AECOM

New England Transportation Consortium (NETC)

NETC 20-3

Investigating Thermal Imaging Technologies and Unmanned Aerial Vehicles to Improve Bridge Inspections

Task 2 Interim Report

Field Demonstration and Data Analysis

2/11/2022

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- John “Sam” Maxim, Maine Department of Transportation (Technical Committee Chair)
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16. Abstract
The overall research objective is to focus on developing UAV-based inspection and analysis protocols using infrared (IR) thermal imaging to determine the existence and extent of concrete delamination, with emphasis on the underside of bridge decks.

The second task of this research project includes field testing of handheld and UAV mounted thermal cameras in comparison to traditional inspection methods. The field testing was performed at five bridge sites in Massachusetts and Rhode Island. Handheld thermal cameras tested include the Flir E96, Flir E86, Flir E8, Flir C5, Seek Shot Pro, and Fluke TiX580. Drone mounted thermal cameras include the DJI Matrice 210 with Zenmuse XT2, DJI Matrice 300 with Zenmuse XT2, Parrot Anafi USA, and Skydio X2.

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SI* (MODERN METRIC) CONVERSION FACTORS				
APPROXIMATE CONVERSIONS TO SI UNITS				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yard	0.765	cubic meters	m^3
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short ton (2000 lb)	0.907	megagrams ("metric ton")	Mg ("t")
		TEMPERATURE (EXACT DEGREES)		
°F	Fahrenheit	5 (F-32) / 9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE AND PRESSURE OR STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPA
APPROXIMATE CONVERSIONS FROM SI UNITS				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yard	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yard	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg ("t")	megagrams ("metric ton")	1.103	short ton (2000 lb)	T
		TEMPERATURE (EXACT DEGREES)		
°C	Celsius	1.8C + 32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE AND PRESSURE OR STRESS		
N	newtons	0.225	poundforce	lbf
kPA	kilopascals	0.145	poundforce per square inch	lbf/in^2

* SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380

(Revised March 2003)

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LIST OF ABBREVIATIONS

Avg = Average
BIN = Bridge Identification Number
CS = Condition State
Delam = Delamination
DOT = Department of Transportation
EMI = Electromagnetic Interference
FAA = Federal Aviation Administration
FOV = Field of View
Hr = Hour
HSA = Hollow Sounding Area
Hz = Hertz
IR = Infrared
Lb = Pound
LF = Linear Feet
LWIR = Long Wave Infrared
MassDOT = Massachusetts Department of Transportation
mK = milliKelvin
mm = millimeter
MP = Megapixels
mph = Miles per hour
MSX – Multi-Spectral Dynamic Imaging
n/a = Not applicable
NBE = National Bridge Element
NETC = New England Transportation Consortium
NBIS = National Bridge Inspection Standards
NDE = Non-destructive Evaluation
RGB = Red, Green, Blue
SF = Square Feet
Temp = Temperature
UAV = Unmanned Aerial Vehicle
UAS = Unmanned Aircraft System

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Introduction

This report was developed as part of New England Transportation Consortium (NETC) research project 20-3 Investigating Thermal Imaging Technologies and Unmanned Aerial Vehicles (UAV) to Improve Bridge Inspections. The overall research objective is to focus on developing UAV-based inspection and analysis protocols using infrared (IR) thermal imaging to determine the existence and extent of concrete delamination, with emphasis on the underside of bridge decks.

Task 2 for this research project includes field demonstration of commercially available handheld long wave infrared (LWIR) thermal cameras and drone technologies recommended as part of the Task 1 Interim Report dated 6/4/2021. The handheld thermal camera equipment included as part of Task 2 included the Flir E96, Flir E86, Flir E8, Flir C5, Fluke TiX580, and Seek Shot Pro. The drones included the Parrot Anafi USA, Skydio X2, DJI Matrice 210 V2 with Zenmuse XT2, and DJI Matrice 300 with Zenmuse XT2. The field testing of these technologies was performed at five bridge sites located in Massachusetts and Rhode Island. The specific methodologies varied per bridge and will be discussed later in this report. Guidance is provided in thermal image processing and analysis for defect identification and validation based on test results at five bridges. The intent was to determine the effectiveness of potential implementation methods without the need for specialized staff or software to perform the analysis.

General Discussion of Handheld Thermal Cameras

Several models of handheld thermal cameras were utilized for this research project. This section will discuss several of the traits and characteristics of the cameras that were utilized. The discussion is limited to the use of the cameras and does not include discussion on the specific field-testing sites and associated data of this research project. The data analysis will be discussed later in this report.

Flir E96 and E86

The Flir E96 and E86 are handheld pistol grip style thermal cameras (Figure 1). These cameras are very similar with only minor differences in sensor resolution between the two Table 1 provides specifications and Table 2 provides observations made during field testing.

Figure 1 – Views of Flir E96 Thermal Camera (Flir E86 Similar)

Both thermal cameras utilize different interchangeable lenses in 24-degree (17-millimeter (mm)), 42-degree (10 mm), and 14-degree (29 mm) fields of view (FOV). For this research project, the Flir E96 was outfitted with the 42-degree (10 mm) lens and the Flir E86 was outfitting with the 24-degree (17 mm) lens.

Table 1 - Flir E96 and E86 Specifications

Attributes	Flir E96	Flir E86
Cost*	$12,239	$11,219.00
Thermal Resolution (pixels)	640x480	464x348
RGB Resolution (MP)	5 MP	5 MP
FOV (degrees)	Variable (42°, 24°, or 14°)	Variable (42°, 24°, or 14°)
Frame Rate (Hz)	30	30
Thermal Sensitivity (mK)	<30 mK	<30 mK

** Cost based on purchase of the camera with the 42° lens as of 12/8/21. The cost does not include additional lenses or accessories.*

Table 2 - Flir E96 and E86 Observations

Flir E96 and E86 Observations	
Positive	**Negative**
Best thermal resolution and quality	Higher cost than other tested models
Swappable lenses allow flexibility to choose best field of view based on bridge height	Additional lenses cost extra
Touch screen and manual tactile controls allow for easy modification of settings	Swapping lenses in field can result in dirt/debris entering sensor and degrading image quality
1-Touch Level/Span allows automatic adjustment of level to provide best possible data by touching the screen	Size of camera means that it would not be able to be used simultaneously with other inspection tasks
Pistol-grip allows for one handed operation	Camera can get heavy for extended periods
Laser distance measure helps improve focus of images and can be used to verify what is being viewed since the red dot is visible	
Laser distance measure allows better data quality capture during night and low light conditions	
Swappable batteries allow for extended use	
R_JPEG (editable radiometric jpeg) files are viewable by standard computer software	

Note that the positive and negative observations included in Table 2, and similar tables later in this report, are not intended to be direct comparisons to each other but are intended to simply be a list of observations.

Flir E8

The Flir E8 is a handheld pistol grip style thermal camera (Figure 2). It should be noted that the Flir E8 has been discontinued and is no longer available for purchase. The Flir E8-XT is the replacement model and has similar specifications. Per the equipment vendor, the E8-XT can detect a higher temperature range than the E8 but otherwise is similar. Table 3 provides specifications and Table 4 provides observations made during field testing.

Figure 2 – Views of Flir E8 Thermal Camera

Table 3 - Flir E8-XT Specifications

Attributes	Flir E8-XT
Cost*	$3,059.99
Thermal Resolution (pixels)	320x240
RGB Resolution (pixels)	640x480
FOV (degrees)	45°x34°
Frame Rate (Hz)	9
Thermal Sensitivity (mK)	<50 mK

** Cost based on purchase of the camera as of 12/8/21. The cost does not include additional accessories.*

Table 4 - Flir E8 Observations

Flir E8 Observations	
Positive	**Negative**
More affordable than some other higher end models	Fixed lens/focal length results in less detail when at a distance
Lighter than some other higher end models	Thermal resolution is 320x240 which captures less detailed compared to higher end models
Manual tactile controls are easy to use	Internal memory only
Swappable batteries allow for extended use	Can be difficult to know where it is being aimed
Easy to use with one hand	Size of camera means that it would not be able to be used simultaneously with other inspection tasks
R_JPEG (editable radiometric jpeg) files are viewable by standard computer software	Focus is based on image contrast which may result in out of focus images during nighttime or in low light

Flir C5

The Flir C5 is a compact style thermal camera (Figure 3). Table 5 provides specifications and Table 6 provides observations made during field testing.

Figure 3 - Views of Flir C5 Thermal Camera

Table 5 - Flir C5 Specifications

Attributes	Flir C5
Cost*	$719.99
Thermal Resolution (pixels)	160x120
RGB Resolution (MP)	5 MP
FOV (degrees)	54°x 42°
Frame Rate (Hz)	8.7
Thermal Sensitivity (mK)	<70 mK

** Cost based on purchase of the camera as of 12/8/21. The cost does not include additional accessories.*

Table 6 - Flir C5 Observations

Flir C5 Observations	
Positive	**Negative**
More affordable than most other thermal cameras	Fixed lens/focal length results in less detail when at a distance
Compact and lightweight option that is easy to carry on your person and is portable	Thermal resolution is 160x120 which captures less detailed compared to other models
Easy to use with one hand	Internal memory only
R_JPEG (editable radiometric jpeg) files are viewable by standard computer software	Controls are touch screen and can be hard to manipulate if wearing gloves or have dirty fingers
	Internal battery only
	Focus is based on image contrast and low light performance is limited – blurry and out-of-focus images are possible in the dark

Seek Shot Pro

The Seek Shot Pro is a compact style thermal camera (Figure 4). Table 7 provides specifications and Table 8 provides observations made during field testing. This camera was not utilized for regular field testing but was rather intended to provide some additional imagery and provide experience with other thermal camera manufacturers.

Figure 4 - Views of Seek Shot Pro Thermal Camera

Table 7 - Seek Shot Pro Specifications

Attributes	Seek Shot Pro
Cost*	$699
Thermal Resolution (pixels)	320x240
RGB Resolution (MP)	3
FOV (degrees)	57°
Frame Rate (Hz)	<9
Thermal Sensitivity (mK)	<70 mK

** Cost based on purchase of the camera as of 12/8/21. The cost does not include additional accessories.*

Table 8 - Seek Shot Pro Observations

Seek Shot Pro Observations	
Positive	**Negative**
More affordable than most other thermal cameras	Fixed lens/focal length results in less detail when at a distance
Compact and lightweight option that is easy to carry on your person and is portable	IR sensor produces noise and grain which obscures data
Mobile application (Seek View) can edit images and has "LiveView" feature for connected phone to view thermal image	No desktop software available for post processing. Photos can only be processed in camera or mobile application (Seek View)
Easy to use with one hand	Internal battery only
	Controls are touch screen and can be hard to manipulate if wearing gloves or have dirty fingers
	Controls to lock thermal span our very small and difficult to use
	Can be difficult to tell where the camera is aimed

Fluke TiX580

The Fluke TiX580 is an expert series thermal camera (Figure 5). It should be noted that this thermal camera was not recommended as part of the Task 1 Interim Report. This camera was substituted as an alternative to the Fluke Ti480 Pro since the specific model was not available for rental during the trial period. The use of a TiX580 provided similar thermal resolution and specifications to the Ti480 Pro and provided the opportunity to test a different style of camera. Table 9 provides specifications and Table 10 provides observations made during field testing. This camera was not utilized for regular field testing but was rather intended to provide some additional imagery and provide experience with other thermal camera manufacturers and software.

Figure 5 - Views of Fluke TiX580 Thermal Camera

Table 9 - Fluke TiX580 Specifications

Attributes	Fluke TiX580
Cost*	$19,000
Thermal Resolution (pixels)	640x480
RGB Resolution (MP)	5
FOV (degrees)	32°x24°
Frame Rate (Hz)	60
Thermal Sensitivity (mK)	<50 mK

** Cost based on purchase of the camera as of 12/8/21. The cost does not include additional accessories.*

Table 10 - Fluke TiX580 Observations

Fluke TiX580 Observations	
Positive	**Negative**
Swappable batteries	Most expensive of tested models
MicroSD card allows for easy transfer of data	Camera is heavier than other tested models
Camera is capable of adding interchangeable lenses	Sensor image quality did not appear to be consistent during field testing
240° rotating screen allows for more comfortable data capture	Numerous settings can be adjusted which can result in the camera being less user friendly
Laser distance measure helps improve focus of images and can be used to verify what is being viewed since the red dot is visible	Size of camera means that it would not be able to be used simultaneously with other inspection tasks
Laser distance measure allows better data quality capture during night and low light conditions	Fluke editable thermal images (.IS2 format) are not viewable outside of Fluke Connect Software
Radiometric files (.IS2 format) can be post processed using Fluke Connect desktop software	Relatively new camera which means vendors don't have experience to assist with issues, need to communicate directly with Fluke customer support

General Discussion of Drone Mounted Thermal Cameras

Several models of drone mounted thermal cameras were utilized for this research project. This section will discuss several of the traits and characteristics of the drones and thermal cameras that were utilized. This section is limited to discussion on the use of the drones and cameras and does not include discussion on the specific field-testing sites and associated data of this research project. The data analysis will be discussed later in this report.

Parrot Anafi USA

The Parrot Anafi USA is a compact ruggedized drone equipped with integrated 21 megapixel (MP) wide angle sensor, 16 MP zoom sensor, and Flir Boson 320x256 thermal camera (Figure 6). Table 11 provides specifications and Table 12 provides observations made during field testing.

Figure 6 - Views of Parrot Anafi USA

Table 11 - Parrot Anafi USA Specifications

Attributes	Parrot Anafi USA
Order of Magnitude Base Cost	$7,500
Weight (lb)	1.00
Size	11.10” x 14.69” x 3.30”
Max Wind Speed Resistance (mph)	32.88
Max Flight Time (minutes)	32
Launch Capabilities	Hand Launch Capable
IR Sensor Resolution (pixels)	320x256
IR Field of View (degrees)	50°
Frame Rate (Hz)	60
Thermal Sensitivity (mK)	<60
Visual Sensor Resolution (MP)	Wide = 21 MP, Tele=16 MP
Gimbal Pitch Range	-140° to +90°

Table 12 - Parrot Anafi USA Observations

Parrot Anafi USA Observations	
Positive	**Negative**
Compact and light weight drone that is easy to transport	Drone had major control issue during testing – see write up below
Capable of GPS denied flight navigation	Drone has numerous warning alerts for "magnetic perturbations" when flying near steel bridges.
Gimbal can look straight up (+90°) at the underside of bridge decks	Control software had limited control of thermal camera settings, specifically for control of thermal span (temperature range)
High quality (21 MP) visual sensor	Thermal imagery is overlaid onto the visual image as a picture-in-picture which prevents other applications for imagery (i.e. stitching or photogrammetry)
Drone capable of stable flights in high winds	Thermal camera is non-radiometric and cannot be post processed
Controller can be used with phone or tablet which provides more flexibility in the field	Drone does not have any obstacle detection and avoidance technology
	Drone screen can be difficult to see in the field due to sun glare

The Parrot Anafi USA had a major control issue during field testing. The intent was to capture thermal data at four of the five bridges included as part of field testing. However, during the second day of test flights of the drone, the control signal completely cut out and was unable to be re-established. The drone was hovering in place while the flight crew attempted to reconnect. After approximately 15 minutes without success, one of the flight crew grabbed the drone out of the air and manually disconnected the battery with the props in motion. The alternative would have been to let the drone enter return-to-home mode after the battery reached critical levels, which would have resulted in the drone flying up into the bridge deck and the loss of the drone. At the time of the disconnect, the drone was approximately 20 feet away from the controller with no objects in between. The flight was being performed beneath a steel bridge, so electromagnetic interference (EMI) may have been a contributing factor.

Following the incident, AECOM submitted a support ticket to Parrot with the flight logs and applicable forms. Parrot support did not identify anything out of the ordinary regarding the Wi-Fi connection between the drone and control. The drone rental vendor has since sent the physical controller to Parrot support so that the physical hardware could be tested and evaluated. At the time of this report submission, AECOM did not have any additional information regarding the controller. Overall, the incident resulting in a lack of confidence and trust in the drone. For this reason, additional use of this drone was very limited during the research project.

A few flights were performed with the drone within 5 feet of the ground and some imagery was capture with the drone on the ground in order to have some thermal imagery for review. With the drone flights near ground level, magnetic perturbation errors still occurred. Due to safety concerns related to the control signal and EMI interference, the drone was not flown in order to collect data for the research project.

The Anafi USA thermal has two viewing modes – relative mode and spot mode. Relative mode displays a general view of the thermographic of a scene, on a colored scale, graduated from 0 to 100 (Figure 7). Spot mode allows the user to reduce the span so that only the coldest or hottest spots of an image are colorized. This mode only allows the user to modify one end of the span (Figure 8). Neither mode allowed the user to set a custom span for viewing and capturing the thermal data. Using the existing modes did not seem very intuitive for thermal tuning for concrete delamination identification.


Figure 7 - Relative Mode Screenshot


Figure 8 - Spot Mode Screenshot

The default image for thermal data capture is a picture-in-picture (Figure 9). The unmerged visual and thermal images are unable to be obtained. This prevents an unaltered visual image from being used as a visual cross check to the thermal data. Additionally, the picture-in-picture is a bit limiting in that the default imagery is unable to be used to develop a 3d model or orthomosaic image. The user can adjust the level of zoom in the image to trim out portions of the visible RGB image, however, there is still a sliver of the visual image that is visible along the left edge (Figure 10).

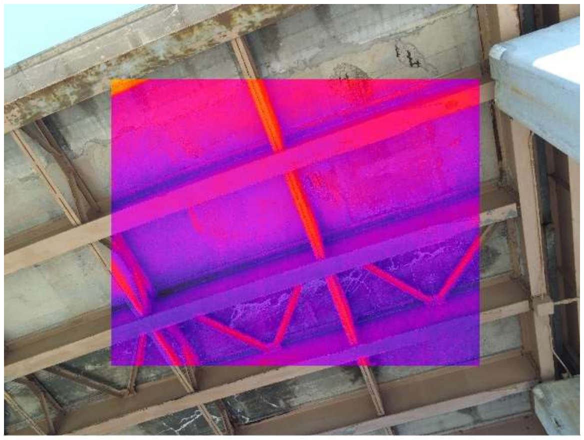


Figure 9 - Picture-in-Picture Thermal Image


Figure 10 - Zoomed in Thermal Image

Some additional sample imagery from the Parrot Anafi USA is included as Figure 11 and Figure 12.

