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POLLUTION PREVENTION OF METAL CASTING INDUSTRY

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Abstract: ***In recent years, environmental concerns of pollution and resource depletion represent major concerns for society. Air quality in the vicinity of large cities is linked with serious health hazards. Many of these health hazards are associated with nitrogen oxides (NOx) and volatile organic compounds (VOCs) in the air, which in turn are caused by high traffic volumes and combustors. These pollutants may also travel long distances to produce secondary pollutants, such as acid rain or ozone (Beeldens 2006).Release and transfer reporting are limited to the approximately 600 chemicals on the TRI list. Therefore, a large portion of the emissions from industrial facilities are not captured by TRI.***

We know that the waste released by the metal casting industry in the process of producing the products and the effect of these waste to the atmosphere. The best source of comparative pollutant release information is the Toxic Release Inventory (TRI). Pursuant to the Emergency Planning and Community Right-to-Know Act, TRI includes self-reported facility release and transfer data for over 600 toxic chemicals. Facilities within SIC Codes 20 through 39 (manufacturing industries) that have more than 10 employees, and that are above weight-based reporting thresholds are required to report TRI on-site releases and off-site transfers. Because TRI requires consistent reporting regardless of sector, it is an excellent tool for drawing comparisons across industries. TRI data provide the type, amount and media receptor of each chemical released or transferred.

Among the necessary evils those being faced by modern societies, as we commonly quote as modern problems which are challenging the very existence of human society itself are the three great "P"s. They are Population, Poverty and Pollution. Yet again among the various kinds of pollutions, the air pollution is not only perilous but also fatal in its finest terms.

As a preliminary indicator of the environmental impact of the industry's most commonly released chemicals, the notebook briefly summarizes the toxicological properties of the top five chemicals (by weight) reported by each industry.

Chronic manganese poisoning, however, bears some similarity to chronic lead poisoning. Occurring via inhalation of manganese dust or fumes, it primarily involves the central nervous system. Early symptoms include languor, speech disturbances, sleepiness, and cramping and weakness in legs. A stolid mask- like appearance of face, emotional disturbances such as absolute detachment broken by uncontrollable laughter, euphoria, and a spastic gait with a tendency to fall while walking are seen in more advanced cases. Chronic manganese poisoning is reversible if treated early and exposure stopped. Populations at greatest risk of manganese toxicity are the very young and those with iron deficiencies.

Ecologically, although manganese is an essential nutrient for both plants and animals, in excessive concentrations manganese inhibits plant growth. Environmental Fate. Significant zinc contamination of soil is only seen in the vicinity of industrial point sources. Zinc is a stable soft metal, though it burns in air. Zinc bio concentrates in aquatic organisms

Key words: Released waste, Zinc and Zinc Compounds

1. Introduction

The metal casting industry makes parts from molten metal according to an end-user's specifications. Facilities are typically categorized as casting either ferrous or nonferrous products. The metal casting industry described in this notebook is categorized by the Office of Management and Budget (OMB) under Standard Industrial Classification (SIC) codes 332 Iron and Steel Foundries and 336 Nonferrous Foundries (Castings). The die casting industry is contained within the SIC 336 category since die casting establishments primarily cast nonferrous metals. OMB is in the process of changing the SIC code system to a system based on similar production processes called the North American Industrial Classification System (NAICS). (In the NAIC system, iron and steel foundries, nonferrous foundries, and die casters are all classified as NAIC 3315.)

In addition to metal casting, some foundries and die casters carry out further operations on their cast parts that are not the primary focus of this notebook. Examples include heat treating (e.g. annealing), case hardening, quenching, descaling, cleaning, painting, masking, and plating. Such operations can contribute significantly to a facility's total waste generation. Typical wastes generated during such operations include spent cyanide baths, salt baths, quenchents, abrasive media, solvents and plating wastes. Foundries and die casters that produce ferrous and nonferrous castings generally operate on a job or order basis, manufacturing castings for sale to others companies. Some foundries, termed captive foundries, produce castings as a subdivision of a corporation that uses the castings to produce larger products such as machinery, motor vehicles, appliances or plumbing fixtures. In addition, many facilities do further work on castings such as machining, assembling, and coating. (1)

