Intertek

ETL SEMKO

TEST REPORT

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ASTM E119-05a

Fire Tests of Building Construction and Materials

1-HR FIRE RESISTANCE TEST OF A
NON-LOADBEARING STRAW BALE WALL

Project No. 3098054B

July 31, 2006

Prepared for:

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Intertek ETL SEMKO

ABSTRACT

A 12 ft x 14 ft non-loadbearing wall constructed with 7.5 pcf rectangular wheat straw bales stacked in a running bond pattern, clad on each surface with 1" of earthen-plaster, produced, assembled and tested as described herein, successfully met the conditions of acceptance as outlined in ASTM Method E119-05a Fire Tests of Building Construction and Materials for a fire endurance rating of 1-hour.

Michael E. Dey
Project Manager, Fire Resistance

8/4/06
Date

Reviewed and approved:

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INTRODUCTION[1]

"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 temperature exposure

[1] **ASTM E119-05a Standard Test Methods for Fire Tests of Building Construction and Materials ASTM** International, Volume 04.07 Building Seals and Sealants, etc.

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.

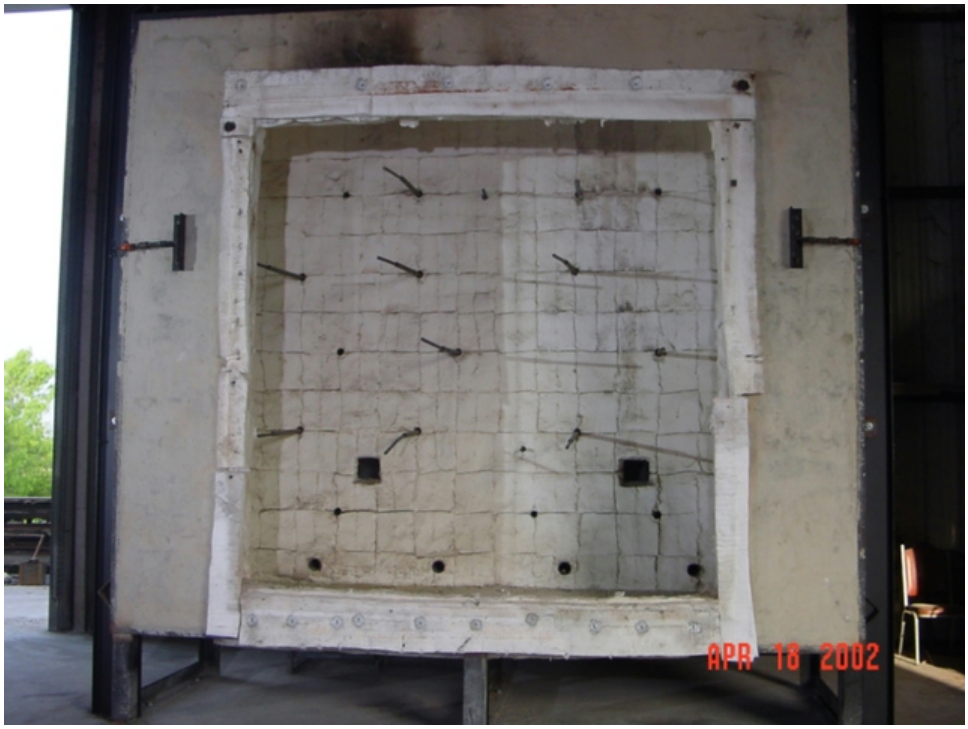
4.4.6 The effect of fire endurance of conventional openings in the assembly, that is electrical receptacle outlets, plumbing pipe, etc., unless specifically provided for in the construction tested."

TEST PROCEDURE

Test Furnace

The test furnace is designed to allow the specimen to be uniformly exposed to the specified time-temperature conditions. It is fitted with 6 propane/air burners positioned on the left and right side walls, designed to allow an even heat flux distribution across the face of a test specimen while allowing no direct flame impingement. The maximum energy input into the furnace is 15 MBtu/hr. The furnace operator has controls which allow the following items to be varied during the test: the overall energy input into the furnace; the air/gas ratio to the burners; and, the input of additional air beyond that passing through the burners. The furnace opening is 14 ft wide, 12 ft tall and 4 ft deep. It may be fitted with a collar that reduces the front opening to 10 ft x 10 ft, if desired. Furnace pressures may be maintained at any value from +0.15" W.C. to -0.15" W.C. Any full-size vertical fire test furnace will have a pressure difference between the bottom and top of approximately 0.01 in. W.C. per vertical foot after operating temperatures are reached. For this reason, the furnace is operated by controlling the pressure within the furnace (with respect to the laboratory ambient pressure) by regulating the pressure at a specific horizontal plane in the furnace. The furnace pressure will often be adjusted so that the "neutral pressure plane" (that where the pressure difference between the furnace interior and the laboratory ambient is zero) is at a desired location: for instance; at the top, at a point $^{1}/_{3}$ of the way down from the top, or at the bottom of the specimen.

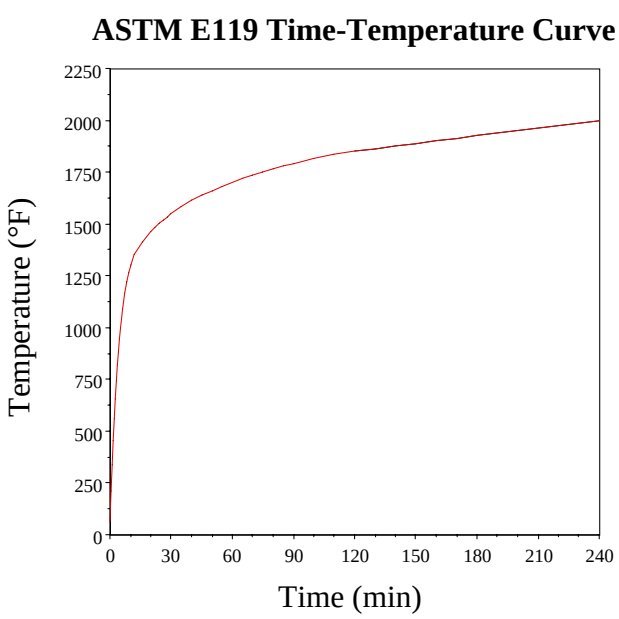
The temperature within the furnace is determined to be the mathematical average of thermocouples located symmetrically within the furnace and positioned six inches away from the vertical face of the test specimen. The materials used in the construction of these thermocouples are those suggested in the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



This photograph of the vertical furnace shows it with a concrete adapter in place which reduces its opening to 120" x 120". Without the adapter the furnace will accept test specimens 144" tall x 168" wide. The furnace is 48" deep, with burners on the sides, so that no flame impingement on the specimen occurs.

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.

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



Time (min)	Temperature (°F)
0	68
5	1000
10	1300
20	1462
30	1550
60	1700
90	1792
120	1850
180	1925
240	2000

Figure 1

Fire Endurance Test

The fire exposure is continued on the specimen with its applied load if applicable, until failure occurs, or until the specimen has withstood the test conditions for the desired fire endurance rating.

Hose Stream Test

"11.1 Where required by the conditions of acceptance, the hose stream test shall be conducted to subject the specimen described in 11.2 or 11.3 to the impact, erosion, and cooling effects of a hose stream.
11.1.1 Exemption – The hose stream test shall not be required in the case of constructions having a resistance period, indicated in the fire endurance test, of less than 1 h.

