



TEST REPORT

**OMEGA POINT
LABORATORIES, INC.**
16015 Shady Falls Road
Elmendorf, TX 78112
(v) 210-635-8100
(f) 210-635-8101
800-966-5253
www.opl.com

ASTM E119-00a

Fire Tests of Building Construction and Materials

Contego Passive Fire Barrier Latex Over a W10X49 Column

Project No. 16539-114323

July 21, 2003

Prepared for:
Contego International, Inc.
5815 Phoenix, No. 4
Dallas, TX 75231



Abstract

*A W10X49 structural steel column, clad with a 94.9 mil (0.0949inch, 2.41mm) thick coating of Contego Passive Fire Barrier Latex met the requirements of **ASTM E119-00a Standard Test Methods for Fire Tests of Building Construction and Materials** for a fire resistance rating of 88 minutes.*

This report and the information contained herein is for the exclusive use of the client named herein. Omega Point Laboratories, Inc. authorizes the client to reproduce this report only if reproduced in its entirety.

The description of the test procedure, as well as the observations and results obtained, contained herein are true and accurate within the limits of sound engineering practice. These results apply only for the specimens tested, in the manner tested, and may not represent the performance of other specimens from the same or other production lots nor of the performance when used in combination with other materials.

The test specimen identification is as provided by the client and Omega Point Laboratories, Inc. accepts no responsibility for any inaccuracies therein. Omega Point did not select the specimen and has not verified the composition, manufacturing techniques or quality assurance procedures.

This report does not imply certification of the product by Omega Point Laboratories, Inc. Any use of the Omega Point Laboratories name, any abbreviation thereof or any logo, mark, or symbol therefor, for advertising material must be approved in writing in advance by Omega Point Laboratories, Inc. The client must have entered into and be actively participating in a Listing & Follow-up Service program. Products must bear labels with the Omega Point Laboratories Certification Mark to demonstrate acceptance by Omega Point Laboratories, Inc. into the Listing program.

Deggary N. Priest, President

July 21, 2003

Date

Reviewed and approved:

William E. Fitch, P.E. No. 55296

Date: July 21, 2003



Omega Point Laboratories, Inc.
16015 Shady Falls Road
Elmendorf, Texas 78112-9784
210-635-8100 / FAX: 210-635-8101 / 800-966-5253
www.opl.com / e-mail: dnpriest@ix.netcom.com



TABLE OF CONTENTS

ITEM	PAGE
Introduction	1
Test Procedure	4
Test Specimen Construction	7
Test Results and Observations	9
Conclusions	11
Appendices	
Appendix A: Thermocouple Locations	12
Appendix B: Thermocouple Data	14
Appendix C: Photographs	25
Last Page of Report	27



INTRODUCTION¹

"The performance of walls, columns, floors, and other building members under fire exposure conditions is an item of major importance in securing constructions that are safe, and that are not a menace to neighboring structures nor to the public. Recognition of this is registered in the codes of many authorities, municipal and other. It is important to secure balance of the many units in a single building, and of buildings of like character and use in a community; and also to promote uniformity in requirements of various authorities throughout the country. To do this it is necessary that the fire-resistive properties of materials and assemblies be measured and specified according to a common standard expressed in terms that are applicable alike to a wide variety of materials, situations, and conditions of exposure.

Such a standard is found in the methods that follow. They prescribe a standard exposing fire of controlled extent and severity. Performance is defined as the period of resistance to standard exposure elapsing before the first critical point in behavior is observed. Results are reported in units in which field exposures can be judged and expressed.

The methods may be cited as the "Standard Fire Tests," and the performance or exposure shall be expressed as "2-h," "6-h," "1/2-h," etc.

When a factor of safety exceeding that inherent in the test conditions is desired, a proportional increase should be made in the specified time-classification period.

The ASTM E119 test procedure is identical or very similar to the following standard test methods:

UL 263
UBC 7-1
NFPA 251
ANSI A2.1
ULC S101

The analogous test standard in the International Organization of Standardization (ISO), ISO 834 Fire-resistance Tests – Elements of Building Construction, is very similar to the above U.S. test methods. Its exposure curve, as well as the method used to measure temperatures within the furnace result in a slightly less severe

¹ **ASTM E119-00a Standard Methods of FIRE TESTS OF BUILDING CONSTRUCTION AND MATERIALS**, ASTM International, Volume 04.07 Building Seals and Sealants, etc.



temperature exposure than the E119 test for the first two hours. The ISO 834 test requires a slightly greater positive pressure within the furnace. For those reasons, the E119 test can be considered to be slightly more severe for tests of 2 h duration or less, only if the test article is not likely to be affected by a higher furnace pressure. (BS 476 Pt 20 Fire tests on building materials and structures is virtually identical to the ISO 834 test method, as is the new CEN standard, EN 1363-1.)

1. Scope

The test methods described in this fire-test-response standard are applicable to assemblies of masonry units and to composite assemblies of structural materials for buildings, including bearing and other walls and partitions, columns, girders, beams, slabs, and composite slab and beam assemblies for floors and roofs. They are also applicable to other assemblies and structural units that constitute permanent integral parts of a finished building.

1.2 It is the intent that classifications shall register comparative performance to specific fire-test conditions during the period of exposure and shall not be construed as having determined suitability for use under other conditions or after fire exposure.

1.3 *This standard is used to measure and describe the response of materials, products, or assemblies to heat and flame under controlled conditions, but does not by itself incorporate all factors required for fire hazard or fire risk assessment of the materials, products or assemblies under actual fire conditions.*

1.4 These test methods prescribe a standard fire exposure for comparing the test results of building construction assemblies. The results of these tests are one factor in assessing predicted fire performance of building construction assemblies. Application of these test results to predict the performance of actual building construction requires the evaluation of test conditions.

1.5 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.7 The text of this standard references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

4. Significance and Use

4.1 This test method is intended to evaluate the duration for which the types of assemblies noted in 1.1 will contain a fire, retain their structural integrity or exhibit both properties dependent upon the type of assembly involved during a



predetermined test exposure.

4.2 The test exposes a specimen to a standard fire controlled to achieve specified temperatures throughout a specified time period. When required, the fire exposure is followed by the application of a specified standard fire hose stream. The test provides a relative measure of the fire-test-response of comparable assemblies under these fire exposure conditions. The exposure is not representative of all fire conditions because conditions vary with changes in the amount, nature and distribution of fire loading, ventilation, compartment size and configuration, and heat sink characteristics of the compartment. Variation from the test conditions or specimen construction, such as size, materials, method of assembly, also affects the fire-test-response. For these reasons, evaluation of the variation is required for application to construction in the field.

4.3 The test standard provides for the following:

4.3.1 For walls, partitions and floor or roof assemblies:

4.3.1.1 Measurement of the transmission of heat.

4.3.1.2 Measurement of the transmission of hot gases through the assembly, sufficient to ignite cotton waste.

4.3.1.3 For load bearing elements, measurement of the load carrying ability of the test specimen during the test exposure.

4.3.2 For individual load bearing assemblies such as beams and columns:

4.3.2.1 Measurement of the load carrying ability under the test exposure with some consideration for the end support conditions (that is, restrained or not restrained).

4.4 The test standard does not provide the following:

4.4.1 Full information as to performance of assemblies constructed with components or lengths other than those tested.

4.4.2 Evaluation of the degree by which the assembly contributes to the fire hazard by generation of smoke, toxic gases, or other products of combustion.

4.4.3 Measurement of the degree of control or limitation of *the passage of* smoke or products of combustion through the assembly.

4.4.4 Simulation of the fire behavior of joints between building elements such as floor-wall or wall-wall, etc., connections.

