Organic Hazardous Air Pollutant Emission Factors
For Iron Foundries

Prepared by: Air Quality Committee (10-E)
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Introduction

The purpose of this document is to provide iron foundries with guidance on the selection of organic hazardous air pollutant (HAP) emission factors for the pouring, cooling, and shakeout (PCS) operations and to a limited extent for core/No-Bake mold making operations. The emission factors in the attached tables are applicable to the process conditions listed in the referenced documents. If process conditions are different, the emission factors provided in the attached tables should be adjusted accordingly to account for the differences. However, if the process conditions are significantly different, the emission factors in the attached tables may not provide an accurate estimate even after making the adjustment and therefore should not be used.

THE INFORMATION PROVIDED IN THIS DOCUMENT IS NOT BY ITSELF ADEQUATE FOR MAKING A DETERMINATION ON WHETHER A FACILITY IS A MAJOR SOURCE OF HAPs. IT ONLY PROVIDES THE ORGANIC EMISSION FACTORS FOR THE PROCESSES LISTED ON THE INCLUDED EMISSION TABLE. ADDITIONAL HAP EMISSION SOURCES AT THE FACILITY WILL NEED TO BE IDENTIFIED AND A HAP EMISSION INVENTORY PERFORMED FOR THE ENTIRE FACILITY TO DETERMINE THE FACILITY'S MAJOR SOURCE STATUS.

Background

During the late 1990's it became apparent that there was a need for more accurate information on the types and quantities of organic HAPs emitted from the PCS operations in iron foundries. In addition while there was a patch work of data being generated by various sources, there was no single source that a foundry could consult to estimate their PCS HAP emissions. To address this first need, the Casting Emissions Reduction Program (CERP) was created to evaluate the HAP emission potential of various mold and coremaking processes and systems. To address the second need, the American Foundry Society's (AFS) Air Quality Committee (10E) formed an emission factor subcommittee.

This subcommittee was tasked with reviewing existing emission data and to summarize that data. Various sources were consulted, including the data generated by CERP. The attached table is the product of that subcommittee's work. During the course of its work the subcommittee determined that HAP emissions from PCS were not understood well and that guidance was necessary to insure consistent use of available emission factors. This document provides such guidance.

Besides the PCS operations, other processes within a foundry can also emit organic HAPs. These other processes however are more easily quantified with traditional methods, such as using information in Material Safety Data Sheets (MSDS), raw materials' "Certificate of Analysis" and purchasing records.

Inorganic HAPs (i.e. metals) emitted from foundry processes can be calculated from particulate emission factors or from stack testing results. The "EPA MACT Background Document for Iron and Steel Foundries" (EPA-453/R-02-013, 12/1/02) provides data on inorganic HAPs present in particulate emissions from different iron foundry sources. This document also provides a method of estimating these emissions from a bag house catch analysis.

Using the Emission Table

The majority of the HAP emissions from pouring cooling and shakeout originate from either the volatilization and/or thermal decomposition of organic materials present in the mold or cores. Tests performed by CERP have shown that the emissions from the mold and core components are additive. In other words, the emissions from a test of a non-cored green sand mold can be added to the values of a test on a core component to provide an accurate estimate of emissions from a green sand mold containing that core. This relationship is particularly strong when the PCS emission data for the core component is collected while it is contained in a mold that is devoid of any organic materials.

In addition, CERP testing has shown that the quantity of HAPs emitted during PCS operations is directly proportional to the surface area of the casting. In other words, all other factors being equal the greater the surface area, the greater the emissions.

With the above relationships in mind, the attached emission factors are provided in six separate tables:

- Table A. Green sand Mold Emissions
- Table B. Core Emissions
- Table C. Cored Green sand Mold Emissions
- Table D. No-Bake Mold Emissions
- Table E. Lost Foam Emissions
- Table F. Core/Mold Making, Mixing and Storage Emissions

The tables list the major process description as "Process Conditions" followed by the total HAP emission factor and a reference publication. The reference publication is the source of the total HAP emission factor and includes the HAP data along with relevant process parameters.