11.2 The hose stream test shall be conducted on a duplicate test specimen.
11.2.1 The duplicate specimen shall be exposed to the effects of the hose stream immediately after being subjected to a fire endurance test for a time period of one-half the fire endurance classification period determined from the fire endurance test on the initial specimen.
11.2.2 The length of time that the duplicate specimen is subjected to the fire endurance test shall not exceed 1 h.
11.3 Optional Program – As an alternative procedure, conduct the hose stream test on the initially tested specimen immediately following its fire endurance test.
11.4 In conducting the hose stream test, direct the hose stream first at the middle and then at all parts of the exposed face of the specimen. Any changes in direction shall be made slowly.
11.5 *Stream Equipment and Details* - The stream shall be delivered through a $2^1/_2$-in. (64-mm) hose discharging through a National Standard Playpipe of corresponding size equipped with a $1^1/_8$-in. (28.5-mm) discharge tip of the standard-taper smooth-bore pattern without shoulder at the orifice. The water pressure and duration of the application shall be as prescribed [in the table below]:

Conditions For Hose Stream Test		
Resistance Period	Water Pressure at Base of Nozzle,psi (kPa)	Duration of Application, min/100 ft^2 (9 m^2) exposed area
8 h and over	45 (310)	6
4 h and over if less than 8 h	45 (310)	5
2 h and over if less than 4 h	30 (207)	$2^1/_2$
1-1/2 h and over if less than 2 h	30 (207)	$1^1/_2$
1 h and over if less than 1-1/2 h	30 (207)	1
Less than 1 h, if desired	30 (207)	1

11.6 *Nozzle Distance* - The distance between the tip of the nozzle and the center of the exposed surface shall be determined by the deviation from normal between the center of the nozzle axis and the center of the exposed surface of the specimen. The distance shall be 20 ft (6 m) when the axis through the center of the nozzle is normal to the center of the exposed surface. This distance shall be decreased by an amount equal to 1 ft (305 mm) for each 10° of deviation from the normal."

Correction Factor

When the indicated resistance period is $^1/_2$ 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

18. Conditions of Acceptance – [Nonloadbearing Walls]

18.1 Regard the test as successful when the following conditions are met:
18.1.1 The wall or partition has withstood the fire endurance test without passage of flame or gases hot enough to ignite cotton waste, for a period equal to that for which classification is desired.

18.1.2 The wall or partition shall has [sic] withstood the fire and hose stream test as specified in Sections 10 and 11, without passage of flame, of gases hot enough to ignite cotton waste, or of passage of water from the hose stream. The assembly shall be considered to have failed the hose stream test if an opening develops that permits a projection of water from the stream beyond the unexposed surface during the time of the hose stream test.

18.1.3 Transmission of heat through the wall or partition during the fire endurance test shall not have been such as to raise the [average] temperature on its unexposed surface more than 250°F (139°C) above its initial temperature.

[The E119 standard further states:]

7.4 Where the conditions of acceptance place a limitation on the rise of temperature of the unexposed surface, the temperature end point of the fire endurance period shall be determined by the average of the measurements taken at individual points; except that if a temperature rise of 30% [325°F above initial temperature] in excess of the specified limit occurs at any one of these points, the remainder shall be ignored and the fire endurance period judged as ended.

TEST SPECIMEN CONSTRUCTION

The observations and test results in this report are relevant only to the sample tested. This report by itself does not imply that the material, product, or service is or has ever been under an Intertek certification program.

The 12-ft tall x 14-ft wide wall assembly was constructed with rectangular wheat straw bales with the following nominal physical properties: 36-in long, 14-in tall (straw oriented horizontally), 18-in wide, 42.3 lbs each (7.5 pcf). Because the thickness of the bales was greater than the depth of the frame, the bales were installed flush to one side of the frame (the heated side). ½" plywood was placed under the bottom course and above the top course to assist in keeping the bales in plane. The bales were stacked in a running bond pattern 10 courses high, completely filling the test frame. The wheat straw bales had two polypropylene ties per bale (PolyLine 430, GREENLEE®, 210 lb strength). The ties were placed in the wall in the "on-bottom" orientation, meaning that the poly ties were contained within the wall around the top and bottom of the bales, not directly exposed to the fire. The gaps at the intersections of the stacked bales were stuffed with a mud and straw mixture that was prepared using locally available dirt plus a small amount of chopped straw mixed with enough water to hold its shape, then pushed as far into the cracks as possible. The wall was constructed in a loadbearing test frame, which has a moveable bottom beam with hydraulic actuators below the

beam. To impose a load on a wall, a hydraulic pump is used to apply pressure to the jacks which exert a force on the bottom beam and the wall is simply squeezed against the top of the test frame. This wall was intended to carry a superimposed load of 600 lbs / lineal foot during the test, so after the bales were stacked, this load was applied prior to the application of the earthen clay mixture. Though attempts were made to straighten the bales and keep them straight before and during application of the earthen plaster, the wall still had a significant bulge when the plaster was applied, thus becoming permanent. The bales had no interior or exterior vertical pinning. The earthen plaster was applied in two coats, each nominally ½" thick. The mix consisted of 3 parts clay, 2 parts chopped straw, 6 parts sand, and water to a sprayable consistency. The second coat was applied using hand trowels.

The first coat was spray-applied on June 5, 2006 by representatives of DCAT. Beginning the next day, a large box fan was placed in front of the wall to assist in drying. On June 22, the second coat was applied with hand trowels. Each coat was nominally ½" thick. Two small wooden boxes were filled with earthen plaster taken from the mix used on both days of application. These samples were sent to a local lab and compression tests were performed in accordance with ASTM C42. Those results are located in Appendix E.

The wall was allowed to sit for 28 days prior to testing. On the morning of the test, the moisture content within the bales was measured, near each thermocouple and at three depths – exposed side, center of bale, and unexposed side. The readings were taken with a Protimeter Balemaster moisture meter. The average moisture content of 27 readings was 11.1%.

Construction drawings are located in Appendix A.

THERMOCOUPLES

All temperatures monitored on the unexposed surface of this wall assembly were measured using 24 GA., electrically-welded, Type K Chromel-Alumel, glass-glass insulated (Special Limits of Error: ±1.1°C) thermocouples, purchased with calibration certifications and lot traceability.

To meet the requirements of ASTM E119, nine thermocouples were installed on the unexposed surface of the wall and covered with 6 in. x 6 in. x 0.40 in. thick dry, felted, mineral fiber pads, held in place with a small daub of silicone adhesive on each corner. These thermocouples were distributed across the unexposed surface of the wall.

TEST RESULTS AND OBSERVATIONS

The test wall, contained in a loadbearing frame assembly, was placed in front of the Laboratory's 10-ft x 10-ft vertical wall furnace on July 20, 2006. The wall assembly was 12-ft x 14-ft, but only 100-ft^2 is required for qualification. Because the wall surface wasn't flat, when the assembly was clamped to the furnace, the unexposed surface developed a vertical crack in the plaster, approximately 3/16" to ¼" wide and extended up much of the wall. Due to the bulge in the wall, and because of the eccentric load condition caused by the bales being flush with one side of the frame and extending past the other side, the Client decided to run the test in a non-loadbearing condition.

The thermocouples were connected to the data acquisition system and their outputs verified. The laboratory air temperature was 89°F, with a humidity of 70%. At 10:10 a.m., the furnace was fired and the standard E119 time-temperature curve followed for a period of 60 minutes. The pressure difference between the inside of the furnace (measured by a pressure tap located approximately 1/3 of the way down from the top of the specimen, on the horizontal centerline of the furnace) and the laboratory ambient air, was maintained at -0.03 in. of water column throughout the entire test, following the first five minutes of the test, which resulted in the neutral pressure plane being positioned at the top of the test assembly.

