Casting Emission Reduction Program

www.cerp-us.org

Operated by

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US Army Contract W15QKN-05-D-0030

FY2006 Tasks

WBS # 2.2.2

Particulate Matter Sampling Method Comparison Proposed Test Plan

1413-222 NA

May 2008

(Revised for public distribution - August 2008)

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Particulate Matter Sampling Method Comparison
Proposed Test Plan

Technikon # 1413-222 NA

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

Director of Analytical Measurement Technologies	*//Original Signed//* Sue Anne Sheya, PhD	Date
Vice President of Operations	*//Original Signed//* George Crandell	Date

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Executive Summary

The objective of this study is to evaluate and compare the various promulgated and proposed methods for sampling and measuring both filterable and condensable particulate matter (PM) from industrial emission points. A thorough evaluation can best be accomplished by simultaneously sampling from a single complex source using the existing EPA Method 201A for filterable particulate combined with both the promulgated Method 202 and the modified "dry" Method 202 for condensable particulate, along with dilution tunnel methodologies CTM-039 and a commercial system, and comparing the results. Emissions from pouring, cooling and shakeout of digitally printed molds at the Research Foundry at Technikon, LLC will be used as the source of stack gases for the PM comparison testing.

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1.0 INTRODUCTION

1.1. Background

Technikon, LLC is a privately held contract research organization located in McClellan, California, a suburb of Sacramento. Technikon offers emissions research services to industrial and government clients specializing in the metal casting and point source emissions areas. Technikon operates the Casting Emission Reduction Program (CERP). CERP is a cooperative initiative between the Department of Defense (US Army) and the United States Council for Automotive Research (USCAR). The parties to the CERP Cooperative Research and Development Agreement (CRADA) include The Environmental Leadership Council of USCAR, a Michigan partnership of Chrysler Corporation, Ford Motor Company, and General Motors Corporation; the U.S. Army Research, Development, and Engineering Command (RDECOM-ARDEC); the American Foundry Society (AFS); and the Casting Industry Suppliers Association (CISA). The US Environmental Protection Agency (US EPA) and the California Air Resources Board (CARB) also have been participants in the CERP program and rely on CERP published reports for regulatory compliance data. All published reports are available on the CERP web site at www.cerp-us.org.

1.2. CERP/Technikon Objectives

The primary objective of CERP is to evaluate materials, equipment, and processes used in the production of metal castings. Technikon's facility was developed to evaluate alternative materials and production processes designed to achieve significant air emission reductions. The facility's principal testing arena is designed to measure airborne emissions from individually poured molds. This testing facility enables the repeatable collection and evaluation of airborne emissions and associated process data.

1.3. Report Organization

This report is divided into three sections. The first section is the introductory section. Section 2.0 gives the background and summary of the methodologies used for PM collection and measurement. Appendix A contains the proposed test plan for the study, which will be conducted by Technikon under another contract.

1.4. Study Objective

The objective of this study is to evaluate and compare the various promulgated and proposed methods for sampling and measuring both filterable and condensable particulate matter from industrial stacks.

2.0 BACKGROUND

Particulate matter (PM) emissions can generally be classified as filterable or condensable, and are defined by size fraction as total PM, PM_{10}, (PM with an aerodynamic diameter of 10 micrometers or less, or $PM_{2.5}$ (PM with aerodynamic diameter of 2.5 micrometers or less). Typically, EPA's validated reference test methods for PM (EPA Methods 5 and 17) measure only material that is collected on and ahead of the filter media of a sampling device. The type and size of material collected depends upon the temperature at which the filter media is maintained. These methods collect particulate at filter temperatures of the stack or higher. As a result, these test methods only capture the non-gaseous particulate material and do not capture the vaporous material that will condense in the atmosphere. This captured material is referred to as filterable particulate matter because it is the material that can be filtered out of the gas stream at the indicated temperature.

Other methods that are similar to Methods 5 and 17 are the PM_{10} methods, Methods 201 and 201A. These methods measure in-stack PM_{10} and the difference in these sampling trains and Methods 5 and 17 is that the probe nozzle is replaced by a cyclone, which has an aerodynamic cut size of 10 µm. The methods require only that the material collected behind the cyclone up to the filter be recovered and analyzed. Some source testers recover and weigh the larger than 10 µm material that is collected in and ahead of the cyclone. The summing of this material with the material following the cyclone up to the filter will result in a value similar to Method 17. However, as with Method 17, it may not give the same results as Method 5. With Methods 201 or 201A, the results should be reported as filterable PM_{10}. If the larger than 10 µm material is added to the PM_{10} material, the results should be reported as total filterable PM, with a note that describes the sampling train.

