NIOSH

Recommendations for Control of Occupational Safety and Health Hazards . . .

Foundries

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
PUBLIC HEALTH SERVICE
CENTERS FOR DISEASE CONTROL
NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH

Cover photograph: This mural, representing the foundries industry, is one of fourteen murals depicting industrial scenes now on permanent display at the Greater Cincinnati International Airport. The murals, designed by Winold Reiss in the early 1930's, originally adorned the walls of Cincinnati's Union Terminal Railway Station.

RECOMMENDATIONS FOR CONTROL OF OCCUPATIONAL SAFETY AND HEALTH HAZARDS.... FOUNDRIES

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control
National Institute for Occupational Safety and Health
Division of Standards Development and Technology Transfer

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FOREWORD

The Occupational Safety and Health Act of 1970 (Public Law 91-596) states that the purpose of Congress expressed in the Act is "to assure so far as possible every working man and woman in the Nation safe and healthful working conditions and to preserve our human resources...by," among other things, "providing for research in the field of occupational safety and health...and by developing innovative methods, techniques, and approaches for dealing with occupational safety and health problems." Later in the Act, the National Institute for Occupational Safety and Health (NIOSH) is charged with "the development of criteria for new and improved occupational safety and health standards" to "make recommendations" concerning these standards to the Secretary of Labor. NIOSH responds to this charge by preparing Criteria Documents which contain recommendations for occupational safety and health standards.

A Criteria Document critically reviews the scientific and technical information available on the prevalence of hazards, the existence of safety and health risks, and the adequacy of control methods. The information and recommendations presented are intended to facilitate specific preventive procedures in the workplace. In the interest of wide dissemination of this information, NIOSH distributes these documents to other appropriate governmental agencies, health professionals in organized labor, industry, and academia, and to public interest groups. We welcome suggestions concerning the content, style, and distribution of these documents.

The ancient art of metal casting has long been considered to be a hazardous, dusty, noisy, and hot occupation. Many changes have occurred in foundry technology and materials, especially during the past few years; however, the basic processes and these potential hazards, have remained much the same for about 336,000 workers in U.S. foundries. This document seeks the improved protection of the health and safety of these workers.

This document was prepared by the Division of Standards Development and Technology Transfer, NIOSH. I am pleased to acknowledge the contributions made by consultants, reviewers, and the staff of the Institute. However, responsibility for the conclusions reached and the recommendations made belongs solely to the Institute. All comments by reviewers, whether or not incorporated into the final version, are being sent with this document to the Occupational Safety and Health Administration (OSHA) for consideration in standard setting.

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I. INTRODUCTION

The production of metal castings is a complex process that has long been associated with worker injuries and illnesses that are related to exposure to chemical and physical agents generated by or used in the casting process. Foundry workers may be exposed to numerous health hazards, including fumes, dusts, gases, heat, noise, vibration, and nonionizing radiation. Chronic exposure to some of these hazards may result in irreversible respiratory diseases such as silicosis, an increased risk of lung cancer, and other diseases. The foundry worker may also be exposed to safety hazards that can result in injuries including musculoskeletal strain, burns, eye damage, loss of limb, and death. The major categories of adverse health effects include: (1) malignant and nonmalignant respiratory diseases; (2) traumatic and ergonomic injuries due to falling or moving objects, lifting and carrying, etc.; (3) heat-induced illnesses and injuries; (4) vibration-induced disorders; (5) noise-induced hearing loss; and (6) eye injuries. The occurrence of these problems in a foundry should be considered as Sentinel Health Events (SHE's) [1] and may indicate a breakdown in adequate hazard controls or an intolerance to hazards in specific workers. The means for eliminating or significantly reducing each hazard are well known, widely acknowledged, and readily available. However, recent technological changes introduce new chemical and physical agents, as well as new process machinery, which could create further risks to worker safety and health.

