APPENDIX C. Foundry processes and potential health-related hazards (by process)

Molding and coremaking	Melting	Pouring	Shakeout and cleaning
Acrolein	Acetylene	Acetylene	Acrolein
Aluminum oxide	Aluminum (fume)	Acrolein	Aluminum (dust)
Ammonia	Antimony (fume)	Aluminum (fume)	Antimony (dust)
Bentonite clay	Asbestos	Beryllium	Beryllium (dust)
Carbon dioxide	Cadmium (fume)	Carbon dioxide	Chromium (dust)
Carbon monoxide	Beryllium (fume)	Cadmium (dust)	Carbon monoxide
Cereal	Carbon dioxide	Carbon monoxide	Copper (dust)
Diphenylmethane (MDI) diisocyanate	Chlorine	Copper (fume)	Iron (dust)
Dimethylethylamine	Chromium (fume)	Cresol	Iron oxide (dust)
Ethyl alcohol	Carbon monoxide	Chromium (fume)	Formaldehyde
Ethyl silicate	Copper (fume)	Dimethylphenol	Lead (dust)
Formaldehyde	Dimethylphenol	Diphenylmethane diisocyanate	Magnesium (dust)
Furfuryl alcohol	Hexachloroethane	Ethane	Magnesium oxide (dust)
Graphite	Hot environment	Ethene	Manganese (dust)
Hexamethylene-tetramine	Hydrogen chloride	Formaldehyde	Metal dusts and oxides
Hot environment	Hydrogen fluoride	Hot environment	Molybdenum (dust)
Hydrogen chloride	Hydrogen sulfide	Hydrogen sulfide	Nickel (dust)
Hydrogen cyanide	Iron (fume)	Iron (fume)	Noise
Isopropyl alcohol	Iron oxide	Iron oxide	Polycyclic aromatic hydrocarbon
Methyl alcohol	Lead (fume)	Isophorone	Silica
Mica	Magnesium (fume)	Lead (fume)	Sulfur oxides
Noise	Magnesium oxide	Magnesium (fume)	Tellurium (dust)
Phenol	Manganese (fume)	Magnesium oxide	Thermal decomposition products of binder
Phosphine	Methane	Manganese (fume)	Tin (dust)
Silica	Molybdenum (fume)	Molybdenum (fume)	Vanadium (dust)
Sodium silicate	Nickel (fume)	Nickel (fume)	Vibration
Sulfur dioxide	Nitrogen	Nitrogen oxides	Zinc (dust)
Talc	Nitrogen oxides	Optical radiation	Zirconium
Trichloroethane	Noise	Polycyclic aromatic hydrocarbons (benzo(a)pyrene, methylbenzanthracene,naphthalene)	
Triethylamine	Optical radiation	Sulfur oxides	
Vibration	Tellurium (fume)	Tellurium (fume)	
Xylene	Tin (fume)	Tin (fume)	
	Tin oxide	Tin oxide	
	Titanium (dust)	Titanium (fume)	
	Titanium (fume)	Toluene	
	Ultraviolet radiation	Ultraviolet radiation	
	Vanadium (fume)	Vanadium (fume)	
	Zinc oxide (fume)	Zinc oxide (fume)	
	Zirconium (fume)	Zirconium (fume)	

Adapted from references in Appendix B

APPENDIX D. NIOSH sampling and analytical methods for foundry hazards

Hazard/Chemical	Methods		
	Sampling	Analytical	Number
Acetylene	Grab sample or combustible gas meter	Gas chromatography for grab sample	--
Acrolein	Solid sorbent tube. 2-(Hydroxymethyl) piperidine on XAD-2, 120 mg/60 mg. Flowrate 0.01 to 0.1 L/min. Sample size 1.5 to 48 L	Gas chromatography, nitrogen-specific detector	2501
Ammonia	Adsorption on sulfuric acid-treated silica gel. Desorption with 0.1 N sulfuric acid	Specific ion meter with ammonia gas sensing probe	S347(5)
Asbestos	Filter. 0.8-1.2 μm cellulose ester membrane, 25 mm diameter. Flowrate $\geq$0.5 L/min. Sample size 40 L (at 0.1 fiber/mL) to 1920 L (at 0.1 fiber/mL)	Microscopy, phase contrast	7400
Benzene	Solid sorbent tube. Coconut shell charcoal 100 mg/50 mg. Flowrate $\leq$0.20 L/min. Sample size 2 (10 min sample) to 30 L	Gas chromatography, flame ionization detector	1500
Cadmium (dust)	Filter. 0.8 μm cellulose ester membrane. Flowrate 1 to 3 L/min. Sample size 25 L (at 0.1 mg/m^3) to 1,500 L	Atomic absorption, flame	7048
(fume)	Filter. 0.8 μm cellulose ester membrane. Flowrate 1 L/min. Sample size 10 to 400 L	X-ray fluorescence	7200
Carbon dioxide	5-liter five-layer gas sampling bag. Flowrate 0.05 liter/min (not less than 0.01 liters/min). Sample size 3 to 4 liters	Gas chromatography	S249