4.4.5 Measurement of flame spread over surface of tested element.

4.4.6 The effect of fire endurance of conventional openings in the assembly, that is electrical receptacle outlets, plumbing pipe, etc., unless specifically provided for in the construction tested."



TEST PROCEDURE

Horizontal Test Furnace

The 12' x 18' x 7' deep horizontal test furnace is designed to allow the test specimen to be uniformly exposed to the specified time-temperature conditions. It is fitted with 12 symmetrically-located premixed propane/air gas burners, located 6 feet below the top ledge of the furnace, and designed to allow an even heat flux distribution across the under surface of a horizontal test specimen. Furnace pressures may be maintained at any value from +0.5" W.C. to -0.05" W.C. at the exposed surface of the test article. The burners, when fully fired, will deliver 20 MBtu/hr total heat input. The furnace consists of a structural steel frame, lined with sheet metal and insulated with a six inch thick layer of ceramic fiber. One wall of the furnace contains a personnel door to allow access to the inside with the test article in place.



12' x 18' Horizontal Fire Resistance Furnace

The temperature within the furnace is determined to be the mathematical average of thermocouples located symmetrically within the furnace and positioned twelve inches away from the test specimen. The materials used in the construction of these thermocouples are those suggested in the test standard. During the perfor-



mance of a fire exposure test, the furnace temperatures are recorded every 15 seconds and displayed for the furnace operator to allow control along the specified temperature curve. For report presentation purposes, the data is saved once per minute.

The fire exposure is controlled to conform with the standard time-temperature curve shown in Figure 1, as determined by the table below:

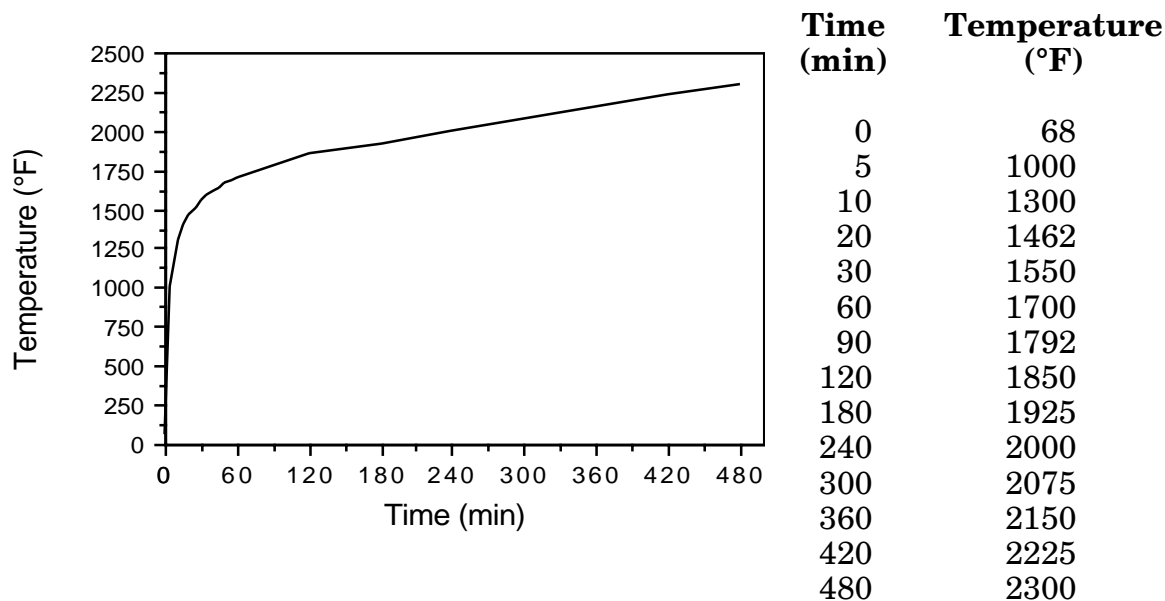


Figure 1

The furnace interior temperature during a test is controlled such that the area under the time•temperature curve is within 10% of the corresponding area under the standard time•temperature curve for 1 hour or less tests, 7.5% for those less than 2 hours and 5% for those tests of 2 hours or more duration.

Temperatures of Steel

The temperatures at the interior of structural steel elements were monitored using 1.5 mm diameter, Inconel® stainless steel sheathed 30 GA. type K thermocouples inserted into appropriately-sized holes drilled to the center of each section. Such thermocouples were located in groups of three at four levels along the height of each column, as described in the standard. The thermocouple leads were held tight to the structural steel by covering them with short pieces of 1/4" wide shim stock steel, spot-welded to the steel on each side of the thermocouple lead. Temperature



readings were taken at intervals not exceeding 1.0 minute. The temperatures on each level of each test specimen during the test was taken to be the average value of all three thermocouples on that level. The exact thermocouple locations may be found in Appendix A: Thermocouple Locations.

Correction Factor

When the indicated resistance period is $\frac{1}{2}$ h or over, determined by the average or maximum temperature rise on the unexposed surface or within the test sample, or by failure under load,, a correction shall be applied for variation of the furnace exposure from that prescribed, where it will affect the classification, by multiplying the indicated period by two thirds of the difference in area between the curve of average furnace temperature and the standard curve for the first three fourths of the period and dividing the product by the area between the standard curve and a base line of 68°F (20°C) for the same part of the indicated period, the latter area increased by 3240°F•min to compensate for the thermal lag of the furnace thermocouples during the first part of the test. For a fire exposure in the test higher than standard, the indicated resistance period shall be increased by the amount of the correction. For a fire exposure in the test lower than standard, the indicated resistance period shall be similarly decreased for fire exposure below standard. The correction is accomplished by mathematically adding the correction factor, C , to the indicated resistance period.

The correction can be expressed by the following equation:

$$C = \frac{2 I (A - A_s)}{3 (A_s + L)}$$

where:

- C = correction in the same units as I ,
- I = indicated fire-resistance period,
- A = area under the curve of indicated average furnace temperature for the first three fourths of the indicated period,
- A_s = area under the standard furnace curve for the same part of the indicated period, and
- L = lag correction in the same units as A and A_s (54°F•h or 30°C•h (3240°F•min or 1800°C•min))



CONDITIONS OF ACCEPTANCE

The E119 standard regards the test as successful if the following condition is met:

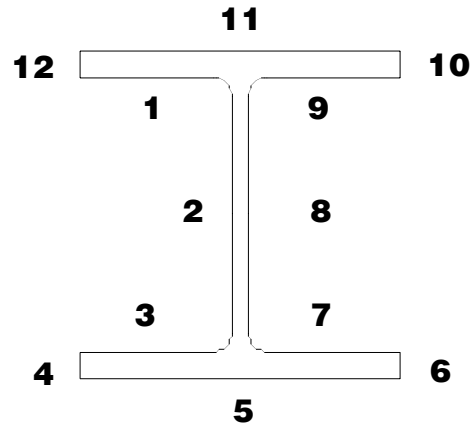
Transmission of heat through the protection during the fire endurance test does not raise the average temperature of the steel at any one of the four levels above 1000°F (538°C), or does not raise the temperature above 1200°F (649°C) at any one of the measured points.

TEST SPECIMEN CONSTRUCTION

The protective coating identification is as provided by the client and Omega Point Laboratories, Inc. accepts no responsibility for any inaccuracies therein. Omega Point did not select the material and has not verified the composition, manufacturing techniques or quality assurance procedures.

