Casting Emission Reduction Program

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US Army Contract DAAE30-02-C-1095

FY2003 Tasks

WBS # 6.1.2

Core Binder Supplemental Additions to Compensate for Tensile Strength Loss When Adding Anti Veining Compound to Wedron 530 Silica Sand/ISOCURE® Cores

Technikon #1410-612 GF

October 2004

(revised for public distribution)

United States Environmental Protection Agency

CISA

AMERICAN FOUNDRY SOCIETY, INC.

UNITED STATES COUNCIL FOR AUTOMOTIVE RESEARCH

DaimlerChrysler Ford Motor Company General Motors

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WBS # 6.1.2

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

Process Engineering Manager:	*// Original Signed //* Steven Knight	Date
VP Measurement Technologies:	*// Original Signed //* Clifford Glowacki, CIH	Date
VP Operations:	*// Original Signed //* George Crandell	Date
President:	*// Original Signed //* William Walden	Date

The data contained in this report were developed to assess the change in core material mechanical properties. You may not obtain the same results in your facility.

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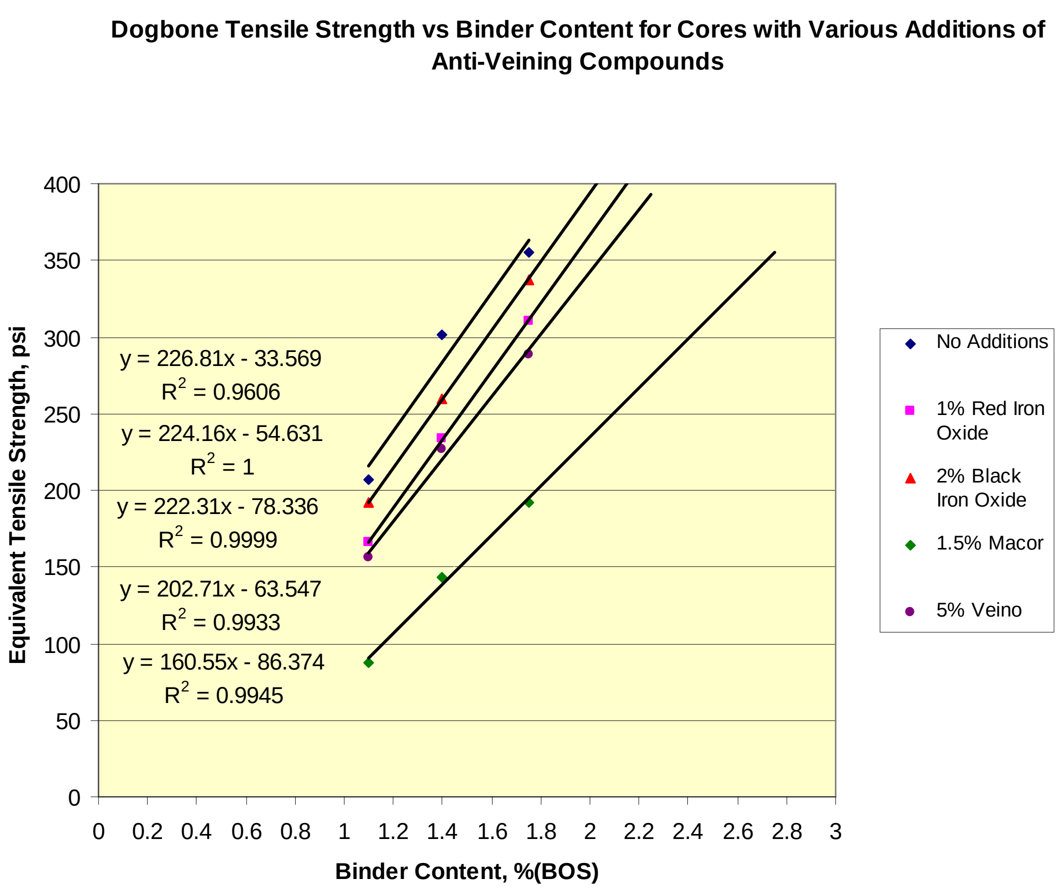
Executive Summary

The objective of this testing was to determine how much additional Ashland 305/904 cold box binder would be necessary to add to Wedron 530 cores containing 1.10-1.75% binder to compensate for tensile strength loss consequent due to the addition of various anti –veining compounds.

The dogbone tensile test pieces were prepared using a Hobart lab mixer and tested using a Thwing-Albert tensile tester as described in report Capability Comparison Study: Thwing-Albert QC-3A & Dietert 405 Tensile Testers And Klein Eccentric Oscillatory & Hobart Epicentric Sand Mixers 1410-610-FX.

Figure 1-1 graphically summarizes the dogbone tensile strengths achieved from mixtures of Wedron 530 sand, 1.10-1.75% (BOS) additions of Ashland ISOCURE® 305/904 binder with various anti-veining compounds added at the concentration recommended by the CERP Steering Committee.