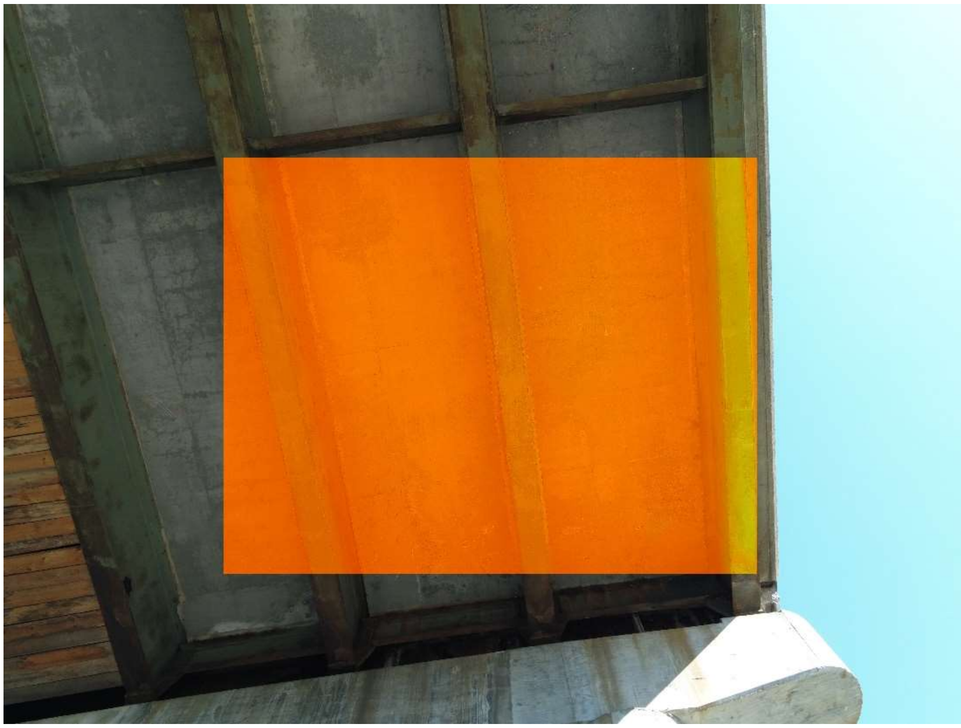


Figure 11 - Parrot Anafi USA Sample Imagery

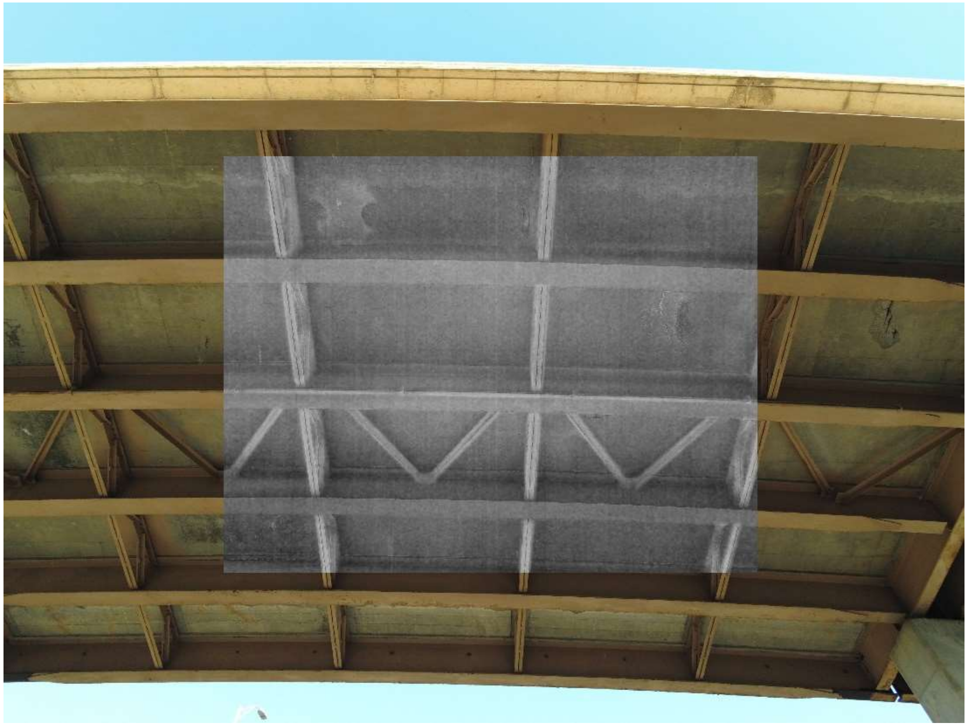


Figure 12 - Parrot Anafi USA Sample Imagery

Skydio X2

The Skydio X2 is a compact ruggedized drone equipped with integrated 12.3 MP wide angle sensor and Flir 320x256 thermal camera (Figure 13). Table 13 provides specifications and Table 14 provides observations made during field testing.

The Skydio X2 is a relatively new drone with limited supply which made it difficult to procure for field testing. The drone was unable to be procured for field testing in October 2021. However, AECOM was able to procure one in January 2022 to field test at one bridge site. However, due to high winds and limited wind resistance for the drone model, full data collection was not performed (see discussion on the following page).

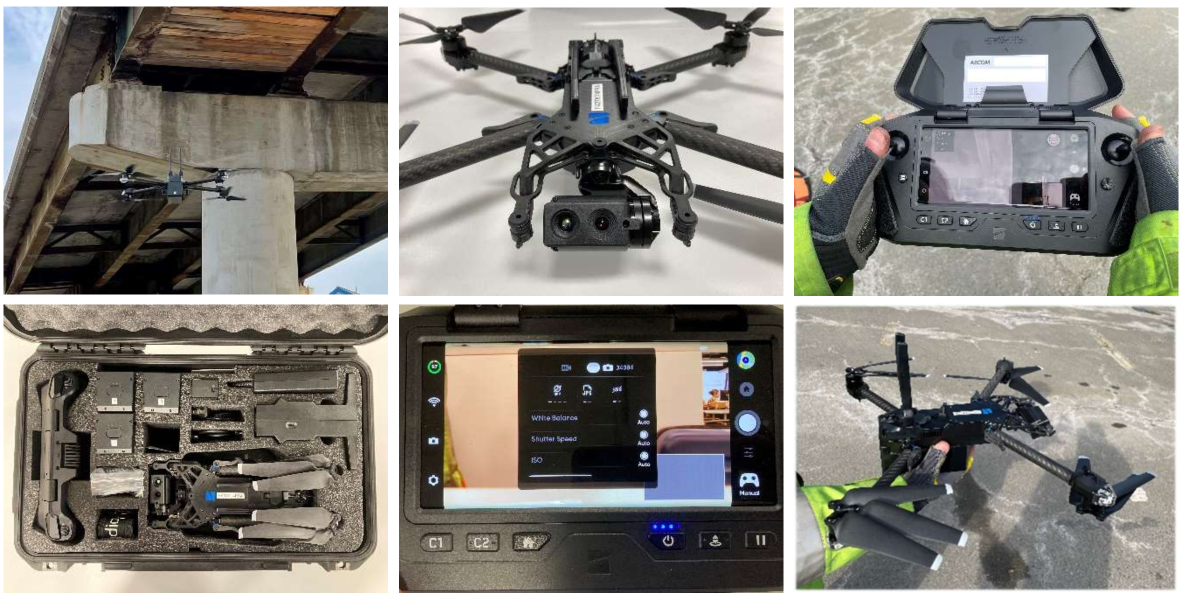


Figure 13 - Views of Skydio X2

Table 13 – Skydio X2 Specifications

Attributes	Skydio X2
Order of Magnitude Base Cost	$14,499
Weight (lb)	2.92
Size	26.1” x 22.4” x 8.3”
Max Wind Speed Resistance (mph)	23
Max Flight Time (minutes)	35
Launch Capabilities	Hand launch and recovery
IR Sensor Resolution (pixels)	320x256
IR Field of View (degrees)	46°
Frame Rate (Hz)	60
Thermal Sensitivity (mK)	<60
Visual Sensor Resolution (MP)	12
Gimbal Pitch Range	-110° to +45° (see discussion below)

Table 14 – Skydio X2 Observations

Skydio X2 Observations	
Positive	**Negative**
Drone has robust obstacle avoidance system based on six visual cameras located around the drone	Drone gimbal is limited to +45° with default software. Subscription enterprise software can increase gimbal range to +90°
Drone is capable of hand launch and recovery which allows operations for more terrains	Drone can bounce a few feet in each direction during wind (see discussion below)
Capable of GPS denied flight navigation	Control software had extremely limited control of thermal camera settings (see discussion below)
Compact drone that is easy to transport	Thermal camera is non-radiometric and cannot be post processed
	Thermal camera field of view is relative narrow (more telephoto) which makes low clearance bridges more time consuming to survey
	Drone screen can be difficult to see in the field due to sun glare

The drone wind speed resistance is listed as 23 mph by the manufacturer. However, during field testing, the drone was bouncing around a few feet in each direction resulting in unstable flight at wind speeds lower than the listed limits. A handheld anemometer measured the wind speeds during field testing. The readings generally ranged between 5 mph and 15 mph but did hit 18 mph during strong gusts. The drone flight was erratic with the bottom of the drone constantly tilting approximately 90 degrees back and forth. This movement was prohibitive for landing the drone. The drone was flown behind a building on the site to block the winds and safely land. Due to the unstable flight in the wind and inability to land in the wind, it was decided to cease further flights for safety reasons. Unfortunately, this meant that full data collection was not performed. However, the brief flights still provided some limited thermal imagery and insights into the drone itself. Refer to Figure 14 through Figure 16 on the following page for thermal imagery from the Skydio X2.

The Skydio X2 gimbal system is only capable of +45° upward views using the default Skydio control software. The gimbal is capable of +90° views if the pilot opts to purchases an annual enterprise software subscription, which is approximately $2500 per year. For the purposes of performing an underside of deck survey, the 45° upward view can be a bit limiting.

The thermal camera is limited in terms of control and features. The pilot is unable to set a manually temperature span and there are no modes to adjust how that span is created with automatic settings. However, delaminations were visible with the default automatic settings during field testing (Figure 15). There is no temperature scale included as part of the imagery, only the gradient thermal image is provided. The drone provides four color palettes (white hot, black hot, rainbow, and iron bow). Additionally, the imagery is non-radiometric which means it is unable to be post processed after collection. The thermal camera focal range is more of a telephoto view than anticipated, which can limit the effectiveness of the drone for this application for low vertical clearance bridges.

Figure 14 – Skydio X2 Sample Imagery

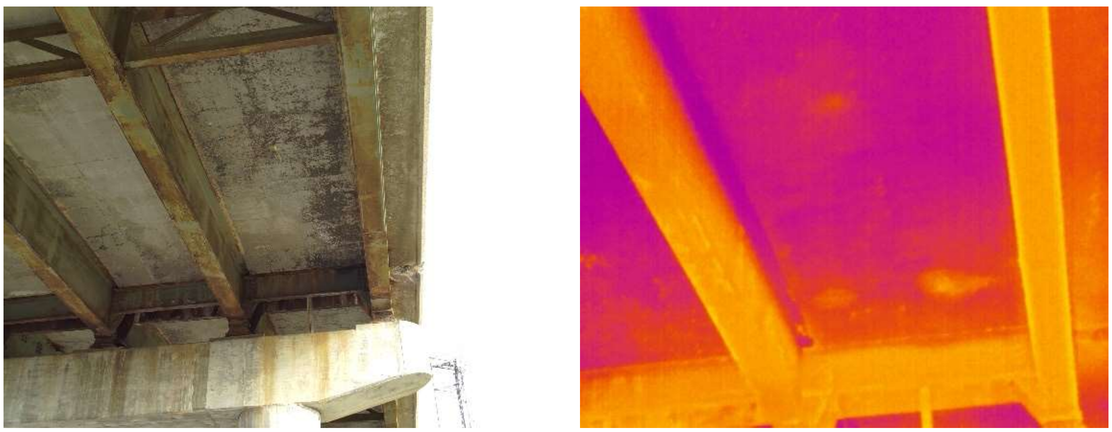


Figure 15 - Skydio X2 Sample Imagery

Figure 16 - Skydio X2 Sample Imagery

DJI Matrice 210 RTK V2 with Zenmuse XT2

The DJI Matrice 210 is an established commercial drone capable of performing a wide variety of tasks (Figure 17). The drone features interchangeable payloads which allow a wide flexibility of applications. This research project featured the use of the Zenmuse XT2 thermal camera. The XT2 has multiple versions with 640x512 or 336x256 thermal resolution, 9mm, 13mm, 19mm, or 25mm focal lengths, and 9 Hz or 30 Hz frame rates. For the research project, the 640x512, 13mm, 30 Hz version was used. The XT2 also features a 12-megapixel visual RGB camera. There are a variety of additional visual camera sensor payloads that can be mounted on the Matrice 210. Table 15 provides specifications and Table 16 provides observations made during field testing.

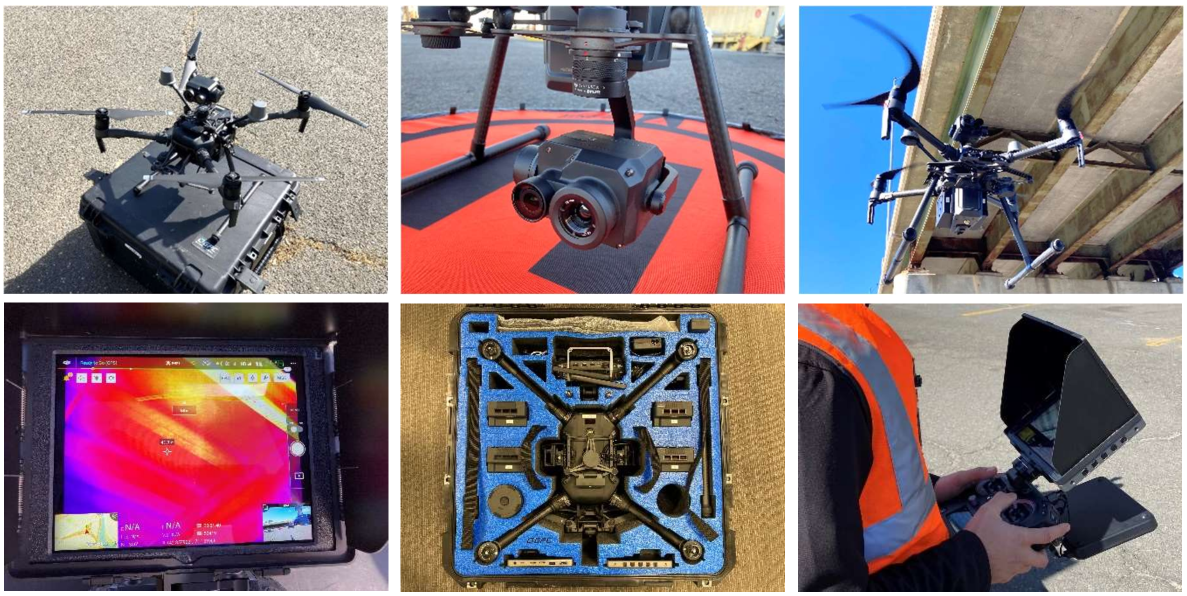


Figure 17 - Views of DJI Matrice 210 and Zenmuse XT2

Table 15 - DJI Matrice 210 with Zenmuse XT2 Specifications

Attributes	M210 with XT2
Order of Magnitude Base Cost	$27,000 +/-
Weight (lb)	10.82
Size	25.32” (diagonal)
Max Wind Speed Resistance (mph)	26.86
Max Flight Time (minutes)	33
Launch Capabilities	Ground Launch Only
IR Sensor Resolution (pixels)	640x512
IR Field of View (degrees)	45°
Frame Rate (Hz)	30
Thermal Sensitivity (mK)	<50
Visual Sensor Resolution (MP)	12 MP
Gimbal Pitch Range	-45° to +130° (for upward mounting)

Table 16 - DJI Matrice 210 with Zenmuse XT2 Observations

DJI Matrice 210 with Zenmuse XT2 Observations	
Positive	**Negative**
Drone allows for two controllers (one for pilot and one for sensor operator)	Sensor needs to be mounted to face upward or downward – less flexibility during individual flights
Interchangeable sensors allow for flexibility based on operational needs	Size of drone makes flights under low clearance bridges (<18’) high risk and more prohibitive
Weatherproof (capable of flying in the rain) and capable of flying in high winds	DJI geofencing can cause additional steps during planning and coordination phases
XT2 camera is radiometric and can be post processed	Drone is large and bulky, making transportation more difficult
Drone controller is capable of displaying sensor feed to television screen through HDMI	Matrice 210 is no longer being supported by DJI with no new sensors being made for this model of drone and existing sensors becoming hard to find
Obstacle avoidance sensors along front, bottom, and top of drone which offer some collision avoidance	XT2 sensor does not allow manual setting of the temperature span but it can be adjusted after flight operations on the computer
	Drone needs clear, flat surface to launch and land

The Matrice 210 is a very robust commercial drone capable of performing flights in the challenging environments for this application. The drone can be controlled with two controllers; one to pilot the drone and the other to control the sensor, which allows the pilot to focus on flying the drone. This drone is capable of flights in high winds and precipitation. Due to the size of the drone, it will not be the most effective method of data capture for bridges with low vertical clearances. The drone also must have flat space in order to take off and land, which could cause operational limits for some bridges where these flat spaces are not readily available without traffic closures.

The Zenmuse XT2 is able to simultaneously capture both thermal and visual imagery which is necessary to visually cross check the thermal data. The drone controller is capable of displaying both images at once allowing the cross check to be performed live during data capture. Some sample imagery of the Zenmuse XT2 can be seen in Figure 18 and Figure 19.

Figure 18 - Zenmuse XT2 Sample Imagery

Figure 19 - Zenmuse XT2 Sample Imagery

The biggest drawback to the XT2 sensor is the difficulty in manually setting a temperature span. In the settings, contrast (span) and brightness (level) can be adjusted as a slider (Figure 20). However, these are not portrayed as temperature values but rather numbers ranging from 0 to 10,000 with the slider being difficult to set to a specific value as it occupies a small portion of the screen. The span and level can be also adjusted using the “Sky Exclude” setting which are intended to de-emphasize the impact of the sky horizon in the imagery, however, the feature was intended for imagery that is looking downward. Neither of these methods are particularly intuitive and do not give the user any significant control. However, the XT2 is radiometric, so the user can adjust the span and level using Flir Tools and Flir Thermal Studio. This does add extra steps for data processing, which increases the amount of time needed for data analysis.

