Casting Emission Reduction Program

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Significant Reduction in the Emission Characteristics Of the Green Sand Process

Technikon # 1411-318

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Technikon # 1411-318

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1.0 Abstract

As a result of the metal casting process, emissions are generated by the thermal decomposition of organic material in the greensand and, if cores are present decomposition of the core binder. Through changes in the blended minerals in the green sand molds, the addition of minerals to the prepared core sand, and selection of the green sand release agents, significant reductions in VOCs, HAPs, carbon monoxide, and carbon dioxide emissions can be accomplished. This reduction in emissions has been determined during actual metal casting with advanced analytical methods and equipment that have been developed by Technikon for the Casting Emission Reduction Program (CERP) in Sacramento, California.

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2.0 Introduction

During the last ten (10) years, a number of development studies have been completed at various foundries, technical centers, universities, and research facilities on the emission characteristics of foundry processes (LaFay, Neltner, April 2002). For this particular investigation, a series of studies has been completed at Technikon, which operates CERP, that supplies valuable information that was utilized to develop the significant reduction in the emission characteristics of the green sand process. These studies review the characteristics of the emissions that were the result of the metal casting process from the green sand, green sand release agents, contribution of the emission characteristics from the core process (and the subsequent return of the core material into the green sand) and the greensand release agents. Each one of these processes contributes uniquely to the emission characteristics, so they were investigated individually. Table 1 summarizes the test protocol used for the development of a baseline data set that was used to evaluate the emission reductions from the greensand/core/mold release system being tested.

Table 1 Testing Parameters

Type of Process tested	Coated Core, Greensand with Seacoal, Iron PCS Baseline	Coated Core with Anti-Vein Greensand Graphite Parting Spray, Iron PCS
Test Plan Number	1411 121 GB	8011 001 GC
Greensand System	Wexford W450, Western and Southern Bentonite, Seacoal	Wexford W450 and H&G Premix
Metal Poured	Iron	Iron
Casting Type	4-on Step Core	4-on Step Core
Core Binder	1.4% Ashland ISOCURE® 305/904	1.4% Ashland ISOCURE® 305/904
Core Coating	Ashland Velvaplast® CGW 9022SL	Ashland Velvaplast® CGW 9022SL
Anti-Veining Material	None	5% H&G Vein Away HT
Parting Spray	Petroleum Oil Based	H & G AQUA PART® II Graphite
Number of molds poured	3 Conditioning + 9 Sampling	3 Conditioning + 3 Sampling
Test Dates	7/14/04 > 7/16/04	8/9/04 > 8/10/04
Emissions Measured	TGOC as Propane, HC as Hexane, 68 Organic HAPs and Target Analytes	TGOC as Propane, HC as Hexane, 68 Organic HAPs and Target Analytes
Process Parameters Measured	Total Casting, Mold, Binder Weights; Metallurgical data, % LOI; Stack Temperature, Moisture Content, Sand Temperature, Pressure, and Volumetric Flow Rate	Total Casting, Mold, Binder Weights; Metallurgical data, % LOI; Stack Temperature, Moisture Content, Sand Temperature, Pressure, and Volumetric Flow Rate

3.0 Investigations That Contributed To Final Test Evaluation

3.1 CONTRIBUTION OF GREEN SAND EMISSION CHARACTERISTICS WITHOUT SEACOAL AND RELEASE AGENTS

A series of investigations was completed to evaluate the contribution of green sand release agents on the emission characteristics that occurs during the metal casting process. The materials that were investigated included: petroleum oil based green sand release agent, vegetable oil based green sand release agent, and water based green sand release agent containing graphite. These products are commercially available and widely used materials that can be used in molding machines and spray application devices (LaFay, Neltner, 2002).

For this investigation, there are a number of specific details that require discussion. The first consideration was the selection of the casting that was used in the metal casting process. The team selected the star casting design that was produced on an Osborn Molding Machine (Figures 1, 2, and 3).

