



Casting Emission Reduction Program

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**Draft of
Industrial Hygiene Aspects of Foundry
Processes
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Industrial Hygiene Aspects of Foundry Processes

Technikon# 1409-329

This report has been reviewed for completeness and accuracy and approved for release by the following:

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Acronyms

ACGIH	American Conference of Government Industrial Hygiene
BETX	Sum of Benzene, Ethylbenzene, Toluene & Xylene isomers
ECP	Ester Cured Phenolic
LOI	Loss on Ignition
OSHA	Occupational Safety Health Administration
PCS	Pouring, Cooling & Shakeout
PEL	Permissible Exposure Limit
PEP	Polyether Polyol
PU	Phenolic Urethane
PUCB	Phenolic Urethane Cold Box
PUNB	Phenolic Urethane No-Bake
SUM OF HAPs	Some of Hazardous Air Pollutants measured
SUM OF VOCs	Sum of Volatile Organic Compounds measured
TLV	Threshold Limit Value

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Executive Summary

This document is a draft of a paper that will be completed under FY2003 SOW and submitted for publication.

Workplace exposure to hazardous materials in the metal casting industry has been the topic of many publications and presentations over the last thirty (30) years. Most have focused on the physical hazards such as heat and physical stress, silica, and a limited number of organic components contained in or the result of decomposition of the various binder systems. Technikon LLC, a privately held contract research organization located in McClellan, California, a suburb of Sacramento operates the Casting Emission Reduction Program (CERP) under contract to the US Department of Defense. The research at the CERP has led to the development of analysis methods for many Hazardous Air Pollutants (HAP) that have not been reported in the technical literature. All testing was conducted in the Technikon Research Foundry in McClellan, California.

The CERP target analyte list contains over one hundred (100) specific compounds that are routinely measured to concentrations of ten (10) to one hundred (100) parts per billion. This report details those organic compounds emitted from major metal casting processes such as core making, mold making, and pouring, cooling and shakeout activities. The information is subdivided by the type of metal being cast, the chemistry of the binder system used to prepare the core or mold, and the type of molding or core making process. The specific compounds found in each scenario are ranked in order of the amount of compound emitted compared to the weight of metal cast, sand used, and /or binder used. Recommended methods for the determination of the emitted compounds are also listed with the respective OSHA PEL's and ACGIH TLV's to assist the reader in workplace monitoring activities.

The results of the testing conducted in the Technikon Research foundry are not suitable for use in establishing worker exposures or as general air emission factors. The specific materials used; the specific castings produced; the specific processes employed; and the specific testing conditions produce results unique to the Technikon Research foundry. The data produced are intended to demonstrate the relative potential for worker exposures from the use of alternative materials, equipment and processes. A number of process parameters such as casting surface area, sand to metal ratios, pouring temperatures, stack flow rates, ventilation, LOI levels, seacoal and resin contents, and the type of foundry can have a significant impact on actual emissions in the workplace.

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Introduction

This document is a draft of a paper that will be completed under FY2003 SOW and submitted for publication.

Since the inception of workplace exposure monitoring in the late 1960s and early 1970s, the literature has contained numerous reports of the hazardous airborne materials emitted by materials used in metal casting processes. Landmark work done by Scott, Bates, and James at Southern Research Institute¹⁻⁵ and others⁶⁻¹⁰ defined the initial effort to evaluate employee exposure to potentially hazardous emissions from foundry processes. Other more recent work may be found in references 11 through 14. This report does not seek to evaluate or recreate the work reported to the open literature. It does attempt to expand the reader's knowledge of what airborne emissions might be present in the metal casting workplace and suggests that product (material) substitution may be a viable work practice change that can reduce worker exposures in a cost effective and environmentally friendly manner. A table is provided at the end of this report that shows the entire CERP analyte list, CAS numbers, OSHA and ACGIH exposure limits, and the OSHA and NIOSH methods that may be used to determine the concentration of these analytes in the workplace.

The Casting Emission Reduction Program (CERP) is a cooperative initiative between the Department of Defense (US Army) and the United States Council for Automotive Research (USCAR). Its purpose is to evaluate alternative casting materials and processes that are designed to reduce air emissions and/or produce more efficient casting processes. Other technical partners directly supporting the project include: the American Foundry Society (AFS); the Casting Industry Suppliers Association (CISA); the US Environmental Protection Agency (US EPA); and the California Air Resources Board (CARB). The primary objective of CERP is to evaluate the impact of new materials, equipment, and processes on airborne emissions from the production of metal castings.