Adapted from sampling and analytical methods as indicated by NIOSH criteria documents and Manual of Analytical Methods [286,287,288,289,290,291,292,293]

APPENDIX D. NIOSH sampling and analytical methods for foundry hazards--Continued

Hazard/Chemical	Methods		
	Sampling	Analytical	Number
Carbon monoxide	5-liter five-layer gas sampling bag. Flowrate 0.05 liter/min (not less than 0.01 liters/min). Sample size 3 to 4 liters	Electrochemical analysis	S340(4)
Carbon tetrachloride	Solid sorbent tube. Coconut shell charcoal, 100 mg/50 mg. Flowrate 0.01 to 0.2 L/min. Sample size varies	Gas chromatography, flame ionization detector	1003
Chlorine	Midget fritted bubblers with 10 ml sampling solution, 1-2 liters/min for 15 min + 6 ml 0.005% methyl orange to 100 ml H20 + 0.15-0.20 ml of 5.0 N HCL + 1 drop butanol (optional)	Colorimetry using spectrophotometery	209
Chromium VI	Filter. 0.8 μm cellulose ester membrane. Flowrate 1 to 4 L/min. Sample size 8 L (at 0.025 mg/m^3) to 400 L	Atomic absorption, flame	7024
Coal tar	0.8 μm silver membrane filter preceded by Gelman type A or equivalent glass filter (3 piece)	Weighing after extraction	217
Cresol	Solid sorbent tube. Silica gel, 150 mg/75 mg. Flowrate 0.01 to 0.2 L/min. Sample size 5 L (at 5 ppm) to 20 L	Gas chromatography, flame ionization detector	2001
Crystalline silica	1. Cyclone plus filter. 10 mm nylon cyclone plus 5 μm PVC membrane. Flowrate 1.7 L/min. Sample size 800 L (at 0.05 mg/m^3) to 1,000 L	1. X-ray powder diffraction	7500

Adapted from sampling and analytical methods as indicated by NIOSH criteria documents and Manual of Analytical Methods [286,287,288,289,290,291,292,293]

APPENDIX D. NIOSH sampling and analytical methods for foundry hazards--Continued

Hazard/Chemical	Methods		
	Sampling	Analytical	Number
	2. Cyclone plus filter. 10 mm nylon cyclone plus 0.8 μm or 5 μm PVC or MCE membrane. Flowrate 1.7 L/min. Sample size 400 to 800 L	2. Visible absorption spectrophotometry	7601
	3. Cyclone plus filter. 10 mm nylon cyclone plus 0.8 μm or 5 μm PVC or MCE membrane. Flowrate 1.7 L/min. Sample size 400 to 800 L	3. Infrared absorption spectrophotometry	7602
Diphenylmethane diisocyanate (MDI)	Impinger. Solution of 1-(2-methoxyphenyl)-piperazine in toluene. Flowrate 1 L/min. Sample size 350 to 600 L	High performance liquid chromatography, ultraviolet detection	5505
Ethanol	Solid sorbent tube. Coconut shell charcoal, 100 mg/50 mg. Flowrate 0.05 L/min. Sample size 0.1 to 1 L	Gas chromatography, flame ionization detection	1400
Formaldehyde	Filter plus impingers. 1 μm PTFE membrane and 2 impingers, each with 20 ml. 1% sodium bisulfite solution. Flowrate 0.2 to 1 L/min. Sample size 2 L at 1 min) to 100 L	Visible absorption spectrophotometry	3500
Furfuryl alcohol	Adsorption on Porapak Q. Desorption with acetone	Gas chromatography	S365(4)
Hot environments	WBGT or WGT	--	--
Hydrogen cyanate/ cyanate salts	Filter plus bubbler. 0.8 μm cellulose ester membrane plus 10 ml. 0.1 N KOH. Flowrate 0.5 to 1 L/min. Sample size: (min) 10 L at 5 mg/m^3 (as CN^-); (max) 180 L at 11 mg/m^3 (as CN^-)	Ion-specific electrode	7904

