



Casting Emission Reduction Program

Prepared by:

TECHNIKON LLC

5301 Price Avenue ▼ McClellan, CA, 95652 ▼ (916) 929-8001

www.technikonllc.com

US Army Task N256
**Computerized Modeling
Spatial Distribution Emissions Study
CERP Test BT**

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COMPUTERIZED MODELING
Spatial Distribution Emissions Study
CERP Test BT
Subtask 2.2.1

Reviewed and Approved by

George R. Crandell



Date: 4/26/01

The data contained in this report were developed to assess the relative emissions profile of the product or process being evaluated. You may not obtain the same results in your facility. Data was not collected to assess casting quality, cost, or producibility

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Executive Summary

This report reviews the casting emission study that characterized the generation of air emissions within a green sand mold poured with gray iron. The results show that emissions are dependent on spatial position and temperature distribution throughout the green sand mold.

It must be noted that the reference and product testing performed is not suitable for use as emission factors or for purposes other than evaluating the relative emission reductions associated with the use of alternative materials, equipment, or processes. The emissions measurements are unique to the specific castings produced, materials used, and testing methodology associated with these tests, and should not be used as the basis for estimating emissions from actual commercial foundry applications.

B. Background

The mechanism for generation of emissions from coreless greensand molds was previously described to follow a heat transfer model (CERP report: Process Variable Evaluation 21 September 2000). In that report, the emissions were shown to be proportional to the amount of materials with potential to emit whose temperature had exceeded a threshold temperature to emit. The temperature distribution at any time within the mold results from the instantaneous metal-mold interfacial temperature that decreases with time being mitigated by the complex thermal conductivity of the mold material, the heat adsorptive evaporation of volatile components, and the heat generation from oxygen fed combustion. The metal-mold interfacial temperature results from the temperature of the metal and a balance between the amount of heat energy available from adjacent metal and the rate at which the mold dissipates that heat.

The mold sand thermal conductivity is small relative to the heat available. Within the test period, chosen to represent a typical foundry casting pouring and cooling period, the high temperatures rise. These facts raise several interesting questions, which this study attempts to answer:

1. Are the emissions generated only in the high temperature surface combustion zone; or anywhere where the temperature merely exceeds the material's threshold temperature to emit?
2. What temperatures are emissions generated?
3. What determines the temperature threshold of emissions?
4. Once generated, do the emitted vapors merely pass out of the mold to be detected or do they re-condense into the mold to escape immediate detection.
5. Do the condensed emissions continue to be emitted yet a second or third time as the sand temperature increases?
6. When chemicals are emitted at high temperature, do they decompose and/or recombine into chemicals that were not originally there?

C. Objective

The objective of this study is to identify patterns of analyte concentration and relate these patterns to position, temperature, and time variables in an attempt to identify any of the methods by which detected emissions are generated.

It must be noted that the results from the reference and product testing performed are not suitable for use as emission factors or for other purposes other than evaluating the relative emission reductions associated with the use of alternative materials, equipment, or manufacturing processes. The emissions measurements are unique to the specific castings produced, materials used, and testing methodology associated with these tests. These measurements should not be used as the basis for estimating emissions from actual commercial foundry applications.

D. Experimental Procedure

Selected individual analyte emissions were continuously measured over a 45-minute period at various distances from the hot mold-metal interface of a greensand mold poured with gray cast iron at 2630° Fahrenheit. The measured emissions were related in time to the sample position and the sand temperature.

The test molds, 24 by 36 by 28 inches high weighing 1300-1400 pounds, were hand rammed into flasks molded greensand. The nominal composition of the molding sand was 85% lake sand (impure silica sand), 7% western and southern bentonite in a 4:1 ratio, 5% Seacoal (bituminous coal), and 3% water. The mold pattern was an 18 by 28 by 1-inch high flat plate with connecting pouring basin and down sprue. The total poured weight was about 140 pounds.