The steel column, purchased and prepared by Laboratory personnel, had a 16" x 16" x 1/4" thick steel plate welded to each end, to stop the coating from expanding longitudinally, and to make the column self-standing. It was then sand-blasted to a clean, oil free condition, and 12 1/16" diameter Inconel® sheathed, 30 GA. Type K thermocouples were attached, three at each of four levels (See Appendix A Thermocouple Locations), by inserting the tip of the thermocouple assembly into a small hole drilled to the center of the steel section. The thermocouple leads were then securely attached to the steel column by placing short pieces of 1/4" wide shim stock steel over the wire and spot-welding on either side. The column and thermocouple wires were then painted with a standard red-oxide primer. Representatives of Contego then visited the laboratory facility and spray-applied the Contego Passive Fire Barrier Latex to a dry-film thickness of 0.0949 inches (2.41 mm), with a standard deviation (108 thickness measurements) of 0.0066 inches (0.17 mm). Thickness measurements were performed by Laboratory personnel. Thicknesses were determined at twelve locations at each of nine equidistant heights on the column, the results of which are given in the table below. The twelve measuring points are indicated in the drawing below:





	1	2	3	4	5	6	7	8	9	10	11	12
1	97.0	87.0	94.5	93.0	91.0	97.5	86.5	104.0	91.0	86.0	93.5	98.0
2	94.0	92.0	90.5	100.0	101.0	112.0	85.0	109.0	98.0	96.0	94.0	112.0
3	96.0	94.0	97.5	103.0	92.0	103.0	98.5	106.5	87.5	97.5	94.5	107.0
4	92.5	91.0	96.0	96.5	94.5	105.0	95.0	98.0	92.5	93.0	98.5	96.5
5	94.5	92.0	94.5	99.0	90.5	92.5	93.5	98.0	87.0	90.5	97.0	100.0
6	99.0	91.0	94.0	97.0	94.0	96.5	89.0	98.5	91.0	92.0	95.5	100.0
7	98.0	90.5	95.0	97.0	92.5	89.0	85.5	106.0	85.5	93.5	94.5	90.0
8	91.0	100.0	100.0	97.0	96.5	106.0	88.5	103.0	92.0	103.0	92.0	106.0
9	74.5	97.0	81.0	94.5	101.5	89.0	72.0	87.0	81.5	97.5	93.0	94.0
Avg	92.9	92.7	93.7	97.4	94.8	98.9	88.2	101.1	89.6	94.3	94.7	100.4

Overall Avg. 94.9 mil 2.41 mm
Std. Dev. 6.6 mil 0.17 mm

Laboratory personnel witnessed the application of material and determined the thickness of the fire protection material. The drying of the fire barrier material was very fast. Nominally 4" x 6" pieces of 20 GA. galvanized steel were sprayed with the Contego Passive Fire Barrier Latex to thicknesses of 20, 40, 60, 80 and 95 mils. All were at constant weight within 24 hours. The column was left at ambient temperature for a minimum of five days prior to testing.



The column section used in this evaluation is presented in the table below:

Column Size	Hp/A Factor (m⁻¹)	W/D Factor (lb/in/ft)	Avg. Coating Thickness [in (mm)]
W10X49	162	0.83	0.0949 (2.41)

The height of the furnace walls was increased 28" with the addition of concrete masonry units lined with ceramic fiber blanket. The furnace was sealed following the insertion of the column, by covering with a fiber-insulated flat lid assembly. (Two other columns, both of them round hollow sections, were tested in the furnace with the W10X49, but are not reported on herein.)

TEST RESULTS AND OBSERVATIONS

The thermocouples were connected to the data acquisition system and their outputs verified. The furnace was then fired along the ASTM E119-00a time-temperature curve for a period of 93 minutes. The furnace was fired at 12:49 PM on June 26, 2003 and the pressure maintained at +0.01 inches of water column (with respect to the laboratory ambient pressure), measured at a point approximately 1 in. under the exposed surface of the test specimen for the duration of the test following a five minute stabilization period.

Observations made during the test are as follows:

Time (min:sec)	Observation
0:00	Furnace fired at 12:49 PM.
1:20	Fire barrier material turning dark.
2:15	Outer flanges charring and intumescent, but not inside the web yet.
10:30	Some cracking in the ash layer on the outside flange. Inner flanges are intumescent and turning gray.
11:30	Fire barrier material turning light gray.
87:48	Column exceeds allowable temperature.
93:00	Furnace extinguished and allowed to cool.

The maximum fire resistance of the beam was determined by a single thermocouple in Level A (top set of three thermocouples) exceeding 1200°F at 88 minutes. The



average of all three thermocouples in Level A exceeded 1000°F at 90 minutes. The Contego Passive Fire Barrier Latex intumesced well and the protection remained firmly attached throughout the fire test until around 88 minutes, at which point it began to slough off.

In accordance with the E119 test standard, a calculation for any correction to the indicated fire resistance period was done. The correction factor was then mathematically added to the indicated fire resistance period, yielding the fire resistance period achieved by this specimen:

ITEM	DESCRIPTION	TEST VALUE
<i>C</i>	correction factor	-0.11 min (-7 seconds)
<i>I</i>	indicated fire-resistance period	88 min
<i>A</i>	area under the curve of indicated average furnace temperature for the first three fourths of the indicated period	98 739°F•min
<i>A_s</i>	area under the standard furnace curve for the same part of the indicated period	99 084°F•min
<i>L</i>	lag correction	3240°F•min
	FIRE RESISTANCE PERIOD ACHIEVED BY THIS SPECIMEN ==>	88

Note: The standard specifies that the fire resistance be determined to the nearest integral minute. Consequently, if the correction factor is less than 30 seconds, and the test specimen met the criteria for the full indicated fire resistance period, no correction is deemed necessary. That was the case for this project.

Listings and plots of the furnace control temperatures and specimen unexposed surface temperatures may be found in Appendix B. A photographic documentation of the test has been included in Appendix C.



CONCLUSIONS

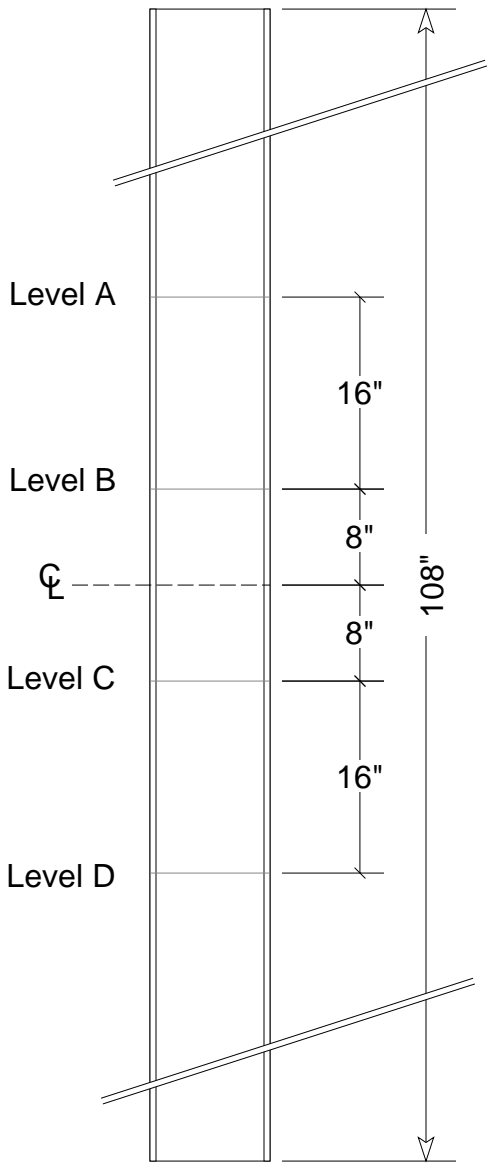
The test specimen identification is as provided by the client and Omega Point Laboratories, Inc. accepts no responsibility for any inaccuracies therein. Omega Point did not select the specimen and has not verified the composition, manufacturing techniques or quality assurance procedures.