Figure 1-1 Dogbone Tensile Strength with and without Anti-Veining Compound Addition



When the regression equations for the test pieces containing the anti-veining compounds are each set equal to the equation for the test pieces having no additions and solved for the binder content, Table 1-1 results. Table 1-1 expresses each binder concentration in terms of the binder concentration in the "no addition" cores. Table 1 is equating supplemental binder requirements to compensate for tensile strength loss due to anti-veining compound additions to Wedron 530 core sand mixtures containing 1.10-1.75% (BOS) Ashland ISOCURE® 305/904 binder.

Table 1-1 Regression Equations

Anti Veining Addition	Relative Binder Necessary to have Equal Tensile Strength
No Addition	
1% Red Iron Oxide	C=1.02 * C (no addition) + 0.20
2% Black Iron Oxide	C=1.01 * C (no addition) + 0.09
1.5% Mixed Material (Macor®)	C=1.41 * C (no addition) + 0.33
5% Aluminum Silicate (Veino®)	C=1.12 * C (no addition) + 0.15

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 metal casting and emissions measurement technologies. 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). Its purpose is to evaluate alternative casting materials and processes that are designed to reduce air emissions and/or produce more efficient casting processes. Other technical partners directly supporting the project include: the American Foundry Society (AFS); the Casting Industry Suppliers Association (CISA); the US Environmental Protection Agency (US EPA); and the California Air Resources Board (CARB).

1.2 CERP OBJECTIVES

The primary objective of CERP is to evaluate the impact of new materials, equipment, and processes on airborne emissions from the production of metal castings. To accomplish this objective, the Technikon facility was created to evaluate alternate materials and production processes designed to achieve significant airborne emission reductions, especially for organic Hazardous Air Pollutants (HAPs). HAP emissions reduction from the alternative materials, equipment and production processes is expressed as a comparison to similar emissions from a baseline or reference test. These alternate materials, equipment, and processes may need to be further adapted and defined so that they will integrate into current commercial greensand casting facilities smoothly and with minimal capital expenditure.

Testing is conducted in order to evaluate the impact on air emissions from a proposed alternative material, equipment or process. The Technikon foundry is a simple, general-purpose mechanically assisted foundry, which was adapted and instrumented to allow the collection of detailed emission measurements, using methods based on USEPA air testing protocols. Measurements are taken during pouring, casting cooling, and shakeout processes performed on discrete mold and/or core packages under tightly controlled conditions not feasible in a commercial foundry.

Castings are randomly selected to evaluate the impact of the alternate material, equipment, or process on the quality of the casting.

The results of the testing conducted at the foundry are not suitable for use as general emission factors. The specific materials used (gray iron from an electric melt furnace, greensand with seacoal, and a cold box core with a relatively old resin binding system); the specific castings produced; the specific production processes employed; and the specific testing conditions (relatively low stack velocity, long sampling times, high capture rates) produce emission results unique to the materials, castings, casting processes and measurement conditions used. The data produced are intended to demonstrate the relative emission reductions from the use of alternative materials, equipment and processes, and not the absolute emission levels that would be experienced in commercial foundries. A number of process parameters such as casting surface area, sand to metal ratios, pouring temperatures, stack flow rates, LOI levels, seacoal and resin contents and the type of foundry (Cope & Drag versus Disa, for example) can have a significant impact on actual emission levels.

The foundry provides simultaneous detailed individual emission measurements using methods based on US EPA protocols for the melting, pouring, sand preparation, mold making, and core making processes. The core making area of the foundry contains three core blowers: a Georg Fischer Core Blower for the preparation of automotive block cores, a Redford Core Blower that is used for the production of step cores, and a second smaller Redford Core Blower to produce dogbone tensile test specimens used in this test

1.3 REPORT ORGANIZATION

This report has been designed to document the methodology and results of a specific test plan that was used to evaluate the impact of anti-veining compound additions to core formulations on the core tensile strength. Section 2 of this report includes a summary of the methodologies used for data collection and analysis, QA/QC procedures, and data management and reduction methods. Specific data collected during this test are summarized in Section 3 of this report with detailed data included in appendices of this report. Section 4 of this report contains a discussion of the results.

The raw data for this test series are included in a data binder that is maintained at the Technikon facility.

1.4 SPECIFIC TEST PLANS AND OBJECTIVES

This report contains the results of testing performed to assess how much supplemental binder was required to mitigate the impact on tensile strength of adding anti-veining compounds to core sand mixes. A summary of the test plan for the individual test series is shown in Table 1-2.