Published scientific data on occupational injuries and illnesses in foundry workers, working conditions, and the engineering controls and work practices used in sand-casting foundries are reviewed in this document. Based on an evaluation of the literature, recommendations have been developed for reducing the safety and health risks related to working in sand-casting foundries. Because of the diversity and complexity of the foundry industry, this document is limited to those facilities that pour molten metal into sand molds. Although die, permanent mold, investment, and other types of casting are not specifically addressed, many of the processes and materials are similar to those used in sand casting; the recommendations in this document may apply to those foundries as well. However, only those processes, materials, and work procedures specific to sand casting are discussed. The specific operations in die and permanent mold casting are excluded from the scope of the document because process equipment and work procedures differ from those in sand casting, and the hazards to safety in die and permanent mold casting could not be adequately covered here. In addition, most die and permanent mold castings (with the exception of gravity cast permanent mold casting) are not constructed with sand cores and do not require the extensive cleaning operations necessary for sand castings.

The foundry operations that have been studied include: (1) handling raw materials such as scrap metal and sand; (2) preparing sand; (3) making molds and cores; (4) reclaiming sand and other materials used in mold and core production; (5) melting and alloying metals; (6) pouring; (7) removing cores and shaking out castings; (8) rough cleaning of castings including chipping, grinding, and cut-off operations; (9) maintaining and repairing equipment used in coremaking, moldmaking, and in melting, pouring, shakeout, and rough cleaning operations; and, (10) cleaning foundry areas in which molding, coremaking, melting, pouring, and rough cleaning of castings occur. Patternmaking operations have not been included because not all foundries have patternmaking shops, and hazards in patternmaking are related more to wood, metal, and plastic fabrication operations. Also, final cleaning and other ancillary processes, such as welding, arc-air gouging, heat treating, annealing, x-ray inspection of castings, machining, and buffing, are not discussed in this document.

II. INDUSTRY AND PROCESS DESCRIPTION

Founding or casting, is the metal-forming process by which molten metal is poured into a prepared mold to produce a metal object called a casting. These metal-casting operations are carried out in facilities known as foundries [2]. All founding involves the melting of metal, but production of metal castings varies greatly depending on many factors such as the mold material; type of metal cast; production rate; casting size; and age, size, and layout of the foundry. The primary way to cast metals is by using sand and a bonding agent as mold materials [3]. Sand casting is best suited for iron and steel because of their high melting temperatures, but it is also used for nonferrous metals such as aluminum, brass, bronze, and magnesium [3,4,5,6,7].

The production of castings where sand is used as a mold material requires certain basic processes. These include (1) preparing a mold and core into and around which the molten metal may be poured, (2) melting and pouring the molten metal, and (3) cleaning the cooled metal casting with eventual removal of molding material and extraneous metal [2,3,4,5,6,8]. A schematic diagram of the overall foundry process is presented in Figure II-1. Some of the terms common to foundry processes are defined in the Glossary for Foundry Practice [9] and in Chapter X (Appendix A - Glossary of Terms).

A. Industry Description

In 1983, the metal-casting industry produced approximately 27.8 million tons of metal casting and employed approximately 336,200 workers [10], and encompassed a major segment of our national economy. Based on total sales, the cast metals industry is the sixth largest industry in the United States. Total tonnage and dollar value of casting production, which had increased in the 1970's, has declined during the past several years. In 1979, a total of 18.9 million tons of metal castings were produced vs. 15.3 million tons produced in 1981 and 10.5 million tons in 1982. In recent years, the foundry industry has had a trend toward fewer, but larger, foundries [10].

The majority of castings are component parts used in a wide range of industries with 90% of all durable goods using castings to some degree [10]. Cast parts range in size from a fraction of an inch and weighing a fraction of an ounce, such as individual teeth on a zipper, to those measuring 30 feet (9 meters) or more and weighing many tons, such as the huge propellers and stern frames on ocean liners, frames for pumps and milling machines, etc. [10,11].

The Standard Industrial Classifications (SIC) used by the U.S. Department of Commerce categorizes plants according to their major end products. Foundries that make cast metal items for independent sale, the jobbing foundries, are listed in several SIC groups under two major categories: (1) ferrous foundries, which include gray ductile iron, malleable iron, and

