Appendix H: Stationary Emission Methodology

Appendix H: Stationary Emission Methodology

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Appendix H: Stationary Emission Methodology

H1 OVERVIEW

This section discusses the methodology for calculating emissions from stationary and area sources at airports and air bases. Detailed data is necessary for determining emissions from stationary and area sources. Many airports and air bases will have this information readily available since it is needed for Title V Operating Permits (or synthetic minor permits depending on the situation). For air bases, the USAF document *Calculation Methods for Criteria Air Pollutant Emission Inventories* (Reference 23) also should be consulted for further guidance.

Typical stationary and area sources at airports and air bases are listed in Table H-1.

Table H-1: Stationary And Area Emissions Sources

Combustion Sources	Non-Combustion Sources
Boilers Space Heaters Emergency Generators Incinerators Fire Training Facilities Aircraft Engine Testing	Fuel Storage Tanks Painting Operations Deicing Operations Solvent Degreasers Sand/Salt Piles

Emission indices referenced in this section are typically given as pounds of pollutant emitted to the atmosphere per a quantity of fuel or other material consumed. In some cases, the pollutants for which emission indices are provided do not match those included in the emissions inventory. For example, the scope of an airport emissions inventory may include CO, NO_x, SO_2, HC, and PM-10 emissions. However, for some operations, the EPA emission index is given as PM instead of PM-10, or as Volatile Organic Compounds (VOC) instead of HC or Total Organic Compounds (TOC). Guidance on the differences between the pollutants and interpretation of emission indices is given in the introduction to the EPA *Compilation of Air Pollutant Emission Factors* (Reference 71), also known as AP-42.

H2 COMBUSTION SOURCES

The basic methodology for calculating emissions from each of these sources is fairly simple; the quantity of fuel burned is multiplied by an emission index to determine the emission of each pollutant. These pollutants commonly include the NAAQS pollutants CO, SO_2, and PM-10. HC and NO_x emissions may also be included in the inventory, as they are precursors to the formation of ozone, another NAAQS pollutant.

This section is divided into five parts. The first considers emissions from boilers and space heaters. Emissions from these stationary and area combustion sources are estimated using emission indices developed for boilers as presented in Sections 1.1-1.5 of Volume I of the EPA *Compilation of Air Pollutant Emission Factors*. The second part describes the methodology and available information on calculating emissions from emergency generators. The third part considers emissions from small incinerators that are present on some airports and air bases. The fourth part of this section discusses pollutant emissions arising from live fire-fighting training exercises. The fifth and final part considers emissions associated with the testing of aircraft engines, either attached to the aircraft or isolated in a testing chamber.

H2.1 Boilers and Space Heaters

H2.1.1 Methodology

EPA provides emission indices for a wide range of boilers, but provides little emission information specific to space heaters. For the purposes of airport and air base emissions inventories, it can be assumed that the emission indices provided for boilers are applicable to space heaters of a comparable size and fuel type.

Pollutant emissions from boilers and space heaters can be calculated using a methodology based on fuel consumption rates and pollutant emission indices. Emissions of each pollutant are calculated by multiplying the fuel consumption rate by the emission index specific to each pollutant. This technique is repeated for each boiler or space heater on the airport or air base to obtain total emissions for these stationary combustion sources.

Total pollutant emissions from one stationary combustion source in this category may be estimated by applying Equation H-1:

$$\mathbf{E_{ti} = \Sigma\,(F \times EI_i)}$$

Where:

E_{ti} - total emissions of pollutant i, in pounds, from the stationary source for given time period

F - total amount of fuel consumption for given time period; liquid fuels should be expressed in terms of thousand gallons, natural gas as million cubic feet (mcf), and coal as tons.

EI_i - emission index for pollutant i (pounds pollutant per thousand gallons, mcf, or ton of fuel)

i - pollutant (CO, NO_x, SO_2, PM or PM-10, HC)

Equation H-1: Total Pollutant Emissions for Stationary Combustion Source

The emission index is multiplied by the total fuel consumption to estimate pollutant emissions from the boiler or space heater. The accuracy of this methodology depends upon the ability to determine an appropriate emission index for each pollutant. The following section describes how to obtain EPA-approved emission indices for each combustion source.

H2.1.2 Data Sources

The particular data inputs required for the emissions calculation methodology for each source (e.g., boiler or space heater) are listed in paragraphs 2.1.2.1 through 2.1.2.7.

H2.1.2.1 Rate of Fuel Consumption

Calculations for the emissions from airport and air base stationary combustion sources depend on knowing the amount of fuel burned by those sources over the time period being studied. This information should be obtained from the airport operator or base operations department.

H2.1.2.2 Emission Indices

Emission indices for most stationary combustion sources found at airports and air bases are given in Sections 1.1-1.5 of Volume I of EPA’s *Compilation of Air Pollutant Emission Factors*. Emission indices have been developed by EPA that take into consideration several factors that have a significant impact on pollutant emissions, including:

- Fuel type
- Fuel sulfur content
- Fuel ash content
- Boiler type
- Pollution control equipment

The emission indices are calculated by obtaining from Volume I of *Compilation of Air Pollutant Emission Factors* the uncontrolled emission index based on fuel type and boiler type, and correcting for the reduction of pollutants by any air pollution control equipment in operation. In addition, the SO_2 emission index is affected by the fuel sulfur content, and the PM emission index is affected by the fuel ash content. The methodology for obtaining the proper emission indices is expressed by Equation H-2.

$$\mathbf{EI_i = UI_i \times (1 - CF/100) \times FM_i}$$

Where:

EI_i - emission index for pollutant i (pounds of pollutant per thousand gallons, mcf, or ton of fuel)
UI_i - uncontrolled emission index for pollutant i (pounds of pollutant per thousand gallons, mcf, or ton of fuel)
CF - air pollution control factor (%)
FM_i - fuel modifier (fuel weight percent sulfur for SO_2 emission index; fuel weight percent ash for PM emission index; ignore for other pollutants)
i - pollutant (CO, SO_2, PM, NO_x, or HC)

Equation H-2: Emission Factors for Boilers and Space Heaters

H2.1.2.3 Fuel Type

All emission indices for boilers given in Volume I of *Compilation of Air Pollutant Emission Factors* depend upon the type of fuel burned. At airports and air bases, the most common fuel types are distillate fuel oil, residual fuel oil, diesel fuel, natural gas, and occasionally jet fuel. A small number of air bases may burn coal in large boilers. The type of fuel burned may be obtained from the airport operator, fuel supplier, or base operations department.