The molding sand was prepared without seacoal and contained only a blend of 5:2 ratio of Western (Sodium) Bentonite and Southern (Calcium) Bentonite at 7% with 40 to 45% compactability. Without the Seacoal present, the investigators had the opportunity to determine the contribution of the green sand release agents to the emission characteristics. In this series of investigations, 40 grams of green sand release agent was added to the surface of the pattern

Figure 1 Osborn Molding Operation

Figure 2 Star Castings (4 on pattern)

Figure 3 Individual Star Casting

so that each of the materials could be investigated under the same conditions (Figures 4 and 5).

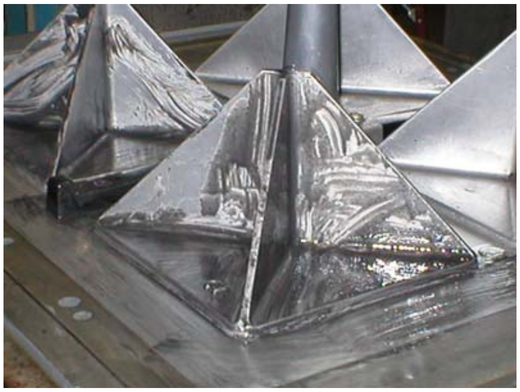

Figure 4 Green Sand Release Agent on Pattern

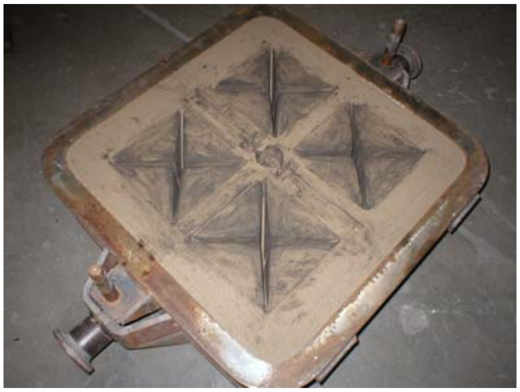

Figure 5 Release Agent (Transferred) on Mold

The following graphical emissions data was collected from pouring, cooling and shakeout of this combination of materials (Figure 6).

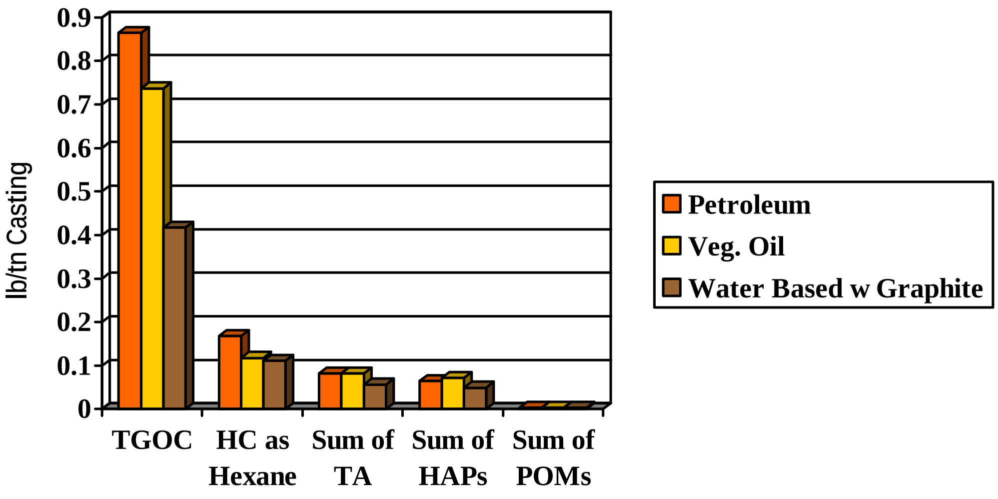

Figure 6 Emission Characteristics of Green Sand Release Agents

3.2 CONTRIBUTION OF MINERAL ADDITIVES INTO THE PREPARED CORE SAND AND THE RESULTING EMISSION CHARACTERISTICS

Another series of investigations were completed to determine the effect that mineral additives have upon the emission characteristics of core sand and the return of the core sand into a green sand molding system. For this investigation, the same molding equipment was utilized; however, a step core pattern (4 on) was used (Figure 7, 8, 9 and 10). The molding sand was prepared with the same ratio of Western (Sodium) Bentonite to Southern (Calcium) Bentonite at the 7% clay level and 40 to 45% compactability. In this investigation, Seacoal was added at the level of 5.4% to simulate traditional molding sand and a petroleum based green sand release agent was utilized.

