GUIDANCE FOR TOXIC RELEASE INVENTORY REPORTING FOR THE IRON AND STEEL FOUNDRY INDUSTRY

REVISED MAY 2026

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Disclaimer

This document is provided by the American Foundry Society (AFS) for informational and educational purposes only. It is intended to assist foundries in understanding Toxic Release Inventory (TRI) reporting obligations under Section 313 of the Emergency Planning and Community Right-to-Know Act (EPCRA) and is not a substitute for the applicable statutes, regulations, or official guidance issued by the U.S. Environmental Protection Agency or any state or local authority.

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Section 1
Guidance and TRI Introduction

1.1 Overview

This Guidance assists iron and steel foundries in estimating reportable releases of EPA Toxic Release Inventory (TRI) chemicals to the environment under SARA Title III Section 313 and 40 CFR Part 372. This Guidance does not seek to address basic TRI concepts such as TRI chemical identification, determining the amount of a TRI chemical contained in mixtures, etc. These concepts are fundamental and are covered elsewhere. This Guidance should be viewed as a companion to the available USEPA TRI reporting resources.

In addition to the introduction section, this Guidance includes the following:

- Section 2 includes an introduction to foundry operations for readers who are new to the industry.
- Section 3 includes a detailed discussion of TRI chemicals most widely reported by the foundry industry, as well as a more inclusive list of other possible TRI chemicals. While this section is extensive, a foundry should not assume that reporting any one chemical is necessary. Instead, the facility should evaluate its materials and operations to identify whether a TRI chemical is present. If a TRI chemical is present, the foundry should determine whether a report is necessary. Reporting obligations are contingent upon whether the chemical meets specific thresholds for "manufacture," "process," or "otherwise use," as well as the nature and quantity of its release or transfer. Facilities should review their operations and compare chemical usage against established thresholds and reporting criteria for each section, rather than assuming a blanket reporting requirement for all TRI chemicals identified within the section.
- Section 4 discusses release types and some quantification methods.
- Section 5 discusses specific foundry issues for TRI Reporting.
- Section 6 presents Other Information.
- Section 7 provides Miscellaneous Information.

1.2 Applicability and Limitations

The foundry industry dates back to before 3000 BC and took root in the United States in 1645, when the Saugus Iron Works in Massachusetts became the country's first casting facility—marking the beginning of the American iron and steel industry. Over centuries, foundry technology has evolved significantly, with advancements in sand casting, alloying, and large-scale industrial production shaping the modern landscape. Despite its long and dynamic history, the saying "no two foundries are alike" remains true.

With that in mind, the operations, materials, and TRI-listed chemicals referenced in this Guidance are not universally applicable to all foundries. Rather, they represent possible operations, materials, and

potentially present TRI chemicals. Simply put, each foundry's TRI chemical releases to environmental media are unique to its specific processes.

Similarly, the release estimation methodologies discussed in this Guidance are presented as potential approaches, rather than definitive best practices for the industry.

1.3 Regulatory Framework

The EPA's Toxics Release Inventory (TRI) Program was established under Section 313 of the Emergency Planning and Community Right-to-Know Act (EPCRA) of 1986 to enhance public access to information on toxic chemical releases from industrial facilities.

Under this program, facilities in designated industries—including iron and steel foundries—must report their annual releases of TRI-listed chemicals to the air, water, and land. The Pollution Prevention Act (PPA) of 1990 further expanded TRI reporting to include waste management and source reduction activities. TRI regulations, codified in 40 CFR Part 372, define reporting thresholds, chemical lists, and compliance requirements.

Over the years, TRI has evolved through rulemaking and legislative updates, incorporating Persistent, Bioaccumulative, and Toxic (PBT) chemicals, as well as certain per- and polyfluoroalkyl substances (PFAS). By fostering environmental transparency, the TRI enables communities, regulators, and industries to track and mitigate the impacts of toxic chemical releases more effectively.

1.4 Reporting Thresholds

The Toxics Release Inventory (TRI) reporting thresholds determine whether a facility must report its use, processing, or release of certain toxic chemicals under the EPA's TRI Program. These thresholds vary based on how a chemical is managed—whether it is manufactured, processed, or otherwise used—and are set to ensure that significant environmental releases are documented.

For most TRI-listed chemicals, the standard reporting thresholds are 25,000 pounds for manufacturing or processing and 10,000 pounds for otherwise used chemicals per calendar year. However, Persistent, Bioaccumulative, and Toxic (PBT) chemicals, such as lead compounds and mercury, have much lower thresholds due to their long-term environmental impact. Facilities must carefully track their chemical usage and emissions to determine if they meet or exceed these thresholds, ensuring compliance with TRI reporting requirements.

In summary, TRI requires reporting when facilities exceed specific chemical thresholds, as follows:

- Manufactured or Processed: 25,000 pounds per calendar year.
- Otherwise Used: 10,000 pounds per calendar year.
- Persistent, Bioaccumulative, Toxic (PBT) Chemicals: chemical-specific thresholds of 100 pounds per calendar year or lower (refer to EPA TRI guidance for chemical-specific reporting thresholds).

1.5 Form Selection – Form A versus Form R

Facilities subject to Toxics Release Inventory (TRI) reporting must determine whether to submit a more simplified Form A or the more detailed Form R based on the chemical and chemical usage.

Form R is the standard reporting form required when a facility exceeds TRI reporting thresholds for a listed chemical. Form A is a simplified certification statement that facilities may use if the chemical being reported meets all the following conditions:

- **Non-PBT Chemical:** The chemical is not a Persistent, Bioaccumulative, Toxic (PBT) chemical (Form A is strictly prohibited for PBT chemicals and PFAS).
- **Usage Limit:** The chemical has been manufactured, processed, or otherwise used in an amount under 1 million pounds during the calendar year.
- **Waste Management Limit**: The total annual waste management quantity for the chemical (sum of releases, recycling, energy recovery, and treatment) does not exceed 500 pounds.

Section 2
Foundry Processes

2.1 Foundry Processes

The equipment and raw materials used in an iron and steel foundry are determined by several key factors, including production needs, material specifications, and economic considerations.

Factors Influencing equipment selection include:

1. Type of Metal Produced – Foundries specializing in carbon steel, alloy steel, or cast iron require different furnaces, molds, and finishing equipment.
2. Melting Process – Foundries may use electric arc furnaces, induction furnaces, or cupola furnaces, depending on efficiency, cost, and environmental impact.
3. Casting Method – The choice between sand casting, investment casting, or die casting affects moldmaking equipment and finishing tools.
4. Production Scale – Large-scale foundries require automated pouring systems, robotic handling, and high-capacity furnaces, while smaller operations may rely on manual processes.
5. Environmental Regulations – Compliance with EPA air quality standards influences dust collection systems, emissions controls, and waste management equipment.

Table 2-1 provides and defines a number of foundry processes. To also provide a better overview of iron and steel foundry flow, an overall process flow diagram for green sand foundry operations is provided as **Figure 2-1** and a process flow diagram depicting a possible process flow of a chemically bonded mold- or core-making operations is provided in **Figure 2-2**. Tables and Figures are consolidated in Appendix A and B, respectively.

To supplement the above table and figures, the following sections provide a little more narrative around each foundry operation that may be installed at your facility.

2.1.1 Charge Handling

Incoming scrap is received via **truck or rail** and stored in **piles or bins** at designated locations. The scrap is then transferred and weighed using an overhead crane equipped with an electromagnet for efficient handling.

Alloys and fluxes—including carbon, magnesium, molybdenum, copper, chromium, and vanadium—are stored in designated areas. These materials are added to the furnace either automatically or manually, based on specifications and analysis to ensure the proper composition of the final metal product.

2.1.2 Melt Shop Operations

The Melt Shop is where raw materials are transformed into molten metal for casting. This high-temperature environment houses induction furnaces, cupola furnaces, and electric arc furnaces, which efficiently melt iron and steel alloys while maintaining precise

chemical composition and temperature control. Key portions of Melt Shop operations are described below.

Melting and Refining Process
The process begins with charge preparation, where scrap metal, pig iron, and alloying elements are weighed and loaded into the furnace. During melting and refining, impurities are removed, and metallurgical adjustments are made to achieve the desired properties.

- Inoculation and alloying further enhance the metal's strength, ductility, and machinability before it is transferred to pouring stations for casting.
- Automated ladle handling and pouring systems may be installed to ensure consistency in casting quality.

Flux and Slag Removal
Flux is added to the molten metal to extract impurities, forming slag at the surface. Because foundries use clean scrap, impurities are minimal. The slag is skimmed off manually to ensure a clean molten metal surface before casting.

Desulfurization
Desulfurization is a critical refining process that removes sulfur impurities from molten iron, improving mechanical properties and ductility.

- Sulfur can cause brittleness, cracking, and poor machinability, making it unsuitable for high-performance applications.
- Foundries use desulfurizing agents such as calcium carbide, magnesium, or soda ash, which react with sulfur to form slag that can be separated from molten iron.
- This process is typically performed in ladle refining, where controlled slag chemistry and mixing enhance sulfur removal efficiency.

Inoculation for Ductile Iron
Inoculation is a key metallurgical treatment in ductile iron production that enhances graphite formation and prevents carbide precipitation.

- Inoculants, typically ferrosilicon alloys containing calcium, barium, or aluminum, refine the microstructure of molten iron.
- Effective inoculation promotes graphite nucleation, ensuring uniform graphite distribution, which improves strength, ductility, and machinability.
- Stream inoculation during pouring optimizes graphite formation and casting quality.

Holding and Pouring Furnaces
A foundry may have a holding furnace to maintain molten metal at a consistent temperature and composition before pouring.

- Unlike melting furnaces, which liquefy raw materials, holding furnaces focus on heat preservation, alloy stabilization, and controlled metal delivery.

- These furnaces prevent temperature fluctuations, which can lead to casting defects.
- They also reduce energy consumption by minimizing reheating cycles and are typically induction-based, gas-fired, or electric resistance-heated, with advanced refractory linings for thermal efficiency and metal purity.

Hot Metal Transfer
Hot metal transfer refers to the safe and efficient movement of molten metal from melting furnaces to casting stations or refining units while maintaining:

- Metal temperature
- Chemical composition
- Cleanliness (minimizing heat loss and contamination)

Pouring Furnaces
In some cases, a pouring furnace is installed to:

- Receive molten metal and provide an additional buffer for the molding line.
- Use natural gas burners to heat the vessel during initial startup and keep the pouring spout hot, preventing the molten iron from cooling against cold refractory surfaces during pouring.

Air Pollution Control
To minimize particulate emissions, foundries may install air pollution control devices on any of the above operations to control particulate matter. In addition to a fabric filtration device, a cupola melting furnace often uses combustion devices to reduce carbon monoxide and organic emissions.

2.1.3 Coremaking

Coremaking is a critical process in iron and steel foundries, where sand-based cores are produced to create internal cavities and complex geometries in castings. These cores are placed inside molds before molten metal is poured, ensuring precise hollow sections or intricate design features in the final product.

Coremaking Process Overview

1. Core Sand Preparation – Foundries use silica sand mixed with binders to create strong, heat-resistant cores.
2. Core Formation – Sand mixtures are packed into core boxes, which shape the cores using manual or automated methods.
3. Curing and Hardening – Cores are hardened using heat, gas, or chemical reactions, depending on the binder system.
4. Finishing and Coating – Cores may be trimmed, coated, or reinforced to improve surface quality and durability.
5. Core Assembly and Placement – Finished cores are positioned within molds, ensuring proper alignment before casting.

Types of Coremaking Methods

- Green Sand Cores – Made from moist sand, used for simple shapes.
- Resin-Bonded Cores – Hardened with chemical binders, ideal for complex geometries.
- Shell Cores – Created using heated core boxes, producing thin, high-strength cores.
- Cold Box Cores – Cured with gas catalysts, offering fast production and precision.

2.1.4 Pouring, Cooling and Shakeout

During pouring, molten metal is poured into a mold. Due to the extreme heat contacting the carbon in the mold and the resin in the core, CO and volatile organic compounds (VOCs) are generated. Vents throughout the mold allow hot gases produced during pouring to escape, where they typically auto-ignite. To enhance auto-ignition, some foundries may have natural gas mold vent pilot burners strategically placed at the mold conveyor to ignite vent gases that have not already ignited.

The cast molds are then conveyed through cooling to allow controlled cooling of the molten iron to form the required metal crystalline structure. Emissions from the pouring stations and cooling may be vented to a particulate matter control device.

Once the iron castings solidify, the mold generally is opened, and the sand mold enters the shakeout conveyor where the molds are broken, and the castings separated from the mold and core sand. Emissions from the shakeout operations are generally vented to a particulate matter air pollution control device.

2.1.5 Sand Handling and Mechanical Reclamation

After shakeout, sand may either be returned to the sand handling system via a conveyor or manually managed, depending on its condition. Sand deemed spent at this stage may be disposed of or repurposed.

If green sand molding is used, sand from shakeout passes through a screening sieve and a sand cooler, where air and water help achieve the desired cooling effect and moisture content. The recycled sand is then transferred to storage, where it is blended with raw materials to create new green sand.

Due to impurities introduced by resin-based core sand heating and carbon from green sand, a portion of the recycled sand must be removed from the system and disposed of. Sand destined for landfill or beneficial reuse may be temporarily stored in indoor or outdoor piles or designated silos, consistent with applicable waste and stormwater requirements.

Dust and emissions from the sand screen sieve, sand cooler, and used sand storage may be ducted to a particulate matter air pollution control device to maintain environmental compliance.

2.1.6 Thermal Reclamation

Iron foundry thermal reclamation is a process used to recover and recycle spent foundry sand by applying high-temperature treatment to remove residual binders, contaminants, and organic materials. This method helps foundries reduce waste disposal costs, minimize environmental impact, and improve sand quality for reuse in molding and core-making applications. Thermal reclamation may have a mechanical pre-treatment section where spent sand is first crushed and screened to remove large debris and metal particles. Then, the sand may be heated in a fluidized bed furnace or rotary kiln, effectively burning off organic materials and binders. Finally, the reclaimed sand is cooled and sieved to ensure proper grain size distribution before reuse.

2.1.7 Finishing

After castings are cooled, foundry finishing operations are the final steps in the casting process, where raw castings are cleaned, refined, and prepared for their intended application. These operations ensure that castings meet dimensional accuracy, surface quality, and mechanical property requirements.

Key foundry finishing operations may include:

- Shakeout and Sand Removal – Castings are separated from molds, and excess sand is removed using vibratory shakeout machines or air-blast systems.
- Degating and Riser Removal – Excess metal from gates, risers, and sprues is cut off using abrasive saws, torches, or shearing equipment.
- Grinding and Surface Finishing – Castings undergo grinding, shot blasting, or tumbling to remove rough edges, flash, and surface imperfections.
- Heat Treatment – Some castings require annealing, normalizing, or quenching to enhance strength, ductility, and wear resistance.
- Machining and Final Processing – Precision machining operations such as drilling, milling, and turning refine critical dimensions and tolerances.
- Inspection and Quality Control – Castings are checked for dimensional accuracy, defects, and metallurgical properties using X-ray, ultrasonic, or dye penetrant testing.

2.1.8 Moldmaking

While some molds may be classified as permanent or semi-permanent, many iron and steel foundries use either a “green sand” or “chemically bonded sand” process.

Green Sand Mold Making

Green sand molding is a widely used casting method that utilizes a mixture of sand, clay (bentonite), water, and additives to create molds for metal casting. The term "green" refers to the moisture content in the sand, not its color.

Composition: Typically consists of 75-85% sand, 5-11% clay, 2-4% water, and other additives to enhance mold strength and durability.

Process: The sand mixture is packed around a pattern, forming a mold cavity. Once the molten metal is poured, the moisture evaporates, solidifying the casting.

Advantages: Green sand is reusable, cost-effective, and ideal for high-volume production of iron and steel castings.

Limitations: Surface finish may be rougher compared to chemically bonded molds, and dimensional accuracy can vary.

Chemically-Bonded Moldmaking
Chemically bonded molding, also known as resin-bonded sand casting, uses chemical binders instead of clay to harden the sand mold before casting.

Types of Chemical Bonding:

- Self-hardening (No-Bake): Sand is mixed with a binder and hardening agent, allowing it to cure naturally over time.
- Triggered hardening: Uses heat or gas to activate the hardening process, forming a rigid mold.

Advantages: Produces smoother surface finishes, higher dimensional accuracy, and is suitable for complex castings.

Limitations: More expensive than green sand, and chemical emissions must be managed. Both methods have their place in foundry operations, with green sand being preferred for cost efficiency and recyclability, while chemically bonded molds are ideal for precision casting and intricate designs.

2.1.9 Other Sources of TRI Chemicals

Other sources of TRI chemicals in the foundry industry may cover any of the following operations.