Table 1-2 Number of Dogbone Tensile Test Pieces to be Made from the Compositions Listed

Additions - Binder % BOS	1.1 %	1.4 %	1.75 %
No additions	30	30	30
1 % Ashland Red iron oxide fine	30	30	30
2 % Chesapeake Specialties SpherOX fine	30	30	30
1.5 % Mixed Material (J.S. McCormick Macor®)	30	30	30
5 % Aluminum Silicate (Ashland Veino®)	30	30	30

2.0 Test Methodology

2.1 Mixing followed the Ashland Specialty Chemical Co. protocol for preparing core sands in a Hobart mixer.

Figure 2-1 Hobart Epicentric Sand Mixer

Figure 2-2 Redford/Carver Dogbone Core Machine

Figure 2-3 Three-on Dogbone Core Box

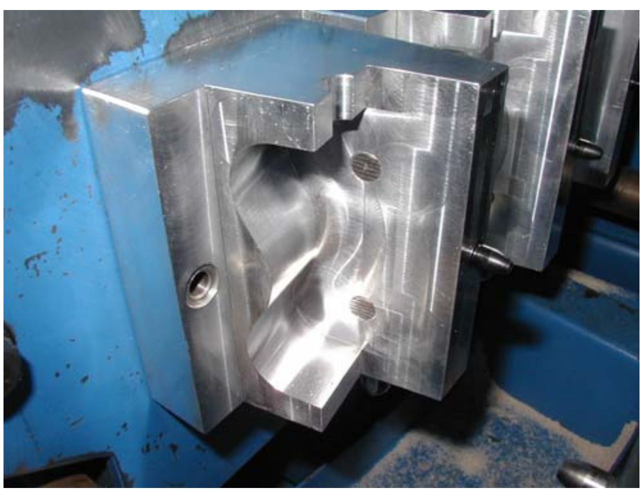
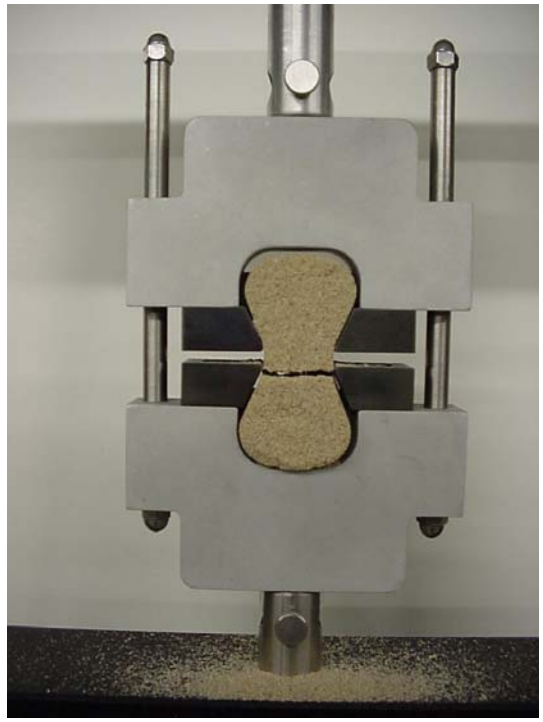


Figure 2-4 Weighing Dogbones to 0.1 gram Resolution

Figure 2-5 Thwing-Albert QC-3A Tensile Tester

Figure 2-6 Tested Dogbones



2.2 DESCRIPTION OF TESTING PROGRAM

The testing was conducted at the Technikon foundry core room and materials laboratory using methods based on the AFS Mold & Core Testing manual 3rd addition. No air emission measurements were required for this test series.

16 Triethylamine (TEA) gassed sets of 30 cores each were made with Wedron 530 sand having 1.1, 1.4, & 1.75 % Ashland ISOCURE® 305LF/904GR binder mixed in the Hobart mixer for 4 minutes at 72-77 ^{o}F. The cores were all batch, blow cycle and cavity identified, aged 24 hours and broken on the Thwing-Albert tensile tester. One set at each binder concentration contained one of four anti veining compounds. One set at each binder concentration had no anti-veining compound additions as a reference. One additional set without anti-veining compound was produced to provide warm up tensile test pieces for the Thwing Albert tensile tester.

TEST PLAN REVIEW AND APPROVAL

The proposed test plan was reviewed by the Technikon personnel and approved by the CERP Steering Committee. Table 2-1 lists the process parameters that were monitored during each test. The analytical equipment and methods used are also listed. The test plan is included in this report in Appendix A.

Table 2-1 Process Parameters Measured

Parameter	Analytical Equipment and Methods
Core weight	Mettler SB12001 electronic platform scale (gravimetric)
Sand Temperature	Fluke 52 thermocouple
LOI	Denver analytic (AFS procedure 5100-00-S)
Sand batching weight	Mettler SB12001 electronic platform scale (gravimetric)
Core machine pressure	Machine mounted pressure gauge
TEA gas & purge air temperature	Chromolox temperature controller
Tensile tester ambient temperature	Room ambient air temperature control system

DATA REDUCTION, TABULATION AND PRELIMINARY REPORT PREPARATION

The analytical results of the LOI and tensile tests are included in Section 3 of this report. Calibrations and other QA/QC measurements are kept on file at Technikon.

REPORT PREPARATION AND REVIEW

The preliminary draft report was reviewed by Technikon to ensure its completeness, consistency with the test plan, and adherence to the prescribed QA/QC procedures. Appropriate observations, conclusions and recommendations are added to the report to produce a Draft Report. The Draft Report is reviewed by the Vice President-Measurement Technologies, the Vice President-Operations, the Manager-Process Engineering, the Technikon President, and the CERP Steering Committee. Comments are incorporated into a draft Final Report prior to final signature approval and distribution.

