



Casting Emission Reduction Program

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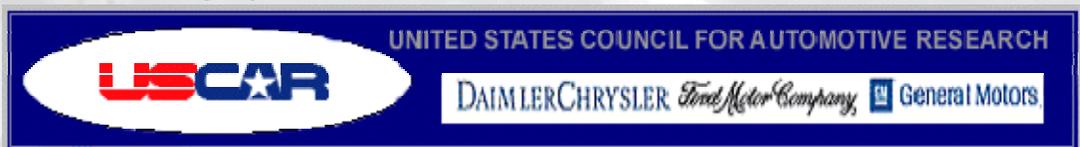
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US Army Task N256 No Bake Furan Iron Capability Study

Technikon # 1256-2312 DJ

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Capability Study to Determine the Requirements Of Furan / Iron No-Bake Molds for Emission Testing

CERP Test DJ
WBS #2.3.1.2

28 March 2001

Furan Iron No-Bake Emission Capability Study, Test Series DJ- Results

WBS 2.3.1.2
Reviewed and Approved by:  Date: 29 March 2001

Clifford Glowacki, CIH

Measurement Technologies

WBS 2.3.1.2
Reviewed and Approved by:  Date: 29 March 2001

George Crandell

Operations

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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Table of Contents

INTRODUCTION 1
Study Summary..... 3
Study Background..... 3
Objective 3
Experimental Procedure..... 4
Series Results 4
 METHOD M-18 (GC/FID):..... 4
 METHOD M-18 (GC/MS) 5
 HYDROCARBON AS HEXANE 5
 NIOSH 2002 5
 METHOD TO-11 6
 NIOSH 2505 6
 OSHA 72..... 6
Series Conclusions 7
Process Summary 9
Background 9
Objective 10
Experimental Procedure..... 10
Results..... 10
Conclusions..... 11

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INTRODUCTION

The Casting Emission Reduction Program (CERP) conducted a Capability Study at its Pre-Production foundry involving Furan No-Bake molds. “No-Bakes” represent a class of materials and manufacturing methods that were previously untested at CERP. No-Bake is a molding process that can be used for aluminum and gray iron casting. This Study uses strictly iron casting. To avoid redundancy, the Furan No-Bake molds will be referred to as “No-Bake” throughout this Report. The purpose of the capability study was to determine the manufacturing requirements and the range of process and air emission measurement variation involved with No-Bake molds in iron.

The conclusions formed from the DJ Test Series were used as the basis for the test study to examine Furan No-Bake Baseline Emissions (published under a separate cover). As a result of the test, the methods and criteria essential for iron No-Bake baseline testing have been developed.

The Appendix to this report contains the detailed process and operational information that supports the text of this report. It is not included in this document but can be obtained electronically or in hard copy by contacting the Technikon offices at (916) 929-8001 or by logging on to <http://www.technikonllc.com> and requesting an electronic version.

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.

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Study Summary

This report contains the results of the study that determined the sampling requirements necessary for manufacturing No-Bake molds for emission testing from the chemical family Furan Iron No Bake binder systems.

The objective of this test series is to identify the sampling flow rates that would provide sufficient sample data for the determination of each target compound on its specific sampling media. Samples were collected at several sampling flow rates for each chemical family during the 75-minute test. The samples were analyzed for selected target compounds.

The following flow rates were determined for upcoming Furan No-Bake Iron Baseline testing.

| | |
|---|--------------|
| M-18 ((by Gas Chromatograph/Flame Ionization Detector (GC/FID): | 25 ml/min |
| M-18 (by Gas Chromatograph/Mass Spectrometer (GC/MS): | 25 ml/min |
| HC as Hexane: | 500 ml/min |
| NIOSH 2002: | 750 ml/min |
| TO-11: | 750 ml/min |
| NIOSH 2505: | 1,000 ml/min |
| OSHA 72: | 1,700 ml/min |

Study Background

Screening tests are required prior to formal testing of binder systems involving chemistries that have not been used.

Foundry binder systems use a variety of chemical reactions. Different binders produce different amounts and types of emissions during use. Sampling and analysis procedures must be to each binder system to obtain accurate and repeatable test results.

Objective

The objective of this test series is to identify the sampling flow rates that would provide sufficient sample for the determination of each target compound on its specific sampling media.

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.

Experimental Procedure

In the Pre-Production foundry, castings are produced individually. Molds are constructed manually, and brought into a hooded enclosure containing a shaker table, where the castings are poured. A heated sample probe is set into the exhaust stack of the hood to enable collection of total emissions from the pouring, cooling, and shakeout phases of the casting process.