- Casting Painting: The application of paint to a metal casting after it has solidified and undergone initial finishing processes.
- Refractory Lining: The refractory linings of ladles and furnaces are subjected to extreme wear and stress throughout the casting process and must be routinely replaced.
- Rust Preventative: A low-VOC content rust preventative may be applied to the casting prior to shipping or storage to reduce or prevent corrosion.
- Fuel Combustion Units: Such as natural gas or diesel-fired fuel burner equipment such as air makeup units, emergency generators, etc.

Section 3
TRI Chemicals in the Foundry Industry

Table 3-1 provides a list of the most common TRI chemicals reported by the foundry industry. **Table 3-2** provides a more extensive list including those provided in **Table 3-1** along with other possible TRI chemicals found in the foundry industry. **Table 3-3** provides a list of TRI chemicals that may be released during the pouring, cooling, and shakeout of green sand molds with chemically-bonded cores.

In addition to the above chemicals, the reviewer should also review the following potential TRI chemicals: toluene, xylene, formaldehyde, barium, ethylene glycol, mercury, sulfuric acid, dioxin, methanol, and benzo(g,h,i)perylene.

Understanding the sources, uses, and, if applicable, the incidental manufacturing of TRI chemicals within foundry operations is essential for accurate reporting, regulatory compliance, and pollution prevention efforts. This section examines how TRI chemicals are introduced, transformed, and managed across key foundry processes, including melting, pouring, cooling, shakeout, coremaking, and finishing.

Community interest in environmental matters, including environmental justice considerations, may influence how foundries communicate and document TRI chemical generation and releases. By identifying the specific operations responsible for TRI chemical generation, foundries can implement effective waste management strategies, optimize recycling and treatment methods, and minimize environmental impact while maintaining production efficiency. While many strategies may be difficult to implement, this section provides information for foundries to consider as they continue reducing their environmental impact.

3.1 Aluminum Dust or Fume

3.1.1 Primary Sources of Aluminum Dust and Fume

The following discusses the primary sources of aluminum dust and fume in the foundry manufacturing process.

Deoxidation and Alloying Operations

Aluminum Deoxidizers: Iron and steel foundries may use aluminum as a deoxidizing agent during melting and refining operations. Aluminum metal is added to molten steel to remove dissolved oxygen, forming aluminum oxide (Al_2O_3) and generating aluminum-containing fumes during this highly exothermic reaction.

Ferroaluminum Additions: Foundries use ferroaluminum alloys to introduce controlled amounts of aluminum into steel compositions. During addition and dissolution, aluminum volatilization creates fumes containing metallic aluminum particles and aluminum compounds.

Raw Material Sources

Aluminum-Containing Scrap: Processing scrap materials containing aluminum components, such as automotive parts with aluminum engine blocks mixed with steel components, can generate aluminum dust during handling and melting operations.

Aluminum Coated Materials: Galvanized or aluminized steel scrap contains aluminum coatings that volatilize during melting, creating aluminum-containing fumes and dusts.

Aluminum Wire and Rod: Foundries using aluminum wire for cored wire injection or aluminum rod for alloying additions may generate dust during handling, cutting, and feeding operations.

3.1.2 Furnace and Ladle Operations

Electric Arc Furnace (EAF) Operations: During electric arc furnace operations, aluminum additions for deoxidation create intense aluminum fume generation, particularly during the refining period when aluminum is added to adjust chemistry and remove oxygen.

Ladle Metallurgy: Secondary refining operations in ladles often involve aluminum additions for final deoxidation and composition adjustment. These operations typically occur with less sophisticated fume capture systems than primary melting, potentially increasing fugitive aluminum emissions.

3.1.3 Specific TRI-Reportable Aluminum (Fume or Dust)

The EPA TRI program specifically lists “Aluminum (fume or dust)” as a reportable chemical. This listing captures aluminum particles generated during high-temperature operations. The following distinguishes between the two:

Aluminum Fume: Ultrafine particles formed by condensation of aluminum vapor, typically generated during high-temperature melting and alloying operations.

Aluminum Dust: Larger particles created through mechanical processes such as grinding, cutting, handling, or abrasion of aluminum-containing materials.

3.1.4 Emission and Release Pathways

Air Emissions

Primary Emissions: Direct release of aluminum fume from furnaces, ladles, and other high-temperature operations represents the most significant emission pathway. These emissions may be controlled through baghouses, scrubbers, or other air pollution control devices.

Secondary Emissions: Handling of aluminum-containing materials, maintenance operations, and material transfer may generate aluminum dust through mechanical action rather than thermal processes.

Fugitive Emissions: Uncontrolled releases from melting, tapping, casting, and material handling contribute to total aluminum emissions.

Waste Streams

Baghouse Dust: Air pollution control devices collect aluminum-containing dusts that may require TRI waste reporting.

Furnace and Ladle Dusts: Cleaning and maintenance of melting equipment generates aluminum-containing dusts that require proper characterization and potential TRI reporting.

Slag and Dross: While aluminum typically reports to metal phases rather than slag, some aluminum-containing compounds may concentrate in furnace slag or ladle dross.

3.1.5 Reporting Challenges and Considerations

Release Pathway Documentation

Aluminum releases may occur through multiple pathways, including stack emissions, fugitive dust, wastewater, stormwater, and solid waste disposal. Facilities should verify how TRI-MEweb handles aluminum fume or dust reporting for each release medium. In some cases, TRI-MEweb may identify water-release sections as not applicable because the reportable form of the chemical cannot exist in water.

Process-Specific Sources

Consider all potential aluminum sources including melting operations, pouring, shakeout, and finishing operations like grinding where aluminum-containing alloys might generate reportable emissions.

3.1.6 Regulatory and Reporting Considerations

TRI Thresholds – Manufactured, Otherwise Used (all others)

As identified above, aluminum dust or fume sources in foundries include:

- Aluminum present in scrap metal and alloys (aluminum may be manufactured in the form of fume or dust – See Q453 in 2019 TRI Q&A guidance document).
- Deoxidizers and degassing agents containing aluminum
- Aluminum-containing flux materials
- Refractory materials with aluminum oxide content

3.2 Chromium and Chromium Compounds

Chromium in scrap, alloys and refractory materials makes chromium compounds one of the most commonly reported TRI chemicals in the iron and steel foundry industry. Accurate identification and quantification require careful evaluation of raw materials, process chemistry, and emission control systems.

3.2.1 Primary Sources of Chromium Compounds

Raw Materials and Feedstock

Stainless Steel Scrap: The most significant source of chromium compounds in iron and steel foundries comes from stainless steel scrap processing. When stainless steel containing 10-20% chromium is melted, oxidation reactions create chromium oxides and other chromium compounds that may be TRI-reportable.

Ferrochrome Alloy Additions: Foundries producing stainless steel or chromium-containing alloys use ferrochrome as an alloying agent. During melting operations, chromium oxidation produces compounds such as chromium(III) oxide (Cr_2O_3) and other chromium-oxygen complexes.

Chrome Ore and Chrome Sand: Some foundries use chromite sand (chrome ore) in molding applications due to its high melting point and thermal conductivity. Chromite naturally contains chromium compounds, and thermal processing may release or transform these into TRI-reportable forms.

Refractory Materials

Chrome-Containing Refractories: High-temperature furnace linings often contain chromium compounds for enhanced thermal resistance. Chrome-magnesia bricks and chrome-alumina refractories can release chromium compounds during heating cycles, thermal shock, or refractory degradation.

Ladle and Tundish Linings: Chrome-based refractory materials used in ladle linings and tundish applications may contribute chromium compounds through wear, thermal cycling, and chemical attack by molten metal.

3.2.2 Process-Generated Chromium Compounds

Melting Operations: Chromium and its compounds can be present in iron and steel foundry melting operations due to their role in alloy composition and material properties. Chromium is commonly added to iron and steel to enhance corrosion resistance, hardness, and heat resistance, making it a critical element in stainless steel and other specialized alloys. During the melting process, trace amounts of chromium can volatilize or oxidize, contributing to airborne emissions or slag formation (chromium oxidizing during melting would count towards manufacturing threshold). Additionally, scrap metal used as feedstock may contain residual chromium from previous applications, further introducing it into the melting environment.

Slag Formation: Chromium compounds concentrate in furnace slag during melting operations. Slag handling, processing, and disposal may release chromium-containing dusts or require reporting of chromium compounds in waste streams.

Fume and Dust Generation: High-temperature operations generate fumes containing chromium compounds that may be captured by air pollution control devices or released to the atmosphere.

Pouring, Cooling and Shakeout: Chromium and its compounds can be found in iron and steel foundry pouring, cooling, and shakeout operations due to their presence in alloy formulations and process residues. During pouring, molten metal containing chromium is transferred into

molds, where oxidation and fume generation can introduce chromium compounds as a stack or fugitive emission point. As the castings cool, surface reactions may produce chromium oxides or other residual compounds, which can become airborne or settle as particulate matter. The shakeout process can further release chromium-containing dust through mechanical agitation and handling.

Shotblasting and Grinding: Chromium and its compounds can be present in iron and steel foundry shot blasting and grinding operations due to the abrasion and surface treatment of metal castings. Shot blasting can dislodge chromium or likely chromium compound particles embedded in the metal or present in residual coatings, releasing airborne dust that may contain chromium compounds. Similarly, grinding operations can generate fine metallic particulates, including chromium and its compounds, which become suspended in the air or settle in the work area.

3.2.3 Specific TRI-Reportable Chromium Compounds

The EPA TRI program lists several chromium compounds commonly found in foundry operations:

Chromium (CAS 7440-47-3): Elemental chromium metal, though this form is less common in foundry emissions compared to chromium compounds.

Chromium Compounds (N090): This broad category captures various chromium-containing chemicals not individually listed, allowing foundries to report total chromium content in compound form.

3.2.4 Emission and Release Pathways

Air Emissions

Stack Emissions: Melting furnaces, ladle operations, and other high-temperature processes (i.e., pouring, cooling, shakeout) generate chromium-containing particulates and fumes that may be released through stack emissions after passing through air pollution control devices. In addition, abrasive operations such as shotblasting and grinding may emit chromium compounds present in the casting.

Fugitive Emissions: Uncontrolled releases from furnace charging, tapping operations, slag handling, material transfer and other foundry operations may contain chromium compounds.

Waste Streams

Baghouse Dust: Air pollution control devices collect dust containing chromium compounds that could be characterized for TRI reporting.

Slag and Furnace Waste: Solid wastes from melting operations may contain chromium compound concentrations, particularly when processing stainless steel or using chrome-containing refractories.

Refractory Waste: Spent refractory materials from furnace maintenance and rebuilding may contain chromium compounds requiring proper characterization and potential TRI reporting.

Water Releases

Stormwater: Stormwater that comes in contact with chromium compound particulates or dusts may result in release reporting.

3.2.5 Reporting Challenges and Considerations

Chemical Form Determination

Foundries should determine whether chromium exists in reportable compound forms versus elemental forms. High-temperature oxidizing conditions typically favor compound formation, but analytical verification may be necessary for accurate reporting.

3.2.6 Regulatory and Reporting Considerations

TRI Thresholds – Manufactured (melting), Processed (scrap, alloys) or Otherwise Used (for refractories)

As identified above, chromium compounds in foundries include:

- Chromium in scrap metal inputs (oxidation of chromium during melting may result in manufacturing of chromium compounds)
- Ferrochrome or other intentionally added chromium alloys
- Chrome-containing refractories and their consumption rates

3.3 Copper and Copper Compounds

The widespread presence of copper in scrap materials and the intentional use of copper in specialized alloys makes copper and copper compounds common TRI chemicals in foundry operations. Accurate reporting requires comprehensive evaluation of copper sources, process losses, and emission control effectiveness across all operations handling copper-containing materials.

3.3.1 Primary Sources of Copper and Copper Compounds

Raw Materials and Feedstock

Copper-Bearing Scrap: Iron and steel foundries frequently process scrap materials containing copper components. Automotive scrap, electrical equipment, plumbing fixtures, and industrial machinery often contain copper wiring, fittings, and components that introduce copper into the melting process.

Copper Contamination in Steel Scrap: Even when not intentionally added, copper commonly appears as a contaminant in steel scrap. Copper content in recycled steel can range from trace levels to several tenths of a percent, depending on scrap source and sorting effectiveness.

Copper Wire and Electrical Components: Incomplete removal of copper wiring from steel scrap contributes copper to the melt, with copper losses occurring through oxidation and volatilization during furnace operations.

Intentional Copper Additions

Copper Alloying: Some steel grades, particularly weathering steels and certain corrosion-resistant alloys, intentionally contain 0.2-0.5% copper for enhanced atmospheric corrosion resistance. These applications require direct copper additions or copper-containing master alloys.

Copper Shot and Granules: Foundries may add metallic copper in shot or granular form for precise alloy chemistry control, generating copper fume during dissolution in molten steel.

Cuprous Oxide Additions: Some specialized applications use copper compounds such as cuprous oxide for specific metallurgical purposes, directly introducing copper compounds into the process.

3.3.2 Process-Generated Copper Emissions

High-Temperature Oxidation

Copper Volatilization: During steel melting operations, copper exhibits relatively high vapor pressure at steelmaking temperatures, leading to preferential loss through volatilization and fume formation.

Copper Oxide Formation: In oxidizing atmospheres, metallic copper converts to copper oxides (CuO, Cu_2O) (resulting in the manufacturing of copper compounds) that may become airborne as particulates or concentrate in furnace dusts.

Slag Partitioning: Copper exhibits complex behavior in steelmaking slags, with some copper reporting to slag phases while other portions volatilize, creating multiple emission pathways.

Foundry Operations

Melting Operations: Copper or likely copper compounds can be found in iron and steel foundry melting operations due to its presence in raw materials and alloying elements used in metal production. Scrap metal, a common feedstock in foundries, often contains copper from previous applications, such as electrical wiring, plumbing components, and industrial machinery. Additionally, copper is sometimes intentionally added to iron and steel formulations to enhance corrosion resistance and mechanical properties. During the melting process, trace amounts of copper may volatilize or become part of emissions due to elevated temperatures and oxidation reactions, contributing to its detection in environmental reporting. Proper handling and emissions control measures are necessary to comply with regulatory requirements and minimize potential environmental impacts.

Ladle Operations: Secondary processing of copper-containing alloys in ladles generates additional copper emissions through continued oxidation and temperature exposure.

Pouring, Cooling and Shakeout: Copper or likely copper compounds, can be present in iron and steel foundry pouring, cooling, and shakeout operations due to its retention in molten metal and subsequent exposure during handling. As iron and steel alloys are poured into molds, residual copper—originating from scrap metal contamination or intentional alloying—remains within the castings. During cooling, the metal solidifies, and surface oxidation or thermal expansion can cause copper compounds to form or release particulates. The shakeout process, which involves separating castings from sand molds and removing excess material, can generate airborne dust and metallic residues containing trace amounts of copper.

Shotblasting and Grinding: Copper or likely copper compounds can be found in iron and steel foundry shot blasting and grinding operations due to the abrasion and surface treatment of metal castings. As cast components undergo shot blasting, copper particles embedded within the metal or present as residual contamination can be released into the surrounding environment. Similarly, grinding operations can generate fine metallic dust, including trace amounts of copper or copper compounds, which may become airborne or settle in work areas.

3.3.3 Specific TRI-Reportable Forms

The EPA TRI program lists copper and copper compounds commonly found in foundry operations:

Copper (CAS 7440-50-8)

Elemental copper metal represents a TRI-reportable form in foundry operations. This includes:

Copper Fume: Ultrafine metallic copper particles formed through vapor-phase condensation during high-temperature operations.

Copper Dust: Larger copper particles generated through mechanical handling, grinding, or abrasion of copper-containing materials.

Copper Compounds

Copper Compounds (N100): EPA TRI includes a broad category for copper compounds, allowing reporting of various copper-containing chemicals not individually listed.

3.3.4 Emission and Release Pathways

Air Emissions

Primary Stack Emissions: Melting furnaces generate copper-containing fumes that may be released through stack emissions after passing through air pollution control systems. Similarly, copper or copper compounds may be generated by the other above listed foundry operations and exhausted through an air pollution control device or may be directly emitted from a stack.

Fugitive Emissions: Uncontrolled releases from charging operations, tapping, casting, and material handling contribute to atmospheric copper emissions.

Waste Streams

Baghouse Dust: Air pollution control devices collect copper-containing particulates that often concentrate copper content above original emission levels.

Furnace Dust and Scale: Cleaning operations generate copper-containing dusts that require characterization for TRI reporting purposes.

Slag and Dross: Copper-containing residues from melting operations may require evaluation for copper content and potential waste reporting.

Water Releases

Stormwater: Stormwater that comes in contact with copper and/or copper compound particulates or dusts may result in releases.

3.3.5 Reporting Challenges and Considerations

Chemical Form Determination

Oxidation State: Determining whether copper exists in metallic form versus oxide forms affects TRI reporting categories and may require analytical verification.

Temperature Effects: High-temperature processing favors metallic copper volatilization, while lower-temperature operations may generate more copper oxide forms.