Green sand Molds and Green sand Cored Molds

Tables A, B, and C relate to PCS HAP emissions from green sand molds or green sand cored molds. Table A lists two green sand emissions factors. This table is to be used for castings made from green sand molds using seacoal as the only carbonaceous additive. The first row is for a casting with "average" surface area and no cores. The second row is for a casting with a "very high" surface area and no cores. Castings with thin cross sections or fins would fall in this category.

Table B provides "core only" HAP emission factors for different coremaking binder systems. Research done at CERP has shown that the HAP emissions from cores can be numerically added to the HAP emissions from sand molds to arrive at total core/mold package emissions. This calculation allows estimation of a HAP emission factor for a specific core/mold package by adding the appropriate core emission factor to the appropriate mold emission factor.

Table C lists the measured combined core/mold HAP emission factors for three different core/mold combinations based on actual emission testing of cored green sand molds. The first row is considered a very high emitting combination of an older phenolic urethane core binder system formulation, at a very high binder level, and a green sand mold made with high carbonaceous additives producing four-cylinder engine blocks. The second row represents a step block core pattern, a lower surface area part, but again with high emitting core and green sand formulation. The third row lists the emission factor used by EPA during the MACT rulemaking process as the average HAP emission factor for PCS operations in a green sand foundry. These factors, combining core and sand mold emissions, may be used if the process specification for an individual foundry matches those specified in Table C.

The emission factors listed represent emissions from specific types of core and mold materials at formulations stated in the emission tests. Emission factors for molding sand and core mixes where the levels of organic binders or carbonaceous additive are different from those stated in Table C, can be estimated by assuming a direct linear relationship. In other words, if a green sand line actually runs a 4 percent loss on ignition (LOI) its emission factor can be estimated as 80 percent of the emission factor provided in Table C which represents a percent LOI (i.e. 100 x 4 percent/5 percent%) This same relationship holds true for core binder emissions as well.

Please note that in addition to the variability in emission factors due to of the level of carbonaceous additives (in this case, seacoal), differences in the volatility of different carbonaceous additives can introduce additional and sometimes unpredictable variability in emissions.

No-Bake Molds

Table D lists HAP emission factors for typical No-Bake molding processes - phenolic urethane, furan, and ester-cured phenolic resin systems. The phenolic urethane system is the most commonly used and emission factors for three different binders are listed on Table D. Please note that the HAP emission factors for phenolic urethane No-Bake binder systems can exhibit a high level of variability as this binder system is often specially formulated to meet specific casting quality requirements and therefore can have different emission characteristics and tensile strengths. The furan and ester cured No-Bake emission factors listed are typical of these processes, however, these binders are generally not interchangeable with the phenolic urethane systems.

Other Casting Processes

Table E lists an emission factor for the lost foam casting (LFC) process. This emission factor is the only currently published emission factor for the LFC process and was quoted in the EPA MACT Background Document for Iron and Steel Foundries.

Some foundry casting processes such as permanent mold and centrifugal casting do not have any organic HAP emissions from the metal mold and the only organic HAP emissions will result from organic cores, if used. In addition, mold release sprays and washes are other potential sources of HAP emissions from these casting processes.

Core/Mold Making, Mixing and Storage

Table F lists the core- and mold-making, mixing and storage HAP emissions for phenolic urethane binders measured under controlled process conditions at CERP. Please note that the emission factors provided do not include any triethylamine catalyst HAP emissions.

Examples

Green sand PCS HAP Emission Factor

Situation: The average casting poured does not use a core and does not have thin or finned sections.

Solution: Choose the average surface area HAP emission factor of 0.213 pounds per ton of iron poured (Table A, First Row).

Look at the process specification in Table A and the referenced report and determine if you run a 5 percent LOI with a 100 percent seacoal sand formulation. If so, then use this HAP emission factor. If you use higher or lower LOI level adjust HAP emission factor accordingly using a direct linear relationship. If other carbonaceous additives are used other than seacoal, or in addition to seacoal, this HAP emission factor is not applicable and other sources of emission factors should be sought.

Cored Green sand Mold PCS HAP Emission Factor

Situation: The average casting is poured in a green sand mold made with 5 percent LOI sand containing seacoal, does not have thin or finned sections, and uses a modern phenolic urethane core at 1.1 percent binder level.