Figure 20 - M210 & XT2 Settings Screen

The DJI Matrice 210 is at the end of its service life and is no longer being supported by DJI which makes replacement parts, batteries, and sensors difficult to find. DJI has shifted production to the Matrice 300, which is the replacement model for this specific drone. While the Matrice 210 is a very capable drone, it would be very difficult to obtain all of the necessary equipment for this drone if it was not already owned and being operated. The Zenmuse XT2 sensor is in a similar situation where it is also at the end of its service life and is no longer being produced making it difficult to find to purchase. The Zenmuse XT2 is being replaced by the Zenmuse H20T.

DJI Matrice 300 RTK with Zenmuse XT2

The DJI Matrice 300 is the replacement model for the Matrice 210 and is intended to be a commercial drone work horse similar to the Matrice 210 (Figure 21). The Zenmuse XT2 thermal camera was also used in conjunction with the Matrice 300 for this research project. The XT2 used with the Matrice 300 was also the 640x512, 13mm, 30 Hz version was used. Table 17 provides specifications and Table 18 provides observations made during field testing.

MassDOT Aeronautics Division provided the use of their DJI Matrice 300 RTK and Zenmuse XT2 for data collection at one of the bridge sites in January 2022.

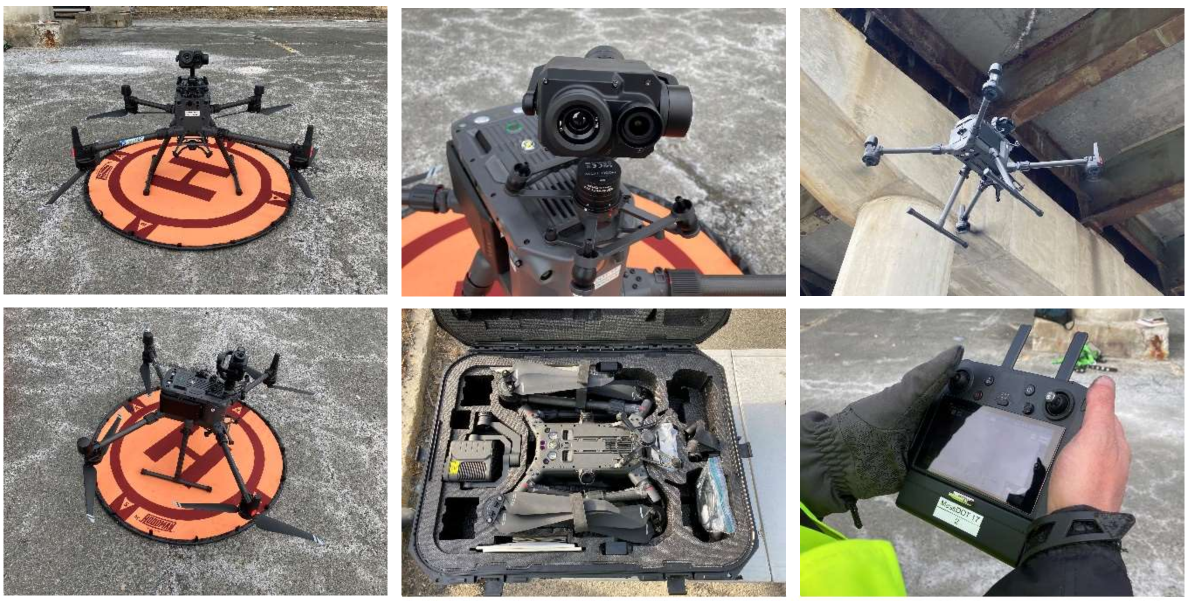


Figure 21 - Views of DJI Matrice 300 and Zenmuse XT2

Table 17 - DJI Matrice 300 with Zenmuse XT2 Specifications

Attributes	M300 with XT2
Order of Magnitude Base Cost	$29,800 +/-
Weight (lb)	13.89 lb
Size	31.89” x 26.38” x 16.93”
Max Wind Speed Resistance (mph)	33.55
Max Flight Time (minutes)	55 min
Launch Capabilities	Ground Launch Only
IR Sensor Resolution (pixels)	640x512
IR Field of View (degrees)	45°
Frame Rate (Hz)	30
Thermal Sensitivity (mK)	<50
Visual Sensor Resolution (MP)	12 MP
Gimbal Pitch Range	-45° to +130° (for upward mounting)

Table 18 - DJI Matrice 300 with Zenmuse XT2 Observations

DJI Matrice 300 with Zenmuse XT2 Observations	
Positive	**Negative**
Drone allows for two controllers (one for pilot and one for sensor operator). Pilot control and roles can be swapped during flight	Sensor needs to be mounted to face upward or downward – less flexibility during individual flights
Interchangeable sensors allow for flexibility based on operational needs	Size of drone makes flights under low clearance bridges (<18') high risk and more prohibitive
Weatherproof (capable of flying in the rain) and can fly stable in high winds	DJI geofencing can cause additional steps during planning and coordination phases
XT2 camera is radiometric and can be post processed	Drone is large and bulky, making transportation more difficult
Long battery life (+/- 45 minutes with XT2)	Drone needs clear, flat surface to launch and land
Drone has directional obstacle sensors on each side of the drone that can be customized to set minimum distances	XT2 sensor does not allow manual setting of the temperature span but it can be adjusted after flight operations on the computer
Drone controller is capable of displaying sensor feed to television screen through HDMI	Drone controller screen can be difficult to see in the field with glare

The Matrice 300 is the replacement model for the Matrice 210. Similar to the Matrice 210, it is a very robust commercial drone. The drone can be controlled with two controllers; one to pilot the drone and the other to control the sensor, which allows the pilot to focus on flying the drone. The control system for this drone allows the pilots to swap roles mid-flight, which can be used to ensure visual line of sight by the pilot. This drone also offers a battery life of approximately 45 minutes with the XT2, which far exceeds comparable drones.

This drone is capable of flights in high winds and precipitation. Due to the size of the drone, it will not be the most effective method of data capture for bridges with low vertical clearances. The drone also must have flat space in order to take off and land, which could cause operational limits for some bridges where these flat spaces are not readily available without traffic closures.

Comments related to the Zenmuse XT2 are the same as previously discussed with the Matrice 210 drone. Refer to the section "DJI Matrice 210 RTK V2 with Zenmuse XT2."

Considerations for Thermal Data Capture and Analysis

Thermal Data Basics

Thermal cameras capture infrared radiation being emitted by objects and converts the data into temperature measurements. This information is portrayed visually using colors, generally with darker colors representing cooler temperatures and brighter colors representing warmer temperatures. Some terminology that will be used within this report includes:

- Temperature Range: The maximum and minimum temperatures within the camera's field of view.
- Temperature Span: The portion of the temperature range that is being viewed. Temperatures outside the limits of the span will be colored the same as the maximum and minimum values. The span is chosen automatically by the camera software based on the maximum and minimum temperatures in the field of view or manually selected by the user. However, not all thermal cameras are capable of having a manually selected span.
- Level: The mid-point or "center" of the span.

Thermal cameras are capable of displaying different items as overlays on the camera screen and final image. The most common displays include the temperature scale, span maximum/minimum temperatures, date and time, GPS coordinates, distance to focus point, emissivity, and measurement toolboxes and temperatures. These can be adjusted in the camera settings as well as with post processing analysis software. See Figure 22 below for a typical thermal image overlay for Flir.

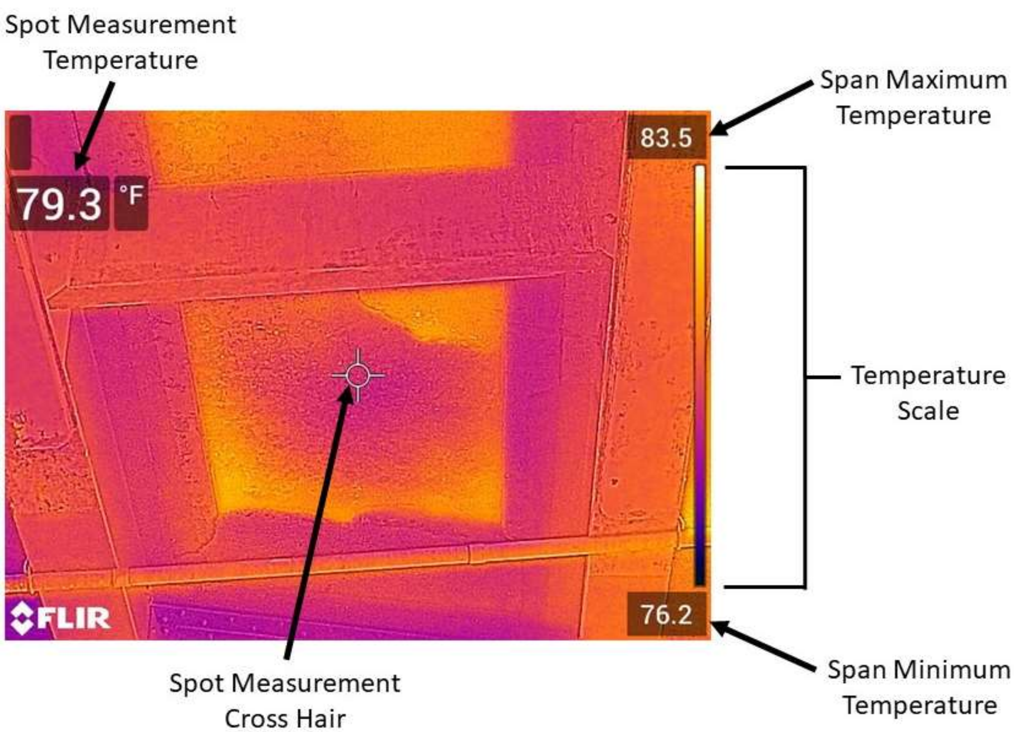


Figure 22 - Example Overlay for Flir Cameras

Thermal data is primarily portrayed as thermal only, visual RGB image, a thermal image with blended visual components (varies by specific manufacturer), and picture-in-picture (Figures 23 through 26). The blended thermal and visual imagery is typically patented by manufacturers and is as follows for the field-tested thermal cameras:

- Flir: Multi-Spectral Dynamic Imaging (MSX) - This mode adds visual light details, specifically edge and outline details without decreasing the thermal image transparency.
- Fluke: IR-Fusion - This mode blends the visual and thermal images. The user can adjust the transparency between the thermal and visual images.
- Seek: SeekFusion – This mode blends the visual and thermal images. The user can adjust the transparency between the thermal and visual images.

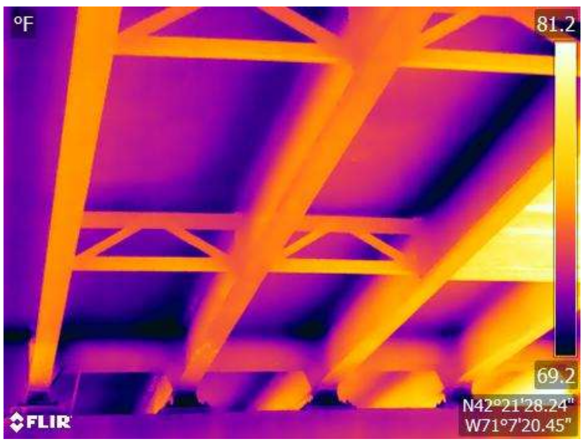


Figure 23 - Thermal Image


Figure 24 - Visual RGB Image

Figure 25 - Thermal Image with MSX Overlay

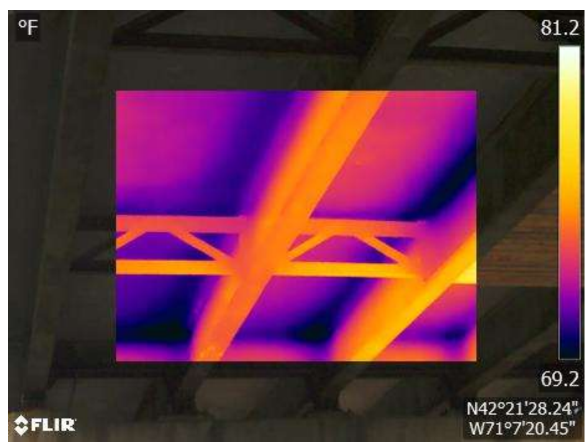


Figure 26 - Picture in Picture Image

While the blended thermal and visual images may provide the most context, it can create an image that includes excessive details that could make the thermal data harder to interpret. Figure 27 below shows a thermal only image and a thermal MSX image of the underside of a deck with extensive cracking and efflorescence. These details can affect the coloring of the temperature gradient and make an image harder to interpret. It is also possible that MSX will make an out of focus thermal image look to have proper focus because the visual image is in focus.

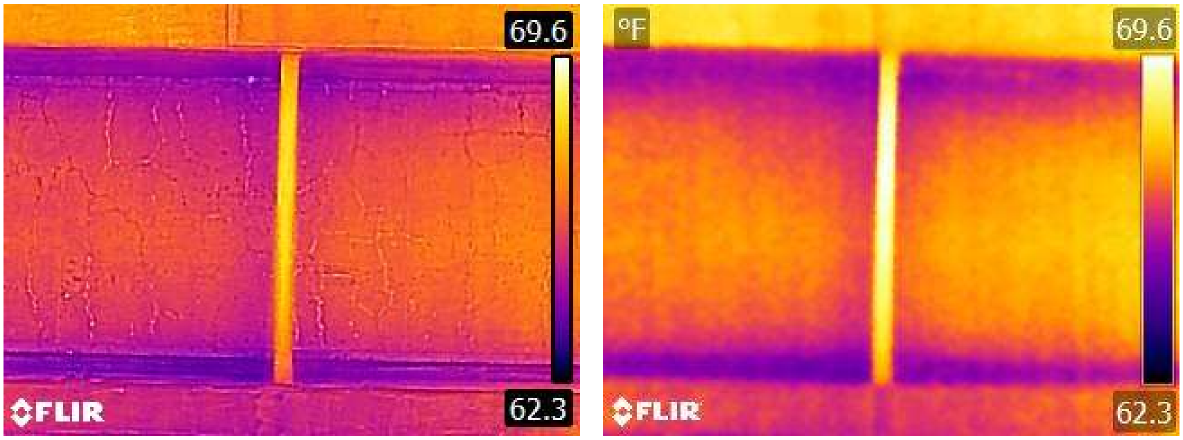


Figure 27 – Thermal MSX Image (Left) and Thermal Only Image (Right) of Deck with Visible Cracking

The user of the thermal camera should be aware that the thermal and visual blended imagery has the potential for misalignment as separate cameras are being used to develop these. Depending on the manufacturer and specific product, the alignment can be adjusted automatically by the camera or manually by the user. For products with interchangeable lenses, like the Flir E86 and E96, the lens needs to be calibrated properly or the misalignment is unable to be corrected. While these misalignments will cause the blended images to be improperly aligned, the misalignment will not affect the quality of the thermal data. Refer to Figures 28 and 29 for examples of misalignment.

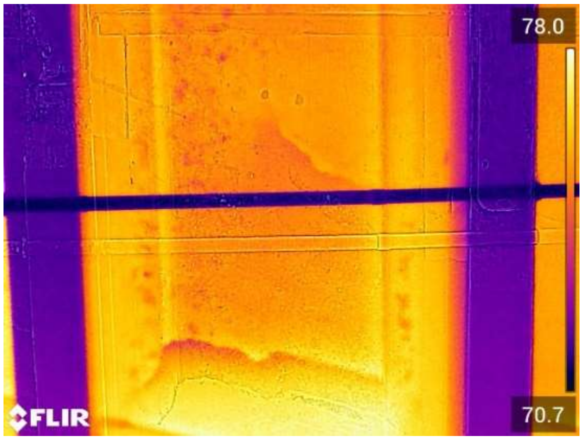


Figure 28 - Misalignment of MSX Overlay

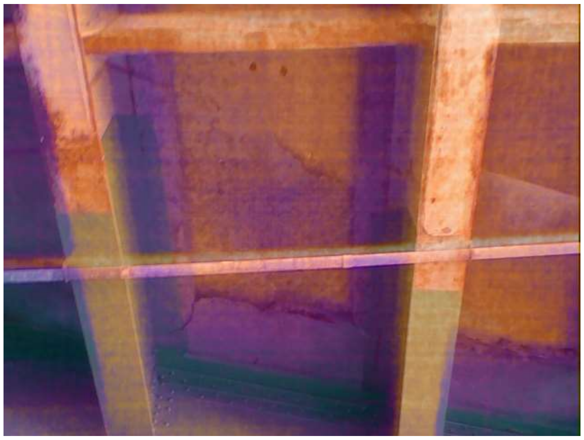


Figure 29 - Misalignment of Seek Fusion

Color Palettes

Thermal cameras offer different color palettes for viewing thermal data. The specific number and naming will differ by manufacturer and specific thermal camera model. Color palettes are a user setting that can be changed in the field. For thermal cameras that capture radiometric data, the color palette is able to be changed during post processing with thermal analysis software. For non-radiometric cameras, the palette will not be able to be changed after the image is captured. Refer to Figure 30 for color palette samples for the Flir E96. Other Flir thermal cameras will have similar color palettes. Refer to Figure 31 for some select color palette samples for the Zenmuse XT2. The XT2 has additional color palettes available beyond those shown in the figure.

Additional discussion on the selection of color palette will be included as part of Task 3 of this research project.