3.3.6 Regulatory and Reporting Considerations

TRI Thresholds – Manufactured (melting), Processed (Scrap, alloys); Otherwise Used (for flux materials, other uses with no intent to incorporate into end product)

As identified above, copper and/or copper compounds in foundries include:

- Copper as an alloy
- Copper in scrap (copper compounds may be manufactured during melting operations)
- Copper-containing flux materials or deoxidizers
- Copper in electrical components and equipment maintenance
- Copper-based anti-seize compounds and lubricants

Note: See Section 5 for discussion on “intent”

3.4 Lead and Lead Compounds

The extreme volatility of lead at foundry operating temperatures makes it one of the most significant TRI chemicals in iron and steel foundry operations, even when present at relatively low concentrations in raw materials. Effective management requires comprehensive approaches addressing source control, process optimization, and emission control system performance.

3.4.1 Primary Sources of Lead and Lead Compounds

Raw Materials and Feedstock

Lead-Contaminated Scrap: The most significant source of lead in iron and steel foundries comes from contaminated scrap materials. Automotive scrap containing lead-based wheel weights, battery components, or lead-bearing solder represents a major lead input source, even as lead use in automotive applications has declined over time.

Electronics and Electrical Scrap: Older electrical equipment, circuit boards, and electronic components contain lead-tin solders and lead-based coatings that introduce lead into the melting process when inadequately separated during scrap preparation.

Painted Steel Components: Steel scrap from demolition, bridges, and industrial equipment may contain lead-based paint, particularly materials manufactured before 1978 when lead paint was widely used for corrosion protection.

Galvanized Materials with Lead: Older galvanized steel materials may contain lead as an impurity in the zinc coating, contributing to lead emissions during high-temperature processing.

Legacy Contamination Sources

Lead Shot and Ammunition: Steel scrap from military applications, shooting ranges, or hunting areas may contain embedded lead shot or bullet fragments that introduce metallic lead into the melting process.

Plumbing Components: Older plumbing fixtures, pipes, and fittings contain lead-based solders and lead-containing brass alloys that contribute to lead content in processed scrap.

Lead-Bearing Alloys: Historical use of leaded steels for machinability enhancement, though largely discontinued, may still appear in recycled materials from older equipment and machinery.

3.4.2 Process-Generated Lead Emissions

High-Temperature Oxidation

Lead Vapor Formation: Lead exhibits extremely high vapor pressure, making it one of the most volatile metals encountered in foundry operations. During electric arc furnace operations, 80-95% of input lead typically volatilizes and reports to fume emissions.

Lead Oxide Formation: In oxidizing atmospheres, lead oxidizes to form lead oxides (PbO, Pb_3O_4) that become airborne as ultrafine particulates, creating both inhalation hazards and TRI reporting obligations (this could result in the manufacturing of lead oxides).

Preferential Volatilization: Lead volatilizes preferentially compared to iron, copper, and most other common metals, concentrating in emission control dust rather than remaining in finished products.

Foundry Operations

Melting Operations: Lead and its compounds can be present in iron and steel foundry melting operations due to their occurrence in scrap metal and to a much lesser extent trace amounts in alloying materials. Scrap feedstock may contain residual lead from prior applications, such as coatings, soldered components, and leaded alloys, which may become incorporated into the molten metal during melting. At elevated temperatures, lead can volatilize, oxidize, or migrate into slag, contributing to airborne emissions and waste stream contamination. Additionally, trace amounts of lead may be introduced from certain alloy formulations used to enhance machinability and mechanical properties.

Ladle and Tundish Operations: Secondary processing operations may generate additional lead emissions through continued volatilization and oxidation reactions.

Pouring, Cooling and Shakeout: During pouring, molten metal containing residual lead that was not volatilized during melting is transferred into molds, where elevated temperatures may volatilize lead or produce particulate emissions. As the metal cools and solidifies, surface oxidation and thermal contraction can result in the formation of lead residues, which may be released. The shakeout process can generate airborne dust or metal fragments containing trace amounts of lead.

3.4.3 Specific TRI-Reportable Forms

Lead (CAS 7439-92-1)

Though less likely than lead compounds, it is possible elemental lead may be TRI-reportable including:

Lead Fume: Ultrafine metallic lead particles formed through vapor condensation during high-temperature operations.

Lead Dust: Larger lead particles generated through mechanical processes or collected by emission control systems.

Lead Compounds

Lead Compounds (N420): EPA TRI includes broad categories for lead compounds, capturing various lead-containing chemicals not individually listed.

Specific Lead Compounds: Individual compounds that may be encountered include:

- Lead oxide (PbO) - formed through high-temperature oxidation
- Lead dioxide (PbO_2) - less common but possible under specific oxidizing conditions
- Lead sulfate - may form in presence of sulfur-containing materials
- Lead silicate - possible formation with silica-containing refractories or slags

3.4.4 Emission and Release Pathways

Air Emissions

Primary Stack Emissions: Lead-containing fumes generated during melting operations and pouring represent the most significant emission pathway, even after passing through air pollution control devices.

Fugitive Emissions: Uncontrolled releases during tapping, metal transfer and pouring operations may contribute to fugitive lead emissions.

Waste Streams

Baghouse Dust: Air pollution control devices collect lead-containing particulates from those operations identified above.

Sludges and Precipitates: Historically, wet scrubbers may generate lead-containing sludges requiring characterization and potential TRI reporting.

Water

Stormwater Runoff: Lead-containing dusts and particulates may contribute to stormwater releases.

3.4.5 Industry-Specific Considerations

Lead as Unwanted Contaminant: Most iron and steel foundries consider lead a problematic contaminant that must be minimized to prevent environmental compliance issues and product quality problems.

Scrap Specifications: Many foundries implement strict lead limits in purchased scrap to control environmental emissions of lead.

Minimal Lead Exposure: Iron foundries typically encounter lower lead levels than steel foundries due to different scrap sources and less aggressive melting conditions.

Lead Paint Contamination: Cast iron scrap from older buildings and infrastructure may contain lead paint contamination requiring evaluation.

3.4.6 Regulatory and Reporting Considerations

TRI Thresholds – Lead and lead compounds are a PBT with a reporting threshold of 100 pounds. De Minimis concentrations were removed in 2001 (except for brass/bronze alloy) and reporting threshold lowered to 100 pounds due to EPA designation of lead as a PBT.

TRI Thresholds – Manufactured (melting), Processed (scrap)

As identified above, lead and lead compounds in foundries include:

- Lead and lead compounds in scrap metal inputs (oxidation of lead during melting may result in manufacturing of lead compounds). EPA does not discern whether the chemical is wanted or unwanted.
- Residual lead and/or lead compounds may be processed at operations that follow melting.

3.4.7 Risk Management Strategies

Source Control

Enhanced Scrap Sorting: Improved scrap preparation and lead source identification can significantly reduce lead inputs and associated TRI reporting obligations.

Supplier Requirements: Implementing lead content specifications for purchased scrap helps control lead inputs at the source.

3.5 Manganese and Manganese Compounds

The essential role of manganese in steel and iron production makes manganese compounds among the most commonly reported TRI chemicals in foundry operations. Unlike contaminant metals such as lead or mercury, manganese represents an intentional and necessary component of most foundry products.

3.5.1 Primary Sources of Manganese and Manganese Compounds

Essential Raw Materials and Alloying Agents

Ferromanganese Additions: Manganese represents one of the most widely used alloying elements in iron and steel production. Foundries routinely add ferromanganese (containing 75-80% manganese) or silicomanganese (containing 65-68% manganese) to virtually all grades. Manganese is a crucial element in steelmaking, primarily used to increase hardness, strength, and wear resistance. It also acts as a deoxidizer, removing oxygen and sulfur impurities from molten metal, which helps prevent brittleness and cracking in final products. Additionally, manganese improves toughness and workability, making steel more resistant to impact and abrasion. Foundries utilize ferromanganese in various grades to tailor compositions for specific applications, such as high-strength structural steel, automotive components, and wear-resistant machinery parts.

Manganese Metal: Some foundries use electrolytic manganese metal for precise alloy chemistry control, particularly in specialty steel production where exact manganese content is critical for mechanical properties.

Manganese in Iron Production

Manganese in Cast Iron: Gray iron, ductile iron, and other cast iron grades typically contain 0.5-1.2% manganese for metallurgical control, requiring manganese additions during melting operations.

Nodular Iron Applications: Ductile iron production may require careful manganese control to optimize nodular graphite formation, involving both additions and removal techniques.

3.5.2 Process-Generated Manganese Emissions

Melting Operations: Manganese is added to the metal to improve hardness, strength, and wear resistance, making it a critical component in high-performance alloys. During the melting process, manganese acts as a deoxidizer, helping to eliminate oxygen and sulfur impurities that can weaken the final product. However, at elevated temperatures, manganese can volatilize or oxidize, leading to airborne emissions and slag contamination (possibly creating a "manufactured" compound). Additionally, scrap metal used as feedstock may contain residual manganese from previous applications, further contributing to its presence in the melting environment.

Slag Reactions: Manganese compounds concentrate in dry furnace slags, and slag handling operations may generate manganese-containing dusts through mechanical disturbance.

Pouring, Cooling and Shakeout: Manganese and its compounds can be present in iron and steel foundry pouring, cooling, and shakeout operations due to their role in alloy composition and impurity control. During pouring, molten steel containing manganese is transferred into molds, where elevated temperatures may cause minor volatilization or oxidation, leading to potential airborne emissions. As the metal cools, surface oxidation or thermal stress can contribute to the formation of manganese-containing residues. The shakeout process can generate metallic dust and particulate matter containing manganese, increasing exposure risks.

Shotblasting and Grinding: Shotblasting, which removes oxidation layers, scale, and surface contaminants, can dislodge manganese particles embedded in the metal generating airborne dust containing manganese compounds. Similarly, grinding operations produce fine metallic particulates, including manganese, which may become suspended in the air or accumulate in the workspace.

3.5.3 Specific TRI-Reportable Forms

Manganese (CAS 7439-96-5)

Elemental manganese metal represents one TRI-reportable form, though it is less common in emissions compared to manganese compounds.

Manganese Compounds (CAS N050)

The EPA TRI program includes a broad category for manganese compounds, which encompasses the majority of manganese-containing chemicals found in foundry operations:

Manganese Oxides: Various oxide forms including:

- Manganese monoxide (MnO) - most common in steel operations
- Manganese dioxide (MnO_2) - formed under oxidizing conditions
- Manganese tetroxide (Mn_3O_4) - mixed oxide form

Manganese Silicates: Formed through reactions with silica-containing refractories and slags.

Manganese Sulfides: Generated during desulfurization reactions, though these typically remain in the metal or slag phases rather than becoming airborne.

3.5.4 Emission and Release Pathways

Air Emissions

Primary Stack Emissions: Melting, pouring, cooling, shakeout, and casting cleaning operations generate manganese-containing particulates that may be released through stack emissions after air pollution control.

Fugitive Emissions: Uncontrolled releases from charging operations, tapping, slag handling, and ferroalloy addition contribute to atmospheric manganese emissions as well as uncaptured emissions from those operations identified above.

Secondary Emissions: Ladle operations, casting, and material handling generate additional manganese emissions through continued oxidation and mechanical disturbance.

Waste Streams

Baghouse Dust: Air pollution control devices collect manganese-containing particulates that often concentrate manganese above levels found in raw materials.

Slag: Furnace slags contain manganese compounds, and mechanical handling of these materials may generate manganese-containing dusts.

Refractory Waste: Spent refractory materials may contain manganese compounds absorbed from process atmospheres or incorporated during service.

Water

Stormwater Runoff: Manganese dusts and particulates may contribute to stormwater releases.

3.5.5 Regulatory and Reporting Considerations

TRI Thresholds – Manufactured (Melting), Processed (scrap, alloys); Otherwise Used (for others)

As identified above, manganese and/or manganese compounds in foundries include:

- Manganese present in steel alloys and ferromanganese additions
- Manganese in scrap steel materials (manganese is a common alloying element in steel) – may result in a “manufactured” compound
- Manganese-containing flux materials and deoxidizers
- Manganese in certain welding rods and electrodes used for maintenance
- Manganese in some refractory materials

3.6 Nickel and Nickel Compounds

3.6.1 Primary Sources of Nickel and Nickel Compounds

Stainless Steel Production and Processing

Stainless Steel Raw Materials: The most significant source of nickel compounds in iron and steel foundries comes from stainless steel production and processing. Austenitic stainless steels typically contain 8-12% nickel, while some specialty grades contain up to 20% nickel content.

Ferronickel Additions: Foundries producing stainless steel use ferronickel (containing 20-40% nickel) as a primary alloying agent. During melting operations, nickel oxidation produces various nickel compounds including nickel oxide (NiO) and complex nickel-iron oxides.

Nickel Metal Additions: Some foundries use electrolytic nickel metal or nickel pellets for precise chemistry control, particularly in specialty stainless steel grades or nickel-based superalloys.

Specialty Alloy Applications

Nickel-Based Superalloys: Foundries producing aerospace, chemical processing, or high-temperature applications work with nickel-based alloys containing 40-80% nickel, creating substantial nickel compound emissions.

Inconel and Hastelloy Production: Specialized foundries producing high-nickel alloys for corrosion resistance and high-temperature applications handle significant nickel quantities in various compound forms.

Tool Steel Applications: Some tool steels and specialty steels contain 1-5% nickel for enhanced toughness and hardenability, contributing to nickel compound formation during processing.

Contamination Sources

Nickel-Plated Components: Steel scrap containing nickel-plated parts introduces nickel into the melting process, with nickel coatings volatilizing at iron and steel foundry melting temperatures.

Electronics and Battery Scrap: Improper scrap sorting may introduce nickel-cadmium batteries, electronic components, or nickel-containing alloys into steel scrap streams.

3.6.2 Process-Generated Nickel and Nickel Compound Emissions

High-Temperature Oxidation and Volatilization

Nickel Oxide Formation: During melting operations in oxidizing atmospheres, metallic nickel converts to nickel oxide (NiO) and other nickel-oxygen compounds that become airborne as ultrafine particulates. This may result in a “manufactured” nickel compound.

Volatilization Characteristics: While nickel is less volatile than elements like lead or zinc, elevated temperatures in melting operations still result in measurable nickel volatilization and compound formation.

Foundry Operations

Melting Operations: Nickel and its compounds, listed under the Toxic Release Inventory (TRI), are commonly found in iron and steel foundry melting operations due to their role in alloy formulation and scrap metal composition. Nickel is a critical element in stainless steel and high-strength alloys, improving corrosion resistance, toughness, and heat resistance. During the melting process, nickel may volatilize, oxidize, or become incorporated into slag, leading to potential airborne emissions or waste stream contamination. Additionally, scrap metal used as feedstock often contains residual nickel from prior applications, further introducing it into the melting environment.

Ladle Metallurgy Operations: Secondary refining operations involving nickel additions or stainless steel processing create additional nickel compound emissions through continued oxidation reactions.

Pouring, Cooling and Shakeout: During pouring, molten metal containing nickel is transferred into molds, where elevated temperatures may cause minor volatilization or oxidation, potentially introducing nickel-containing emissions into the surrounding environment. As the castings cool and solidify, surface oxidation and thermal contraction can result in nickel residues forming on the metal's surface. The shakeout process can generate airborne metallic dust or particulate matter containing nickel.

Shotblasting and Grinding: Nickel and its compounds can be present in iron and steel foundry shot blasting and grinding operations due to their role in alloy composition and surface treatment processes. Shot blasting, which removes oxidation layers, scale, and contaminants, can dislodge nickel particles embedded in the metal or present in coatings, generating airborne dust containing nickel compounds. Similarly, grinding operations produce fine metallic particulates, including nickel, which may be exhausted to an air pollution control device or remain suspended in the air.

3.6.3 Specific TRI-Reportable Forms

Nickel (CAS 7440-02-0)

Elemental nickel metal, though this form is less common in foundry emissions compared to nickel compounds.

Nickel Compounds (CAS N495)

The EPA TRI program includes a broad category for nickel compounds, encompassing the majority of nickel-containing chemicals found in foundry operations:

Nickel Oxide (NiO): The most common nickel compound in foundry emissions, formed through high-temperature oxidation of metallic nickel.

Complex Nickel Oxides: Mixed metal oxides containing nickel, iron, chromium, and other elements commonly found in stainless steel processing emissions.

3.6.4 Emission and Release Pathways

Air Emissions

Primary Stack Emissions: Melting furnaces, pouring, cooling, shakeout and finishing operations generate nickel-containing particulates released through stack emissions after air pollution control treatment.

Fugitive Emissions: Uncontrolled releases from furnace charging, tapping operations, slag handling, ferroalloy addition or uncaptured emissions from the other foundry operations may contribute to atmospheric nickel emissions.

Waste Streams

Baghouse Dust: Air pollution control devices collect nickel-containing particulates that often concentrate nickel above levels found in raw materials.

Wet Scrubber Sludges: Facilities using wet emission control systems may generate nickel-containing sludges requiring evaluation for TRI waste reporting.

