X. APPENDICES

APPENDIX A. Glossary of Terms

ACID BOTTOM AND LINING — In a melting furnace, the inner bottom and lining composed of refractory materials that have an acid reaction in the melting process, e.g., sand, siliceous rock, ganister, or silica bricks.

AIR FURNACE — A reverberatory-type furnace in which metal is melted by the flame from fuel burning at one end of the hearth, passing over the bath toward the stack at the other end of the hearth. Heat is also reflected from the roof and side walls.

AIR RAMMER — Pneumatically operated ramming tool.

AIR SETTING — The characteristic of some materials, such as refractory cements, core pastes, binders, and plastics, to take permanent set at normal air temperatures (20-25°C, 68-77°F).

ALLOY — A substance composed of two or more chemical elements of which at least one is a metal; usually possesses properties different from those of the components.

ALLOYING ELEMENTS — Chemical elements constituting an alloy; in metals, usually limited to metallic or metalloid elements added to modify the properties of the base metal.

ANCHOR — Appliance for holding cores in place in molds.

ANNEALING — A process involving heating and cooling applied to alter mechanical or physical properties, particularly to reduce hardness. The term is also applied to treatments intended to produce a definite microstructure or to remove gases. Any annealing process will usually reduce stresses, but if the treatment is applied for the sole purpose of such relief, it should be designated as stress relieving.

ARBORS — Metal shapes embedded in and used to support either green or dry sand cores.

ARRESTER, DUST — Equipment for removing dust from air handled by ventilation or exhaust systems.

BAIL — Hoop or arched connection between the crane hook and ladle or between crane hook and mold trunnions.

APPENDIX A. Glossary of Terms--Continued

BAKED CORE — A core that has been heated through sufficient time and temperature to produce the desired physical properties attainable from its oxidizing or thermosetting binders.

BALL MILL — A mill in which material is finely ground by rotation in a steel drum along with pebbles or steel balls. The grinding action is provided by the collision of the balls with one another and with the shell of the mill.

BANKING THE CUPOLA — Keeping the cupola hot by adding coke charges when iron is not being melted in the cupola, such as overnight.

BASIC BOTTOM AND LINING — In a melting furnace, the inner lining and bottom composed of materials that have a basic reaction in the melting process, usually crushed, burned dolomite, magnesite, magnesite bricks, or basic slag.

BEDDING A CORE — Resting an irregular-shaped core on a bed of sand for drying.

BED HEIGHT — The measured height of the cupola bed above the tuyeres before the first metal charge is added.

BENCH — A frame support on which small molds are made.

BENCH MOLDER — A craftsman who makes molds for smaller type castings.

BENTONITE — A colloidal clay derived from volcanic ash and employed as a binder in connection with synthetic sands or added to ordinary natural (clay-bonded) sands where extra strength is required; found in South Dakota, Wyoming, and the South Central States.

BINDER — A bond, usually other than clay, that is added to foundry sand, such as cereal, pitch, oil, sulfite byproduct, etc.

BINDERS, PLASTIC OR RESIN — Thermosetting synthetic resin materials, usually phenol formaldehyde or urea formaldehyde, used as bonding agents for core sands. These materials are adapted to curing in all types of commercial baking equipment. Granular phenol formaldehyde resins are used in the shell molding process.

BLACKING	Carbonaceous materials such as graphite or powdered carbon which are usually mixed with a binder and frequently suspended in water or other liquids; used as a thin facing applied to surfaces or molds or cores to improve casting finish.
BLAST	Air driven into the cupola or furnace for combustion of fuel.
BLAST FURNACE	In ferrous metallurgy, a shaft furnace supplied with an air blast (usually hot) and used for producing pig iron by smelting iron ore in a continuous operation. The raw materials (iron ore, coke, and limestone) are charged at the top, and the molten pig iron and slag that collect at the bottom are tapped out at intervals. In nonferrous metallurgy, a shaft type of vertical furnace, similar to the type used for smelting iron, but smaller, is used for smelting coarse copper, lead, and tin ores.
BLAST GATE	Sliding plate in the cupola blast pipe to regulate airflow.
BLASTING	A process for cleaning or finishing metal objects by using an air blast or centrifugal wheel that throws abrasive particles against the surfaces of the workpieces.
BLAST PIPE	A pipe that carries pressurized air, usually the section between the blower or fan and the cupola windbox.
BOND STRENGTH	A binding property of foundry sand that resists structural change.
BRIDGING	Local freezing across a mold before the metal below solidifies; solidification of slag within the cupola at or just above tuyeres, or "hanging up" of a large charge piece.
BUCKET	A vessel such as a tub or scoop for hoisting or conveying materials. Types include elevator, clamshell, dragline, grab, loading, or dumping.
BUNG	A removable top section or roof of an air furnace.
BURDEN	A collective term of the component parts of the metal charge for a cupola melt.

APPENDIX A. Glossary of Terms--Continued

CAPTIVE FOUNDRY — A foundry that is part of a manufacturing establishment.

CASTING, CENTRIFUGAL — A process of filling molds by pouring the metal into a sand or permanent mold that is revolving about either its horizontal or vertical axis or by pouring the metal into a mold that is subsequently revolved before the metal solidifies.

CASTING, SAND — A casting produced in a mold made of green sand, dried sand, or a core sand.

CHAPLETS — Metal supports or spacers used in molds to keep cores or parts of the mold that are not self-supporting in their proper positions during the casting process.