2.3 QUALITY ASSURANCE AND QUALITY CONTROL (QA/QC) PROCEDURES

Detailed QA/QC and data validation procedures for the process parameters, are included in the "Technikon Testing, Quality Control and Quality Assurance, and Data Validation Procedures Manual" In order to ensure the timely review of critical quality control parameters, the following procedures are followed:

- Immediately following the individual runs performed for each test, specific process parameters were reviewed by the Manager-Process Engineering to ensure that the parameters are maintained within the prescribed control ranges. Where data are not within the prescribed ranges, the Manager-Process Engineering and the Vice President-Operations determine whether the individual test samples should be invalidated or flagged for further analysis.

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3.0 Test Results

Table 3-1 shows the average tensile strength of thirty (30) dogbone pieces for each kind of composition.

Figure 3-1 displays the average tensile strength of 30 dogbone pieces vs. binder content for sands having various anti-veining compounds added.

Table 3-2 shows the regression equations to determine the equivalent amount of binder required to mitigate the effects of adding anti-veining compound.

The detail of this data is in Appendix B.

Table 3-1 Average Tensile Strength of 30 Dogbone Pieces for Each Composition.

Binder Content, % (BOS)	1.1	1.4	1.75
Anti Vein Addition	**Tensile Strength, psi**		
No Addition	206.6	301.2	355.4
1% Red Iron Oxide	165.8	233.7	310.4
2% Black Iron Oxide	191.7	259.6	337.5
1.5% Mixed Material	87.8	142.9	192.5
5 % Aluminum Silicate	156.1	226.5	288.3

Figure 3-1 Average Tensile Strength of 30 Dogbone Pieces vs. Binder Content

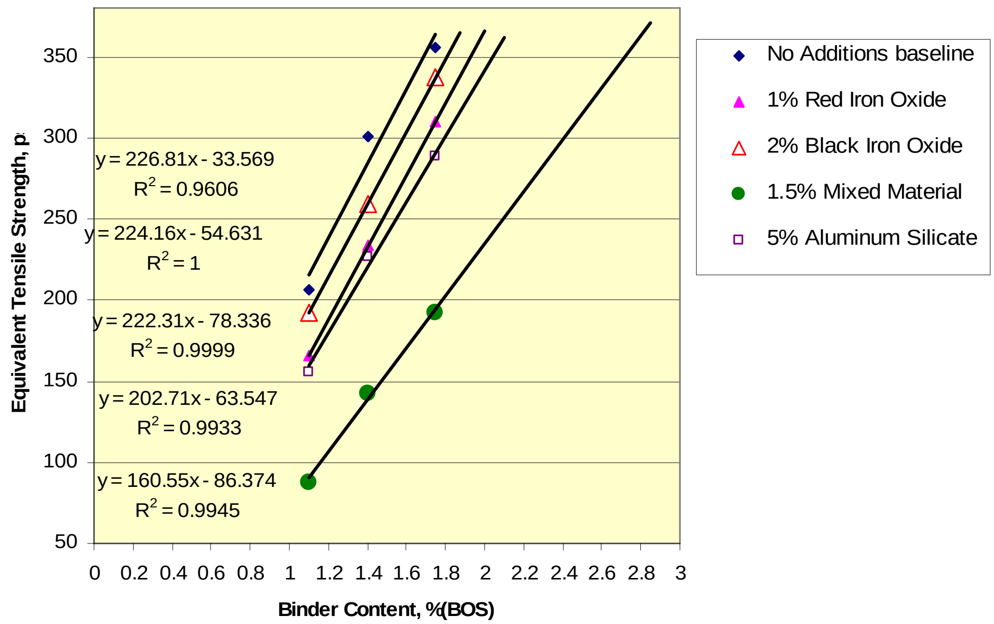

Table 3-2 Regression Equations for Binder Requirement

Anti Veining Addition	Relative Binder Necessary to Have Equal Tensile Strength
No Addition	
1% Red Iron Oxide	C=1.02 * C (no addition) + 0.20
2% Black Iron Oxide	C=1.01 * C (no addition) + 0.09
1.5% Mixed Material	C=1.41 * C (no addition) + 0.33
5% Aluminum Silicate	C=1.12 * C (no addition) + 0.15

4.0 Discussion of Results

Tensile strength was nearly linear with binder concentration in the range investigated for all materials.

Based on the nearly identical slopes of the tensile strength vs. binder concentration curves for no anti-veining compound, red iron oxide, and black iron oxide these oxides had little impact on the mechanisms creating tensile strength of ISOCURE® 305/904 cores. The impact on supplemental binder requirements were minimal reflecting only the change in aggregate size distribution.

Aluminum Silicate, while it had more impact, demonstrated no new mechanisms. By contrast the Mixed Material demonstrating the most dramatic deterioration of tensile strength required the most supplemental binder addition to mitigate the effects.

In order to determine the amount of binder required to mitigate strength loss relative to “no additions” at 1.4% binder use Figure 3-1. Start at a binder content on the “no addition” line and move at constant strength to the right until the line representing the desired mixture is intercepted. Read straight down to the binder content scale to read the binder requirement to give equivalent strength.