Water

Stormwater Runoff: Nickel-containing dusts and particulates may contribute to stormwater releases.

3.6.5 Industry-Specific Considerations

Stainless Steel Foundries

High Nickel Content: Stainless steel foundries represent the highest potential for nickel compound emissions due to intentional nickel content in products ranging from 8-20% in common grades.

Iron Foundries

Minimal Nickel Exposure: Gray iron and ductile iron foundries typically encounter minimal nickel levels unless processing contaminated scrap or producing nickel-containing specialty irons.

3.6.6 Regulatory and Reporting Considerations

TRI Thresholds – Manufactured (melting), Processed (scrap, alloys); Otherwise Used (for others)

As identified above, nickel compounds in foundries include:

- Nickel present in stainless steel scrap and alloys (formation of oxides may result in manufacturing of nickel compounds)
- Nickel in specialty steel alloys and superalloys

- Nickel-containing welding rods and electrodes
- Nickel in some refractory materials

Note: See Section 5 for discussion on “intent”

3.7 Zinc and Zinc Compounds

The extremely high volatility of zinc at foundry temperatures and the widespread use of galvanized steel in modern applications make zinc compounds among the most common TRI chemicals in iron and steel foundry operations. Zinc and zinc compound emissions are largely unavoidable when processing galvanized scrap.

3.7.1 Primary Sources of Zinc Compounds

Galvanized Steel Processing

Galvanized Steel Scrap: The most significant source of zinc compounds in iron and steel foundries comes from processing galvanized steel scrap. Galvanized coatings typically contain 99%+ metallic zinc, with coating weights ranging from 0.5-2.0 oz/ft² (150-600 g/m²), representing substantial zinc input when processing automotive, construction, and appliance scrap.

Hot-Dip Galvanized Materials: Structural steel, sheet metal, pipe, and wire products with hot-dip galvanized coatings introduce zinc directly into melting operations. The zinc coating volatilizes rapidly at steelmaking temperatures, creating zinc oxide fumes.

Electrogalvanized Components: Thinner zinc coatings from electrogalvanizing processes still contribute to zinc emissions, though at lower levels than hot-dip galvanized materials.

Contamination Sources

Zinc-Coated Fasteners: Nuts, bolts, and other fasteners with zinc plating contribute to overall zinc input, though typically at lower levels than structural galvanized materials.

Paint and Coating Residues: Zinc-rich primers and protective coatings on steel components introduce zinc compounds that may volatilize during high-temperature processing.

3.7.2 Process-Generated Zinc Emissions

High-Temperature Volatilization

Extreme Volatility: Zinc exhibits the highest vapor pressure of common metals at iron and steel foundry melting temperatures, with volatilization rates approaching 95-99%.

Zinc Oxide Formation: In oxidizing atmospheres, metallic zinc rapidly converts to zinc oxide (ZnO), forming characteristic white/gray fumes that are highly visible and easily recognizable in foundry operations.

Foundry Operations

Melting: Zinc and its compounds, listed under the Toxic Release Inventory (TRI), can be present in iron and steel foundry melting operations due to their occurrence in scrap metal and alloy formulations. Zinc is commonly used in galvanized steel and protective coatings to enhance corrosion resistance, and when scrap metal containing zinc is melted, trace amounts can be introduced into the molten metal. At elevated temperatures, zinc can volatilize or oxidize, leading to airborne emissions or slag contamination.

3.7.3 Specific TRI-Reportable Forms

Zinc (CAS 7440-66-6)

Elemental zinc metal (reporting when in fume or dust form and not when in solution or slurry forms), though less common in emissions compared to zinc compounds due to rapid oxidation at elevated temperatures.

Zinc Compounds (CAS N982)

The EPA TRI program includes zinc compounds as a generic category, encompassing the majority of zinc-containing chemicals found in foundry operations:

Zinc Oxide (ZnO): The predominant zinc compound in foundry emissions, formed through oxidation of metallic zinc at elevated temperature (resulting in a “manufactured” zinc compound). Zinc oxide represents the characteristic white fume generated during galvanized scrap processing.

Zinc Ferrite ($ZnFe_2O_4$): Mixed oxide compound that may form through interaction between zinc oxide and iron oxide at elevated temperatures in furnace environments.

Zinc Silicate: May form through reactions with silica-containing refractories, slags, or fluxes, though less common than zinc oxide.

3.7.4 Emission and Release Pathways

Air Emissions

Stack Emissions: Zinc-containing fumes represent one of the most visible and concentrated emission sources in foundry operations, with zinc oxide fumes easily recognizable by their characteristic appearance.

Fugitive Emissions: Uncontrolled releases during charging of galvanized scrap, furnace operation, and material handling contribute significantly to atmospheric zinc emissions.

Waste Streams

Baghouse Dust: Air pollution control devices collect zinc-containing particulates, which can concentrate zinc in collected dust.

Scrubber Sludges: Wet emission control systems generate zinc-containing sludges that require potential TRI reporting.

Water

Stormwater Runoff: Zinc-containing dusts and particulates may contribute to stormwater releases.

3.7.5 Industry-Specific Considerations

Steel Foundries

Galvanized Scrap Dependence: Most steel foundries process some galvanized scrap due to its prevalence in automotive, construction, and appliance applications, making zinc emissions nearly universal in steel operations.

Scrap Sorting Challenges: Complete removal of galvanized coatings from steel scrap is economically impractical, resulting in inevitable zinc inputs and emissions.

Iron Foundries

Lower Zinc Exposure: Gray iron and ductile iron foundries typically process less galvanized scrap than steel foundries, resulting in lower but still significant zinc emission levels.

3.7.6 Regulatory and Reporting Considerations

Zinc and zinc compounds may fall into different TRI activity categories depending on the source of the zinc, the facility's intent, and whether melting or other high-temperature operations transform zinc into reportable zinc compounds.

Processed - Intentional Alloying:

- Other metals, such as bronze, brass, steel, magnesium, and zinc, are also used to produce castings in foundries
- Zinc is intentionally added to create brass alloys (copper-zinc alloys) and bronze alloys containing zinc
- Bronze is composed primarily of copper with various combinations of tin, zinc, lead, and aluminum
- When foundries intentionally melt and cast zinc-containing alloys like brass or certain bronzes, the zinc would be "processed"

Otherwise Used - From Scrap Materials:

- Zinc may enter foundries as a component of galvanized steel scrap.
- When galvanized steel scrap is melted, the zinc coating may need to be evaluated as processed, otherwise used, and/or as contributing to manufactured zinc compounds depending on the facility's intent, the role of the zinc in the material, and the chemical form generated during melting.

- Zinc may also be present as an impurity in other scrap metals processed by the foundry

Zinc would likely be present in fume or dust form when generated during production processes and should be evaluated as a facility-generated material.

TRI Classification:

Processed - When zinc is intentionally used as an alloying element in brass, bronze, or other zinc-containing alloys that the foundry produces

Otherwise Used or Other Applicable Activity Category - When zinc enters the process through raw materials that are not intentionally incorporated into the final product, or when the zinc coating is not the intended component being processed, facilities should evaluate whether otherwise-used thresholds apply. Facilities should also evaluate whether melting manufactures zinc compounds such as zinc oxide.

- Galvanized steel scrap melting
- Impurities in other raw materials
- Contamination in recycled metals

Threshold Determination: Iron and steel foundries would need to calculate both categories:

- Zinc intentionally added for alloying purposes = "processed"
- Zinc present in galvanized scrap and other raw materials = evaluate as processed, otherwise used, and/or manufactured zinc compounds based on intent, material role, and chemical transformation during melting

Most iron and steel foundries reporting zinc should evaluate galvanized scrap and zinc-bearing raw materials carefully. Depending on the facility's operations, zinc may be counted as processed, otherwise used, and/or as manufactured zinc compounds generated during melting. The basis for the selected activity category should be documented.

3.8 Ammonia

The widespread use of nitrogen-containing organic binders in modern foundry operations makes ammonia one of the more common TRI chemicals generated by iron and steel foundries, particularly those with extensive core-making operations. Accurate reporting requires careful evaluation of binder systems to properly quantify annual ammonia releases.

3.8.1 Primary Sources of Ammonia in Foundry Operations

Mold and Core Binder Systems

Shell Molding Processes: Shell molding using phenolic resins may generate ammonia during shell formation and casting operations.

Green Sand Molding and Phenolic Urethane Cold Box Systems: While less common than resin-bonded systems, some green sand operations using organic additives may generate trace ammonia emissions during pouring operations. Phenolic-Urethane Cold Box (PUCB) binder

systems contain nitrogen-containing compounds that generate ammonia when exposed to the extreme heat of molten metal during pouring operations.

Urea-Formaldehyde Resins: Used in cold-box and warm-box core-making processes, urea-formaldehyde binders decompose during casting to release ammonia, formaldehyde, and other nitrogen compounds.

Combustion and Thermal Processes

Incomplete Combustion: Combustion processes involving nitrogen-containing fuels or operating under sub-optimal conditions may generate ammonia as a combustion byproduct, particularly in reducing atmospheres or at moderate temperatures.

3.8.2 Specific TRI-Reportable Forms

Ammonia (CAS 7664-41-7)

Ammonia gas (NH_3) is specifically listed as a TRI-reportable chemical. Key characteristics include:

High Volatility: Ammonia's high vapor pressure ensures rapid release from molten metal contact zones and efficient transport through mold vent systems.

3.8.3 Emission and Release Pathways

Air Emissions

Direct Venting: The primary release pathway involves direct venting of ammonia gas through mold vent systems during and immediately after metal pouring operations. These emissions can either be captured and directed to a stack or remain fugitive.

Stack Emissions: Foundries with emission control systems may release ammonia through stacks after passing through baghouses, scrubbers, or other control devices.

Fugitive Emissions: Uncontrolled releases from mold handling, core storage, and sand system operations contribute to total ammonia emissions.

Emission Control Interactions

Baghouse Limitations: Conventional fabric filter baghouses provide minimal ammonia removal due to ammonia's gaseous nature at typical operating temperatures.

Wet Scrubbing Systems: Acid scrubbing systems can effectively capture ammonia through acid-base neutralization reactions, converting gaseous ammonia to ammonium salts in scrubber liquor.

3.8.4 Industry-Specific Considerations

Core- and Moldmaking Operations

Shell Core Systems: Shell core production typically generates significant ammonia emissions.

Hot-Box and Warm-Box: These processes may generate lower ammonia emissions due to different binder chemistry and curing mechanisms.

3.8.5 Casting Process Variables

Metal Temperature: Higher pouring temperatures increase thermal decomposition rates and ammonia generation from binder systems.

Core Volume: Larger, more complex castings with extensive core systems generate proportionally higher ammonia emissions per casting.

Cycle Time: Faster production cycles may not allow complete ammonia evolution before mold opening, potentially increasing fugitive emissions during shakeout operations.

3.8.6 Regulatory and Reporting Considerations

TRI Thresholds – Manufactured (resin system); Otherwise Used (cleaning solutions)

As identified above, sources of ammonia in foundries include:

- Generated from urea-formaldehyde resin systems during shell core making processes
- Released from certain core binders and sand additives during thermal decomposition
- Generated from nitrogen-containing organic compounds in foundry processes
- Present in some cleaning solutions and maintenance chemicals

Note: See Section 5 discussion on incidental manufacturing.

3.9 Benzene

The widespread use of organic binder systems in modern foundry operations, combined with benzene's formation during high-temperature thermal decomposition, makes benzene one of the most significant TRI chemicals from both environmental and health perspectives in iron and steel foundries.

3.9.1 Primary Sources of Benzene in Foundry Operations

Carbon-Containing Raw Materials

Metallurgical Coke: Some foundry operations use coke as a carbon source or fuel, and coke naturally contains trace benzene that can be released during handling, storage, or high-temperature processing.

Coal Tar Products: Foundries using coal tar-based binders, pitch, carbon anodes or other coal-derived materials introduce benzene-containing organic compounds that volatilize during processing.

Organic Binder Systems

Phenolic Resins: The most significant source of benzene in iron and steel foundries comes from thermal decomposition of phenolic-based binder systems used in sand molding and core-making operations. When phenolic resins are exposed to the extreme heat of molten metal (2800-3000°F), thermal cracking produces benzene along with other aromatic compounds.

Cold-Box Binder Systems: Phenolic-urethane cold-box systems generate benzene during casting operations when organic binders decompose under thermal stress.

Shell Molding Processes: Shell molding using phenolic resin-coated sand generates benzene during both shell formation (curing) and casting operations, though quantities during curing are typically much lower than during metal contact.

Hot-Box and Warm-Box Systems: These thermally-activated binder systems may generate benzene during both curing processes and subsequent casting operations, with the majority of emissions occurring during metal pouring.

Combustion Sources

Natural Gas Combustion: While high-quality natural gas contains minimal benzene, trace quantities may be present and released during combustion processes in furnaces, ladles, or heating equipment.

3.9.2 Process-Generated Benzene Formation

Thermal Decomposition Chemistry

Aromatic Ring Formation: High-temperature pyrolysis of organic compounds can lead to aromatic ring formation and incidental benzene generation through complex thermal cracking reactions. In cupola operations, these emissions are typically destroyed by combustion chambers/afterburners, the quantity of benzene “manufactured” would still need to be compared to TRI reporting threshold for manufacturing activities.

Temperature-Dependent Reactions: Benzene formation from organic materials follows temperature-dependent kinetics, with peak formation typically occurring at temperatures between 1000-1500°F (538-816°C), well within the range experienced during metal casting.

Catalytic Effects: Iron and other metals can catalyze aromatic compound formation from organic precursors; potentially increasing benzene yields during thermal decomposition processes.

Pouring and Casting Operations

Core Decomposition: During metal pouring, organic cores experience severe thermal shock leading to rapid organic compound decomposition and benzene formation. The enclosed nature of cores can create localized high-temperature zones promoting aromatic compound formation.

Mold-Metal Interface: The interface between molten metal and organic-bonded sand creates ideal conditions for thermal decomposition and benzene generation.

Venting and Gas Evolution: Benzene generated during casting operations escapes through mold vents, core vents, and sand permeability, often auto-igniting at vent points due to elevated temperatures.

3.9.3 Specific TRI-Reportable Forms

Benzene (CAS 71-43-2)

Benzene (C_6H_6) is specifically listed as a TRI-reportable chemical with the following characteristics relevant to foundry operations:

High Volatility: Benzene's vapor pressure ensures rapid volatilization from high-temperature zones and efficient transport through foundry ventilation systems.

Stability: Benzene's aromatic stability allows it to survive high-temperature conditions that might destroy other organic compounds, increasing the likelihood of atmospheric release.

3.9.4 Emission and Release Pathways

Air Emissions

Direct Venting: The primary release pathway for benzene involves direct venting through mold and core vent systems during and immediately after metal pouring operations. These emissions may be captured and vented through a stack or remain fugitive.

Stack Emissions: Foundries with emission control systems may release benzene through stacks after passing through baghouses or other control devices that are typically ineffective for volatile organic compounds.

Fugitive Emissions: Uncontrolled releases occur during mold handling, core storage, sand system operations, and shakeout processes.

Emission Control Interactions

Afterburners/Combustion Chambers: When employed during cupola melting, provide significant destruction of benzene.

Baghouse Limitations: Conventional fabric filter baghouses provide minimal benzene removal due to benzene's volatile nature at typical baghouse operating temperatures.

3.9.5 Industry-Specific Considerations

Core-Making Operations

Core Complexity: Complex castings requiring extensive core systems generate proportionally higher benzene emissions due to increased organic binder content and thermal exposure.

Production Volume: High-volume core production operations may generate substantial annual benzene quantities approaching or exceeding TRI reporting thresholds.

Casting Process Variables

Metal Temperature: Higher pouring temperatures accelerate thermal decomposition reactions and increase benzene generation rates from organic materials.

Casting Size: Larger castings with more extensive mold and core systems may generate higher absolute benzene quantities per casting.

Cooling Rate: Rapid cooling may trap some organic compounds before complete decomposition, while slow cooling allows extended reaction time for benzene formation.

Cycle Time: Faster production cycles may not allow complete benzene evolution before mold opening, potentially increasing fugitive emissions during shakeout operations.

3.9.6 Quantification and Reporting Challenges

Emission Factor Development

Binder-Specific Factors: Benzene emission rates vary significantly with organic binder type, composition, and thermal exposure conditions.

Process Variables: Temperature profiles, residence times, and oxygen availability all influence benzene formation and emission rates.

Destruction Efficiency: Auto-ignition and thermal destruction rates affect net benzene emissions and could be considered in emission calculations.

3.9.7 Control and Minimization Strategies

Source Reduction

Binder Optimization: Mold sand system optimization, such as reduction of seacoal or replacement with lower-emitting alternatives. Minimizing organic binder usage through improved sand preparation, core design, and process optimization reduces benzene formation sources.

Material Substitution: Replacing coal tar-based or petroleum-derived materials with alternatives containing lower benzene precursors.