The W10X49 structural steel column ($H_p/A = 162$), clad with a 94.9 mil (0.0949inch, 2.41mm) thick coating of Contego Passive Fire Barrier Latex constructed and tested as described herein met the requirements of **ASTM E119-00a Standard Test Methods for Fire Tests of Building Construction and Materials** for a fire resistance rating of 88 minutes.

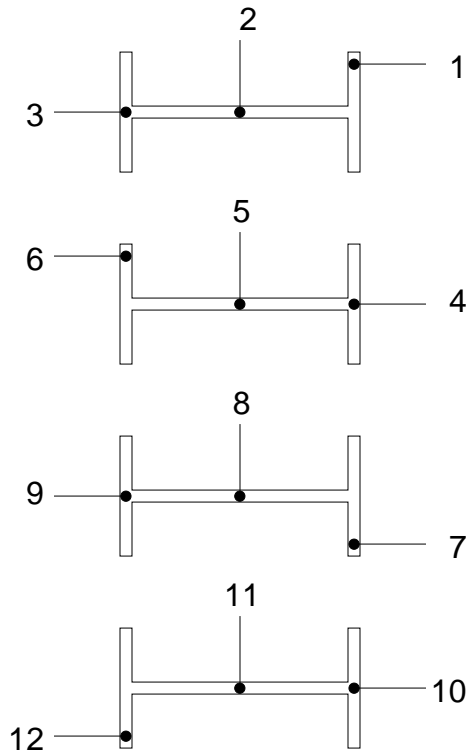


APPENDIX A
THERMOCOUPLE LOCATIONS





ELEVATION VIEW



CROSS-SECTION VIEWS AT EACH LEVEL

Note:
 1.5 mm \varnothing Inconel-sheathed Type K thermocouples were inserted into holes drilled to the center of the section and the leads attached to the steel by small rectangular pieces of thin sheet steel, spot welded to the steel item.

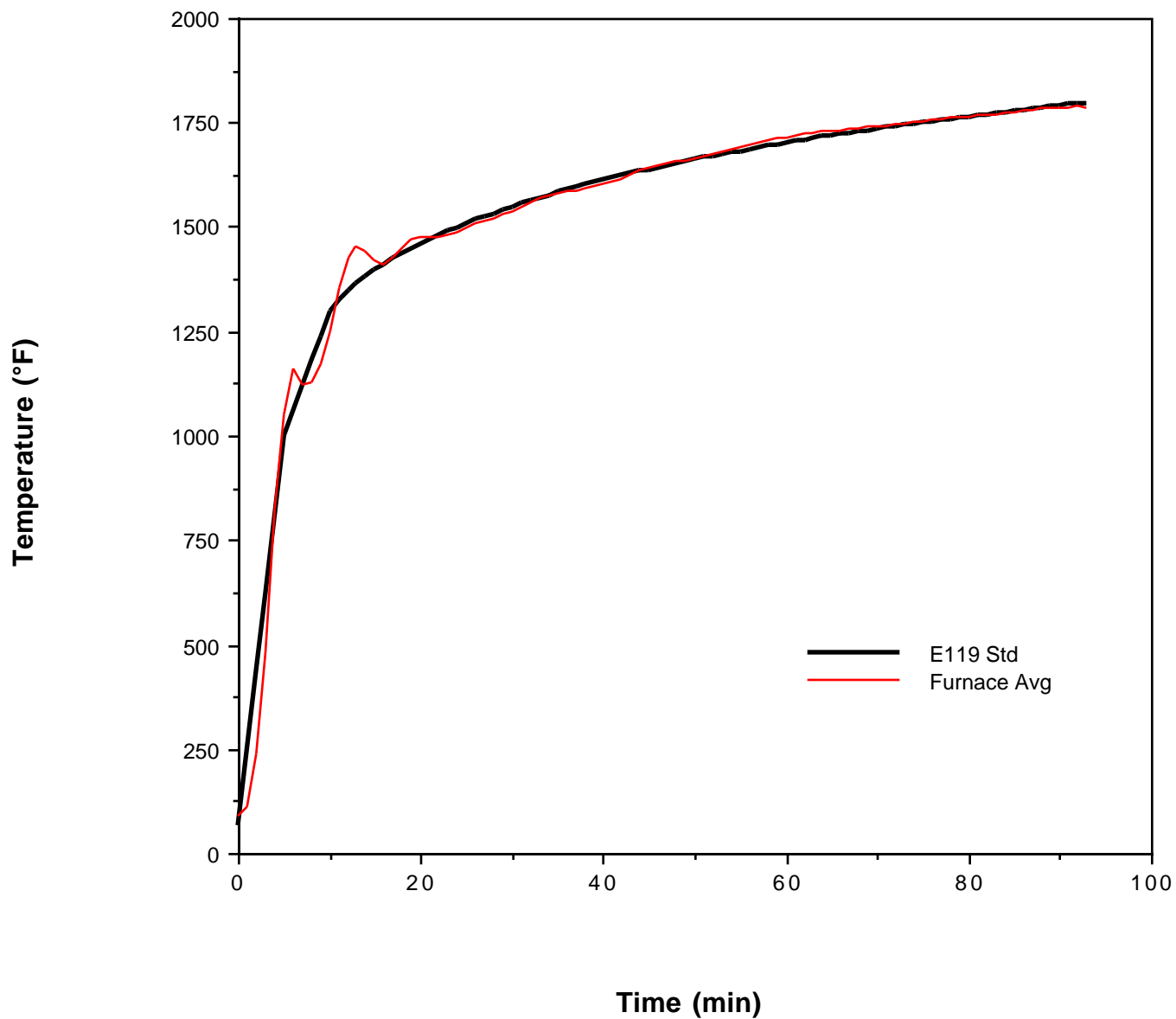
OMEGA POINT LABORATORIES, INC. Project No. 16539-114323
CONTEGO
Fig. 1 Thermocouples on Wide Flange Column

Scale: 3/4"=1'