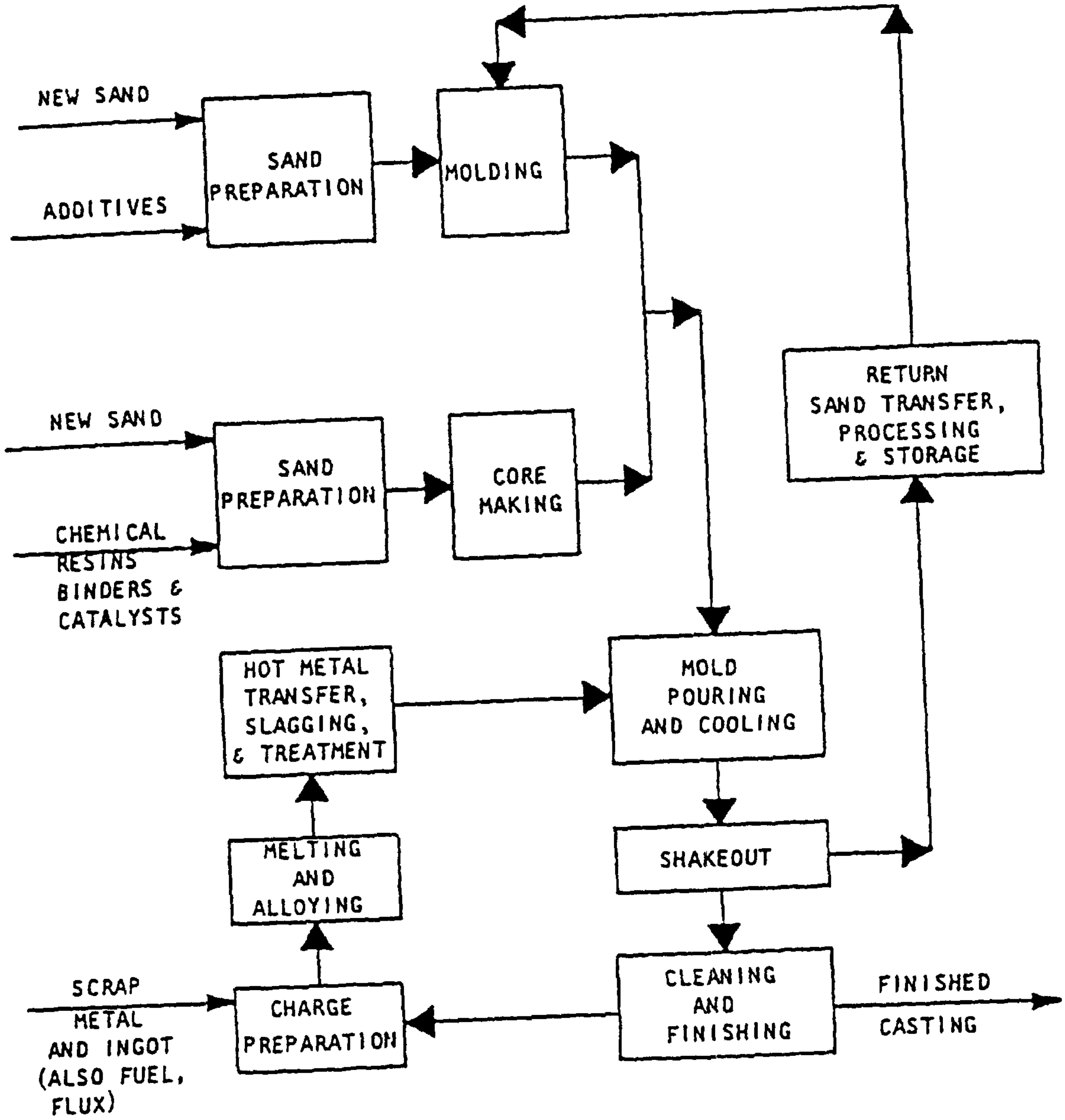

FIGURE II-1. Schematic diagram of overall foundry process

Adapted from reference [7]

steel foundries; and (2) nonferrous foundries, which include aluminum, brass, bronze, copper-based alloys, zinc, magnesium, etc. [10].

In addition to the 3,180 jobbing foundries in 1983, there were 824 captive foundries that produced metal castings for use within a larger manufacturing process. Because the captive metal-casting operations are incorporated within many different industrial classifications, such as Motor Vehicles, Agricultural Equipment, and Plumbing Fixtures Manufacture, the number of captive foundries in the United States is not readily apparent within the foundry SIC's [10].