This can also be calculated using the equations in Table 3-2. These equations are valid only in the area near 1.1-1.75% Based on Sand (BOS) binder. Because of the linear appearance of the tensile strength vs. binder graphs it is not unreasonable to expect that small differences in the quantity of anti-veining compound would have proportional impact on the core tensile strength.

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APPENDIX A APPROVED TEST PLAN AND INSTRUCTIONS FOR TEST GF

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Series GF

Improve Casting Process: Core Binder Content for Constant Strength Cores Containing Sand Additives Ashland Isocure® 305-9044 Binder

Test Plan and Process Instructions

The following work is to be performed under the above task number.

Make several 4000 gram sand batches in the Hobart mixer according to the following matrix. Make batches from Wedron 530 sand, 70-80°F and Ashland ISOCURE® 305/904 binder in a 55/45 ratio. The mixing will follow the Ashland protocol.

Additions	Binder % BOS	1.1 %	1.4 %	1.75 %
No additions		2	1	1
1 % Ashland Red iron oxide fine		1	1	1
2 % Chesapeake Specialties SpherOX fine		1	1	1
1.5 % J.S. McCormick Macor®		1	1	1
5 % Ashland Veino®		1	1	1

Use the first batch of 1.1 % binder with no additions to warm up the R/C dogbone core machine. Then make one batch each for a total of 15 variations. Make a set of dogbones from each batch within 30 minutes of the time that the mixing is done. Document the sand temperature, mixing length and clock time when mixing is done, dogbone manufacture start and stop clock time. Mark each core with manufactured sequence number and coded composition as follows:

Legend:		
	A= 1.1 % binder	R = Red Iron Oxide
	B = 1.4 % binder	B = Black Iron Oxide
	C = 1.75 % binder	M = Macor®
		V = Veino®

E.g. "7BM" would be the 7th core made and the composition would be 1.4 % binder with a Macor addition.

Make as many dogbones as a batch will accommodate, usually 9-10 bones.

24 hours after manufacturing completion begin pulling the bones on the Thwing-Albert Tensile tester.

Save one core from each batch for a triplet of Loss on Ignition (LOI) cores.

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APPENDIX B PROCESS DATA DETAILS

Table B1. Tensile Strength of dogbones made from mixtures of Wedron 530 sand, Ashland ISOCURE® 305/904 binder, and various anti-veining compounds.

DOG BONE TENSILE LOG						
Sand Batch#						5-Aug-04
Binder	Ashland 305/904					
batch	number	Time of test hh:mm	North dog psi	Middle dog psi	South dog psi	comments
1	1AT	7:45	193.1	199.2	177.6	
1	2AT	7:46	188.2	202.8	193.7	TEST
1	3AT	7:47	186.80	183.6	171.9	TEST
1	4AT	7:49	180.60	183.2	183.1	TEST
1	5AT	7:52	153.70	175.3	157	TEST
1	6AT	7:54	183.60	187	170	TEST
1	7AT	7:56	163.70	163.6	176.3	TEST
2	A1	7:58	215.30	209.4	211.6	
2	2A	8:00	201.20	215.6	207.1	
2	3A	8:02	191.90	198	191.7	
2	4A	8:03	200.20	211.4	202.8	
2	5A	8:04	200.30	211.2	206.9	
2	6A	8:05	195.70	209.5	206.8	
2	7A	8:07	239.10	244.7	243	
2	8A	8:08	197.10	197.5	180.53	
2	9A	8:09	219.00	205	192	
2	10A	8:11	197.10	198.3	199.2	206.64
3	1B	8:12	302.50	299.3	292.5	
3	2B	8:13	295.00	299.3	296.8	
3	3B	8:15	299.00	294.2	293.7	
3	4B	8:16	323.3	315.7	305	
3	5B	8:18	291.9	285.6	296.9	
3	6B	8:20	304.4	288	317.4	
3	7B	8:21	293	302.5	292.1	
3	8B	8:22	306.90	305.6	287.6	

DOG BONE TENSILE LOG						
Sand Batch#						5-Aug-04
Binder	Ashland 305/904					
batch	number	Time of test hh:mm	North dog psi	Middle dog psi	South dog psi	comments
3	9B	8:28	317.70	307.1	310.5	
3	10B	8:30	313.10	296.4	302.7	301.19
4	1C	8:31	363.10	348.6	367.2	
4	2C	8:33	354.90	360.5	379.4	
4	3C	8:34	351	373.7	352.2	
4	4C	8:36	359.8	343.4	352.7	
4	5C	8:37	353.9	373	343	
4	6C	8:38	370	354.6	364.1	
4	7C	8:39	345.1	348.9	338.3	
4	8C	8:41	352	358.4	356.5	
4	9C	8:42	363.6	350.6	341.2	
4	10C	8:44	347.8	353.2	340.9	355.39
5	1AR	8:45	173	174.4	174.4	
5	2AR	8:46	176.3	182.3	170.2	
5	3AR	8:48	166.7	171.6	168.6	
5	4AR	8:49	168.3	166.9	160.9	
5	5AR	8:51	153.6	162	156.3	
5	6AR	8:53	176.4	166.2	155.3	
5	7AR	8:54	183	169.2	164.7	
5	8AR	8:55	168.4	153.3	157.4	
5	9AR	8:56	162.7	157.1	145.3	
5	10AR	8:57	167.8	165.9	155.5	165.79
6	1BR	9:18	233.7	228.2	244.5	
6	2BR	9:20	239.8	241.9	217.5	
6	3BR	9:21	222.9	236.7	237.7	
6	4BR	9:23	229.7	233.8	229.5	
6	5BR	9:24	236.5	223.4	225.1	
6	6BR	9:25	229.2	235.3	232.6	
6	7BR	9:26	233.5	243.5	246.2	
6	8BR	9:28	245.8	235.8	217.7	
6	9BR	9:29	245.2	229	227	

