

Appendix F: Ground Support Equipment and Aerospace Ground Equipment Emission Methodology

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Appendix F: Ground Support Equipment and Aerospace Ground Equipment Emission Methodology

F1. OVERVIEW

A wide variety of ground equipment services large aircraft while they are unloading and loading passengers and freight at an airport or air base. The following is a list of common Ground Support Equipment (GSE) and Aerospace Ground Equipment (AGE) types, along with a brief description.

- **Air Start Units** — Provide large volumes of compressed air to an aircraft's main engines for starting. Air start units are also called air compressors.
- **Air Conditioning Units** — Provide conditioned air to ventilate and cool parked aircraft.
- **Aircraft Tugs** — Tow aircraft in the terminal gate area or on the tarmac. They also tow aircraft to and from hangers for maintenance. These are broken into two categories: tugs for narrow body aircraft and tugs for wide body aircraft.
- **Baggage Tractors** — Equipment used at airports to haul baggage between the aircraft and the terminal.
- **Belt Loaders** — Mobile conveyor belts used at airports to move baggage between the ground and the aircraft hold.
- **Buses** — Shuttle personnel between facility locations.
- **Cargo Moving Equipment** — Various types of equipment employed to move baggage and other cargo around the facility and to and from aircraft. This category includes forklifts, lifts, and cargo loaders.
- **Cars** — Move personnel around the facility.
- **Deicers** — Vehicles used to transport, heat, and spray deicing fluid.
- **Ground Heaters** — Mobile units that provide heated air to heat the parked aircraft.
- **Ground Power Unit (GPU)** — Mobile ground-based generator units that supply aircraft with electricity while they are parked at the facility. GPUs also are called generators.
- **Light Carts** — Mobile carts that provide light.
- **Other** — Small miscellaneous types of equipment commonly found at facilities such as compressors, scrubbers, sweepers, and specialized units.
- **Pickups** — Move personnel and equipment around the facility.
- **Service Vehicles** — Specially modified vehicles to service aircraft at facilities. This category includes fuel trucks, maintenance trucks, service trucks, lavatory trucks, and bobtail tractors (a truck body that has been modified to tow trailers and equipment).
- **Vans** — Move personnel and equipment around the facility.
- **Weapons Loader** — Equipment employed at air bases to move weapons, such as bombs, between the ground and the aircraft hold.

There is also a wide variety of equipment that services the airport. This equipment may be assigned to various departments of the facility including administration, emergency response, police department, operations, engineering and construction, automotive, mechanical maintenance, and landscaping/gardening. The types of equipment servicing the airport vary from

cars and pick-ups to generators and lawn mowers. This equipment is also included in the GSE or AGE inventory.

While GSE and AGE are commonly fueled by gasoline or diesel, many different types of GSE and AGE are commercially available that operate on alternative fuels or electricity. Examples of alternative fuels are compressed natural gas, liquefied natural gas, and liquefied petroleum gas (commonly propane). Different fuels have different emission characteristics for the same piece of equipment.

There are both exhaust and evaporative-related emissions from GSE and AGE. The following discusses the methodology, data inputs, and data sources for calculating exhaust emissions from GSE and AGE. For information on calculating evaporative-related emissions from GSE and AGE (e.g., refueling losses), see the California Air Resources Board 1995 publication titled *Documentation of Input Factors for the New Off-Road Mobile Source Emissions Inventory Model*.

F2. METHODOLOGY

This section discusses the methodology for calculating exhaust emissions from GSE and AGE that service aircraft as well as airports and air bases.

For aircraft GSE and AGE, exhaust emissions from each GSE/AGE type is calculated using site-specific GSE/AGE type and usage information combined with non-site-specific inputs (e.g., brake horsepower, load factor, emissions indices). Emissions from each GSE/AGE type are totaled to obtain the total emissions inventory. This methodology can be used to calculate the pollutant emissions from an individual type of equipment for one LTO of a given aircraft type or for the entire inventory period independent of aircraft type based on the period the equipment usage represents (e.g., hours of use required for the equipment type to service one LTO of an aircraft type or for the entire inventory period). If the equipment usage is based on the hours required to service one LTO of an aircraft type, the activity for each aircraft type is applied to the GSE or AGE emissions per LTO calculated to obtain the total inventory emissions for conventional and alternative fuel GSE or AGE. This approach is very flexible since emissions can be calculated for as many or as few aircraft and LTOs as desired and for any inventory period. If total usage hours for the inventory period (e.g., hours per year) are used, it is not necessary to apply aircraft activity to the resulting emissions.

For airport GSE and air base AGE, GSE or AGE types and corresponding usage required for the entire inventory period are needed. This type and usage information is then combined with the remaining inputs to the emissions calculation to obtain GSE or AGE emissions for the given inventory period. In general, only limited calculation input data is readily available, as discussed below in Section F3.