Solution: Use the average surface area green sand mold HAP emission factor of 0.213 pounds per ton of iron poured to represent the green sand mold emissions (Table A, First Row)

Use the newer technology phenolic urethane core emission factor of 0.368 pounds per ton of iron (Second row, Table B). As shown in Table B, the process specification for this test is 1.75 percent binder level. At 1.1 percent binder level the core emissions are estimated to be 0.368 x (1.1/1.75) = 0.231 pounds HAP per ton.

The total HAP emissions from this mold/core package would then be 0.213 + 0.231 = 0.444 pounds per ton of iron poured.

Cored Green sand Mold PCS HAP Emission Factor

Situation: The casting poured is a four cylinder engine block in a greensand mold made with 5 percent LOI sand containing seacoal, with an older technology phenolic urethane resin coated sand core at 1.75 percent binder level.

Solution: This situation is a direct match with the combined mold and core HAP emission factor test listed in Table C as 0.643 pounds of HAPs per ton of iron poured.

Summary

This document is meant to give general guidance to foundries on HAP emission factors for certain foundry processes. Many published research reports and papers are available to validate the methods suggested in this document. Foundries will need to verify that their process specifications approximate those stated in the reference documents and account for any differences.

The tables included in this document provide organic HAP emission factors for some sources of HAPs in sand foundries. However, it is important to note that these are not the only sources of HAP emissions and all emission sources within a facility must be considered in developing a comprehensive HAP inventory for regulatory purposes.

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Iron Pouring, Cooling and Shakeout Organic Hazardous Air Pollutant Emissions

Table A. Green sand Mold Emissions (PCS)

Process Conditions	Emission Factor (lb HAPs/ton of metal)	CERP* Test Number, Publication/Revision Date and Process Description
Average surface area green sand parts with seacoal as the only carbonaceous additive.	0.213	1256-1311DQ, 4/26/2001 – Green sand test using only seacoal at 5.0% LOI and sodium silicate (inorganic) step block cores.
Very high surface area green sand parts with seacoal as the only carbonaceous additive.	0.378	1256-1231DE, 7/30/2003 - CERP Production Foundry Test with seacoal at 5.0% LOI and star pattern. No cores.

Table B. Core Emissions (PCS)

Process Conditions	Emission Factor (lb HAPs/ton of metal)	CERP* Test Number, Publication/Revision Date and Process Description
Old technology phenolic urethane cold box cores. This emission factor is representative of an older binder system requiring high core binder levels.	0.397	1409-125 FB, 7/1/2003 - Phenolic urethane step block core emission test at 1.75% binder level.
Newer technology phenolic urethane cold box cores. This emission factor is representative of a newer technology binder system capable of low binder levels.	0.368	1256-11 GSA.3 CM, 12/15/2000 - Phenolic urethane step block core emission test at 1.75% binder level. This binder system is capable of running at much lower than 1.75% binder levels.
Alkaline phenolic/CO2 coated cores.	0.122	*1411-111 GE, 8/1/2004 - Coated alkaline phenoloc cores at 2.0% binder.* **report.**
Phenolic novolac (shell) cores.	0.295	1410-177FU, 9/1/2004 - Uncoated cores at 3.0% resin level.
Phenolic hot box cores.	0.061	*1411-122 GH, 10/1/2004 - Step block cores at 1.2% binder level.*
Furan warm box cores.	0.050	*1411-123 GJ - Furan warm box step block* cores.
Oil sand cores.	*0.137*	*1411-124 GM - Oil sand step block cores*.
Use for core emissions of a greensand mold with no core.	0.000	Core emissions are not present in a mold with no core. Use zero.