The 1984 Metal Casting Industry Census Guide [10] estimated a total of 4,004 foundries employing 336,200 workers in the United States, of which the captive foundries produced approximately 45% of the total tonnage. Data on the types of furnaces used are presented in Table II-1. Table II-2 presents data on the size of these foundries and the types of metal cast. Some foundries cast more than one type of metal, and, therefore, the number of foundries listed by type of metal cast is larger than the actual 4,004 separately identified foundries. Table II-3 lists occupations grouped by job category in foundries where different exposures to hazardous physical or chemical agents may occur or where safety hazards may exist. In some small foundries, workers will have more than one job function and may be exposed to hazards in two or more of the occupations listed.

TABLE II-1. Melting furnace usage, 1984

Type of furnace	Number
Cupolas	537
Open hearth	17
Air	13
Electric arc	355
Channel induction	536
Coreless induction	1,087
Crucible	2,039
Reverberatory	538
Noncrucible	193
Total	5,315

Adapted from reference [10]

TABLE II-2. Analysis of foundries in the United States, 1984

Characteristics	Number of foundries
Size of foundries (Number of workers)	
≥1,000	26
500 - 999	56
250 - 499	174
100 - 249	518
50 - 99	597
20 - 49	952
<20	1,681
Total	4,004
Casting methods	
Carbon dioxide mold	499
Centrifugal	240
Die-casting	620
Investment mold	355
Permanent mold	608
Plaster mold	179
Green sand	2,765
Shell mold	445
Total	5,711
Type of metal cast	
Aluminum	2,197
Brass and bronze	1,447
Ductile iron	564
Exclusive nonferrous	2,346
Gray iron	1,156
Magnesium	103
Malleable	87
Nonferrous departments	534
Steel	684
Zinc	729
Total	9,847

Adapted from reference [10]

TABLE II-3. Occupations with potential exposure to safety and health hazards in foundries

Department	Job category
Cleaning and finishing	Burners Casting repair welders Chippers Grinders Sandblasters Shakeout men Tumbler operators
Coremaking	Bench coremakers Core assemblers Core-oven tenders Core-sand mixers Sand technicians Miscellaneous
Melting and pouring	Brick masons Crucible melters Cupola tenders Electric furnace tenders Furnace changers Laborers including ladlemen Ladle pourers
Miscellaneous	Carpenters Crane operators Electricians Floor sweepers Forklift operators Mechanical pipe fitters Mechanics Millwrights Truck drivers
Molding	Bench molders Floor molders Machine molders Molders' helpers Mulling machine operators

Adapted from reference [3]

B. Process Description

A pattern is a form made of wood, metal, or other suitable material, such as polystyrene or epoxy resin, around which molding material is packed to shape the mold cavity [3,5,8,9]. The pattern is the same shape as the final casting, except for certain features which are designed to compensate for contraction of the liquid metal when cooling and an allowance to facilitate removing the pattern from the sand or other molding medium [3]. The pattern determines the mold's internal contour mold and the external contour of the finished casting. Although patterns are required to make molds, many foundries do not make their own patterns. The hazards in patternmaking are primarily those present in woodworking industries, and, consequently, the recommended controls are similar to those for woodworking.

1. Molding

The mold provides a cavity into which molten metal is poured to produce a casting. Sand combined with a suitable binder is packed rigidly around a pattern so that a cavity of corresponding shape remains when the pattern is removed. The physical and chemical properties of sand account for its wide use in producing castings. Sand can be formed into definite shapes, it prevents fusion caused by the high temperature of the metal, and it contains enough permeability to permit gases to escape. The sand mold is friable, and after the metal is cast, it can be readily broken away for removal of the casting [3,4,5].

Types of sand molding include green, dry, no-bake, shell, hot- and cold-box, skin-dried, and dry sand-core molds. Green-sand molding, the most widely used molding process, is composed of sand, clay, water, and other materials [3,5,12]. In green-sand molding, the mold is closed, and the metal is poured before appreciable drying occurs. Depending on the type of clay used, these molds may contain 3-5% moisture [3,5,12,13]. Both ferrous and nonferrous castings are produced in green-sand molds.