The cope mold (top half) was outfitted with a gas collection manifold with four (4) Stephan diffusion tubes to gather vapor samples at selected distances from the hot face. Adjacent to the sample end of each Stephan diffusion tube was a thermocouple appropriate to the temperature and a conductivity device to assess water condensation. The manifold was supplied with dry nitrogen at the same flow rate that the Airsense mass spectrometer, used to analyze the gases, drew gas from the manifold. With this arrangement, the sample volume in the mold was neither purged nor evacuated so that only a diffused sample of emission gas should reach the manifold and the mass spectrometer.

Several Test runs were done to map the time variant spatial temperature distribution and the collect simultaneous or spatially specific gas emission samples.

E. Results

1. The list of detected emission analytes from this test conformed to those of the greensand sand baseline test AY. Boiling points for the analytes indicated ranged from -6 to 505° Fahrenheit. Flashpoints ranged from -17 to 228° Fahrenheit.
2. The emissions come off in two stages:
 - a. Internal surface combustion during the filling of the mold in the presence of air.
 - b. Anaerobic distillation and decomposition after the mold is full of metal.
3. The combustion analytes are primarily CO, CO₂, methane and oxygen rich chemical families such as aldehydes and ketones. They are mostly derivatives of benzene and simpler compounds. The concentration of these analytes reduces quickly after the mold is full of iron.
4. The distillation analytes are alkanes C₆ through C₁₃, benzene, toluene, Xylene, & phenol with methyl, ethyl, and butyr variations. The concentration of the distillation and decomposition analytes progresses through the mold in the shape of a moving bell curve as the heat from the cooling metal raises the sand temperature toward the boiling point of the particular source analyte.
5. The bell shaped curve begins to separate cleanly from the combustion peak at 4 inches from the hot face. Up to that distance the curves are merged and compressed in time because the sand temperature is rising faster than the materials are evaporating.
6. A select diversity of secondary simpler analytes are created when the temperature of the source analyte gasses are raised in temperature above 400° F.
7. The presence of water limits the sand temperature to the boiling point of water, 212° Fahrenheit at 1 atmosphere pressure. The sand temperature does exceed the boiling temperature of water during the 45 minutes of casting cooling much beyond 4 inches from the hot metal interface.
8. The height of the sand temperature peak becomes less and of longer duration as the distance from the hot face increases.
9. Detected analytes, whose boiling points are near or less than ambient or the initial sand temperature, are byproducts of the process because they would have boiled away before the test had begun.

F. Conclusions

The following conclusions relate to the questions posed in Section B. Background.

1. Emissions are generated through out the mold wherever the sand temperature exceeds the threshold temperature to emit. Those emissions generated at the surface are dominated by the byproducts of oxidation such as CO₂ and CO and decomposition principally methane. The emissions generated internally are primarily distillation products and include the basic aromatic ethyl, methyl, & butyr variations of benzene, phenol, toluene, & Xylene as well as a few alkane chains. A selection of ketones and aldehydes was also present in lesser quantities possibly generated as the oxygen was being excluded from the mold during the latter stages of filling.
2. The emission appear at temperature from ambient to the metal pouring temperature. The

distillation mechanism appears at temperatures below 300°F. The decomposition products appear to be limited to the initial high temperature-pouring period within the first minute.

3. The emission temperature threshold appears to follow the flash point and the vapor pressure of the analytes as they approach their boiling points.
4. Only when the vapor contains enough energy to escape the mold before it gives up enough energy to lower its temperature below its boiling point does it become a detectable analyte.
5. The emissions forced to pass through the mold selectively re-condense, each to their own vapor pressure curves, and then are re-volatilized as the heat raises the backup sand temperature. This mechanism is responsible for the broadening of the temperature peaks because it takes more energy to volatilize the increased mass of the original materials present plus the accumulated condensates
6. The mold metal interface and the first fractional inches of sand are the only place where the sand reaches a high enough temperature to selectively decompose the organic materials. This is due to the low thermal conductance of the sand and the heat absorptive capacity of any water present. The presence of small amounts of analytes whose boiling points are above the sand temperature after the high temperature has been rid of its organic contents is evidence that some recombination has gone on. Those materials of higher molecular weight have condensed into the sand where they remain or are volatilized at a later time when the sand temperature comes up.