Most of these castings are produced from recycled metals. There are thousands of cast metal products, many of which are incorporated into other products. Almost 90 percent of all manufactured products contain one or more metal castings (LaRue, 1989). It is estimated that on average, every home contains over a ton of castings in the form of pipe fittings, plumbing fixtures, hardware, and furnace and air conditioner parts. Automobiles and other transportation equipment use 50 to 60 percent of all castings produced - in engine blocks, crankshafts, camshafts, cylinder heads, brake drums or calipers, transmission housings, differential casings, U-joints, suspension parts, flywheels, engine mount brackets, front-wheel steering knuckles, hubs, ship propellers, hydraulic valves, locomotive undercarriages, and railroad car wheels. The defense industry also uses a large portion of the castings produced in the entire world. Typical cast parts used by the military include tank tracks and turrets and the tail structure of the F-16 fighter (Walden, 1995). Some of other common castings include: pipes and pipe fittings, valves, pumps, pressure tanks, manhole covers, and cooking utensils. Figure 1 shows the proportion of various types of castings produced in the U.S.

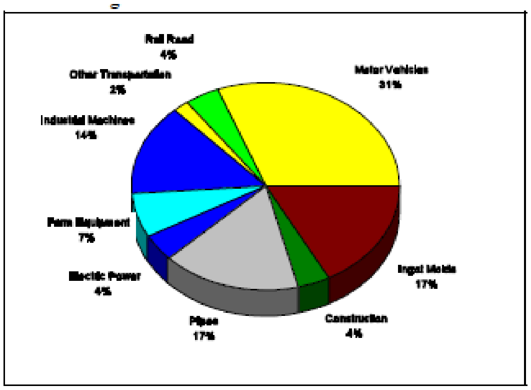

Fig.1 Use of cast metal products.

Among the necessary evils those being faced by modern societies, as we commonly quote as modern problems which are challenging the very existence of human society itself are the three great “P”s. They are Population, Poverty and Pollution. Yet again among the various kinds of pollutions, the air pollution is not only perilous but also fatal in its finest terms. In the present context, Air pollution is a major crisis that modernization and urbanization is facing. On a daily basis civil, industrial and military activities generate an enormous amount of organic and inorganic pollutants which inevitably end up in our atmosphere, soil, rivers and oceans. Air pollution abatement strategies are essentially based on electrostatic filters and membranes to reduce fine suspension particulate matters (SPM), chemical derivatives, mutagens and materials derived out of catalytic processes to purify air from hazards like SOx, NOx, CO, vaporized organics and formaldehyde like substances.(2)

1.1 Iron and Steel (Ferrous) Castings

Depending on the desired properties of the product, castings can be formed from many types of metals and metal alloys. Iron and steel (ferrous) castings are categorized by four-digit SIC code by the Bureau of Census according to the type of iron or steel as follows:

SIC 3321 - Gray and Ductile Iron Foundries SIC 3322 - Malleable Iron Foundries SIC 3324 - Steel Investment Foundries SIC 3325 - Steel Foundries, Not Elsewhere Classified

Gray and Ductile Iron make up almost 75 percent of all castings (ferrous and nonferrous) by weight (see Figure 2). Gray iron contains a higher percentage of carbon in the form of flake graphite and has a lower ductility than other types of iron. It is used extensively in the agricultural, heavy equipment, engine, pump, and power transmission industries. Ductile iron has magnesium or cerium added to change the form of the graphite from flake to nodular. This results in increased ductility, stiffness, and tensile strength (Loper, 1985).

Malleable iron foundries produce only about two percent of all castings (ferrous and nonferrous). Malleable iron contains small amounts of carbon, silicon, manganese, phosphorus, sulfur and metal alloys to increase strength and endurance. Malleable iron has excellent machinability and a high resistance to atmospheric corrosion. It is often used in the electrical power, conveyor and handling equipment, and railroad industries. (3)

Compared to steel, gray, ductile, and malleable iron are all relatively inexpensive to produce, easy to machine, and are widely used where the superior mechanical properties of steel are not required (Loper, 1985).