Although the CERP's primary mission involves the reduction of emissions to the environment outside the metal casting facility, the results can be very useful in understanding the environment inside the casting facility.

The following sections will provide a brief description of the greensand molding process, No-Bake and Precision Sand molding process and the Cold Box core making process. Emissions data in pounds of emission per pound of metal poured or pounds of emission per pound of binder used will be presented for several different systems. These data can be used by the industrial hygiene professional to estimate the total amount of emissions produced in his/her facility per unit time. Then, knowing the process capture efficiency, the amount of emissions entering the workplace can be estimated. The data can also be used to compare the emissions from different materials, the same materials in different processes or different parts of the same process. However, since the concentration of any material in a facility is specific to that facility, the industrial hygiene professional will still have to collect air samples to document worker exposure, if any, in a facility.

Finally, it is beyond the scope of this report to present all of the CERP data that has been produced from testing several thousand molds and cores. Therefore, this report only contains data on the most abundant compounds found. Detailed data and results for all of the identified compounds are available on the Technikon website at Technikonllc.com. Additional reports are posted on a regular basis.

RESEARCH FOUNDRY PROCESS

Mold Pouring, Cooling, and Shakeout

Figure 1 shows a diagram of the Research Foundry process.

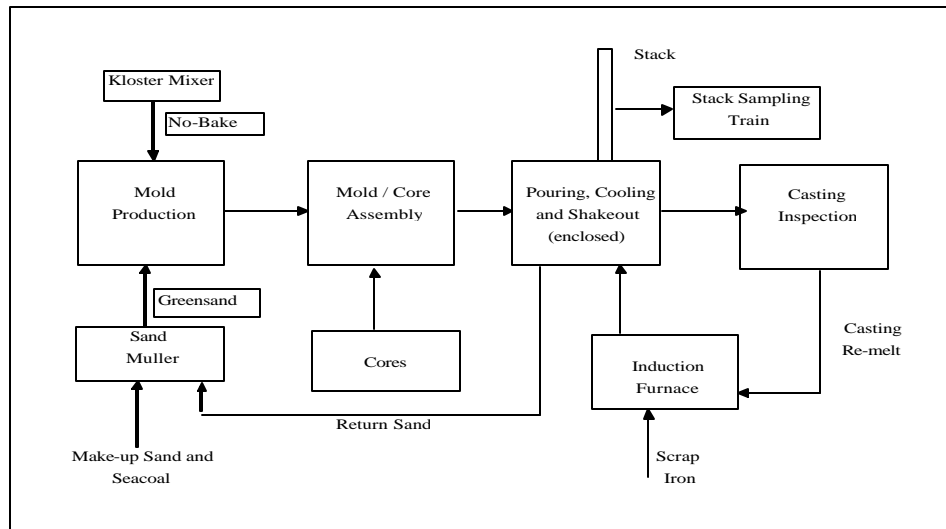


Figure 1 Foundry Process

GREENSAND MOLDING

Greensand molding has been used for many decades to produce molds for ferrous metal casting. It is still the primary molding method in large automotive iron foundries. The green sand used for iron castings consists of sand, bentonite clay, seacoal (finely ground bituminous coal), and water. There are many additives that affect the mold strength, density, and other properties. The one commonality is the presence of organic material such as the seacoal, cereal, sugar, lignite and/or other carbonaceous additive. It is this carbonaceous additive that produces the volatile emissions when the mold is poured with iron at 2,600°F to

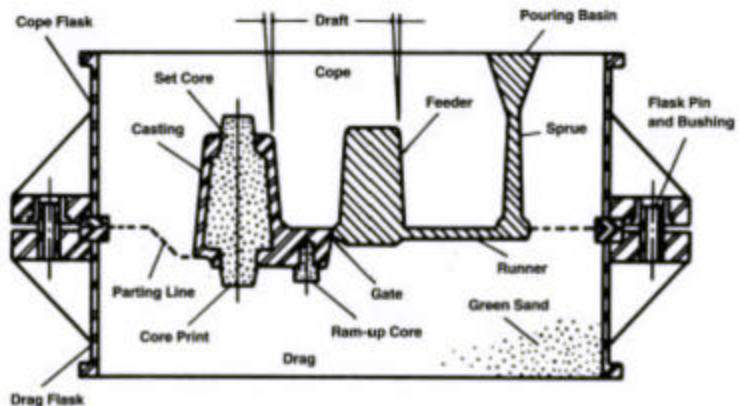


Figure 2 Greensand Mold with Core

2,700°F. Depending on the part being cast, the mold may or may not have a core. The following diagram shows the components of a mold containing a core.