Figure 7 Osborn Pattern

Figure 8 Sample Core containing Additive

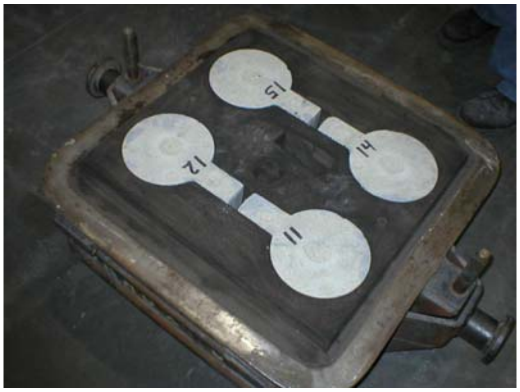

Figure 9 Mold containing Cores

Figure 10 Step Castings Produced

The core sand mixture was prepared with a 1.4% phenolic urethane binder in silica sand containing various levels of minerals added to determine the impact that these minerals had upon the emission characteristics. The minerals were selected based upon the chemistry of the products and were added based upon the recommendation of the manufacturer in the published data sheets. The minerals additives included: a ceramic aluminum silicate, red iron oxide, black iron oxide, and a blended product containing organic and inorganic materials. Table 2 contains a listing of the additives and the selected addition rates. Figure 11 is a graphical representation of the resulting emission characteristics determined from the study.

Table 2 Core Sand Additives and Addition Rates

Core Sand Additive	Percentage BOS
Red Iron Oxide	1.0
Black Iron Oxide	2.0
Aluminum Silicates	5.0
Blended Material	1.5

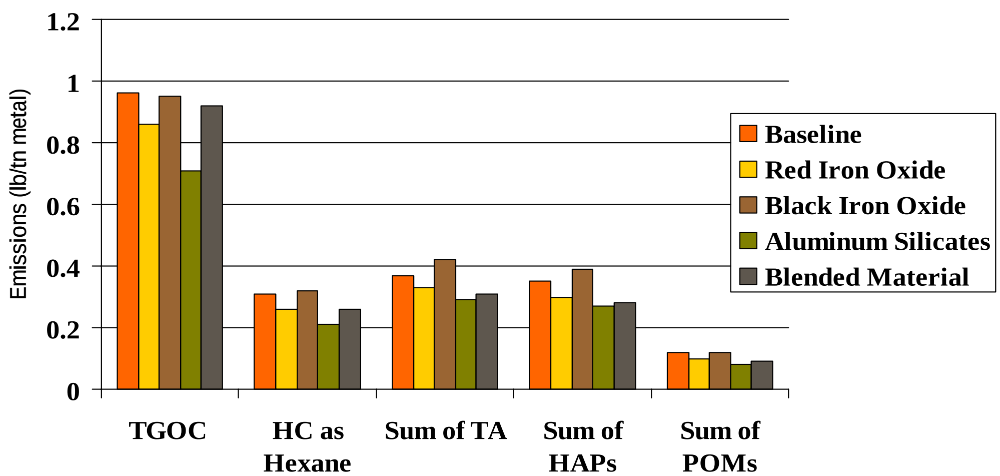

Figure 11 Emissions Characteristics of Core Sand Additives

4.0 Test Evaluation Utilizing Information from Previous Studies

In order to significantly reduce the emission characteristics from foundry molding sand, core sand, and subsequent return of the core sand into molding sand, the reduction in selected materials, addition of minerals into the core sand, and changes in the molding process have to occur. For this investigation the following materials were utilized:

1. A water-based green sand release agent containing graphite was used. The graphite would eliminate the need for development of lustrous carbon on the mold metal interface during the metal casting process (LaFay, Neltner, 2004).
2. All of the Seacoal was removed from the molding sand. Cellulose was added to the green sand to reduce mold wall movement.
3. A predominately Western (Sodium) Bentonite sand system was used with the addition of a molding sand additive to enhance the performance of the bentonite.
4. A blended aluminum silicate mineral was added to the phenolic urethane core sand mixture at a 5% level.