Table C. Cored Greensand Mold Emissions (PCS)

Process Conditions	Emission Factor (lb HAPs/ton of metal)	CERP* Test Number, Publication/Revision Date and Process Description
Very complicated castings with a high phenolic urethane core content using seacoal as the only greensand carbonaceous additive. This emission factor is representative of a very high emitting greensand cored mold package with an older phenolic urethane core binder at a high binder level.	0.643	1256-122DD, 4/10/2003 - A CERP production foundry test producing engine block castings. Greensand mix used seacoal as carbonaceous additive at a 5.0% LOI. Core package used an older technology phenolic urethane binder at 1.75% binder level.
An average casting with an older phenolic urethane core binder system at a very high binder levels and seacoal as the only carbonaceous additive.	0.5424	0001-003, 11/11/1999 - An emission test using seacoal as the only carbonaceous additive at 5.0% LOI and step block cores made with an older phenolic urethane binder system at 1.75% binder level.
Emission factor used by the USEPA in the MACT Background Document to represent the average greensand foundry HAP emissions. The emission factor is a composite of different systems but primarily heavily cored castings using furan hot box cores.	0.285	0001-002, 2/26/2003 - This CERP Mexico Study representing greensand molds with seacoal at 5.0% LOI and a combination of cores but primarily phenolic hot box. This study is quoted as the "general medium HAP emission estimate" in the MACT Background Document EPA-453/R-02-013.

*** CERP(Casting Emission Reduction Program, Technikon, LLC) Reports available at cerp-us.org.**

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Table D. No-Bake Mold Emissions (PCS)

Process Conditions	Emission Factor (lb HAPs/ton of metal)	CERP* Test Number, Publication/Revision Date and Process Description
A high emitting phenolic urethane No-Bake mold package with very high core tensile strengths.	2.00	1256-1211DG, 4/10/2003 - Irregular gear pattern in phenolic urethane No-Bake molds at 1.10% binder level and high core tensile strengths.
An average emitting phenolic urethane No-Bake mold package with average tensile strengths.	1.521	1410-113FP, 3/1/2004 - Irregular gear pattern in phenolic urethane No-Bake molds at 1.10% binder level and medium core tensile strengths.
A low emitting phenolic urethane No-Bake binder with low core tensile strengths.	1.16	1256-1112 DP, 12/1/2003 - Irregular gear pattern in phenolic urethane No-Bake molds at 1.10% binder level and low core tensile strengths.
A average furan No-Bake mold package.	1.08	1256-1115DX, 5/18/2001 - Irregualr gear pattern in furan No-Bake molds at 1.30% binder level with an irregular gear castings.
An ester cured phenolic No-Bake mold package.	0.803	1256-1116DZ, 6/22/2001 - Irregular gear pattern in ester Cured Phenolic No-Bake binder at 1.10% binder level.

Table E. Lost Foam Process Emissions (PCS)

Process Conditions	Emission Factor (lb HAPs/ton of metal)	CERP* Test Number, Publication/Revision Date and Process Description
Lost foam casting process (LFC) or expendable pattern process (EPC).	1.02	EPA -453/R-02-013, 12/1/2002 - Emission factor referenced in EPA MACT background document. (Twarog, 1991, "Identification of Emissions and Solid Waste Generated from EPC Process." AFS, June 4, 1991)

Core/Mold Make Organic Hazardous Air Pollutant Emissions

Table F. Core/Mold Making, Mixing and Storage Emissions

Process Conditions	Emission Factor (lb HAPs/lb of resin)	CERP* Test Number, Publication/Revision Date and Process Description
Combined core mixing, core make, and storage emission factor for an older technology phenolic urethane core binder at a high binder level.	<0.002	1409-123EQ, 12/9/2002 - Emissions from an older phenolic urethane core binder at 1.75% binder level. Test does not include TEA (a HAP). Some analytes below quantitation level.
Combined core mixing, core make, and storage emission factor for a newer technology phenolic urethane core binder at two different binder levels.	0.001 <0.074	1409-111ER, 12/21/2002 - Emissions from a newer technology phenolic urethane core binder at 1.20% and 1.75% binder levels. Test does not include TEA (a HAP). Some analytes below quantitation level.
Combined mold sand mixing, mold making, and storage emission factor for a new phenolic urethane No-Bake mold package.	<0.002	1409-124EY, 5/29/2003 - No-Bake mold making emissions using a phenolic urethane binder at 1.30% binder level. Some analytes below quantitation level.
Oil Sand core curing (baking).	*0.0036*	*1411-124 GM, Oil sand step block cores.*

*** CERP(Casting Emission Reduction Program, Technikon, LLC) Reports available at cerp-us.org.**