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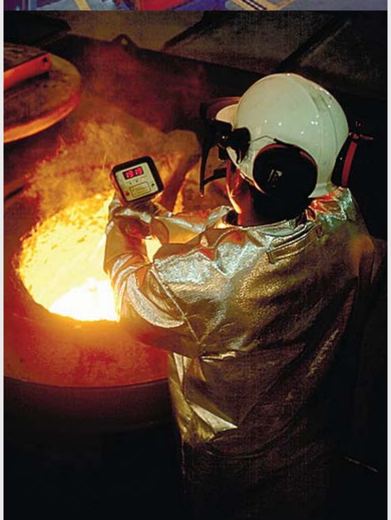

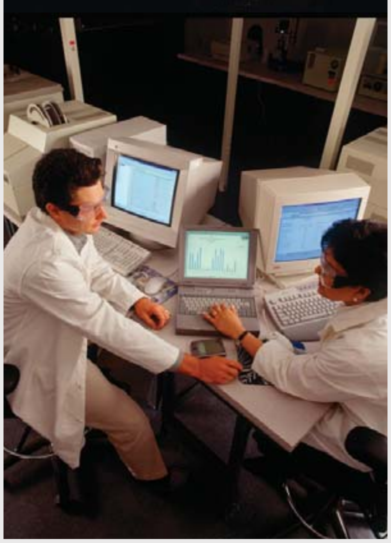

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The Addition of Cellulose to Molding Sand When Reducing Seacoal for Emission Reduction during Pouring, Cooling, and Shakeout

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

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Abstract

This investigation reviewed the importance of the addition of a cellulose based material when seacoal is reduced because of the intention by a foundry to reduce emission characteristics in green sand during the pouring, cooling, and shakeout (PCS) phases of the metal casting process. Seacoal addition to green sand had been determined to be the major cause of Hazardous Air Pollutants (HAPs) from PCS. Since the addition of cellulose does not negatively impact the emission characteristics as shown in a recent Casting Emission Reduction Program (CERP) report, it is an ideal additive to prevent and/or reduce expansion defects. Expansion defects (rattails, buckles, and scabs) can potentially occur if cellulose is not added to the green sand when seacoal is reduced.

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1.0 INTRODUCTION

The addition of cellulose into green sand molding has been a practice for many years. In 1929, Brotz received a patent on the use of wood fibers in the foundry indusrty[1]. In a recent AFS Transaction (01-001) the variations in cellulose were reviewed. This discussion will review the importance of cellulose as an additive to reduce expansion defects when seacoal is reduced with the goal to reduce air emissions caused by organic materials during the "pouring, cooling, and shakeout" phase of the metal casting process.

Both seacoal and cellulose have been added to green sand separately to reduce expansion defects in iron and steel castings[2,3]. The primary reason that seacoal has demonstrated the ability to reduce expansion defects is referred to as "The Cushion Theory."[2] The basic concept to this theory is simple; a coking material is formed as a result of the decomposition of seacoal during the metal casting process that results in the reduction and/or elimination of penetration defects. When seacoal is reduced in the green sand, an increase in expansion defects could occur. This has been observed in foundries that have reduced the quantity of seacoal in the green sand system for environmental improvements. To compensate for this occurrence, the addition of cellulose to green sand can reduce and/or eliminate the expansion defect. In essence, it is a low emission alternative to compensate for the expansion characteristics of green sand when the seacoal is reduced.

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2.0 EMISSION TESTING AT CERP WITH CELLULOSE FORMULATION IN THE MOLDING SAND

The goal of CERP is to test products and processes that can reduce HAPs. Seacoal has been identified as the major contributor to green sand HAP emissions.

Two tests conducted at CERP (Report numbers 1411-114 GL, August 2005 and 8011-011 GC, November 2004)[4] will be reviewed in this paper.

In report number 1411-114 GL, a comparison was completed between the baseline molding sand containing a pre-blend of Western Bentonite, Southern Bentonite, and Seacoal and a pre blend that was formulated with Western Bentonite, Southern Bentonite, Cellulose and no Seacoal. This report establishes that seacoal is the major source of combustibles that cause air emission (74% reduction in HAPs) and that cellulose alone was not a significant emission source.

Table 2-1 shows the air emission reduction in HAPs between a baseline containing seacoal (FK) and a blend that does not contain seacoal (GL).