H2.1.2.4 Fuel Ash Content

To calculate an emission index for particulate matter, an estimate of the ash content of the fuel is often required. This may be obtained from the fuel supplier, airport operator, or base operations department, or may be taken from calculation of default ash content of fuels as described in Section 1.3 of Volume I of *Compilation of Air Pollutant Emission Factors*.

H2.1.2.5 Fuel Sulfur Content

To calculate an emission index for sulfur dioxide, an estimate of the sulfur content of the fuel is required. This may be obtained from the fuel supplier, airport operator, or base operations department.

H2.1.2.6 Combustion Source Equipment Type

Specific information on the type of equipment and fuel used for each boiler or space heater should be obtained from the airport operator or from the manufacturer. Equipment classification should conform with the categories specified in Volume I of *Compilation of Air Pollutant Emission Factors*. Two examples of boiler classifications given in the *Compilation of Air Pollutant Emission Factors* (for which uncontrolled emission indices are given) are “Distillate oil fired commercial/institutional/residential combustor” and “Natural gas-fired small industrial boiler.” Therefore, boilers are classified by fuel and equipment types by *Compilation of Air Pollutant Emission Factors*. Space heaters are not specifically discussed in Volume I of *Compilation of Air Pollutant Emission Factors*. For the purposes of airport and air base emissions inventories, it can be assumed that the emission indices provided for boilers are applicable to space heaters of a comparable size and fuel type.

H2.1.2.7 Air Pollution Control Factor

Information on air pollution control equipment and control efficiency should be obtained from the airport operator or base operations department. This figure should be expressed as a percent reduction from the uncontrolled emission level.

H2.2 Emergency Generators

Two methodologies are given here: EPA’s AP-42 method (paragraph 2.2.1), which calculates emissions based on the capacity rating of generator engines, and the U.S. Air Force’s method (paragraph 2.2.3), which calculates emissions based on the amount of fuel consumed. The choice of method is likely to rest upon the type of facility being studied (e.g., AP-42 for civilian airports, USAF method for military bases).

H2.2.1 Methodology (EPA AP-42)

Pollutant emissions from emergency generators are calculated using a methodology based on the generator capacity, generator usage rate, and pollutant emission indices. Emissions are calculated by multiplying the power capacity of each generator by the number of hours the generator was operated and by the emission index for each specific pollutant.

Total pollutant emissions from an emergency generator may be estimated by applying Equation H-3.

$$E_{ti}\ \Sigma\ [GC \times T \times UI_i \times (1 - CF/100)]$$

Where:

E_{ti} - total emissions of pollutant i, in pounds, from the emergency generator for inventory time period
GC - generator power capacity rating (horsepower)
T - time (in hours) generator was operated during inventory time period
UI_i - uncontrolled emission index for pollutant i (pounds pollutant per horsepower-hour of power output)
CF - air pollution control factor (%)
i - pollutant (CO, NO_x, SO_2, PM-10, HC)

Equation H-3: Pollutant Emissions for Emergency Generators (AP-42 Method)

H2.2.2 Data Sources (EPA AP-42)

The particular data inputs required for the emissions calculation methodology for each emergency generator are listed in the following paragraphs (2.2.2.1. through 2.2.2.4).

H2.2.2.1 Capacity of Generator Engine

Available from the manufacturer, airport operator, or base operations department. This should be expressed in terms of horsepower (or kilowatts, if metric emission indices from AP-42 are used).

H2.2.2.2 Time of Generator Use

Available from airport operator or base operations department. This should be expressed in hours of generator operation.

H2.2.2.3 Emission Indices

Uncontrolled emission indices for gasoline and diesel industrial engines are given in Section 3.3 of EPA’s *Compilation of Air Pollutant Emission Factors.* The type of fuel burned should be available from the fuel supplier, airport operator, or base operations department.

H2.2.2.4 Air Pollution Control Factor

Information on any air pollution control equipment and control efficiency should be obtained from the airport operator or base operations department. This figure should be expressed as a percent reduction from the uncontrolled emission level. Air pollution control methods for emergency generators include steam injection, water injection, and selective catalytic reduction for NO_x control.

H2.2.3 Methodology (U.S. Air Force)

Pollutant emissions from emergency generators are calculated using a methodology based on the quantity of fuel burned and pollutant emission indices. Emissions are calculated by multiplying the quantity of fuel burned by the emission index for each specific pollutant.

Total pollutant emissions from an emergency generator may be estimated by applying Equation H-4:

$$\mathbf{E_{ti} = \Sigma\ [F\ x\ UI_i\ x\ (1 - CF/100)]}$$

Where:

E_{ti} - total emissions of pollutant i, in pounds, from the emergency generator for given time period
F - total quantity of fuel burned, in thousands of gallons (or million cubic feet for natural gas), for given time period
UI_i - uncontrolled emission index for pollutant i (pounds pollutant per thousand gallons of fuel or mcf gas burned)
CF - air pollution control factor (%)
i - pollutant (CO, NO_x, SO_2, PM-10, HC)

Equation H-4: Pollutant Emissions for Emergency Generators (USAF Method)

H2.2.4 Data Sources (U.S. Air Force)

The particular data inputs required for the emissions calculation methodology for each emergency generator are specified in the following paragraphs (2.2.4.1 through 2.2.4.3).

H2.2.4.1 Quantity of Fuel Burned

Available from the fuel supplier, airport operator, or base operations department. This should be expressed in terms of thousands of gallons of fuel burned, or in the case of natural gas, million cubic feet.

