REPORT ON COMPARATIVE AIR LEAKAGE PERFORMANCE:
Knight Wall with Carlisle 705FR-A and Dow Styrofoam Ultra SL
Compared To
Z-Girts with Carlisle 705FR-A and Roxul CavityRock

PROJECT: Knight Wall and Z-Girt Air Leakage Evaluation

LOCATION: Sanford Contracting
1400 Iron Horse Park
North Billerica, Massachusetts

TEST DATE: March 28, 2017

PREPARED FOR: PACE Representatives Inc.
One Rockdale Street, Suite 200
Braintree, MA 02184

SUBMITTED BY:

Edward Mannix
Vice President of Operations

BUILDING ENCLOSURE
ASSOCIATES, LLC

Charlestown Navy Yard
31 Fifth Street, Boston, MA 02129
Tel: (617) 520 9555
Fax: (617) 520 9554
BuildingEnclosureAssociates.com

REPORT DATE: April 5, 2017

PROJECT NUMBER: 31855

DOCUMENT CONTROL NO.: R9.1.12.08.13

INTRODUCTION

Building Enclosure Associates LLC (BEA) was retained by Pace Representatives to evaluate the air leakage rate differences between Knight Wall System's HCI System and a typical Z-Girt wall assembly. The specific objective of the mockup design and testing was to determine whether Knight Wall's increased the number of screw penetrations and fasten through the rigid insulation and AVB would result in a measurable increase in the air leakage. Pace Representatives, BEA and Sanford Contracting collaborated on the design of a mockup wall assembly and testing protocol that could provide accurate comparative performances.

As a secondary priority, Pace also requested that a thermal review be performed of the fully assembled wall mockup using infra-red imaging.

This report documents the construction of the wall assemblies tested along with the results of the air infiltration and thermal performance tests performed by BEA and witnessed by the following personnel:

Thomas Sanford	Sanford Contracting Inc.
Christopher Armstrong	PACE Representatives
Ed Mannix	BEA
Russell Young	BEA
Eric Illich	BEA

PURPOSE OF TESTING

The intent of the testing program was to evaluate the difference in the air infiltration rate and thermal performance of Knight Wall System's HCI System and a typical Z-Girt wall assembly.

PERFORMANCE SPECIFICATIONS

Air Infiltration Criteria:

Since project specific criteria were not stated for this testing: BEA tested at 1.57 psf, the most common pressure differential for testing air leakage in air barriers, wall assembles and building envelopes. Air infiltration rate was measured continuously throughout the construction of the exterior wall systems in accordance with an adaptation of the ASTM E 2357 testing procedure.

TEST DESCRIPTION:

Apparatus

Tests were conducted using a portable test unit consisting of a regulated vacuum blower, a digital flow meter and digital manometer all connected to the mockup wall assembly. Calibration of all measurement equipment maintained with National Institute of Standards and Technology (NIST) traceability. Additionally, two remote thermometers were utilized throughout the testing to record variations in temperature and humidity inside and outside the test chamber.

Pressure Measuring Apparatus: Dwyer Series 475 Mark III digital manometer with an accuracy of ±0.5% F.S.

Air Flow Metering System: Digital air flow meter with the range of 0.00035 cfm to 7.06 cfm and an accuracy ±2% of reading (or ±0.002 cfm if greater) and resolution of 0.0000353 cfm. This test was the first use of the air flow meter since its calibration at an NIST lab on February 10, 2017.

Thermal Imaging: A FLIR T620 Thermal Imaging Camera with an accuracy of ±2% within the working temperature range and calibrated to the International Temperature Scale (ITS-90) at the SP Technical Research Institute of Sweden was used to obtain thermal images and record surface temperatures on the inboard side of the mockup assembly. Two wireless thermometers were used to document the air temperature on the exterior side (inside thermal chamber) of the mockup assembly during the thermal performance testing.

<u>Test Methods</u>
Unless noted otherwise testing was performed in accordance with the following specifications and methods.

Air Infiltration - ASTM E 2357
"Standard Test Method for Determining Air Leakage of Air Barrier Assemblies"
The ASTM E2357 test *"method is intended to simulate the performance of various air barrier materials/accessories when combined into an assembly. Based on the results of the measurements, this procedure then assigns an air leakage rating for the air barrier assembly."*

This test method was modified to measure the air infiltration rate difference between the installation of Knight Wall System's brackets and a traditional Z-Girt system. To eliminate and\or minimize the potential influence of extraneous factors a single mockup wall assembly was utilized to measure both conditions and the tests were run contiguously to mitigated environmental variations. Multiple air flow measurements were made of the wall assembly before securing any portions of the exterior wall assembly and again after installing the exterior wall assemblies. For control purposes, four 3/16" holes were drilled in the inboard side of the mockup assembly and then sealed with tape. Multiple measurements were taken with the holes sealed and unsealed prior to any other measurements being taken and again after all other testing had been completed. The before and after measurements of the control holes provided assurance that extraneous factors did not influence the test results.

The air flow rate measured prior to beginning the testing is considered to be from extraneous sources. This measurement served as the baseline from which the change in air flow rate was measured. The baseline air flow is subtracted from the flow rate measurement taken upon completion of the first specimen to determine the net increase in air flow from the construction of the specimen. The total air flow rate after completion of the first specimen also serves as the baseline for determining the net increase in air flow rate of the second specimen.