The molds were prepared to a standard composition by the Technikon production team. Greensand was mixed in a muller and “hand rammed” into the mold. Figure 3 shows the type of greensand mold used for this study with inorganic (sodium silicate) cores installed.



Figure 3 Greensand Mold

DRY SAND MOLD SYSTEMS

No-Bake is the term given to those mold -making processes that use dry sand, a chemical binder and a liquid chemical catalyst instead of heat to initiate the cure of the binder system. The predominant binder chemistry used involves the reaction of a phenolic resin with a polymeric isocyanate. This reaction of a phenolic resin with a polymeric isocyanate produces a polymer that is referred to as a phenolic urethane. Other No-Bake binder systems use ester cured phenolic, furan, and polyether urethane chemistries. Precision sand molds are also dry sand molds that are produced via the Cold Box process. A brief description of the Cold Box process may be found in the following section entitled “Core Room”

The sand and binder for the dry sand molds were mixed with a Kloster ribbon mixer, discharged to a pattern box on a vibration table and, following cure, manually stripped and assembled.

Figure 4 shows the preparation of the dry sand No-Bake molds.



Figure 4 Dry Sand Molds

The completed molds are placed in a temporary total enclosure assembly that meets the criteria of US EPA Method 204. All pouring, cooling, and shakeout activities took place within the enclosure. Emissions were transported through a heated insulated stainless steel duct to the sampling location. Figures 5 and 6 show these locations.



Figure 5 **Mold Enclosure**

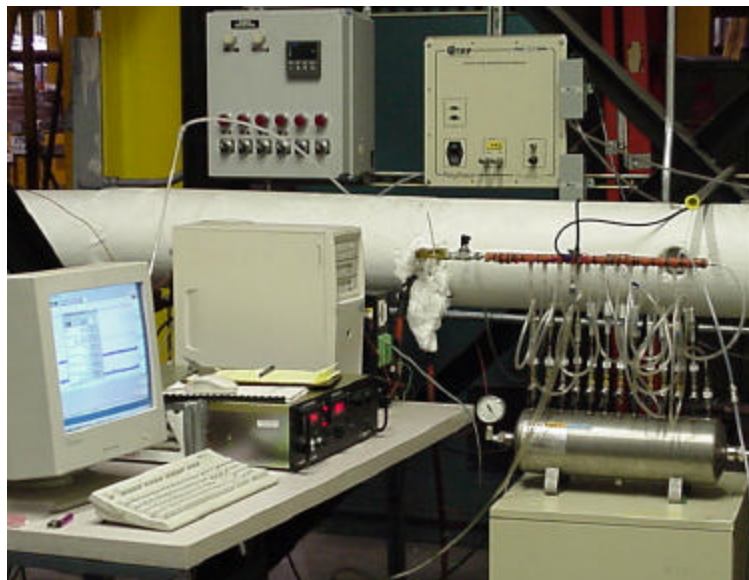


Figure 6 **Sampling Location**

CORE ROOM – COLD BOX

Cold Box is the term given to those core-making processes that use dry sand, a chemical binder and a gaseous chemical catalyst instead of heat to initiate the cure of the binder system. The predominant binder chemistry used involves the reaction of a phenolic resin with a polymeric isocyanate. This reaction of a phenolic resin with a polymeric isocyanate produces a polymer