EPA Method 202, Determination of Condensable Particulate Emissions from Stationary Sources, is the only promulgated method available to measure and quantify condensable PM (CPM) emissions. Gaseous components can be partially absorbed in the impinger solutions required in the method, and chemically react to form material counted as CPM. A modification to improve the method by eliminating the water in the impingers has been made to reduce the formation of these CPM artifacts. This method has recently been published as OTM-28.

Conditional Test Method (CTM)-039 is a dilution sampling procedure that approximates the formation of particles that form in a plume downstream of a stack as the stack gases are cooled by mixing with ambient air. CTM-039 uses a PM_{10} cyclone followed by a $PM_{2.5}$ cyclone so both size cuts can be obtained. This method provides results directly in terms of total PM_{10} and total $PM_{2.5}$. Unfortunately, this method requires extremely large and bulky sampling equipment which is expensive to operate and is vulnerable to wall losses of CPM. EPA has a second conditional test method, OTM-27, that also combines two cyclones in series, a PM_{10} cyclone followed by a $PM_{2.5}$ cyclone. The cyclones are located in the stack, as in a Method 201 or 201A train. The difference in the two methods is that CTM-039 does not have to be combined with Method 202 to obtain both filterable and condensable fractions, whereas OTM-27 does.

2.1. Scope of Study

The great interest by government and industry in solving the problem of accurately sampling and measuring condensable particulate can best be accomplished by simultaneously sampling from a single complex source using the existing Method 202, the modified "dry" Method 202 (OTM-28), and dilution tunnels and comparing the results. CERP and Technikon have provided the means for a unique opportunity to generate data that can not only provide answers to many of the existing questions regarding particulate matter method sampling, but also can provide data that will be publicly shared.

The proposed sampling scheme could encompass CTM-039, OTM-27 in combination with the standard Method 202, OTM-27 in combination with the modified Method 202 (OTM-28), and a prototype dilution sampling system currently under construction and testing by Desert Research Institute (DRI) and Baldwin Environmental, Inc (BEI).

Any or all of these methods would be used for particulate matter comparison testing on the 6" stack off of the Research Foundry Total Enclosure Hood at Technikon for pouring, cooling and shakeout of iron. Either PM_{10} or $PM_{2.5}$ cyclones or both will be used for selecting the size fraction of the filterable PM for Method 201A.

A total of 2-4 sampling devices would be run simultaneously and PM results compared.

Six to eight runs of 75 - 90 minutes should be adequate to obtain both sufficient materials for accurate mass measurements and for statistical analysis.

Molds and cores could be designed to specifically produce a broad spectrum of airborne pollutants besides PM, including oxides of sulfur and nitrogen, ammonia, hydrocarbons, and inorganics. Most likely, the molds to be used will be molds produced using the ProMetal® RTC S-15 digital printer. The molds will be made using a furfuryl alcohol based binder with toluenesulfonic acid activator. This binder system will result in sulfur dioxide, hydrocarbons, and inorganic airborne emissions.

Gas analyses will be undertaken in addition to PM sampling so that gas emissions results from this test can be used as a product comparison emissions test to CERP 1412-HRb, which discussed the pouring, cooling and shakeout emissions from digitally printed 4-on gear molds.

Continuous monitoring of NO_x, total gaseous hydrocarbons, methane, CO and CO_2 can be easily conducted for all runs. In addition, anionic and cationic analyses on the impinger solutions, elemental and organic carbon analysis on the PM formed, and speciated chemical analysis on gas emissions all can easily be added to the sampling protocol.