H2.2.4.2 Emission Indices

Uncontrolled emission indices for emergency generators powered by reciprocating engines are given in

Table H-2. Note that for two of the emission indices, the percent of sulfur in the fuel must be obtained to calculate the emission indices. The type of fuel and sulfur content should be available from the fuel supplier, airport operator, or base operations department.

H2.2.4.3 Air Pollution Control Factor

Information on any air pollution control equipment and control efficiency should be obtained from the airport operator or base operations department. This figure should be expressed as a percent reduction from the uncontrolled emission level. Again air pollution control methods for emergency generators include steam injection, water injection, and selective catalytic reduction for NO_x control.

Fuel	Emission Indices (lb/10^3 gallons fuel or mcf gas)					
	CO	PM	PM-10	NO_x	SO_2[1]	VOC
Distillate Oil (Diesel)	130.0	42.5	32.0	604.0	141(S)	49.3
Kerosene/Naphtha (Jet Fuel)	102.0	33.5	32.0	469.0	128(S)	32.1
Gasoline (Mogas)	7128.0	11.4	6.2	185.0	123(S)	344.0
Natural Gas (lb/million cubic feet)	430.0	10.0	10.0	3400.0	840(S)	82.9
LPG (Propane or Butane)	129.0	5.0	5.0	139.0	91(S)	83.0
Residual/Crude Oil	102.0	33.5	30.8	469.0	152(S)	32.1

Table H-2: **Uncontrolled Emission Indices For Emergency Generators Powered By Reciprocating Engines**[2]

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[1] Note: (S) signifies the fuel sulfur content, expressed as weight percent sulfur, which is multiplied by the coefficient given to obtain the emission index for SO_2.

[2] Source: Jagielski, Kurt D., and Robert J. O'Brien, *Calculation Methods for Criteria Air Pollutant Emission Inventories*, p. 80 (Reference 23). SO_2 emissions calculated by assuming all fuel sulfur is emitted as SO_2.

H2.3 Incinerators

H2.3.1 Methodology

Pollutant emissions from incinerators are calculated by multiplying the mass of waste burned by the emission index for each specific pollutant.

Total pollutant emissions from an incinerator may be estimated by applying Equation H-5:

$$\mathbf{E_{ti} = \Sigma\ [F \times UI_i \times (1 - CF/100)]}$$

Where:

E_{ti} - total emissions of pollutant i, in pounds, from the incinerator for given time period
F - total mass of waste burned, in tons, for given time period
UI_i - uncontrolled emission index for pollutant i, in pounds of pollutant per ton of waste burned
CF - air pollution control factor (%)
i - pollutant (CO, NO_x, SO_2, PM-10, HC)

Equation H-5: Pollutant Emissions for Incinerators

H2.3.2 Data Sources

The particular data inputs required for the emissions calculation methodology for each incinerator are listed in the following paragraphs (2.3.2.1. through 2.3.2.3).

H2.3.2.1 Mass of Waste Burned

Available from the airport operator or base operations section. This should be expressed in terms of tons of waste burned.

H2.3.2.2 Emission indices

Uncontrolled emission indices based on the type of incinerator are given in Section 2.1.7 of Volume I of the EPA *Compilation of Air Pollutant Emission Factors*. Uncontrolled emission indices for PM, SO_2, CO, TOC, and NO_x are provided. EPA provides emission indices for two types of industrial/commercial incinerators likely to be operated at airports: multiple chamber and single chamber. The type of incinerator design should be obtained from the airport operator or base operations section.

H2.3.2.3 Air Pollution Control Factor

Emissions from incinerators are sometimes controlled by scrubbers or gas-fired afterburners. Information on equipment and control efficiency should be obtained from the airport operator or base operations section. This figure should be expressed as a percent reduction from the uncontrolled emission level.

H2.4 Fire Training Facilities

H2.4.1 Methodology

ARFF training facilities are distinguished by the type of fuel burned in the simulations: approximately one half burns propane, and the other half burns jet fuel, diesel fuel, or gasoline. The former have been constructed in recent years due in part to concerns over the air emissions derived from the burning of jet fuel and other fuels. The burning of jet fuel and other fuels tends to produce a column of smoke (particulate matter) that can extend for miles, whereas emissions from the burning of propane are much less smoky.

Air pollutants from the burning of training fires at airports include PM, CO, NO_x, SO_2, and VOC. Emission indices for these pollutants depend upon the type of fuel burned, and have been estimated based on measured emissions from the uncontrolled burning of each fuel. Using these emission indices, total pollutant emissions from a training fire can calculated using the methodology given here.

The methodology for calculating emissions from training fires at airports is straightforward. The quantity of jet fuel burned in each fire is determined, and this is multiplied by the emission indices to calculate the total pollutant emissions to the atmosphere for each fire. Total emissions from one training fire are calculated using Equation H-6.

$$\mathbf{E_{ti} = \Sigma\ (QF \times EI_i)}$$

Where:

E_{ti} - total emissions of pollutant i, in pounds

QF - quantity of fuel burned in training fire (10^3 gallons)

EI_i - emission index (pounds of pollutant i emitted per 10^3 gallons of fuel burned)

i - pollutant (PM, CO, SO_2, NO_x, VOC)

Equation H-6: Total Emissions for Training Fires

H2.4.2 Data Sources

The following information is required to estimate pollutant emissions from training fires: total fuel consumption per fire and emission indices based on the quantity of fuel burned.

H2.4.2.1 Quantity of Fuel Burned Per Training Fire

Available from the aircraft rescue and fire fighting (ARFF) department, airport operator or base operations section. This figure should be expressed in terms of thousands of gallons.

H2.4.2.2 Emission Index

Error! Reference source not found. provides emission indices for each of the fuels commonly burned in ARFF training facilities. Emission indices are given in terms of pounds of pollutant per 1000 gallons of fuel burned.