Process Modifications

Temperature Management: Optimizing pouring temperatures and cooling profiles can influence benzene formation kinetics and total generation.

Atmosphere Control: Managing local atmospheres around casting operations may influence benzene formation reactions and destruction efficiency.

Venting Optimization: Improved venting design can enhance auto-ignition efficiency and direct emissions toward control systems.

3.9.8 Regulatory and Reporting Considerations

TRI Thresholds – Manufacturing (Byproduct), Otherwise Used (Binders)

As identified above, benzene sources in foundries include:

- Generated during thermal decomposition of carbonaceous additives (seacoal) in green sand molding
- Produced as a byproduct during metal melting and pouring operations
- Released from coal tar-based binders and core making materials

3.10 Naphthalene

The use of coal-derived materials, particularly foundry coke in cupola operations, along with naphthalene sources in carbon-containing raw materials and organic binder systems makes naphthalene one of the most significant TRI chemicals for iron foundries.

3.10.1 Primary Sources of Naphthalene in Foundry Operations

Organic Binder Systems

Coal Tar-Based Binders: Traditional foundry binders derived from coal tar contain naphthalene as a natural component, releasing it during core curing and casting operations.

Petroleum-Derived Binders: Some petroleum-based binder systems may contain naphthalene depending on the specific hydrocarbon feedstock and refining processes used in their manufacture.

Coal-Derived Raw Materials

Foundry Coke: The most significant source of naphthalene in foundries comes from foundry coke used in cupola furnace operations for iron melting. Foundry coke, derived from coal carbonization, naturally contains naphthalene and other polycyclic aromatic hydrocarbons (PAHs) that volatilize during high-temperature combustion.

Petroleum Coke: Alternative carbon sources such as petroleum coke may contain lower but still reportable levels of naphthalene, particularly when derived from heavy crude oil sources with higher aromatic content.

Coal Tar Pitch Binders: Some foundries use coal tar pitch-based binders in specialty molding applications, particularly for large steel castings requiring high-temperature binder systems. Coal tar pitch contains significant naphthalene concentrations (typically 8-12%) that release during thermal processing.

Coal Dust Additions: Some foundries add coal dust to molding sand mixtures to create reducing atmospheres and improve casting surface quality. Coal dust thermal decomposition releases naphthalene along with other organic compounds.

Carbon-Containing Raw Materials

Carbonaceous Reductants: Carbon materials used for deoxidation or atmosphere control may contain naphthalene precursors that form naphthalene during high-temperature processing.

Scrap Contamination: Steel scrap contaminated with coal tar, creosote, or other coal-derived preservatives introduces naphthalene into melting operations.

Electrode Materials: Graphite electrodes used in electric arc furnaces may contain trace naphthalene levels, though typically at much lower concentrations than coal-derived materials..

Combustion Sources

Natural Gas Combustion: While high-quality natural gas contains minimal naphthalene, trace quantities may be present or formed during combustion processes in furnaces, ladles, or heating equipment.

3.10.2 Process-Generated Naphthalene Formation

High-Temperature Pyrolysis

Coke Combustion: During coke burning in cupola furnaces, incomplete combustion creates conditions favorable for naphthalene formation from hydrocarbon precursors in the fuel matrix.

Thermal Cracking: High-temperature conditions in foundry operations can crack larger organic molecules to form naphthalene through pyrolytic processes, particularly in reducing atmospheres with limited oxygen availability.

Aromatic Ring Formation: Under specific temperature and atmosphere conditions, smaller organic compounds may undergo cyclization and condensation reactions to form naphthalene and related aromatic compounds.

Pouring and Casting Operations

Core Decomposition: During metal pouring, organic cores experience severe thermal shock leading to rapid organic compound decomposition and naphthalene formation. The enclosed nature of cores can create localized high-temperature zones promoting aromatic compound formation.

Mold-Metal Interface: The interface between molten metal and organic-bonded sand creates conditions for thermal decomposition and naphthalene generation.
Venting and Gas Evolution: Naphthalene generated during casting operations escapes through mold vents, core vents, and sand permeability, often auto-igniting at vent points due to elevated temperatures.

3.10.3 Specific TRI-Reportable Forms

Naphthalene (CAS 91-20-3)

Naphthalene ($C_{10}H_8$) is specifically listed as a TRI-reportable chemical with the following characteristics:

Physical Properties: Naphthalene exists as a solid at room temperature but readily sublimes and volatilizes at foundry operating temperatures, creating both solid particulate and vapor-phase emissions.

Thermal Stability: Naphthalene remains relatively stable at moderate temperatures but may undergo further reactions at extreme foundry temperatures to form larger PAH compounds.

Emission Behavior: Naphthalene's moderate volatility ensures its presence in both particulate and gaseous emission fractions from foundry operations.

3.10.4 Emission and Release Pathways

Air Emissions

Direct Venting: The primary release pathway for naphthalene involves direct venting through mold and core vent systems during and immediately after metal pouring operations.

Stack Emissions: Foundries with emission control systems may release naphthalene through stacks after passing through baghouses or other control devices that are typically ineffective for volatile organic compounds.

Fugitive Emissions: Uncontrolled releases occur during mold handling, core storage, sand system operations, and shakeout processes.

Waste Streams

Baghouse Dust: Air pollution control devices collect naphthalene-containing particulates, with naphthalene potentially concentrated in collected dust through condensation processes.

Spent Sand: Foundry sand exposed to naphthalene-containing emissions or direct contact with coal-derived materials may retain naphthalene requiring evaluation for waste reporting.

Water Releases

Scrubber Water: Wet emission control systems may absorb naphthalene from gas streams, creating naphthalene-containing liquid waste streams.

Stormwater Runoff: Naphthalene-containing dusts and materials may contribute to stormwater contamination, particularly in areas where coal or coke materials are stored or handled.

3.10.5 Industry-Specific Considerations

Iron Foundries with Cupola Operations

Highest Risk Operations: Iron foundries operating cupola furnaces face the greatest naphthalene generation potential due to direct coke combustion and high-temperature pyrolytic conditions.

Coke Selection: The naphthalene content of foundry coke varies with coal source and coking process conditions, affecting emission potential.

Operational Practices: Cupola charging procedures, air blast rates, and temperature control affect naphthalene formation and emission rates.

Core-Making Operations

Binder Selection: Foundries using phenolic-based binder systems generate significantly higher naphthalene emissions than those using inorganic or alternative organic binder systems.

Core Complexity: Complex castings requiring extensive core systems generate proportionally higher naphthalene emissions due to increased organic binder content and thermal exposure.

Production Volume: High-volume core production operations may generate substantial annual naphthalene quantities approaching or exceeding TRI reporting thresholds.

Casting Process Variables

Metal Pouring Temperature: Higher pour temperatures increase the thermal decomposition of carbonaceous additives, resulting in greater naphthalene volatilization. Different alloys require different pouring temperatures, directly impacting emission rates.

Mold Contact Time: The duration molten metal remains in contact with the mold affects the extent of carbonaceous material pyrolysis. Longer contact times or slower cooling rates increase naphthalene generation.

Seacoal Concentration: Hazardous air pollutants (HAPs) and volatile organic compounds (VOCs) are generated and released during the metalcasting process because of the pyrolysis of the carbonaceous additives in the molding sand. Higher seacoal percentages in green sand directly correlate with increased naphthalene emissions.

3.10.6 Quantification and Reporting Challenges

Emission Factor Development

Source-Specific Factors: Naphthalene emission rates vary significantly with fuel type, combustion conditions, and process parameters, requiring source-specific emission factor development.

Temporal Variations: Batch cupola operations create intermittent naphthalene emissions that complicate annual emission calculations.

Binder-Specific Factors: Naphthalene emission rates vary significantly with organic binder type, composition, and thermal exposure conditions.

Process Variables: Temperature profiles, residence times, and oxygen availability all influence naphthalene formation and emission rates.

Destruction Efficiency: Auto-ignition and thermal destruction rates affect net naphthalene emissions and should be considered in emission calculations.

3.10.7 Control and Minimization Strategies

Material Replacement

Core Binders: Replacement of core binders with naphthalene-depleted formulations.

Fuel Selection and Management

Alternative Fuels: Transitioning from coke-fired cupolas to electric melting systems eliminates primary naphthalene sources.

Low-PAH Coke: Selecting foundry coke with reduced naphthalene and PAH content can significantly decrease emission potential.

Fuel Preparation: Proper coke sizing and moisture control may affect combustion characteristics and naphthalene formation rates.

Process Modifications

Combustion Optimization: Optimizing air blast rates, fuel-to-air ratios, and temperature profiles can minimize incomplete combustion and secondary naphthalene formation.

Atmosphere Control: Managing furnace atmospheres to promote complete combustion reduces conditions favoring naphthalene formation.

3.10.8 Regulatory and Reporting Considerations

TRI Thresholds – Manufactured (Byproduct); Otherwise Used (Binders, Coal Tar)

As identified above, naphthalene is typically found in foundry operations through:

- **Thermal decomposition products** - During the casting process, organic binders and additives can thermally decompose, potentially forming naphthalene
- **Core and mold binders** - Chemical binders used in foundry sand systems may contain naphthalene as a component or contaminant
- **Coal-tar-based products** - Some foundry materials historically derived from coal tar sources contain naphthalene

3.11 Phenol

The widespread use of phenolic resin binder systems in modern foundry operations makes phenol one of the most commonly generated TRI chemicals in iron and steel foundries.

3.11.1 Primary Sources of Phenol in Foundry Operations

Cupola

Coincidental Manufacturing: The coincidental manufacturing of phenol can be significant from cupola operations, but readily destroyed via thermal oxidation (or captured via wet scrubbing). Generation and treatment of phenol may need to be addressed within the TRI report.

Phenolic Resin Systems

Phenol-Formaldehyde Binders: The most significant source of phenol in iron and steel foundries comes from phenolic resin binder systems used extensively in sand molding and core-making operations. These systems include:

- **Hot-Box Core Systems**: Phenol-formaldehyde resins cured with heat generate phenol emissions during both the curing process and subsequent thermal decomposition when contacted by molten metal.
- **Warm-Box Core Systems**: Similar to hot-box systems but operating at lower curing temperatures, these systems still generate phenol through resin decomposition during casting operations.
- **Shell Core and Molding Processes**: Shell cores and to a more limited extent molds created using phenolic resins release phenol during shell formation and casting operations, particularly when shell sands are heated above decomposition temperatures.

Furan-Phenolic Systems: Some foundries use furan resins modified with phenolic components, creating additional phenol emission sources during thermal processing.

Cold-Box Phenolic Systems: Certain cold-box binder systems incorporate phenolic components that decompose during metal pouring to release phenol vapors.

Organic Additives and Coatings

Carbonaceous Additives: Some carbon-based additives used in molding sands contain phenolic compounds that volatilize during casting operations.

Lustrous Carbon Formers: Additives designed to create lustrous carbon layers on casting surfaces may contain phenolic precursors that generate phenol during thermal decomposition.

3.11.2 Process-Generated Phenol Formation

Thermal Decomposition Chemistry

Temperature-Dependent Release: Phenol generation from phenolic resins follows predictable thermal decomposition patterns, with significant release beginning around 400-500°F (204-260°C) and peak generation occurring at 600-800°F (316-427°C).

Resin Network Breakdown: Elevated temperatures break the cross-linked phenolic resin network, releasing free phenol along with formaldehyde and other organic compounds.

Catalytic Effects: Presence of metal oxides and certain refractory materials may catalyze phenolic resin decomposition, affecting both reaction rates and product distribution.

Pouring and Casting Operations

Core Decomposition: Cores experience the most severe thermal shock during metal pouring, generating concentrated phenol emissions that escape through vents and mold interfaces.

Mold Wall Reactions: Direct contact between molten metal and phenolic-bonded sand creates intense local heating that drives rapid phenol release.

Gas Evolution Patterns: Phenol generation peaks during the initial metal pouring phase and continues at decreasing rates during casting solidification and shakeout.

Secondary Formation Processes

Pyrolysis Reactions: Incomplete combustion or pyrolysis of organic materials under reducing conditions can generate phenol as a secondary product from larger organic molecules.

Thermal Cracking: High-temperature thermal cracking of complex organic compounds may produce phenol along with other aromatic compounds.

3.11.3 Specific TRI-Reportable Forms

Phenol (CAS 108-95-2)

Phenol (C_6H_5OH) is specifically listed as a TRI-reportable chemical with the following characteristics relevant to foundry operations:

Moderate Volatility: Phenol's vapor pressure allows significant volatilization at foundry operating temperatures while remaining sufficiently stable for atmospheric transport.

Thermal Stability: Phenol exhibits reasonable thermal stability at moderate temperatures but decomposes under extreme foundry conditions.

Water Solubility: Phenol's moderate water solubility affects emission control system design and may influence partitioning in wet scrubbing systems.

3.11.4 Emission and Release Pathways

Air Emissions

Direct Venting: Primary release occurs through mold vent systems during metal pouring as phenol vapor generated from resin decomposition escapes through designed venting paths.

Stack Emissions: Stack emissions of captured phenol may occur during coremaking, moldmaking, pouring, cooling and shakeout operations identified above.

Fugitive Emissions: Uncaptured releases from the above operations and other fugitive sources (possibly core storage) may contribute to total phenol emissions.

Emission Control Interactions

Afterburner/Oxidizer: Near complete destruction at or in excess of 1,350 degrees Fahrenheit.

Baghouse Performance: Conventional fabric filter baghouses provide limited phenol removal since phenol exists primarily as vapor rather than particulate matter at typical baghouse operating temperatures.

Wet Scrubbing Systems: Water-based scrubbing systems can achieve moderate phenol removal through dissolution, though removal efficiency depends on pH, temperature, and contact time.

3.11.5 Industry-Specific Considerations

Core-Making Operations

Hot-Box Systems: Foundries using hot-box core-making with phenolic binders generate the highest phenol emissions due to both curing operations and subsequent casting decomposition.

Production Volume Effects: High-volume core production operations may generate substantial annual phenol quantities that exceed TRI reporting thresholds even with relatively low per-core emission rates.

Curing Oven Emissions: Core curing ovens represent concentrated phenol emission sources during the resin curing process, often requiring dedicated emission control systems.

Shell Core and Molding Operations

Shell Production: Shell molding operations generate phenol emissions during both shell formation (heating phase) and casting operations (metal contact phase).

Pattern Temperature: Higher pattern temperatures during shell formation increase phenol release rates during the molding process itself.

Casting Process Variables

Metal Temperature: Higher pouring temperatures accelerate phenolic resin decomposition and increase phenol generation rates.

Core Complexity: Castings requiring extensive core systems generate proportionally higher phenol emissions due to larger resin-bonded sand volumes.

Mold Size: Larger molds with higher phenolic binder content create greater potential for phenol generation during casting operations.

3.11.6 Quantification and Reporting Challenges

Emission Factor Development

Resin-Specific Factors: Phenol emission rates vary significantly with resin type, phenol content, and cure conditions, requiring binder-specific emission factors.

Process-Dependent Variables: Core curing conditions, metal pouring temperatures, and cooling rates all influence phenol generation, complicating emission factor applications.

3.11.7 Threshold Evaluation

Manufacturing vs. Processing: Determining whether phenol generation constitutes manufacturing or processing.

Multi-Source Integration: Phenol emissions from core-making, casting, and potentially emission control systems require integrated evaluation for threshold determinations.

3.11.8 Control and Minimization Strategies

Binder System Alternatives

Binder Optimization: Minimizing binder usage through improved sand properties and core design reduces total phenol generation potential.

Low-Phenol Binders: Selecting phenolic resins with reduced free phenol content can significantly decrease phenol emission potential.

Alternative Binder Chemistry: Inorganic binder systems or non-phenolic organic binders may eliminate phenol generation sources entirely.

Process Modifications

Temperature Control: Optimizing core curing temperatures and metal pouring temperatures can minimize unnecessary phenol generation while maintaining product quality.

Atmosphere Management: Controlling curing oven atmospheres and foundry ventilation can influence phenol formation rates and emission patterns.

Rapid Cooling: Accelerated cooling techniques may reduce the duration of high-temperature exposure and limit continued phenol generation.

Emission Control Technology

Wet Scrubbing: Alkaline scrubbing systems can achieve moderate phenol removal through chemical absorption and neutralization reactions.

3.11.9 Regulatory and Reporting Considerations

TRI Thresholds – Otherwise Used (Core and Mold Making), Manufactured (if not present in materials during pouring, cooling, and shakeout)

As identified above, phenol is typically found in foundry operations through:

- Phenolic Binder Systems - Phenol-formaldehyde resins are actively used as binders for foundry sand in core and mold making.
- Thermal Decomposition Product – Phenol is generated from the pyrolysis of foundry resins during the casting process.
- Cupola – Generation and destruction of phenol.

3.12 Polymeric MDI

Polymeric MDI (methylene diphenyl diisocyanate) is used in iron and steel foundries primarily as a core sand binder system, with specific applications and release points.