CHARGE — A given weight of metal or fuel introduced into the cupola or furnace.

CHARGING DECK — The floor from which furnace charging is performed, located at or just below the charging doors.

CHILL — The addition of solid metal to molten metal in a ladle to reduce temperature before pouring; the depth to which chilled structure penetrates a casting.

CHIPPING OUT — The process of removing slag and refuse materials attached to the cupola or furnace lining after a heat has been run.

COKE BED — First layer of coke placed in the cupola. Also the coke used as the foundation in constructing a large mold in a flask or pit.

COPE — Upper or topmost section of a flask, mold, or pattern.

CORE — A preformed sand aggregate inserted into a mold to shape the interior or that part of a casting that cannot be shaped by the pattern.

CORE BLOWER — A coremaking machine where sand is blown into the corebox by means of compressed air.

COREBOX — A wood, metal, or plastic structure, having a cavity shaped like the desired core to be made therein.

CORE DRIERS — Supports used to hold cores in shape while being baked; constructed from metal or sand for conventional baking or from plastic material for use with dielectric core-baking equipment.

CORE, GREEN SAND	A core formed from the molding sand and generally an integral part of the pattern and mold, or a core made of unbaked molding sand.
CORE GRINDER	Machine for grinding a taper on the end of a cylindric core or for grinding a core to a specified dimension.
CORE KNOCKOUT MACHINE	A mechanical device for removing cores from castings.
CORE WASH	A suspension of fine clay or graphite applied to cores by brushing, dipping, or spraying to improve the cast surface of the cored portion of the castings.
CRANE	A hand- or power-operated machine for lifting heavy weights. Types include electric, gantry, jib, or monorail cranes.
CRUCIBLE	A ceramic pot or receptacle made of materials, such as graphite or silicon carbide, which have relatively high thermal conductivity and which are bonded with clay or carbon and are used in melting metals; sometimes, pots made of cast iron, steel, or wrought steel. The area in the cupola between the bottom and the tuyere is also known as the crucible zone.
CUPOLA	A cylindric furnace lined with refractories for melting metal in direct contact with the fuel by forcing pressurized air through openings near the base of the furnace.
CUPOLA DROP	The sand bottom, bed, and unmelted charges dropped from the cupola at the end of a heat or production cycle.
CUPOLA DUST ARRESTER	A device attached to the stack of a cupola that removes dust and sparks from the outgoing gases.
DIRECT-ARC FURNACE	An electric-arc furnace in which the metal being melted is one of the poles.
DRAG	Lower or bottom section of a mold or pattern, originally called a nowel.
DROSS	Metal oxides in or on the surface of molten metal.
DRY PERMEABILITY	The property of a molded mass of bonded or unbonded sand, dried at 105-110°C (220-230°F) and cooled to room temperature, allowing passage of gases out of the mold during pouring of molten metal.

APPENDIX A. Glossary of Terms--Continued

DRY STRENGTH	The maximum compressive, shear, tensile, or traverse strength of a sand mixture that has been dried at 105-110°C (220-230°F) and cooled to room temperature.
FACING SAND	A specially prepared molding sand mixture used in the mold adjacent to the pattern to produce a smooth casting surface.
FETTLING	The process of removing all runners and risers and of cleaning off adhering sand from the casting; also refers to the removal of slag from the inside of the cupola (British).
FLASK	Metal or wood frame without a top or a fixed bottom that is used to hold the sand from which a mold is formed; usually consists of two parts, cope and drag.
FLOWABILITY	The property of a foundry sand mixture which enables it to fill pattern recesses and move in any direction against pattern surfaces under pressure.
FLUX	A material or mixture of materials that causes other compounds with which it comes into contact to fuse at a temperature lower than their normal fusion temperature.
FURNACE, RESISTANCE	A furnace that heats by the resistance of electrical conductors.
FURNACE, REVERBERATORY	A furnace having a vaulted ceiling that deflects the flame and heat toward the hearth or the surface of the charge to be melted.
FURNACE, TILTING	A melting furnace that can be tilted to pour the molten metal.
GATE	End of the runner in a mold where molten metal enters the casting or mold cavity; sometimes applied to entire assembly of connected channels, to the pattern parts that form them, or to the metal that fills them, and sometimes is restricted to mean the first or main channel.
GREEN PERMEABILITY	The ability of a molded body of tempered sand to permit passage of gases through its mass.
GREEN SAND	A naturally bonded sand or a compounded molding sand mixture that has been tempered with water for use while still damp or wet.

APPENDIX A. Glossary of Terms--Continued

HAND SHANK — A pouring ladle carried and used by one man.

INDIRECT-ARC FURNACE — An electric-arc furnace in which the metal bath is not one of the poles of the arc.

INDUCTION FURNACE — A melting furnace that utilizes electrical induction heat.

INOCULANT — Materials that, when added to molten metal, modify the structure and thereby change the physical and mechanical properties to a degree not explained on the basis of the change in composition resulting from their use.

KNOCKOUT — Operation of removing sand cores from casting; in investment casting, the process of jarring the mold to remove the investment and casting from the flask.

LADLE — Metal receptacle, frequently lined with refractories, used for trans- porting and pouring molten metal. Types include hand, bull, crane, bottom-pour, holding, teapot, trolley, shank, lip-pour, buggy, truck, mixing, and reservoir.