To increase the statistical significance of the evaluation, the sampling rate was increased by decreasing the stud spacing to half the typical distance of 16" on center. This effectively doubled the number of penetrations per square foot over a typical wall construction.

Thermal Evaluation

In order to compare the relative thermal behavior of the two systems the following protocol was utilized:

- After completion of the air infiltration measurement, the interior side of the mockup wall assembly was removed and the studs and inboard side of the sheathing exposed.
- On the exterior side of the wall, an enclosure was constructed of DOW Styrofoam insulation panels to form a thermal chamber. The Styrofoam panels were secured to the top and ends of the mockup assembly and an insulated panel was placed on the concrete floor at the base of the wall. The thermal chamber had a depth of approximately three feet off the face of the mockup wall.
- Remote thermal sensors were placed on the face of the cladding (approximately 4' off the floor) in the middle of each of the two wall systems.
- Liquid Nitrogen was introduced through the top of the thermal chamber at the mid-point between the two systems being evaluated.
- The temperature inside the chamber was lowered to approximately 70^{o} F (seventy) below the ambient room temperature and maintained throughout the testing.
- Temperature readings were taken on the inboard side of the specimens throughout the test at the same three spots along the vertical centerline of each system. Temperature sampling locations were between the girt and screw locations to avoid the spots subjected to the most severe thermal influence.

SITE CONDITIONS

Indoor - *Tests performed inside Sanford Contracting's fabrication facility*

Temperature: 56 °F

Relative Humidity: 50 - 60%

TEST SPECIMEN DESCRIPTION

A mockup wall assembly was constructed by Sanford Contracting to the following design specifications:

Framing and Sheathing

- Dimensions: Height: 8', Width: 16'
- 128 Square Feet
- 16 gauge 2" X 6" perimeter panel frame
- 16 gauge 2" X 6" vertical steel stud framing spaced 8" O.C
- ½" DensGlass sheathing secured to steel stud framing using ¼" X 2" self-tapping screws spaced approximately 1' O.C. DensGlass was installed on both interior and exterior side of metal studs.
- Carlisle 705FR-A Fire Resistant Air and Vapor Barrier applied to exterior side of mockup wall
- For the purpose of measuring air flow, the inboard side of the wall assembly was enclosed in DensGlass covered with Carlisle CCW–705 Air and Vapor Barrier. The sides, top and bottom of the wall assembly were also sealed to create an air tight unit.

Knight Wall System HCI System

The following Knight Wall System was constructed on the left (from exterior) half of the mockup wall assembly.

- 18 gauge Horizontal HCI-GIRT vertically spaced 12" O.C., Top HCI GIRT spaced 16" O.C.
- Every other HCI-GIRT fastened with 2 fasteners, 8" O.C. Other HCI-Girt fastened with 2 fasteners, 16" O.C. Self-tapping fasteners installed with ThermaStop thermal insulating washer.
- 3" Dow Styrofoam Ultra SL Insulation

Z-Girt System

The following Z-Girt system was constructed on the right (from exterior) half of the mockup wall assembly.

- 16 gauge Horizontal Z-Girt spaced 12" O.C., Top Z-Girt spaced 16" O.C.
- Every other Z-Girt fastened with one ¼" x 2" self-tapping fastener spaced 8" O.C. Other Z-Girts fastener spacing is 16"O.C.
- ⅛" plastic shim placed between Z-girt and AVB at each fastener location.
- 4" Roxul CavityRock mineral fiber insulation
- Dow Corning 790 silicone sealant over fastener heads

Exterior Cladding (applied to both halves of the mockup wall assembly)

- Rieder Oko Skin 5.79" x 70.87" x ½" with 1/8" space between boards. Cladding installed vertically.
- 14 total boards installed on each system.
- Exterior cladding only fastened to girts where fastener spacing is 16" O.C.

TEST RESULTS

Air Infiltration tests
ASTM E 2357 at a negative pressure differential of 1.57 psf
(Minimum of five readings taken at each stage)

Net CFM Change from wall construction

Specimen	Fastener Penetrations Includes 2 missed screws In each specimen	cfm @ 1.57 Resulting from assembly
Knight Wall HCI System	138	0.0071
Z-Girt system	70	0.0064

Total CFM Measurements at 1.57 PSF Pressure Differential

Test Stage	Before Installation of Exterior Wall Assemblies	After Installation of Exterior Wall Assemblies
a) Control hole: #1 unsealed	0.3765	0.3909
b) Control holes: #1 & #2 unsealed	0.4686	0.4866
c) Control holes: #1, 2 & 3 unsealed	0.5594	0.5686
d) Control holes: #1, 2, 3 & 4 unsealed	0.6353	0.6491
e) Total chamber with control holes sealed:	0.2942	0.3077
f) Total with Z-Girt half of wall installed:	0.2942	0.3006
g) Total with Knight Wall installed:	0.3006	0.3077

Thermal Tests

Temperature readings in degrees Fahrenheit taken from inboard side of sheathing at end of 2.5 hour test		
Temperature Reading Location	Z-girt system	Knight Wall HCI System
Ambient Room Temperature	56.0	56.0
Interior Chamber, on cladding @ 4 feet from floor	-12.0	-12.0
Inboard side of sheathing @ 1½ feet from floor	39.9	48.8
Inboard side of sheathing @ 4 feet from floor	50.2	52.5
Inboard side of sheathing @ 7 feet from floor	50.7	53.4