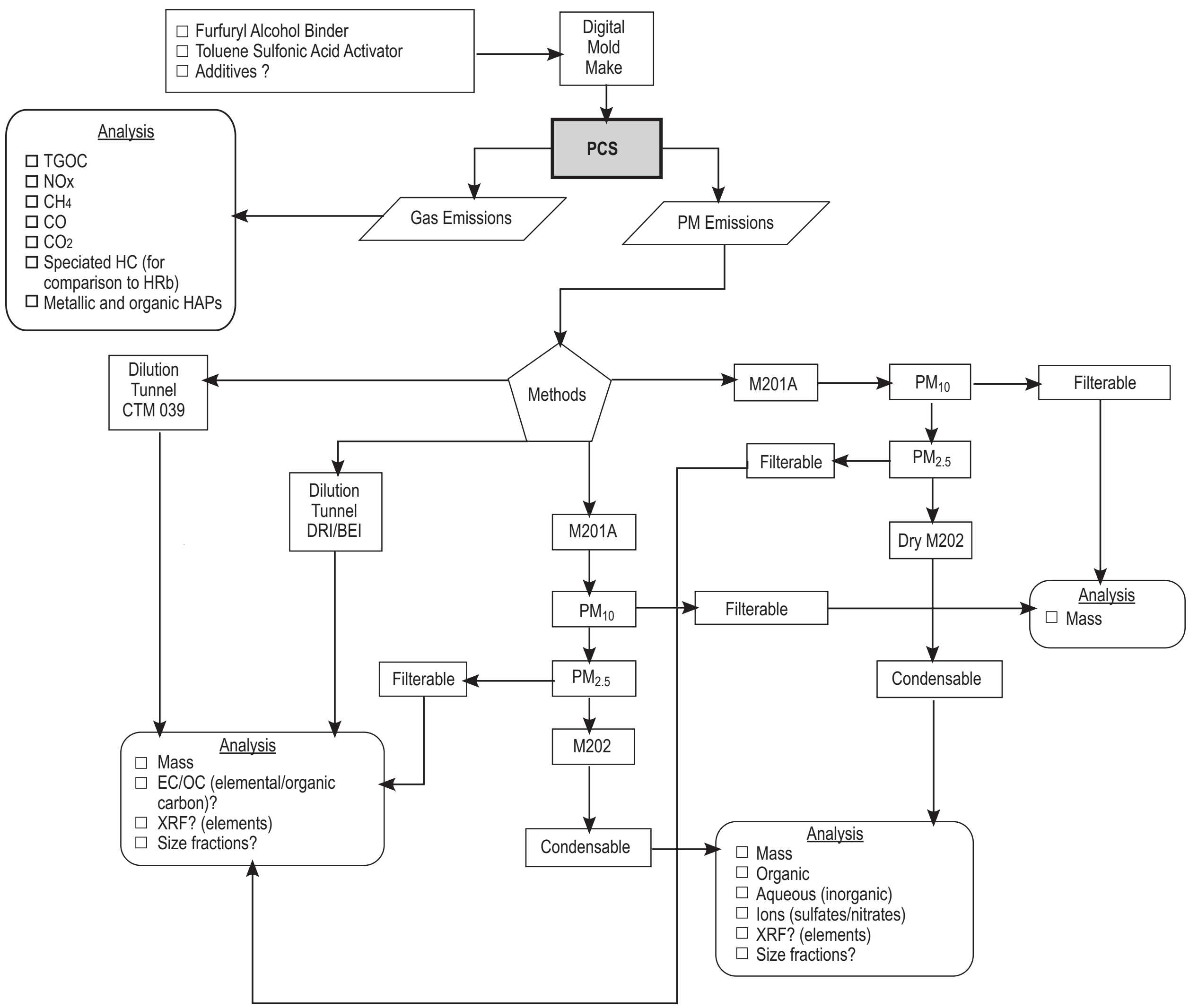
Analyzing for generated pollutants other than PM mass could provide understanding into the formation and fate of compounds that may become condensable artifacts. Speciated sampling and conducting a mass balance of chemical species from the gas emissions and the condensate from Method 202 can accomplish this.

All gas analysis would be conducted using Technikon's existing on-line gas analyzers. PM sampling and analysis would be accomplished through a combination of existing labware and cyclones at Technikon, borrowing of the CTM-039 dilution system from EPA's subcontractor, Mactec, and renting the DRI/BEI system.