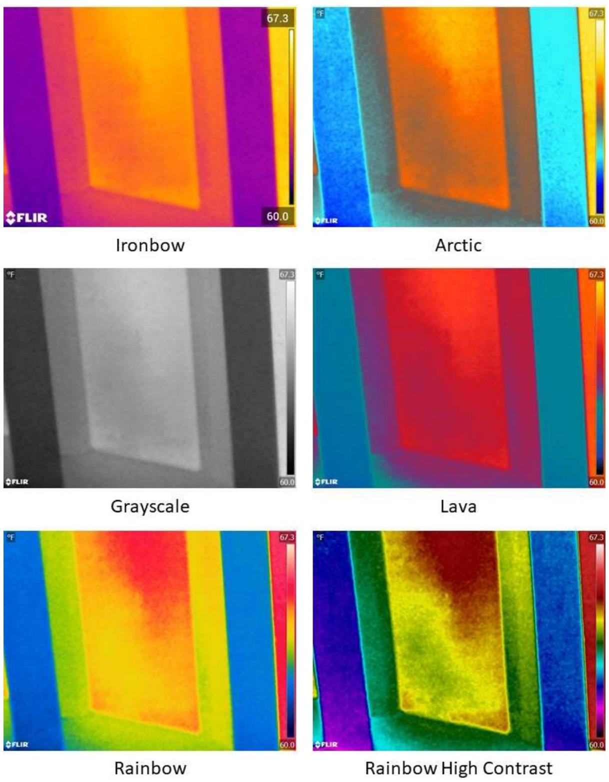


Figure 30 - Color Palettes for Flir E96

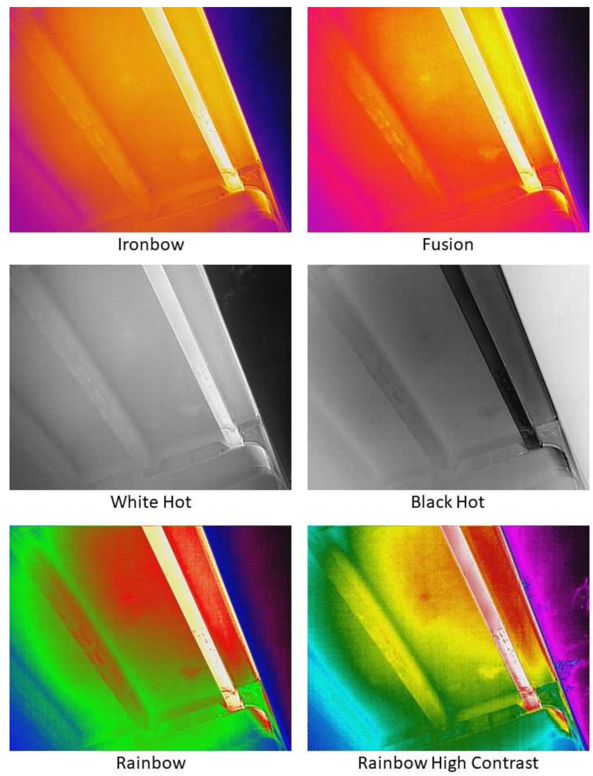


Figure 31 - Select Color Palettes for Zenmuse XT2

Data Capture Considerations

Thermal camera sensors can be damaged by intensive energy sources, such as the sun. The sun can cause permanent burn-in effects, which appear as light trails. These types of damage are generally not covered by vendor warranties. The use of thermal cameras for concrete delamination detection along the underside of bridges requires the camera to be pointed upward; inspectors need to be aware of the sun's position relative to the bridge and must exercise caution.

Thermal camera automatic settings will generally cause the thermal span to automatically adjust based on the objects visible for the sensor. This can cause the thermal span to increase in size which would make delamination detection more difficult. Some of the factors that can cause this increase in span include:

- Adjacent utilities or light fixtures that generate heat (Figure 32)
- Nearby wildlife, such as roosting pigeons (Figure 33)
- Moisture and water leakage (Figure 34)
- Visible sky along the edge of bridges or through joints (Figure 35)

Figure 32 - Lighting Fixture affecting Thermal Span

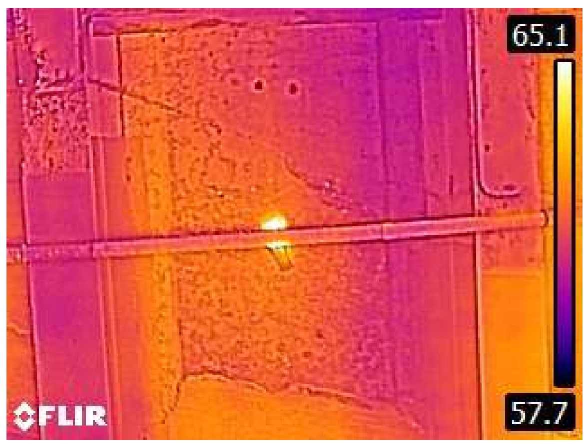


Figure 33 - Pigeon affecting Thermal Span

Figure 34 - Water Leakage affecting Thermal Span

Figure 35 - Visible Sky affecting Thermal Span

In order to avoid potential issues with an automatic temperature span, the thermal cameras should be set to use manual temperature spans wherever possible. However, this is not possible for some thermal cameras. Additional guidance will be provided in the Task 3 Interim Report.

Data Processing

Thermal data can be post processed after data collection for radiometric imagery. Radiometric imagery stores the temperature data within the image which allows it to be edited after capture. Non-radiometric imagery captures the gradient image without any temperature data. Table 19 provides processing information for the field-tested thermal cameras.

Table 19 - Thermal Camera Processing Information

Thermal Camera	Radiometric / Non-radiometric	Processing Software
Flir C5	Radiometric	Flir Tools, Flir Thermal Studio
Flir E8	Radiometric	
Flir E86	Radiometric	
Flir E96	Radiometric	
Fluke TiX580	Radiometric	Fluke Connect
Seek Shot Pro	Radiometric	Seek View (mobile app only)
Parrot Anafi USA	Non-radiometric	None
Skydio X2	Non-radiometric	None
Zenmuse XT2	Radiometric	Flir Tools, Flir Thermal Studio

Thermal processing software can modify settings in order to post process thermal imagery. This includes changing the type of image (thermal only, visual only, blended thermal/visual), adding or removing measurement spots or boxes, changing color palettes, and adjusting the temperature span.

Beyond thermal analysis software, photo editing and manipulation software, such as Adobe Lightroom, could be a potential tool as well. Lightroom can edit images to edit contrast, highlights, shadows, blacks, whites, and midtones which may assist in identify delaminations within thermal images. Additionally, Lightroom has a transform tool, which can be used to resize, scale, and warp images vertically and horizontally to change the perspective of the image. This tool can be useful for straightening the image so that the shapes of delamination can be more easily determined and translated into sketches.

Some of the thermal imagery for Bridge 07001 has been processed using Lightroom to see if editing photo properties can assist with identification of delamination. Refer to Data Collection and Analysis discussion of Bridge 07001 later in this report.

In-depth discussion on processing software, file types, and analysis protocols are not included as part of the scope of this Task 2 Interim Report. Additional discussion on specific file types and processing software will be included as part of the Task 3 Interim Report.

Data Analysis for Defect Identification

It is important to note that the user must have some experience with thermal data in order to properly analyze the imagery for defect identification. Temperature readings are affected by many factors which can cause false positive identification. Thermal data should be cross checked against visual imagery whenever possible to ensure that there are no false positives for defects. Factors that affect temperature readings include:

- Type of material (Figure 36)
- Thickness of material (Figure 37)
- Reflective materials (Figure 38)
- Angle of data capture (Figure 39)
- Paint or other protective coatings (Figures 40 through 42)
- Shadows (Figure 43)
- Surface texture (i.e. honeycombing, scaling, etc.) (Figure 44)
- Dirt and debris that may be present along the surface
- Moisture or water leakage (Figure 45)
- Internal voids (box beam and box girder superstructures) (Figures 46 and 47)

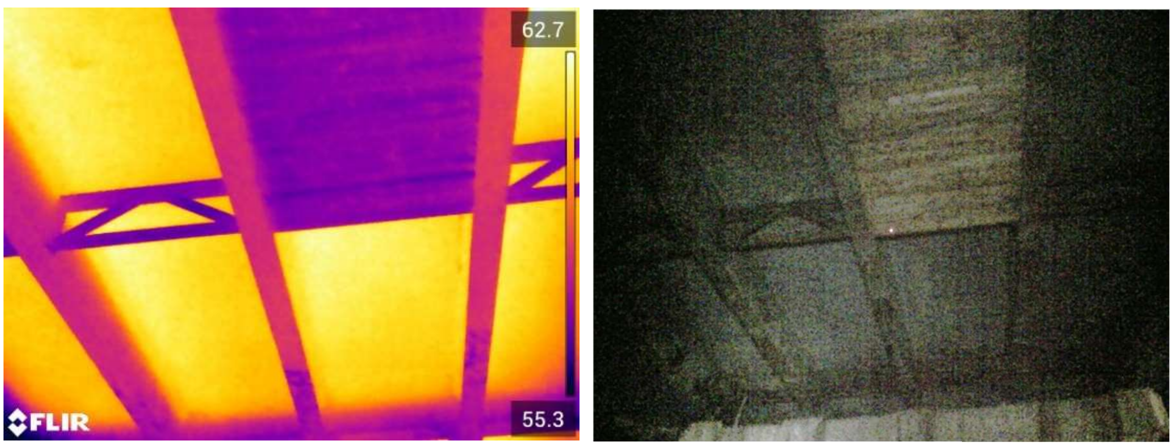


Figure 36 - Concrete, Steel, and Timber along Underside of Bridge Deck

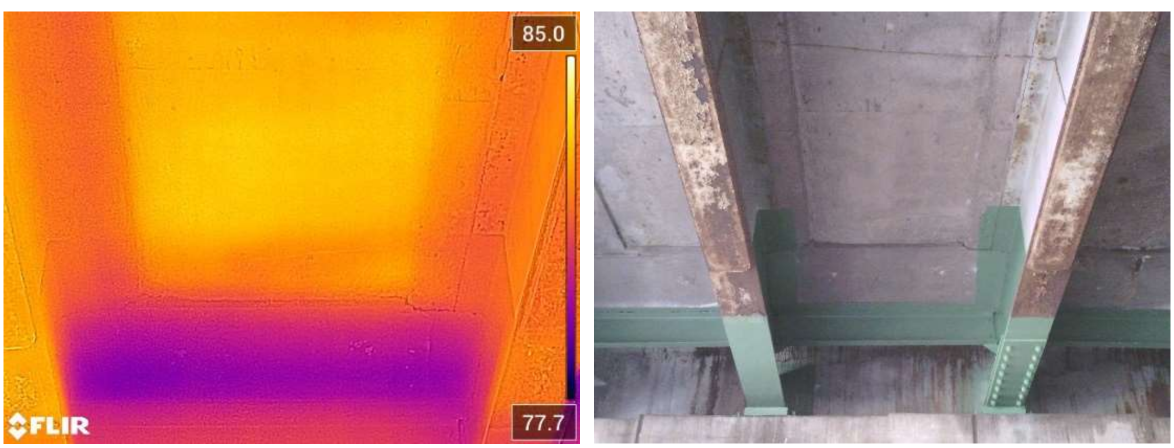


Figure 37 –Temperature Differentials along Girders and Abutment

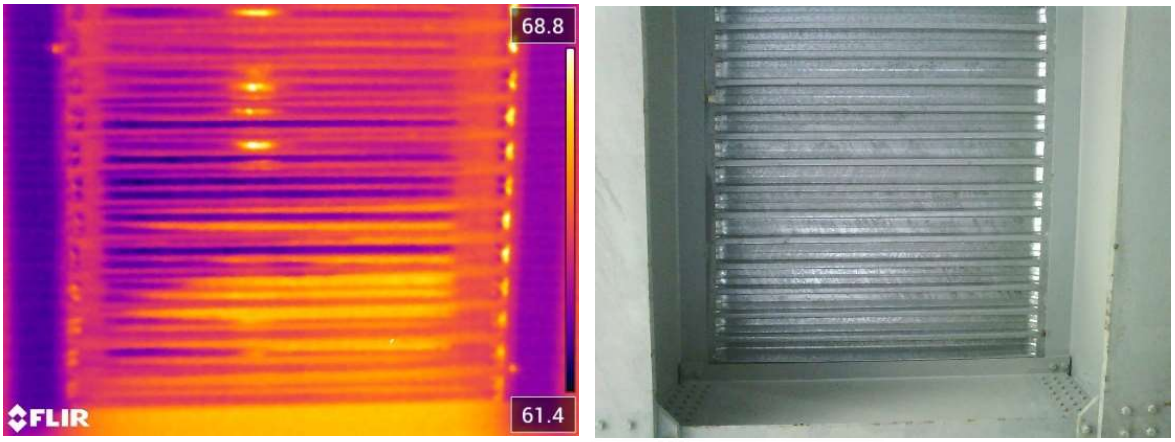


Figure 38 – Temperature Differential due to Reflection in SIP Forms

Figure 39 - Temperature Differential at Edge of Pier Cap caused by Angle of Data Capture