Adapted from sampling and analytical methods as indicated by NIOSH criteria documents and Manual of Analytical Methods [286,287,288,289,290,291,292,293]

APPENDIX D. NIOSH sampling and analytical methods for foundry hazards--Continued

Hazard/Chemical	Methods		
	Sampling	Analytical	Number
Hydrogen fluoride	Filter plus treated filter. 0.8 μm cellulose ester membrane followed by a Na_2CO_3 treated cellulose pad. Flowrate 0.2 to 0.5 L/min. Sample size 3 to 100 L	Ion-specific electrode	7902
Hydrogen sulfide	Adsorption on molecular sieve. Sample size 5 liters. Flowrate 0.15 to 0.2 liters/min.	Gas chromatography with a flame photometric detector in the sulfur mode	296(6)
Inorganic fluorides	Solid sorbent tube. Washed silica gel, 400 mg/200 mg with glass fiber filter plug	Ion-chromatography	7903
Inorganic lead	Filter 0.8 μm cellulose ester membrane. Flowrate 1 to 4 L/min. Sample size 300 to 800 L	Atomic absorption, flame	7082
Inorganic mercury	Solid sorbent tube. 30 mg silvered Chromosorb P, with glass fiber prefilter. Flowrate 0.01 to 0.2 L/min. Sample size 0.5 to 7 L	Atomic absorption, flameless	6000
Iron and iron oxide	Filter. 0.8 μm cellulose ester membrane. Flowrate 1 L/min. Sample size 10 to 400 L	X-ray fluorescence	7200
Methyl alcohol	Solid sorbent tube. Silica gel, 100 mg/50 mg. Flowrate 0.02 to 0.2 L/min. Sample size 1 L (at 200 ppm) to 5 L	Gas chromatography, flame ionization detector	2000
Nitrogen oxides	Passive. Palmes tube with three triethanolamine-treated screens. Sampling time: (min) 15 min at 5 ppm; (max) 8 hr at 10 ppm	Visible absorption spectrophotometery	6700

Adapted from sampling and analytical methods as indicated by NIOSH criteria documents and Manual of Analytical Methods [286,287,288,289,290,291,292,293]

APPENDIX D. NIOSH sampling and analytical methods for foundry hazards--Continued

Hazard/Chemical	Methods		
	Sampling	Analytical	Number
Noise	'A' weighted sound level audiometer	--	--
Phenol	Bubbler. 0.1 N sodium hydroxide. Flowrate 0.2 to 1 L/min. Sample size 26 to 240 L	Gas chromatography, flame ionization detector	3502
Polycyclic aromatic hydrocarbons	Solid sorbent tube, coconut shell charcoal, 100 mg/50 mg. Flowrate and volume vary	Gas chromatography, flame ionization detector	1501
Sulfur dioxide	0.8 μm cellulose membrane filter/ midget impinger containing 15 ml-0.3 N hydrogen peroxide solvent	Titration, colorimetry	S308(4)
Toluene	Adsorption on charcoal in tube. Flowrate 0.20 liter/min. Desorption with carbon disulfide	Gas chromatography with flame ionization detector	S343
Trichloroethane (methyl chloroform)	Solid sorbent tube, coconut shell charcoal, 100 mg/50 mg. Flowrate 0.01 to 0.2 L/min. Sample size varies	Gas chromatography, flame ionization detector	1003
Triethylamine	Midget bubbler with 10 ml. 0.05 M sulfuric acid. Basification with 4 M sodium hydroxide	Gas chromatography, flame ionization detector	S152
Ultraviolet radiation	Phototubes and meters. Narrow band filters	--	--
Vanadium	Filter. 0.8 μm, cellulose ester membrane. Sample size 5 to 2,000 L	Inductively coupled argon plasma, atomic emission spectroscopy	7300