LADLE, BULL — A large ladle for carrying molten metal, usually designated as a transfer ladle.

LINING — The inside refractory layer of firebrick, clay, sand, or other material in a furnace or ladle.

METAL PENETRATION — A casting surface defect appearing as if the metal has filled voids between the sand grains without displacing them.

MOLD — The form, made of sand, metal, or any other investment material, that contains the cavity into which molten metal is poured to produce a casting of definite shape and outline.

MOLDING, PIT — Molding method in which the drag is made in a pit or hole in the floor.

MOLD WASH — Usually an aqueous emulsion containing various compounds, such as graphite, silica flour, etc., used to coat the face of the cavity in the casting mold.

MULLING — Process of mixing sand and clay particles by compressing, stirring, and rubbing actions.

APPENDIX A. Glossary of Terms--Continued

PARTING COMPOUND — A material dusted or sprayed on patterns or mold halves to prevent adherence of sand and to promote easy separation of cope and drag parting surfaces when cope is lifted from drag.

PARTING LINE — A line on a pattern or casting corresponding to the separation between the cope and drag portions of a sand mold.

PATTERN — A form of wood, metal, or other materials around which molding material is placed to make a mold for casting metals.

RAMMING — The operation of packing sand around a pattern in a flask to form a mold.

RUNNER — A channel through which molten metal or slag is passed from one receptacle to another; in a mold, the portion of the gate assembly that connects the downgate or sprue with the casting ingate or riser. The term also applies to similar portions of master patterns, pattern dies, patterns, investment molds, and the finished castings.

RUNOUT — A casting defect caused by incomplete filling of the mold due to molten metal draining or leading out of some part of the mold cavity during pouring; escape of molten metal from a furnace, mold, or melting crucible.

SAND — A loose, granular material resulting from the disintegration of rock. Sand refers to the size of grain and not to mineral composition. Diameter of the individual grains can vary from approximately 6 to 270 mesh. Most foundry sands are principally made up of the mineral quartz (silica) because it is plentiful, refractory, and inexpensive.

SAND, BANK — Sedimentary deposits, usually containing less than 5% clay.

SAND, DUNE — Windblown deposits of sand.

SAND MOLDING — Sands which contain over 5% natural clay; usually between 10 and 20%.

SAND, SILICA — Although most foundry sands contain a high percentage of silica, the term silica sand is generally reserved for those that show a minimum of 95% silica content. Many high grade silica sands will analyze better than 99% pure silica.

SANDS, MISCELLANEOUS	Include zircon, olivine, calcium carbonate, black sands (lava grains), titanium minerals, etc.
SCRAP (METAL)	Metal to be remelted; includes sprues, gates, risers, defective castings, scrapped machinery, and fabricated items such as rail or structural steel.
SEACOAL	A term applied to finely ground coal that is mixed with sands for foundry facings.
SHAKEOUT	The operation of removing castings from the mold or a mechanical unit for separating the molding materials from the solidified metal casting.
SHELL MOLDING	A process for forming a mold from resin-bonded sand mixtures that are brought into contact with preheated metal patterns, resulting in a firm shell with a cavity corresponding to the outline of the pattern.
SLAG	A nonmetallic covering that forms on the molten metal from impurities contained in the original charge, some ash from the fuel, and any silica and clay eroded from the refractory lining. Slag is skimmed off prior to tapping the heat.
SLAG HOLE	An opening in the front or back of a cupola through which the slag is drawn off.
SNAGGING	A grinding process for the rough cleaning of castings.
SPRUE	The vertical channel connecting the pouring basin with the skimming gate, if any, and the runner to the mold cavity--all of which together may be called the gate. In top-poured castings, the sprue may also act as a riser. Sometimes used as a generic term to cover all gates and risers that are returned to the melting unit for remelting; also applies to similar portions of master patterns, pattern dies, patterns, investment molds, and the finished castings.
SWARF	The stream of particles produced tangentially from an abrasive tool contact point.
TAP HOLE	Opening in the furnace breast through which the molten metal is tapped into the spout.
TAPPING	Removing molten metal from the melting furnace by opening the tap hole and allowing the metal to run into a ladle.

TRANSFER LADLE — A ladle that may be supported on a monorail or carried on a shank and used to transfer metal from the melting furnace to the holding furnace or from furnace to pouring ladles.

TUCKING — Pressing sand with the fingers under flask bars, around gaggers, and into other places where the rammer does not give the desired density.

TUMBLING BARRELS — Rotating barrels in which castings are cleaned, also called rolling barrels and rattlers. Usually, small, star-shaped castings are loaded with the castings to aid the cleaning process.

TUYERE — An opening in the cupola shell and refractory lining through which the airblast is forced.