DOG BONE TENSILE LOG						
Sand Batch#						5-Aug-04
Binder	Ashland 305/904					
batch	number	Time of test hh:mm	North dog psi	Middle dog psi	South dog psi	comments
6	10BR	9:30	249.3	231.2	228.2	233.68
7	1CR	9:33	325.3	322.3	326.2	
7	2CR	9:35	308.1	325.3	311.8	
7	3CR	9:36	316.5	321.4	299.8	
7	4CR	9:37	310.3	320	304	
7	5CR	9:39	309.5	306.9	304.3	
7	6CR	9:41	301.1	316	302.6	
7	7CR	9:43	305.4	312.1	300	
7	8CR	9:45	311	320.4	306.5	
7	9CR	9:46	309.4	313.2	301.9	
7	10CR	9:47	306.1	302.9	290.3	310.3533
8	1AB	9:49	189.9	214.7	213	
8	2AB	9:50	202.9	204.2	191.2	
8	3AB	9:52	192.9	196.8	191.1	
8	4AB	9:53	183.2	194.9	175.7	
8	5AB	9:55	185.1	193.7	179.9	
8	6AB	9:56	191.7	194.8	188.1	
8	7AB	9:57	201.2	196	172.2	
8	8AB	9:59	192.3	184.1	166.9	
8	9AB	10:01	197.3	191.6	185.4	
8	10AB	10:03	195.8	196.8	188.6	191.7333
9	1BB	10:04	267.7	274.9	260.3	
9	2BB	10:05	256.7	271.2	249.9	
9	3BB	10:06	265.5	266.1	258.1	
9	4BB	10:08	254.2	249.2	258	
9	5BB	10:09	254.8	255.3	253.1	
9	6BB	10:11	261.1	243.5	251.1	
9	7BB	10:13	260.3	275.8	251.6	
9	8BB	10:15	268.8	276.3	250.4	
9	9BB	10:17	261.8	257.8	244.4	
9	10BB	10:20	266.3	273.3	250.4	259.5967

DOG BONE TENSILE LOG						
Sand Batch#						5-Aug-04
Binder	Ashland 305/904					
batch	number	Time of test hh:mm	North dog psi	Middle dog psi	South dog psi	comments
10	1CB	10:21	341.1	344.8	339.6	
10	2CB	10:22	329.9	355.6	344.1	
10	3CB	10:27	336	337.8	330.3	
10	4CB	10:29	317.3	338.7	325.1	
10	5CB	10:31	329.8	345.5	332.2	
10	6CB	10:33	345.5	337.6	333.4	
10	7CB	10:36	338.7	327.7	334.6	
10	8CB	10:38	340.6	336.9	327.7	
10	9CB	10:42	346.3	339.8	319.7	
10	10CB	10:44	350.5	357.5	339.8	337.47
11	1AM	11:37	86.8	88.7	87.4	
11	2AM	11:38	89.4	88.9	88.7	
11	3AM	11:40	95.8	90.7	87.2	
11	4AM	11:42	76.9	89.4	87.3	
11	5AM	11:43	85.1	85.4	86.2	
11	6AM	11:44	86	82.3	85.4	
11	7AM	11:45	88.8	84.9	83.4	
11	8AM	11:46	100.1	97.1	93.9	
11	9AM	11:47	92.3	86.1	78.8	
11	10AM	11:49	88.1	86	87.4	87.81667
12	1BM	10:57	148.7	134.6	154.2	
12	2BM	10:59	120.7	139.1	141.2	
12	3BM	11:00	174.6	140.4	147	
12	4BM	11:02	138.4	140.5	141.3	
12	5BM	11:04	147.3	144.6	147.3	
12	6BM	11:05	145.2	148.5	142.4	
12	7BM	11:08	149.7	150.1	136.2	
12	8BM	11:13	148	143.3	143.2	
12	9BM	11:21	141.8	133	131.9	
12	10BM	11:33	143.6	143.8	125.5	142.87
13	1CM	11:53	175.8	191.5	176.1	