Observations made during the test are as follows:

Time (min:sec)	Observation
0:00	Start of test
13:00	Small pieces of the finish (trowel-applied) coat popping off the exposed side of the wall
28:00	Flaming through cracks in the exposed surface
36:00	Light smoke issuing from a crack in the top left of the exposed side
42:00	Section of clay and straw fell away from the bottom right of the exposed side
58:00	Orange glow visible through crack on unexposed side
60:00	Furnace extinguished and assembly moved into position for the hose stream test
64:24	Hose stream test begins
65:24	Hose stream test ends

The wall withstood the fire and hose stream tests without passage of flame, of gases hot enough to ignite cotton waste, or of the passage of water from the hose stream. No openings developed that permitted a projection of water from the stream beyond the unexposed surface during the time of the hose stream test. Transmission of heat through the wall during the fire endurance test did not raise the average temperature on the unexposed surface more than 250°F, nor any individual temperature more than 325°F.

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
C	correction factor	-0.10 minutes -6 seconds
I	indicated fire-resistance period	60 minutes
A	area under the curve of indicated average furnace temperature for the first three fourths of the indicated period	58 129 (°F•min)
As	area under the standard furnace curve for the same part of the indicated period	58 288 (°F•min)
L	lag correction	3240
	FIRE RESISTANCE PERIOD ACHIEVED BY THIS SPECIMEN ==>	60 minutes

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.

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

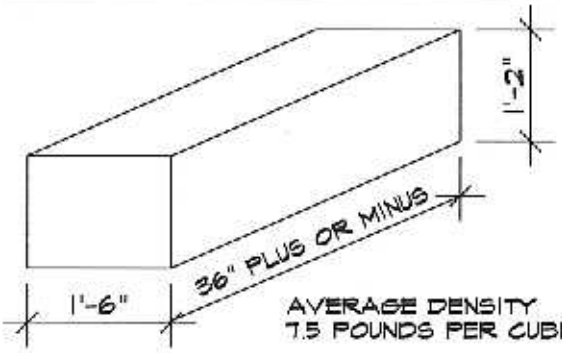
CONCLUSIONS

The observations and test results in this report are relevant only to the sample tested. This report by itself does not imply that the material, product, or service is or has ever been under an Intertek certification program.

A 12 ft x 14 ft non-loadbearing wall constructed with 7.5 pcf rectangular wheat straw bales stacked in a running bond pattern, clad on each surface with 1” of earthen-plaster, produced, assembled and tested as described herein, successfully met the conditions of acceptance as outlined in ASTM Method E119-05a Fire Tests of Building Construction and Materials for a fire endurance rating of 1-hour.