A recently developed approach to dry-sand molding is the "V PROCESS" which uses unbonded sand with a vacuum. The dry-molding sand is rigidized by vacuum packing it in a plastic film during mold production. The plastic film is vacuum formed against the pattern; the flask is positioned and filled with dry unbonded sand and then covered with a plastic film and made rigid by drawing a vacuum through the sand [14].

Dry-sand molds are oven dried to a depth of 0.5 inch (1 centimeter) or more. Molds are baked at 150-370°C (300-700°F) for 4-48 hours depending upon the binders used, the mass of the mold, the amount of sand surface to be dried, and the production cycle requirements [3,5]. Dry-sand molds are generally used for larger castings, such as large housings, gears, and machinery components. Large molds and pit molds are usually skin dried to remove surface moisture to a depth of 0.5 inch by air or torch drying.

No-bake systems are used for molding; these systems cure at room temperature. No-bake sand systems include the furan, alkyd oil, oil-oxygen, sodium silicate ester, phenolic, phosphate, urethane, and cement molding processes [3,5,15,16]. All of these are composed of sand with binder materials and are made by the sand-molding methods; these molds have a very low water content, usually less than 1% except sodium silicate-carbon dioxide (CO_2) and cement molds.

Molds can also be made by using the shell, hot-box, and cold-box processes. The shell and hot-box processes need heat to cure the binder system; the cold-box process uses a gas to cure the binder system. See Section II.B.2. Coremaking, for a more detailed description of these procedures.

Silica sand is used for most sand-molding operations; however, olivine, zircon, and chromite sands have also been used as substitutes for silica sand in ferrous, as well as nonferrous, foundries [17,18]. Naturally bonded sand is cohesive because it contains clay or bonding material as mined; synthetically bonded sand is formed by mixing sand with a binding agent, e.g., western or southern bentonite clays, kaolin, or fireclay [9,12,16]. The term synthetic is somewhat of a misnomer because it is not the sand that is synthesized but the sand-clay mixture [12].

Synthetically bonded sands are used in foundries producing castings from high melting point metals such as steel because the composition of these sands is more readily controlled. Various mixtures of naturally bonded and synthetically bonded sands have had limited use for malleable and gray iron. Naturally bonded sands are generally satisfactory for the lower melting point metals [3,5].

Although the basic molding ingredients are sand and clay, other materials are often added in small amounts for special purposes. For example, carbonaceous materials such as seacoal, pitch, and lignite are added to provide a combustible thermal expansion cushion, as well as a reducing atmosphere, and to improve the casting surface finish. Cereals, gelatinized starches, and dextrin provide a reducing atmosphere, increase dry strength, and reduce the friability of air-dried molds [16].

Sand molds, especially for large castings, frequently require special facing sands that will be in contact with the molten metal. Facing sands are specially formulated to minimize thermal expansion and are usually applied manually by the molder. Mold coatings or washes, are used to obtain better casting finishes. The coating is applied by spraying, brushing, or swabbing to increase the refractory characteristics of the surface by sealing the mold at the sand-metal interface. Mold coatings resemble paints and generally contain a refractory filler, a vehicle, a suspension agent, and a binder. The mold coating filler material for steel castings is usually zircon or chromite flour; the vehicle is water or commercial grade alcohol. The suspension agent is bentonite or sodium algenate. When an alcohol vehicle is used, the molds are usually torch dried to burn off the alcohol [3].

Sand may be prepared and conditioned for molding by mixing ingredients in a variety of mechanical mullers and mixers. Conditioning of molding sands may include mixing sand with other ingredients such as clay and water, mulling the ingredients, cooling the sand from shakeout, and removing foreign material from the sand [3,5]. Usually, mixers are not used for clay-bonded sands. Sand is reclaimed by one of three methods: (1) using air separators to remove fines, such as silica flour and clay (dry reclamation), (2) slurrying sand with water (wet reclamation), or (3) heating sand to remove carbonaceous and clay materials (thermal reclamation) [3].

Prepared sand is discharged from the mixer or muller and is transferred to the molding area. Types of molding include: bench molding (molds manually prepared on a bench), floor molding (performed on the foundry floor), pit molding (molds are made within depressed areas of the floor), and machine molding [4].