Fuel	**Emission Index (lb/10^3 gallons fuel)**				
	CO	**PM**	**NO_x**	**SO_2**	**VOC**
Propane	34.8	117.2	6.4	0.02	31.8
JP-4	3584	960	26.88	3.8	128
JP-8	4487	1014	33.65	6.8	135

Table H-3: Emission Indices For Uncontrolled Fuel Burning in Training Fires[3]

H2.5 Aircraft Engine Testing

H2.5.1 Methodology

Pollutant emissions from aircraft engine testing are computed using a similar methodology to that given previously for the aircraft LTO cycle emissions. For each engine being tested, pollutant emission indices and fuel flow rates for each mode of aircraft operation are available from published data. During testing, the engine is taken through a sequence of power levels simulating actual flight conditions. Knowledge of the test times and fuel flow rates for each of these steps allows the calculation of emissions from each testing step. The methodology for calculating overall emissions from aircraft is expressed by Equation H-7:

$$\mathbf{E_{ti} = \Sigma (N \; x \; TM_j \; x \; FF_j/1000 \; x \; EI_i)}$$

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[3] Sources: Propane: PM, VOC: Letter from D. Joynt (Symtron, Inc.) to P. Forward (EEA, Inc.), February 12, 1996 (Reference 25). Emission indices given therein based on Robert S. Levine (National Institute of Standards and Technology) memorandum to C. Lenhoff and D. King, AAI Corporation, December 9, 1992 (Reference 26).
CO, NO_x: Estimate based on emission indices for flares given in Section 13.5 of Volume I of *Compilation of Air Pollutant Emission Factors*.
SO_2: *Compilation of Air Pollutant Emission Factors*, Volume I, Section 1.5, assuming propane sulfur content of 0.2 g/100 scf.
JP-4,8: PM, VOC: Letter from D. Joynt (Symtron, Inc.) to P. Forward (EEA, Inc.), February 12, 1996. Emission indices given therein based on Robert S. Levine (National Institute of Standards and Technology) memorandum to C. Lenhoff and D. King, AAI Corporation, December 9, 1992. JP-8 data are estimates based on JP-4 test results.
CO, NO_x: Jagielski, Kurt D., and Robert J. O'Brien, *Calculation Methods for Criteria Air Pollutant Emission Inventories*, p. 14. JP-8 data are estimates based on JP-4 test results.
SO_2: Calculated by assuming all fuel sulfur emitted as SO_2. Fuel sulfur content for JP-4 taken as average for 1979-1989 from Dickson, Cheryl L. and Paul W. Woodward, *Aviation Turbine Fuels, 1989* (Reference 13). JP-8 sulfur content assumed equivalent to Jet A sulfur content, from same document.

Where: E_{ti} - total emissions of pollutant i
N - number of test cycles performed
TM_j - average test time, in minutes per test, for mode j
FF_j - fuel flow rate, in pounds per minute, while in testing mode j
EI_i - emission index in pounds of pollutant i emitted per 10^3 lbs fuel burned
i - pollutant (CO, PM-10, SO_2, NO_x, HC)
j - testing mode

Equation H-7: Total Emissions for Aircraft Engine Testing

H2.5.2 Data Sources

Detailed data inputs are required to calculate emissions from aircraft engine testing. Data inputs and sources are listed in the following paragraphs (2.5.2.1. through 2.5.2.5).

H2.5.2.1 Number of Test Cycles Performed

Maintenance personnel should be consulted to determine the typical number of test cycles performed upon each aircraft.

H2.5.2.2 Test Time for Each Mode

Aircraft engine test time for each testing mode varies with the engine type, goals of the test, and equipment used. Site-specific information on test times should be obtained from the maintenance personnel performing the testing.

H2.5.2.3 Engine Fuel Flow

The default average fuel consumption rate, in pounds per minute, of an engine in each operational mode, is provided in EPA's *Procedures for Emission Inventory Preparation*, Volume IV, Chapter 5 (Reference 82) and in the *ICAO Engine Exhaust Emissions Databank* (Reference 27). For military aircraft, the EPA procedures document should be used.

H2.5.2.4 Engine Emission Indices

Pollutant emission indices for an aircraft engine are listed by operating mode, generally, in pounds of pollutant per 1000 pounds of fuel consumed. Average emission index data for engines by operating mode is included in EPA's *Procedures for Emission Inventory Preparation,* Volume IV, Chapter 5 (for both civil and military aircraft engines) and in the *ICAO Engine Exhaust Emissions Databank* (for civil aircraft engines only).

H2.5.2.5 Engine Type

Potential sources of site-specific data on engine types being tested include airline maintenance, base operations section, and sampling. If site-specific engine data for commercial airlines is not available but the aircraft operator is known, then an appropriate default engine can be chosen based on the operator's national fleet. Airline fleet data, including aircraft engine model, is published in Bucher & Co.'s *JP Airline-Fleets International* (Reference 2) and Jet Information Services' *World Jet Inventory* (Reference 24). If the aircraft operator is not known, default, typical aircraft-engine data is provided in EPA's *Procedures for Emission Inventory Preparation,* Volume IV, Chapter 5. For military aircraft, site-specific information on engine types being tested may be obtained from the maintenance section of the air base where testing occurs. Default aircraft engine data is also listed in the EPA document listed above.

H3 NON-COMBUSTION SOURCES

Each type of non-combustion stationary and area source requires a different methodology to be used for calculating the rate of emissions, as described in the following paragraphs.

H3.1 Fuel Storage Tanks

H3.1.1 Methodology

Table H-4 shows the “pathways” of HC emissions from the three types of fuel storage tanks commonly found at airports.

As Table H-4 shows, there are a number of “pathways” for evaporated HC to escape from fuel storage tanks and enter the atmosphere. Accurate calculation of emissions escaping through each of these pathways requires information on the tank structure, fuel type, meteorology, and operating practices. In general, fixed-roof tanks tend to be older and result in the greatest atmospheric emissions. The presence of a volume of vapor space above the level of liquid in the tank promotes evaporation of the fuel hydrocarbons and their subsequent release to the atmosphere through the breather valve. Tanks equipped with a floating roof are able to reduce evaporative emissions by eliminating the vapor space between the liquid level in the tank and the tank roof. However, some emissions do occur through various seals and openings and because fuel clings to the tank walls as the liquid level and roof are lowered.