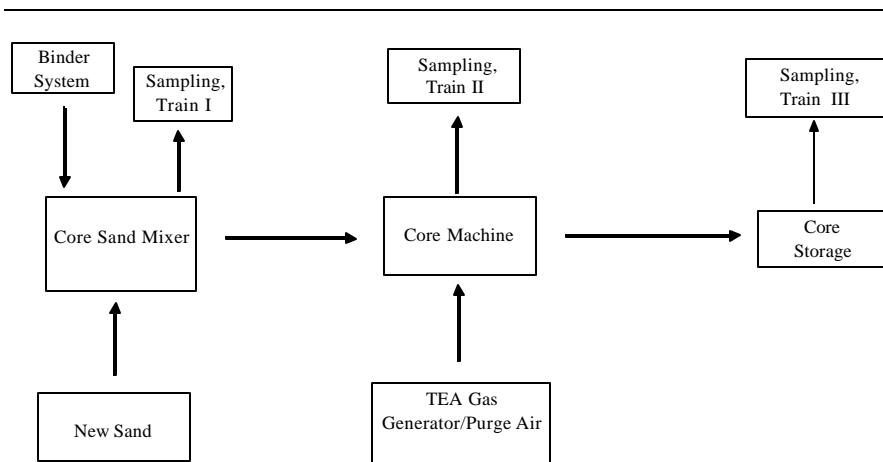


Figure 7 **Core Making Process**

that is referred to as a phenolic urethane. The primary Cold Box catalyst used is triethylamine although other tertiary amines such as dimethylethylamine and dimethylisopropylamine are also used. Other Cold Box chemistries include epoxy/acrylic binders with sulfur dioxide co-reactant and alkaline phenolics with either methyl formate or carbon dioxide co-reactant. These processes are also used to make “Precision Mold” packages.

These processes are also used to make “Precision Mold” packages.

The core room emissions studies presented were all conducted on the phenolic urethane Cold Box process. Figure 7 shows the core making process.

SAND MIXING

Sand was mixed with quantities of designated binder in a covered fifty (50) pound capacity paddle type cylindrical mixer. A mixer cover was fabricated out of 0.25-inch polymethyl-methacrylate and positioned approximately 0.06 inches above the mixer rim. The covered mixer met US EPA Method 204 criteria as a temporary total enclosure. The headspace of the mixer was continuously sampled through a stainless steel probe that was located approximately 0.5 inches below the cover. Figure 8 shows the mixer with the sample probe exiting the mixer to the left.



Figure 8 Sand Mixing

CORE MAKING

Sand for step cores was prepared in the mixer and discharged into the Redford-Carver core machine hopper (see Figure 8). The sand is then introduced (blown) into the machine's single cavity core box. The core-making machine was contained in a temporary total enclosure TTE meeting US EPA Method 204 criteria. An aliquot of the triethylamine (TEA) gas catalyst was heated to 84°F and allowed to expand into the piping leading to the core box. Finally, heated purge air pushed the catalyst through the sand in the core box to cure the binder creating the solid core. All gases were exhausted to a wet gas scrubber charged with sulfuric acid at pH 2 or less. The sampling location was in the exhaust line to the scrubber. Figure 9 shows the enclosed core machine and Figure 10 the sampling location.



Figure 9 Core Machine in TTE

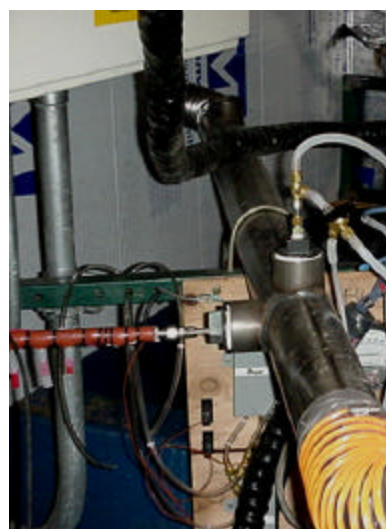


Figure 10 Sampling location

CORE STORAGE

The storage segment of the study consisted of placing one (1) core in each of four (4) individual storage flow-through sampling enclosures as soon as the cores are removed from the core machine. Replacement air was allowed to enter under the lower edge of the enclosure through a regulated annular gap to replace the sample air extracted from the top. Both the air temperature and velocity through the enclosures could be varied. Figure 11 shows the storage domes and sampling apparatus.



Figure 11 Storage Domes and Sampling Apparatus

Results

The results section of this report, as presented in tables, is divided into greensand and dry sand emissions for pouring, cooling and shakeout (PCS) activities and emissions from core making activities. In addition to the amounts of the most abundant specific compounds, the following tables include other data such as the Sum of VOCs and the Sum of HAPs. The dry sand pouring/cooling/shakeout results and the core room results also show results for "Total Aromatic Petroleum Distillate." This is primarily the volatile solvents from the binder system being tested but, for the dry sand PCS, also includes the binder thermal decomposition products such as BETX.