A casting study was completed utilizing this mix of materials. The green sand molds (without seacoal) were prepared with 96.5% Western (sodium) Bentonite, 3% Cellulose, 0.5% Soda Ash, and 240 ounces (per ton of prepared preblend) of a polymeric additive that is utilized to enhance performance of the Bentonite at 7% with a 40 to 45% compactability. The cores were produced with a phenolic urethane binder system at 1.4% binder with the addition of a blended aluminum silicate mineral additive. The molding sand and cores were prepared and cast in a controlled environment to evaluate the emission characteristics of the combined processes (Figures 12 and 13).

Figure 12 Prepared Molds and Cores

Figure 13 CERP Testing

Table 3 shows comparison process data for the baseline test that consisted of cored greensand molds (Test GB) and the casting study that is the subject of this paper (Test GC).

Table 4 and Figures 14, and 15 show the emission results from this casting study in tabular form (Table 4) and graphical form showing summary data (Figure 14), and individual target analyte data (Figure 15). The % Changes in **bold** have a 95% confidence interval that the changes are statistically valid and not the result of test variability.

The data in Table 4 show a significant reduction in VOC, HAPs, carbon monoxide, and carbon dioxide emissions from the test mix compared to the selected baseline.

Table 3 Process Data Comparison

Greensand PCS		
	Test GB	**Test GC**
Test Dates	**7/15-16/04**	**8/9-10/04**
Cast Weight (all metal inside mold), Lbs.	**106.45**	**109.33**
Pouring Time, sec.	**24**	**15**
Pouring Temp ,°F	**2633**	**2630**
Pour Hood Process Air Temp at Start of Pour, °F	**86**	**88**
Core Mixer auto dispensed batch weight, Lbs	**49.08**	**50**
Calibrated auto dispensed core binder weight, Lbs	**0.69**	**0.70**
Core binder calibrated weight, %BOS	**1.41**	**1.40**
Core binder calibrated weight, %	**1.39**	**1.38**
Total uncoated core weight in mold, Lbs.	**29.61**	**29.15**
Total binder weight in mold, Lbs.	**0.41**	**0.40**
Core LOI, %	**1.15**	**1.48**
Weight of H& G VeinAway HT, Lbs.	**NA**	**1.37**
Total dried core coating weight in mold. Lbs	**0.36**	**0.13**
Dogbone tensile test (Thwing-Albert psi)	**236**	**202**
Core age, hrs.	**75**	**138**
Muller Batch Weight, Lbs.	**944**	**904**
H & G Premix. Lbs.	**NA**	**3.8**
GS Mold Sand Weight, Lbs.	**615**	**635**
Weightof H&G AquaPart II-graphite mold rel., gm	**NA**	**40.4**
Mold compactability, %	**55**	**56**
Mold Temperature, °F	**83**	**89**
Average Green Compression , psi	**21.4**	**21.9**
GS Compactability, %	**49**	**49**
GS Moisture Content, %	**2.51**	**2.70**
GS MB Clay Content, %	**7.49**	**7.78**
MB Clay reagent, ml	**28.9**	**30.0**
1800°F LOI - Mold Sand, %	**5.30**	**1.31**
900°F Volatiles , %	**0.51**	**0.41**

Table 4 Comparison of Emission Results

Analytes	Test GB Lb/Tn Metal	Test GC Lb/Tn Metal	% Change from Test GB
TGOC as Propane	2.454	1.191	**-51**
HC as Hexane	0.8289	0.4250	**-49**
Sum of Target Analytes	0.6581	0.3558	**-46**
Sum of HAPs	0.5484	0.3204	**-42**
Sum of POMs	0.0565	0.0535	-5
Individual Organic HAPs			
Benzene	0.1821	0.0707	**-61**
Toluene	0.0773	0.0196	**-75**
Phenol	0.0773	0.0755	-2
o,m,p-Xylene	0.0555	0.0118	**-79**
o,m,p-Cresol	0.0377	0.0309	**-18**
Methylnaphthalenes	0.0256	0.0267	4
Aniline	0.0213	0.0299	**40**
Naphthalene	0.0203	0.0129	**-36**
Hexane	0.0167	0.0032	**-81**
Dimethylnaphthalenes	0.0105	0.0139	**32**
Ethylbenzene	0.0096	0.0016	**-83**
Acetaldehyde	0.0080	0.0163	**104**
Formaldehyde	0.0020	0.0030	**50**
Other VOCs			
Trimethylbenzenes	0.0204	0.0076	**-63**
Octane	0.0190	ND	**NA**
Heptane	0.0117	0.0013	**-89**
Ethyltoluenes	0.0111	0.0038	**-66**
Undecane	0.0100	0.0002	**-98**
Nonane	0.0079	ND	**NA**
Decane	0.0070	0.0003	**-96**
Dodecane	0.0053	0.0013	**-75**
Dimethylphenols	0.0023	0.0097	**322**
Tetradecane	0.0022	0.0037	**68**
Other Analytes			
Carbon Dioxide	9.996	6.038	**-40**
Carbon Monoxide	4.231	2.680	**-37**