In some cases, the patterns are dusted with a parting powder or washed with a parting liquid to ease the release of metal from the mold after pouring. Before World War II, the parting powders were almost entirely composed of silica dust [19], but due to the silicosis hazard, nonsilica materials such as nonsiliceous talc have sometimes been substituted. The use of liquid parting washes has also reduced the hazard of silica dust exposure.

2. Coremaking

A core defines the internal hollows or cavities desired in the final casting. Cores are composed mainly of sand but may contain one or more binder materials, including organic binders such as oils and resins and inorganic binders such as cements and sodium silicate. A gas or liquid catalyst may be used, depending upon the formulation. Many factors, including moisture content, porosity, core complexity, quantity of cores required, and raw material used, need to be considered when selecting the core formulation and process best suited for a particular application.

Most of the techniques used to make a sand mold also apply to making a sand core. Cores are made by mulling or mixing the required ingredients and then manually or mechanically putting these materials into a corebox. The principal corebinding systems are listed in Table II-4 [20].

Phenol-formaldehyde resins are currently used in the oven-baking, shell, hot- and cold-box, and no-bake processes. Most of the shell cores and molds are produced by these resins [21]. The cores and molds are produced by dumping a resin-coated sand onto a heated pattern, holding the core materials for a sufficient time to achieve curing at the pattern surface, dumping excess sand out of the core, and then stripping the hollow-cured shell from the pattern [13]. Hexamethylenetetramine (Hexa) in amounts of 10-17% (based on resin weight) is used as a catalyst

TABLE II-4. Types of core binders

	Thermosetting	Self-setting
Organic	Shell: dry blend, warm coat (solvent), and hot coat	No-bake: alkyd oil furans phenolics urethanes
	Hot box: furan and phenolic	Cold box (gassing): silicate CO_2 urethane amine furan SO_2
	Oven: core oils phenolics	No-bake: silicate ester phosphate cements/silicates/slags fluid sands
Inorganic	Silicates: (warm box)	

Adapted from reference [20]

for the curing reaction [21]. Lubricants such as calcium stearate or zinc stearate are added to the resin-sand mixtures for easy release of the core from the pattern and to improve the fluidity of the sand [3].

Hot-box cores are typically solid, rather than shells, and contain resins that polymerize rapidly in the presence of acids and heat. Resins used for hot-box cores include modified furan resins, composed of urea-formaldehyde and furfuryl alcohol, or urea-phenol-formaldehyde, commonly called phenolic resins. Furan and phenolic resin in the presence of a mold catalyst will polymerize to form a solid bonding agent. Urea is not a constituent of these resins in steel foundries because it can cause casting defects [3]. More recently, urea-free phenol-formaldehyde-furfuryl alcohol resinous binders have been developed for use in producing hot-box cores [13].

Cold-box systems require the use of a gaseous catalyst rather than heat to cure the binder systems and to produce a core or a mold. There are three cold-box "gassing" systems: one uses carbon dioxide (CO_2) and a sodium silicate binder; another uses amine gases (TEA - triethylamine; DMEA - dimethylethylamine) and a two part binder system composed of a diphenylmethane diisocyanate (MDI); the third gassing system uses sulfur dioxide (SO_2) gas and a two part binder system made up of a furan binder and a peroxide, usually methyl ethyl ketone peroxide (MEKP). In the presence of the catalyst gas, each binder system forms a (solid) resin film which serves as the sand binder. Following introduction of the amine or SO_2 catalyst, air is used to sweep the remaining gas vapors from the core (or mold), after which the sand core (or mold) is removed from the pattern. Not all the vapors are completely purged, and some offgassing may continue. Chemical scrubbers are used to remove the amines and SO_2 gases from the air purge cycle and from the work areas. The CO_2 gassing cold-box system requires no air scrubbing.

No-bake binders represent modifications of the oleoresinous, furan, sodium silicate, phenol-formaldehyde, and polyurethane binder systems. Various chemicals are incorporated in an unheated corebox to cause polymerization [13].

3. Melting

Cupolas and electric, crucible, and reverberatory furnaces are used to melt metals. For melting iron, especially gray iron, the cupola furnace is most often used [5,10,22,23]. Many fundamental cupola designs have evolved through the years including the conventional refractory-lined cupola and the unlined water-cooled cupola [23,24].