DOG BONE TENSILE LOG						
Sand Batch#						5-Aug-04
Binder	Ashland 305/904					
batch	number	Time of test hh:mm	North dog psi	Middle dog psi	South dog psi	comments
13	2CM	11:55	192.2	201.8	194.2	
13	3CM	12:52	182.8	181.5	191.9	
13	4CM	12:53	200.5	204.2	198.8	
13	5CM	12:55	199.3	194.2	187	
13	6CM	12:56	208	198.5	194.1	
13	7CM	12:58	199	198.3	185	
13	8CM	12:59	191.9	196.9	184.7	
13	9CM	1:01	203.9	193.1	182.2	
13	10CM	1:02	194.4	194.1	179.6	192.5167
14	1AV	1:04	162	162	156.6	
14	2AV	1:05	160.4	162.6	156	
14	3AV	1:07	166.1	168.6	155.1	
14	4AV	1:08	162.8	157.7	151.5	
14	5AV	1:09	159.1	162.3	150.7	
14	6AV	1:11	158	160.4	145.2	
14	7AV	1:12	152.3	157.6	139.5	
14	8AV	1:13	157.3	162.3	150.6	
14	9AV	1:14	151.2	147.6	145.3	
14	10AV	1:15	161.8	149.2	150	156.06
15	1BV	1:23	245.2	248.9	226	
15	2BV	1:25	225.9	232.8	225.2	
15	3BV	1:27	224.7	214.7	221.8	
15	4BV	1:29	224	220.6	216.5	
15	5BV	1:31	236.9	214.9	230.1	
15	6BV	1:32	224.9	218.2	226	
15	7BV	1:34	222.1	231.5	220.1	
15	8BV	1:36	231.5	226.5	224.7	
15	9BV	1:38	229.7	237.5	220.9	
15	10BV	1:39	228.2	225.6	219.8	226.5133
16	1CV	2:02	297.6	299.3	281	
16	2CV	2:06	300	305.2	296.1	

DOG BONE TENSILE LOG						
Sand Batch#						5-Aug-04
Binder	Ashland 305/904					
batch	number	Time of test hh:mm	North dog psi	Middle dog psi	South dog psi	comments
16	3CV	2:08	284.4	282.7	280.8	
16	4CV	2:09	290.2	289.7	279.5	
16	5CV	2:11	290.4	288.2	286.8	
16	6CV	2:12	294.3	291.5	276.4	
16	7CV	2:14	303.2	297.3	280.8	
16	8CV	2:16	280.2	294.7	283.1	
16	9CV	2:17	289.3	289.4	280	
16	10CV	2:19	278.4	279.1	279.5	288.3033

Table B2. Representative 1800^{o}F LOI for test sand batches. Coding follows Appendix A instructions.

TECHNIKON

GF DOG BONE LOI									Analyst:	Mary Beth Prendergast	
Applicable AFS Test Specs:			AFS 5100-00-S								
Sand Molding Date	Sand Sampling Date	Production Sample #	Dish wt. (gms)	Dish & Sample wt. (gms)	Sample wt. (gms)	Time in	Time out	Dry Wt. (gms)	Weight change	%LOI @1800* Lost on Ignition	LOI% ave 3 samples
8/4/04	8/5/04	1AT	67.669	82.6872	15.0182	9:15	11:15	82.5361	0.1511	1.01	
8/4/04	8/5/04	2AT	57.8867	72.8958	15.0091	9:15	11:15	72.7434	0.1524	1.02	
8/4/04	8/5/04	3AT	49.6922	64.6988	15.0066	9:15	11:15	64.5478	0.1510	1.01	1.01
8/4/04	8/5/04	1A	63.7655	78.7482	14.9827	9:15	11:15	78.5909	0.1573	1.05	
8/4/04	8/5/04	2A	59.2229	74.2228	14.9999	9:15	11:15	74.0668	0.1560	1.04	
8/4/04	8/5/04	3A	58.9461	73.9503	15.0042	9:15	11:15	73.7918	0.1585	1.06	1.05
8/4/04	8/5/04	1B	60.3509	75.3673	15.0164	11:15	13:15	75.1673	0.2000	1.33	
8/4/04	8/5/04	2B	52.2104	67.2097	14.9993	6:00	8:00	67.0168	0.1929	1.29	
8/4/04	8/5/04	3B	56.6145	71.6264	15.0119	6:00	8:00	71.4338	0.1926	1.28	1.30
8/4/04	8/5/04	1C	66.6188	81.6241	15.0053	11:15	13:15	81.3824	0.2417	1.61	
8/4/04	8/5/04	2C	64.0413	79.0642	15.0229	11:15	13:15	78.8254	0.2388	1.59	
8/4/04	8/5/04	3C	57.3673	72.344	14.9767	11:15	13:15	72.1088	0.2352	1.57	1.59
8/4/04	8/5/04	1AR	60.3502	75.3541	15.0039	10:00	12:00	75.1998	0.1543	1.03	
8/4/04	8/5/04	2AR	61.1378	76.1515	15.0137	10:00	12:00	75.9999	0.1516	1.01	
8/4/04	8/5/04	3AR	53.8582	68.8647	15.0065	10:00	12:00	68.7157	0.1490	0.99	1.01
8/4/04	8/5/04	1BR	66.6078	81.6298	15.0220	10:00	12:00	81.4348	0.1950	1.30	
8/4/04	8/5/04	2BR	64.0348	79.0462	15.0114	10:00	12:00	78.8534	0.1928	1.28	
8/4/04	8/5/04	3BR	57.3677	72.3671	14.9994	10:00	12:00	72.1763	0.1908	1.27	1.28
8/4/04	8/5/04	1CR	52.2047	67.2089	15.0042	12:30	14:30	66.9717	0.2372	1.58	
8/4/04	8/5/04	2CR	56.6134	71.6181	15.0047	12:30	14:30	71.381	0.2371	1.58	
8/4/04	8/5/04	3CR	52.4448	67.4458	15.0010	12:30	14:30	67.2084	0.2374	1.58	1.58
8/4/04	8/5/04	1AB	59.9185	74.9171	14.9986	12:30	14:30	74.7831	0.1340	0.89	
8/4/04	8/5/04	2AB	63.3463	78.3458	14.9995	12:30	14:30	78.2132	0.1326	0.88	
8/4/04	8/5/04	3AB	56.3158	71.3159	15.0001	12:30	14:30	71.1817	0.1342	0.89	0.89