APPENDIX B. Health hazards potentially present in foundries--Health effects and exposure limits (by agent)

Agent	Process/Use	Major health effects	Primary target site	Standard or limit*	Reference
Acetylene	Melting and pouring emission; cutting torch	Intoxication; incoordination; unconsciousness; asphyxia	CNS	ACGIH - Asphyxiant NIOSH - 2,500 ppm (2,662 mg/m^3) ceiling	[88] [264]
Acrolein	Core ovens decomposition product; pouring and shakeout where oil sand cores are used	Eye, nose, throat irritation; lacrimation; pulmonary edema	Eyes, lungs, airways	ACGIH - 0.1 ppm (0.25 mg/m^3) OSHA - 0.1 ppm (0.25 mg/m^3)	[88] [141]
Aluminum and aluminum oxide	Melting and pouring of aluminum alloys; deoxidant for steel alloys; mold wash refractory; ladle and furnace refractory	Respiratory effects (potential pulmonary fibrosis)	Lungs	ACGIH - 10 mg/m^3 (tentative)	[88] [265]
Ammonia	Coremaking decomposition product of nitrogen-containing binding materials	Respiratory irritant; gastritis; laryngeal and lung edema	Lungs, airways	ACGIH - 25 ppm (18 mg/m^3) NIOSH - 50 ppm (34.8 mg/m^3), 5-min ceiling OSHA - 50 ppm (35 mg/m^3)	[88] [77] [141]

*Unless specified, ACGIH TLV's, NIOSH REL's, or OSHA PEL's are 8-hour time-weighted averages (TWA's).
§No established limit or standard

APPENDIX B. Health hazards potentially present in foundries--Health effects and exposure limits (by agent)--Continued

Agent	Process/Use	Major health effects	Primary target site	Standard or limit*	Reference
Antimony	Metal alloy for copper and lead	Pulmonary congestion; heart, kidney, and liver effects; dermatitis; rhinitis	Kidney, liver, skin, nose, lungs	ACGIH - 0.5 mg/m^3 as Sb NIOSH - 0.5 mg/m^3, 10 hr OSHA - 0.5 mg/m^3	[88] [266] [141]
Asbestos	Furnace lining and some protective clothing; previously used in riser sleeves	Asbestosis; mesothelioma	Lungs	ACGIH - Human carcinogen Amosite - 0.5 fibers >5 µm/cc Chrysotile - 2.0 fibers >5 µm/cc Crocidolite - 0.2 fibers >5 µm/cc Other Forms - 2.0 fibers >5 µm/cc NIOSH - All Forms - 0.1 fibers >5 µm/cc OSHA - All Forms - 2.0 fibers >5 µm/cc; 10 fibers >5 µm/cc ceiling	[88] [267]
Bentonite clay	Mold binding agent	Nuisance dust	Lungs	ACGIH - 10 mg/m^3 (total dust)	[88]
Benzene	Core wash; solvent	Leukemia; CNS depression; dermatitis	CNS, skin, blood	ACGIH - 10 ppm (30 mg/m^3) (suspect human carcinogen) NIOSH - 1 ppm (3.2 mg/m^3), 60-min ceiling OSHA - 10 ppm; 25 ppm acceptable ceiling; 50 ppm maximum ceiling, 10-min	[78] [88] [141]
Beryllium	Melting and pouring; copper alloy	Berylliosis; lung cancer; dermatitis	Lungs, skin	ACGIH - 0.002 mg/m^3 (suspect human carcinogen) NIOSH - 0.5 µg/m^3, 10 hr OSHA - 2 µg/m^3; 5 µg/m^3 acceptable ceiling; 25 µg/m^3 maximum ceiling, 30-min	[143] [88] [141]

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APPENDIX B. Health hazards potentially present in foundries--Health effects and exposure limits (by agent)--Continued

Agent	Process/Use	Major health effects	Primary target site	Standard or limit*	Reference
Cadmium	Alloying element; protective coating	Metal fume fever; cadmium poisoning; emphysema; pulmonary edema; renal changes; potential carcinogen	Lungs, kidney	ACGIH - 0.05 mg/m^3 NIOSH - Reduce exposure to lowest feasible limit OSHA - Fume: 0.1 mg/m^3, 0.3 mg/m^3 ceiling; dust: 0.2 mg/m^3, 0.6 mg/m^3 ceiling	[268] [88] [141] [269]
Carbon dioxide	Silicate-CO_2 process; melting and pouring emission; ladle preheaters; core ovens; space heaters; welding	Asphyxiation; acute O_2 deficiency	All	ACGIH - 5,000 ppm (9,000 mg/m^3) NIOSH - 10,000 ppm (18,000 mg/m^3), 10 hr; 30,000 ppm (5,400 mg/m^3), 10-min ceiling OSHA - 5,000 ppm (9,000 mg/m^3)	[270] [88] [141]
Carbon monoxide	Melting and pouring emission; decomposition product of coremaking	Behavioral and neuro-physiologic changes; heart effect; acute O_2 deficiency	Blood, heart, CNS	ACGIH - 50 ppm (55 mg/m^3) NIOSH - 35 ppm (40 mg/m^3), 200 ppm (229 mg/m^3) ceiling OSHA - 50 ppm (55 mg/m^3)	[88] [141]
Cereal	Binder material	Nuisance dust	Lungs	§	[13]
Chlorine	Degassing agent for non-ferrous agent	Irritation of eyes, nose, and throat; pulmonary edema and congestion; anoxia	Mucous membranes, lungs	ACGIH - 1 ppm (3 mg/m^3) NIOSH - 0.5 ppm (1.45 mg/m^3), 15-min ceiling OSHA - 1 ppm (3 mg/m^3) ceiling	[81] [88] [141]

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§No established limit or standard

APPENDIX B. Health hazards potentially present in foundries--Health effects and exposure limits (by agent)--Continued