3.12.1 Primary Sources of Polymeric MDI in Foundry Operations

Cold-Box Core Binder Systems

Phenolic Urethane Cold-Box Binders: The most significant source of polymeric MDI (methylene diphenyl diisocyanate) in iron and steel foundries comes from phenolic urethane cold-box core-making systems. These two-part binder systems consist of:

- Part I: Phenolic resin component containing phenol-formaldehyde resins
- Part II: Polyurethane component containing polymeric MDI as the primary isocyanate crosslinking agent

Cold-Box Process Chemistry: During core production, polymeric MDI reacts with phenolic hydroxyl groups to form urethane linkages, curing the sand mixture into rigid cores. Unreacted MDI may remain in finished cores and be released during subsequent thermal processing.

Commercial cold-box binder systems typically contain 20-40% polymeric MDI in the polyurethane component, making it a substantial constituent that can lead to significant TRI reporting obligations.

Core-Making Operations

Sand Mixing: During the core-making process, polymeric MDI exposure occurs when the two-part binder system is mixed with sand, creating potential for both worker exposure and fugitive emissions.

Core Curing: The curing process may involve incomplete polymerization, leaving unreacted MDI monomers and oligomers that can volatilize during subsequent heating operations.

Core Storage and Handling: Freshly made cores may continue to release trace quantities of unreacted MDI during storage, handling, and placement in molds prior to casting.

Thermal Decomposition Chemistry

High-Temperature Breakdown: When molten metal contacts cores made with MDI-containing binders, extreme temperatures (2800-3000°F for iron, 2900-3100°F for steel) cause thermal decomposition of the polyurethane bonds.

Pyrolysis Products: Thermal breakdown of MDI-containing polymers generates various decomposition products.

Core Gas Evolution: The confined geometry of cores during casting concentrates thermal decomposition reactions, maximizing MDI release rates during the critical pouring and initial cooling phases.

3.12.2 Process-Generated MDI Emissions

Core-Making Emissions

Mixing Operations: During sand mixing with cold-box binders, mechanical agitation and chemical reactions may generate MDI-containing aerosols and vapors.

Curing Emissions: The curing process involves chemical reactions that may release unreacted MDI, particularly under suboptimal curing conditions or with aged binder systems.

Casting-Related Emissions

Pouring Operations: The primary MDI emission source occurs during metal pouring when thermal decomposition breaks down MDI-containing polymers in cores.

Mold Venting: MDI decomposition products escape through mold vent systems, creating both stack emissions (if collected) and fugitive emissions (if uncontrolled).

Cooling Phase: Continued thermal decomposition occurs during cooling as heat penetration continues through core materials, extending MDI emission periods beyond initial pouring.

Secondary Emission Sources

Core Knockoff and Shakeout: Mechanical removal of cores from castings may generate dust containing unreacted MDI bound in the sand matrix.

Sand Reclamation: Thermal or mechanical sand reclamation processes may release additional MDI from binder residues adhering to reclaimed sand particles.

3.12.3 Specific TRI-Reportable Forms

Polymeric MDI (CAS 9016-87-9)

Technical Definition: Polymeric MDI consists of a mixture of methylene diphenyl diisocyanate isomers and higher molecular weight oligomers, typically containing:

- 4,4'-MDI (primary component)
- 2,4'-MDI (minor isomer)
- Higher oligomers and prepolymers

TRI Reporting Category: Polymeric MDI is specifically listed as a TRI chemical, requiring reporting when annual usage or release thresholds are exceeded.

Chemical Behavior: The polymeric nature affects volatility, with lower oligomers being more volatile than higher molecular weight polymers, influencing emission characteristics during thermal processing.

3.12.4 Emission and Release Pathways

Air Emissions

Direct Venting: Primary release occurs through mold vent systems during casting operations, with emissions potentially captured by foundry ventilation and emission control systems.

Stack Emissions: Foundries with emission control systems may release MDI through stacks after passing through baghouses or other control devices, though conventional particulate controls provide limited MDI removal.

Fugitive Emissions: Uncontrolled releases from core-making areas and casting operations contribute to overall MDI releases.

Waste Streams

Used Core Sand: Cores removed from castings may contain MDI polymer residues.

Baghouse Dust: Air pollution control devices may collect MDI-containing particulates, though gaseous MDI components likely pass through conventional fabric filters.

Liquid Waste: Wet scrubbing systems, if used, may capture water-soluble MDI decomposition products in scrubber liquor requiring waste characterization.

3.12.5 Industry-Specific Considerations

Core-Intensive Operations

Complex Castings: Foundries producing complex castings with extensive core requirements (such as engine blocks, transmission housings, or intricate iron castings) proportionally use more MDI-containing binders.

High-Volume Production: Large foundries with continuous core-making operations may exceed TRI reporting thresholds due to cumulative annual MDI usage in binder systems.

Precision Casting: Applications requiring tight dimensional tolerances often specify cold-box binder systems for superior core strength and surface finish, increasing MDI usage.

3.12.6 Quantification and Reporting Challenges

Usage-Based Calculations

Binder Consumption: The most straightforward approach involves calculating annual polymeric MDI usage based on binder consumption records and manufacturer specifications for MDI content.

Purchase Records: Tracking cold-box binder purchases and MDI content percentages provides baseline data for TRI threshold evaluations.

Processing: Not all purchased MDI becomes polymerized in cores; some portion may be lost during mixing, handling, and storage operations. The bulk of the MDI reacts at coremaking and is not emitted during the core- or moldmaking process.

Emission Factor Development

Thermal Decomposition Rates: Developing emission factors requires understanding what fraction of core-bound MDI volatilizes during casting operations.

Temperature Dependence: MDI release rates vary with metal temperature, core size, and thermal exposure time, complicating emission factor applications.

Core Geometry Effects: Complex cores with high surface-to-volume ratios may exhibit different MDI release characteristics than simple geometric shapes.

Analytical Challenges

Sampling Difficulties: MDI's reactivity and tendency to polymerize creates challenges for direct emission measurements.

Matrix Interferences: Other foundry emissions may interfere with MDI quantification methods.

Decomposition Products: Distinguishing between unreacted MDI and thermal decomposition products requires sophisticated analytical approaches.

3.12.7 Control and Minimization Strategies

Process Modifications

Binder Optimization: Minimizing binder usage through improved core design and sand preparation reduces overall MDI consumption and potential emissions.

Alternative Systems: Evaluating alternative binder systems that do not contain MDI can eliminate TRI reporting obligations while potentially reducing health and safety concerns.

Curing Optimization: Ensuring complete curing reactions maximizes MDI polymerization and minimizes unreacted MDI available for thermal decomposition.

3.12.8 Regulatory and Reporting Considerations

TRI Thresholds – Otherwise Used

- Polymeric MDI is a key component in phenolic urethane cold box (PUCB) binder systems used for foundry cores and molds. These resins are used in cold-box polyurethane systems, where they polymerize in the presence of a second component through an addition reaction. Facilities should evaluate actual annual reportable amounts, releases, and Form A eligibility based on site-specific binder usage, SDS information, and TRI reporting criteria. If total annual reportable amounts are 500 pounds or less and no PBT chemicals are involved, Form A may be available if all other eligibility requirements are met.

Section 4
Release Categories and Estimation Methods

4.1 Air Releases

The emissions profile of each foundry is unique to its operation. A detailed review of Safety Data Sheets (SDSs), supplier data, available emission characterizations, operating parameters, etc. can be a helpful start when attempting to quantify TRI chemical releases. When characterizing releases for TRI reporting purposes, both fugitive and stack emissions are reportable releases but must be reported separately.

The following provides a discussion on estimating TRI releases to air.

4.1.1 Use of Emission Factors

Great care should be taken in determining what emission factors are most appropriate for the operation. Some industrial operations can use published emission factors. However, the range of values in published emission factors for the foundry industry is very broad and typically metallic HAP data is limited.

Variations in material types, equipment, process parameters, ventilation, and control systems result in very different emission rates from foundry to foundry. Because of the significant variability in the processes, the foundry industry continuously struggles to develop an industry emission factor standard or even publish ranges.

Foundry emissions must be reviewed to determine if they are a function of the raw material composition or created by process reactions. Emissions from coating operations can typically be estimated by calculating the total mass of the chemical component purchased using SDS information from suppliers. These emissions would then be related to material usage or in some cases process emission factors would be developed per ton of cores, sand, or metal.

4.1.2 Sources of Emissions Information

The following provides a list of sources of emissions information:

- Supplier Data
- Plant- or process-specific stack test data.
- Stack testing data
- Baghouse dust analysis for metallic compounds
- Safety Data Sheets (SDS) – Sections 3 and 15 with Section 15 taking precedence
- Organic Hazardous Air Pollutant Emission Factors for Iron Foundries, American Foundry Society, 2007 (References reports for breakdown by species.)
- National Emission Standard for Hazardous Air Pollutants (NESHAP) for Iron and Steel Foundries –Background Information for Proposed Standard, EPA-543/R-02-013, 2002

- AFS Total HAP calculator - cursory estimate for use in calculating total HAPs emitted (no species)
- AFS/CISA "Form R Reporting of Binder Chemicals Used in Foundries," Fourth Edition.
- Ohio Cast Metals Association (OCMA) Coremaking Study
- PUCB, PUNB coremaking and storage
- AP-42/FIRE
- The Casting Emission Reduction Program (CERP/Technikon, LLC)

4.1.3 Steps for Estimating Emissions

The following presents steps for estimating the release of TRI chemicals via stack or fugitive:

1. Determine possible TRI chemicals that may be emitted from each emission point. Component substances listed on a SDS at a concentration below 0.1% for substances subject to control requirements and below 1.0% for all other listed substances may not need to be considered. This determination will be made using the information sources listed above.
2. Determine appropriate emission factors. Possible approaches include using:
    a. SDS
    b. Mass balance (Unlikely to account for condensable emissions.)
    c. Stack testing
    d. Emission factors from the sources listed previously in this section.
3. Estimate actual emissions of each TRI chemical at each emission point.

4.1.4 Metallic Particulate Estimates

The concentrations of TRI metals in the exhaust streams from foundries can be extremely low. Foundry operations that are expected to include minor quantities of TRI reportable metals include:

- Arc Melting Furnaces
- Induction Melting Furnaces
- Cupola Melting Furnace
- Holding Furnaces
- Inoculation
- Pouring, cooling, and shakeout
- Casting Cleaning
- Casting Grinding

Metallurgical differences in castings can contribute to differences in the composition of particulate matter releases to air. These differences can be monitored and used in estimating the quantity of metallic emissions.

Foundries can estimate releases of metallic emissions to air by using an emission factor or stack test data. The concentration of reportable metals in the baghouse dust or scrubber sludge may be representative of air emission rates.

The collected baghouse or scrubber solids can be analyzed for the concentration of metallic constituents using a solid waste totals analysis method. An analytical lab or the State Lab of Hygiene should be contacted to determine the appropriate analytical method and sampling procedures. This method provides an economical method of identifying reportable air emissions from controlled sources.

Terms:
Particulate Emissions (PM)
Manganese (Mn)
mg/kg = mg/L = ppm

Process Data:
Production Rate: 100,000 tons melt in a cupola.
PM_{Total} Emission Factor: 0.02 lb PM_{Total}/ton melt
Mn Baghouse Catch Analysis: 10,000 ppm Mn

Sample Calculation:
A cupola melts 100,000 tons of metal and non-metallics per year and is equipped with a baghouse. Based on a recent stack test, the PM_{Total} emission factor was determined to be 0.02 lb PM_{Total}/ton melt. The foundry analyzes the baghouse dust collected quarterly for total metals. The average total manganese concentration for the previous year was 10,000 ppm.

Total annual stack emissions of manganese from the cupola:

*= (PM_{Total} Emission Factor) * (Mn Baghouse Catch Analysis [ppm] / 1,000,000 [ppm]) * (Production Rate)*

*= (0.02 lb PM_{Total}/ton melt) * (10,000 ppm_{Mn} / 1,000,000 ppm) * (100,000 tons melt)*

= 20 lb Mn per year released to the air from the cupola

4.1.5 Ammonia from Shell Core Sand (Resin Coated Sand)

When binder system chemicals are used in a core/mold making process, the chemical is either reacted/consumed in the process, released to the environment (air fugitives), or remains in the finished core/mold. The percentage that remains within the core/mold may be released from the cores prior to their use; be thermally destroyed (pyrolyzed)/changed during pouring and cooling of the casting; remain in the core unchanged and mixed with the molding sand at shakeout; or remain in the core butt; remain in the core if it is discarded and not used to produce a casting; may volatilize and recondense in the molding sand during pouring/cooling; may volatilize and be released in the gases coming off the mold during pouring/cooling; or may volatilize and be released

in the gases coming off the mold during pouring/cooling but be destroyed/changed as these gases burn.

Ammonia is generated/manufactured as a breakdown product from the hexamethylenetetramine (hexa). As the hexa breaks down, 40%-50% is converted to ammonia. Therefore, for TRI purposes, the ammonia is considered manufactured and would be a waste byproduct, making the ammonia generated applicable to the 25,000 lb threshold for manufactured chemicals.

Of the ammonia generated/manufactured during the core making process, 50% is reacted/consumed and 50% is released to the air as a fugitive, with 0% remaining within the core/mold.

Sample Calculations:
A foundry uses 10,000 tons per year of a resin-coated sand to make cores. The SDS shows that resin-coated sand consists of 1% hexamethylenetetramine (hexa).

> Total Section 5.1 (of the Form R) – Fugitive or Non-Point Air Emissions of ammonia from the core making process:
>
> *= (Resin-Coated Sand Usage * 2,000 lb/ton) * (% Hexa) * (% Ammonia Generated as a Breakdown Reaction of Hexa) * (% Released to Air as Fugitive)*
>
> *= (10,000 tons * 2,000 lb/ton) * (1%) * (40%) * (50%)*
>
> *= **40,000 lb ammonia** released to the air as a fugitive from the core making process*

4.1.6 MDI from Phenolic Urethane Cold Box Systems

When binder system chemicals are used in a core/mold making process, the chemical is either reacted/consumed in the process, released to the environment (air fugitives), or remains in the finished core/mold. The percentage that remains within the core/mold may be released from the cores prior to their use; be thermally destroyed (pyrolyzed)/changed during pouring and cooling of the casting; remain in the core unchanged and mixed with the molding sand at shakeout; or remain in the core butt; remain in the core if it is discarded and not used to produce a casting; may volatilize and recondense in the molding sand during pouring/cooling; may volatilize and be released in the gases coming off the mold during pouring/cooling; or may volatilize and be released in the gases coming off the mold during pouring/cooling but be destroyed/changed as these gases burn.

Polymeric MDI is 99.99% reacted/consumed during the core making process, 0% is released to the air as a fugitive during the core making process, and 0.01% remains within the core/mold.

Sample Calculations:
A phenolic urethane coldbox binder is used to make cores. This binder consists of two components, Part I and Part II. Annual usage totals are 400,000 lb of Part I and 325,000 lb of Part II. The SDS shows that Part II consists of 75% polymeric MDI (N120).

For this example, it is assumed that the polymeric MDI that remains in the core is 100% volatilized and released in the gases coming off the mold during pouring/cooling. The gas stream from the pouring/cooling process is captured and routed through a stack. The capture efficiency is assumed to be 98%.

Total fugitive emissions of polymeric MDI from the core making process:

*= (Part II Chemical Usage) * (% Polymeric MDI) * (% Released to Air as Fugitive)*

*= (325,000 lb) * (75%) * (0%)*

= 0 lb polymeric MDI released to the air as a fugitive from the core making process

Total fugitive emissions of polymeric MDI from the pouring/cooling process:

*= (Part II Chemical Usage) * (% Polymeric MDI) * (% Remaining in the Core) * (% Volatilized in the Pouring/Cooling Process) * (1 - % Capture Efficiency)*

*= (325,000 lb) * (75%) * (0.01%) * (100%) * (1 – 98%)*

= 0.49 lb polymeric MDI released to the air as a fugitive from the pouring/cooling process

Total Section 5.1 (of the Form R)– Fugitive or Non-Point Air Emissions of Polymeric MDI:

= (Fugitive Release from Core Making Process) + (Fugitive Release from Pouring/Cooling Process)

= (0 lb polymeric MDI) + (0.49 lb polymeric MDI)

*= **0.49 lb polymeric MDI** released to the air as fugitive air emissions*

Total Section 5.2 (of the Form R) – Stack Emissions of Polymeric MDI from the pouring/cooling process:

*= (Part II Chemical Usage) * (% Polymeric MDI) * (% Remaining in the Core) * (% Volatilized in the Pouring/Cooling Process) * (% Capture Efficiency)*

*= (325,000 lb) * (75%) * (0.01%) * (100%) * (98%)*

*= **23.89 lb polymeric MDI** released to the air as a stack emission from the pouring/cooling process*

4.2 TRI Chemical Process Water and Stormwater Releases

Estimating the amount of TRI chemicals in liquid waste streams requires facilities to test for the total concentration of the analyte. The units of these analytes are commonly mg/L, or parts per million (ppm).