Table 1 Greensand PCS Emissions in Pounds per Ton of Metal Poured

Analyte	Greensand with Sea- coal Iron	Greensand with Seacoal Replacement Iron	Greensand with Seacoal Replacement Iron	Greensand with Seacoal Replacement Iron	Greensand with PU Core A Iron	Greensand with PU Core B Iron	Greensand with PU Core Aluminum
Sum of VOCs	0.4722	0.3305	0.1896	0.1607	0.471	0.324	0.230
Sum of HAPs	0.3160	0.2533	0.1571	0.1084	0.316	0.263	0.154
Benzene	0.1244	0.0793	0.0566	0.0389	0.139	0.125	0.006
Toluene	0.0836	0.0547	0.0392	0.0244	0.032	0.028	0.005
Aniline	ND	ND	ND	ND	0.092	0.058	0.019
o,m,p-Xylene	0.0620	0.0430	0.0219	0.0217	0.016	0.010	ND
Aniline	ND	ND	ND	ND	0.092	0.058	0.019
Phenol	0.0046	0.0054	0.0020	0.0017	0.014	0.012	0.062
Ethyl Benzene	0.0099	0.0065	0.0046	0.0030	0.002	0.001	ND
Naphthalene	0.0153	0.0034	0.0013	0.0008	0.023	0.003	0.026
Acetaldehyde	0.0077	0.0387	0.0238	0.0121	0.006	0.015	0.009
o,m,p-Cresol	ND	ND	ND	ND	0.005	0.007	0.018
Trimethylbenzenes	ND	ND	ND	ND	0.063	0.025	0.044

Table 2 No-Bake Dry Sand PCS Emissions in Pounds per Ton of Metal Poured

Analytes	PUNB A Iron	PUNB B Iron	PUNB C Iron	PUNB D Iron	PUNB E Iron	ECP B Iron	Furan A Iron	Furan B Iron	Furan C Iron	PUNB F Aluminum	PEP A Aluminum
Total Aromatic Petroleum Distillates	11.1	3.91	3.63	11.0	4.76	2.37	1.72	1.46	1.03	30.0	0.951
Sum of VOCs	4.06	1.47	1.64	1.73	1.80	0.901	1.10	1.10	0.958	6.48	0.342
Sum of HAPs	2.00	1.23	1.45	1.16	1.37	0.803	1.08	1.08	0.934	1.79	0.282
Phenol	0.942	0.591	0.843	0.718	0.618	0.121	0.044	0.275	0.032	0.310	0.021
o,m,p – Cresol	0.500	0.029	0.102	0.058	0.026	0.047	ND	0.001	ND	0.889	ND
Benzene	0.299	0.277	0.266	0.229	0.29	0.318	0.818	0.670	0.625	0.004	0.004
Dimethylnaphthalenes	0.086	0.004	<0.001	0.012	0.003	0.001	ND	ND	ND	0.020	0.016
Toluene	0.056	0.047	0.044	0.045	0.048	0.054	0.106	0.074	0.086	0.009	0.011
Naphthalene	ND	0.183	0.089	ND	0.28	0.015	ND	ND	ND	0.262	0.017
Formaldehyde	0.021	0.027	0.024	0.019	0.024	0.084	0.025	0.034	0.035	0.001	0.009
Acetaldehyde	0.004					0.069	0.066	0.020	0.157	0.091	0.114
o,m,p- xylene	0.031	0.024	0.015	0.028	0.033	0.032	ND	ND	ND	0.009	0.005
Dimethylphenol	1.07	0.025	0.001	0.001	0.042	0.032	ND	ND	DN	3.65	ND
Dimethylbenzene	0.299	0.051	0.025	0.051	0.068	BD	ND	ND	ND	ND	0.026
Trimethylbenzene	0.216	0.092	0.062	0.103	0.146	0.013	ND	ND	ND	0.146	0.005
Tetradecane	0.141	ND	0.003	0.187	0.002	ND	ND	ND	ND	ND	ND
Butylbenzene	0.116	ND	0.002	<0.001	0.004	ND	ND	ND	ND	ND	ND
Dodecane	0.060	ND	ND	0.038	0.038	ND	ND	ND	ND	ND	ND
Indan	0.057	0.019	0.023	0.057	0.028	ND	ND	ND	ND	0.286	ND
Undecane	0.033	ND	0.006	0.016	ND	ND	ND	ND	ND	ND	ND
Butyraldehyde/ Methacrolein	0.021	0.034	0.020	0.020	0.032	0.013	ND	ND	ND	0.003	0.011
Carbon Monoxide	4.18	ND	5.44	4.11	ND	4.32	5.99	5.33	5.62	0.84	ND