A 13-channel sample train was used to collect stack samples. A sorbent tube was placed in each channel, with a critical orifice in line with the tube to control the sampling flow rate, and thereby, the volume of stack gas to be sampled.

Hazardous Air Pollutant (HAP) and Volatile Organic Compound (VOC) emissions were collected on sorbent tubes to determine optimal tube loading for future Furan Iron No-Bake baseline testing. The molds were poured with iron, and were the standard 4-on AFS variable-tooth gear made from Wexford 450 laces and. Molds were bonded with Furan No-bake resin at $1.3\% \pm 0.05\%$ (BOS), using Delta 06-1505 resin, and Delta 17-240w Acid Catalyst at $25\% \pm 5\%$ of resin content.

Stack gas samples were collected on sorbent tubes from the third test pour only, out of a total of three pours in test series DJ. Samples were collected at high and low tube loadings for Method M-18, to determine the loading that provided the lowest detection limits for each analytical method, while maintaining the integrity of the analytical data. Results are discussed in the conclusions section of this report for each analytical method.

Sorbent tube samples were submitted to Clayton Group Services Laboratory for analysis. Analytical results were examined for evidence of sample overload, characterized by breakthrough, analyte results that grossly exceeded the calibrated range of the method, poor chromatographic performance, or other factors having a detrimental effect on the data.

Series Results

Results of this test series for all detected HAP and VOC compounds are provided in appendices that are being maintained in the Technikon offices. Results will be discussed for each analytical method separately.

METHOD M-18 (GC/FID):

Samples for this method were collected on Carbopak thermal desorption tubes. Initial Total Hydrocarbon Content (THC) results suggested reduced emissions from the Furan Iron No-Bake system when compared to a phenolic-urethane iron system, so samples were collected at an increased flow rate to preserve detection limits for the method. A flow rate of 60 ml/min was selected for the furan system, and an additional sample was collected at the nominal iron flow rate of 25 ml/min as well. Over the course of the 75-minute sample collection period, these flow rates translated to sample volumes of 4,500, and 1,900 ml, respectively on the Carbopak tubes.

Analytical results for the 60 ml/min sample showed that two analytes exceeded the upper limit of calibration for the method, 10,000 nanograms (ng) Benzene was found at 16,000 ng, and toluene was found at 39,000 ng. All other compounds were within the calibrated range of the analytical method. No analytes were detected in the breakthrough sample, so the capacity of the Carbopak desorption tube was adequate at the 60-ml/min-flow rate. The corresponding results for benzene and toluene at a flow rate of 25 ml/min, were 5,900 ng, and 14,000 ng respectively. Although toluene was out of the calibrated range at both flow rates, benzene did come into range at the lower flow rate. Because benzene and toluene comprise the overwhelming majority of emissions detected in this mold system, the lower flow rate of 25 ml/min was selected due to the increased accuracy in analytical results that could be achieved by staying close to, or within, the calibrated range of the method.

METHOD M-18 (GC/MS)

A single sample for this method was collected during this test series, at a flow rate of 25 ml/min. Correct flow rates for this method can also be inferred due to the fact that samples are collected on the same media as the M-18 samples analyzed by GC/FID. The most important difference between the two methods is that the M-18 (MS) method has a calibrated maximum of 2,000 ng, whereas the maximum for the M-18 (GC/FID) method is five times higher, at 10,000 ng. For this reason, collection of samples at the higher flow rate of 60 ml/min would not provide acceptable results.

HYDROCARBON AS HEXANE

Samples for this method are collected on activated charcoal sorbent tubes containing a front and back section. Therefore, it is not necessary to collect separate breakthrough samples, since the back section of the tube is analyzed separately and can provide breakthrough information. In this case breakthrough is defined as a result for any analyte detected in the back section that exceeds 10% of the total amount detected in the sum of the front and back sections. Due to the fact that these samples are extracted, and can therefore be diluted for re-analysis if the upper limit of calibration for the method is exceeded, considerably more flexibility in selecting a sample flow rate is available.

Samples were collected at a single flow rate of 500 ml/min for this analysis, corresponding to a sample volume of 38,000 ml. The initial flow rate was selected based on preliminary THC results. Method results showed HC as Hexane detected at 760 microgram (ug), well below the maximum calibrated range for the method. The largest amount of any single analyte detected was benzene, at an average of 158 ug. At these loadings, the adsorption capacity of the charcoal tube is also not a factor, and no breakthrough was observed from the back half of the tube.

NIOSH 2002

Samples for this method are collected on silica gel sorbent tubes. These tubes also contain a front and back section, which are analyzed separately, so that sample breakthrough may be evaluated without need of a separate breakthrough tube. As with all sample preparation methods

utilizing an extraction procedure, these samples can be diluted for re-analysis if the upper limit of calibration for the method is exceeded.