Adapted from sampling and analytical methods as indicated by NIOSH criteria documents and Manual of Analytical Methods [286,287,288,289,290,291,292,293]

APPENDIX D. NIOSH sampling and analytical methods for foundry hazards--Continued

Hazard/Chemical	Methods		
	Sampling	Analytical	Number
Xylene	Solid sorbent tube, coconut shell charcoal, 100 mg/50 mg. Flowrate $\leq$0.20 L/min. Sample size 12 to 23 L	Gas chromatography, flame ionization detector	1501
Zinc oxide	Filter. 0.8 μm PVC membrane, 25 mm diameter, in open-face cassette. Flowrate 1 to 3 L/min. Sample size 10 to 400 L	X-ray powder diffraction	7502

Adapted from sampling and analytical methods as indicated by NIOSH criteria documents and Manual of Analytical Methods [286,287,288,289,290,291,292,293]

APPENDIX E. NIOSH recommendations for medical monitoring for foundry hazards

Hazard	Medical recommendations	Reference
Acetylene	Monitoring as specified by criteria document	[264]
Ammonia	Monitoring as specified by criteria document	[77]
Antimony	Comprehensive physical exam, chest x ray, electrocardiogram, and pulmonary function studies	[266]
Asbestos	Chest x ray, pulmonary function studies, and monitoring as specified in NIOSH testimony	[294]
Benzene	Complete blood count (CBC) with indices	[78]
Cadmium	Chest x ray, pulmonary function studies, CBC, blood urea nitrogen, special blood studies, urinalysis, and monitoring as specified by current intelligence bulletin	[295]
Carbon dioxide	Monitoring as specified by criteria document	[270]
Carbon monoxide	Monitoring as specified by criteria document	[71]
Carbon tetrachloride	Ability to use appropriate respirators and liver function tests	[296]
Chlorine	Monitoring as specified by criteria document	[81]
Chromium (VI)	Chest x ray, sputum cytology, liver function tests, and urinalysis	[67]
Coal tar	Chest x ray, pulmonary function studies, sputum cytology, liver function tests, and urinalysis	[87]
Cresol	CBC, liver function tests, urinalysis, and monitoring as specified by criteria document	[271]

APPENDIX E. NIOSH recommendations for medical monitoring for foundry hazards--Continued

Hazard	Medical recommendations	Reference
Crystalline silica	Chest x ray and pulmonary function tests	[54]
Diphenylmethane diisocyanate (MDI)	Pulmonary function studies and monitoring as specified by criteria document	[82]
Formaldehyde	Ability to use appropriate respirators and monitoring as specified by current intelligence bulletin	[85]
Furfuryl alcohol	Ability to use appropriate respirators and monitoring as specified by criteria document	[86]
Hot environment	Monitoring as specified by criteria document	[97] [165]
Hydrogen cyanide/ cyanide salts	Ability to use appropriate respirators and monitoring as specified by criteria document	[276]
Hydrogen fluoride (Inorganic fluorides)	Visual tests, chest x rays, and pulmonary function tests	[277]
Hydrogen sulfide	Ability to use appropriate respirators and monitoring as specified by criteria document	[91]
Isopropyl alcohol	Chest x ray, ability to use appropriate respirators, liver function tests, and monitoring as specified by criteria document	[278]
Lead, inorganic	CBC, special blood studies, urinalysis, and monitoring as specified by criteria document	[64]
Methyl alcohol	Monitoring as specified by criteria document	[280]

APPENDIX E. NIOSH recommendations for medical monitoring for foundry hazards--Continued

Hazard	Medical recommendations	Reference
Nickel, inorganic	Chest x ray, pulmonary function studies, sputum cytology, and monitoring as specified by criteria document	[68]
Nitrogen oxides	Pulmonary function studies and ability to use appropriate respirators	[281]
Noise	Audiograms	[92]
Phenol	Ability to use appropriate respirators, CBC, and urinalysis	[282]
Sulfur dioxide	Ability to use appropriate respirators and monitoring as specified by criteria document	[90]
Toluene	CBC and urinalysis	[79]
Trichloroethane	Monitoring as specified by criteria document	[284]
Ultraviolet radiation	Monitoring as specified by criteria document	[98]
Vanadium	Chest x ray and pulmonary function studies	[285]
Xylene	CBC, liver function tests, and urinalysis	[80]
Zinc oxide	Monitoring as specified by criteria document	[66]