Tank type	Standing Storage Emissions	Working Emissions
Fixed roof	**Breathing emissions:** Changes in temperature or pressure cause imbalance between internal and external vapor pressure. Breather valves are opened to equalize pressure, allowing emission of evaporated hydrocarbons.	**Displacement emissions:** During filling of tank, liquid displaces gas inside tank, forcing it to be expelled through the breather valve. **Air saturation emissions:** During fuel removal, air drawn into the tank becomes saturated with hydrocarbons and expands, thus causing an imbalance of vapor pressure with the atmosphere. This imbalance is relieved by venting to the atmosphere.
External floating roof	**Rim seal, roof fitting emissions:** Emissions occur from rim seals and roof fittings due to slight imbalances in internal and external vapor pressure. Exposure of floating roof to wind increases emission rate.	**Clingage emissions:** As roof is lowered during withdrawal, fuel clings to the tank walls and evaporates when exposed to the atmosphere. Evaporation rate increases with wind speed.
Internal floating roof	**Rim seal, deck fitting, deck seam emissions:** Emissions occur from rim seal, deck fitting, and deck seam due to slight imbalances in internal and external pressure. Lower emissions because roof is protected from wind.	**Clingage emissions:** As roof is lowered during withdrawal, fuel clings to the tank wall and evaporates. Wind does not increase the evaporation rate.

Table H-4: Pathways of Hydrocarbon Emissions To Atmosphere From Fuel Storage Tanks[4]

A methodology for calculating the sum of hydrocarbon emissions from above-ground and below-ground fuel storage tanks is given in Section 7.1, Volume I of EPA's *Compilation of Air Pollutant Emission Factors*. A wide range of storage tanks is covered in this document, including fixed roof, internal floating roof, external floating roof, variable vapor space, and pressure tanks. The general methodology is to identify each of the major pathways for hydrocarbons to escape from storage tanks to the atmosphere, and use available information to estimate emissions through each pathway. An overview of information requirements is given below. The two main categories of emissions are standing storage emissions, which result from changes in the surrounding temperature and barometric pressure, and working emissions, which result from the loading or withdrawal of fuel. In both cases, emissions result from higher pressure inside the tank than outside, causing the hydrocarbon vapor to escape through any available opening. Depending on the tank type, these openings or pathways include breather vents, rim seals, deck fittings, and deck seams.

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[4] Sources: EPA's "Fuel Storage Tanks," *Compilation of Air Pollutant Emission Factors,* Volume I, Section 7.1. and Jagielski, Kurt D., and Robert J. O'Brien, *Calculation Methods for Criteria Air Pollutant Emission Inventories,* p. 14.

The general methodology for calculating storage tank hydrocarbon emissions may be expressed by Equation H-8:

$$\mathbf{E_{HC} = E_S + E_W}$$

Where:

E_{HC} - total hydrocarbon emissions from a single tank over a given time period
E_S - standing storage emissions from the tank
E_W - working emissions from the tank

Equation H-8: Hydrocarbon Emissions for Storage Tanks

The methodologies for calculating E_S and E_W are different for each tank type. These methodologies are described in the Section 7.1, Volume I of *Compilation of Air Pollutant Emission Factors*, and are implemented in the EPA computer model *TANKS* (Reference 84).

H3.1.2 Data Sources

A number of data sources are required for an accurate assessment of standing storage and working emissions from fuel storage tanks. These include the type of tank, physical dimensions of the tank, fuel type, climatic data, rate of fuel throughput, and other tank-specific characteristics. Detailed information on data requirements is given in Section 7.1, Volume I of *Compilation of Air Pollutant Emission Factors*. An overview of these requirements and the likely sources of obtaining this information is given in paragraphs 3.1.2.1. through 3.1.2.5.

H3.1.2.1 Type of Storage Tank

The three most common main types of fuel storage tanks are fixed roof, external floating roof, and internal floating roof tanks. Descriptions of the different tank types is given in Section 7.1, Volume I of *Compilation of Air Pollutant Emission Factors*. Tank information may be obtained from the airport operator, base operations department, fueling contractor, or by visual inspection.

H3.1.2.2 Fuel Type

Fuel vapor pressure and density for each storage tank are required to calculate emission losses. Specification of the type of fuel stored in the tank allows the use of default values for vapor pressure and density given in Section 7.1, Volume I of *Compilation of Air Pollutant Emission Factors* and included in the *TANKS* program.

H3.1.2.3 Climatic Data

Average wind speed, average daily ambient temperature range, average daily solar insulation, and average atmospheric pressure values are each required for the emission calculation. The EPA program *TANKS* contains a database of the necessary climatic information for over 250 cities in the United States, so that only the closest nearby city needs to be specified by the user.

H3.1.2.4 Fuel Throughput

An estimate of annual throughput of fuel for each tank should be obtained from the airport operator, fueling contractor, or base operations department.

H3.1.2.5 Tank-Specific Characteristics

Tank-specific characteristics used in calculating emission losses include one or more of the following: physical dimensions of the tank, type of seals, breather vent settings, tank paint color, number of vacuum breakers, number of columns, effective column diameter, deck fitting types, and deck seam length. This information may be obtained from the airport operator, fueling contractor, base operations department, tank manufacturer, or by visual inspection of the tank. In many cases, default values are given in *Compilation of Air Pollutant Emission Factors* and are incorporated into the *TANKS* program.

H3.2 Coating or Painting Operations

H3.2.1 Methodology

Painting operations emit volatile hydrocarbons (HC) to the atmosphere through evaporation of the paint vehicle, thinner, or solvent used to facilitate the application of the coatings. The main factor affecting HC emissions from painting operations is the volatile content of the coatings, which averages around 15% for water-based coatings to over 50% for solvent-based coatings[5]. Most, if not all, of the volatile portion of the coating evaporates during or following application. To reduce these emissions, paint manufacturers have reduced the VOC content of coatings in recent years. In addition, air pollution control equipment, such as activated carbon adsorption of hydrocarbon emissions or destruction of hydrocarbons in an afterburner, is available for use in some applications.