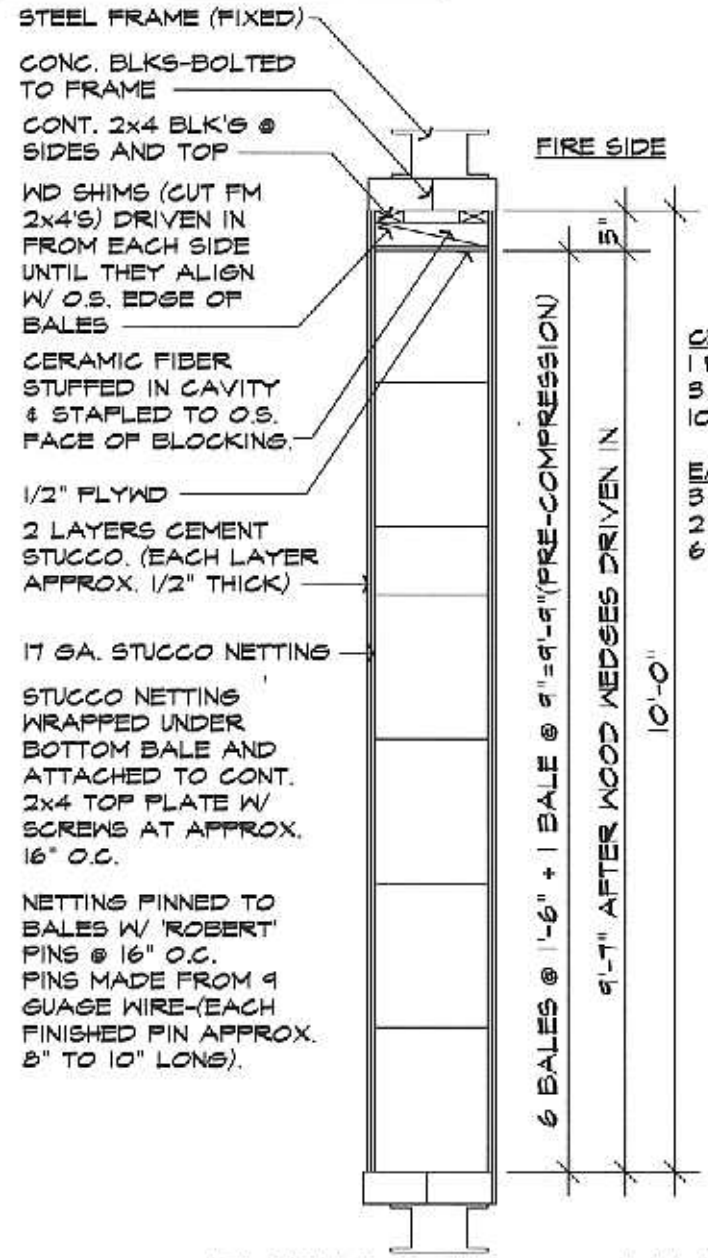
APPENDIX A

CONSTRUCTION DRAWINGS



AVERAGE DENSITY
7.5 POUNDS PER CUBIC FOOT

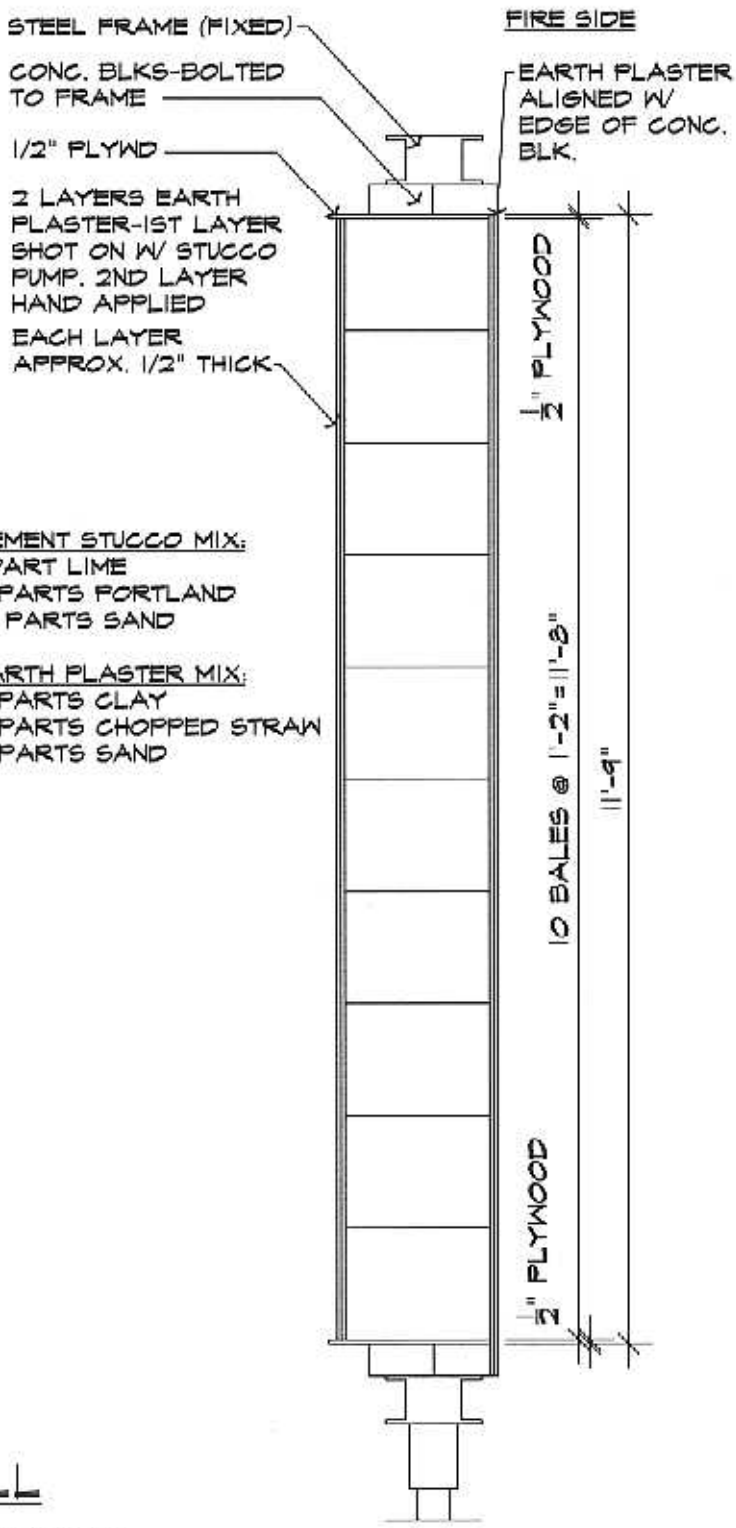
'AVERAGE' BALE



CEMENT STUCCO WALL

CEMENT STUCCO MIX:
1 PART LIME
3 PARTS PORTLAND
10 PARTS SAND

EARTH PLASTER MIX:
3 PARTS CLAY
2 PARTS CHOPPED STRAW
6 PARTS SAND



AFTER SCRATCH COAT WAS APPLIED, WALL WAS 'WETTED' DOWN ON BOTH SIDES. 6 MIL POLY WAS THEN WRAPPED OVER STRUCTURE AND TAPED TO THE FRAME TO HOLD MOISTURE IN.

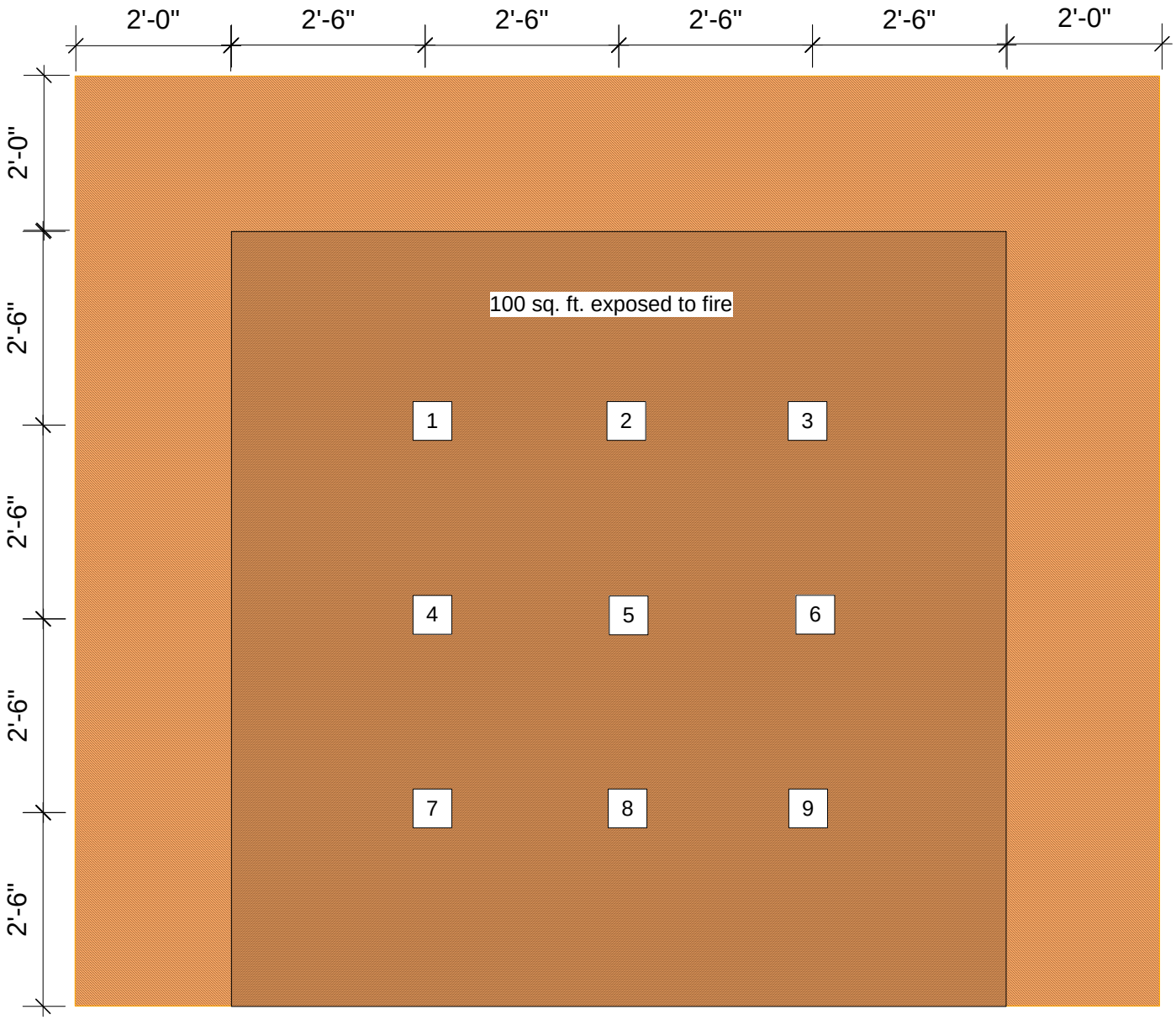
EARTH PLASTER WALL

0' 6" 1' 2' 3' 4' 5'

BENJAMIN OBREGON ARCHITECT 13429 OVERLAND PASS, AUSTIN TEXAS 78738
OFFICE: 512) 263-0177 FAX: 512) 263-5765 WEB: SustainableDesignCenter.com E-MAIL: bobregon@austinrr.com

APPENDIX B

THERMOCOUPLE LAYOUT



ELEVATION VIEW

Note:

The unexposed surface was instrumented with 24 GA, fiberglass insulated Type K thermocouples as indicated in the standard, held under 6" x 6" x 0.4" thick mineral fiber pads. The TCs were located as near as possible to the locations indicated, but due to irregularities in the stucco surface, some pads were moved slightly to areas where the pad would be in full contact with the stucco surface.