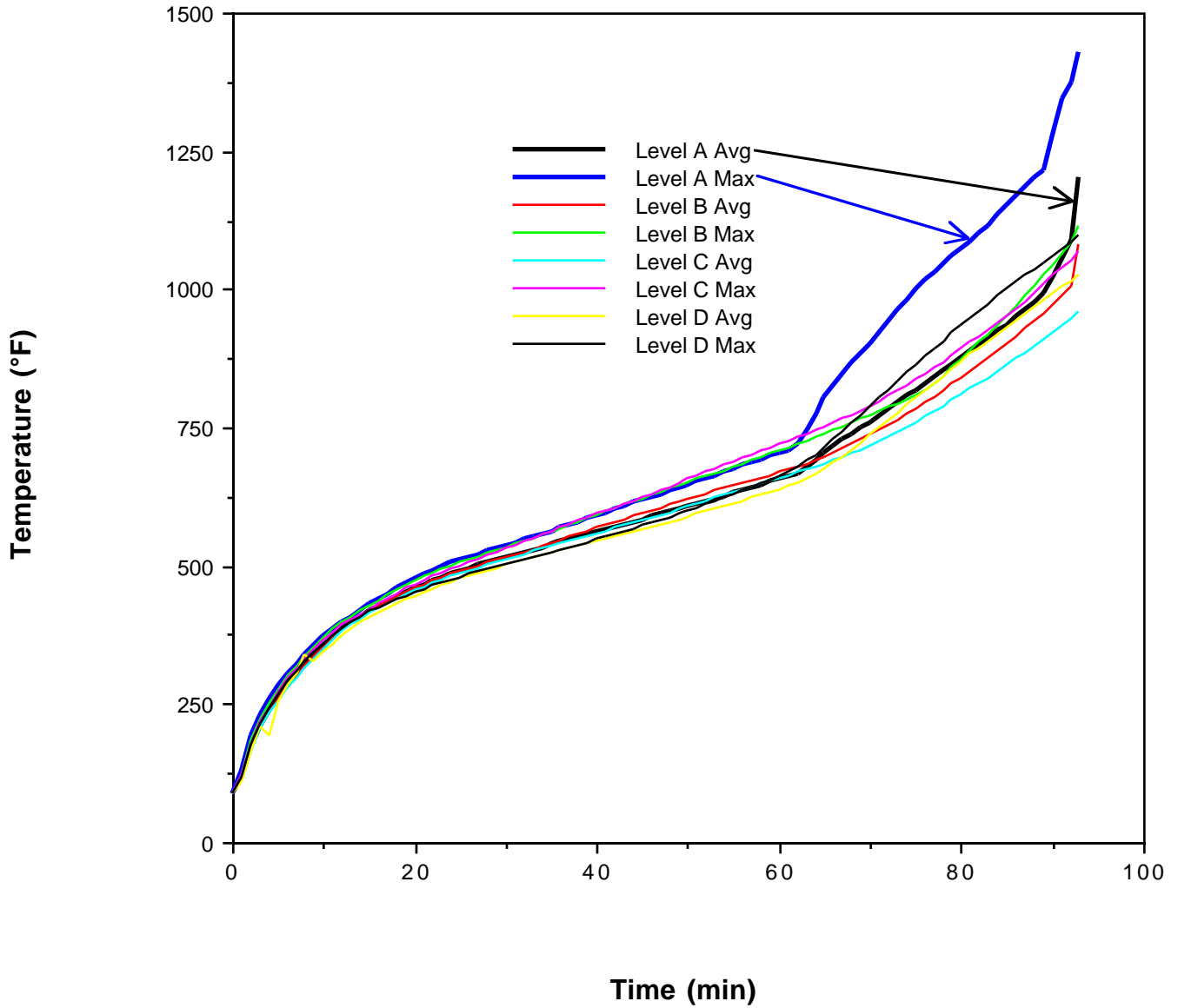
APPENDIX B
THERMOCOUPLE DATA



Project No. 16539-114323
Contego International
Furnace Interior Temperature



Project No. 16539-114323
Contego International
W10X49 Steel Temperature



Time (min)	E119 Std Average (°F)	Furnace Average (°F)	Integration of Furnace Average (°F•min)	Integration of E119 Std Average (°F•min)	Error (%)	W10X49	W10X49	W10X49	W10X49	W10X49
						Level A Avg Temp (°F)	Level A Max Temp (°F)	Level B Avg Temp (°F)	Level B Max Temp (°F)	Level C Avg Temp (°F)
0	68	91	0	0	0.00	89	90	90	90	89
1	254	112	242	755	-68.0	118	131	115	122	113
2	441	238	1,101	3,365	-67.3	172	194	168	183	165
3	627	481	3,672	7,838	-53.2	211	232	207	221	204
4	814	821	9,150	14,176	-35.4	240	259	236	251	233
5	1000	1047	17,686	22,377	-21.0	264	284	261	277	257
6	1060	1159	28,053	31,931	-12.1	287	307	284	302	281
7	1120	1124	38,867	42,091	-7.66	304	322	302	320	298
8	1180	1129	49,410	52,851	-6.51	321	338	319	337	315
9	1240	1171	60,161	64,211	-6.31	338	355	336	354	332
10	1300	1249	71,464	76,171	-6.18	355	371	354	370	349
11	1328	1355	83,740	88,631	-5.52	370	385	370	385	365
12	1347	1423	96,900	101,305	-4.35	384	397	384	397	380
13	1364	1453	110,594	114,164	-3.13	397	408	397	408	393
14	1381	1443	124,440	127,194	-2.17	408	420	408	417	403
15	1396	1418	138,071	140,383	-1.65	418	430	418	427	413
16	1410	1411	151,533	153,720	-1.42	427	440	427	437	422
17	1424	1425	165,004	167,196	-1.31	435	450	436	448	432
18	1436	1448	178,665	180,802	-1.18	444	460	444	457	439
19	1448	1468	192,550	194,531	-1.02	452	469	452	466	447
20	1459	1476	206,593	208,377	-0.86	459	477	459	474	455
21	1470	1475	220,670	222,334	-0.75	466	485	466	481	461
22	1480	1476	234,743	236,396	-0.70	472	492	473	488	468
23	1490	1481	248,842	250,559	-0.69	479	499	479	494	474
24	1499	1488	263,001	264,818	-0.69	485	505	484	500	480
25	1508	1498	277,241	279,169	-0.69	491	511	490	505	485
26	1517	1507	291,578	293,609	-0.69	496	516	495	511	491
27	1525	1515	306,003	308,134	-0.69	501	521	500	516	496
28	1533	1522	320,504	322,740	-0.69	506	526	505	522	501
29	1541	1530	335,077	337,426	-0.70	511	531	510	528	507
30	1549	1538	349,734	352,188	-0.70	516	536	515	534	512
31	1556	1549	364,470	367,024	-0.70	521	541	520	539	516
32	1563	1559	379,315	381,931	-0.69	525	547	524	545	521
33	1570	1567	394,254	396,907	-0.67	529	552	529	550	526
34	1576	1573	409,269	411,950	-0.65	534	557	535	556	531
35	1583	1579	424,346	427,058	-0.64	539	563	540	561	536
36	1589	1583	439,477	442,229	-0.62	543	569	546	567	540
37	1595	1588	454,646	457,462	-0.62	548	575	551	573	545
38	1601	1593	469,866	472,754	-0.61	553	580	557	579	549
39	1606	1598	485,135	488,105	-0.61	557	586	563	586	554
40	1612	1601	500,444	503,512	-0.61	562	592	568	592	558
41	1617	1605	515,790	518,974	-0.61	566	597	573	598	563
42	1623	1616	531,209	534,491	-0.61	571	602	578	604	568
43	1628	1626	546,730	550,059	-0.61	575	608	584	610	572
44	1633	1635	562,354	565,680	-0.59	580	614	589	616	577
45	1638	1642	578,053	581,350	-0.57	584	619	594	622	582
46	1643	1647	593,821	597,069	-0.54	589	625	600	628	587
47	1648	1651	609,631	612,837	-0.52	593	630	604	633	592
48	1652	1656	625,484	628,651	-0.50	598	636	610	639	597
49	1657	1659	641,370	644,512	-0.49	602	640	614	644	602
50	1661	1665	657,302	660,417	-0.47	607	646	619	650	608
51	1666	1671	673,291	676,367	-0.45	612	652	625	656	612
52	1670	1676	689,337	692,360	-0.44	617	657	630	661	617