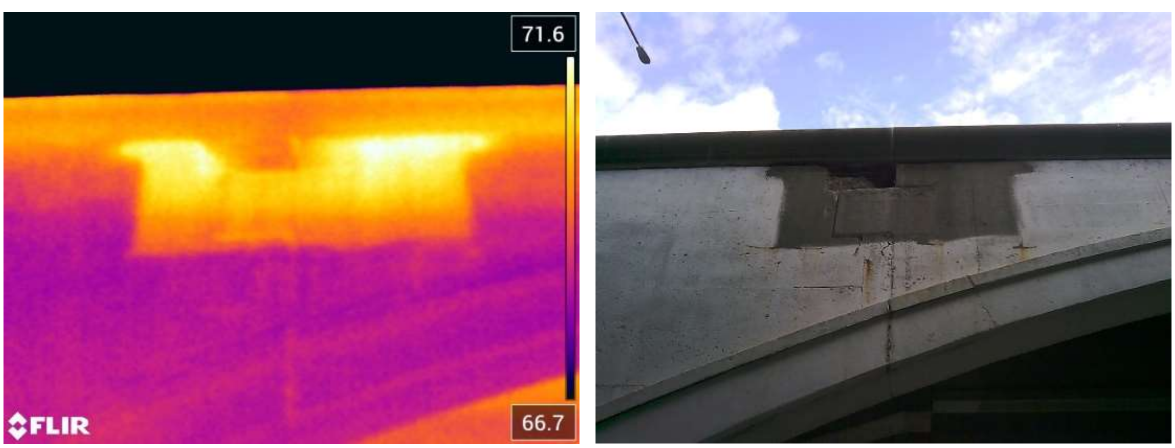


Figure 40 - Temperature Differential where Paint is Missing

Figure 41 - Temperature Differential caused by Paint Failure along Top Flange

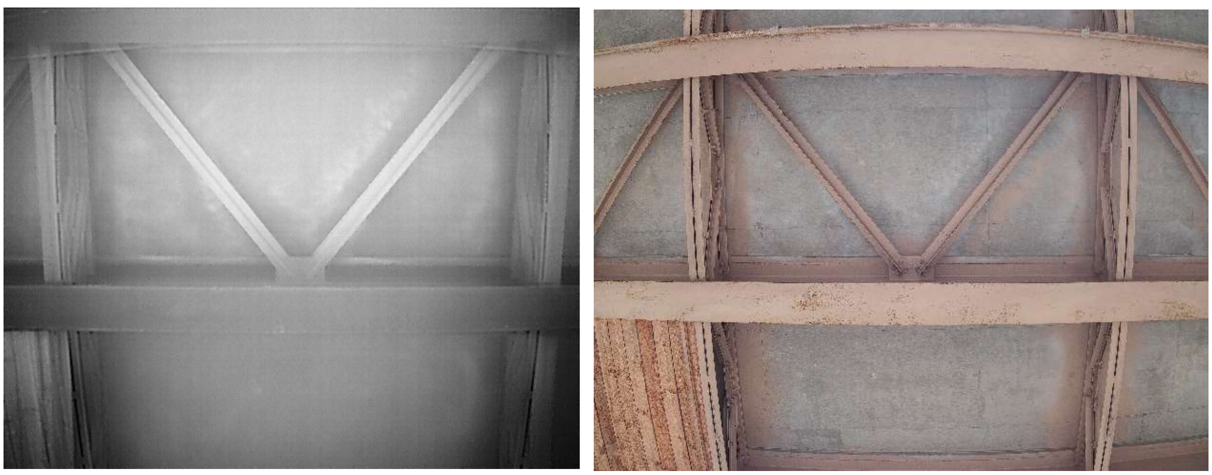


Figure 42 - Temperature Differential caused by Paint Overspray

Figure 43 – Temperature Differential caused by Shadow

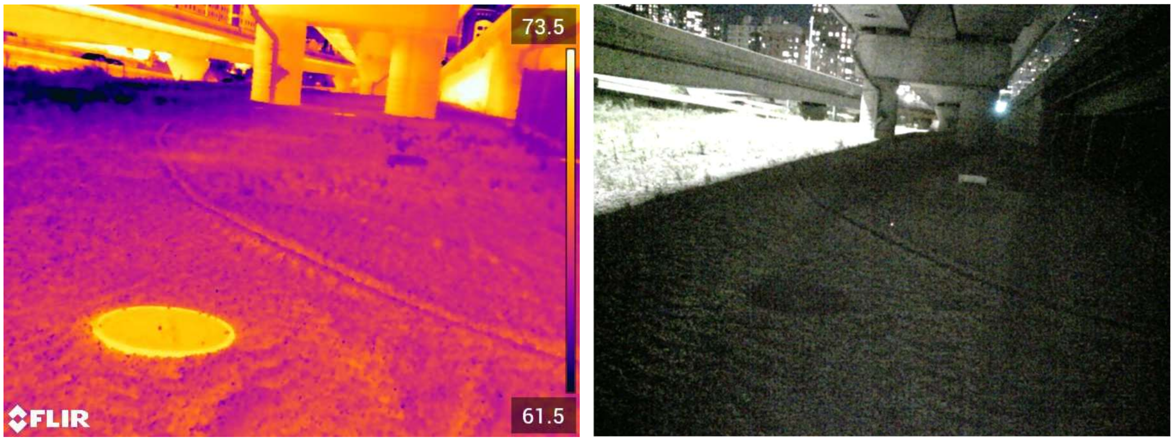


Figure 44 – Temperature Differential caused by Texture of Gravel

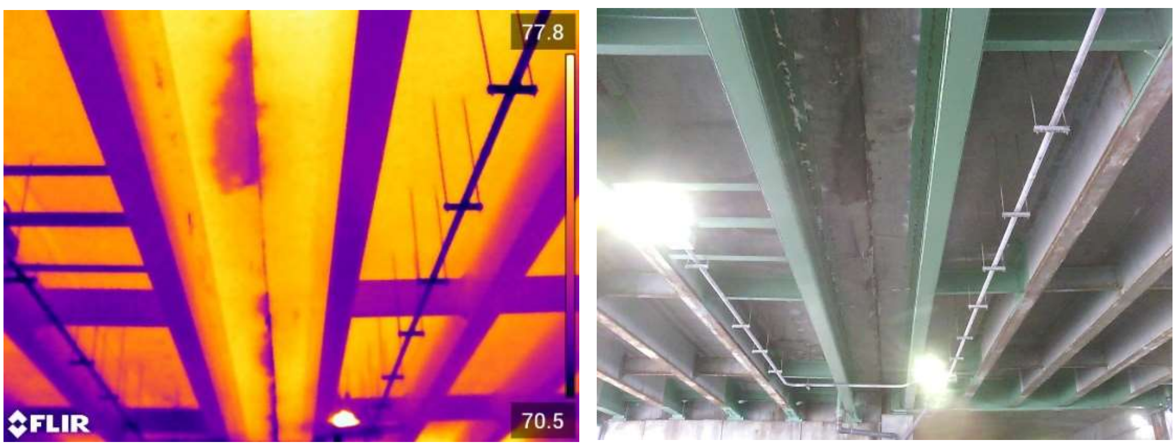


Figure 45 – Temperature Differential caused by Leakage along Joint

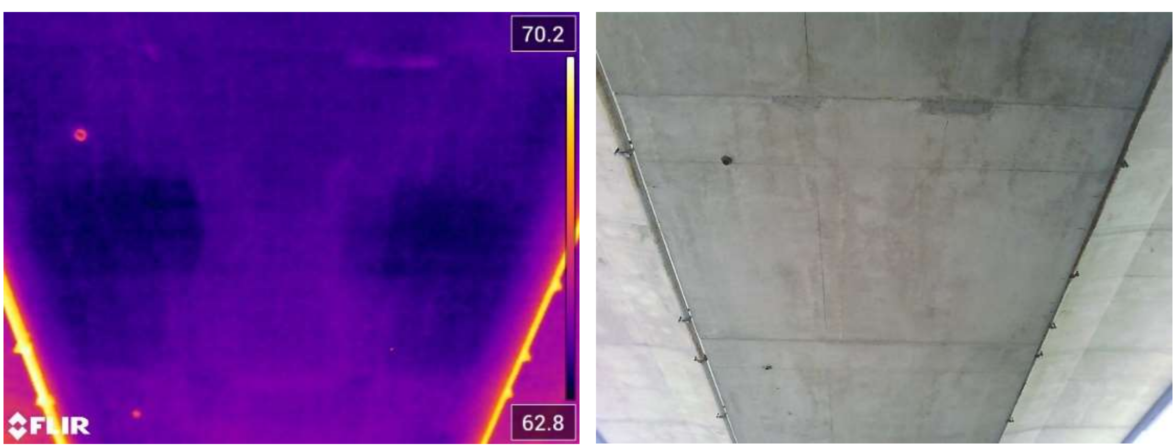


Figure 46 - Temperature Differentials caused by Internal Deviation Blocks and Drain Pipes)

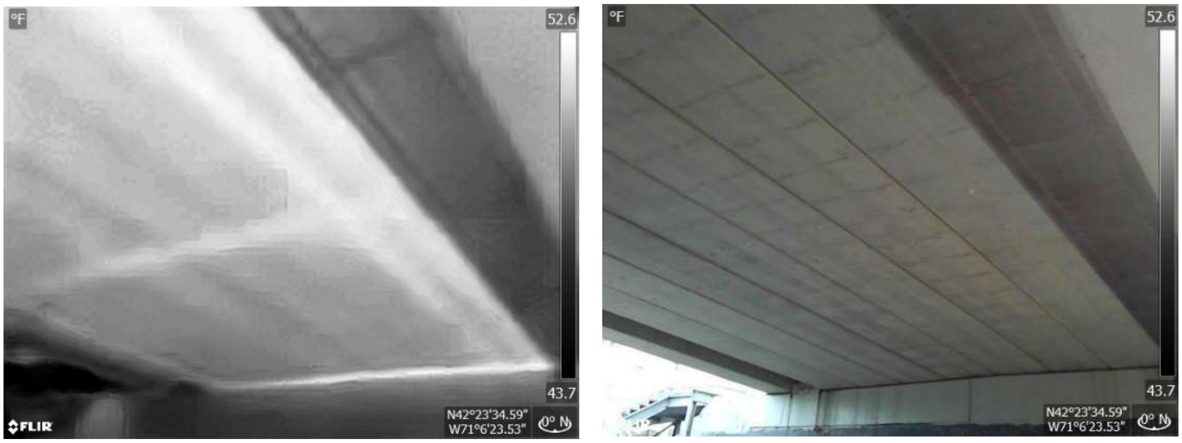


Figure 47 - Temperature Differential caused by Voids and Internal Diaphragms

However, there were still limitations for this visual cross check, especially near the edges of the deck. Depending on the conditions, the visual image of the deck could be washed out from sun glare (Figure 48) or under exposed due to the adjacent sky (Figure 49). Contrast caused by shadows can also result in overexposure of portions of the visible image removing needed detail (Figure 50).

Figure 48 - Sun Glare obscuring Deck

Figure 49 - Underexposed Deck

Figure 50 - Overexposed Surface Removing Detail

Data analysis for the five bridges will be discussed in depth in the "Data Collection and Analysis on Five Bridges" section. The thermal imagery collected for each bridge will be included within the related appendices. Based on the data analysis, thermal imagery was able to detect the following types of deficiencies:

- Minor delaminations detected only through manual sounding (Figure 51)
- Minor delaminations with cracking (Figure 52)
- Delamination without visible separation (Figure 53)
- Delaminations with cracking and visible separation (Figures 54 and 55)
- Delaminations along previous repairs due to voids / overpour (Figure 56)
- Both sound patches and delaminations with patches (Figures 57 and 58)

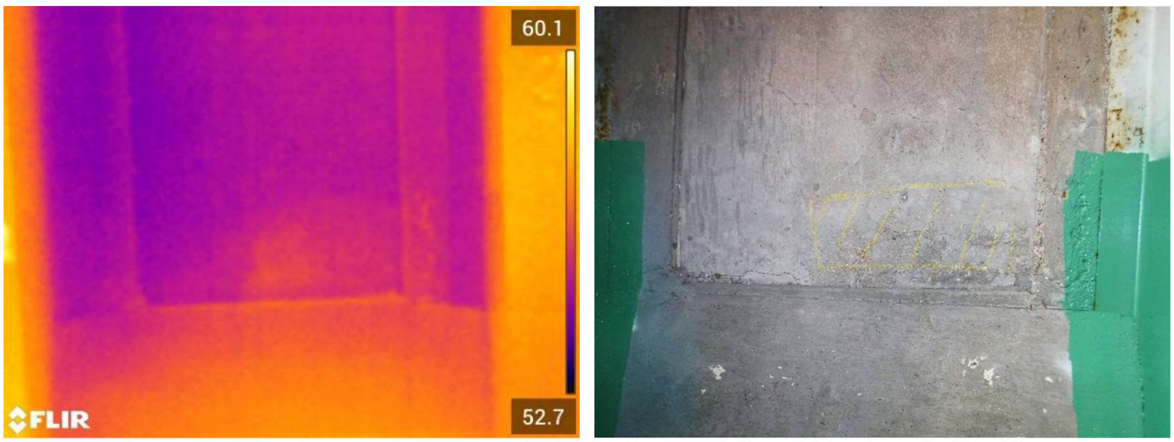


Figure 51 - Minor Delamination

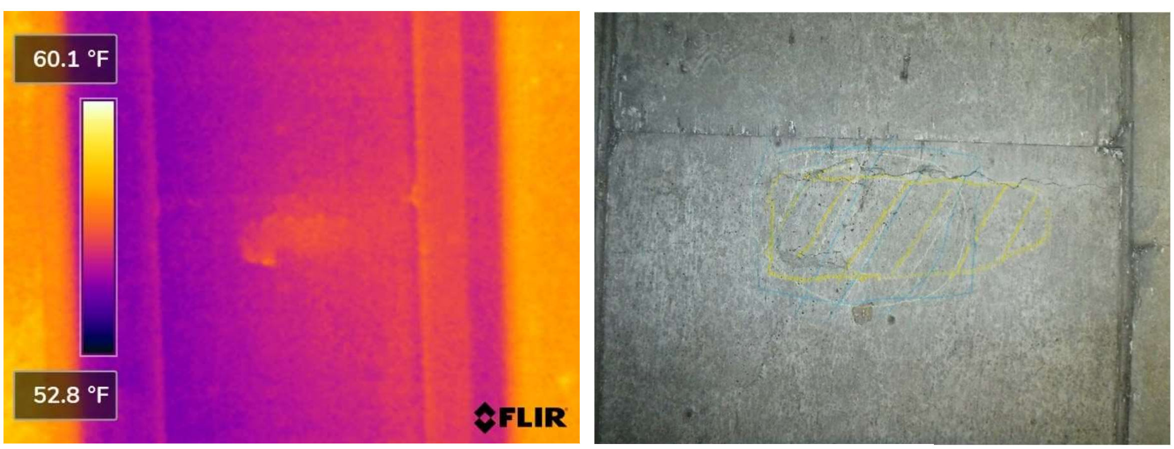


Figure 52 - Delamination with Cracking

Figure 53 - Delamination without Visible Separation

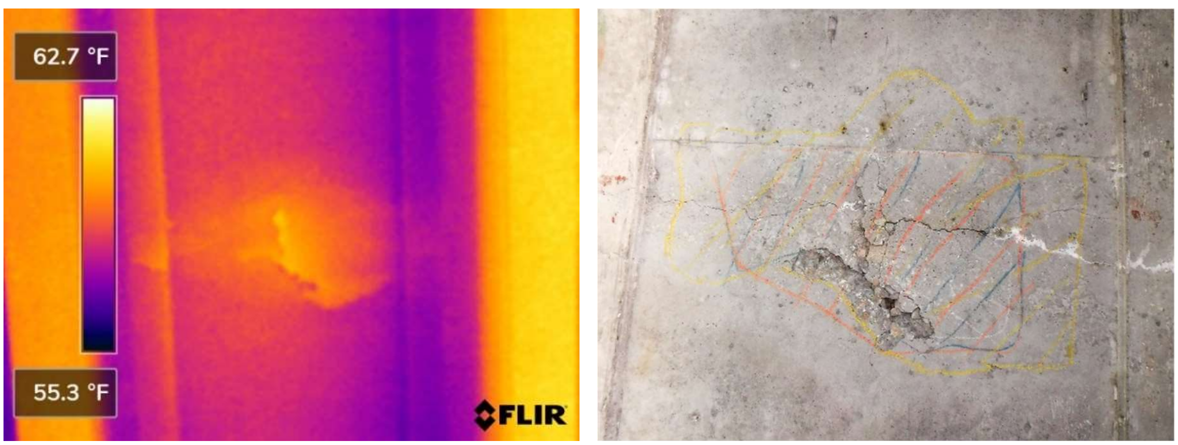


Figure 54 - Delamination with Cracking and Visible Separation

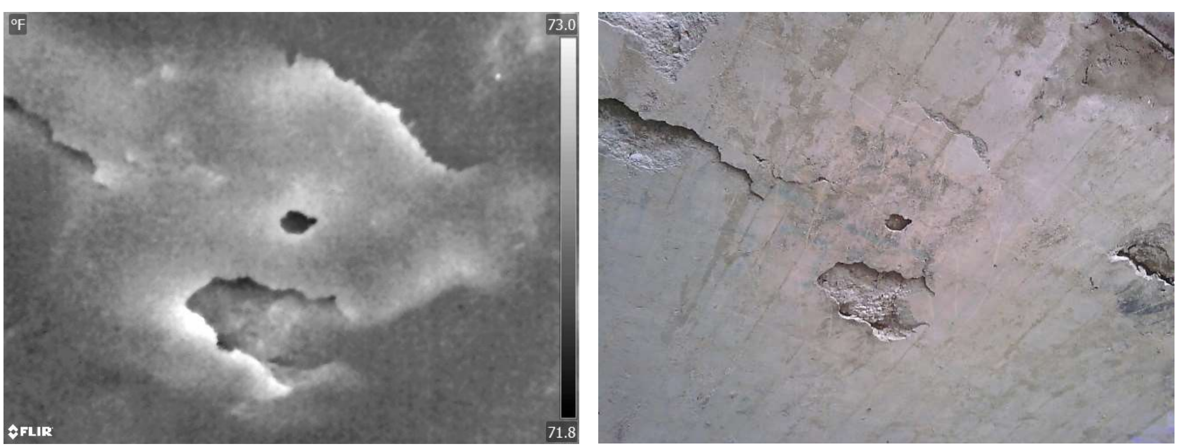


Figure 55 - Delamination with Visible Separation

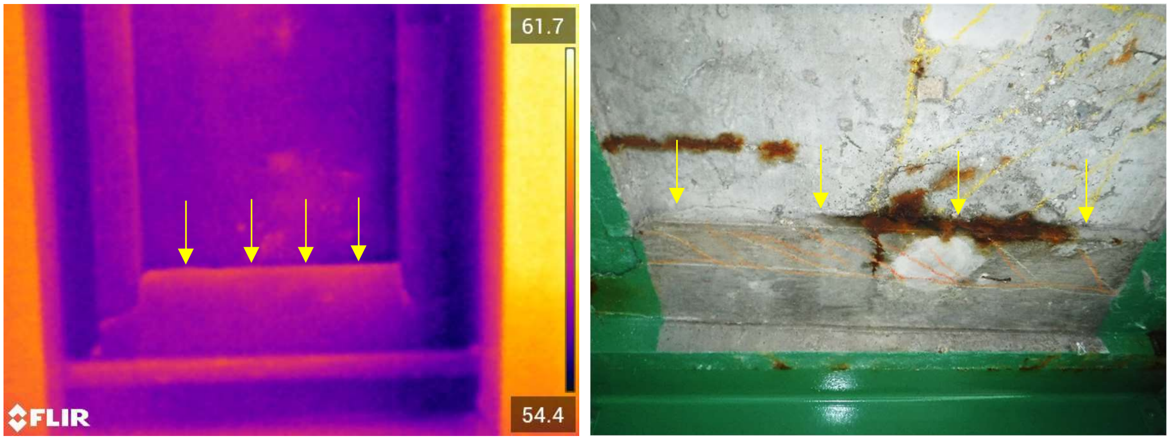


Figure 56 - Delamination along Repair due to Void / Overpour

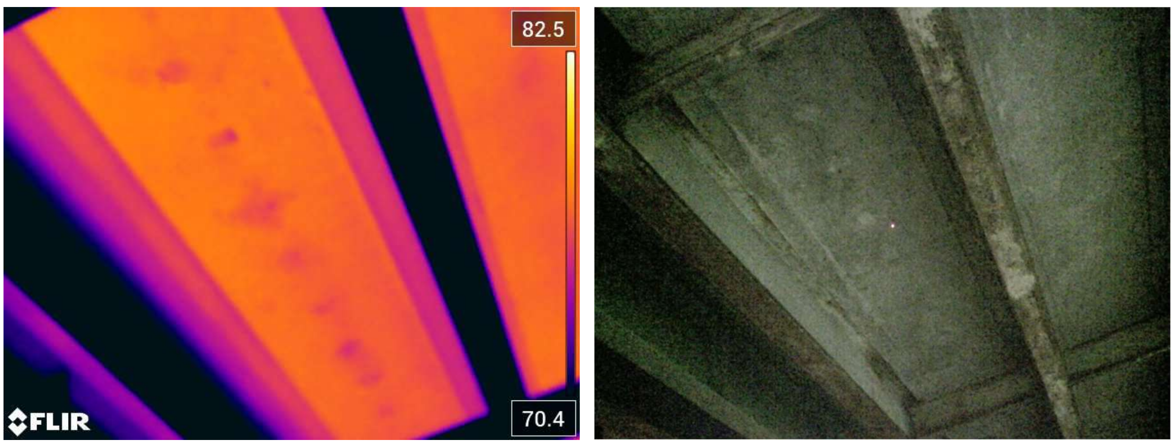


Figure 57 - Sound Patches and Delaminated Patches

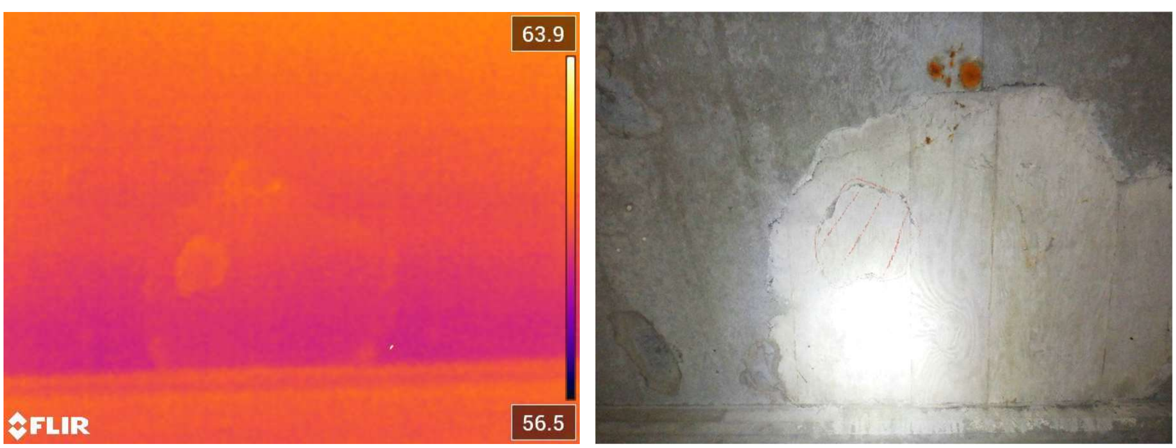


Figure 58 - Delamination within Otherwise Sound Patch

Data Collection and Analysis on Five Bridges

Five bridges were identified for field testing and data collection for this research project. The research project identified one or two spans per bridge to use for this research project. These bridges include:

- Bridge S-17-039 (BIN 4E5) carrying Route 28 in Somerville, MA
- Bridge B-16-033 (BIN 4EU) carrying Morrissey Boulevard in Boston, MA
- Bridge 07001 carrying I-195 Westbound in Providence, RI
- Bridge S-24-083 (BIN 114) carrying I-291 Line K Ramp in Springfield, MA
- Bridge B-16-369 (BIN 4RT) carrying I-90 Eastbound Off-Ramp in Boston, MA

The specific limits of each bridge and general methodology for the field testing are discussed in the individual bridge sections below.