Table 2-1 Summary of Tests FK and GL Average Emissions – Lb/Tn Metal

Analytes	Baseline Average Test FK	Average Test GL	% Change from Baseline FK
Emission Indicators			
TGOC as Propane	3.3541	0.7048	-79
HC as Hexane	0.4015	0.17	-58
Sum of Target VOCs	0.4294	0.0948	-78
Sum of Target HAPs	0.3437	0.0877	-74
Sum of Target POMs	0.0197	0.0024	-88
Target Organic VOCs Including HAPs and POMs			
Benzene	0.145	0.0292	-80
Acetaldehyde	0.0035	0.0207	485
Toluene	0.0744	0.0121	-84
Xylenes	0.0506	0.0091	-82
Formaldehyde	0.0028	0.0036	28
Phenol	0.0072	0.0024	-67
Hexane	0.0128	0.0021	-84
Heptane	0.0122	0.002	-83
Naphthalene	0.0127	0.0019	-85
Ethylbenzene	0.0084	0.0015	-81
Criteria Pollutants and Greenhouse Gases			
Carbon Monoxide	NT	2.7522	NA
Carbon Dioxide	NT	5.8533	NA
Nitrogen Oxides	NT	0.0022	NA

Individual results constitute > 95% of mass of all detected target analytes for GL.

Bold numbers indicate those compounds whose calculated t-statistic is significant at alpha=0.05.

Any discrepancies apparent in percent difference calculations are due to rounding. Calculations were performed on number prior to rounding to four decimal places.

ND: Non Detect; NA: Not Applicable; NT: Not Tested.

Table 2-2 compares the air emission results of a PCS from a greensand system containing PU cores (Test GB) as compared to Test GC. In test GC the seacoal system was replaced with a blend of cellulose and seacoal (PU cores remained) resulting in a 42% emission reduction. Table 2-2 shows the air emission reduction in HAPs between a baseline containing seacoal (GB) and a blend that contains a blend of seacoal and cellulose (GC).

Table 2-2 Summary of Test Plans GB and GC Average Results – Lb/Tn Metal

Analytes	Test GB Lb/Tn Metal	Test GC Lb/Tn Metal	% Change from Test GB
Emissions Indicators			
TGOC as Propane	2.454	1.191	-51
HC as Hexane	0.8289	0.425	-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	0.008	0.0163	104
Formaldehyde	0.002	0.003	50
Other VOCs			
Trimethylbenzenes	0.0204	0.0076	-63
Octane	0.019	ND	NA
Heptane	0.0117	0.0013	-89
Ethyltoluenes	0.0111	0.0038	-66
Undecane	0.01	0.0002	-98
Nonane	0.0079	ND	NA
Decane	0.007	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	2.68	-37

Individual results constitute >95% of mass of all detected Target Analytes.

ND: Non Detect; NA: Not Applicable

3.0 INVESTIGATION INTO EXPANSION DEFECT REDUCTION WITH THE ADDITION OF CELLULOSE WHEN SEACOAL IS REDUCED

3.1. A Brief Understanding of Expansion Defects

Figure 3-1 is a drawing from the AFS International Atlas of Casting Defects and is an excellent reference to understand expansion defects. The definition of an expansion defect (scab or rattail) found in this atlas states: “The crust does not separate completely from the backing sand. Because of the expansion of the silica, the crust shears toward the region adjacent to the mold wall (Figure 3-1). The edges of the crust are raised, causing the formation of rat tails (R) or, if the edges rise sufficiently to permit metal infiltration beneath the crust, the formation of scabs (S).” (Figure 3-2)

Figure 3-1 Drawing of the Formation of Expansion Defects.

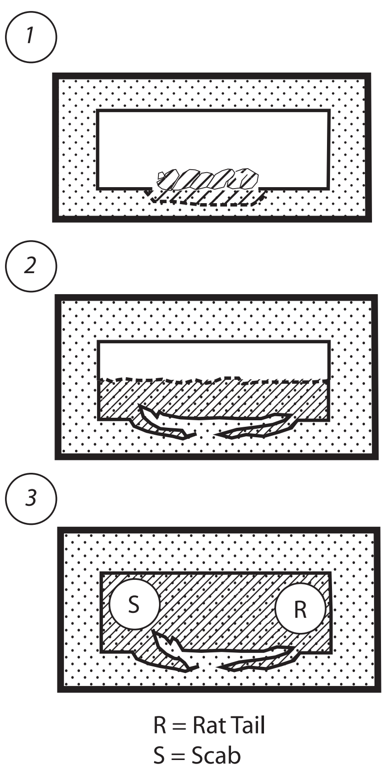
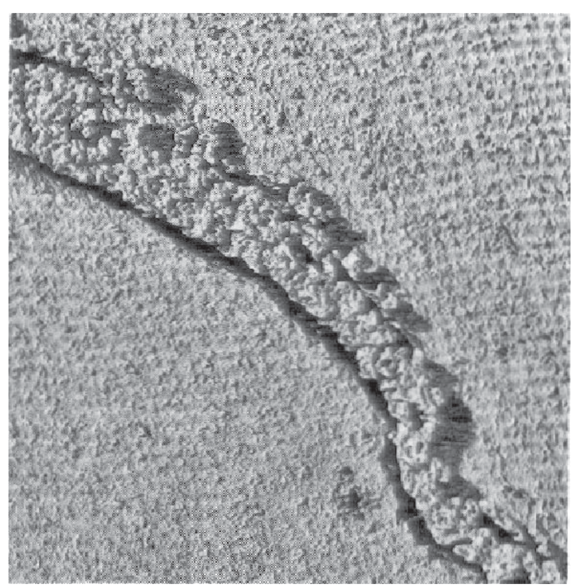