Agent	Process/Use	Major health effects	Primary target site	Standard or limit*	Reference
Chromium	Melting, pouring, and grinding of low alloy and stainless steel and chrome alloys; chromite sand constituent	Nephritis; lung cancer; skin ulcers; dermatitis; allergic reactions; lung irritation	Kidney, lungs, skin	ACGIH - Chromium: 0.5 mg/m^3; chromium VI, water soluble: 0.05 mg/m^3; carcinogenic, chromium VI, certain water insoluble: 0.05 mg/m^3 NIOSH - Carcinogenic Cr (VI): 1 µg/m^3; other Cr (VI): 25 µg/m^3, 10 hr, 50 µg/m^3 15-min ceiling OSHA - Chromic acid and chromates: 0.1 mg/m^3 acceptable ceiling; soluble chromic, chromous salts as Cr: 0.2 mg/m^3; metal and insoluble salts: 1 mg/m^3	[67] [88] [141]
Copper	Melting, pouring, and grinding of copper and alloys	Acute respiratory irritation; metal fume fever	Lungs	ACGIH - Fume: 0.2 mg/m^3; dust and mist: 1 mg/m^3 OSHA - Fume: 0.1 mg/m^3; dust and mist: 1 mg/m^3	[88] [141]
Cresol	Pouring decomposition product of green sand molds	Dermatitis; kidney; hepatic damage; CNS depression; nausea; cough	Skin, kidney, liver, CNS, lungs	ACGIH - 5 ppm (22 mg/m^3) NIOSH - 2.3 ppm (10 mg/m^3) OSHA - 5ppm (22 mg/m^3)	[271] [88] [141]

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§No established limit or standard

APPENDIX B. Health hazards potentially present in foundries--Health effects and exposure limits (by agent)--Continued

Agent	Process/Use	Major health effects	Primary target site	Standard or limit*	Reference
Diphenylmethane diisocyanate (MDI)	Binder component for urethane binders; decomposition product	Irritation; occupational asthma	Respiratory tract, eyes	ACGIH - 0.02 ppm (0.2 mg/m^3) ceiling NIOSH - 50 µg/m^3; 200 µg/m^3, 10-min ceiling OSHA - 0.02 ppm (0.2 mg/m^3) ceiling	[82]
Dimethylethylamine (DMEA)	Catalyst for cold box binder systems	Skin irritation; corneal edema; contact dermatitis	Eyes, lungs, skin	§	[272]
Dimethylphenol	Decomposition emission from melting and pouring	Necrosis; nausea; neurologic impairment; renal and hepatic damage	Gastrointestinal tract, CNS, liver, kidney	§	[273]
Ethane	Melting, pouring, and shakeout decomposition product	Asphyxia	Lungs	ACGIH - Asphyxiant	[274] [88]
Ethene	Melting, pouring, and shakeout decomposition product	Asphyxia	Lungs	§	
Ethyl alcohol	Constituent in hot coating in shell molding	Liver and heart muscle lesions; gastritis	Liver, heart	ACGIH - 1,000 ppm (1,900 mg/m^3) OSHA - 1,000 ppm (1,900 mg/m^3)	[88] [141]

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§No established limit or standard

APPENDIX B. Health hazards potentially present in foundries--Health effects and exposure limits (by agent)--Continued

Agent	Process/Use	Major health effects	Primary target site	Standard or limit*	Reference
Ethyl silicate	Binder	Eye and respiratory tract irritation; kidney, liver, and lung changes possible	Eyes, kidney, liver, lungs, skin	ACGIH - 10 ppm (85 mg/m^3) OSHA - 100 ppm (850 mg/m^3)	[274] [141]
Formaldehyde	Emission in molding, pouring, and shakeout areas from decomposition of binder materials	Headache; allergic reaction; pulmonary edema; eye and skin irritation; potential carcinogen	Lungs, eyes, skin	ACGIH - 1 ppm (1.5 mg/m^3) (industrial substances suspect of carcinogenic potential for man) NIOSH - Reduce to lowest feasible level OSHA - 3 ppm; 5 ppm acceptable ceiling; 10 ppm maximum ceiling, 30-min	[84] [85] [88] [141]
Furfuryl alcohol	Component of furan resin binders	Lacrimation; irritation; allergies	Eyes, skin	ACGIH - 10 ppm (40 mg/m^3) NIOSH - 50 ppm (200 mg/m^3), 10 hr OSHA - 50 ppm (200 mg/m^3)	[86] [88] [141]
Graphite	Mold release agent; foundry aggregate in non-ferrous applications; green sand additive; furnace electrode; combustion soot in furnaces; ladle heating and core ovens; decomposition product of organic binders	Graphite pneumoconiosis	Lungs	ACGIH - Nuisance particulate: 5 mg/m^3 (respirable dust); 10 mg/m^3 (total dust <1% quartz)	[69] [275] [88]

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§No established limit or standard

APPENDIX B. Health hazards potentially present in foundries--Health effects and exposure limits (by agent)--Continued