Samples were collected at a single flow rate of 750 ml/min for this analysis, corresponding to a sample volume of 56,000 ml. The initial flow rate was selected based on preliminary THC results. Method results showed Dimethylaniline detected at 58 ug, well below the maximum calibrated range for the method. Phenol was also detected, at 46 ug, and aniline was not detected (at a DL of 4 ug). At these loadings, the adsorption capacity of the silica gel tube is not a factor, and no breakthrough was observed from the back half of the tube.

METHOD TO-11

Samples for this method are collected on Waters Sep-Pak Cartridges. Analytes are derivatized with a reagent contained in the cartridge, during extraction. These samples are also extracted, so they can be diluted for re-analysis if the upper limit of calibration for the method is exceeded. As a result, considerably more flexibility in selecting a sample flow rate is available.

Samples were also collected at a single flow rate of 750 ml/min for this analysis, corresponding to a sample volume of 56,000 ml. The initial flow rate was selected based on preliminary THC results. Method results showed acetaldehyde detected at 47 ug, well below the maximum calibrated range for the method. Acetone was also detected at 26 ug, formaldehyde at 12 ug, and additional minor constituents were also detected from 3 ug down to less than 1 ug. Although a breakthrough sample was not analyzed, at these loadings, the adsorption capacity of the sep-pak cartridge is not a factor.

NIOSH 2505

Samples for this method are collected on Poropak Q sorbent tubes. These tubes contain a front and back section, so that sample breakthrough may be evaluated without need of a separate breakthrough tube. As with all sample preparation methods utilizing an extraction procedure, these samples can be diluted for re-analysis if the upper limit of calibration for the method is exceeded.

Samples were collected at a single flow rate of 1,000 ml/min for this analysis, corresponding to a sample volume of 75,000 ml. The initial flow rate was selected based on preliminary THC results. Method results showed that furfuryl alcohol, the only analyte tested for in this method, was not detected (at a DL of 3 ug).

OSHA 72

Samples for this method are collected on activated charcoal sorbent tubes. These tubes contain a front and back section, so that sample breakthrough may be evaluated without need of a separate breakthrough tube. As with all sample preparation methods utilizing an extraction procedure, these samples can be diluted for re-analysis if the upper limit of calibration for the method is exceeded.

Samples were collected at a single flow rate of 1,000 ml/min for this analysis, corresponding to a sample volume of 75,000 ml. The initial flow rate was selected based on preliminary THC results. Method results showed that furfural, the only analyte tested for in this method, was detected at 4 ug. This value is at the limit of detection for the method.

Series Conclusions

The objective of this test series was accomplished, and flow rates have been assigned for the upcoming Furan No-Bake baseline testing that will be poured in iron.

The following single flow rates were determined for upcoming Furan No-Bake Baseline testing.

| | |
|-------------------|--------------|
| M-18 (by GC/FID): | 25 ml/min |
| M-18 (by GC/MS): | 25 ml/min |
| HC as Hexane: | 500 ml/min |
| NIOSH 2002: | 750 ml/min |
| TO-11: | 750 ml/min |
| NIOSH 2505: | 1,000 ml/min |
| OSHA 72: | 1,700 ml/min |

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Process Summary

This report contains the process requirements necessary to manufacture No-Bake molds for the purpose of testing emissions from Furan No-Bake binder systems being poured with iron. This capability study was conducted in conjunction with other capability studies performed under WBS 2.3.

All data in support of this summary report is retained under test series DJ in the archives of Technikon LLC. The emission measurement requirements for Furan No-Bake molds were evaluated concurrently. These results are presented in a separate report, titled CERP Test CQ.

Background

The research conducted at CERP has measured the emissions from several other core and greensand mold materials. Emission testing of foundry sand molds bound with a family of chemical binders known as “No-Bakes” is a logical extension of the current and historical research activities conducted at CERP. The equipment available for this type of research includes two emission testing foundries, one for discreet single mold detailed material testing, and one for dynamic material testing under production conditions.

No-Bakes represent a family of core/mold manufacturing materials in general use in the foundry industry. Historically, cores were manufactured from animal protein and oxidizable vegetable oils requiring drying or baking. While still in use, these materials tend to be inconsistent and are either slow or energy and labor intensive. By contrast, No-Bakes lend themselves to mechanization and cure without baking by delayed chemical interaction of their components. Use of this class of material requires definition of a “*strip time*”. This is when the material strength has sufficiently developed to permit removal of the core/mold from the core box. Additionally, it is important to not exceed the “*bench life*” when placing the material in the corebox. If exceeded, the chemical curing will have processed to such an extent that the coated sand grains will not bind together to form the desired shape.