Figure 3-2 Expansion Defect Picture Showing Scab in Buckle



3.2. The Ability of Seacoal to Reduce Expansion Defects

Figure 3-3 Coke Button with Lustrous Carbon in Crucible.

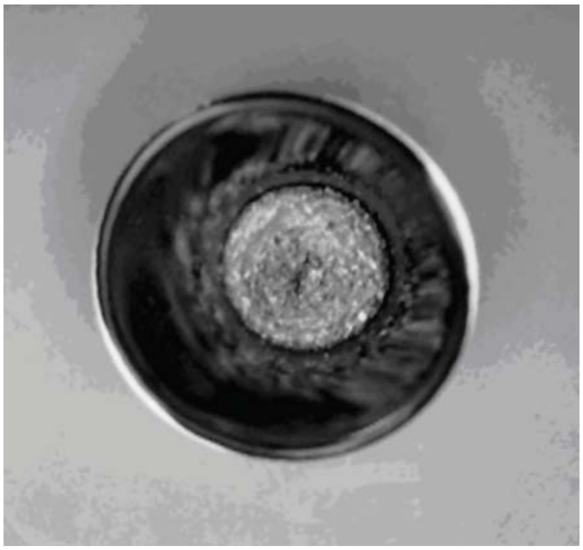
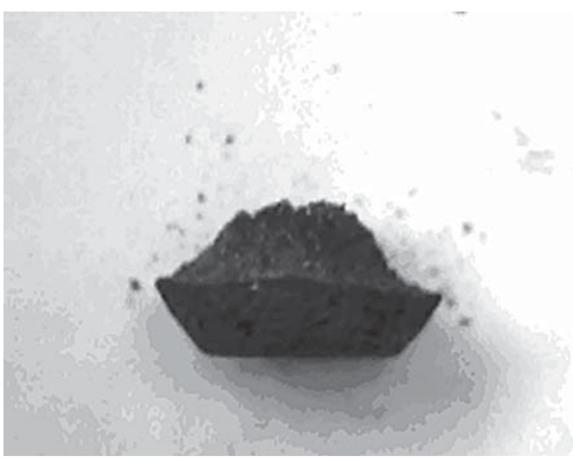


Figure 3-4 Coke Button Showing Free-Swelling Characteristic



One of the traditional methods to look at the reduction of expansion defects with seacoal is to study the formation of "coke buttons". A "coke button" is formed when the volatile matter of the seacoal has been released. An example of a seacoal "coke button" can be found in Figures 3-3 and 3-4. The determination of the value of the free-swelling characteristics of seacoal can be evaluated using ASTM test procedures (ASTM Designation D720-91 Standard Test Method for Free-Swelling Index of Coal). The ability for seacoal to develop into a free-swelling material is responsible for the elimination and/or reduction of expansion defects in green sand. Reducing the amount of seacoal to achieve emission reductions will reduce the ability for green sand to resist expansion defects.

3.3. The Ability of Cellulose to Reduce Expansion Defects

Cellulose has been used for years as an additional additive to reduce expansion defects. This approach is most commonly used in making steel castings in green sand molds. The application of cellulose as a material to reduce and/or eliminate expansion defects is based upon the "fibrous" nature of the product itself.

Seacoal utilizes the decomposition characteristics of the material as the method for reducing and/or eliminating expansion defects. It is important to note that the very characteristic that reduces and/or eliminates expansion defects is the principal source of the emissions of seacoal during pouring, cooling and shakeout of the metal casting process. The "fibrous" characteristics of cellulose are shown in Figures 3-5 and 3-6. Figure 3-5 is microscopic view of cob flour and Figure3- 6 is a microscopic view of wood flour.

Figure 3-5 Microscopic View of Cob Flour.