Bridge S-17-039 (BIN 4E5)

Bridge S-17-039 (Bridge Identification Number (BIN) 4E5) is a nine-span structure carrying State Route 28 (McGrath Highway) over Washington Street, turn-arounds, and relief areas in the City of Somerville (Figure 59). The structure carries northbound and southbound traffic with a closed southbound off-ramp at the south end of the bridge. The bridge is composed of simply supported steel multi-beams, some of which frame into steel cross girders and some of which bear on reinforced concrete piers and abutments, supporting a reinforced concrete deck.

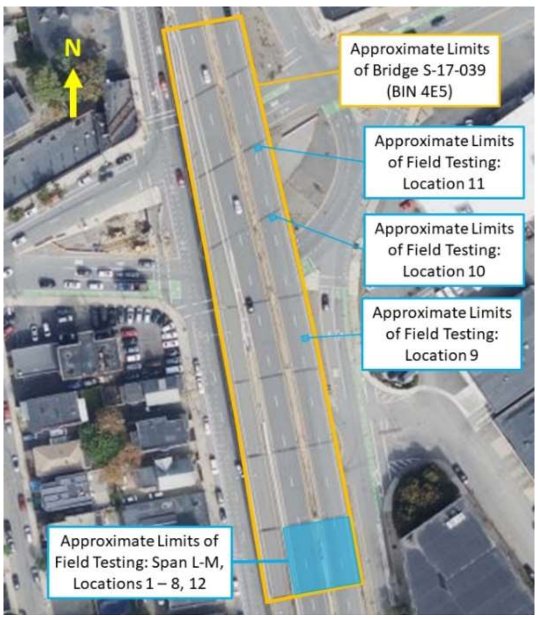


Figure 59 - Layout for BIN 4E5

The bridge was originally built in 1951, rebuilt in 1983, and recently underwent a rehabilitation in 2015. The 2015 rehabilitation included several areas of full depth deck repairs as well as replacement of the deck along the longitudinal joint. According to the January 2020 Routine Inspection Report, the deck condition was rated 6 – Satisfactory. The National Bridge Element (NBE) quantities within the report indicated that Element 12 – Reinforced Concrete Deck had 2,774 square feet (SF) rated as Condition State (CS) 2 for the defect "Delamination/Spall/Patched Area."

There were three approaches for this bridge as follows:

1. Collect repeated thermal imagery of several locations over time to determine optimal weather and temperature conditions for data collection
2. Compare imagery of different handheld thermal cameras and thermal resolutions
3. Survey the underside of the deck using handheld thermal cameras to perform a cross check of the traditional inspection and thermal imagery


Figure 60 - Underside of Span L-M

The first step for this bridge was to perform an inspection of the bridge using traditional methods, specifically hammer sounding for delamination detection. The traditional inspection was performed on 9/3/21 using a 35' bucket truck to access the underside of the deck. The mainline portion of Span L-M (Beams 6 through 16) was selected to receive a hands-on inspection to map existing delaminations and spalls (Figure 60). This span was chosen because it crosses an unoccupied relief area allowing for easy access for repeated data collection.

The traditional inspection was performed without any existing references of previously documented deficiencies. One trained bridge inspector performed an inspection of the underside of the deck. The inspector boomed up in each diaphragm bay to take a close look at the deck and sounded suspect areas (I.e. areas with efflorescence, rust staining, or adjacent to cracking). It should be noted that the deck was not sounded 100% and that the bridge inspector used experience and judgement for the inspection. Identified areas were marked with an outline and hatch marks with lumber crayon (Figure 61). These areas were then documented onto a framing plan of the span. Twenty-six deficiencies consisting of delamination and/or spalling were identified within this span, (Figure 62). The full deficiencies and measurements for the traditional inspection findings sketch can be found in Appendix A-1. The traditional inspection of this span took approximately 2 hours.


Figure 61 - Hatched Delamination

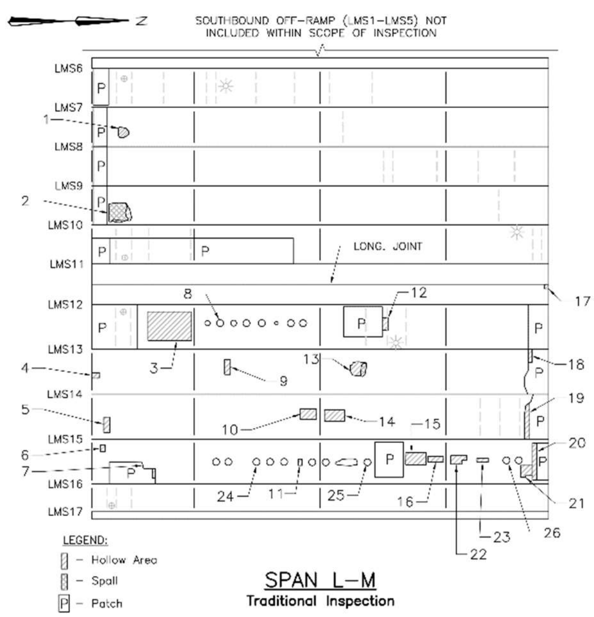


Figure 62 - Span L-M Traditional Inspection Findings

Additionally, the inspectors reviewed the 2020 Routine Inspection report to identify previously identified deficiencies along the underside of the deck outside of Span L-M that could be used for repeated thermal data capture. The list was initially surveyed on foot to eliminate locations that did not include delamination or were directly above or adjacent to the roadways below. The remaining spots received a hands-on inspection using the bucket truck to identify the limits of delamination. The identified delaminations were also marked with an outline and hatch marks and the inspector updated the existing deficiency text description and dimensions.

Figure 63 - Marked Location for Repeated Data Collection

Eleven locations of identified delamination were selected for repeated data collection. In the middle of the data collection, an additional 12th location that was sound was added to serve as a control. In order to ensure consistency with data collection, each location was numbered sequentially with pink spray paint used to mark standing locations during data collection (Figure 63). The locations of delamination were selected to represent varying severity. These locations are shown in Figure 59 and Figure 64. Table 20 on the following page provides a summary of the repeated locations. Measurements and imagery of each repeated location can be found in Appendix A-2.

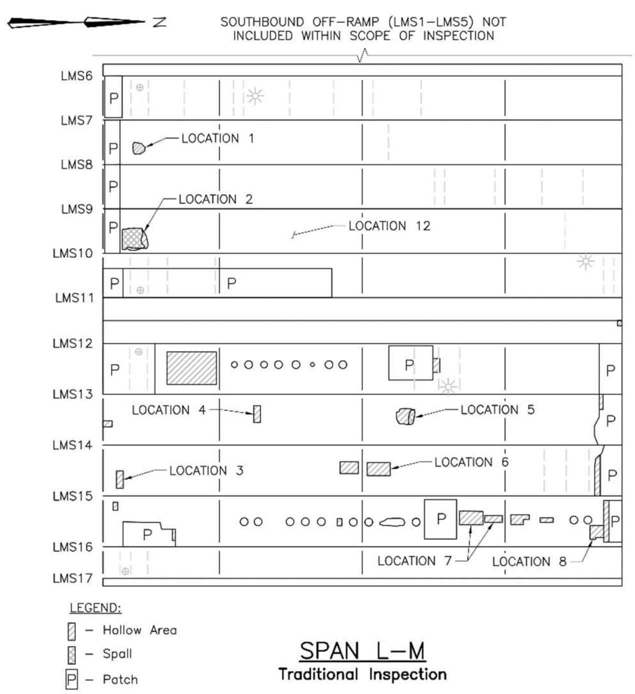


Figure 64 - Span L-M Locations for Data Collection

Table 20 – 4E5: Summary of Repeated Location for Data Collection

Location	Span	Bay	Brief Description
1	L-M	7	Hollow sounding area
2	L-M	9	Spall with adjacent hollow sounding area
3	L-M	14	Minor hollow sounding area
4	L-M	13	Hollow sounding area
5	L-M	13	Spall with adjacent hollow sounding area
6	L-M	14	Minor hollow sounding area
7	L-M	15	Hollow sounding area containing hollow patches
8	L-M	15	Hollow sounding area and hollow sounding previous repair
9	P-R	13	Spall with adjacent hollow sounding area
10	R-S	13	Hollow sounding area
11	S-T	11	Hollow sounding area
12	L-M	9	None

These locations were used to perform consistent repeated data capture. AECOM performed 16 site visits between 9/13/21 and 10/7/21 in order to capture thermal data at different temperatures, times of day, and weather conditions. The repeated data capture was performed for all locations, with exceptions for technical issues with the cameras or skipping locations at times of days where the camera would end up looking towards the sun which would damage the sensor. This repeated data collection was performed using the Flir C5, Flir E8, Flir E86, and Flir E96. The Fluke TiX580 and Seek Shot Pro were used to perform limited data collection in order to include some data from other manufacturers for comparison. Refer to Appendix A-3 for the captured thermal imagery for each location. It should be noted that the contact sheets used for portraying the images did reduce the image quality. The thermal imagery within this appendix is named as follows: Camera_Location_Field Visit_Original Image Name. For example, E8_Loc02_01_FLIR0032 is the image taken with the Flir E8 at Location 2 during the first data set.

In general, the thermal cameras were left on the default settings and input parameters (i.e. emissivity and reflected temperature) were not modified to attempt to obtain true temperature values. True temperature values are not required for this application since the identification of concrete delamination is based on temperature differences between the concrete and not on the specific temperature itself.

Determination of Optimal Conditions for Data Collection

The Flir E96 thermal data was used to determine the optimal weather and atmospheric conditions for data collection. The weather temperature and conditions for each field visit were documented in Appendix A-4. The weather data was taken from the General Edward Lawrence Logan International Airport Weather Station, which is approximately 4 miles from the bridge site.

Two AECOM staff members reviewed the imagery for the E96 camera. The data was compiled into charts to identify each location as a simple yes or no. In cases, where no thermal image was taken, it was identified as not applicable (n/a). The two sets of data were compiled to identify which data sets had the most identified delaminations between the two AECOM staff members. The maximum number possible was 24 (11 delaminations and 1 sound control location with two AECOM staff). Refer to Appendix A-5 for charts identifying which delaminations were identified by each AECOM staff member and Table 21 on the following page for a summary chart.

Table 21 – 4E5: Summary of Identification of Delaminations

Data Set	Staff 1			Staff 2			Combined Totals		
	# Yes	# No	# n/a	# Yes	# No	# n/a	# Yes	# No	# n/a
1	10	1	1	10	1	1	20	2	2
2	1	10	1	4	7	1	5	17	2
3	3	8	1	4	7	1	7	15	2
4	10	1	1	9	2	1	19	3	2
5	9	2	1	9	2	1	18	4	2
6	6	5	1	8	3	1	14	8	2
7	7	4	1	7	4	1	14	8	2
8	6	5	1	6	5	1	12	10	2
9	0	11	1	1	10	1	1	21	2
10	4	7	1	6	5	1	10	12	2
11	3	8	1	4	7	1	7	15	2
12	10	1	1	11	0	1	21	1	2
13	4	7	1	5	6	1	9	13	2
14	3	8	1	5	6	1	8	14	2
15	5	6	1	3	8	1	8	14	2
16	11	0	1	11	0	1	22	0	2
17	11	0	1	11	0	1	22	0	2
18	5	6	1	4	7	1	9	13	2
19	0	12	0	3	8	0	3	20	0
20	0	12	0	3	9	0	3	21	0
21	11	1	0	11	1	0	22	2	0
22	11	1	0	11	1	0	22	2	0
23	11	1	0	11	1	0	22	2	0
24	3	9	0	4	8	0	7	17	0
25	3	9	0	2	10	0	5	19	0
26	3	9	0	4	8	0	7	17	0
27	10	1	1	8	3	1	18	4	2
28	10	2	0	8	4	0	18	6	0
29	11	1	0	11	1	0	22	2	0
30	10	2	0	10	2	0	20	4	0
31	11	1	0	8	4	0	19	5	0
32	3	9	0	8	4	0	11	13	0

Data sets with approximately 90% (19 of 22) identified delaminations were considered to be successful for data collection. Eleven data sets met this criterion; specifically, 1, 4, 12, 16, 17, 21, 22, 23, 29, 30, and 31. Refer to Table 22 and Table 23 for Temperature and Atmospheric Conditions for these data sets.

Table 22 – 4E5: Summary of Temperature during Most Successful Data Collection Periods

Data Set	Time	Temp. at Time of Testing (°F)	Temp. 1 Hour Prior (°F)	Temp. 2 Hours Prior (°F)	Temp. 3 Hours Prior (°F)	Temp. 6 Hours Prior (°F)
1	1:40 to 2:02 pm	82	79	78	78	70
4	10:38 to 10:46 am	83	82	80	76	71
12	7:49 to 7:55 pm	64	64	65	67	71
16	7:47 to 7:55 pm	70	72	72	76	81
17	8:45 to 8:50 pm	70	70	72	72	80
21	6:52 to 6:59 pm	65	65	66	68	73
22	7:34 to 7:51 pm	65	65	66	68	72
23	7:59 to 8:06 pm	67	68	69	71	75
29	9:36 to 9:51 am	63	59	55	52	51
30	10:59 to 11:05 am	66	64	61	57	51
31	9:24 to 9:45 am	64	63	62	59	56

Based on the temperatures for these data sets, it can be inferred that a temperature change of at least 7 degrees Fahrenheit over a 6-hour period is necessary for detection of delamination. These data sets have between 7- and 15-degree temperature swings over a 6-hour period.

The time of day and whether the temperature is increasing or decreasing does not seem to have a significant impact. Five of these data sets have increasing temperatures and six of these data sets have decreasing temperatures.

Table 23 – 4E5: Summary of Atmospheric Conditions for Most Successful Data Collection Periods

Data Set	Dew Point (°F)	Humidity (%)	Wind Speed (mph)	Last Rainfall
1	57	45	9	6 hours prior
4	71	67	13	2 days prior
12	55	72	5	16 hours prior
16	66	87	13	7 hours prior
17	66	87	10	8 hours prior
21	61	87	7	Rain during data collection
22	61	87	7	Rain during data collection
23	46	47	13	13 hours prior
29	45	50	15	3 days prior
30	44	45	10	3 days prior
31	52	64	0	30 hours prior

The dew point, humidity, and wind speed did not appear to have an impact on successful delamination detection. The values range greatly during within these data sets. These data sets were primarily collected within 72 hours of rainfall. It should be noted that in several data sets, the delaminated areas did not appear as anticipated. Generally, during morning hours, delaminations will heat up quicker and be warmer than the adjacent deck. However, in several data sets, delaminated areas actually were cooler than the adjacent deck during the morning hours. It is believed that this was caused by water collecting and being trapped within the deck at these locations. Since destructive methods were not included within the scope of the research project, it was unable to be confirmed if water was trapped in the deck at these locations.

Comparison of Different Thermal Resolutions

The thermal imagery taken repeatedly at the locations provides direct comparison imagery for the different Flir thermal cameras. The intent was to compare the imagery based on a real-world situation, in this case, an inspector surveying the bridge deck from the ground below. The quality of the thermal imagery in terms of detail and quality will not be able to be directly compared, as the distances from the object being captured were not adjusted to compensate for the differences in field of view.

For this activity, the captured imagery for the E96, E86, E8, and C5 cameras was reviewed by one AECOM staff member to identify whether the delamination was visible within each thermal image. The data was compiled into charts to identify each location as a simple yes or no. In cases, where no thermal image was taken, it was identified as not applicable (n/a). Refer to Appendix A-6 – Identification of Delamination charts. For the E96 camera, only one of the AECOM staff member results were used. The results of the identification are included as Tables 24 and 25 below.

Table 24 – 4E5: Comparison of Delamination Identification by Location

Camera	Totals per Location	Location										
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
E96	Yes (#)	17	20	12	20	18	15	24	14	23	21	21
	Yes (%)	53.1%	62.5%	37.5%	62.5%	56.3%	46.9%	75.0%	45.2%	71.9%	65.6%	65.6%
	No (#)	15	12	20	12	14	17	8	17	9	11	11
	No (%)	46.9%	37.5%	62.5%	37.5%	43.8%	53.1%	25.0%	54.8%	28.1%	34.4%	34.4%
E86	Yes (#)	11	12	10	14	15	11	12	11	16	18	18
	Yes (%)	52.4%	57.1%	45.5%	63.6%	68.2%	50.0%	54.5%	50.0%	72.7%	81.8%	81.8%
	No (#)	10	9	12	8	7	11	10	11	6	4	4
	No (%)	47.6%	42.9%	54.5%	36.4%	31.8%	50.0%	45.5%	50.0%	27.3%	18.2%	18.2%
E8	Yes (#)	9	12	7	12	11	9	11	6	10	14	15
	Yes (%)	45.0%	57.1%	33.3%	57.1%	52.4%	42.9%	52.4%	30.0%	47.6%	66.7%	71.4%
	No (#)	11	9	14	9	10	12	10	14	11	7	6
	No (%)	55.0%	42.9%	66.7%	42.9%	47.6%	57.1%	47.6%	70.0%	52.4%	33.3%	28.6%
C5	Yes (#)	7	6	6	8	10	8	6	6	10	10	10
	Yes (%)	36.8%	31.6%	31.6%	42.1%	52.6%	42.1%	31.6%	31.6%	55.6%	55.6%	55.6%
	No (#)	12	13	13	11	9	11	13	13	8	8	8
	No (%)	63.2%	68.4%	68.4%	57.9%	47.4%	57.9%	68.4%	68.4%	44.4%	44.4%	44.4%

The percentage in the table are adjusted to account for any n/a identification in the charts. Location 12 is omitted because no delamination was present at that location.