The strength of a core/mold depends on several factors such as temperature, resin content, ratio to resins or catalysts used to control the speed of the chemical reactions, and the mechanics of packing the coated sand together. To evaluate the sand and the resin coating systems, trial batches are made and tested using cured coated sand tensile test bars called “dogbones”. The dogbones are tested at various standard times after they are made. It is important to control the strength of the sand. Sand strength has a direct effect on the ability to handle the core/molds, and on the reliability of decomposition at the desired interval during shakeout. Controlling these factors assures a standard emission profile.

The Furan chemical system tested uses a two-part resin system consisting of a primary resin and a co-reactant activated by a liquid catalyst in a manner similar to the resin system reported under CERP tests CW (2.3 GSA.1) & CP (2.3 GSA.2). The reaction rates of all the core binder chemical resin systems are known to be temperature sensitive. To verify the performance of the catalyst a pre-test evaluation of the catalyst requirements was conducted. The targeted amount of

25% catalyst, based on the resin content, was verified to perform well with sand maintained in the temperature range 70-80°F.

It is intended that this resin system be used with cast iron poured at 2600-2650°F. One of the requirements of all core or mold binder systems is to breakdown after a designated period of time from the heat of the cooling casting to allow the sand to separate from the casting. At the same time the physical handling strength requirements of the core for setting in a mold must be maintained.

Objective

The objective of this report is to determine the process requirements necessary to manufacture No-Bake molds for testing emissions from Furan No-Bake binder systems poured with iron.

Experimental Procedure

The Furan chemical system uses a single one-part resin activated by a liquid acid catalyst compared to a two-part resin system catalyzed by a liquid Amine for Phenolic Urethane (PU). At a nominal 25%, the catalyst content is significantly higher than that found in the phenolic urethane's typical 7%. The increase is too great in the organic content to be dismissed when comparing the emissions from the two chemical systems. To minimize the amount of catalyst used a pre-test, an evaluation of the catalyst requirements, was conducted to normalize the amount of catalysts used.

Furan produces cores that are, at best, 40% of the strength of the cores produced by the PU system used in test series CW and CP. To adjust for this difference, the resin content was raised from the 1.1% to 1.3% used for PU based on sand. This resin system cured much slower compared to the PU system as a result of cold temperatures. In order to remove future seasonal sensitivity for all the resin systems, the base sand will be preheated as needed to provide sand in the range of 70-80°F at the mixer.

The same tooling used to make PU cores/molds is used to make furan cores/molds; however, the cope and drag halves are each 7 inches high. A square plate support pedestal was found necessary to support the center of the mold in order to prevent failure of the mold prior to shakeout when poured at 2630°F.

Results

After a series of nine molds were made, three were selected and poured to determine the resin content, physical size and configuration, and hardware necessary to satisfy mechanical and emission test requirements to have a stable test cell. The final production methods and molding properties that will be used for emission testing are:

1. Cope height: 7 inches.
2. Drag height: 7 inches.
3. Resin content: 1.3% based on sand for a phenolic urethane family binder system.
4. In-gates dimensions: 1.50 inches wide by 0.12 inches high so castings separate during shakeout and the cope mold can pass to the catch pan.
5. Vertical sprue: 3-inch diameter, round pouring cup to reduce splash.
6. Support frame height: Top of mold at 28 inches above where frame rests on the shakeout. This provides two-sided support to the mold. A center support was also required.
7. Weighted frame setting: On the perimeter of the mold to minimize run outs.
8. Half-inch re-bar "J" hooks: Insert through 0.75-inch riser vents into the risers to hang castings separately from the sand during and after shakeout.
9. Pour time: 20-30 seconds.
10. Cooling time: 45 minutes.
11. Active shakeout time: 15 minutes.
12. Total emission-sampling time: 75 minutes.

A substantial percentage of the molds made would have failed due to runouts through warped parting lines. A second set of more rigid tools was created to control dimensions but proved insufficient in controlling warpage. The Furan material requires drying as part of its strengthening mechanism but cannot dry fast enough while in the core/mold tool. When the molds were unboxed from the tooling and closed they appeared to hold strength but the sand mass crept under its own weight, opening up the parting line.

The final solution was to make sure the four open face edges of the tools were co-planar in order to ensure flatness while being screened off. Additionally, new flat and rigid moldboards were made in-house to create a fully supported surface.

A more comprehensive description of the results can be obtained at the Technikon office.

Conclusions

In conclusion, this report accomplished the objective of determining the process requirements essential to manufacture No-Bake molds for the purpose of testing emissions from Furan No-Bake binder systems.