Time (min)	E119 Std Average (°F)	Furnace Average (°F)	Integration of Furnace Average (°F•min)	Integration of E119 Std Average (°F•min)	Error (%)	W10X49	W10X49	W10X49	W10X49	W10X49
						Level A Avg Temp (°F)	Level A Max Temp (°F)	Level B Avg Temp (°F)	Level B Max Temp (°F)	Level C Avg Temp (°F)
53	1674	1682	705,439	708,395	-0.42	621	663	635	667	623
54	1678	1687	721,599	724,472	-0.40	626	669	640	672	628
55	1682	1693	737,816	740,590	-0.37	631	675	645	678	633
56	1686	1698	754,087	756,749	-0.35	637	681	650	684	638
57	1690	1703	770,401	772,946	-0.33	642	687	655	690	643
58	1694	1707	786,770	789,182	-0.31	646	692	659	695	648
59	1698	1711	803,178	805,457	-0.28	652	698	664	702	653
60	1701	1715	819,624	821,768	-0.26	656	704	669	708	658
61	1705	1719	836,112	838,117	-0.24	661	709	674	713	663
62	1709	1721	852,636	854,501	-0.22	668	720	680	720	669
63	1712	1724	869,170	870,922	-0.20	680	746	685	726	674
64	1716	1729	885,753	887,377	-0.18	693	775	691	732	679
65	1719	1731	902,374	903,867	-0.17	706	803	697	739	685
66	1722	1731	919,005	920,390	-0.15	717	827	704	745	690
67	1726	1733	935,646	936,948	-0.14	728	847	712	752	696
68	1729	1736	952,306	953,538	-0.13	738	866	720	759	702
69	1732	1739	969,001	970,160	-0.12	748	882	728	766	710
70	1735	1740	985,717	986,815	-0.11	758	899	737	773	716
71	1738	1742	1,002,448	1,003,501	-0.10	770	921	746	779	724
72	1742	1744	1,019,202	1,020,218	-0.10	783	943	755	787	732
73	1745	1747	1,035,975	1,036,966	-0.10	795	963	764	793	741
74	1748	1749	1,052,769	1,053,744	-0.09	807	982	774	800	750
75	1751	1752	1,069,594	1,070,552	-0.09	819	1000	785	808	760
76	1753	1756	1,086,452	1,087,389	-0.09	831	1017	795	815	769
77	1756	1757	1,103,334	1,104,255	-0.08	841	1031	806	829	779
78	1759	1760	1,120,238	1,121,150	-0.08	853	1047	817	843	789
79	1762	1762	1,137,166	1,138,073	-0.08	864	1061	828	857	799
80	1765	1764	1,154,111	1,155,024	-0.08	875	1074	840	872	809
81	1768	1766	1,171,077	1,172,003	-0.08	887	1087	852	887	820
82	1770	1767	1,188,062	1,189,009	-0.08	899	1103	864	903	830
83	1773	1769	1,205,061	1,206,042	-0.08	909	1114	876	918	840
84	1776	1772	1,222,081	1,223,101	-0.08	924	1134	890	936	852
85	1778	1775	1,239,134	1,240,187	-0.08	936	1151	902	951	862
86	1781	1777	1,256,212	1,257,299	-0.09	950	1168	915	968	874
87	1783	1780	1,273,313	1,274,436	-0.09	964	1185	929	987	885
88	1786	1784	1,290,450	1,291,599	-0.09	978	1202	943	1005	897
89	1788	1785	1,307,614	1,308,786	-0.09	991	1216	957	1025	909
90	1791	1786	1,324,785	1,325,999	-0.09	1024	1283	971	1045	923
91	1793	1787	1,341,970	1,343,236	-0.09	1056	1344	988	1064	934
92	1796	1789	1,359,177	1,360,497	-0.10	1089	1374	1007	1084	946
93	1798	1787	1,376,378	1,377,782	-0.10	1202	1429	1083	1113	960

Time (min)	W10X49	W10X49	W10X49	W10X49	W10X49	W10X49	W10X49	W10X49	W10X49	W10X49
	Level C Max Temp (°F)	Level D Avg Temp (°F)	Level D Max Temp (°F)	Level A TC #1 (°F)	Level A TC #2 (°F)	Level A TC #3 (°F)	Level B TC #4 (°F)	Level B TC #5 (°F)	Level B TC #6 (°F)	Level C TC #7 (°F)
0	89	89	89	89	89	90	90	90	89	89
1	120	111	117	120	131	103	103	122	119	118
2	178	163	174	177	194	146	146	183	176	173
3	216	196	212	216	232	185	184	221	215	212
4	245	228	244	245	259	215	213	251	243	241
5	271	251	270	272	284	237	235	277	270	267
6	297	274	293	296	307	259	257	302	294	290
7	314	292	309	312	322	279	278	320	308	304
8	331	309	327	328	338	296	296	337	324	320
9	348	326	344	346	355	314	314	354	341	337
10	365	342	358	363	371	331	332	370	359	354
11	379	357	373	379	385	347	348	385	376	371
12	392	372	386	395	397	361	363	397	391	386
13	403	385	398	408	408	375	377	408	405	400
14	412	396	408	420	417	387	390	417	417	411
15	421	406	417	430	426	397	401	426	427	421
16	431	415	425	440	433	407	410	433	437	431
17	441	423	432	450	440	415	419	440	448	441
18	450	431	439	460	447	424	428	448	457	450
19	459	439	446	469	454	432	437	454	466	459
20	467	446	452	477	460	439	444	460	474	467
21	475	452	457	485	466	447	452	466	481	475
22	482	458	463	492	471	454	459	471	488	482
23	488	465	469	499	477	461	466	476	494	488
24	494	470	474	505	482	468	472	481	500	494
25	500	476	479	511	487	474	478	486	505	500
26	506	481	484	516	492	480	484	491	511	506
27	512	486	489	521	496	486	489	495	516	512
28	519	491	493	526	501	491	495	499	522	519
29	525	496	498	531	507	496	500	503	528	525
30	531	501	502	536	511	500	504	508	534	531
31	537	505	506	541	516	505	509	511	539	537
32	544	510	511	547	519	509	513	515	545	544
33	550	515	515	552	523	513	517	520	550	550
34	556	518	518	557	528	518	522	526	556	556
35	563	523	523	563	532	522	527	532	561	563
36	569	527	528	569	535	526	532	538	567	569
37	575	531	533	575	539	531	537	544	573	575
38	581	535	537	580	543	535	542	549	579	581
39	587	540	542	586	547	539	548	554	586	587
40	593	544	547	592	550	544	552	559	592	593
41	600	548	552	597	554	548	558	564	598	600
42	605	552	557	602	557	553	563	568	604	605
43	611	556	562	608	560	557	568	574	610	611
44	618	561	567	614	564	562	572	579	616	618
45	624	565	572	619	567	566	577	583	622	624
46	630	570	578	625	571	572	583	588	628	630
47	636	574	583	630	574	576	587	592	633	636
48	642	579	588	636	578	581	593	597	639	642
49	649	583	594	640	581	586	598	601	644	649
50	656	588	599	646	585	591	603	605	650	656
51	662	593	605	652	588	596	609	609	656	662
52	669	598	611	657	592	601	614	614	661	669