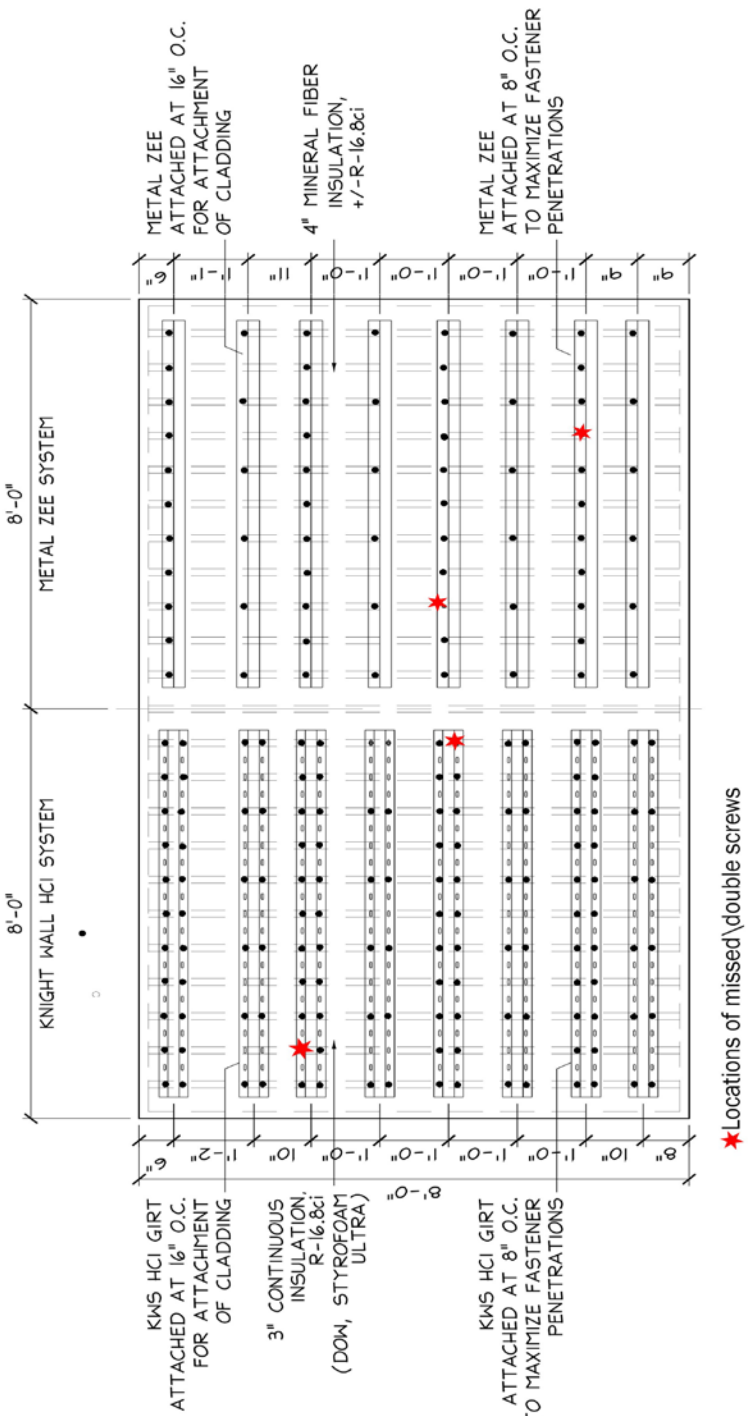
The readings listed above were taken on the inboard side of the mockup during the thermal test and the sample locations deliberately avoided the coldest spots at the screw penetrations. Readings were taken at the midpoint between the studs and the midpoints between the screws. The readings listed above with taken with a laser thermometer from approximately two feet off the surface off the inboard surface of the wall to limit the size of the area being sampled. Random readings taken of broader areas from further off the wall indicated that the Knight Wall half of the mockup was between 2 to 6 degrees warmer overall than the Z-girt side.