Table 3 Core Mixing Emissions in Pounds per Pound of Binder

Core Mixing	PUCB A	PUCB B	PUCB C	PUCB D	PUCB E
Total Aromatic Petroleum Distillates	0.0021	< 0.0001	0.0006	0.0012	0.0017
Phenol	< 0.0001	< 0.0001	<0.0001	0.0001	ND
Formaldehyde	< 0.0001	< 0.0001	<0.0001	<0.0001	ND
Propylene Carbonate	NA	0.0001	NT	NT	NT
o,m,p - Cresol	NA	ND	<0.0001	ND	ND
Naphthalene	ND	NA	ND	ND	ND
1- Me Naphthalene	ND	NA	ND	ND	ND
2- Me Naphthalene	ND	NA	ND	ND	ND
Tetraethyl Silicate	NT	NT	0.0013	NT	NT

Table 4 Core Making Emissions in Pounds per Pound of Binder

Core Making	PUCB A	PUCB B	PUCB C	PUCB D	PUCB E
Total Aromatic Petroleum Distillates	0.0752	0.0436	0.0276	0.0643	0.0569
Sum of VOCs	0.0014	0.0005	0.0137	0.0021	0.0004
Sum of HAPs	0.0014	0.0005	0.0002	0.0021	0.0004
Phenol	0.0003	0.0003	0.0001	0.0005	0.0003
Formaldehyde	0.0001	< 0.0001	<0.0001	<0.0001	0.0001
Propylene Carbonate	ND	0.0002	NT	NT	NT
o,m,p - Cresol	ND	ND	0.0001	ND	<0.0001
Naphthalene	0.0004	NA	ND	0.0005	ND
1- Me Naphthalene	0.0003	NA	ND	0.0004	ND
2- Me Naphthalene	0.0004	NA	ND	<0.0001	ND
Tetraethyl Silicate	NT	NT	0.0137	NT	NT

Table 5 Core Storage Emissions in Pounds per Pound of Binder

Core Storage	PUCB A	PUCB B	PUCB C	PUCB D	PUCB E
Total Aromatic Petroleum Distillates	0.0171	0.0074	0.0053	0.0217	0.0069
Sum of VOCs	0.0008	0.0002	0.0069	0.0011	ND
Sum of HAPs	0.0008	0.0002	<0.0001	0.0011	ND
Phenol	ND	ND	ND	<0.0001	ND
Formaldehyde	< 0.0001	< 0.0001	<0.0001	<0.0001	ND
Propylene Carbonate	NA	0.0002	NT	NT	NT
o,m,p - Cresol	NA	NA	ND	ND	ND
Naphthalene	0.0002	NA	ND	0.0004	ND
1- Me Naphthalene	0.0003	NA	ND	0.0004	ND
2- Me Naphthalene	0.0003	NA	ND	0.0002	ND
Tetraethyl Silicate	NT	NT	0.0069	NT	NT

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Conclusions

This report contains a compilation of emission data from testing at the CERP. The primary systems in use in foundries, Green Sand, PUNB and PUCB have been evaluated in detail. The data shows that there are significant differences in the emissions from the various molds, binders, and metal systems tested. Therefore, the potential for employee exposure in the workplace may vary greatly. The data also show that judicious selection of materials can be an effective tool to minimize the environmental impact of metal casting emissions while continuing to produce quality product.

Table 6 with the complete CERP analyte list follows.