Steel castings make up about 10 percent of all castings (ferrous and nonferrous). In general, steel castings have better strength, ductility, heat resistance, durability and weld ability than iron castings. There are a number of different classes of steel castings based on the carbon or alloy content, with different mechanical properties. A large number of different alloying metals can be added to steel to increase its strength, heat resistance, or corrosion resistance (Loper, 1985). The steel investment casting method produces high- precision castings, usually smaller castings. Examples of steel investment castings range from machine tools and dies to golf club heads. (4)

2. Releases

Releases are an on-site discharge of a toxic chemical to the environment. This includes emissions to the air, discharges to bodies of water, releases at the facility to land, as well as contained disposal into underground injection wells.

2.1. Releases to Air

Releases to Air(Point and Fugitive Air Emissions) -- Include all air emissions from industry activity. Point emissions occur through confined air streams as found in stacks, vents, ducts, or pipes. Fugitive emissions include

Metal Casting Industry Chemical Releases and Transfers equipment leaks, evaporative losses from surface impoundments and spills, and releases from building ventilation systems.

2.2. Releases to Water

Releases to Water(Surface Water Discharges) -- encompass any releases going directly to streams, rivers, lakes, oceans, or other bodies of water. Releases due to runoff, including storm water runoff, are also reportable to TRI.

2.3. Releases to Land

Releases to Land occur within the boundaries of the reporting facility. Releases to land include disposal of toxic chemicals in landfills, land treatment/application farming, surface impoundments, and other land disposal methods (such as spills, leaks, or waste piles). (5)

Underground Injection -- is a contained release of a fluid into a subsurface well for the purpose of waste disposal. Wastes containing TRI chemicals are injected into either Class I wells or Class V wells. Class I wells are used to inject liquid hazardous wastes or dispose of industrial and municipal wastewater beneath the lowermost underground source of drinking water. Class V wells are generally used to inject non-hazardous fluid into or above an underground source of drinking water. TRI reporting does not currently distinguish between these two types of wells, although there are important differences in environmental impact between these two methods of injection.

3. Transfers

Transfer is a transfer of toxic chemicals in wastes to a facility that is geographically or physically separate from the facility reporting under TRI. Chemicals reported to TRI as transferred are sent to off-site facilities for the purpose of recycling, energy recovery, treatment, or disposal. The quantities reported represent a movement of the chemical away from the reporting facility. Except for off-site transfers for disposal, the reported quantities do not necessarily represent entry of the chemical into the environment.

3.1. Transfers to POTWs

Transfers to POTWs are wastewater transferred through pipes or sewers to a publicly owned treatments works (POTW). Treatment or removal of a chemical from the wastewater depends on the nature of the chemical, as well as the treatment methods present at the POTW. Not all TRI chemicals can be treated or removed by a POTW. Some chemicals, such as metals, may be removed, but are not destroyed and may be disposed of in landfills or discharged to receiving waters.

3.2. Transfers to Recycling

Transfers to Recycling are sent off-site for the purposes of regenerating or recovery by a variety of recycling methods, including solvent recovery, metals recovery, and acid regeneration. Once these chemicals have been recycled, they may be returned to the originating facility or sold commercially.

3.3. Transfers to Treatment

Transfers to Treatment are wastes moved off-site to be treated through a variety of methods, including neutralization, incineration, biological destruction, or physical separation. In some cases, the chemicals are not destroyed but prepared for further waste management.

3.4. Transfers to Disposal

Transfers to Disposal are wastes taken to another facility for disposal generally as a release to land or as an injection underground is found in the fact that the most frequently reported chemical (copper) is reported by only 45 percent of the facilities and over half of the TRI chemicals were reported by fewer than ten facilities. The variability in facilities' pollutant profiles may be attributable to the large number of different types of foundry processes and products. For example, foundries casting only ferrous parts will have different pollutant profiles than those foundries casting both ferrous and nonferrous products.

4. Pollution Prevention Opportunities

The best way to reduce pollution is to prevent it in the first place. Some companies have creatively implemented pollution prevention techniques that improve efficiency and increase profits while at the same time minimizing environmental impacts. This can be done in many ways such as reducing material inputs, re-engineering processes to reuse by-products, improving management practices, and employing substitution of toxic chemicals. Some smaller facilities are able to actually get below regulatory thresholds just by reducing pollutant releases through aggressive pollution prevention policies. (6)

The Pollution Prevention Act of 1990 established a national policy of managing waste through source reduction, which means preventing the generation of waste. The Pollution Prevention Act also established as national policy a hierarchy of waste management options for situations in which source reduction cannot be implemented feasibly. In the waste management hierarchy, if source reduction is not feasible the next alternative is recycling of wastes, followed by energy recovery, and waste treatment as a last alternative.