Agent	Process/Use	Major health effects	Primary target site	Standard or limit*	Reference
Hexachloroethane	Degassing and grain refining agent for aluminum	CNS depression; potential carcinogen; irritation	CNS	ACGIH - 10 ppm (100 mg/m^3) NIOSH - Reduce exposure to lowest feasible level OSHA - 1 ppm (10 mg/m^3)	[88] [141]
Hexamethylene-tetramine	Catalyst in shell molding	Skin rash; urinary tract irritation; GI disturbance; nephritis with high exposure	Skin, kidney	§	[58] [274]
Hot environments	Melting and pouring; shakeout; core ovens; heat treating; welding; cranes	Heat illnesses; increased cardio-vascular and respir-atory strain; heat stroke	Heart, lungs, circulatory system, liver, and kidney	ACGIH - variable NIOSH - variable	[97] [165]
Hydrogen chloride	Mist produced in degassing and fluxing of nonferrous metals	Irritation; burns; tooth erosion; nasal and oral mucosa ulceration; respir-atory irritation	Skin, teeth, mucosa, lungs	ACGIH - 5 ppm (7 mg/m^3) ceiling OSHA - 5 ppm	[58] [88] [141] [274]
Hydrogen cyanide	Decomposition product of nitrogen-containing binding agents	Dermatitis; asphyxia; death; neurologic changes	Skin, CNS, cardiovas-cular system, liver, kidney	ACGIH - 10 ppm (10 mg/m^3) ceiling NIOSH - 4.7 ppm (5 mg CN/m^3), 10-min ceiling OSHA - 10 ppm (11 mg/m^3) (Skin)	[88] [141] [276]

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§No established limit or standard

APPENDIX B. Health hazards potentially present in foundries--Health effects and exposure limits (by agent)--Continued

Agent	Process/Use	Major health effects	Primary target site	Standard or limit*	Reference
Hydrogen fluoride	Decomposition product of flux	Eye, nose and skin irritation; skin ulcers; bone effects; GI effects	Skin, eyes, nose, bones	ACGIH - 3 ppm (2.5 mg/m^3) NIOSH - 3 ppm (2.5 mg F/m^3), 10 hr; 6 ppm (5.0 mg F/m), 15-min ceiling OSHA - 3 ppm	[88] [141] [277]
Hydrogen sulfide	Emission at slag quenching operations; melting and pouring decomposition product; shakeout	Irritation; nervous system changes; respiratory paralysis; eye irritation	CNS, lungs	ACGIH - 10 ppm (14 mg/m^3) NIOSH - 10 ppm (15 mg/m^3), 10-min ceiling OSHA - 20 ppm acceptable ceiling; 50 ppm maximum ceiling, 10-min	[88] [91] [141]
Iron and iron oxide	Melting, pouring, and grinding of iron and steel; shakeout; sand and core wash additive	Pulmonary irritation	Lungs	ACGIH - Iron oxide fume: 5 mg/m^3 OSHA - Fume: 10 mg/m^3	[88] [141] [274]
Isophorone	Decomposition product of melting and pouring	Respiratory and mucosa irritation; dermatitis	Lungs, mucosa	ACGIH - 5 ppm (25 mg/m^3) ceiling OSHA - 25 ppm (140 mg/m^3)	[88] [141]
Isopropyl alcohol	Solvent for core and mold washes	Mucous membrane irritation	Mucosa	ACGIH - 400 ppm (980 mg/m^3) NIOSH - 400 ppm, 10 hr; 800 ppm, 15-min ceiling OSHA - 400 ppm (980 mg/m^3)	[88] [141] [278]

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§No established limit or standard

APPENDIX B. Health hazards potentially present in foundries--Health effects and exposure limits (by agent)--Continued

Agent	Process/Use	Major health effects	Primary target site	Standard or limit*	Reference
Lead	Alloying agent to copper base alloys; melting and pouring; grinding of lead, iron, and steel	Kidney, blood, GI and nervous system changes	Kidney, blood, CNS, gastro-intestinal tract	ACGIH - 0.15 mg/m^3 NIOSH - <100 µg/m^3, 10 hr; air level to be maintained so that worker blood lead remains ≤60 µg/100g OSHA - 50 µg/m^3	[64] [88] [141]
Magnesium and magnesium oxide	Melting and pouring of ductile (nodular) iron and magnesium; core wash refractory	Metal fume fever	Lungs	ACGIH - MgO fume: 10 mg/m^3 OSHA - MgO fume: 15 mg/m^3	[88] [141] [279]
Manganese	Alloying element in iron and steel; melting, pouring, and grinding of ferrous alloys; and sand addition	Pulmonary diseases; pneumonia; nervous system changes	Lungs, CNS	ACGIH - Dust and compounds: 5 mg/m^3 ceiling; fume: 1 mg/m^3 OSHA - 5 mg/m^3 ceiling	[88] [195] [141]
Methane	Emission from ovens, furnaces, and cupolas; pouring; shakeout	Asphyxiant	Lungs	ACGIH - Asphyxiant	[274] [88]
Methyl alcohol	Decomposition product of grinder systems or core washes that contain methyl alcohol; pouring; shakeout	Narcosis; dermatitis; blindness; metabolic acidosis; mucous membrane irritation	Skin, CNS	ACGIH - 200 ppm (260 mg/m^3) NIOSH - 200 ppm, 10 hr; 800 ppm, 15-min ceiling OSHA - 200 ppm (260 mg/m^3)	[88] [141] [280]

*Unless specified, ACGIH TLV's, NIOSH REL's, or OSHA PEL's are 8-hour time-weighted averages (TWA's).
§No established limit or standard

APPENDIX B. Health hazards potentially present in foundries--Health effects and exposure limits (by agent)--Continued