Table 25 – 4E5: Summary of Delamination Identification by Camera

Summary of Delamination Identification					
Camera	Total # of Data Points	Total Delamination Identified		Total Delamination Not Identified	
		Qty	%	Qty	%
E96	351	205	58.4%	146	41.6%
E86	240	148	61.7%	92	38.3%
E8	229	116	50.7%	113	49.3%
C5	206	87	42.2%	119	57.8%

The E86 has the highest percentage of delaminations identified followed by the E96, E8, and C5. It is important to note that the data does not provide an even comparison of the thermal cameras. Each camera had a different number of data collection periods. The Flir E96 was used to collect imagery more frequently, often with data collection at the beginning and end of each field visit. This could have caused more data to be captured during less ideal periods compared to the other thermal cameras. Additionally, the Flir E86 and E96 were equipped with different lenses. The E96 used the 42-degree (10 mm) lens and the E86 used the 24-degrees (17 mm) lens. The E86 lens provides a more telephoto or zoomed in view, which would provide higher quality imagery of the delamination and may have improved the likelihood of delamination detection.

In addition to the data provided in this section above, some comparison imagery was developed for visual comparison. Refer to Appendix A-7 – Comparison of Camera Imagery. Twelve sets of images; one for each location; were compiled randomly from the collected data. The imagery includes one set based on the automatic camera settings and another set based on manual settings to try to get similar temperature spans in the imagery.

Cross Check of Traditional Inspection Results with Thermal Imagery

During the field visit the evening of 9/26/21, a thermal survey of the deck was performed using the traditional field inspection deficiency sketch in order to check for additional delaminations that may have been missed. Areas of interest, meaning locations with temperature differentials, were marked on the sketch. This was limited to areas that did not correspond with identified delaminations; data was not collected for the already identified locations. Seventeen additional areas of interest, labeled A through Q, were identified.

A follow up inspection using a bucket truck was performed on 10/25/2021. The intent of the follow up inspection was to check the areas of interest that were identified from thermal survey of the underside of the bridge. See Figure 65 for the location of these areas of interest. Only the areas of interest were checked, and hammer sounded to ascertain whether the areas of interest were delamination that were missed during the traditional inspection. Refer to Appendices A-8-1 and A-8-2 for the sketch of the thermal survey and follow up inspection and for thermal and visual imagery of each area of interest. The results are summarized in Table 26.

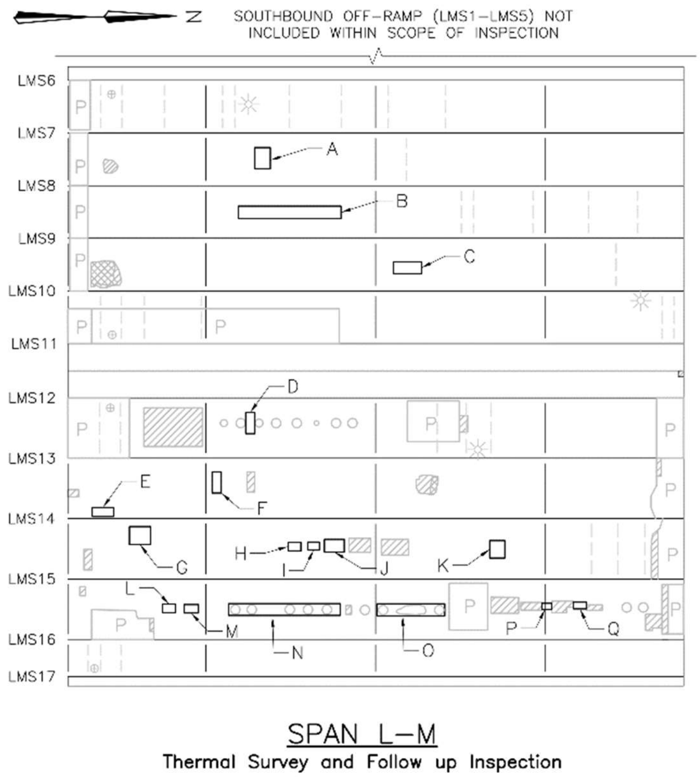


Figure 65 - Areas of Interest from Thermal Survey

Table 26 – 4E5: Follow Up Inspection Findings

Area of Interest	Follow up Insp. Description	Comment(s)
A	No Delamination Found	No apparent cause for differential
B	No Delamination Found	No apparent cause for differential
C	No Delamination Found	No apparent cause for differential
D	Minor delamination	
E	Delamination in deck and haunch	
F	No Delamination Found	No apparent cause for differential
G	No Delamination Found	Minor discoloration of deck at location
H	No Delamination Found	Discoloration and poor consolidation at location
I	No Delamination Found	Discoloration and poor consolidation at location
J	Minor delamination	
K	Minor delamination	
L	No Delamination Found	Patches, discoloration, and poor consolidation at location
M	No Delamination Found	Patches, discoloration, and poor consolidation at location
N	Minor delamination with hollow sounding patches	
O	Minor delamination	
P	Minor delamination	
Q	Minor delamination	

Nine of the areas of interest were false positives with no delamination present; some of these temperature differentials may have been caused by discoloration and poor consolidation of the concrete but not all false positives had an obvious cause (Figure 66). Seven areas of interest were minor delaminations that were hard to distinguish by sounding. Some of these areas may not have been true delaminations caused by corrosion of rebar but caused by poor quality repairs as several were located adjacent to patches, contained hollow sounding patches, and/or had poor consolidation (Figure 67). One location, area of interest E, was a delamination that likely should have been identified during the traditional inspection (Figure 68). The initial traditional inspection and follow up inspection findings are compiled in Appendix A-8-3. The compiled findings have thirty-five deficiencies, which is an increase from the twenty-six identified during the initial traditional inspection.

Figure 66 - False Positive from Thermal Survey

Figure 67 - Minor Delamination from Thermal Survey

Figure 68 - Delamination from Thermal Survey

Bridge B-16-033 (BIN 4EU)

Figure 69 - Layout of BIN 4EU

Bridge B-16-033 (BIN 4EU) is a five-span bridge which carries Morrissey Boulevard over Dorchester Bay in the City of Boston (Figure 69). The bridge is comprised of four reinforced concrete arch spans with a triple double-leaf bascule main span. The arch spans consist of longitudinal and transverse spandrel walls forming a spandrel vault that supports a reinforced concrete deck with bituminous concrete wearing surface. The bridge was originally built in 1927, widened in 1955, rebuilt in 1978, and rehabilitated in 2002.

According to the June 2021 Routine Inspection Report, the arch condition was rated 4 – Poor, which was governed by the condition of the underside of the arches. The National Bridge Element (NBE) quantities within the report indicated that Element 144 – Reinforced Concrete Arch (total quantity 280 linear feet (LF)) had 26 LF in Condition State 2 and 254 LF in Condition State 3 for delamination/spall/patched area.

The approach for this bridge was as follows:

1. Determine whether handheld thermal cameras could verify previous inspection findings
2. Review weather conditions and temperatures against the effectiveness of the thermal data

Verification of Previous Inspection Findings with Thermal Imagery

For the purposes of this research project, the field testing of this bridge was limited to Span 5, which is in the tidal range and accessible during low tide (Figure 70). The vertical clearance beneath this span ranges from approximately 15’-0” along the fascia to 8’-0” near midspan. Since the bridge was recently inspected in June 2021 and included a detailed inspection of the underside of the arch, a full hands-on inspection was not performed of this area. The field testing was for this bridge performed on 9/23/2021. Existing limits of delamination previously marked along the underside of the bridge were spot checked with hammer sounding in several locations to verify that the drawn limits matched the actual limits of the delamination. The Flir E96 and Flir E8 were each used to collect two sets of data. Table 27 provides approximate times of data collection.

Figure 70 – East Elevation of Span 5

Table 27 – 4EU: Times for Data Collection

Data Set	Camera	Start Time	End Time
First	E8	8:19 am	8:41 am
Second	E8	9:40 am	9:53 am
First	E96	7:35 am	8:14 am
Second	E96	9:18 am	9:38 am

The existing underside of arch sketch for span 5 from the 2019 routine inspection report was used as a starting point in the field. Existing deficiencies were reviewed to establish locations for the collection of thermal data. Sixteen locations of delamination were chosen for data collection (Figure 71).

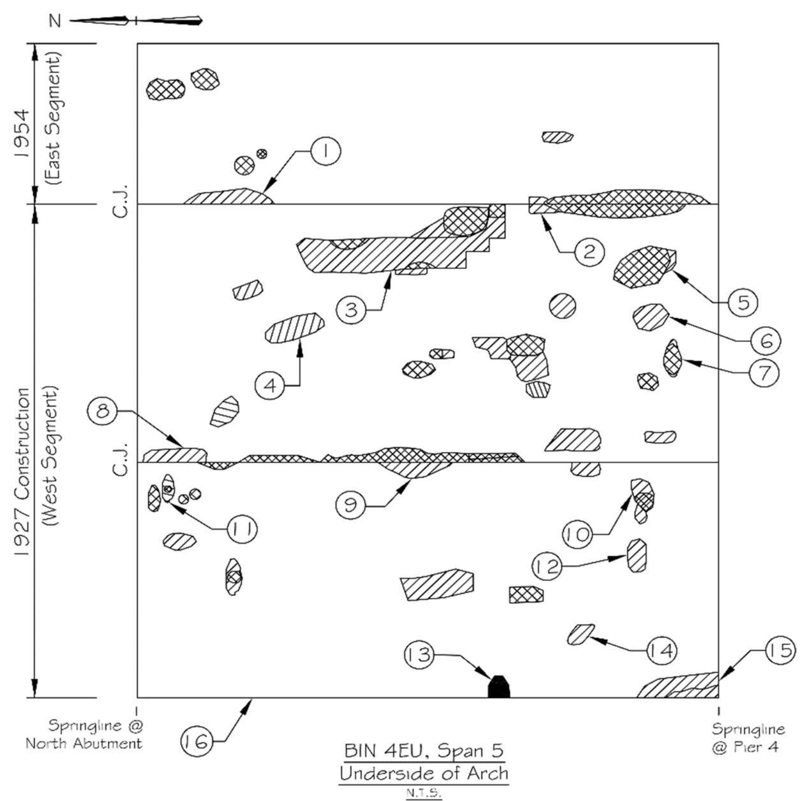


Figure 71 - Underside of Arch for Span 5

The second data set for each camera was post processed using Flir Tools to see if adjusting the color palette and thermal span would increase the detection capabilities. The thermal imagery for the Flir E8 and Flir E96 included as part of Appendix B-1 and Appendix B-2, respectively. The appendix includes one page for each deficiency with the first data set thermal image, first data set visual image, second data set thermal image, and post processed second data set thermal image. The thermal imagery within this appendix is named as follows: Camera_Data Set_Deficiency Number_Type of Image_Original Image Name. The type of image is either IR for a thermal image or RGB for visual image. The post processed images include the letter p following the data set number. For example, E8_02p_01_FLIR0032 is the post processed image taken with the Flir E8 at Deficiency 1 during the second data set.

The thermal imagery for each data set was reviewed to identify whether the delamination was able to be detected from the imagery and further classified as either detected, partially detected, or not detected. These findings are included as Table 28. A summary table is included as Table 29. For the purposes of this report, these terms are defined as the following:

- Identified = The delamination roughly matches the limits identified during the traditional inspection
- Partially Identified = The delamination is visible but is noticeably smaller than the limits identified during the traditional inspection
- Not Identified = No delamination was identified

Table 28 – 4EU: Identification of Delamination by Deficiency

Deficiency Number	Flir E8						Flir E96					
	First Data Set Automatic Settings		Second Data Set Automatic Settings		Second Data Set Post Processed		First Data Set Automatic Settings		Second Data Set Automatic Settings		Second Data Set Post Processed	
	IR Image #	Delam. Detected?	IR Image #	Delam. Detected?	IR Image #	Delam. Detected?	IR Image #	Delam. Detected?	IR Image #	Delam. Detected?	IR Image #	Delam. Detected?
1	1404	No	1482	Yes	1482	Yes	1685	Yes	1749	Yes	1749	Yes
2	1410	No	1492	Yes	1492	Yes	1695	No	1753	Yes	1753	Yes
3	1416	No	1486	Yes	1486	Yes	1691	Yes	1767	Yes	1767	Yes
4	1422	No	1504	Yes	1504	Yes	1713	Yes	1773	Yes	1773	Yes
5	1430	Yes	1494	Yes	1494	Yes	1697	No	1755	Yes	1755	Yes
6	1432	No	1496	Yes	1496	Yes	1699	No	1759	Yes	1759	Yes
7	1434	No	1498	Yes	1498	Yes	1701	No	1783	Yes	1783	Yes
8	1444	No	1508	Yes	1508	Yes	1717	Yes	1789	Yes	1789	Yes
9	1446	No	1520	Yes	1520	Yes	1721	Yes	1799	Yes	1799	Yes
10	1452	No	1514	Yes	1514	Yes	1725	No	1803	Yes	1803	Yes
11	1470	No	1522	Yes	1522	Yes	1743	No	1791	Yes	1791	Yes
12	1454	No	1516	No	1516	No	1727	No	1805	Partial	1805	Partial
13	1462	Yes	1538	Yes	1538	Yes	1737	No	1811	Yes	1811	Yes
14	1456	No	1532	Partial	1532	Partial	1731	No	1807	Partial	1807	Partial
15	1458	Yes	1536	No	1536	No	1733	Yes	1809	Yes	1809	Yes
16	1474	No	1540	Yes	1540	Yes	1745	Yes	1815	Yes	1815	Yes

Table 29 – 4EU: Summary of Findings

Camera	Data Set	# Detected	% Detected	# Partially Detected	% Partially Detected	# Not Detected	% Not Detected
E8	1st	3	18.8	0	0.0	13	81.3
	2nd	13	81.3	1	6.3	2	12.5
	2nd - Processed	13	81.3	1	6.3	2	12.5
E96	1st	7	43.8	0	0.0	9	56.3
	2nd	14	87.5	2	12.5	0	0.0
	2nd - Processed	14	87.5	2	12.5	0	0.0

The E96 was able to successfully identify more delaminations for both the first and second data collection periods. For both the E96 and E8 data sets, the post processing did not increase the ability to detect delamination. However, it should be noted that the second data set provided positive results with easily identified delamination. Post process might improve detection ability for data collected during less than ideal periods.

Review of Weather Conditions and Temperatures

The weather conditions during the second data set yielded good results with both cameras detected over 80% of the delaminations. The temperature for these data sets had an approximately 10-degree increase starting 6 hours before data collection. Table 30 provides the Time, Temperature, and Atmospheric Conditions during Data Collection.

Table 30 - 4EU: Time, Temperature, and Atmospheric Conditions

Camera	E96	E8	E96	E8
Date	9/23/2021	9/23/2021	9/23/2021	9/23/2021
Name	First Run	First Run	Second Run	Second Run
Start Time	7:35 AM	8:19 AM	9:18 AM	9:39 AM
End Time	8:14 AM	8:41 AM	9:38 AM	9:53 AM
Temp at Start (°F)	72	74	78	78
Temp at End (°F)	72	76	78	79
Avg. Temp. (°F)	72	75	78	78.5
Temp 6 Hr Prior (°F)	68	68	68	68
Δ Temp 6 Hr (°F)	4	7	10	10.5
Temp 3 Hr Prior (°F)	68	68	70	70
Δ Temp 3 Hr (°F)	4	7	8	8.5
Temp 2 Hr Prior (°F)	69	70	71	72
Δ Temp 2 Hr (°F)	3	5	7	6.5
Temp 1 Hr Prior (°F)	70	72	74	76
Δ Temp 1 Hr (°F)	2	3	4	2.5
Dew Point (°F)	67	67	67	66
Humidity (%)	84	79	79	64
Wind Speed (mph)	8	9	12	13
Date of Last Rainfall	9/19/2021	9/19/2021	9/19/2021	9/19/2021

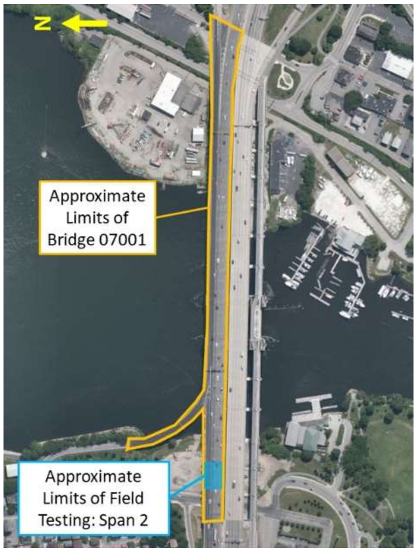


Figure 72 - Layout of Bridge 07001

Bridge 07001 (Washington Bridge)

Bridge 07001, more commonly referred to as Washington Bridge, is a twenty-one-span bridge which carries I-195 Westbound over the Seekonk River and local streets in the City of Providence (Figure 72). The bridge has a few different types of superstructures but is primarily comprised of post-tensioned concrete cantilevers with prestressed concrete drop-in girders. The bridge was built in 1969, rebuilt in 1998, and partially rehabilitated in 2018.

According to the July 2020 Inspection Report, the superstructure was rated 4 – Poor. The National Bridge Element (NBE) quantities within the report indicated that Element 109 Prestressed Open Concrete Girder/Beam (total quantity 14,543 LF) has 1,290 LF in CS2, 1,468 LF in CS3, and 135 LF in CS4. Element 12 – Reinforced Concrete Deck (total quantity 142,880) has 3,572 square feet in CS2, and 714 square feet in CS3.

The approach for this bridge was as follows:

1. Determine whether handheld thermal cameras could verify previous inspection findings
2. Review weather conditions and temperatures against the effectiveness of the thermal data

Verification of Previous Inspection Findings with Thermal Imagery

Figure 73 - Underside of Span 2

For the purposes of this research project, the field testing of this bridge was limited to Span 2, which spans an unoccupied relief area (Figure 73). This included the reinforced concrete bridge deck, post-tensioned concrete cantilevers, and prestressed concrete drop-in beams. The reinforced concrete fascia arch panels were not included due limited accessibility to the interior faces based on the bridge geometry and adjacent cantilevers and beams. The traditional inspection was performed using a 35' bucket truck on 9/28/21.

Previous inspection deficiency charts were used as a starting point in the field and updated during the traditional inspection (refer to Appendix C-1). Deficiencies were reviewed to establish locations for the collection of thermal data with locations of spalls, cracking, and obscured delaminations removed so that only delaminations remained. Twenty-two delaminations along the bridge deck and cantilevers were used for data collection. No locations of delamination were identified along the drop-in beams.