In all cupola designs (Figure II-2), the shell is made of steel plates. In the conventional design, an inside lining of refractory material insulates the shell. In unlined, water-cooled cupolas, cooling water flowing from below the charging door to the tuyeres, or air ports, is used on the outside of the unlined shell. An inside lining of carbon block is used below the tuyeres to the sand bed, to protect the shell from the high interior temperature [5,22,23,24].

The cupola bottom may consist of two semicircular, hinged steel doors that are supported in the closed position by props during operation but can be opened at the end of a melting cycle to dump the remaining charge materials. To prepare for melting, a sand bed 10-60 inches (0.2-1.5 meters) deep is rammed in place on the closed doors to seal the cupola bottom. At the beginning of the melting cycle, coke is placed on top of the sand and ignited, usually with a gas torch or electric starter. Additional coke is added to a height of 4-5 feet (1.2-1.5 meters) above the tuyeres, after which layered charges of metal, limestone, and coke are stacked up to the normal operating height [24].

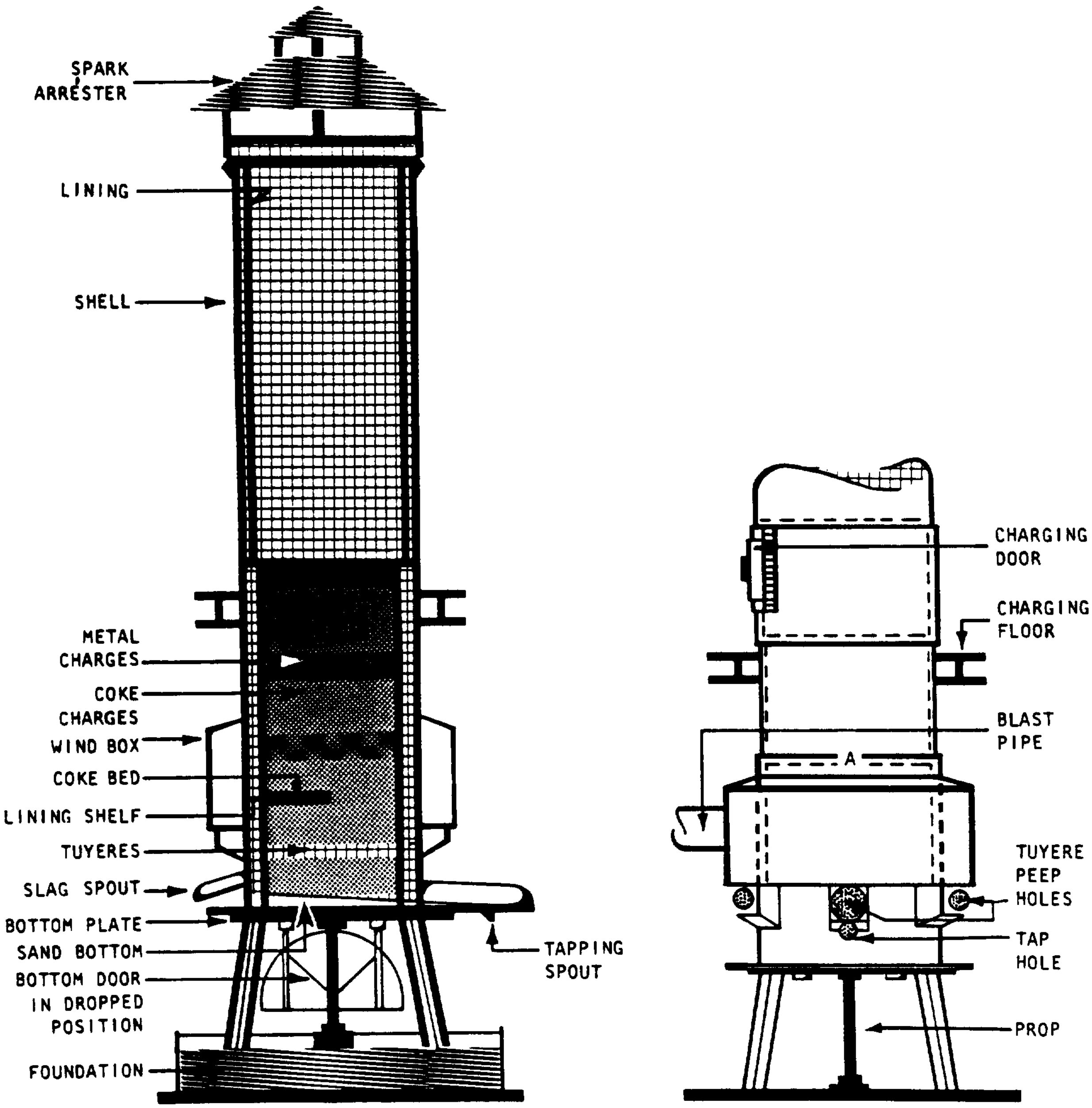

FIGURE II-2. Cupola furnace

Adapted from reference [23]

The airblast is turned on and the melting process begins. Combustion air is blown into the windbox, an angular duct surrounding the shell near the lower end, from which it is piped to tuyeres or nozzles projecting through the shell about 3 feet (0.9 meters) above the top of the rammed sand. As the coke is consumed and the metal charge is melted, the furnace contents move downward in the cupola and are replaced by additional charges entering the cupola through the charging door on top of the furnace.

There are four types of electric furnaces: direct-arc, indirect-arc, induction, and resistance. Melting the metal in direct-arc furnaces is achieved by an arc from an electrode to the metal charge. Direct-arc furnaces are primarily used for melting steel but are also often used for melting iron. In the indirect-arc furnace, the metal charge is placed between the electrodes, and the arc is formed between the electrodes and above the charge [23]. Induction furnaces consist of a crucible within a water-cooled coil and are used for producing both ferrous and nonferrous metals and alloys, e.g., brass and bronze. Resistance furnaces are refractory-lined chambers with fixed or movable electrodes buried in the charge. They are primarily used to melt nonferrous alloys [23,25].

Crucible furnaces, which are used to melt metals with melting points below 1370°C (2500°F), are usually constructed with a shell of welded steel, lined with refractory material, and heated by natural gas or oil burners. Crucible furnaces are classified as tilting, pit, or stationary furnaces and are primarily used in melting aluminum and other nonferrous alloys [23].