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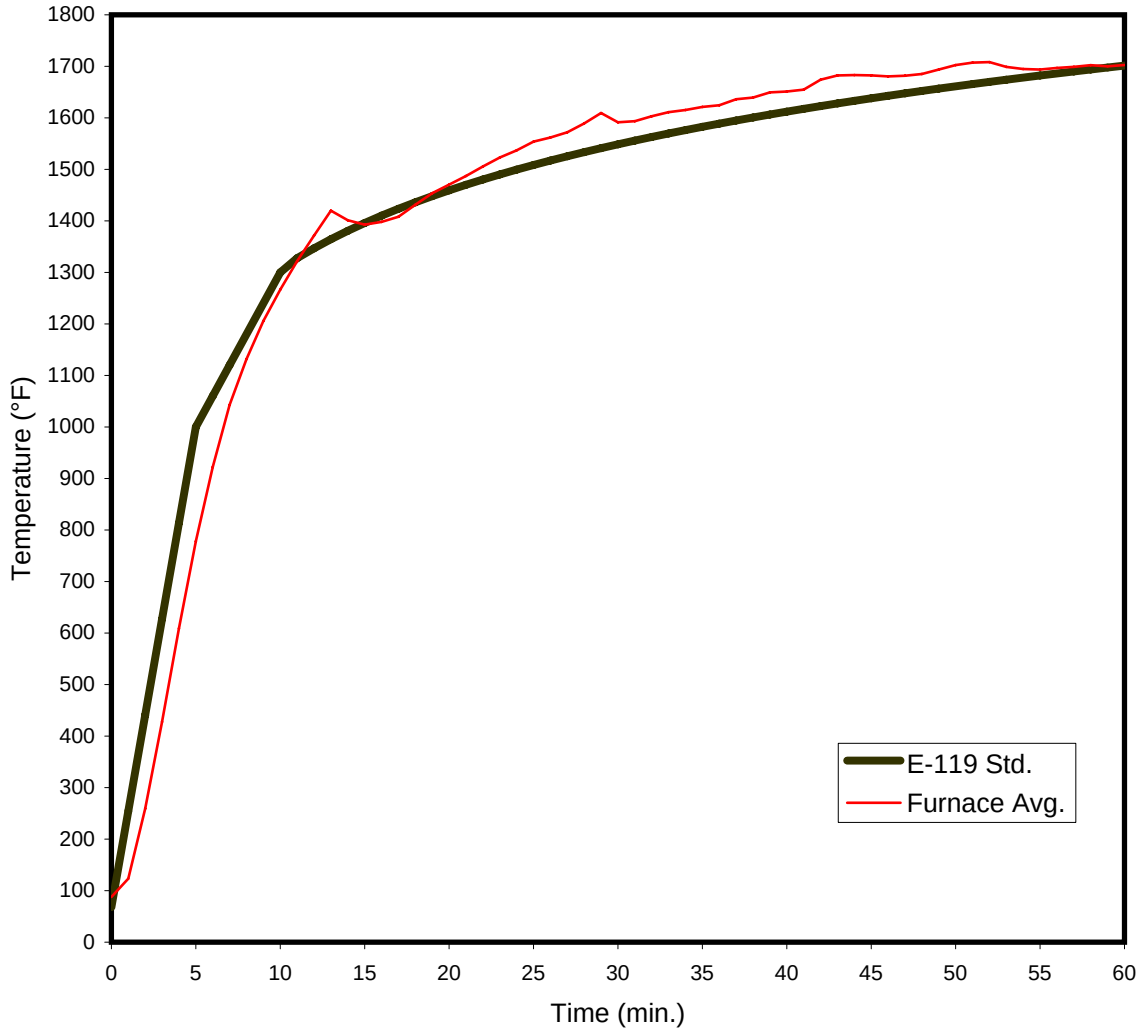
DCAT
Fig. 2 Thermocouple Layout