Table B2 continued.

TECHNIKON

GF DOG BONE LOI								Analyst:	Mary Beth Prendergast		
Applicable AFS Test Specs:			AFS 5100-00-S								
Sand Molding Date	Sand Sampling Date	Production Sample #	Dish wt. (gms)	Dish & Sample wt. (gms)	Sample wt. (gms)	Time in	Time out	Dry Wt. (gms)	Weight change	%LOI @1800* Lost on Ignition	%LOI @1800* Batch Average Lost on Ignition
8/4/04	8/5/04	1BB	67.6683	82.6689	15.0006	6:00	8:00	82.4994	0.1695	1.13	
8/4/04	8/5/04	2BB	57.8835	72.8886	15.0051	6:00	8:00	72.7171	0.1715	1.14	
8/4/04	8/5/04	3BB	49.6917	64.6924	15.0007	6:00	8:00	64.5218	0.1706	1.14	1.14
8/4/04	8/5/04	1CB	63.7612	78.7621	15.0009	6:00	8:00	78.5502	0.2119	1.41	
8/4/04	8/5/04	2CB	59.2172	74.2185	15.0013	6:00	8:00	74.0062	0.2123	1.42	
8/4/04	8/5/04	3CB	58.9437	73.9471	15.0034	6:00	8:00	73.7347	0.2124	1.42	1.41
8/4/04	8/5/04	1AM	60.3495	75.3504	15.0009	8:00	10:00	75.0313	0.3191	2.13	
8/4/04	8/5/04	2AM	61.1284	76.1327	15.0043	8:00	10:00	75.827	0.3057	2.04	
8/4/04	8/5/04	3AM	53.8532	68.8554	15.0022	8:00	10:00	68.541	0.3144	2.10	2.09
8/4/04	8/5/04	1BM	66.6054	81.6057	15.0003	8:00	10:00	81.2592	0.3465	2.31	
8/4/04	8/5/04	2BM	64.0318	79.0355	15.0037	8:00	10:00	78.6911	0.3444	2.30	
8/4/04	8/5/04	3BM	57.3651	72.3659	15.0008	8:00	10:00	72.024	0.3419	2.28	2.29
8/4/04	8/5/04	1CM	52.2072	67.2073	15.0001	10:00	12:00	66.8162	0.3911	2.61	
8/4/04	8/5/04	2CM	56.6207	71.6218	15.0011	10:00	12:00	71.229	0.3928	2.62	
8/4/04	8/5/04	3CM	52.4464	67.4479	15.0015	10:00	12:00	67.0598	0.3881	2.59	2.60
8/4/04	8/5/04	1AV	59.9282	74.9292	15.0010	10:00	12:00	74.7838	0.1454	0.97	
8/4/04	8/5/04	2AV	63.3581	78.3592	15.0011	10:00	12:00	78.2139	0.1453	0.97	
8/4/04	8/5/04	3AV	56.3302	71.3334	15.0032	10:00	12:00	71.1892	0.1442	0.96	0.97
8/4/04	8/5/04	1BV	60.3472	75.3483	15.0011	12:00	14:00	75.1717	0.1766	1.18	
8/4/04	8/5/04	2BV	61.1271	76.1273	15.0002	12:00	14:00	75.9448	0.1825	1.22	
8/4/04	8/5/04	3BV	53.8547	68.8586	15.0039	12:00	14:00	68.6731	0.1855	1.24	1.21
8/4/04	8/5/04	1CV	66.6048	81.6098	15.0050	12:00	14:00	81.3881	0.2217	1.48	
8/4/04	8/5/04	2CV	64.031	79.0354	15.0044	12:00	14:00	78.812	0.2234	1.49	
8/4/04	8/5/04	3CV	57.3651	72.3655	15.0004	12:00	14:00	72.141	0.2245	1.50	1.49

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APPENDIX C GLOSSARY

BOS	Based on Sand
LOI	Loss on Ignition
Mean	Average
Mixedness	A measure of the uniformity of distribution of one set of materials in a matrix of another material.
Standard Deviation	A statistical measure of dispersion about a mean value.
TEA	Triethylamine