Individual results constitute >95% of mass of all detected Target Analytes.
ND: Non Detect; NA: Not Applicable

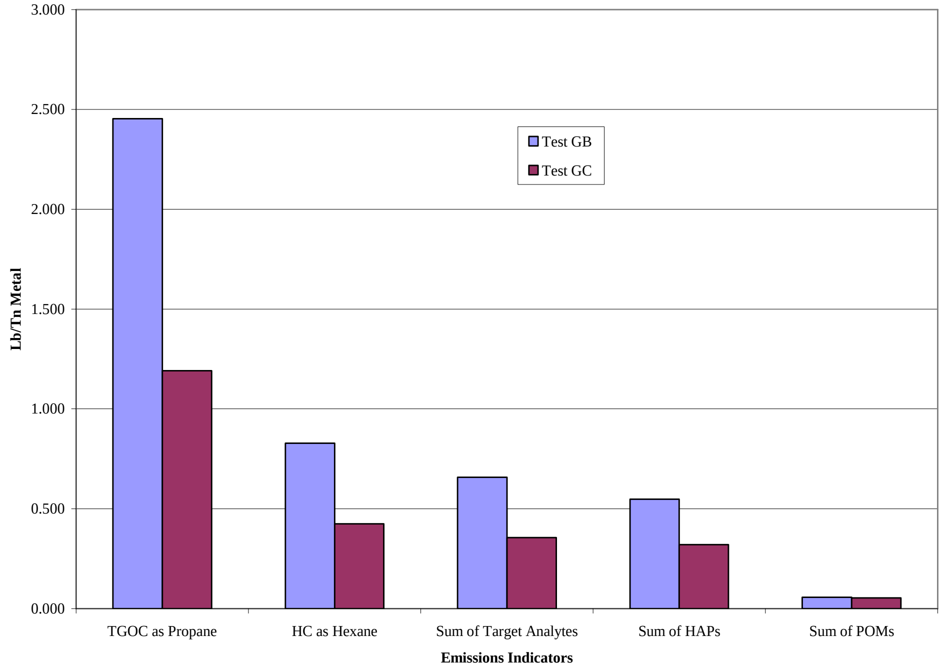

Figure 14 Emission Results Summary from Test Mix vs. Selected Baseline

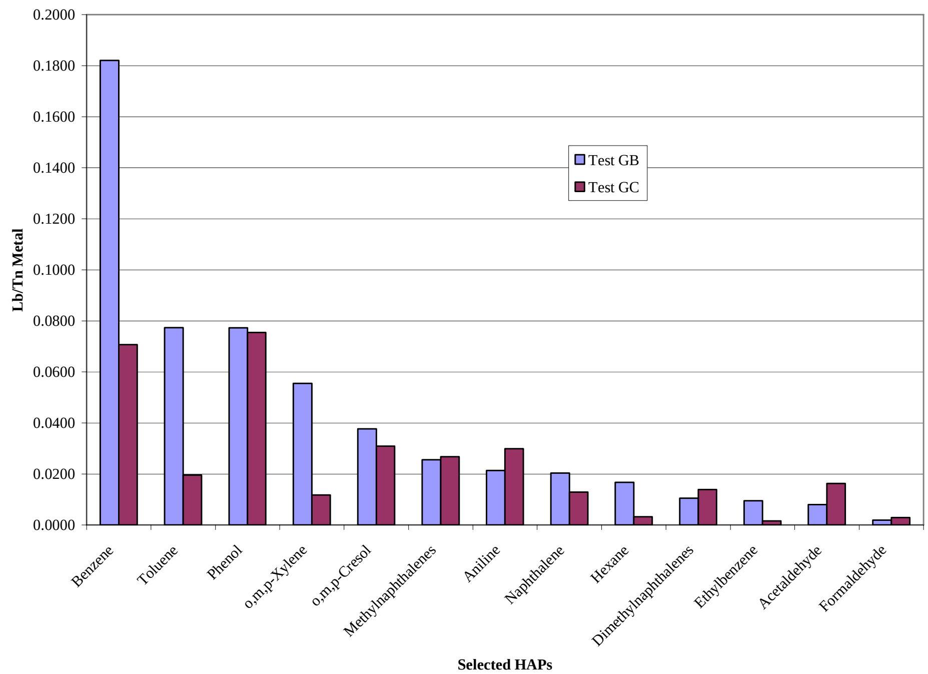

Figure 15 Target Analyte Emission Results from Test Mix vs. Selected Baseline

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6.0 Casting Quality

The step core pattern used in the emission testing did not provide a good opportunity for surface finish comparison. The following photos (Figures 16 through 21) compare the seacoal baseline castings (Test FK) compared to graphite pattern release agent castings (Test FV). This test did not include the H & G greensand additive package that should improve surface finish further. Added testing is planned by CERP to further profile the quality implications of these mixtures.