The methodology for calculating hydrocarbon emissions from painting operations is quite simple. For each type of coating fluid used in painting, the quantity of coating used is multiplied by the VOC content of the coating to obtain the total hydrocarbon emissions from the use of that coating. If any type of air pollution control equipment is in use, then the hydrocarbon emissions estimate is reduced to reflect the effects of the air pollution control. The methodology is expressed by Equation H-9:

$$\mathbf{E_{HC} = \Sigma\ [Q_i \times VOC_i \times (1 - CF/100)]}$$

Where:

E_{HC} - total volatile hydrocarbon emissions from painting operations
Q_i - total quantity of coating type i used in time period being studied (gallons)
VOC_i - VOC content for coating type i (lb VOC emissions/gallon)
CF - air pollution control factor (%)
i - coating type (paint, varnish/shellac, lacquer, enamel, primer)

Equation H-9: Hydrocarbon Emissions For Painting Operations

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[5] Jagielski, Kurt D., and Robert J. O'Brien, *Calculation Methods for Criteria Air Pollutant Emission Inventories*, pp. 60-61.

H3.2.2 Data Sources

To estimate the hydrocarbon emissions from painting facilities at an airport and air bases, four data inputs are required: the type of coating used, the quantity of coating used, an uncontrolled emission index, and an air pollution control factor (if applicable).

H3.2.2.1 Type of Coating

Coatings include paint, varnish and shellac, lacquer, enamel, and primer. The airport operator, maintenance department, aircraft operator, or base operations department should be able to provide information on the type of coatings used.

H3.2.2.2 Quantity of Coating

The quantity of each type of coating used should be obtained and expressed in gallons. Information on the quantity of coating used should be obtained from the base operations section or maintenance department.

H3.2.2.3 VOC Content (by volume)

Material Safety Data Sheets (MSDS) or coating manufacturers should be consulted to obtain the volatile content, expressed in terms of pounds per gallon of solvent or VOC's. If this information is unavailable, default values from Table H-5 may be used.

Surface Coating	VOC Content (lb/gal)
Paint (Solvent Base)	5.6
Paint (Water Base)	1.3
Enamel	3.5
Lacquer	6.1
Primer	6.6
Varnish/Shellac	3.3
Thinner	7.36
Adhesive	4.4

Table H-5: VOC Content Of Common Surface Coatings[6]

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[6] Source: Jagielski, Kurt D. , and Robert J. O'Brien, Calculation methods for criteria Air Pollutants Emission Inventories, p.60.

H3.2.2.4 Air Pollution Control Factor

Air pollution control equipment such as activated carbon adsorption or afterburner destruction of the vapors is sometimes used in painting operations. Information on the demonstrated effectiveness of these control methods should be obtained from the airport maintenance section, base operations department, or equipment manufacturers.

H3.3 Deicing Operations

H3.3.1 Methodology

Hydrocarbon emissions result from the application of deicing fluid to both aircraft and runways. Common aircraft deicing fluids are a mixture of water and propylene glycol or ethylene glycol. These chemicals are slightly volatile and a small fraction of the chemical is likely to evaporate after the deicing fluid is applied. Other chemicals present in runway deicing fluids include urea and other organic and inorganic salts, most of which are unlikely to contribute to HC emissions.

A methodology for estimating HC emissions from aircraft and runway deicing operations based on emission indices from independent sources is presented here. Because of the different practices for deicing of runways and aircraft, these two operations are considered separately and have two different emission indices. A similar methodology is used for both cases, however. The mass of organic chemical consumed (commonly propylene glycol or ethylene glycol) is determined by multiplying the volume of deicing fluid consumed by the density of the fluid and by the concentration of the chemical in the fluid. The calculated mass of organic chemical consumed is multiplied by an emission index to determine the hydrocarbon emissions from the application of the deicing fluid. The overall methodology is expressed by Equation H-10:

$$\mathbf{E_{HC} = \Sigma\ [QF_j\ x\ D_j\ x\ (C_{ij}/100)\ x\ EI_{ij}]}$$

Where:

E_{HC} - annual HC emissions from deicing activities (pounds)
QF_j - quantity of deicing fluid used per year in operation type j (gallons)
D_j - density of deicing fluid used in operation type j (pounds/gallon)
C_{ij} - concentration of chemical i in deicing fluid for operation type j (percent by weight)
EI_{ij} - emission index for chemical used in deicing operation type j (pounds HC emissions per pound of chemical consumed)
i - chemical present in deicing fluid (propylene glycol, ethylene glycol, or other organic compound)
j - deicing operation (runway or aircraft deicing)

Equation H-10: Hydrocarbon Emissions For Deicing Operations

H3.3.2 Data Sources

H3.3.2.1 Quantity of Deicing Fluid Used

Quantities should be expressed in gallons and separated into fluid used for aircraft and runway deicing. This data requirement should not pose a problem because the two operations are usually maintained separately. This information may be obtained from the airport operator, deicing contractor, or base operations department.

H3.3.2.2 Density of Deicing Fluid

This information may be obtained from the maintenance section, base operations department, fluid manufacturer, or by calculation. The density should be expressed as pounds per gallon of fluid. To calculate the density of the deicing fluid, Equation H-11 should be applied. The equation is performed for each component, and results are totaled to obtain the total density.

$$\mathbf{D = \Sigma\, [D_w \times (C_k/100) \times SG_k]}$$

Where:

D - density of deicing fluid (pounds per gallon)
D_w - density of water (8.345 pounds per gallon)
C_k - concentration of component k in deicing fluid (percent)
SG_k - specific gravity of component k; specific gravity is a dimensionless ratio of the weight of the chemical to the weight of water
k - components of deicing fluid (water, ethylene glycol, propylene glycol, urea, polymer additives, etc.)