Process Water and Storm Water Metals – Discharge to Receiving Stream – SARA 313/TRI Section 5.3:

Foundries can estimate releases of metallic emissions to water by using an emission factor or process water / stormwater discharge sample analysis data. Account for discharges to an NPDES permitted outfall or a POTW by using flow data and permit required parameters analyses. Account for discharges to stormwater outfalls by using permit required parameter analyses and flow data (if available) or calculating runoff based on acreage, land use coefficients, and annual rainfall/snow melt.

Terms:

Manganese (Mn)
mg/kg = mg/L = ppm
8.345 lb/gal
7.48 gal/ft3
43,560 sqft/acre
1 foot of snow is equivalent to 1 inch of rain

Process Data:

Operational Days: 250 Days per Year
NPDES Outfall Discharge Rate: 200,000 GPD (0.20 MGD)
Mn NPDES Outfall Concentration: 0.20 mg/L Mn
Mn Stormwater Outfall Concentration: 0.8 mg/L Mn

Stormwater Data:

Annual Rainfall: 35 inches
Stormwater Runoff Acreage: 50 acres
Land Use
- Heavy Industrial Area:
  - Percent Area: 75%
  - Runoff Coefficient: 0.75
- Asphaltic Streets:
  - Percent Area: 15%
  - Runoff Coefficient: 0.85
- Vegetated Area:
  - Percent Area: 10%
  - Runoff Coefficient: 0.10

Sample Calculation:

A foundry discharges an average of 0.20 MGD to an outfall regulated by an NPDES permit. The outfall is a named receiving water, *Little Bend Creek*. The NPDES permit requires daily samples for manganese analysis. The foundry discharges to the outfall 250 days per year. The average concentration of manganese in the outfall is 0.20 mg/L.

Total discharge of Mn from process water out of the NPDES Outfall:

*= (Operational Days Per Year) * (Daily Discharge Flow) * (8.345 lb/gal) * (Mn NPDES Outfall Concentration [ppm] / 1,000,000 [ppm])*

*= (250 days/year) * (200,000 gpd) * (8.345 lb/gal) * (0.20 ppm / 1,000,000 ppm)*

= <u>83.45 lb Mn per year</u> released to water via process water

The facility is located on 50 acres. All stormwater runoff flows to a stormwater outfall that also discharges into *Little Bend Creek*. The foundry is required to collect quarterly stormwater samples to analyze for metals. The flow to the stormwater outfall is unknown but the acreage of the site is 50 acres, and the land use is 75% heavy industrial area, 15% asphaltic streets and 10% vegetated area with mostly flat and some minor slope.

Total discharge of Mn from stormwater out of the Stormwater Outfall:

*Weighted-Average Runoff Coefficient = [(75% * 0.75) + (15% * 0.85) + (10% * 0.10)] / (75% + 15% + 10%) = 0.70*

*Stormwater Runoff Flow = (Rainfall) * (Land Acreage) * (7.48 gal/ft3) *(Weighted-Average Runoff Coefficient)*

*= (35 inches / 12 inches/foot) * (50 acres * 43,560 sqft/acre) * (7.48 gal/ft3) * (0.70) = 33,261,690 gallons per year*

*= (Annual Discharge Flow) * (8.345 lb/gal) * (Mn NPDES Outfall Concentration [ppm] / 1,000,000 [ppm])*

*= (33,261,690) * (8.345 lb/gal) * (0.8 ppm / 1,000,000 ppm)*

= <u>222.05 lb Mn per year</u> released to water via stormwater

Total discharge of Mn from process water and stormwater from the foundry – <u>Section 5.3A</u>:

= (lb Mn from Process Water) + (lb Mn from Stormwater)

*= 83.45 lb Mn + 222.05 lb Mn = **<u>305.50 lb Mn per year</u>** discharged to water from the foundry*

Percent discharge of Mn from stormwater – <u>Section 5.3C</u>:

*= (lb Mn from Stormwater) / (lb Mn total) * 100%*

*= 222.05 lb Mn / 305.50 lb Mn * 100%*

*= **<u>76.68% from stormwater</u>***

Section 5
Specific Foundry TRI Considerations

The section addresses a number of nuances and aspects of the TRI reporting process that deserve special attention in the foundry industry.

5.1 Foundry Returns – Reuse, Recycling or Neither

Because the foundry industry is widely recognized as one of the largest recycling industries in the world, foundries should evaluate whether remelting foundry returns qualifies as recycling for TRI reporting purposes.

To be reported as recycling under TRI, the chemicals or the waste containing the chemicals must undergo a recovery step prior to being used again, such as removing impurities from a solvent. This suggests that simple remelting of foundry returns may not qualify as "recycling" under TRI definitions if no recovery or purification step occurs.

The key distinction appears to be whether the foundry returns undergo any treatment or recovery process before being remelted. If foundry returns are simply collected and remelted back into the same production process without any purification, recovery, or treatment steps, this would likely be considered "reuse" rather than "recycling" for TRI reporting purposes.

However, if the foundry returns undergo processing such as:

- Removal of impurities
- Separation of different metals
- Chemical treatment or refinement
- Any recovery process to restore the material's original properties

Then it would more likely qualify as recycling under TRI reporting. However, simply collecting gates, risers, and returns and charging them back into the melt process does not qualify as on-site recycling for TRI reporting purposes.

5.2 “Processing” versus “Otherwise Used” and Intent

When deciding whether a TRI chemical should be compared against the “processing” versus “otherwise used” reporting thresholds, it is important to determine whether the function or intent of the toxic chemical depends on becoming part of a product. Binder chemicals such as MDI, TEA, and DMIPA are generally classified as “otherwise used” because they react or function during processing and are not intentionally incorporated into the final product distributed in commerce.

For example, a TRI-listed chemical must be intentionally used to be classified as “processed.” According to the EPA TRI guidance, processing refers to incorporating a chemical into a product for distribution in commerce, which includes blending, repackaging, or reacting it to create a new substance.

If a TRI chemical is intentionally added to alloys or coatings in foundry operations, it qualifies as “processed” under TRI reporting. However, if the TRI chemical is incidentally present in scrap metal or generated as a byproduct, it likely falls under “otherwise used.”

5.3 Incidental Manufacturing

Along with other industries, iron and steel foundries may not intentionally create a chemical, but for Toxics Release Inventory reporting, the incidental manufacturing of a chemical is still classified as manufacturing if the chemical is produced as a byproduct or impurity during industrial processes. Facilities must evaluate whether the annual quantity of the incidentally manufactured chemical exceeds the 25,000 pound threshold for TRI reporting.

A foundry specific example of this is the generation of ammonia from the shell mold- and/or core-making process. In the shell coremaking process, resin coated sand is blown into heated core machines causing the viscosity of the coating to decrease. The sand binder releases ammonia and formaldehyde as it begins to polymerize and gradually locks the sand grains together while it cures into a resin. The ammonia is generated from hexamethylene tetramine which serves as the catalyst in traditional shell core binder systems. During the reaction of hexamethylene tetramine with the resin, nitrogen is released from the hexamethylene tetramine in the form of ammonia fumes.

In the above example, the foundry would quantify the ammonia coincidentally manufactured and compare the resultant to the manufacturing threshold of 25,000 pounds to determine if it is a TRI reportable chemical.

5.4 Metal versus Metallic Compound

Iron and steel foundries primarily process metallic compounds rather than pure base metals. This is because the foundry process involves melting, alloying, and casting metals, which often results in the formation of metal oxides, sulfides, and other compounds.

Formation of Metallic Compounds in Foundries

1. **Oxidation Reactions**: When metals like iron or steel are melted at elevated temperatures, they react with oxygen in the air, forming metal oxides. For example, iron reacts with oxygen to create iron oxide (FeO, Fe_2O_3, Fe_3O_4), which can appear as slag or scale on the molten metal surface.

2. **Alloying Process**: Foundries often mix different metals to create alloys with specific properties. During this process, elements like chromium, nickel, and manganese bond with iron, forming metallic compounds that enhance strength, corrosion resistance, or heat tolerance.

3. **Sulfur and Carbon Reactions**: In iron and steel foundries, sulfur and carbon present in raw materials can react with molten metal, forming metal sulfides and carbides. These compounds influence the hardness and machinability of the final product.

4. **Interaction with Fluxes:** Foundries use fluxes like limestone or fluorspar to remove impurities. These fluxes react with metal oxides, forming complex metallic compounds that separate from the molten metal as slag.

These reactions are essential for shaping the final properties of cast metals.

When reporting under regulatory frameworks like the Toxics Release Inventory (TRI), foundries should **focus on metallic compounds** since these are the actual forms in which metals are released into the environment—whether through air emissions, wastewater, or solid waste disposal.

Additionally, metallic compounds pose distinct environmental and health risks compared to base metals. For example, chromium and nickel compounds found in stainless steel production can be more hazardous than their elemental forms. Regulatory agencies often require reporting on these compounds because they have different toxicity profiles and environmental behaviors. By accurately reporting metallic compounds, foundries ensure compliance with environmental regulations and provide a clearer picture of their impact on air, water, and soil quality.

5.5 Metal Containing Compound Threshold Determination

Threshold quantities for metal compounds are based on the total weight of the metal compound, not just the metal portion of the metal compound. The threshold quantities are determined by adding up the total weight of all metal compounds containing the same parent metal. However, release and other waste management calculations are based solely on the weight of the parent metal portion of the metal compounds.

Threshold determinations for metal containing compounds are made separately from parent-metal threshold determinations because they are listed separately under Section 313. Machine shops that operate within foundries may process elemental metals during product finishing activities. Facilities should evaluate TRI reporting thresholds for elemental metals from machine shop operations separately from those for metal compounds generated or processed by foundry operations. If both thresholds are exceeded, reporting under the metal compound category is permissible, provided it accurately reflects the chemical forms released or managed.

5.6 Metal Containing Compound Releases

As discussed above, threshold determinations for the elemental metal and the metal compounds are made separately as they are separate entries on the Section 313 list.

For metal compound, when reporting releases and other waste management activities, releases should be reported as the elemental metal and not as the total mass of the metal compounds.

It would be helpful to review Q180 in the 2019 TRI Q&A document.

5.7 Process Knowledge Versus Analysis

Under EPA Toxics Release Inventory (TRI) reporting requirements, facilities are allowed to use process knowledge rather than analytical testing to estimate chemical releases. This means that foundries and other industries can rely on historical data, engineering calculations, and operational records to determine emissions, rather than conduct costly laboratory analyses.

The EPA recognizes that direct measurement of every release may not be feasible, so facilities can use mass balance equations, emission factors, and safety data sheets (SDSs) to estimate their TRI-reportable quantities. However, process knowledge should be technically justified and documented, ensuring that estimates are reasonable and consistent with industry standards.

5.7.1 Process Knowledge Example – Melt Furnace Air Emissions

- Foundries can use published emission factors and quantities of metal charges and fuel used to estimate air releases of TRI-listed metallic and organic compounds.

- Instead of conducting performance tests or using some form of real-time air monitoring, facilities can apply EPA or industry-recognized emission factors based on known furnace output and fuel usage.

While it is perfectly legitimate to apply process knowledge in TRI reporting, the following should be considered.

- Determining the Scope of Sampling Plans: Each facility can determine the scope of sampling for their industrial by-products based on process knowledge and analytical data. This means understanding which processes are most likely to generate TRI chemicals and focusing sampling efforts there.
- Estimating Emissions from Operations: A detailed review of Safety Data Sheets (SDSs), supplier data, available emission characterizations, and operating parameters, among other things, can be used to determine what may be emitted from their processes and in what potential quantities. This requires in-depth knowledge of their specific operations.
- Selecting Appropriate Emission Factors: Care must be taken in determining which emission factors are most appropriate for a specific foundry operation. This often involves understanding how variations in material types, equipment, process parameters, ventilation, and control systems can impact emission rates.
- Understanding Chemical Reactions: Process knowledge helps foundries understand that "manufactured" products (i.e., those produced through chemical reactions on-site) may not be listed on raw material specification sheets or SDSs but can still be emitted in measurable amounts during the process. An example given is when galvanized scrap is melted in a furnace, measurable amounts of zinc can accumulate in wet scrubber sludge.
- Adjusting Emission Factors: When using reference tests for core emissions, foundries apply process knowledge to adjust emission factors based on their actual core binder levels. For instance, if a reference test was performed with a higher binder level than the facility's, they will know that their lower binder level will result in lower emissions proportional to the binder differences, and they can adjust the emission factor accordingly.
- Recognizing Limitations of Mass Balance: Foundries understand that a simple material balance cannot always be performed for processes like pouring, cooling, and shakeout because not all chemical components in cores and molds react to form other chemical compounds. This process knowledge leads them to rely on stack testing or emission factors from research testing for more accurate estimates.
- Interpreting Analytical Data: Foundries know that TCLP (Toxicity Characteristic Leaching Procedure) numbers should not be used for estimating TRI chemicals. They understand that TCLP measures concentration in liquid leachate, not the total concentration in the solid material, and therefore is not suitable for general mass balance calculations in TRI reporting. They also understand that total concentration data (e.g., mg/kg, ppm) is most accurate for solid waste releases.
- Most facilities lack direct test data on air emissions of TRI-listed metals. However, they often have measurements of total metal concentrations in baghouse dust. These concentrations can reasonably represent the levels of metals in the air stream and may be used to estimate air emissions for TRI reporting purposes.

- Finally, it is important that metal casting facilities with annual emission reporting obligations ensure emissions are consistent when conducting annual emission and TRI reporting.

5.8 TRI De Minimis Exemption

The TRI de minimis Exemption allows facilities to exclude certain low-concentration toxic chemicals from their Toxics Release Inventory (TRI) reporting.

Under 40 CFR Part 372, this exemption applies when a non-Persistent, Bioaccumulative, and Toxic (non-PBT) chemical is present in a mixture at less than 1% by weight, or less than 0.1% for OSHA-defined carcinogens. This means that facilities do not need to count these chemicals toward their manufacturing, processing, or otherwise-used thresholds when determining TRI reporting obligations.

However, the de minimis exemption does NOT apply to PBT chemicals, such as lead compounds, mercury, and dioxins, due to their long-term environmental impact. Foundries using binder chemicals, coatings, or metal alloys should carefully review their Safety Data Sheets (SDSs) to determine whether the de minimis exemption applies to their operations.

When a Safety Data Sheet (SDS) lists a TRI-listed chemical as a concentration range that spans the de minimis threshold (e.g., 0.5%–1.5% for a 1.0% de minimis chemical), the facility cannot tell from the SDS alone whether the chemical qualifies for the de minimis exemption.

Contacting the manufacturer to obtain the actual percent by weight is a reasonable best practice in that situation, and EPA guidance supports it. A few points worth noting: 1) If the manufacturer provides actual concentration data, you use that figure to determine whether the de minimis exemption applies and whether the chemical must be factored into threshold and release calculations; and 2) If the manufacturer won't provide the actual concentration (often citing trade secret/proprietary protection), EPA's general guidance is that you may assume the chemical is present at the **midpoint** of the range, or use the upper bound as a conservative approach. Using the midpoint or high end avoids under-reporting. Keep documentation of your effort to obtain the data and the basis for whatever concentration you ultimately use, in case of an audit.

The following examples address the De Minimis Exemption and the Foundry industry.

5.8.1 De Minimis Example – Binder Chemicals in Core Making

Scenario:

- A foundry uses phenolic urethane binders in its core-making process.
- The Safety Data Sheet (SDS) for the binder lists naphthalene at 0.9% by weight.
- Since naphthalene is a non-PBT chemical and is present at less than 1%, the facility can exclude it from TRI threshold determinations.

Outcome:

- The foundry does not need to count the naphthalene in its core binder toward its TRI reporting threshold.

5.8.2 De Minimis Example – Nickel in Scrap Metal

Scenario:

- A foundry melts scrap in its induction furnace.
- The Safety Data Sheet (SDS) for the incoming scrap metal lists nickel at 0.75% by weight.
- Nickel is a non-PBT, and because its concentration in the raw material is under 1% it qualifies for the de minimis exemption.

Outcome:

- The foundry may exclude nickel in the incoming scrap from threshold calculations if the de minimis exemption applies. However, furnace dust and other byproducts should be evaluated separately because the de minimis exemption does not apply to TRI chemicals coincidentally manufactured as byproducts during manufacturing, processing, otherwise use, or waste management activities.

5.8.3 De Minimis Example – Naphthalene in Core Binder and Coating

Scenario:

- A foundry uses phenolic urethane binders in its core-making process and coats its castings prior to shipping to the customer.
- The Safety Data Sheet (SDS) for the binder lists naphthalene at 0.9% by weight and for the coating lists naphthalene at 2.1% by weight.
- Since naphthalene is a non-PBT chemical and is present at less than 1% in the core binder, the facility can exclude it from TRI threshold determinations, but since the coating lists naphthalene at or above 1% the naphthalene must be included in the TRI threshold determination.