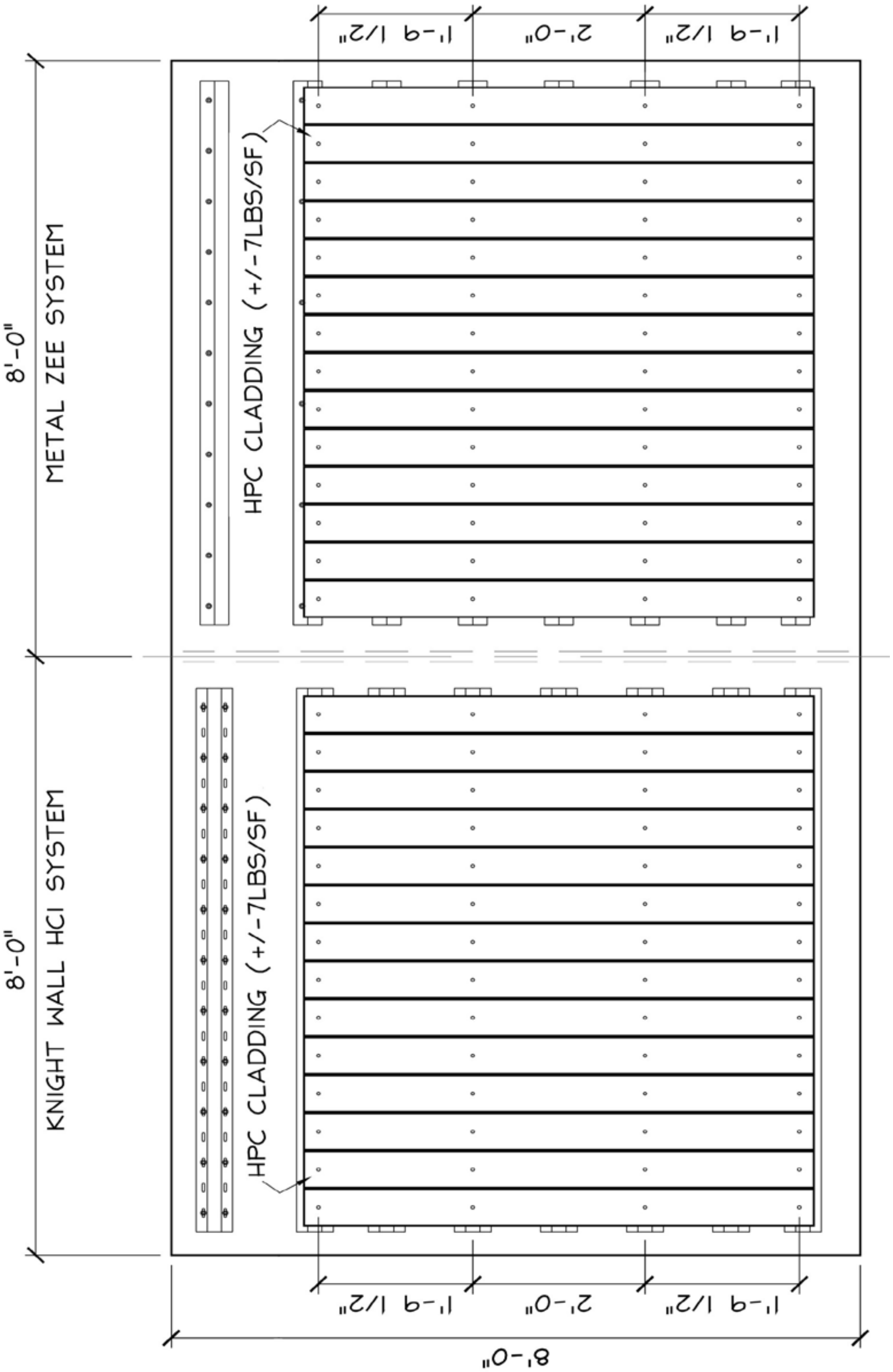
Cold transfer began to appear on the Z-Girt half of the mockup wall approximately 30 minutes into the thermal test. The infrared images revealed horizontal lines at the locations of the z-girts. As the testing progressed the images became more defined and the outline of the 1/8"plastic pads used as thermal isolators became apparent. Although the spacers set the z-girts a 1/8" off the face of the wall, the transfer of cold through the DensGlass was clearly visible.

The thermal images on the Knight Wall half of the mockup were considerably less dramatic and the thermal image appeared relatively uniform when viewing the entire wall at once. In close up views, cooler areas were observed along the edges of the studs at the screw penetration locations. The cooler locations along the studs began to appear approximately an hour and a half into the test. The most pronounced cool spots on the Knight Wall half were at the two screw "misses" (double screws).

After approximately one and half hours, the expansion of the cooler locations seemed to subside. The supply of liquid nitrogen was exhausted after two and half hours of testing and the testing was terminated at that time. We did not observe an appreciable change in the thermal image during the final hour of the test.

APPENDIX A
MOCKUP DESIGN


METAL ZEE ATTACHED AT 16" O.C. FOR ATTACHMENT OF CLADDING
4" MINERAL FIBER INSULATION, +/-R-16.8ci
METAL ZEE ATTACHED AT 8" O.C. TO MAXIMIZE FASTENER PENETRATIONS
8'-0"
METAL ZEE SYSTEM
8'-0"
KNIGHT WALL HCI SYSTEM
KWS HCI GIRT ATTACHED AT 16" O.C. FOR ATTACHMENT OF CLADDING
3" CONTINUOUS INSULATION, R-16.8ci (DOW, STYROFOAM ULTRA)
8'-0"
KWS HCI GIRT ATTACHED AT 8" O.C. TO MAXIMIZE FASTENER PENETRATIONS
Locations of missed\double screws


1'-9 1/2"
2'-0"
1'-9 1/2"
8'-0"
METAL ZEE SYSTEM
HPC CLADDING (+/-7LBS/SF)
8'-0"
KNIGHT WALL HCI SYSTEM
HPC CLADDING (+/-7LBS/SF)
1'-9 1/2"
2'-0"
1'-9 1/2"
8'-0"