Two calculation procedures are discussed below: a conventional/alternative fuel equipment procedure and an electric equipment procedure. A separate calculation procedure is provided for electric GSE and AGE since emissions attributable to the generation of electricity used by the equipment are calculated (instead of from the equipment itself). Once emissions are calculated for all conventional and alternative fuel GSE or AGE as well as electric GSE or AGE, the emissions are summed to obtain the total inventory emissions. For air bases, the USAF document *Calculation Methods for Criteria Air Pollutant Emission Inventories* (Reference 23) also should be consulted for further guidance.

F2.1 Conventional and Alternative Fuel GSE/AGE

For conventional and alternative fuel GSE and AGE, the factors that determine the quantity of pollutant emitted are the brake horsepower, load factor, usage, and emission index. Equation F-1 can be used to calculate the pollutant emissions from an individual type of equipment for one LTO of a given aircraft type or for the entire inventory period independent of aircraft type based on the period the equipment usage represents (e.g., hours of use required for the equipment type to service one LTO of an aircraft type or for the entire inventory period).

$$E_{it} = (\text{BHP}_t \times \text{LF}_t \times U_t \times \text{EI}_{it}) \times \text{CF}$$

Equation F-1: Conventional and Alternative Fuel GSE/AGE Emission Calculation

Where:

E_{it}	-	emissions of pollutant i, in pounds, produced by GSE or AGE type t
BHP_t	-	average rated brake horsepower (BHP) of the engine for equipment type t
LF_t	-	load factor utilized in ground support operations for equipment type t
U_t	-	hours of use for equipment type t (e.g., to service one LTO of an aircraft type or for the entire inventory period)
EI_{it}	-	emission index for pollutant I, in grams per BHP-hr, which is specific to a given engine size and fuel type
i	-	pollutant type (e.g., HC)
t	-	equipment type (e.g., diesel air start unit)
CF	-	0.0022046 unit conversion factor from grams to pounds

F2.2 Electric GSE/AGE

Use of electric GSE or AGE produces no emissions at the airport or air base but generating the electricity needed to operate them does. When electricity is used at an airport or air base to recharge an electric vehicle, local or regional power plants are generating additional electricity to meet this demand. In the case of electric GSE or AGE, the emissions attributable to the generation of electricity for use by the equipment are calculated.

Since emissions associated with electric GSE or AGE occur at the power plant rather than at the point where the equipment is used, the methodology identified above for conventional and alternative fuel GSE and AGE is modified somewhat. For each type of electric GSE or AGE, emissions are calculated based on the emission indices of the electric power plant and the amount of electricity consumed or hours of GSE/AGE usage. Or

$$E_{it} = \text{BHP}_t \times \text{LF}_t \times U_t (\text{EI}_{it} \times \text{CFBHP} \times \text{CFR})$$

Equation F-2 calculates the pollutant emissions attributable to an individual type of electric equipment. As with the conventional and alternative fuel methodology above, the equation can be used to calculate emissions for one LTO of a given aircraft type or for the entire inventory period based on the period the equipment usage represents (e.g., hours of use required for the equipment type to service one LTO of an aircraft type or for the entire inventory period).

$$E_{it} = MWH_t \times EI_{it}$$

Or

$$E_{it} = BHP_t \times LF_t \times U_t (EI_{it} \times CF_{BHP} \times CF_R)$$

Equation F-2: Electric GSE and AGE Emission Calculation

Where:

E_{it}	-	emissions of pollutant i, in pounds, attributable to the use of GSE or AGE type t
MWH_t	-	megawatt hours of electricity consumed by equipment type t (e.g., to service one LTO of an aircraft type or for the entire inventory period)
EI_{it}	-	emission index for pollutant i, in pounds per megawatt hour of electricity consumed
BHP_t	-	average rated brake horsepower (BHP) of the engine for equipment type t
LF_t	-	load factor utilized in ground support operations for equipment type t
U_t	-	hours of use for equipment type t (e.g., to service one LTO of an aircraft type or for the entire inventory period)
i	-	pollutant type (e.g., HC)
t	-	equipment type (e.g., electric baggage tug)
CF_{BHP}	-	0.000746 unit conversion factor from megawatt hours to horsepower hours
CF_R	-	1.125 recharge conversion factor

F3. DATA SOURCES

Data inputs and sources vary somewhat for the conventional and alternative fuel GSE/AGE and electric GSE/AGE emissions calculation procedures. The following identifies the data inputs and sources for calculating emissions from conventional and alternative fuel GSE and AGE as well as electric GSE and AGE. For air bases, the USAF document *Calculation Methods for Criteria Air Pollutant Emission Inventories* (Reference 23) also should be consulted for further guidance.

F3.1 Conventional and Alternative Fuel GSE/AGE

F3.1.1 GSE/AGE Type

GSE/AGE type refers to the equipment (e.g., baggage tug) and fuel (e.g., diesel) type. Potential sources of site-specific GSE/AGE type information are individual aircraft operators for aircraft GSE, the airport operator for airport GSE, or the air base's operations department for air base AGE. For military aircraft, common AGE applications are provided in the USAF's *The Engine Handbook* (Reference 44).