Reverberatory furnaces are usually gas or oil fired and the metal is melted by radiating heat from the roof and side walls of the furnace onto the material being heated. Some furnaces are electrically heated or coal fired and are mainly used to melt nonferrous metals [23].

Molten metal from the melting furnaces is tapped when the metal reaches the desired temperature and may be transferred to a holding furnace for storage, alloying, or super heating, or directly transferred to ladles for pouring molds. When the metal casting has solidified, it is ready for shakeout and cleaning operations.

4. Cleaning

Cleaning operations involve removing sand, scale, and excess metal from the casting [3,5]. The cleaning process includes shakeout; the removal of sprues, gates, and risers; abrasive blasting; and, grinding and chipping operations.

Removing the sprues, gates, and risers is usually the first operation in cleaning. The gating system may be cut or broken off when the castings are dumped out of the flask onto a shakeout screen or table. Sprues, gates, and risers may also be removed by striking them with a hammer. The vibratory action of the shakeout causes the sand to fall from the casting into a hopper below. The cast article is then moved for further cleaning. When the gating system is not removed by impact, it is knocked off by shearing, gas or abrasive cutting, or using band or friction saws. Gas cutting or arc-air gouging is most frequently performed in steel foundries. Surface cleaning operations ordinarily follow removal of the gating system [3,5,7].

Cleaning the castings involves several steps, which vary with the metal used and the desired final finish of the articles. Tumbling mills are used for removing adhered sand from the casting. In a tumbling mill, an abrading agent, such as jack stars, is used to knock off excess sand and small fins. Abrasive blasting is carried out in chambers or cabinets in which sand, steel shot, or grit is propelled against the casting by compressed air or rotating wheels.

Chipping and grinding using pneumatic or hand tools is performed to remove gate and riser pads, chaplets, or other appendages from the casting or to remove adhering molding and core sand. Pneumatic chipping hammers are used to remove fins, scale, burned-in sand, and other small protrusions from castings. Bench, floor stand, or portable grinders are used for small castings; whereas, swing-frame grinders are used for trimming castings that are too heavy to be carried or hand held. For higher melting alloy metals, more cleaning operations are usually required.