Scale = 1:20

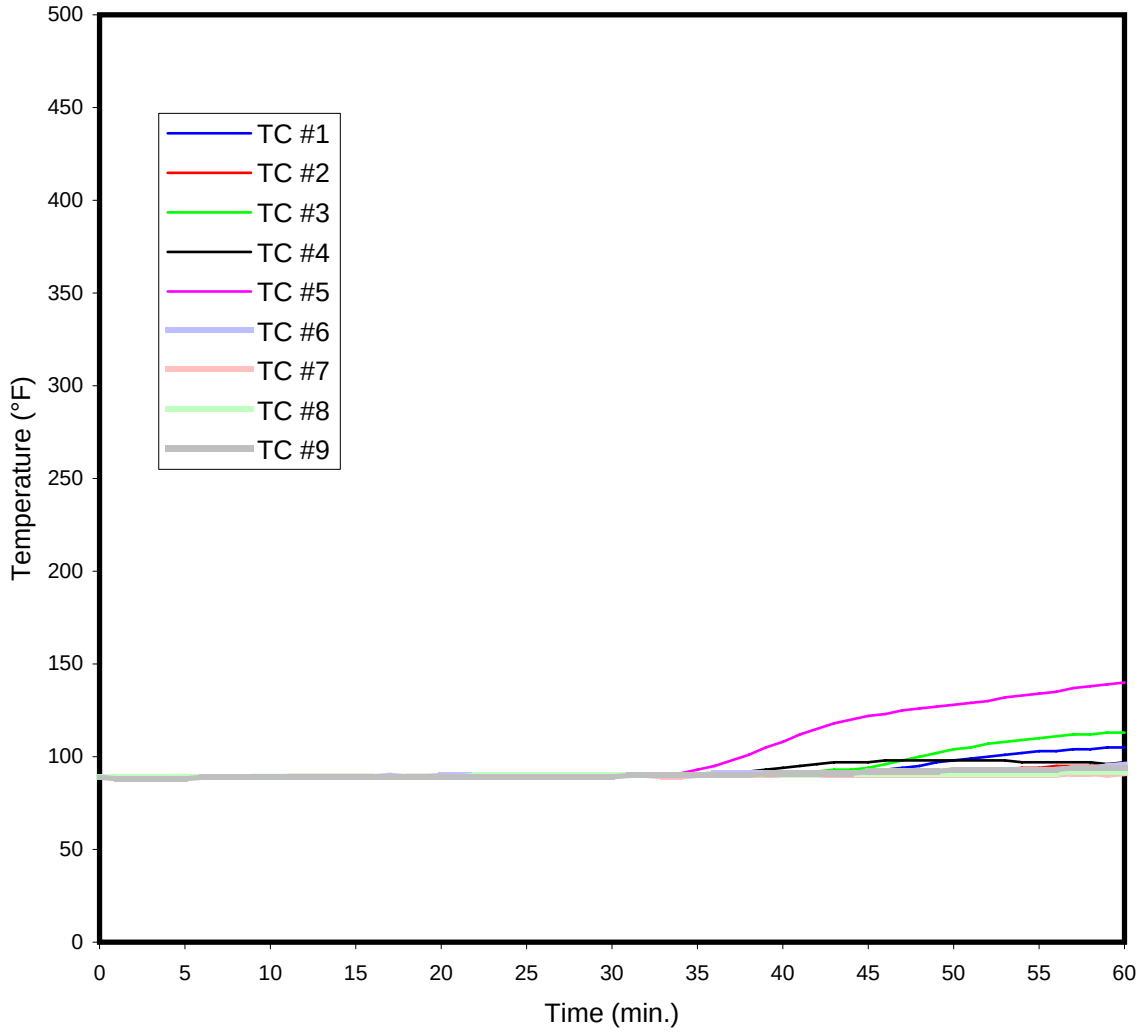
APPENDIX C

TEMPERATURE DATA

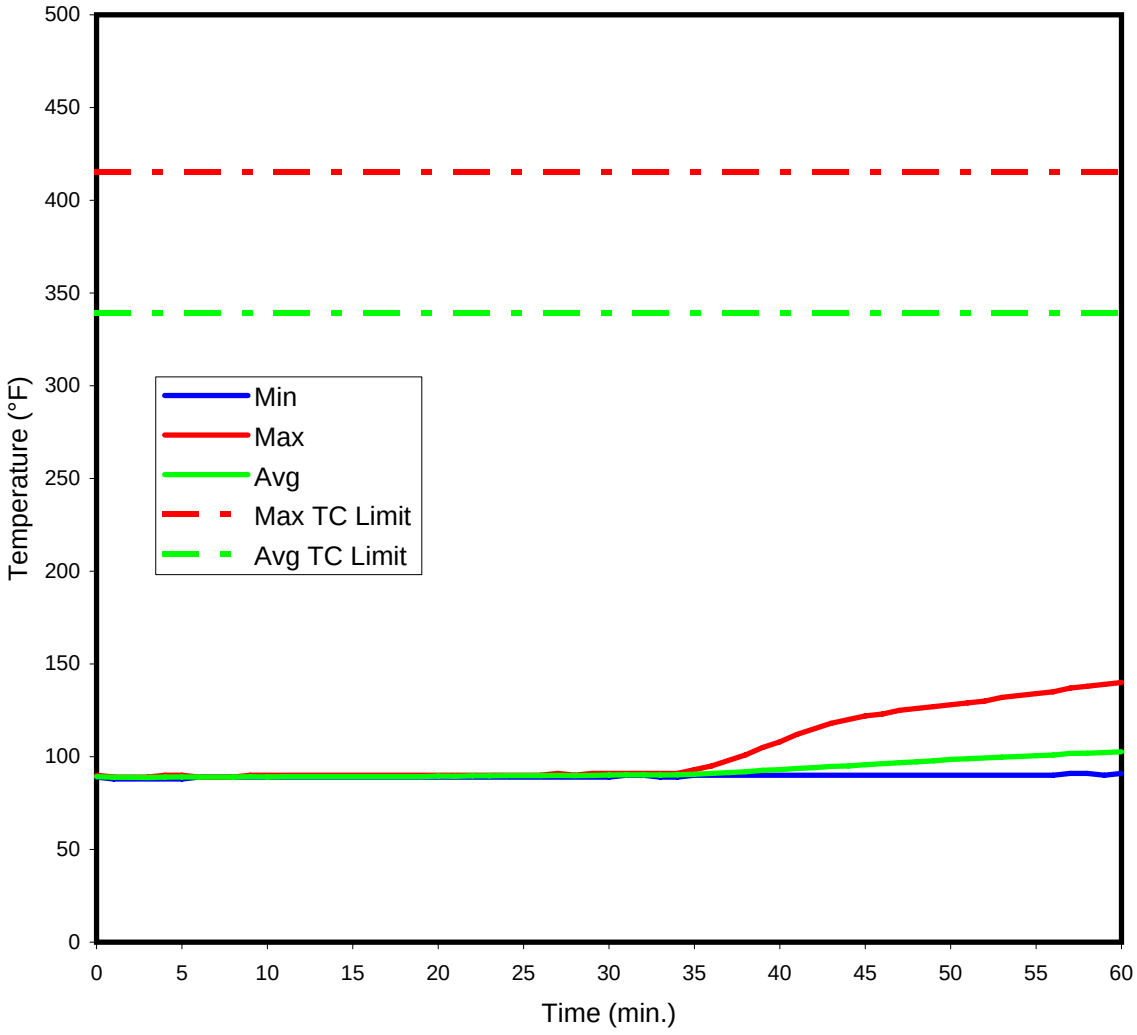
DCAT
Project No. 3098054B
Furnace Interior Temperatures



DCAT
Project No. 3098054B
Individual Cold Side Temperatures



DCAT
Project No. 3098054B
Min, Avg, Max Cold Side Temperatures



Time (min)	E119 Std Average (°F)	Furnace Average (°F)	Integration of Furnace Average (°F•min)	Integration of E119 Std Average (°F•min)	Error (%)	Furnace Probe #1 (°F)	Furnace Probe #2 (°F)	Furnace Probe #3 (°F)
0	68	88	0	0	0.00	88	88	87
1	254	123	38	93	-59.72	167	112	120
2	441	259	161	373	-56.87	339	225	233
3	627	428	436	839	-48.00	497	379	373
4	814	609	887	1491	-40.55	656	544	527
5	1000	778	1512	2330	-35.10	802	700	679
6	1060	922	2294	3292	-30.31	923	832	827
7	1120	1043	3209	4314	-25.62	1031	951	956
8	1180	1132	4228	5396	-21.65	1123	1060	1055
9	1240	1206	5329	6538	-18.50	1198	1153	1138
10	1300	1267	6497	7740	-16.06	1257	1228	1207
11	1328	1322	7723	8986	-14.05	1312	1293	1270
12	1347	1371	9002	10255	-12.22	1357	1346	1326
13	1364	1420	10329	11543	-10.51	1403	1392	1375
14	1381	1401	11672	12847	-9.15	1383	1382	1363
15	1396	1393	13001	14167	-8.23	1374	1375	1360
16	1410	1398	14328	15503	-7.57	1378	1376	1368
17	1424	1408	15663	16851	-7.05	1387	1383	1381
18	1436	1431	17015	18213	-6.58	1408	1402	1404
19	1448	1454	18390	19587	-6.11	1429	1423	1427
20	1459	1470	19784	20973	-5.67	1447	1440	1444
21	1470	1487	21194	22370	-5.25	1463	1457	1460
22	1480	1506	22623	23777	-4.85	1481	1477	1481
23	1490	1523	24069	25194	-4.47	1497	1494	1497
24	1499	1537	25531	26621	-4.09	1509	1510	1512
25	1508	1554	27008	28057	-3.74	1525	1525	1528
26	1517	1562	28498	29502	-3.40	1535	1537	1540
27	1525	1572	29997	30955	-3.09	1544	1548	1550
28	1533	1589	31510	32416	-2.80	1558	1564	1566
29	1541	1609	33041	33886	-2.49	1574	1580	1584
30	1549	1591	34573	35363	-2.23	1562	1571	1573
31	1556	1594	36098	36847	-2.03	1559	1567	1577
32	1563	1603	37628	38338	-1.85	1566	1573	1587
33	1570	1611	39167	39837	-1.68	1572	1580	1596
34	1576	1615	40713	41342	-1.52	1578	1586	1601
35	1583	1621	42263	42853	-1.38	1582	1590	1605
36	1589	1625	43818	44371	-1.25	1586	1595	1609
37	1595	1636	45380	45895	-1.12	1594	1603	1619
38	1601	1639	46950	47424	-1.00	1599	1608	1624
39	1606	1649	48526	48960	-0.89	1607	1615	1637
40	1612	1651	50108	50501	-0.78	1608	1616	1643
41	1617	1655	51693	52048	-0.68	1611	1618	1653
42	1623	1674	53290	53600	-0.58	1629	1631	1682
43	1628	1682	54900	55158	-0.47	1646	1640	1702
44	1633	1683	56514	56720	-0.36	1655	1642	1718
45	1638	1682	58129	58288	-0.27	1659	1643	1720
46	1643	1681	59743	59860	-0.20	1659	1642	1723