Agent	Process/Use	Major health effects	Primary target site	Standard or limit*	Reference
Mica	Mold release agent	Nodular fibrosis	Lungs	OSHA - 20 mppcf (<1% crystalline silica)	[58] [141]
Molybdenum	Melting and pouring of iron and steel	Pneumoconioses; gout	Lungs	ACGIH - Soluble: 5 mg/m^3; insoluble: 10 mg/m^3 OSHA - Soluble: 5 mg/m^3; insoluble: 15 mg/m^3	[88] [141]
Nickel	Fume from melting, pouring, and grinding of nickel and stainless steels	Dermatitis; lung and nasal cancer	Skin, lungs, nose	ACGIH - Metal: 1 mg/m^3; soluble: 0.1 mg/m^3 NIOSH - 15 µg Ni/m^3, 10 hr OSHA - 1 mg/m^3	[68] [88] [141]
Nitrogen	Furnace effluent	Anoxia	CNS	§	[274]
Nitrogen oxides	Melting and pouring	Methemoglobinemia; irritation; edema; dyspnea	Blood, lungs	ACGIH - NO_2: 3 ppm (6 mg/m^3) ceiling NIOSH - NO_2: 1 ppm (1.8 mg/m^3), 15-min ceiling; NO: 25 ppm (30 mg/m^3), 10 hr OSHA - NO_2: 5 ppm (9 mg/m^3) ceiling; NO: 25 ppm (30 mg/m^3)	[88] [141] [281]
Noise	Shakeout; furnaces	Hearing damage; neurologic effects	Ear, CNS	ACGIH - 85 dBA, 115 dBA ceiling NIOSH - 85 dBA, 10 hr; 115 dBA ceiling OSHA - 90 dBA	[88] [92] [141]

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§No established limit or standard

APPENDIX B. Health hazards potentially present in foundries--Health effects and exposure limits (by agent)--Continued

Agent	Process/Use	Major health effects	Primary target site	Standard or limit*	Reference
Paraffin wax fume	Grinding wheel application	Cancer	Skin, lungs, stomach	ACGIH - 2 mg/m^3	[88] [141]
Phenol	Binder-constituent; decomposition product of binding system	Tinnitis; pigmentary changes in skin; skin cancer; liver, CNS, and kidney changes	Skin, liver, CNS, kidney	ACGIH - 5 ppm (19 mg/m^3) NIOSH - 5.2 ppm (20 mg/m^3), 10 hr; 15.6 ppm (60 mg/m^3), 15-min ceiling OSHA - 5 ppm (19 mg/m^3) (Skin)	[88] [141] [282]
Phosphoric acid	Furan resin catalyst	Eye, skin and respiratory tract irritation; dermatitis	Eyes, skin, lungs	ACGIH - 1 mg/m^3 OSHA - 1 mg/m^3	[88] [141]
Polycyclic aromatic hydrocarbons (benzo(a)pyrene, cresol, methylbenzanthracene, naphthalene)	Pouring decomposition product of sand molds; cupola melting	Animal carcinogen and mutagen; skin eruptions; liver and kidney damage; dermatitis; cataracts; nausea; hematuria	Skin, liver, kidney, eyes	Benzo(a)pyrene: ACGIH - suspect human carcinogen Cresol: ACGIH - 5 ppm (22 mg/m^3) NIOSH - 2.3 ppm (10 mg/m^3), 10 hr OSHA - 5 ppm (22 mg/m^3) (Skin) Naphthalene: ACGIH - 10 ppm (50 mg/m^3) OSHA - 10 ppm (50 mg/m^3)	[87] [88] [141] [271] [283]

*Unless specified, ACGIH TLV's, NIOSH REL's, or OSHA PEL's are 8-hour time-weighted averages (TWA's).
§No established limit or standard

APPENDIX B. Health hazards potentially present in foundries--Health effects and exposure limits (by agent)--Continued

Agent	Process/Use	Major health effects	Primary target site	Standard or limit*	Reference
Silica	Molding; coremaking; shakeout; furnace; ladle and furnace refractory cleaning room	Chronic lung disease; silicosis	Lungs	ACGIH - TLV mppcf: $\frac{10\ mg/m^3}{\%\ respirable\ quartz + 2}$ (also other equations) NIOSH - Respirable free silica: 50 µg/m^3, 10 hr OSHA - Respirable quartz: (in mppcf) $\frac{250}{\%\ SiO_2 + 5}$ or $\frac{10\ mg/m^3}{\%\ SiO_2 + 2}$	[54] [88] [141] [226]
Sodium silicate	Sand binder; ladle and furnace refractory binder	Dermatitis; eye and skin burns; respiratory irritation	Skin, eyes, lungs	§	[83] [275]
Sulfur dioxide	Magnesium casting emission; core or mold binder system emission; catalyst for cold box binder system	Respiratory irritation	Lungs	ACGIH - 2 ppm (5 mg/m^3) NIOSH - 0.5 ppm (1.3 mg/m^3), 10 hr OSHA - 5 ppm (13 mg/m^3)	[90] [88] [141]

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APPENDIX B. Health hazards potentially present in foundries--Health effects and exposure limits (by agent)--Continued