APPENDIX B
PROJECT PHOTOGRAPHS

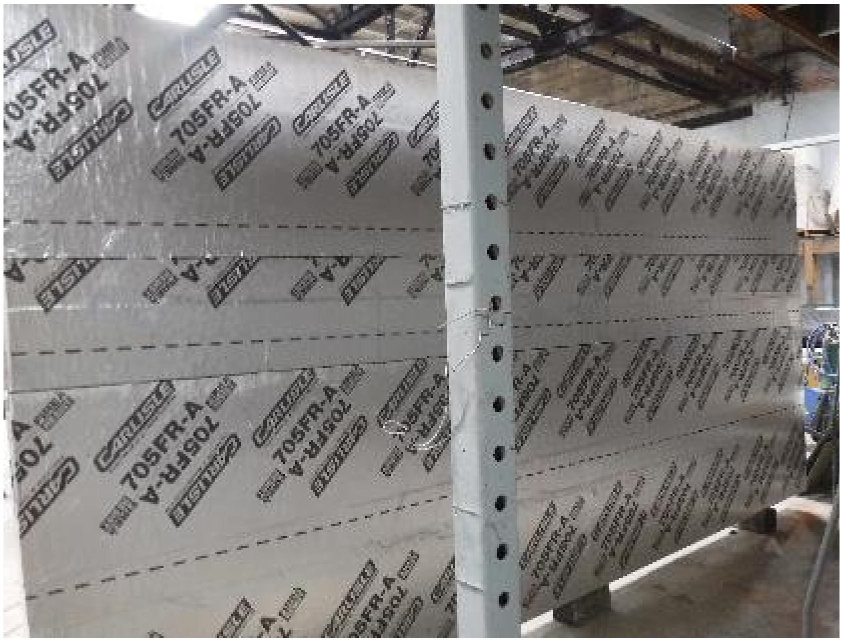
Photograph No. 1

Air Infiltration Chamber

Backside of Mockup wall with Carlisle CCW-705 AVB.

Photograph No. 2

Air Infiltration test apparatus installed



Photograph No. 3

Front side of mockup with Carlisle 705FR-A AVB prior to installation of Z-Girt or Knight Wall system.

Photograph No. 4

Z-Girts being installed on right (from exterior) half of mockup assembly

Photograph No. 5

Z-Girt installation

Thermally isolations spacers behind each fastener.

Missed stud resulting in second penetration

Photograph No. 6

Z-Girt Installation

Sealant being applied over all fasteners

Photograph No. 7

Z-Girt Installation

4” mineral fiber insulation installed to z-girts

Photograph No. 8

Knight Wall Installation

3” rigid Dow insulation placement for Knight Wall System

Photograph No. 9

Knight Wall Installation

HCI-GIRTs being installed

Photograph No. 10

Knight Wall Installation

Fastener placement.

16" O.C.

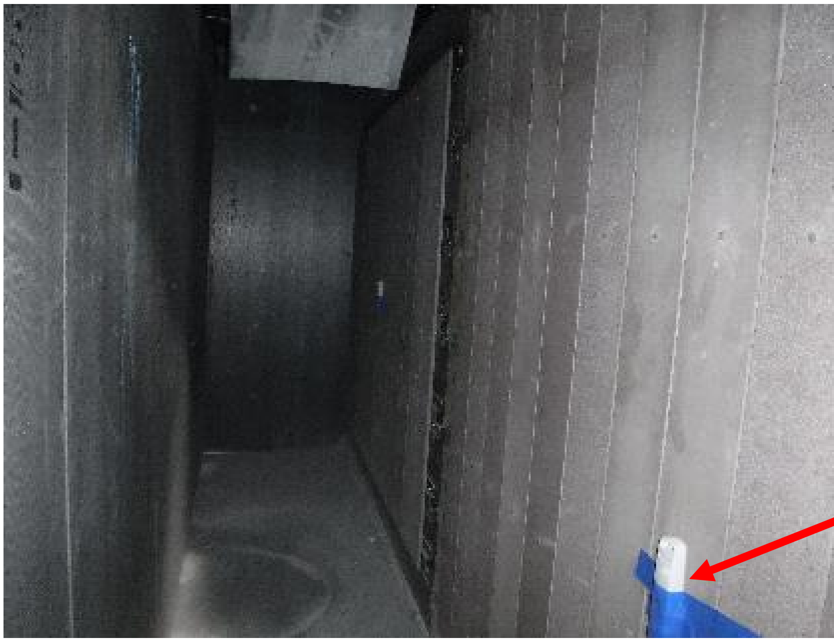
8" O.C

Photograph No. 11

Cladding installed to both Z-Girt and Knight Wall System

Photograph No. 12

Densglass removed from back (interior) side of mockup wall to expose studs and inboard side of sheathing.