In order to encourage these approaches, this section provides both general and company-specific descriptions of some pollution prevention advances that have been implemented within the metal casting industry. While the list is not exhaustive, it does provide core information that can be used as the starting point for facilities interested in beginning their own pollution prevention projects. This section provides summary information from activities that may be, or are being implemented by this sector. When possible, information is provided that gives the context in which the technique can be used effectively. Please note that the activities described in this section do not necessarily apply to all facilities that fall within this sector. Facility-specific conditions must be carefully considered when pollution prevention options are evaluated, and the full impacts of the change must examine how each option affects air, land and water pollutant releases. (7)

Most of the pollution prevention activities in the metal casting industry have concentrated on reducing waste sand, waste electric arc furnace (EAF) dust and desulfurization slag, and increasing the overall energy efficiency of the processes. This section describes some of the pollution prevention opportunities for foundries within each of these areas.

4.1. Waste Sand and Chemical Binder Reduction and Reuse

Disposal of waste foundry sand in off-site landfills has become less appealing to foundry operators in recent years. Landfill disposal fees have increased considerably, especially in areas that suffer from shortages of landfill capacity. Landfill disposal can be a long-term CERCLA liability as well (see Section for a discussion of CERCLA). Currently, about 2 percent of foundry waste sands generated is considered hazardous waste under RCRA requiring expensive special treatment, handling and disposal in hazardous waste landfills. Therefore, there are strong financial incentives for applying pollution prevention techniques that reduce waste foundry sand generation. In fact, for years many foundries have been implementing programs to reduce the amounts of waste sand they generate. Also, the industry is conducting a significant amount of research in this area.

4.2. Casting Techniques Reducing Waste Foundry Sand Generation

The preferable approach to reducing disposal of waste sands is through source reduction rather than waste management and pollution control or treatment techniques. Foundry operators aiming to reduce waste sand may want to examine the feasibility and economic incentives of new casting methods for all or part of their production. A number of the casting techniques described in Section III.A such as investment casting, permanent mold casting, die casting, and lost foam casting generate less sand waste than other techniques.

4.3. Reclamation and Reuse of Waste Foundry Sand and Metal

Although less preferable than source reduction, the more immediate shift in industry practices is towards waste reclamation and reuse. A number of techniques are being used to reclaim waste sand and return it to the mold and core making processes. In addition, markets for off-site reuse of waste foundry sand have also been found. Waste Segregation

A substantial amount of sand contamination comes from mixing the various foundry waste streams with waste sand. The overall amount of sand being discarded can be reduced by implementing the following waste segregation steps:

- Replumbing the dust collector ducting on the casting metal gate cutoff saws to collect metal chips for easier recycling
- Installing a new bag house on the sand system to separate the sand system dust from the furnace dust
- Installing a new screening system or magnetic separator on the main molding sand system surge hopper to continuously clean metal from the sand system
- Separate nonferrous foundry shot blast dust (often a hazardous waste stream) from other nonhazardous foundry and sand waste streams.
- Installing a magnetic separation system on the shot blast system to allow the metal dust to be recycled
- Changing the core sand knockout procedure to keep this sand from being mixed in with system sand prior to disposal

Screen and Separate Metal from Sand

Most foundries screen used sand before reusing it. Some employ several different screen types and vibrating mechanisms to break down large masses of sand mixed with metal chips. Coarse screens are used to remove large chunks of metal and core butts. The larger metal pieces collected in the screen are usually remelted in the furnace or sold to a secondary smelter. Increasingly fine screens remove additional metal particles and help classify the sand by size before it is molded. Some foundries remelt these smaller metal particles; other foundries sell this portion to metal reclaimers. The metal recovered during the screening process is often mixed with coarser sand components or has sand adhering to it. Therefore, remelting these pieces in the furnace generates large amounts of slag, especially when the smaller particles are remelted.