Time (min)	E119 Std Average (°F)	Furnace Average (°F)	Integration of Furnace Average (°F•min)	Integration of E119 Std Average (°F•min)	Error (%)	Furnace Probe #1 (°F)	Furnace Probe #2 (°F)	Furnace Probe #3 (°F)
47	1648	1682	61356	61437	-0.13	1662	1644	1727
48	1652	1685	62971	63019	-0.08	1668	1648	1729
49	1657	1694	64593	64606	-0.02	1678	1655	1749
50	1661	1703	66223	66197	0.04	1688	1664	1765
51	1666	1707	67860	67792	0.10	1695	1670	1772
52	1670	1708	69499	69392	0.16	1697	1672	1775
53	1674	1699	71135	70996	0.20	1689	1666	1768
54	1678	1695	72764	72604	0.22	1687	1662	1769
55	1682	1694	74390	74216	0.23	1685	1662	1767
56	1686	1697	76017	75832	0.24	1689	1664	1773
57	1690	1699	77647	77452	0.25	1690	1667	1776
58	1694	1702	79280	79076	0.26	1692	1669	1785
59	1698	1700	80913	80704	0.26	1690	1669	1778
60	1701	1703	82546	82336	0.26	1694	1672	1783

Max Temp
Max Allowed

Time (min)	Furnace Probe #4 (°F)	Furnace Probe #5 (°F)	Furnace Probe #6 (°F)	Furnace Probe #7 (°F)	Furnace Probe #8 (°F)	Furnace Probe #9 (°F)	Furnace Probe #10 (°F)	Furnace Probe #11 (°F)	Furnace Probe #12 (°F)
0	88	88	87	88	88	87	88	88	88
1	134	142	104	119	110	108	123	142	99
2	316	327	198	239	224	223	250	361	175
3	522	533	329	401	389	389	416	597	307
4	733	739	475	602	574	586	600	812	461
5	914	918	624	808	751	768	781	978	614
6	1068	1050	760	981	897	912	949	1105	762
7	1183	1157	890	1111	1023	1035	1074	1201	901
8	1242	1236	1002	1189	1126	1125	1155	1260	1008
9	1292	1301	1099	1250	1209	1201	1222	1313	1093
10	1340	1351	1179	1304	1276	1261	1280	1352	1164
11	1383	1397	1246	1352	1334	1319	1332	1394	1230
12	1429	1448	1304	1399	1381	1366	1368	1447	1286
13	1472	1483	1362	1443	1441	1399	1413	1493	1362
14	1438	1452	1353	1419	1429	1371	1398	1458	1369
15	1423	1432	1348	1407	1420	1360	1391	1449	1374
16	1426	1427	1355	1410	1424	1368	1398	1460	1387
17	1435	1431	1365	1420	1432	1379	1408	1475	1400
18	1457	1451	1389	1440	1454	1406	1434	1505	1426
19	1479	1473	1412	1461	1478	1425	1458	1527	1453
20	1495	1490	1430	1478	1494	1439	1476	1541	1471
21	1510	1505	1445	1493	1509	1463	1498	1556	1487
22	1530	1525	1463	1512	1527	1477	1516	1572	1506
23	1545	1541	1481	1527	1544	1496	1535	1594	1525
24	1557	1556	1493	1539	1558	1510	1551	1608	1540
25	1573	1571	1510	1556	1574	1529	1571	1627	1557
26	1583	1581	1522	1562	1585	1525	1572	1629	1571
27	1593	1592	1534	1571	1596	1534	1582	1637	1583
28	1609	1607	1547	1586	1612	1557	1603	1660	1601
29	1625	1624	1563	1603	1629	1592	1637	1681	1620
30	1602	1605	1554	1586	1616	1570	1615	1638	1605
31	1601	1601	1549	1587	1611	1592	1629	1645	1604
32	1610	1608	1554	1595	1617	1610	1646	1659	1613
33	1618	1616	1560	1603	1624	1621	1656	1667	1620
34	1622	1621	1566	1607	1630	1621	1656	1667	1628
35	1627	1626	1572	1610	1637	1628	1660	1679	1638
36	1630	1631	1578	1612	1641	1629	1659	1679	1645
37	1640	1641	1586	1621	1650	1653	1675	1695	1656
38	1644	1646	1592	1626	1654	1652	1675	1693	1660
39	1652	1653	1597	1635	1661	1679	1687	1702	1668
40	1653	1651	1597	1634	1661	1694	1688	1698	1670
41	1657	1651	1598	1638	1660	1716	1693	1695	1667
42	1683	1668	1604	1661	1668	1764	1724	1707	1667
43	1696	1676	1606	1671	1670	1783	1732	1701	1665
44	1702	1674	1602	1673	1665	1794	1725	1692	1655
45	1702	1672	1600	1672	1662	1798	1722	1687	1652
46	1700	1669	1598	1669	1660	1796	1717	1684	1649

Time (min)	Furnace Probe #4 (°F)	Furnace Probe #5 (°F)	Furnace Probe #6 (°F)	Furnace Probe #7 (°F)	Furnace Probe #8 (°F)	Furnace Probe #9 (°F)	Furnace Probe #10 (°F)	Furnace Probe #11 (°F)	Furnace Probe #12 (°F)
47	1703	1671	1599	1670	1661	1794	1716	1685	1649
48	1707	1675	1602	1672	1664	1798	1718	1688	1652
49	1720	1683	1606	1680	1669	1808	1725	1696	1656
50	1731	1692	1613	1687	1676	1814	1733	1703	1664
51	1737	1698	1619	1692	1681	1815	1735	1706	1667
52	1738	1699	1619	1691	1684	1816	1732	1704	1672
53	1722	1688	1615	1679	1678	1802	1719	1692	1669
54	1720	1684	1611	1674	1673	1794	1713	1687	1664
55	1719	1683	1610	1672	1672	1798	1709	1686	1663
56	1723	1686	1611	1675	1674	1801	1711	1690	1665
57	1724	1689	1613	1675	1677	1803	1713	1692	1669
58	1726	1691	1617	1677	1681	1804	1715	1695	1675
59	1723	1690	1617	1675	1681	1794	1712	1694	1677
60	1727	1694	1619	1678	1685	1790	1713	1697	1679