Photograph No. 13

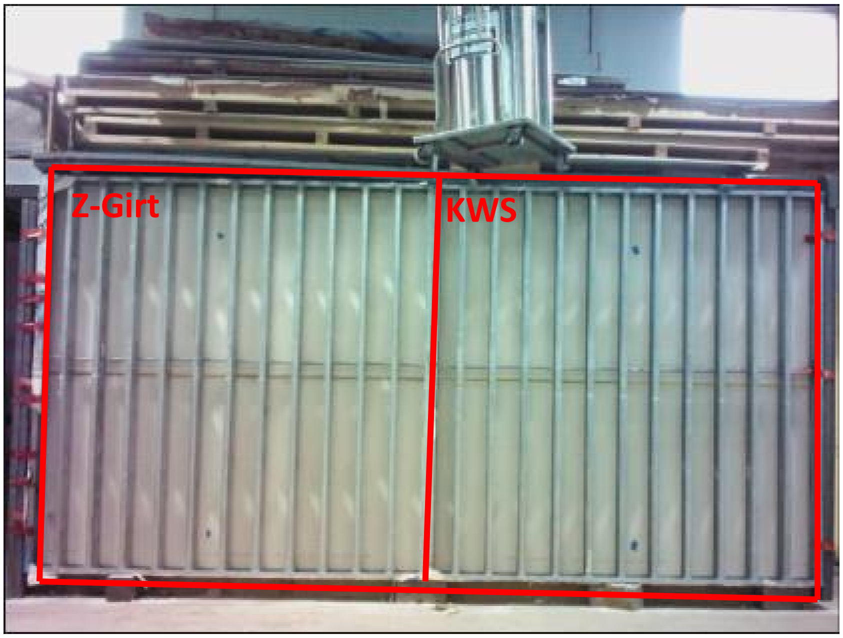
Interior of thermal chamber

Mockup wall to right of photo

Remote thermometer

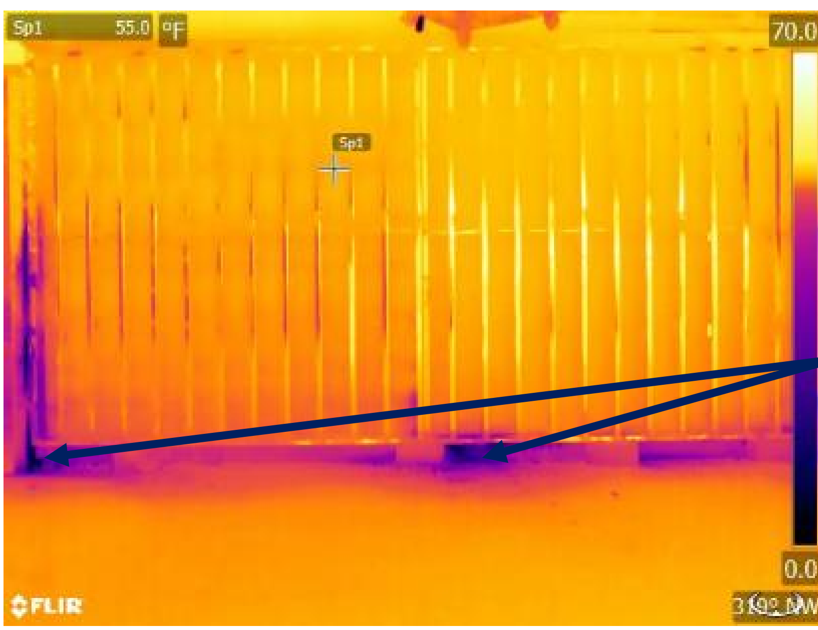
Photograph No. 14

Liquid Nitrogen Tank above thermal chamber



Photograph No. 15

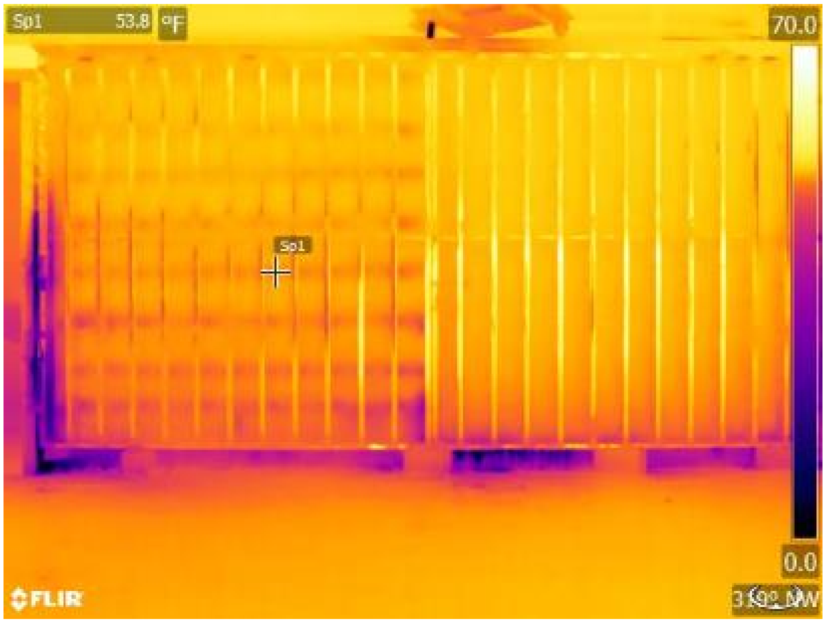
Mockup wall. Z-Girt system on left. Knight Wall System (KWS) on right



Photograph No. 16

Temperature distribution approximately 5 minutes into test. Inboard side of sheathing is fairly uniform at 55°F

Dark areas below mock up wall indicate locations of cold air escaping chamber.