Table 6 CERP Analyte List

Compound	CAS #	OSHA PEL		OSHA Ceiling		ACGIH TWA		Methods	
		ppmv	mg/m ³	ppmv	mg/m ³	ppmv	mg/m ³	OSHA	NIOSH
1,2,3-Trimethylbenzene	526-73-8	Note 1	Note 1			25	102	1005	1500
1,2,4-Trimethylbenzene	95-63-6	Note 1	Note 1			25	102	1005	1500
1,2-Dimethylbenzene	135-01-3	Note 1	Note 1			Note 3	Note 3	1005	1500
1,2-Dimethylnaphthalene	573-98-8	Note 1	Note 1			Note 3	Note 3	1005	1500
1,3,5-Trimethylbenzene	108-67-8	Note 1	Note 1			25	102	1005	1500
1,3-Dimethylbenzene	141-93-5	Note 1	Note 1			Note 3	Note 3	1005	1500
1,3-Diisopropylbenzene	99-62-7	Note 1	Note 1			Note 3	Note 3	1005	1500
1,3-Dimethylnaphthalene	575-41-7	Note 1	Note 1			Note 3	Note 3	1005	1500
1,4-Dimethylbenzene	105-05-5	Note 1	Note 1			Note 3	Note 3	1005	1500
1,4-Dimethylnaphthalene	571-58-4	Note 1	Note 1			Note 3	Note 3	1005	1500
1,5-Dimethylnaphthalene	571-61-9	Note 1	Note 1			Note 3	Note 3	1005	1500
1,6-Dimethylnaphthalene	575-43-9	Note 1	Note 1			Note 3	Note 3	1005	1500
1,8-Dimethylnaphthalene	569-41-5	Note 1	Note 1			Note 3	Note 3	1005	1500
1-Methylnaphthalene	90-12-0	Note 1	Note 1			Note 3	Note 3	1005	1500
2,3,5-Trimethylnaphthalene	2245-38-7	Note 1	Note 1			Note 3	Note 3	1005	1500
2,3,5-Trimethylphenol	697-82-5	Note 2	Note 2					32	2002
2,3-Dimethylnaphthalene	581-40-8	Note 1	Note 1			Note 3	Note 3	1005	1500
2,3-Dimethylphenol	526-75-0	Note 2	Note 2					32	2002
2,4,6-Trimethylphenol	527-60-6	Note 2	Note 2					32	2002
2,4-Dimethylphenol	105-67-9	Note 2	Note 2					32	2002
2,5-Dimethylphenol	95-87-4	Note 2	Note 2					32	2002
2,6-Dimethylnaphthalene	581-42-0	Note 1	Note 1			Note 3	Note 3	1005	1500
2,6-Dimethylphenol	576-26-1	Note 2	Note 2					32	2002
2,7-Dimethylnaphthalene	582-16-1	Note 1	Note 1			Note 3	Note 3	1005	1500
2-Ethyltoluene	611-14-3	Note 1	Note 1					1005	1500

Table 6 CERP Analyte List

Compound	CAS #	OSHA PEL		OSHA Ceiling		ACGIH TWA		Methods	
		ppmv	mg/m ³	ppmv	mg/m ³	ppmv	mg/m ³	OSHA	NIOSH
2-Methylnaphthalene	91-57-6	Note 1	Note 1			Note 3	Note 3	1005	1500
3,4-Dimethylphenol	95-65-8	Note 2	Note 2					32	2002
3,5-Dimethylphenol	108-68-9	Note 2	Note 2					32	2002
3-Ethyltoluene	620-14-4	Note 1	Note 1			Note 3	Note 3	1005	1500
4-Ethyltoluene	622-96-8	Note 1	Note 1			Note 3	Note 3	1005	1500
Acenaphthalene	208-96-8	Note 2	Note 2						5506
Acetaldehyde	75-07-0	200	360					81	2016
Acrolein	107-02-8	0.1	0.25					81	2016
a-Methylstyrene	98-83-9			100	480	50	241	1005	1500
Aniline	62-53-3	5	19			2	7.6	PV2079	2002
Benzaldehyde	100-52-7							52	2016
Benzene	71-43-2	10	32	25	????	0.5	1.6	1005	1500
Biphenyl	92-52-4	0.2	1			0.2	1.3	1005	1500
Butylbenzene	104-51-8					Note 3	Note 3	1005	1500
Butyraldehyde	123-72-8							81	2016
Crotonaldehyde	123-73-9	2	6					81	2016
Cumene	98-82-8	50	245			50	245	1005	1500
Cyclohexane	110-82-7	300	1050			100	344	1005	1500
Decane	124-18-5							1005	1500
Dodecane	112-40-3							1005	1500
Ethylbenzene	100-41-4	100	435			100	434	1005	1500
Formaldehyde	50-00-0	0.75	0.92	2	2.5			81	2016
Heptane	142-82-5	500	2,000			400	1,636	1005	1500
Hexaldehyde	66-25-1							81	2016
Hexane	110-54-3	500	1,800			50	176	1005	1500