Max Temp
Max Allowed

Time (min)	Cold Side Min (°F)	Cold Side Avg (°F)	Cold Side Max (°F)	Cold Side TC #1 (°F)	Cold Side TC #2 (°F)	Cold Side TC #3 (°F)	Cold Side TC #4 (°F)	Cold Side TC #5 (°F)	Cold Side TC #6 (°F)	Cold Side TC #7 (°F)	Cold Side TC #8 (°F)	Cold Side TC #9 (°F)	Lab Ambient (°F)
0	89	89	90	89	90	90	89	89	89	89	89	89	87
1	88	89	89	89	89	89	89	89	89	89	89	88	87
2	88	89	89	89	89	89	89	89	89	89	89	88	87
3	88	89	89	89	89	89	89	89	89	88	89	88	87
4	88	89	90	89	89	90	89	89	89	89	89	88	88
5	88	89	90	89	90	90	89	89	89	89	89	88	88
6	89	89	89	89	89	89	89	89	89	89	89	89	88
7	89	89	89	89	89	89	89	89	89	89	89	89	88
8	89	89	89	89	89	89	89	89	89	89	89	89	88
9	89	89	90	89	90	90	89	89	89	89	89	89	89
10	89	89	90	89	89	90	89	89	89	89	89	89	89
11	89	89	90	89	90	90	89	89	89	89	89	89	89
12	89	89	90	89	90	90	89	89	89	89	89	89	88
13	89	89	90	89	90	90	89	89	89	89	89	89	89
14	89	89	90	89	90	90	89	89	89	89	89	89	88
15	89	89	90	89	90	90	89	89	89	89	89	89	88
16	89	89	90	89	90	90	89	89	89	89	89	89	89
17	89	89	90	89	89	90	89	89	90	89	89	89	89
18	89	89	90	89	90	90	89	89	89	89	89	89	90
19	89	89	90	89	90	90	89	89	89	89	89	89	90
20	89	90	90	90	90	90	89	90	90	89	89	89	91
21	89	89	90	89	90	90	89	90	90	89	89	89	90
22	89	90	90	90	90	90	89	90	90	89	90	89	90
23	89	90	90	90	90	90	89	90	90	89	90	89	90
24	89	90	90	90	90	90	90	90	90	89	90	89	90
25	89	90	90	90	90	90	90	90	90	89	90	89	89
26	89	90	90	90	90	90	90	90	90	89	90	89	91
27	89	90	91	90	91	90	90	90	90	89	90	89	91
28	89	90	90	90	90	90	90	90	90	89	90	89	91
29	89	90	91	90	91	90	90	90	90	89	90	89	91
30	89	90	91	90	91	91	90	90	90	90	90	89	92
31	90	90	91	90	91	91	90	90	90	90	90	90	92
32	90	90	91	90	91	91	90	90	90	90	90	90	91
33	89	90	91	90	91	91	90	90	90	89	90	90	90
34	89	90	91	90	91	91	90	91	90	89	90	90	91
35	90	91	93	90	91	91	90	93	90	90	90	90	91
36	90	91	95	90	91	91	91	95	91	90	90	90	91
37	90	91	98	90	91	91	92	98	91	90	90	90	91
38	90	92	101	91	91	91	92	101	91	90	90	90	91
39	90	93	105	91	91	91	93	105	91	90	91	91	90
40	90	93	108	91	91	91	94	108	91	90	90	91	89
41	90	94	112	91	91	92	95	112	91	90	90	91	89
42	90	94	115	91	91	92	96	115	91	90	90	91	90
43	90	95	118	91	91	93	97	118	91	90	91	91	90
44	90	95	120	91	91	93	97	120	91	90	91	91	91
45	90	96	122	92	92	94	97	122	91	90	91	92	92
46	90	96	123	93	92	96	98	123	91	90	91	92	91

Time (min)	Cold Side Min (°F)	Cold Side Avg (°F)	Cold Side Max (°F)	Cold Side TC #1 (°F)	Cold Side TC #2 (°F)	Cold Side TC #3 (°F)	Cold Side TC #4 (°F)	Cold Side TC #5 (°F)	Cold Side TC #6 (°F)	Cold Side TC #7 (°F)	Cold Side TC #8 (°F)	Cold Side TC #9 (°F)	Lab Ambient (°F)
47	90	97	125	94	92	98	98	125	91	90	91	92	91
48	90	97	126	95	92	100	98	126	91	90	91	92	91
49	90	98	127	97	92	102	98	127	91	90	91	92	92
50	90	99	128	98	93	104	98	128	92	90	91	93	91
51	90	99	129	99	93	105	98	129	92	90	91	93	91
52	90	99	130	100	93	107	98	130	92	90	91	93	91
53	90	100	132	101	93	108	98	132	92	90	91	93	90
54	90	100	133	102	94	109	97	133	92	90	91	93	91
55	90	101	134	103	94	110	97	134	93	90	91	93	91
56	90	101	135	103	95	111	97	135	93	90	91	93	91
57	91	102	137	104	95	112	97	137	94	91	92	94	91
58	91	102	138	104	95	112	97	138	94	91	92	94	92
59	90	102	139	105	96	113	96	139	95	90	92	94	91
60	91	103	140	105	96	113	97	140	96	91	92	94	91
Max Temp	91	103	140	105	96	113	98	140	96	91	92	94	
Max Allowed	414	339	415	414	415	415	414	414	414	414	414	414	

APPENDIX D

PHOTOGRAPHS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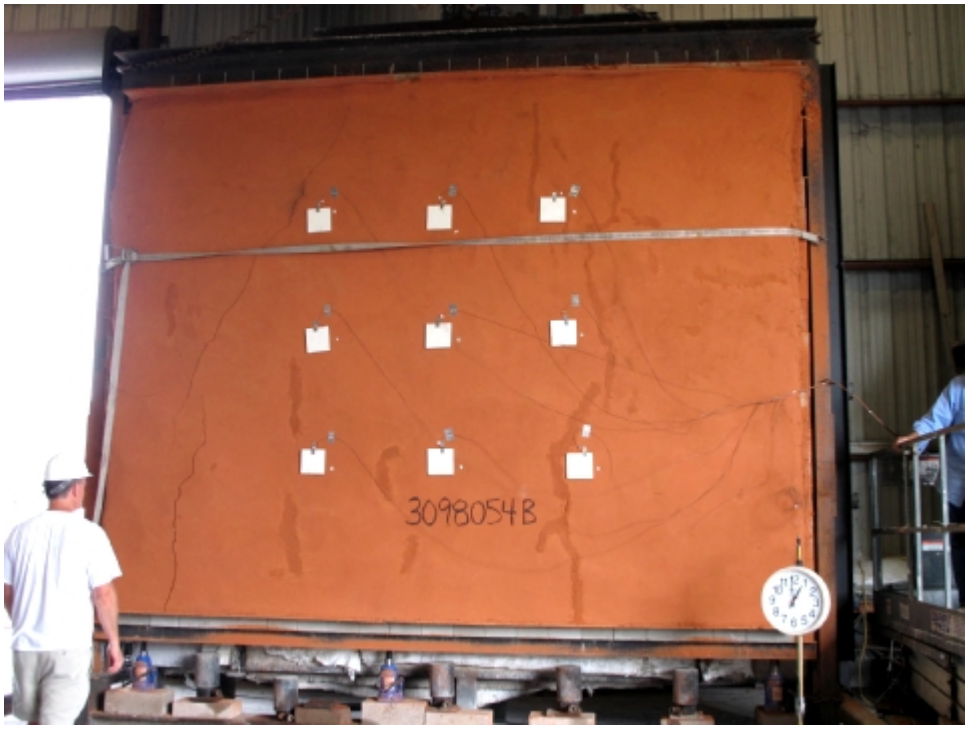
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APPENDIX E

ASTM C42 COMPRESSION RESULTS

LABORATORY TESTING REPORT

Engineering • Testing • Environmental • Facilities • Infrastructure

Raba Kistner

Raba Kistner Consultants, Inc.
12821 W. Golden Lane
P.O. Box 690287, San Antonio, TX 78269-0287
(210) 699-9090 • FAX (210) 699-6426
www.rkci.com

CLIENT: Intertek Testing
16015 Shady Falls Road
Elmendorf, Texas 78112-9784
Attn: Mr. Mike Dey

PROJECT: Testing Services (Intertek)

PROJECT NO.: ASD05-173-00
DATE RECEIVED: 06-30-06
SAMPLED BY: Client
DATE TESTED: 07-20-06
TESTED BY: C. Berger (R-K)
DATE REPORTED: 07-24-06

RE: Compressive Strength – Earthen Plaster & Straw Bale Clay

Earthen Plaster (Cast 06-22-06):			
Specimen No.	Area (sq.in.)	Load (lbs.)	Compressive Strength (psi)
1	36.04	10,940	300
2	36.12	10,260	280
		Average (28 days):	290

Straw Bale Clay (Cast 06-05-06):			
Specimen No.	Area (sq.in.)	Load (lbs.)	Compressive Strength (psi)
1	36.07	7,780	220
2	36.22	8,290	230
		Average (45 days):	225

COPIES TO: Above (1)

KENNETH W. MARQUARDT 23371 LICENSED PROFESSIONAL ENGINEER

RABA-KISTNER CONSULTANTS, INC.

BY: K.W. Marquardt 7/28/06

ASSIGNMENT NO.: S06-038017
/dgp 07-25-06

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