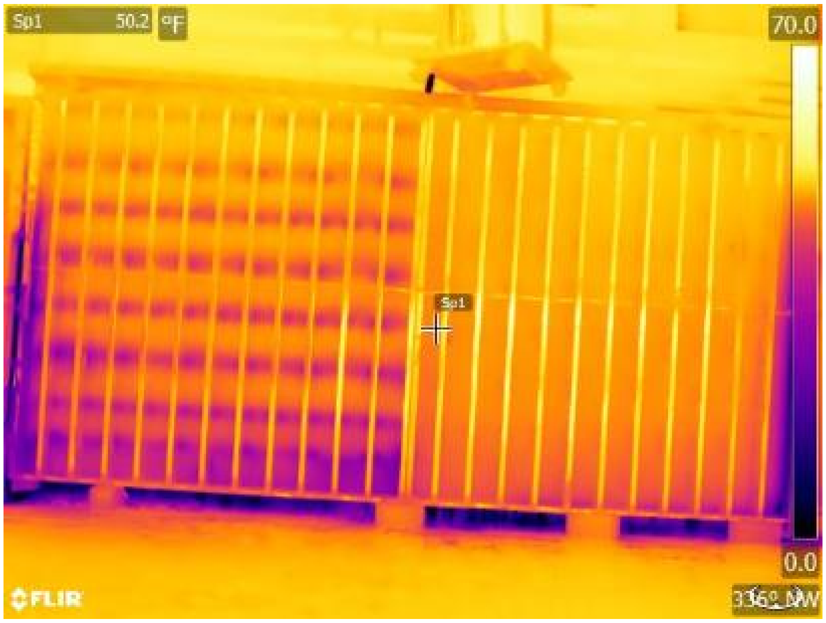


Photograph No. 17

Approximately 30 minutes into test, thermal imaging revealed transfer of cold from Z-Girt beginning to appear.

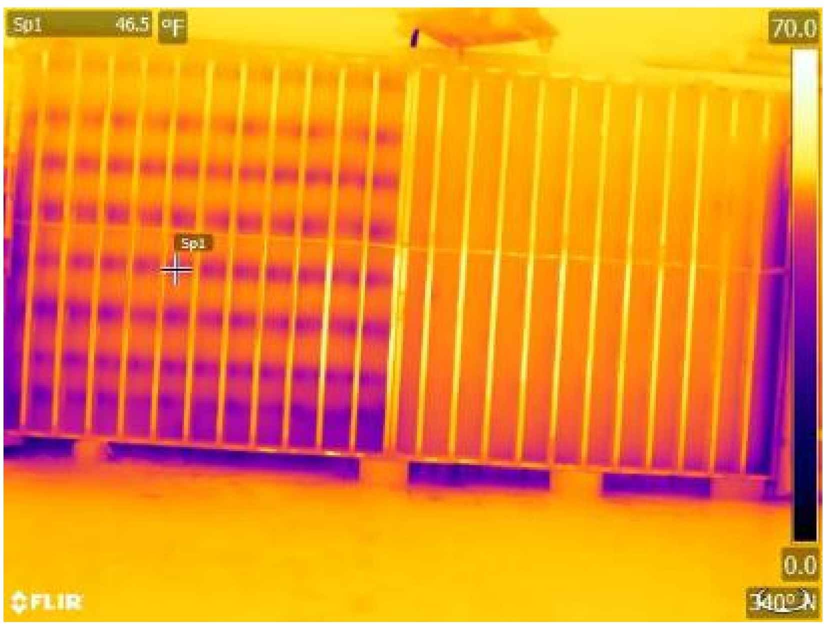
Photograph No. 18

Approximately 1 hour into test, thermal imaging began to clearly indicate location of thermal isolation pads used on the Z-Girt system.



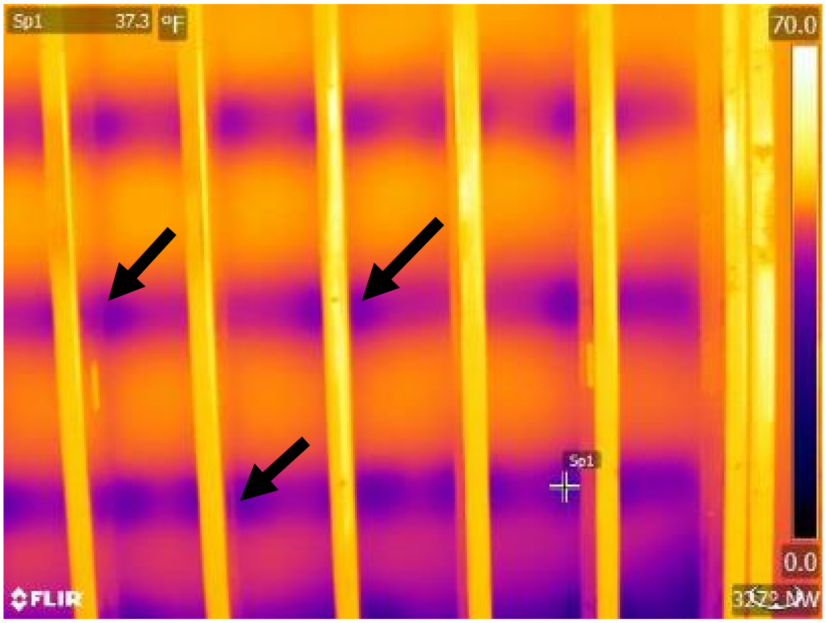
Photograph No. 19

Approximately 1.5 hours into test.