APPENDIX F. OSHA regulations pertaining to the foundry industry

Subpart D, Walking-working Surface; Sections:

- 1910.22-General requirements
- 1910.22(a)-Housekeeping
- 1910.23-Guarding floor and wall openings and holes
- 1910.24-Fixed industrial stairs
- 1910.25-Portable wood ladders
- 1910.26-Portable metal ladders
- 1910.27-Fixed ladders
- 1910.28-Safety requirements for scaffolding
- 1910.29-Manually propelled mobile ladder stands and scaffolds (towers)
- 1910.30-Other working surfaces

Subpart E, Means of Egress; Sections:

- 1910.36-General requirements
- 1910.37-Means of egress, general

Subpart F, Powered Platforms, Manlifts, and Vehicle-Mounted Work Platforms; Sections:

- 1910.66-Power platforms for exterior building maintenance
- 1910.67-Vehicle-mounted elevating and rotating work platforms
- 1910.68-Manlifts

Subpart G, Occupational Hazards and Environmental Control; Sections:

1910.94-Ventilation
- 1910.95-Occupational noise exposure
- 1910.96-Ionizing radiation

Subpart H, Hazardous Materials; Sections:

- 1910.101-Compressed gases (general requirements)
- 1910.102-Acetylene
- 1910.103-Hydrogen
- 1910.104-Oxygen

Subpart I, Personal Protective Equipment; Sections:

- 1910.132-General requirements
- 1910.133-Eye and face protection
- 1910.134-Respiratory protection
- 1910.135-Occupational head protection
- 1910.136-Occupational foot protection
- 1910.137-Electrical protective devices

Subpart J, General Environmental Controls; Sections:

- 1910.141-Sanitation
- 1910.144-Safety color code for marking physical hazards
- 1910.145-Specifications for accident prevention signs and tags

Subpart K, Medical and First Aid; Section:

- 1910.151-Medical services and first aid

Subpart L, Fire Protection; Sections:

- 1910.157-Portable fire extinguishers
- 1910.158-Standpipe and hose systems
- 1910.159-Automatic sprinkler systems
- 1910.160-Fixed extinguishing systems; general
- 1910.161-Fixed extinguishing systems, dry chemical
- 1910.163-Fixed extinguishing systems, water spray and foam

Subpart M, Compressed Gas and Compressed Air Equipment; Section:

- 1910.166-Inspection of compressed gas cylinders
- 1910.167-Safety relief devices for compressed gas cylinders
- 1910.168-Safety and relief devices for cargo and portable tanks storing compressed gases
- 1910.169-Air receivers

Adapted from 29 CFR 1910 [141]

APPENDIX F. OSHA regulations pertaining to the foundry industry--Continued

Subpart H, Hazardous Materials; Sections: Continued

- 1910.105-Nitrous oxide
- 1910.106-Flammable and combustible liquids
- 1910.107-Spray finishing using flammable and combustible materials
- 1910.108-Dip tanks containing flammable or combustible liquids
- 1910.110-Storage and handling of liquefied petroleum gases

Subpart O, Machinery and Machine Guarding; Sections:

- 1910.212-General requirements for all machines
- 1910.213-Woodworking machinery requirements
- 1910.215-Abrasive wheel machinery
- 1910.219-Mechanical power-transmission apparatus

Subpart P, Hand and Portable Powered Tools and Other Hand-held Equipment; Sections:

- 1910.242-Hand and portable powered tools and equipment, general
- 1910.243-Guarding of portable powered tools
- 1910.244-Other portable tools and equipment

Subpart N, Materials Handling and Storage; Entire Subpart.

Subpart Q, Welding, Cutting, and Brazing; Section:

- 1910.252-Welding, cutting, and brazing

Subpart S, Electrical; Entire Subpart.

Subpart Z, Toxic and Hazardous Substances; Sections:

- 1910.1000-Air Contaminants
- 1910.1001-Asbestos
- 1910.1025-Lead

Adapted from 29 CFR 1910 [141]

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