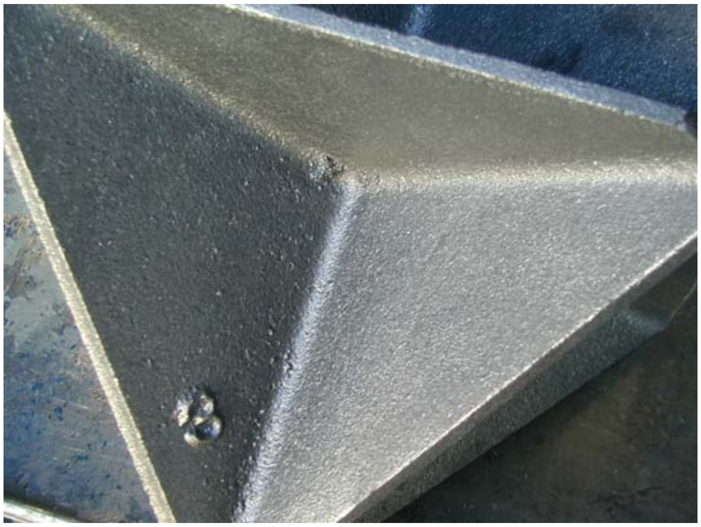

Figure 16 FK001 Best Casting Surface

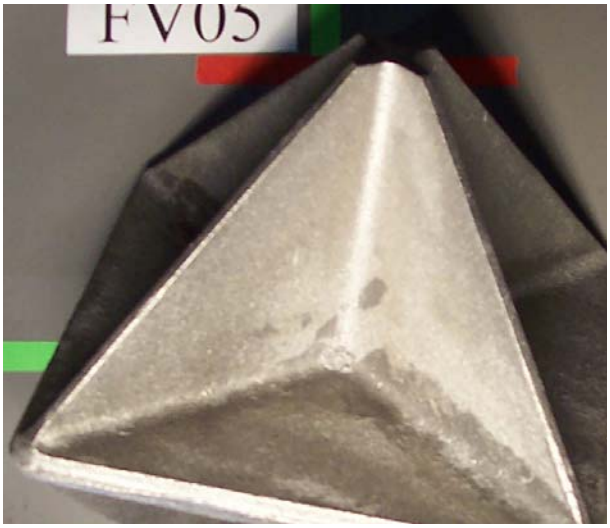

Figure 17 FV005 Best Casting Surface

Figure 18 FK005 Median Casting Surface

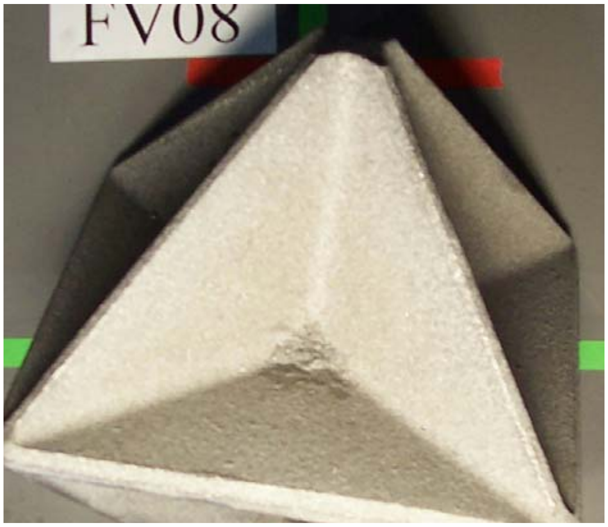

Figure 19 FV008 Median Casting Surface

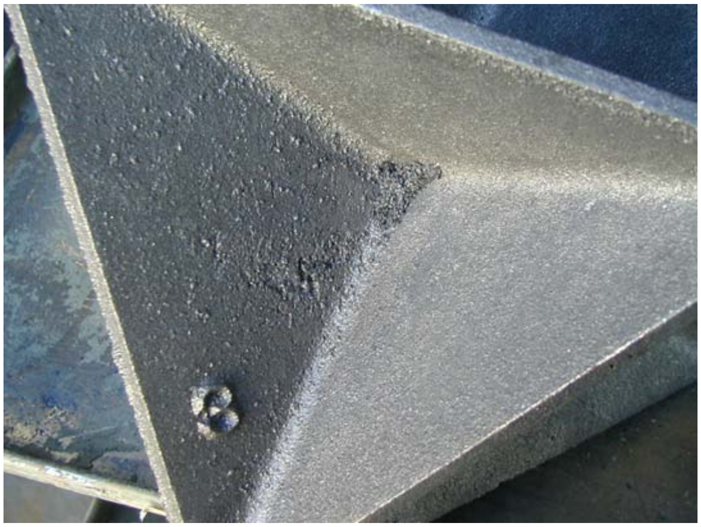

Figure 20 FK004 Worst Casting Surface

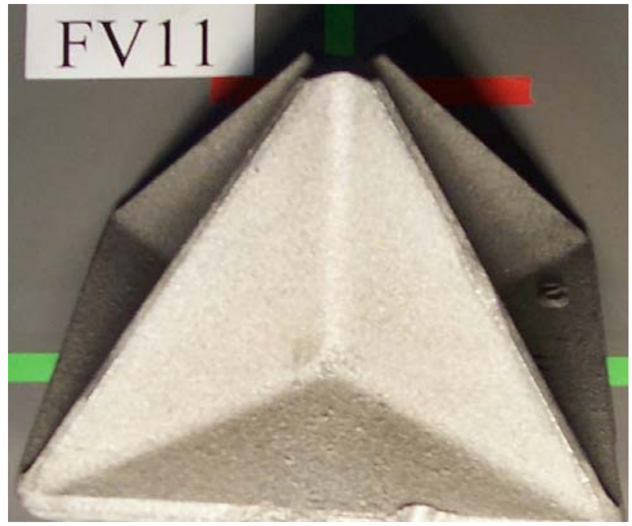

Figure 21 FV011 Worst Casting Surface

7.0 Conclusions

The results from the evaluation of this new greensand formula (without seacoal), phenolic urethane cores with additives and pattern spray with graphite show that:

1. Casting surface quality is comparable to that achieved with a traditional greensand with seacoal.
2. Volatile organic compounds as measured by US EPA Method 25A were reduced by 51%.
3. Hazardous air pollutants as measured by US EPA Method 18 were reduced by 42%
4. Carbon monoxide emissions were reduced by 37%, and
5. Carbon dioxide emissions were reduced by 40%.

Overall, the data clearly show that significant emission reductions can be achieved without sacrificing casting surface quality.

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Acknowledgments

The authors would like to thank the Hill and Griffith Company, Technikon, LLC and CERP for their permission to publish this information.

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