Photograph No. 20

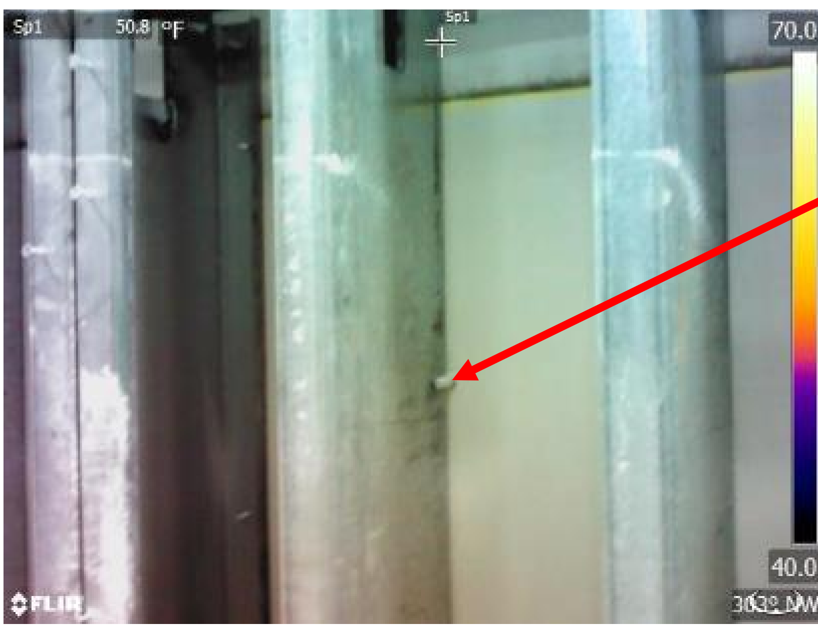
Approximately 2.5 hours into test. No obvious change observed in last hour of test.



Photograph No. 21

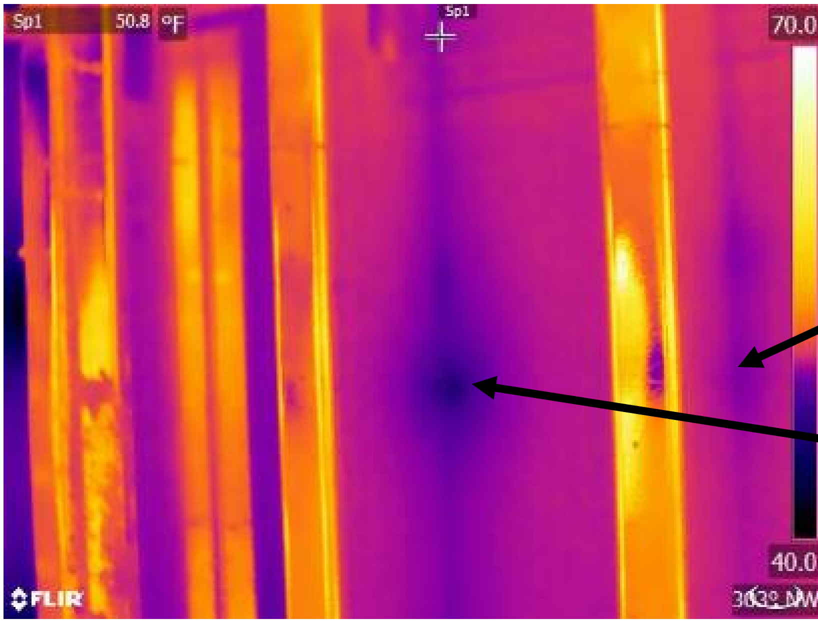
Close up of Z-Girt section of mockup wall.

Darker locations along the horizontal lines are the location of the thermal spacer. This was verified by the screw penetrations at these locations.



Photograph No. 22

Close up of missed stud penetration in Knight Wall System.

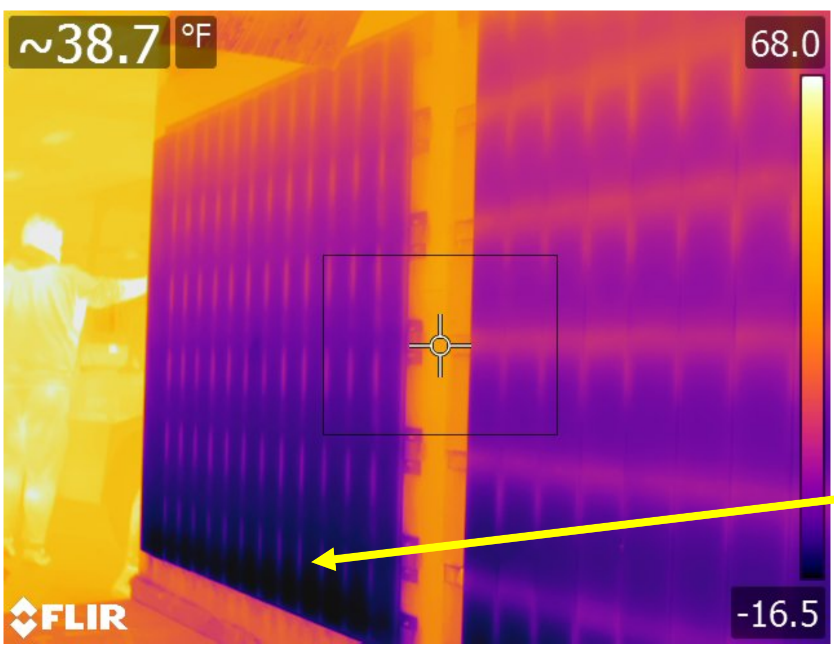


Photograph No. 23

Knight Wall system. Thermal transfer was considerably less noticeable on the Knight Wall half of the mockup. Cool areas were observed at fastener locations at the stud

Missed screw

Bright yellow areas along edge of studs is reflection of heat sources in room such as people.



Photograph No. 24

Exterior side of mockup wall after opening the thermal test chamber following the test.

Z-Girt half of wall to right of image and Knight wall to left of image.

Extreme cold at base of wall