Time (min)	W10X49	W10X49	W10X49	W10X49	W10X49	W10X49	W10X49	W10X49	W10X49	W10X49
	Level C Max Temp (°F)	Level D Avg Temp (°F)	Level D Max Temp (°F)	Level A TC #1 (°F)	Level A TC #2 (°F)	Level A TC #3 (°F)	Level B TC #4 (°F)	Level B TC #5 (°F)	Level B TC #6 (°F)	Level C TC #7 (°F)
53	676	603	617	663	595	606	620	618	667	676
54	682	607	623	669	599	611	625	622	672	682
55	689	612	629	675	602	617	630	626	678	689
56	695	617	635	681	607	622	636	629	684	695
57	701	623	642	687	610	628	642	632	690	701
58	708	627	648	692	614	633	647	635	695	708
59	714	633	655	698	618	639	653	638	702	714
60	720	638	662	704	621	644	658	642	708	720
61	726	644	670	709	625	649	664	645	713	726
62	733	651	679	720	629	655	670	649	720	733
63	739	659	690	746	633	661	676	653	726	739
64	746	667	701	775	637	666	682	659	732	746
65	752	676	714	803	642	672	689	663	739	752
66	758	686	727	827	647	678	698	669	745	758
67	765	697	741	847	652	684	708	676	752	765
68	773	709	757	866	658	690	717	684	759	773
69	781	722	772	882	665	696	728	691	766	781
70	789	736	788	899	672	703	740	699	773	789
71	797	749	804	921	681	709	751	708	779	797
72	807	763	819	943	690	716	763	715	787	807
73	816	777	835	963	700	722	775	725	793	816
74	826	790	849	982	709	730	788	735	800	826
75	836	803	864	1000	720	737	801	745	808	836
76	847	817	878	1017	731	744	814	757	815	847
77	858	830	893	1031	741	752	829	767	823	858
78	869	843	907	1047	753	760	843	778	831	869
79	880	856	921	1061	763	769	857	790	838	880
80	891	869	935	1074	776	776	872	802	847	891
81	903	882	949	1087	790	784	887	813	855	903
82	915	893	960	1103	801	792	903	825	864	915
83	926	906	974	1114	813	801	918	838	872	926
84	939	919	987	1134	827	810	936	853	881	939
85	951	932	1000	1151	839	819	951	863	891	951
86	964	944	1013	1168	854	828	968	877	900	964
87	977	956	1025	1185	870	837	987	890	910	977
88	994	968	1037	1202	885	847	1005	904	919	994
89	1009	980	1049	1216	902	856	1025	918	929	1009
90	1027	992	1061	1283	921	867	1045	932	937	1027
91	1039	1004	1073	1344	946	878	1064	947	953	1039
92	1053	1016	1085	1374	1002	892	1084	966	972	1053
93	1068	1028	1097	1429	1190	987	1113	1031	1106	1068

Time (min)	W10X49	W10X49	W10X49	W10X49	W10X49	Furnace	Furnace	Furnace	Furnace	Furnace
	Level C TC #8 (°F)	Level C TC #9 (°F)	Level D TC #10 (°F)	Level D TC #11 (°F)	Level D TC #12 (°F)	Probe #1 (°F)	Probe #2 (°F)	Probe #3 (°F)	Probe #4 (°F)	Probe #5 (°F)
0	89	89	89	89	89	91	91	91	91	92
1	120	102	101	116	117	107	117	113	117	107
2	178	145	141	173	174	210	259	250	279	217
3	216	183	180	212	failed TC	431	530	495	577	469
4	245	212	211	244	failed TC	736	922	862	953	827
5	271	233	232	270	failed TC	983	1109	1102	1141	1059
6	297	255	254	293	failed TC	1113	1192	1195	1218	1177
7	314	276	274	309	failed TC	1096	1135	1138	1152	1142
8	331	294	291	327	failed TC	1119	1140	1146	1142	1138
9	348	311	308	344	failed TC	1163	1185	1193	1178	1177
10	365	329	325	358	failed TC	1233	1267	1276	1270	1251
11	379	346	341	373	failed TC	1322	1371	1387	1386	1365
12	392	361	357	386	failed TC	1375	1440	1450	1466	1438
13	403	375	371	398	failed TC	1407	1470	1469	1493	1466
14	412	387	384	408	failed TC	1406	1456	1447	1472	1450
15	421	398	395	417	failed TC	1385	1431	1418	1444	1419
16	429	407	405	425	failed TC	1376	1426	1411	1439	1409
17	437	417	414	432	failed TC	1386	1444	1427	1458	1424
18	443	425	423	439	failed TC	1408	1469	1450	1483	1446
19	450	433	431	446	failed TC	1431	1488	1468	1501	1465
20	456	441	439	452	failed TC	1437	1495	1475	1507	1473
21	461	448	446	457	failed TC	1434	1496	1473	1506	1471
22	467	455	453	463	failed TC	1433	1499	1474	1508	1472
23	472	461	460	469	failed TC	1436	1505	1480	1513	1477
24	477	468	466	474	failed TC	1443	1513	1487	1520	1484
25	481	474	472	479	failed TC	1451	1523	1498	1530	1494
26	486	480	478	484	failed TC	1461	1531	1507	1539	1503
27	491	486	483	489	failed TC	1469	1537	1515	1546	1513
28	494	491	489	493	failed TC	1478	1542	1523	1552	1521
29	499	496	494	498	failed TC	1487	1549	1532	1559	1529
30	504	500	500	502	failed TC	1496	1555	1540	1566	1537
31	507	505	504	506	failed TC	1506	1565	1552	1577	1548
32	511	509	509	511	failed TC	1516	1575	1563	1586	1560
33	515	514	514	515	failed TC	1524	1582	1571	1592	1571
34	519	518	518	518	failed TC	1531	1588	1578	1597	1579
35	522	522	523	522	failed TC	1536	1594	1585	1602	1587
36	526	526	528	526	failed TC	1540	1598	1589	1605	1592
37	529	530	533	529	failed TC	1545	1604	1595	1608	1596
38	533	534	537	533	failed TC	1550	1611	1600	1612	1599
39	535	539	542	537	failed TC	1556	1616	1605	1616	1603
40	539	543	547	540	failed TC	1560	1620	1608	1619	1605
41	542	547	552	544	failed TC	1565	1625	1614	1623	1607
42	546	552	557	547	failed TC	1576	1636	1625	1635	1618
43	549	556	562	550	failed TC	1586	1646	1636	1645	1627
44	553	560	567	554	failed TC	1594	1655	1645	1655	1637
45	557	566	572	557	failed TC	1602	1662	1652	1663	1644
46	561	570	578	561	failed TC	1608	1667	1653	1670	1649
47	565	575	583	565	failed TC	1612	1672	1657	1675	1652
48	569	580	588	569	failed TC	1617	1677	1661	1680	1654
49	573	585	594	572	failed TC	1621	1681	1666	1685	1657
50	577	590	599	576	failed TC	1626	1687	1673	1692	1661
51	580	595	605	580	failed TC	1633	1693	1679	1699	1666
52	584	599	611	584	failed TC	1637	1698	1685	1704	1670