A flowchart of the proposed testing is given in Figure 1. In this scenario, PM_{10} is analyzed gravimetrically, while $PM_{2.5}$ is analyzed gravimetrically as well as for size and chemical characterization for elemental and organic carbon fraction, and by x-ray fluorescence for inorganic elemental analysis. This same analysis would be conducted on the PM sampled from the dilution tunnels. Condensable PM obtained from both the “dry” Method 202 impingers and the promulgated Method 202 impingers would undergo similar analysis to that of the filterable $PM_{2.5}$ with the addition of ion chromatography for the determination of artifacts in the condensable fraction. Other potential analytical options are listed in the flow chart with a following question mark.

The test plan is outlined in Appendix A.

Figure 1 Test Plan Flowchart



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APPENDIX A TEST PLAN

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Technikon Test Plan

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Fill-in and check all that apply

♦ **CONTRACT NUMBER:** 1413 **TASK NUMBER** 222 **DOUBLE ALPHA** NA

♦ **SITE:**	☒ On Site at Research Foundry ☐ Off Site at _____
♦ **DATE RANGE:**	From Jun. 1, 08 to Jul. 15, 08
♦ **TEST OBJECTIVE:**	☒ Emissions Testing ☐ Mechanical Properties ☐ Casting Quality ☒ Comparison to HRb ☐ Other _____
♦ **PROCESSES:**	☒ Pouring ☒ Cooling ☒ Shakeout ☐ Mixing ☐ Making ☐ Storage ☐ Other _____
♦ **TEST TYPE:**	☐ Baseline ☒ Product ☐ Other _____
♦ **METAL:**	☒ Iron ☐ Aluminum ☐ Steel ☐ Other _____ Alloy _____ Pour Temp: 2630 ± 10°F
♦ **RUNS:**	Number for Conditioning 0 Duration _____ minutes Number for Testing Samples 6 Duration 75 or 90 minutes
♦ **PROPERTIES TO BE TESTED:**	☐ Mold Strength ☐ Moisture Content ☐ _____ °F LOI% ☒ _____ °F Volatiles ☐ Release Agent ☐ Binder ☐ Clay ☐ Sand ☐ Activator Other _____
♦ **RESULTS TO BE ANALYZED AND REPORTED:**	☒ Emissions: ☒ HAPs ☒ POMs ☒ Criteria Pollutants ☒ Greenhouse Gases ☒ Other PM2.5 ☐ Casting Quality: ☐ Coated Cores ☐ One Cavity ☐ All Cavities ☐ Other _____ ☐ Mechanical Properties: ☐ Tensile Strength ☐ Weight Change ☐ Flowability ☐ Compressibility ☐ Other _____
♦ **BRIEF OVERVIEW:**	*This test will measure airborne emissions from digitally printed 4-on gear molds. Gas emissions will be compared to those from Test HRb. PM filterable and condensable emissions will also be measured. Several collection and measurement methods for PM2.5 will be used simultaneously to allow a direct comparison of PM2.5 sampling methods. The methods to be used include dilution tunnels and cyclones and impingers.*
♦ **ADDITIONAL COMMENTS:**	_