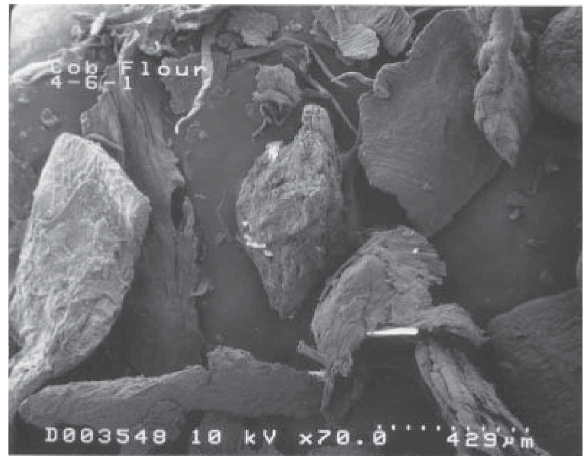
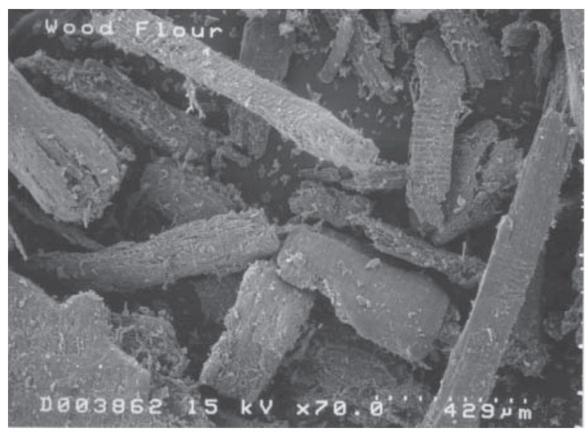


Figure 3-6 Microscopic View of Wood Flour.



3.4. Application of Cellulose Technology in Foundry Practice

A number of foundries in the Midwestern part of the United States have successfully reduced seacoal in their green sand process. The foundries have added between 1 to 3% cellulose (based upon the weight of the pre-blend) while reducing the seacoal content by up to 40%. These foundries produce both ductile and gray iron automotive castings. They have added the cellulose into the pre-blend formula to eliminate the potential to have expansion defects. In addition, by adding cellulose to the green sand there is additional value to the molding sand characteristics because the reduction of seacoal also reduces the "water absorbing material" generated when seacoal and seacoal decomposition by-products are reduced.

Generally, foundries are comfortable at reducing seacoal in the green sand by approximately 40%. There does not appear to be a scientific reason for this "comfort factor", but it is usually the point where most foundries meet the environmental requirements, savings (cellulose is less expensive than seacoal and less volume is required), and desired casting appearance. Research at CERP (Table 3-1) has shown that a reduction in seacoal can be achieved beyond the 40%. It is anticipated that the "Foundry of the Future" will utilize the best green sand technology at a cost reduction while meeting the changing environmental requirements!

Table 3-1 Emission Results Comparison Between Seacoal and Non-Seacoal Mix with Cellulose

Analyte	PCS – Test FK *Sand System Average with Seacoal and Release Agent (lb/ton metal poured)*	PCS – Test GL *Sand System without Seacoal (with Cellulose) and Release Agent Only (lb/ton metal poured)*
Emission Results		
Sum of VOCs	0.43	0.09
Sum of HAPs	0.34	0.09
Sum of POMs	0.02	0.002

Specific cost improvements have been observed in two specific foundries. Each foundry was able to reduce the quantity of seacoal in the molding sand by up to 40% but the addition of cellulose into the pre-blend consumed was required. The addition was at 3% or less (based upon the weight of the pre-blend). Each manufacturing facility was able to reduce the cost of the pre-blend by over $100,000. This reduction in cost of the pre-blend and the resulting improvement in the emission reduction at pouring, cooling and shakeout supported the long term goals of the foundry!

4.0 CONCLUSIONS

Developmental projects at CERP have measured the environmental advantages for the foundry industry to reduce the emission characteristics of green sand during pouring, cooling, and shakeout during the metal casting process. The suppliers to the industry continue to develop and submit to CERP testing low emission alternatives to high emission products such as seacoal. Through the application of the best of these technologies into foundry practice, foundries have been able to reduce their demand on the quantity of seacoal in the molding sand. This has become beneficial for cost reduction initiatives and improved environmental requirements. However, the tendency of molding sand to encounter expansion defects could occur. The addition of cellulose into molding sand will reduce and/or eliminate the occurrence of expansion defects without negatively impacting the improvements gained with the seacoal reduction. The CERP test reports discussed has shown that the addition of cellulose into a pre-blend does not negatively impact the emission characteristics of green sand during pouring, cooling, and shakeout. Production foundries are successfully using cellulose additives to reduce the amount of seacoal in their greensand molding lines.

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5.0 ACKNOWLEDGMENTS AND REFERENCES

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

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