Table 6 CERP Analyte List

Compound	CAS #	OSHA PEL		OSHA Ceiling		ACGIH TWA		Methods	
		ppmv	mg/m ³	ppmv	mg/m ³	ppmv	mg/m ³	OSHA	NIOSH
Indan	496-11-7							1005	1500
Indene	95-13-6					10	47	1005	1500
Isobutylbenzene	538-93-2	Note 1	Note 1			Note 3	Note 3	1005	1500
m,p-Cresol	108-39-4	5	22			5	22	32	2002
p-Cresol	106-44-5	5	22			5	22	32	2002
m,p-Xylene	108-38-3	100	435			100	434	1005	1500
p-Xylene	106-42-3	100	435			100	434	1005	1500
Methacrolein	78-85-3							81	2016
2-Butanone (Methylethylketone)	78-93-3	200	590			200	589	81	2016
N,N-Dimethylaniline	121-69-7	5	25			5	25	PV 2079	2002
Naphthalene	91-20-3	10	50			10	52	1005	1500
Nonane	111-84-2							1005	1500
n-Propylbenzene	103-65-1	Note 1	Note 1			Note 3	Note 3	1005	1500
o-Cresol	95-48-7	5	22			5	22	32	2002
Octane	111-65-9	500	2,350			300	1,399	1005	1500
o-Xylene	95-47-6	100	435			100	434	1005	1500
p-Cymene	99-87-6							1005	1500
Pentanal	110-62-3					50	180	81	2016
Phenol	108-95-2	5	19			5	19	32	2002
Propionaldehyde	123-38-6					20	47	81	2016
Propylbenzene	103-65-1	Note 1	Note 1			Note 3	Note 3	1005	1500
sec-Butylbenzene	135-98-8	Note 1	Note 1			Note 3	Note 3	1005	1500
Styrene	100-42-5	100	425	200	850	20	85	1005	1500
tert-Butylbenzene	98-06-6	Note 1	Note 1			Note 3	Note 3	1005	1500
Tetradecane	629-18-6							1005	1500

Table 6 CERP Analyte List

Compound	CAS #	OSHA PEL		OSHA Ceiling		ACGIH TWA		Methods	
		ppmv	mg/m ³	ppmv	mg/m ³	ppmv	mg/m ³	OSHA	NIOSH
o,m,p-Tolualdehyde	1334-78-7							81	2016
Toluene	108-88-3	200	752	300	1,128	50	188	1005	1500
Tridecane	629-50-5							1005	1500
Undecane	1120-21-4							1005	1500
Carbon Monoxide	630-08-0	50	55			25	29		ASTMD-1945
Pentane	109-66-0	1,000	2,950			600	1,767		ASTMD-1945
Neopentane	463-82-1					600	1,767		ASTMD-1945
Isopentane	78-78-4					600	1,767		ASTMD-1945
Isobutane	75-28-5					1,000	2,372		ASTMD-1945
Propane	74-98-6					1,000	1,800		ASTMD-1945
Diethylene Glycol Monobutyl Ether	112-34-5							7	2549
Acetic Acid	64-19-7	10	25			10	25	ID186SG	2011
Formic Acid	64-78-6	5	9			5	9.4	ID186SG	2011
Furfural	98-01-1	5	20			2	7.9	72	2539
Furfuryl Alcohol	98-00-0	50	200			10	40		2505
Tetra Ethyl Silicate	78-10-4	100	850			10	85		S 264
Triethylamine	121-44-8	25	100			1	4	PV2060	2010
Trimethylol Propane Triacrylate	15625-89-5							55	
1,6-Hexanediol Diacrylate	13048-33-4							55	
Propylene Carbonate	108-32-7							1005	1500
Total Aromatic Petroleum Distillates as Hexane	110-54-3	Note 1	Note 1			Note 3	Note 3	48	1500

Note 1: These compounds do not have individual PELs. They are constituents of Aromatic Petroleum Distillates. Stoddard solvent (CAS#8052-41-3) PEL of 500 ppmv (2,900 mg/m³) has been used as a reference.

Note 2: These compounds do not have individual PELs. They are constituents of Naphtha (Coal Tar). Naphtha (Coal Tar) has a PEL of 100 ppmv (400 mg/m³).

Note 3: These compounds do not have individual TWAs. They are constituents of Aromatic Petroleum Distillates. Stoddard solvent (CAS#8052-41-3) TWA of 100 ppmv (580 mg/m³) has been used as a reference.

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