estimates of emission reductions attributable to these voluntary programs are based on information provided by the ports of Los Angeles, Long Beach, and Oakland in addition to information collected as a part of the ARB's Cargo Handling Equipment Survey. Graphic depiction of the impact of the voluntary emission reduction programs are presented in Figure II-2.

[5] The following districts have no cargo handling emissions associated with them: Amador, Antelope Valley, Butte, Calaveras, Colusa, El Dorado, Feather River, Glenn, Great Basin Unified, Imperial, Kern, Lake, Lassen, Mariposa, Mendocino, Modoc, Monterey Bay, Unified, Northern Sierra, Northern Sonoma, Placer, Sacramento, San Luis Obispo, Santa Barbara, Shasta, Siskiyou, Tehama, and Tuolumne.

**Figure II-2: Baseline vs. Voluntary Programs – Diesel PM Emissions (tons per year)**




Because the majority of the voluntary efforts involved the installation of diesel oxidation catalysts, the ARB staff estimates there are minimal reductions in NOx attributable to the voluntary installation of exhaust aftertreatment control devices on cargo handling equipment. While a small percentage of cargo handling equipment engines are using emulsified fuels, which result in some NOx reductions (up to 20 percent), the ARB staff is unable to quantify the benefits at this time.

Table III-3 below presents the cargo handling equipment emission estimates for the years 2010 and 2020 assuming approximately 6 percent growth per year.

**Table III-3: Cargo Handling Equipment Engines Projected Year 2010 and 2020 Emission Estimates**

| Equipment Types | 2010 Emission, Tons per Day | | | | 2020 Emission, Tons per Day | | | |
|---|---|---|---|---|---|---|---|---|
| | Numbers of Equipment | NOx | HC | Diesel PM | Numbers of Equipment | NOx | HC | Diesel PM |
| Cranes | 470 | 1.83 | 0.10 | 0.06 | 602 | 1.33 | 0.07 | 0.03 |
| Excavators | 29 | 0.18 | 0.01 | 0.01 | 32 | 0.05 | <0.01 | <0.01 |
| Forklifts | 530 | 0.39 | 0.02 | 0.02 | 607 | 0.17 | 0.01 | 0.01 |
| Container Handling Equipment | 738 | 3.43 | 0.18 | 0.12 | 1111 | 1.70 | 0.12 | 0.05 |
| Other General Industrial Equipment | 60 | 0.08 | <0.01 | <0.01 | 93 | 0.04 | <0.01 | <0.01 |
| Sweepers/ Scrubbers | 43 | 0.04 | <0.01 | <0.01 | 64 | 0.02 | <0.01 | <0.01 |
| Tractors/ Loaders/ Backhoes | 132 | 0.17 | 0.01 | 0.01 | 200 | 0.08 | 0.01 | <0.01 |
| Yard Trucks | 2810 | 10.20 | 0.67 | 0.31 | 3790 | 3.02 | 0.37 | 0.09 |
| Total | 4811 | 16.34 | 1.01 | 0.53 | 6500 | 6.41 | 0.58 | 0.18 |

**REFERENCES**

Air Resources Board, Staff Report: Public Meeting to Consider Approval of California's Emissions Inventory for Off-Road Large Compression -Ignited Engines (= 25HP) Using the New OFFROAD Emissions Model, January 2000.