Technikon Test Plan

Fill-in and check all that apply

♦ **CONTRACT NUMBER:** 1413 **TASK NUMBER** 222 **DOUBLE ALPHA** NA

	Cores	**Molds**	**Other**
♦ **PATTERN:**	☐ Step ☐ Other _____ Number _____ Number Cavities _____ Storage Temp: _____°F Storage Age: _____ Dimensions: ☐ Standard (24x24x10/10) ☐ Other _____	☐ Step ☐ Star ☒ Irregular Gear ☒ Other Digital Number 6 Number Cavities 4 Storage Temp: _____°F Storage Age: 40+ hours Dimensions: ☒ Standard (24x24x10/10) ☐ Other _____	☐ Dogbone ☐ Shakeout ☐ Flowability ☐ Other _____ Number _____ Number Cavities _____ Storage Temp: _____°F Storage Age: _____ Dimensions: ☐ Standard (24x24x10/10) ☐ Other _____
♦ **BINDER :**	☐ Cold box ☐ Warm box ☐ Hot box ☐ No-bake ☐ Shell ☐ Oil ☐ Other _____ Concentration _____ (BOS) Ratio ($\frac{P1}{P2}$) _____ Product Name(s) _____	☐ Cold box ☐ Warm box ☐ Hot box ☒ No-bake ☐ Shell ☐ Oil ☐ Other _____ Concentration 1.1% (BOS) Ratio ($\frac{P1}{P2}$) _____ Product Name(s) _____	☐ Cold box ☐ Warm box ☐ Hot box ☐ No-bake ☐ Shell ☐ Oil ☐ Other _____ Concentration _____ (BOS) Ratio ($\frac{P1}{P2}$) _____ Product Name(s) _____
♦ **CHEMISTRY:**	☐ Phenolic Urethane ☐ Furfuryl Alcohol ☐ Low Emission (inc. Sodium Silicate) ☐ Epoxy-Acrylic ☐ Alkaline Phenolic Ester ☐ Other _____	☐ Phenolic Urethane ☒ Furfuryl Alcohol ☐ Low Emission (inc. Sodium Silicate) ☐ Epoxy-Acrylic ☐ Alkaline Phenolic Ester ☐ Other _____	☐ Phenolic Urethane ☐ Furfuryl Alcohol ☐ Low Emission (inc. Sodium Silicate) ☐ Epoxy-Acrylic ☐ Alkaline Phenolic Ester ☐ Other _____
♦ **CATALYST:**	☐ CO_2 Cured ☐ SO_2 Cured ☐ Acid Cured ☐ TEA Cured ☐ Hot Air Cured ☐ Methyl Formate Cured Concentration _____ BOS Concentration_____ BOR ☐ Other _____	☐ CO_2 Cured ☐ SO_2 Cured ☒ Acid Cured ☐ TEA Cured ☐ Hot Air Cured ☐ Methyl Formate Cured Concentration _____ BOS Concentration_____ BOR ☐ Other _____	☐ CO_2 Cured ☐ SO_2 Cured ☐ Acid Cured ☐ TEA Cured ☐ Hot Air Cured ☐ Methyl Formate Cured Concentration _____ BOS Concentration_____ BOR ☐ Other _____

Technikon Test Plan

Fill-in and check all that apply

♦ **CONTRACT NUMBER:** 1413 **TASK NUMBER** 222 **DOUBLE ALPHA** NA

	Cores	Molds	Other
♦ **SAND:**	☐ Greensand ☐ No-Bake ☐ Other _____ Additives _____ to yield ______ %LOI Product Name(s) _____	☐ Greensand ☒ No-Bake ☐ Other _____ Additives _____ to yield 1.0%LOI Product Name(s) _____	☐ Greensand ☐ No-Bake ☐ Other _____ Additives _____ to yield ______ %LOI Product Name(s) _____
♦ **RELEASE AGENT:**	Concentration _____ Application Method _____ Product Name(s) _____	Concentration None Application Method _____ Product Name(s) _____	Concentration _____ Application Method _____ Product Name(s) _____
♦ **COATING:**	☐ None ☐ All Runs ☐ Conditioning Runs Only ☐ Test Runs Only ☐ Baumé _____ ☐ Other _____ Application Method _____ Drying Method _____ Product Name(s) _____	☒ None ☐ All Runs ☐ Conditioning Runs Only ☐ Test Runs Only ☐ Baumé _____ ☐ Other _____ Application Method _____ Drying Method _____ Product Name(s) _____	

This test plan routed to or reviewed by:

- Senior Process Engineer
- Technical Director/Foundry Manager
- Director of Measurement Technologies
- Vice President of Operations
- Applicable Steering Committee Members

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APPENDIX B ACRONYMS AND ABBREVIATIONS

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ACRONYMS & ABBREVIATIONS

AFS	American Foundry Society
ARDEC	(US) Army Armament Research, Development and Engineering Center
CARB	California Air Resources Board
CO_2	Carbon Dioxide
CO	Carbon Monoxide
CERP	Casting Emission Reduction Program
CISA	Casting Industry Suppliers Association
CPM	Condensable Particulate Matter
CTM	Conditional Testing Method
CRADA	Cooperative Research and Development Agreement
DOD	Department of Defense
DOE	Department of Energy
EC	Elemental Carbon
HC	Hydrocarbon
CH_4	Methane
NOx	Nitrogen Oxides
OC	Organic Carbon
PM	Particulate Matter
PCS	Pouring, Cooling, Shakeout
SO_2	Sulfur Dioxide
TGOC	Total Gaseous Organic Concentration
USCAR	United States Council for Automotive Research
US EPA	United States Environmental Protection Agency
WBS	Work Breakdown Structure
XRF	X-Ray Fluorescence