Outcome:

- The foundry must include the naphthalene from the coating in its threshold calculations.

Key De Minimis takeaways for Foundries:

- The de minimis exemption applies only to non-PBT chemicals that are below 1% (or 0.1% for carcinogens) in mixtures.
- PBT chemicals like lead, mercury, and dioxins DO NOT qualify for the de minimis exemption.
- Facilities should check their SDSs to determine whether chemical concentrations fall within de minimis levels.

- If a chemical qualifies for the exemption, it does NOT need to be counted toward TRI reporting thresholds.
- The de minimis exemption does not apply to the manufacture of an EPCRA Section 313 chemical unless that EPCRA Section 313 chemical is manufactured as an impurity and remains in the product distributed in commerce, or if the EPCRA Section 313 chemical is imported below the appropriate de minimis level. The de minimis exemption does not apply to a byproduct manufactured coincidentally as a result of manufacturing, processing, otherwise use, or any waste management activities. The de minimis exemption does not apply to any chemical of special concern (except lead when it is contained in stainless steel, brass, or bronze alloy) or chemical of special concern category.
- Finally, it is extremely important to consult EPA TRI guidance when dealing with TRI chemical content ranges.

5.9 TRI Articles Exemption

The TRI Articles Exemption allows iron and steel foundries to exclude certain materials from Toxics Release Inventory (TRI) reporting if they meet the EPA's definition of an article under 40 CFR Part 372. An article is a manufactured item that maintains its shape and function during normal use and does not release TRI-listed chemicals under standard processing conditions. In foundries, finished castings that are fully solidified and shipped without further processing typically qualify for this exemption. Similarly, machined metal components that do not emit TRI chemicals during handling may also be exempt.

However, if a foundry cuts, grinds, melts, or chemically treats an article in a way that releases TRI-listed substances, the exemption no longer applies, and the facility must report those releases. Additionally, if related waste from an article is fully recycled and documented, and total releases to air, water, and non-recycled waste remain below 0.5 lbs., the exemption may still apply.

According to EPA guidance, an article is exempt from TRI reporting if:

1. Related wastes are fully recycled, and the facility can document this recycling process.
2. Total releases to air, water, and non-recycled waste amount to 0.5 lbs. or less over the course of the reporting year.

However, if an article undergoes processing that alters its shape or causes chemical releases, such as cutting, grinding, or melting, it no longer qualifies for the exemption.

5.9.1 Article Exemption Example – Zinc-Coated Steel Bars

Scenario:

- A foundry stores zinc-coated steel bars to use in production.
- If the facility cuts or melts the bars, zinc emissions occur, making TRI reporting necessary.
- However, if the bars remain intact, are sold or transferred without processing and do not release TRI chemicals, they qualify for the article exemption.

Outcome:

- If the bars are merely stored or sold without processing, they do not require TRI reporting due to the article exemption.
- If they are processed or melted, TRI reporting would be required.

Key Takeaways Regarding the Article Exemption for Foundries

- Articles qualify for exemption if they maintain their shape and do not release TRI chemicals during use.
- Facilities must document recycling when claiming an exemption based on waste reuse.
- If processing an article leads to emissions or disposal, it no longer qualifies for the exemption and must be included in TRI reporting.
- Construction materials such as structural steel I-beams, metal panels, and rebar added during the reporting year are generally exempt from TRI threshold determinations under the Articles Exemption. These items are manufactured with a specific shape and design, serve a structural function, and do not release chemicals under normal conditions of use or installation. As long as the facility does not process these materials in a way that causes the release of toxic chemicals—such as welding, grinding, or melting—the exemption applies, and the chemical content of these materials does not need to be included in TRI calculations.

Section 6
Other TRI Topics

6.1 Best Practices

Foundry Best Practices include the following:

- Inventory TRI Chemicals: Review all raw materials, byproducts, and emissions
    - Maintain an up-to-date chemical inventory at your facility
    - Track how chemicals are managed including releases, recycling, and disposal
- Calculate Thresholds: Sum all uses of each TRI chemical
- Estimate Releases: Use appropriate methods for each release category
- Select Reporting Form: Choose Form A or Form R based on eligibility
- Review historical reports to identify any discrepancies.
- Stay up to date on changes to TRI reporting requirements
- Submit Reports: Due July 1 for previous calendar year

6.2 Useful Guidance

The GuideME online guides and the EPA list of lists are helpful tools during new material reviews. They are available at the following links:

- https://guideme.epa.gov/ords/guideme_ext/f?p=guideme%3Ahome
- https://www.epa.gov/epcra/consolidated-list-lists

Section 7
Miscellaneous Information

7.1 TRI Guidance Acronyms

- AFS. American Foundry Society
- AP-42. EPA report entitled “Compilation of Air Pollutant Emission Factors.”
- CERP. Casting Emissions Reduction Program
- CFR. Code of Federal Regulations
- CISA. Casting Industry Suppliers Association
- EHS. Extremely Hazardous Substance
- EPA. Environmental Protection Agency, as in USEPA
- EPCRA. Emergency Planning and Community Right-to-Know Act
- FIRE. Factor Information Retrieval Software. EPA software for accessing the agency’s emission factors
- g. gram(s)
- gal. gallon(s)
- HAP. Hazardous Air Pollutant
- LOI. Loss on Ignition
- MACT. Maximum Achievable Control Technology. “Iron and Steel Foundry MACT” is commonly used as a synonym for “Iron and Steel foundry NESHAP”
- MDI. Methylene Diphenyl Diisocyanate
- mg/kg. milligram(s) per kilogram
- mg/L. milligram(s) per liter
- MSDS. Material Safety Data Sheet
- NESHAP. National Emission Standard for Hazardous Air Pollutants.
- NFPA. National Fire Protection Association
- OCMA. Ohio Cast Metals Association
- PBT. Persistent, Bioaccumulative, and Toxic
- PCS. Pouring, Cooling and Shakeout
- PM. Particulate Matter
- POTW. Publicly Owned Treatment Works
- ppm. part(s) per million
- PUCB. Polyurethane Cold Box
- PUNB. Polyurethane No-Bake
- SARA. Superfund Amendments and Reauthorization Act
- SW 846. EPA test methods manual entitled “Test Methods for Evaluating Solid Waste, Physical/Chemical Methods.”
- SW 6010B. EPA test method entitled “Inductively Coupled Plasma-Atomic Emission Spectrometry”.
- TCLP. Toxicity Characteristic Leaching Procedure
- TPQ. Threshold Planning Quantity
- TRI. Toxic Release Inventory
- USEPA. United States Environmental Protection Agency

- VOC. Volatile Organic Compound

Appendix A
Tables

Table 2-1. Typical Foundry Operations and their Description

Foundry Operation	Operation Description
Charge Handling	Receipt, handling and storage of metallics, inoculants and flux materials prior to melting
Scrap Preheat	Heating of charge materials prior to melting to remove moisture and impurities
Melt Furnaces	Generally a cupola, induction furnace or arc furnace used to produce molten metal for casting purposes.
Holding Furnaces	Allows an inventory of molten metal while maintaining temperature
Desulfurization	Agents such as calcium carbide, magnesium, or lime are added to molten iron to react with sulfur and form a slag that can be removed from the molten metal
Inoculation	Addition of materials to the molten iron to develop desired metallurgical properties
Pouring	The transfer of molten iron into the void space of a mold
Cooling	The solidification of the molten metal within the mold
Shakeout/Punchout	Separation of solidified casting from the mold
Casting Finishing	Media blasting the casting to clean and then grinding of the casting to remove undesired or excess metal
Sand Handling and Mechanical Reclamation	May include the transferring, storage, mixing, and additional condition in preparation of sand reuse
Thermal Reclamation	System used to recover and reuse spent foundry sand by applying high-temperature processing to remove residual binders, contaminants, and organic materials.
Moldmaking	The forming of sand molds through either the addition of sand with either clay and seacoal or sand combined with chemical binder systems.
Coremaking	Forming of sand assemblies to create cavities within the cast part generally using chemical binder system
Machining	Cutting, drilling, milling, and turning to achieve the required dimensional accuracy, surface finish, and mechanical properties for the final product.
Coating	Applying paint or rust preventative to the finished casting
Quenching	Submersion or saturation of casting in oil or water to obtain desired metallurgical quality

Table 3-1. Most Commonly Reported TRI Chemicals in the Iron and Steel Foundry Industry

Chemical	CAS Number	Industry Use[1]
Aluminum Dust or Fume	7429-90-5	Contained in flux material, refractory material, present in scrap
Chromium Compounds	N090	Scrap, alloy addition, chromite sand, refractory lining materials
Copper & Copper Compounds	7440-50-8 N100	Scrap, alloy addition
Lead Compounds	N420	Scrap (trace), coatings
Manganese and Manganese Compounds	N450	Scrap, alloy addition
Nickel Compounds	N495	Scrap
Zinc Compounds	N982	Scrap (galvanized coatings)
Ammonia	7664-41-7	Shell sand, combustion by-product
Benzene	71-43-2	Combustion by-product including coke, pouring, cooling and shakeout
Naphthalene	91-20-3	Chemical binder component, combustion by-product including pouring, cooling and shakeout
Phenol	108-95-2	Chemical binder component
Diisocyanatos (Polymeric MDI)	N120	Chemical binder component, mold coatings

[1]See Section 3 for more detailed industry use information.

Table 3-2. List of Common and other Possible TRI Chemicals in the Iron and Steel Foundry Industry

Material Category	TRI Chemical	Specific Material	Notes
Alloys	Antimony Compounds	Alloy component	Mainly in steel
	Chromium Compounds	Ferrochrome	
	Copper Compounds	Copper Shot, Copper Ingot, Ferro Copper	
	Manganese Compounds	Ferromanganese	
Charge Materials - Scrap	Cadmium Compounds	Scrap (batteries, electrical, coatings, platings)	
	Chromium Compounds	Scrap (stainless, Platings, Coatings, Fasteners, Catalytic Converters)	
	Copper Compounds	Scrap (copper alloyed, wiring, radiators. catalytic converters)	
	Lead Compounds	Scrap (batteries, wheel weights, electrical, bearings)	Less common
	Manganese Compounds	Scrap (steel, wiring)	Common is steel for durability
	Nickel Compounds	Scrap (Stainless, Batteries, Electroplated)	
	Zinc Compounds	Scrap (galvanized)	
Other Charge Materials	Benzene, Naphthalene, Phenol	Coke	
	Barium	Ferrosilicon	
	Fluorspar	Fluxing Agent	Hydrogen Fluoride is Generated, Not typically used
Green Sand	Benzene, Naphthalene, Phenol	Generated during pouring, cooling and shakeout	
Chemically Bonded Mold and Core Resin	Formaldehyde	Phenolic Urethane (Part I), Furan, Phenolic No Bake, Shell	
	Naphthalene	Phenolic Urethane (Part I/II)	
	Phenol	Phenolic Urethane (Part I), Furan, Phenolic No Bake, Shell	
	Polymeric MDI	Phenolic Urethane (Part II)	
	Triethylamine	Amine Catalyst	Not common
	Dimethylethlamine	Amine Catalyst	Not common
	Ammonia	Shell Sand	Generated during curing
Spend Foundry Sand	Various	TRI Metals identified above, organics	
Mold and Core Coating	Methanol	Alcohol-based Coatings	
	Ethanol	Alcohol-based Coatings	
Pattern Spray and Cleaners	Methylene Chloride, Toluene	Release Agent	
	Toluene, Xylene	Pattern Cleaners	
	Methylene Chloride, Acetone	Core Box Cleaners	
Casting Finishing	Aluminum Dust or Fume	Grinding Wheels	
Casting Coatings	Xylene, Toluene, Ethylbenzene	Rust Preventative	
	Metallic TRI, Organic TRI	Paints/Primers	
Quench Oils	Benzene, Toluene, Xylene		
Refractories	Aluminum Dust or Fume	Furnace and Ladle Lining	
	Chromium Compounds	Furnace and Ladle Lining	
Combustion Byproducts	Ammonia, Metals, Benzene	Miscellaneous Uses	

Table 3-3. Possible TRI Chemicals Used or Generate during Pouring, Cooling, and Shakeout

TRI Chemical	CAS Number
Aluminum Dust/fume	7429-90-5
Cobalt Compounds	N096
Copper Compounds	N100
Chromium Compounds	N090
Lead Compounds	N420
Manganese Compounds	N450
Nickel Compounds	N495
Zinc Compounds	N982
Zinc dust/fume	4770-66-6
Aniline	62-53-3
Acetaldehyde	75-07-0
Ammonia	7664-41-7
Benzene	71-43-2
Butyraldehyde	123-72-8
Formaldehyde	50-00-0
n-Hexane	110-54-3
Naphthalene	91-20-3
Phenol	108-95-2
Styrene	100-42-5
Triethylamine	121-44-8
Toluene	108-88-3
Xylene (mixed isomers)	1330-20-7

Appendix B
Figures

Figure 2.1 – Green Sand Foundry Process Overview

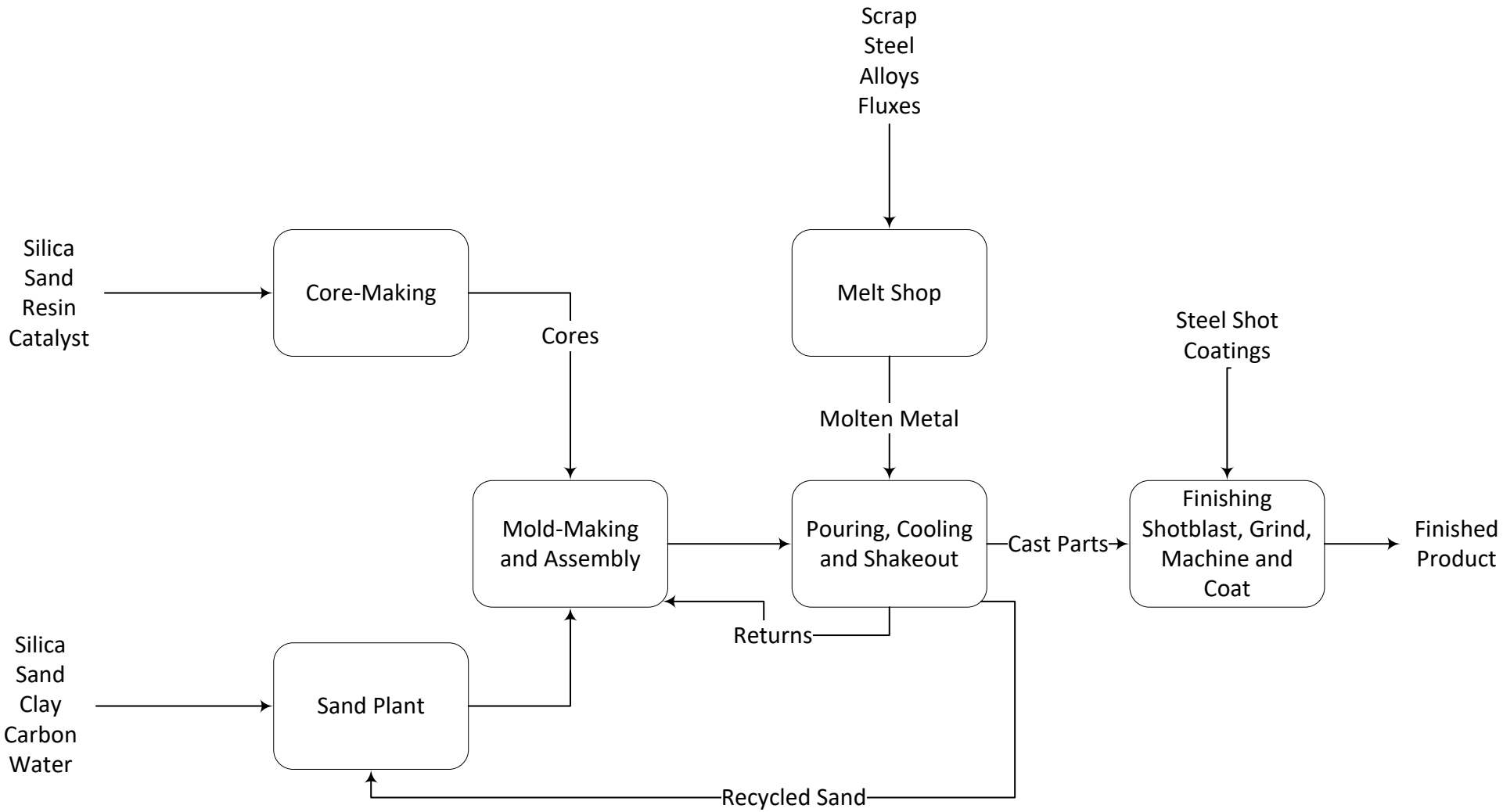

Figure 2.2 – Chemically Bonded Mold- or Core-Making Process Flow Diagram