F3.1.2 Usage

Usage refers to the hours of use for a specific equipment type either to service one LTO of a specific aircraft type or for the entire inventory period. Potential sources of site-specific aircraft GSE/AGE usage information are individual aircraft operators at airports or the air base's operations department. If site-specific data is not available, default aircraft GSE hours per year usage data is provided in the FAA and EPA's *Technical Data to Support FAA's Advisory Circular on Reducing Emissions from Commercial Aviation* (Reference 52).

For airport or air base GSE/AGE the airport operator or air base's operations department can be contacted or default hours per year usage data can be obtained from the *Nonroad Engine and Vehicle Emissions Study (NEVES)* (Reference 78).

F3.1.3 Brake Horsepower

Potential sources of site-specific brake horsepower data are aircraft operators for aircraft GSE, the airport operator for airport GSE, and the air base operations department for AGE. If site-specific information is not available, the FAA and EPA's *Technical Data to Support FAA's Advisory Circular on Reducing Emissions from Commercial Aviation* (Reference 52) lists brake horsepower commonly found on on-road and aircraft GSE/AGE and the *NEVES* lists brake horsepower commonly found on off-road airport and air base GSE/AGE. Default data also may be available from equipment manufacturers.

F3.1.4 Load Factor

Potential sources of site-specific GSE/AGE load factor information are individual aircraft operators for aircraft GSE at airports, the airport operator for airport GSE, or the air base's operations department. If site-specific information is not available, the FAA and EPA's *Technical Data to Support FAA's Advisory Circular on Reducing Emissions from Commercial Aviation* lists load factors commonly found on on-road and aircraft GSE/AGE and the *NEVES* lists load factors commonly found on off-road airport and air base GSE/AGE. Default data also may be available from equipment manufacturers.

F3.1.5 Emission Indices

Emission indices are available for aircraft and airport/air base GSE and AGE. Off-road aircraft GSE emission indices for HC, NO_x, CO, and PM are listed in *Regulatory Strategies for Off-Highway Equipment* (Reference 16) and *Feasibility of Controlling Emissions from Off-Road, Heavy-Duty Construction Equipment* (Reference 15). These emission indices also are provided in the FAA and EPA's *Technical Data to Support FAA's Advisory Circular on Reducing Emissions from Commercial Aviation*. This document also provides SO₂ emission indices for off-road aircraft GSE and on-road GSE emission indices developed by EEA for FAA. Airport non-road emission indices are provided in the *NEVES*.

F3.2 Electric GSE/AGE

F3.2.1 GSE/AGE Type

GSE/AGE type refers to the equipment (e.g., baggage tug) and fuel (i.e., electric) type. Potential sources of site-specific GSE/AGE type information are individual aircraft operators at airports, the airport operator, or the air base's operations department. For military aircraft, common AGE applications are provided in the USAF's *The Engine Handbook*.

F3.2.2 Usage

Usage can either be in hour (e.g., hours per LTO, hours per year) or megawatt hour units. Usage refers to the hours used or megawatt hours of electricity consumed by a specific equipment type either to service one LTO of a specific aircraft type or for the entire inventory period. Potential sources of site-specific GSE/AGE usage information are individual aircraft operators at airports, the airport operator, or the air base's operations department.

F3.2.3 Emission Indices

Emissions generated at the power plant vary from region to region throughout the U.S. based on the power generation technology, fuel used, and emission controls. Table F-1 presents Emission indices for electric power production for all of the U.S. as well as for the Ozone Transport Region (OTR), states outside the OTR and California. The OTR consists of the District of Columbia, Maryland, parts of northern Virginia (e.g., Alexandria, Arlington County, Fairfax, Fairfax County, Falls Church, Loudoun County, Manassas, Manassas Park, Prince William County, and Stafford County), and all states north (e.g., Pennsylvania, Delaware, New Jersey, New York, Connecticut, Rhode Island, Massachusetts, Vermont, New Hampshire, and Maine). The factors relate emissions at a power plant to electricity used at an airport, air base, or other location connected to the power distribution system. The emission indices are based on the regional mix of electricity generation technology and assume an 8% power loss in the transmission and distribution system.

Region	Emission Index (lbs/MWh) ¹		
	HC	CO	NO _x
Ozone Transport Region ²	0.03	0.33	0.88
California	0.04	0.44	0.31
Other U.S.	0.03	0.34	3.97
Total U.S.:	0.03	0.36	3.52

Table F-1: Emissions From Electric Power Consumption³

¹ Represents pounds of pollutant emitted at the point of power generation per megawatt hour of electricity consumed in 2000.

² Source: *Impact of Battery-Powered Electric Vehicles on Air Quality in the Northeast States* (Reference 39)

³ Source: EEA unless otherwise noted. Data has been adjusted to account for 8% transmission and distribution losses.