4.3.1. Reclaim Sand by Dry Scrubbing/Attrition

Reclaiming sand by dry scrubbing is widely used, and a large variety of equipment is available with capacities adaptable to most binder systems and foundry operations. Dry scrubbing may be divided into pneumatic or mechanical systems.

In pneumatic scrubbing, grains of sand are agitated in streams of air normally confined in vertical steel tubes called cells. The grains of sand are propelled upward; they impact each other and/or are thrust against a steel target to remove some of the binder. In some systems, grains are impacted against a steel target. Banks of tubes may be used depending on the capacity and degree of cleanliness desired. Retention time can be regulated, and fines are removed through dust collectors. In mechanical scrubbing, a variety of available equipment offers foundries a number of options. An impeller may be used to accelerate the sand grains at a controlled velocity in a horizontal or vertical plane against a metal plate. The sand grains impact each other and metal targets, thereby removing some of the binder. The speed of rotation has some control over impact energy. The binder and fines are removed by exhaust systems, and screen analysis is controlled by air gates or air wash separators. Additional equipment options include:

- A variety of drum types with internal baffles, impactors, and disintegrators that reduce lumps to grains and remove binder
- Vibrating screens with a series of decks for reducing lumps to grains, with recirculating features and removal of dust and fines
- Shot-blast cleaning equipment that may be incorporated into other specially designed units to form a complete casting cleaning/sand reclamation unit
- Vibro-energy systems that use synchronous and diametric vibration, where frictional and compressive forces separate binder from sand grains.

Southern Aluminum is a high-production automotive foundry in Bay Minette, Alabama. The company recently installed a rotating drum attrition/scrubber sand reclaimer unit to remove lumps and tramp aluminum from its spent green sand and core butts so that it could be used by an asphalt company. Spent sand is fed into one end of the rotating drum where the lumps are reduced and binder is scrubbed off the grains. The sand then enters a screening and classifying section, binder and fines are removed by a dust collector, and clean tramp metal is removed. The company is removing far more aluminum from the sand than expected (about 6,000 pounds per day) resulting in substantial cost savings.

4.3.2. Reclaim Sand with Thermal Systems

Most foundries recycle core and mold sands; however, these materials eventually lose their basic characteristics, and the portions no longer suitable for use are disposed of in a landfill. In the reclamation of chemically bonded sands, the system employed must be able to break the bond between the resin and sand and remove the fines that are generated. The systems employed most commonly are scrubbing/attrition and thermal (rotary reclamation) systems for resin-bonded sands. (8)

Reclamation of green sand for reuse in a green sand system is practiced on a limited basis in the United States. However, reclamation of core sand and chemically bonded molding sand is widespread. A typical system to reclaim chemically bonded sand for reuse in core room and molding operations consists of a lump reduction and metal removal system, a particle classifier, a sand cooler, a dust collection system, and a thermal scrubber (two-bed reactor).

4.3.3. Thermal Calcining/Thermal Dry Scrubbing.

These systems are useful for reclamation of organic and clay-bonded systems. Sand grain surfaces are not smooth; they have numerous crevices and indentations. The application of heat with sufficient oxygen calcines the binders or burns off organic binders. Separate mechanical attrition units may be required to remove calcined inorganic binders. Heat offers a simple method of reducing the encrusted grains of molding sand to pure grains. Both horizontal and vertical rotary kiln and fluidized bed systems are available. Foundries should examine the regulatory requirements of using thermal systems to treat waste sand. The use of these systems may need to be permitted as waste incineration.(9)

5. Summary

Integrated environmental policies based upon comprehensive analysis of air, water and land pollution are a logical supplement to traditional single-media approaches to environmental protection. Environmental regulatory agencies are beginning to embrace comprehensive, multi-statute solutions to facility permitting, enforcement and compliance assurance, education/ outreach, research, and regulatory development issues. The central concepts driving the new policy direction are that pollutant releases to each environmental medium (air, water and land) affect each other, and that environmental strategies must actively identify and address the seinter-relationships by designing policies for the "whole" facility. One way to achieve a whole facility focus is to design environmental policies for similar industrial facilities. By doing so, environmental concerns that are common to the manufacturing of similar products can be addressed in a comprehensive manner. Recognition of the need to develop the industrial "sector-based" approach within the EPA Office of Compliance led to the creation of this document.

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