Agent	Process/Use	Major health effects	Primary target site	Standard or limit*	Reference
Talc	Release agent; binder constituent	Talcosis; nodular fibrosis	Lungs	ACGIH - Respirable dust, no asbestos fibers: 2 mg/m^3; containing asbestos fibers: use asbestos TLV, not to exceed 2 mg/m^3 respirable dust OSHA - Nonasbestos-form containing <1 % quartz: 20 mppcf; fibrous: use asbestos limit	[88] [141]
Tellurium	Alloying agent for ferrous and nonferrous metals	Respiratory irritation	Lungs	ACGIH - 0.1 mg/m^3 OSHA - 0.1 mg/m^3	[88] [141]
Tin and tin oxide	Alloying element; melting and pouring emission	Stannosis; pneumoconiosis; dermal lesions	Lungs, skin	ACGIH - Metal, oxide, and inorganic: 2 mg/m^3; organic: 0.1 mg/m^3 OSHA - Inorganic except oxides: 2 mg/m^3; organic: 0.1 mg/m^3	[88] [141]
Titanium	Alloying element for aluminum; deoxidant for ferrous alloys	Mild pulmonary irritation	Lungs	ACGIH - Titanium dioxide (nuisance particulate): 5 mg/m^3 (respirable dust); 10 mg/m^3 (total dust <1% quartz) OSHA - Titanium dioxide: 15 mg/m^3	[88] [141]
Toluene	Decomposition product of mold materials	Dermatosis; CNS depression; respiratory tract and mucous membrane irritation	Skin, CNS, lungs, mucosa	ACGIH - 100 ppm (375 mg/m^3) NIOSH - 100 ppm (375 mg/m^3), 10 hr; 200 ppm (750 mg/m^3), 10-min ceiling OSHA - 200 ppm; 300 ppm acceptable ceiling; 500 ppm maximum ceiling, 10-min	[79] [88] [141]

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§No established limit or standard

APPENDIX B. Health hazards potentially present in foundries--Health effects and exposure limits (by agent)--Continued

Agent	Process/Use	Major health effects	Primary target site	Standard or limit*	Reference
1,1,1-Trichloroethane	Core and mold wash solvent	CNS depression; liver and kidney damage; lung and skin irritation	CNS, liver, heart, lungs, lymph nodes, skin	ACGIH - 350 ppm (1,900 mg/m^3) NIOSH - 350 ppm (1,910 mg/m^3), 15-min ceiling OSHA - 350 ppm (1,900 mg/m^3)	[88] [141] [275] [284]
1,1,2-Trichloroethane	Core and mold wash solvent	Cancer		ACGIH - 10 ppm NIOSH - Reduce exposure to lowest feasible level OSHA - 10 ppm (45 mg/m^3) (Skin)	[88] [141]
Triethylamine	Catalyst in cold box binder system	Irritation; edema; chemical sensitization	Eyes, lungs	ACGIH - 10 ppm (40 mg/m^3) OSHA - 25 ppm (100 mg/m^3)	[88] [141]
Ultraviolet radiation	Melting and pouring areas	Skin and ocular effects; skin cancer	Skin, eyes	ACGIH - variable (200-315 nm); <1 J/cm^2 for periods <1,000 sec (320-400 nm); <1 mW/cm^2 for periods >1,000 sec (320-400 nm) NIOSH - variable (200-315 nm); <1 J/cm^2 for periods <1,000 sec (315-400 nm); <1 mW/cm^2 for periods >1,000 sec (315-400 nm)	[88] [98] [141]
Vanadium	Alloying element for ferrous alloys	Conjunctiva irritation; nasal mucosa irritation; dyspnea; bronchitis; fatigue	Eyes, skin, lungs	ACGIH - V_2O_5 respirable dust and fume: 0.05 mg/m^3 NIOSH - Vanadium carbide, metallic and alloyed forms: 1 mg/m^3, 10 hr; all other vanadium compounds: 0.05 mg/m^3, 15-min ceiling	[88] [141] [285]

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§No established limit or standard

APPENDIX B. Health hazards potentially present in foundries--Health effects and exposure limits (by agent)--Continued

Agent	Process/Use	Major health effects	Primary target site	Standard or limit*	Reference
Vanadium--Continued				OSHA - V_2O_5 dust: 0.5 mg/m^3 ceiling; V_2O_5 fume: 0.1 mg/m^3 ceiling; ferrovanadium: 1 mg/m^3	
Vibration	Cleaning and fettling	Vibration white finger	Fingers	NIOSH - Jobs should be redesigned to minimize use of vibrating handtools	[173]
Xylene	Core wash and core binder solvent; mold decomposition product	Irritation; narcosis; pulmonary edema	Skin, mucous membranes, lungs, CNS	ACGIH - 100 ppm (435 mg/m^3) NIOSH - 100 ppm (434 mg/m^3), 10 hr; 200 ppm (868 mg/m^3), 10-min ceiling OSHA - 100 ppm (435 mg/m^3)	[80] [88] [141]
Zinc oxide	Melting, pouring, and grinding of zinc, galvanized metal, and brass	Metal fume fever; dermatitis	Lungs, skin	ACGIH - Fume: 5 mg/m^3; total dust 1% quartz: 10 mg/m^3; respirable dust: 5 mg/m^3 NIOSH - 5 mg/m^3, 10 hr; 15 mg/m^3, 15-min ceiling OSHA - Fume: 5 mg/m^3	[66] [88] [141]
Zirconium and Zirconium oxide	Deoxidizer for ferrous alloys; ladle refractory; foundry aggregate; mold and core wash refractory	Allergic granulomas	Skin	ACGIH - 5 mg/m^3 OSHA - 5 mg/m^3	[88] [141]

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§No established limit or standard