Equation H-11: Density of Deicing Fluid

The concentration of each component in the deicing fluid should be obtained from the airport operator, deicing contractor, or fluid manufacturer. Concentrations for all fluid components, including water, should be obtained. Therefore if a solution is given as 48% propylene glycol, then the remainder of the solution (52%) is assumed to be water.

Specific gravity for common deicing fluid components is given in Table H-6.

Fluid Component	Specific Gravity (dimensionless)
Water	1.000
Ethylene Glycol	1.119
Propylene Glycol	1.036
Urea	1.323

Table H-6 : Specific Gravity of Common Deicing Fluid Components[7]

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[7] Source: *CRC Handbook of Chemistry and Physics, 63rd Edition* (Reference 92).

A 50% ethylene glycol deicing fluid is considered as an example. The weight of the ethylene glycol component, following the above equation, is 8.345 pounds/gallon x (50/100) x 1.119 = 4.669 pounds ethylene glycol per gallon of fluid. The other component of the fluid is water, which is also 50% of the fluid by weight. The weight of the water component is 8.345 pounds/gallon x (50/100) x 1.000 = 4.173 pounds water per gallon of deicing fluid. The total density of the deicing fluid, then, is 4.669 + 4.173 = 8.842 pounds/gallon.

H3.3.2.3 Concentration of Chemical in Deicing Fluid (By Weight)

This information should be obtained from MSDS sheets, deicing contractor, or fluid manufacturer. Common solutions are 50% propylene glycol in water or 50% ethylene glycol in water. In many cases, different chemical formulations are used for runway and aircraft deicing.

H3.3.2.4 Emission indices

Emission indices for an ethylene glycol solution applied to a runway and to aircraft have been calculated (Reference 19). An emission index of 0.0067 pounds HC emissions per pound of ethylene glycol applied should be used for runway deicing, and an emission index of 0.00011 pounds HC emissions per pound of ethylene glycol applied should be used for aircraft deicing. One should be careful to note that emissions are given per pound of ethylene glycol rather than per pound of deicing fluid, which also contains water. Equation H-11 takes this into account by employing a concentration factor. The emission indices given for ethylene glycol solutions may also be applied to propylene glycol, which is somewhat less volatile than ethylene glycol.

H3.4 Solvent Degreasers

H3.4.1 Methodology

The use of organic solvents such as chlorinated hydrocarbons, petroleum distillates, ketones and alcohol results in the evaporation of volatile organic compounds (VOC’s) or other hydrocarbons, which are subsequently either disposed of as waste liquids or released to the atmosphere. If water-based alkaline wash systems are used for degreasing, no evaporation of VOC’s or other hydrocarbons occurs.

The methodology for estimating evaporative hydrocarbon emissions from the operation of solvent degreasers is presented here. The methodology is based on the assumption that all solvent consumed by a solvent degreasing unit is either disposed of as waste liquid or released to the atmosphere as hydrocarbon emissions. The emissions to the atmosphere, therefore, are estimated by calculating the difference between the volume of solvent consumed and the volume of solvent disposed as liquid, and multiplying this difference by the density of the solvent. This methodology is expressed by Equation H-12, which computes the hydrocarbon emission for one solvent degreaser:

$$E_{HC} = D \times (QC - QD)$$

Where:

E_{HC} - hydrocarbon emissions from solvent degreasing unit (pounds)
QC - quantity of solvent consumed in solvent degreaser in given time period (gallons)
QD - quantity of solvent disposed of as liquid in given time period (gallons)
D - density of solvent (pounds per gallon)

Equation H-12: Hydrocarbon Emission For Solvent Degreasers

H3.4.2 Data Sources

H3.4.2.1 Quantity of Solvent Consumed

This information, expressed in gallons, should be available from the operator of the solvent degreaser.

H3.4.2.2 Quantity of Solvent Disposed as Liquid

This information, expressed in gallons, should be available from the operator of the solvent degreaser. If no records on solvent disposal are available, then it should be assumed that 100% of the solvent consumed by the solvent degreaser is released to the atmosphere as hydrocarbon emissions.

H3.4.2.3 Density of Solvent

Available from the operator of the solvent degreaser, from the solvent manufacturer, or from Table H-7. Density should be expressed as pounds per gallon.

Solvent	Density (lb/gal)	Solvent	Density (lb/gal)	Solvent	Density (lb/gal)
Acetone	6.604	Ether	6.136	1,1,1-Trichloroethane	11.174
Alcohol (ethyl)	6.604	Isopropyl alcohol	6.555	Trichloro-ethylene	12.219
Alcohol (methyl)	6.751	Methylene Chloride	11.070	Turpentine	7.259
Carbon tetrachloride	13.315	Perchloro-ethylene	13.541	Water	8.345
Chloroform	12.432	Stoddard Solvent	6.497		

Table H-7: Density of Common Solvents Used in Solvent Degreasers[8]

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[8] Source: *CRC Handbook of Chemistry and Physics, 63rd Edition.*

H3.5 Sand/Salt Piles

A methodology for estimating emissions from material storage piles is given in Sections 13.2.4 and 13.2.5 of Volume I of EPA's *Compilation of Air Pollutant Emission Factors*. Methodologies are provided for the two chief emissions sources associated with storage piles: batch loading and unloading of material, and wind erosion of the piles.

H3.5.1 Methodology - Material Loading and Unloading

The major source of particulate emissions during loading and unloading of piles occurs as material is dropped from a loader onto the pile or into a truck. A methodology for calculating the particulate emission index for these events is provided in Volume I of *Compilation of Air Pollutant Emission Factors*, requiring only mean wind speed, material moisture content, and cutoff particle size (i.e. 10 μm if PM-10 is desired). Particulate matter emissions are estimated by multiplying an emission index by the quantity of material transferred to or from the pile during the desired time period. This is expressed by Equation H-13:

$$\mathbf{E_{PM} = 2 \times TH \times EI}$$

Where:

E_{PM} - total particulate emissions from pile loading and unloading

2 - factor representing number of drops material undergoes; once during loading and once during unloading

TH - total throughput of sand and salt stored in pile in given time period (tons)

EI - emission index, given as pounds of particulate matter emitted per ton of material undergoing drop operation

Equation H-13: Particulate Matter Emissions for Sand/Salt Piles

H3.5.2 Data Sources - Material Loading and Unloading

The EPA methodology for calculating emissions during loading and unloading of material piles requires mean wind speed, pile moisture content, and the quantity of material loaded and unloaded.