Time (min)	W10X49 Level C TC #8 (°F)	W10X49 Level C TC #9 (°F)	W10X49 Level D TC #10 (°F)	W10X49 Level D TC #11 (°F)	W10X49 Level D TC #12 (°F)	Furnace Probe #1 (°F)	Furnace Probe #2 (°F)	Furnace Probe #3 (°F)	Furnace Probe #4 (°F)	Furnace Probe #5 (°F)
53	587	605	617	588	failed TC	1643	1704	1691	1710	1675
54	591	610	623	591	failed TC	1649	1710	1697	1715	1681
55	594	615	629	595	failed TC	1654	1716	1704	1722	1687
56	597	621	635	599	failed TC	1658	1721	1708	1726	1691
57	602	626	642	603	failed TC	1662	1727	1712	1732	1696
58	605	631	648	606	failed TC	1667	1731	1717	1737	1700
59	608	637	655	610	failed TC	1671	1735	1721	1741	1704
60	612	642	662	614	failed TC	1675	1740	1725	1744	1708
61	616	647	670	618	failed TC	1679	1744	1729	1749	1712
62	620	653	679	623	failed TC	1681	1745	1729	1751	1713
63	623	659	690	627	failed TC	1682	1748	1733	1755	1716
64	627	664	701	632	failed TC	1687	1754	1739	1761	1721
65	632	671	714	638	failed TC	1687	1756	1739	1762	1722
66	636	675	727	644	failed TC	1688	1756	1740	1763	1723
67	642	682	741	652	failed TC	1688	1758	1742	1765	1724
68	647	687	757	661	failed TC	1691	1761	1745	1769	1728
69	655	693	772	672	failed TC	1693	1764	1747	1772	1731
70	661	699	788	683	failed TC	1695	1765	1749	1774	1733
71	670	705	804	694	failed TC	1695	1768	1751	1776	1735
72	679	711	819	706	failed TC	1697	1771	1753	1779	1737
73	689	718	835	719	failed TC	1699	1772	1754	1782	1740
74	700	725	849	730	failed TC	1701	1776	1757	1784	1742
75	711	732	864	742	failed TC	1704	1778	1760	1788	1746
76	722	739	878	755	failed TC	1707	1782	1763	1791	1749
77	733	747	893	766	failed TC	1709	1783	1765	1792	1751
78	744	754	907	778	failed TC	1710	1786	1768	1795	1754
79	755	761	921	790	failed TC	1713	1788	1769	1797	1756
80	767	770	935	802	failed TC	1715	1789	1771	1799	1757
81	779	778	949	814	failed TC	1716	1793	1774	1802	1760
82	790	786	960	826	failed TC	1717	1794	1773	1803	1762
83	802	791	974	837	failed TC	1717	1796	1775	1806	1764
84	814	802	987	850	failed TC	1720	1798	1779	1809	1767
85	825	810	1000	863	failed TC	1724	1800	1782	1812	1769
86	837	820	1013	874	failed TC	1725	1803	1785	1813	1773
87	849	828	1025	887	failed TC	1727	1807	1787	1817	1775
88	861	836	1037	898	failed TC	1731	1810	1790	1822	1779
89	874	845	1049	910	failed TC	1733	1811	1790	1823	1779
90	886	855	1061	922	failed TC	1733	1813	1792	1825	1781
91	900	864	1073	934	failed TC	1734	1815	1794	1828	1783
92	913	873	1085	946	failed TC	1733	1817	1796	1829	1787
93	927	884	1097	959	failed TC	1722	1816	1796	1829	1785

Time (min)	Furnace Probe #6 (°F)	Furnace Probe #7 (°F)	Furnace Probe #8 (°F)	Furnace Probe #9 (°F)	Furnace Temp Stdev (°F)	Lab Ambient Temp (°F)
0	91	92	91	92	1	90
1	105	111	123	109	6	90
2	198	240	268	222	28	90
3	409	500	482	440	52	90
4	773	842	741	733	82	90
5	1050	1080	945	958	70	90
6	1177	1195	1075	1088	52	90
7	1133	1160	1082	1082	30	90
8	1137	1142	1095	1105	18	90
9	1182	1173	1135	1153	18	89
10	1259	1248	1202	1231	23	89
11	1370	1369	1292	1330	32	90
12	1440	1443	1358	1393	37	89
13	1471	1471	1404	1428	32	90
14	1460	1457	1416	1425	22	90
15	1436	1430	1397	1405	19	90
16	1429	1422	1388	1398	21	90
17	1447	1436	1396	1409	24	90
18	1473	1459	1415	1430	26	91
19	1495	1479	1435	1448	26	91
20	1505	1488	1445	1456	25	91
21	1506	1488	1446	1456	26	91
22	1508	1490	1445	1457	27	91
23	1514	1496	1448	1462	28	91
24	1521	1503	1454	1468	29	91
25	1534	1513	1462	1478	30	90
26	1543	1523	1471	1487	30	90
27	1550	1532	1480	1495	29	91
28	1554	1538	1490	1503	27	91
29	1559	1546	1500	1511	26	91
30	1564	1554	1511	1518	25	91
31	1574	1564	1523	1528	25	91
32	1583	1573	1534	1537	24	92
33	1591	1580	1544	1544	24	92
34	1597	1586	1550	1551	23	92
35	1603	1592	1558	1557	23	91
36	1606	1595	1563	1562	23	92
37	1611	1598	1568	1567	23	91
38	1615	1602	1573	1573	22	92
39	1621	1606	1579	1579	22	92
40	1625	1608	1583	1582	22	92
41	1630	1612	1585	1587	22	92
42	1642	1623	1595	1597	22	92
43	1652	1631	1606	1608	22	93
44	1659	1641	1615	1616	22	92
45	1664	1650	1621	1624	22	91
46	1667	1655	1627	1631	21	92
47	1670	1659	1630	1636	21	92
48	1673	1662	1635	1641	21	93
49	1676	1664	1638	1645	21	93
50	1682	1669	1643	1651	22	93
51	1689	1673	1648	1657	22	93
52	1694	1678	1653	1662	22	93

Time (min)	Furnace Probe #6 (°F)	Furnace Probe #7 (°F)	Furnace Probe #8 (°F)	Furnace Probe #9 (°F)	Furnace Temp Stdev (°F)	Lab Ambient Temp (°F)
53	1700	1683	1659	1669	22	93
54	1706	1689	1664	1675	22	93
55	1712	1695	1670	1681	23	93
56	1717	1700	1674	1685	23	93
57	1722	1705	1677	1690	24	93
58	1727	1710	1682	1695	23	93
59	1730	1714	1685	1698	24	93
60	1734	1718	1689	1702	24	94
61	1738	1723	1693	1707	24	94
62	1740	1726	1695	1708	24	93
63	1743	1730	1697	1710	24	94
64	1749	1734	1704	1716	24	94
65	1750	1737	1705	1717	25	94
66	1751	1738	1706	1718	25	94
67	1753	1742	1707	1720	25	94
68	1755	1745	1708	1722	26	94
69	1758	1748	1711	1725	26	94
70	1759	1750	1712	1726	26	94
71	1762	1754	1713	1728	27	94
72	1764	1756	1714	1729	27	95
73	1766	1759	1716	1731	27	95
74	1768	1764	1717	1733	28	95
75	1771	1769	1720	1736	28	95
76	1775	1772	1723	1738	28	95
77	1776	1774	1724	1740	28	95
78	1780	1777	1727	1743	29	95
79	1782	1779	1729	1745	28	95
80	1784	1782	1730	1746	29	95
81	1787	1785	1731	1748	30	95
82	1788	1788	1731	1750	30	94
83	1790	1790	1734	1750	30	95
84	1793	1795	1736	1753	31	95
85	1796	1797	1739	1756	30	94
86	1799	1800	1740	1758	31	95
87	1801	1803	1742	1761	31	95
88	1805	1807	1745	1764	31	95
89	1807	1811	1745	1765	32	95
90	1809	1813	1743	1765	33	95
91	1812	1815	1741	1765	34	96
92	1814	1819	1742	1767	35	95
93	1813	1819	1741	1760	38	95

APPENDIX C
PHOTOGRAPHS

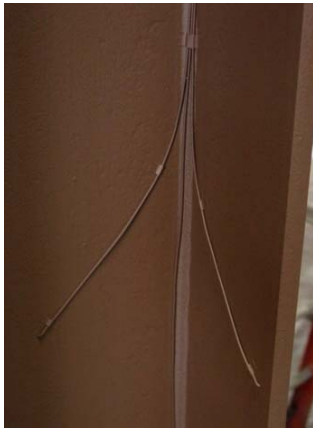




#1: Primed column ready to coat.



#2: Thermocouple attachment.



#3: Thermocouple attachment.



#4: Contego product bucket.



#5: Spraying the W10X49 column.



#6: Spraying the column.



#7: Spraying the column.



#8: Column in furnace.



#9: Column in furnace.



#10: Top of column in furnace.



#11: Furnace with lid on.



#12: Bottom of column after test.