H3.5.2.1 Mean Wind Speed (m/s)

For this calculation, only one figure for the mean wind speed at the airport is required. This may be obtained from the National Climatic Data Center or from the weather station on site.

H3.5.2.2 Pile Moisture Content (%)

This information can be obtained by direct sampling of the piles, or from the maintenance or base operations section. Section 13.2.4 of Volume I of *Compilation of Air Pollutant Emission Factors* provides information on the moisture content of material types by industry, such as 7.4% for a sand pile located at a municipal landfill. This value may be used if moisture content of piles located on the site is not available.

H3.5.2.3 Quantity of Material Loaded and Unloaded (tons)

This information should be obtained from the maintenance or base operations department. Because the methodology takes into account both loading and unloading of the pile, the desired information is the material “throughput” for each pile.

H3.5.3 Methodology - Wind Erosion

The second major source of particulate emissions from sand and salt piles is wind erosion of the piles. A detailed methodology for calculating these emissions is given in Section 13.2.5 of Volume I of *Compilation of Air Pollutant Emission Factors*. This methodology calculates the amount of erosion particulate emissions from the pile by applying an “erosion potential function” to each surface of the pile. The erosion potential function is affected by the following parameters:

- Moisture content of stored material
- Silt content of stored material
- Number of loading/unloading events in given time period
- Percent of pile disturbed in each loading/unloading event
- Physical dimensions of pile
- Threshold friction velocity of the material (i.e. the wind velocity at which wind shear stress is great enough to cause particles to be released from the material surface)
- Surface roughness height of material (a measure of the resistance to wind flow near the surface of the material caused by unevenness or roughness of the material)
- Wind speed and direction

The methodology is too complex to be reduced to a single equation. Although it is possible to perform these calculations by hand, the number of computations required for each pile is very large. EPA has incorporated this methodology into a freely available computer program, named *WIND* (Reference 91). The use of this program is strongly recommended.

H3.5.4 Data Sources - Wind Erosion

The EPA methodology for calculating particulate emissions due to wind erosion of storage piles requires several pieces of information about each pile, as described in paragraphs 3.5.4.1 through 3.5.4.8. As some of these parameters are not commonly available for each storage pile, default values are given in Sections 13.2.4 and 13.2.5 of Volume I of *Compilation of Air Pollutant Emission Factors*.

H3.5.4.1 Moisture Content of Stored Material (%)

This information can be obtained by direct sampling of the piles, or from the maintenance or base operations section. Section 13.2.4 of Volume I of *Compilation of Air Pollutant Emission Factors* provides information on the moisture content of a sand pile located at a municipal landfill: 7.4%. This value may be used as a default if moisture content of piles located on the site is not available.

H3.5.4.2 Silt Content of Stored Material (%)

Silt content is a measure of the percentage of material that passes through a No. 200 sieve. This can be obtained by direct sampling of the pile or from the maintenance or base operations department if this information has been recorded. Section 13.2.4 of Volume I of *Compilation of Air Pollutant Emission Factors* provides the silt content of a sand pile stored at a municipal landfill: 2.6%. This value may be used as a default if silt content of piles located on the site is not available.

H3.5.4.3 Frequency of Loading/Unloading Events

Wind erosion is a factor of the number of times the surface of the pile is disturbed through loading or unloading events. Information on the frequency of loading and unloading events should be obtained from the maintenance or base operations section.

H3.5.4.4 Percentage of Pile Surface Disturbed in Loading/Unloading Events

The methodology for calculating wind erosion assumes that erosion occurs in those surfaces of the pile that have been disturbed by unloading and loading activity. An estimate of the percentage of the pile surface disturbed in each event must therefore be calculated based on the material throughput rate and pile size, or if possible, from information supplied by the operator. Both Section 13.2.5 of Volume I of *Compilation of Air Pollutant Emission Factors* and the *WIND* program and user’s manual describe the specific informational requirements needed for these calculations.

H3.5.4.5 Physical Dimensions of the Pile

Required dimensions include overall pile shape description (either flat, conical, or oval flat-topped), as well as pile height and diameter, expressed in meters. This information is available through direct observation or from the maintenance or base operations section.

H3.5.4.6 Threshold Friction Velocity of the Stored Material

The threshold friction velocity is the wind velocity at which wind shear stress is great enough to cause particles to be released from the material surface. This information can be obtained by sampling of the pile surface according to a method described in the Section 13.2.5 of Volume I of *Compilation of Air Pollutant Emission Factors*. Default parameters based on material type are provided in *Compilation of Air Pollutant Emission Factors* if sampling is not possible; however, threshold friction velocity is not given for either sand or salt. A default figure of 1.02 m/s, measured for overburden material at a coal mine, may be used if no other source of information is available.

H3.5.4.7 Surface Roughness Height of Stored Material (cm)

The surface roughness height is a measure of the resistance to wind flow near the surface of the material caused by unevenness or roughness of the material. For some materials, default parameters based on material type are provided in Section 13.2.5 of Volume I of *Compilation of Air Pollutant Emission Factors*. As with threshold friction velocity, surface roughness height is not explicitly given for sand or salt. A default figure of 0.3 cm may be used, based on a measured value for overburden material at a coal mine.

H3.5.4.8 Wind Speed

Required information is the “fastest mile” of wind recorded daily for the time period being investigated. The fastest mile is the highest measured wind speed, expressed in miles per hour, at which air is measured by an anemometer to travel one mile. This data is available in electronic form in the Local Climatological Data Summaries (LCD’s), provided by the National Climatic Data Center (Reference 29) for most airport weather stations.