The Flir E96 was used to collect two sets of data on 10/7/21. Table 31 provides approximate times of data collection. The second data set was captured with the E96 outfitted with a 24-degree (17mm) lens instead of the 42-degree (10 mm) wide angle lens that was used for the first data set. This was done because the wide-angle lens did not provide adequate detail for the vertical faces at the ends of the cantilevers.

Table 31 – 07001: Time of Data Collection

Data Set	Camera	Start Time	End Time
First	E96	9:18 am	9:54 am
Second	E96	10:00 am	10:13 am

The thermal imagery for the Flir E96 is included as part of Appendix C-2. The appendix includes one page for each deficiency with the first data set visual image, close-up of the deficiency from the traditional inspection, first data set thermal image, second data set thermal image, second data post processed in Flir Tools, and second data post processed in Adobe Lightroom thermal image. The thermal imagery within this appendix is named as follows: Bridge_Camera_Data Set_Deficiency Number_Type of Image_Original Image Name. The type of image is either IR for a thermal image or RGB for visual image. The post processed images include either p1 (for Flir Tools processing) or p2 (for Flir Tools and Lightroom processing) following the type of image. For example, 07001_E96_02_03_IRp2_FLIR0032 is the thermal image processed in Flir Tools and Lightroom taken with the Flir E96 at Deficiency 3 during the second data set.

The thermal imagery for each data set was reviewed to identify whether the delamination was able to be detected from the imagery and further classified as either detected, partially detected, or not detected. These findings are included as Table 32. Summary tables are included as Tables 33 and 34 on the follow page.

Table 32 – 07001: Identification of Delamination by Deficiency

Deficiency # for Thermal Survey	First Data Set Automatic Settings		Second Data Set Automatic Settings		Second Data Set Post Processed (Flir)		Second Data Set Post Processed (Flir + Lightroom)	
	Delam. Identified with IR?	IR Image #	Delam. Identified with IR?	IR Image #	Delam. Identified with IR?	IR Image #	Delam. Identified with IR?	IR Image #
1	No	202	Partial	256	Partial	256	Partial	256
2	No	226	No	280	No	280	No	280
3	No	204	No	258	No	258	No	258
4	No	206	Partial	260	Yes	260	Yes	260
5	No	208	Yes	262	Yes	262	Yes	262
6	No	210	Partial	264	Partial	264	Partial	264
7	No	238	Yes	290	Yes	290	Yes	290
8	No	238	Partial	290	Partial	290	Partial	290
9	No	228	No	282	No	282	No	282
10	No	244	No	294	No	294	No	294
11	Partial	242	Partial	292	Partial	292	Partial	292
12	No	214	Partial	268	Partial	268	Partial	268
13	No	212	No	266	No	266	No	266
14	No	234	No	284	No	284	No	284
15	No	220	Yes	274	Yes	274	Yes	274
16	Yes	218	Yes	272	Yes	272	Yes	272
17	No	246	Partial	296	Partial	296	Partial	296
18	Partial	224	Partial	278	Partial	278	Partial	278
19	No	222	Partial	276	Partial	276	Partial	276
20	No	232	No	288	No	288	No	288
21	Partial	236	Yes	286	Yes	286	Yes	286
22	No	250	No	300	No	300	No	300

The second data set was processed in two different ways to see if additional manipulation of the data could improve the thermal imagery and increase detection. The first method of post processing included adjusting the color palette and thermal span. The second method of post processing built on the first and ran the post processed data through Adobe Lightroom to adjust the image. The color adjustments in Lightroom varied for each image; the adjustments included a variation of increase or decreasing the image contrast, highlights, shadows, whites, and blacks. The specific adjustments varied for each image. Both processed images are included in Appendix C-2.

Table 33 – 07001: Summary of Findings

Data Set	# Detected	% Detected	# Partially Detected	% Partially Detected	# Not Detected	% Not Detected
1st	1	4.5	3	13.6	18	81.8
2nd	5	22.7	9	40.9	8	36.4
2nd - Processed * (FL)	6	27.3	8	36.4	8	36.4
2nd - Processed * (FL, LR)	6	27.3	8	36.4	8	36.4

* *FL = Flir Tools, LR = Adobe Lightroom*

Table 34 – 07001: Summary of Findings by Element

Data Set	Element	# Detected	% Detected	# Partially Detected	% Partially Detected	# Not Detected	% Not Detected
1st	Deck	1	9.1	1	9.1	9	81.8
1st	Cantilever	0	0.0	2	18.2	9	81.8
2nd	Deck	3	27.3	5	45.5	3	27.3
2nd	Cantilever	2	18.2	2	18.2	7	63.6
2nd - Processed* (FL)	Deck	4	36.4	4	36.4	3	27.3
2nd - Processed* (FL)	Cantilever	2	18.2	2	18.2	7	63.6
2nd - Processed* (FL, LR)	Deck	4	36.4	4	36.4	3	27.3
2nd - Processed* (FL, LR)	Cantilever	2	18.2	2	18.2	7	63.6

* *FL = Flir Tools, LR = Adobe Lightroom*

Neither data collection period was very successful in identifying delaminations. The limited effectiveness is partially due to the bridge configuration and geometry created a challenging environment for the thermal data collection. The post-tension concrete cantilevers have embedded anchorage plates at the top of the vertical faces which had several locations of spalling and delamination due to corrosion of the anchorage plates (Figure 74). These areas were difficult to observe from the ground with the Flir E96. The delaminations along the underside of the deck were more likely to be identified than those along the cantilevers.

Figure 74 - Delamination at Top of Vertical Face of Cantilever

Post processing the data did not significantly change the results. As previously discussed, this is partially due to the bridge configuration and geometry. Only one deficiency had improved detection when processed in Flir Tools. The post processing in Adobe Lightroom did not improve detection of delamination for this data set although the adjustments to the image contrast did make the delaminations easier to identify in each image.

Review of Weather Conditions and Temperatures

The weather conditions during the data collection did not yield very positive results despite the larger temperature swing (approximately 16.5 to 18 degrees starting 6 hours prior to data collection). The delamination detection was only able to detect, either fully or partially, approximately 64% of the delamination. Table 35 provides the Time, Temperature, and Atmospheric Conditions during Data Collection.

Table 35 – 07001: Time, Temperature, and Atmospheric Conditions during Data Collection

Date	10/7/2021	10/7/2021
Start Time	9:18 AM	10:00 AM
End Time	9:54 AM	10:13 AM
Temp at Start (°F)	68	71
Temp at End (°F)	71	71
Avg. Temp. (°F)	69.5	71
Temp 6 Hr Prior (°F)	53	53
Δ Temp 6 Hr (°F)	16.5	18
Temp 3 Hr Prior (°F)	54	54
Δ Temp 3 Hr (°F)	15.5	17
Temp 2 Hr Prior (°F)	57	60
Δ Temp 2 Hr (°F)	12.5	11
Temp 1 Hr Prior (°F)	63	66
Δ Temp 1 Hr (°F)	6.5	5
Dew Point (°F)	57	57
Humidity (%)	61	61
Wind Speed (mph)	0	0
Date of Last Rainfall	10/5/2021	10/5/2021

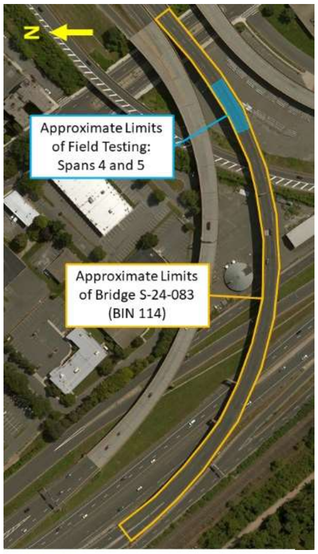


Figure 75 - Layout of BIN 114

Bridge S-24-083 (BIN 114)

S-24-083 (BIN 114) is a two-lane ramp (Ramp K) that carries traffic from I-91 Southbound to I-291 Eastbound over Main Street, a parking lot area, various ramps, I-91, and other relief in the City of Springfield (Figure 75). The bridge is an eighteen-span structure consisting of steel stringers with built-up welded cross girders supporting a reinforced concrete deck with asphalt wearing surface.

The bridge was originally built in 1969, rehabilitated in 1998 which included demolition and replacement of the existing traffic barriers, and had structural steel repairs performed in 2000. According to the August 2021 Routine Inspection report, the deck condition was rated 5 – Fair. The NBE quantities within the report indicated that Element 12 – Reinforced Concrete Deck had 700 square feet rated as Condition State 2 for the defect "Delamination/Spall/Patched Area."

This bridge was selected based on the amount of concrete deterioration to the deck and pier columns, vertical clearance of the bridge (approximately 35 feet to 40 feet for the selected spans), and ease of access since portions of the bridge span MassDOT lots. Spans K4 and K5 were chosen because they span an unused parking lot (Figure 76). This allowed for easy access to the site and prevented unauthorized pedestrians from interfering with the operation. The Pier K3 South Column is also located within this vicinity.

The approach for this bridge follows:

1. Perform UAV-IR survey to identify delaminations along the underside of the deck for two spans and one of the pier columns with no pre-existing deficiency locations for comparison with traditional inspection findings.
2. Review weather conditions and temperatures against the effectiveness of the thermal data

Perform UAV-IR Survey to Identify Delaminations

The UAV-IR survey for this bridge was performed prior to the traditional inspection so that the field team would not have pre-existing knowledge of the location of delaminations. Data collection for Span K4 and the Pier K3 South Column was performed on 10/20/21 and data collection for Span K5 was performed on 10/21/21. The DJI Matrice 210 with Zenmuse XT2 sensor was utilized for data collection. The Parrot Anafi USA was used to capture some imagery with the drone on the ground on 10/20/21. However, it was not used for full data collection because of the control issue discussed earlier in the report. The Skydio X2 was not available at the time of field testing and was not used for data collection.

Figure 76 - Field Testing Location

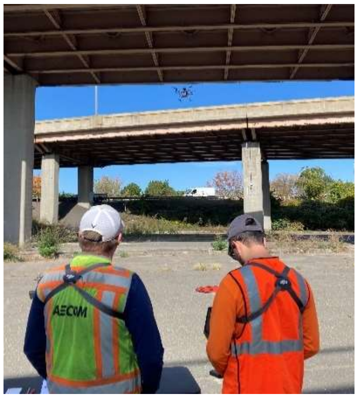


Figure 77 - UAS Pilot and Sensor Operator during Data Collection

Three AECOM staff members were present for field testing. The field team was comprised of one non-destructive evaluation (NDE) specialist with extensive experience analyzing top of bridge deck thermal imagery, one NBIS qualified Team Leader / Part 107 commercial UAS pilot, and one bridge inspection team member / Part 107 commercial UAS pilot. Part 107 is the commercial UAS license established by the Federal Aviation Administration (FAA).

The data collection was performed using dual flight controllers; one dedicated to flying the drone and the other functioning as the sensor operator (Figure 77). The third staff member was present in order to take the field notes which were transcribed onto blank framing plan sketches for the bridge spans.

The drone was flown at an altitude such that the length of one diaphragm bay was able to be captured at a time. The XT2 sensor was positioned to capture imagery as close to perpendicular to the deck as possible (Figure 78). This was easy to accomplish for the interior bays, however, near the ends of the span, the imagery was captured at an angle in order to avoid flying too close to the bridge pier columns (Figure 79). For the data collection, the drone control settings were adjusted to show the thermal image and visual image side-by-side. This allowed the team to cross check the visual data during collection to help identify possible false positive identifications of delamination.


Figure 78 - Thermal Imagery captured Perpendicular to Deck near Center of Bridge Span


Figure 79 - Thermal Imagery Captured at Angle to avoid Pier Columns

For the underside of the spans, the drone was incrementally flown along the diaphragm bays, momentarily stopping at each bay to allow the field staff to identify any delaminations. For the pier column, the drone flew one face of the column at a time, with the drone starting near the top and working downwards. The drone was flown perpendicular to the pier for three of the sides (east, south, and west). The remaining side (north) was captured at an angle since there was limited space between the columns.

When a delamination was identified, the rough shape and approximate location of the delamination were hand drawn onto the framing plan sketches. The thermal image and visual image from the XT2 sensor were captured and also noted on the field sketches. The field sketches were drawn up in AutoCAD with the captured imagery being used to refine the information from the field sketches. In some instances, the limits of the delaminations were traced from the captured imagery.

Figure 80 - Aerial Lift used for Inspection

The traditional inspection was performed on 11/3/21. Two trained bridge inspectors performed an inspection of the underside of the deck with an aerial lift (Figure 80). The inspectors boomed up to each diaphragm bay and sounded suspect areas (i.e. areas with efflorescence, rust staining, or adjacent to cracking). The inspectors marked identified delaminations with an outline and hatch marks with lumber crayon. The traditional inspection for the underside of each span took approximately 2.5 to 3 hours for a total of 6 hours.

The traditional inspection findings, UAV-IR survey findings, and thermal imagery is included in Appendix D. The appendices are grouped by section of bridge; Appendix D-1 is Span K4, Appendix D-2 is Span K5, and Appendix D-3 is the Pier K3 South Column.

The traditional inspection findings were compared against the thermal data that was collected. Figures 81 through 86 on the following pages provide the abridge Traditional Inspection Finding Sketches and UAV-IR Survey Finding Sketches. It should be noted that the traditional inspection sketches include locations of spalling, which were not captured as part of the UAV-IR surveys.

The traditional inspection and UAV-IR survey finding sketches were compared to identify the amount of delaminations that were properly identified. As part of this, each location of delamination was categorized as either identified, partially identified, misidentified, not identified or false positive. These terms are defined below:

- Identified = The delamination roughly matches the limits identified during the traditional inspection
- Partially Identified = The delamination is visible but is noticeably smaller than the limits identified during the traditional inspection
- Misidentified = A location of spalling or sound patch was incorrectly identified as a delamination
- Not Identified = No delamination was identified
- False Positive = A temperature differential was incorrectly identified as a delamination.

This information was compiled into comparison charts are included as Tables 36 through 38. The summary of findings is presented in Table 39.

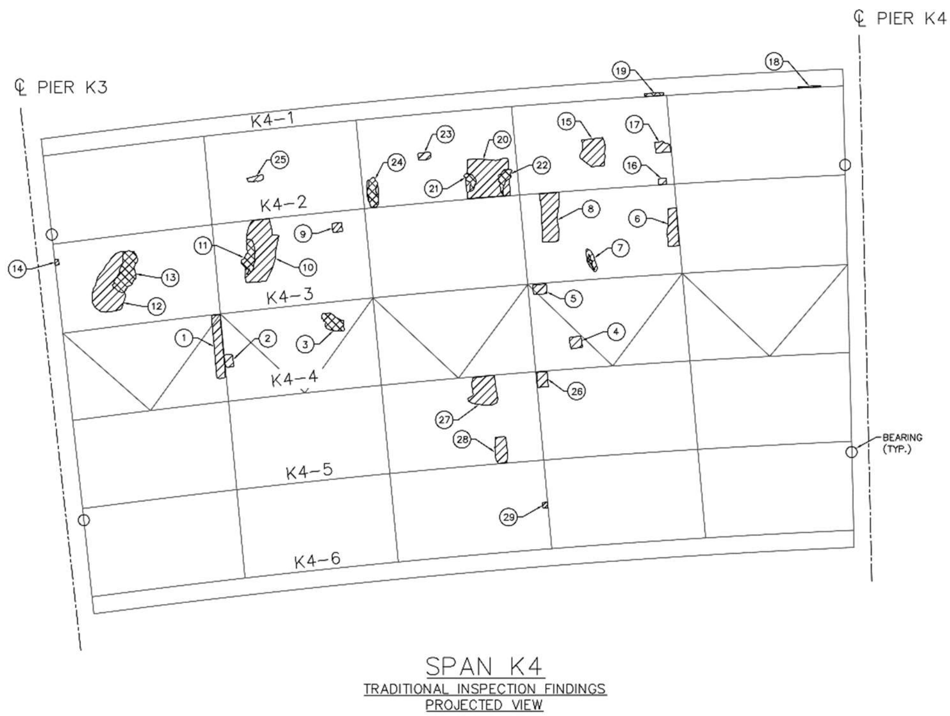


Figure 81 - Span K4 Traditional Inspection Findings

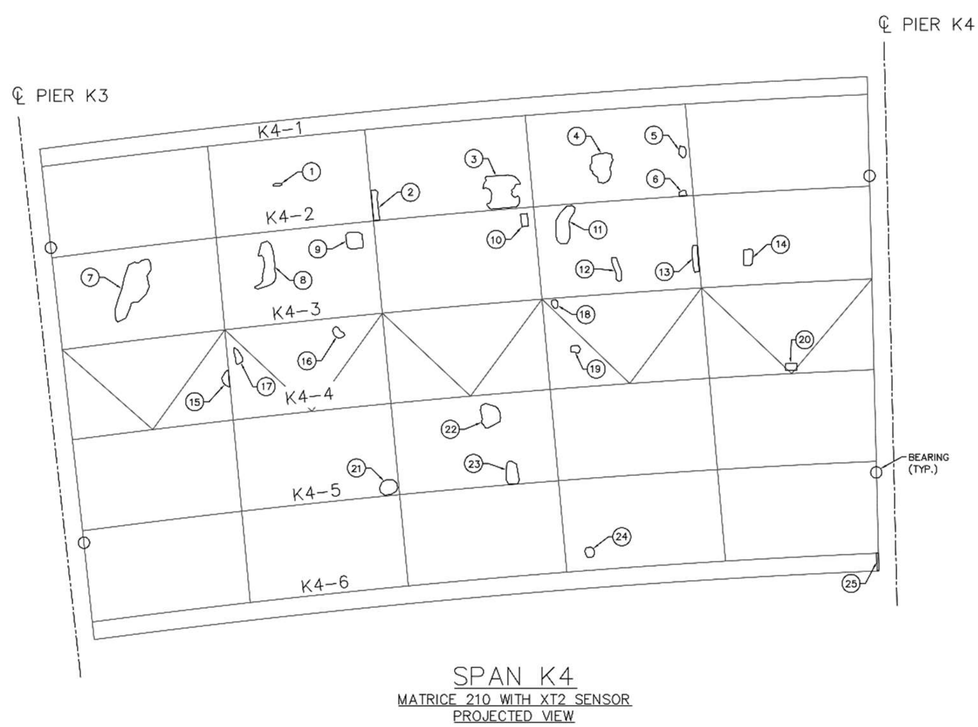


Figure 82 - Span K4 UAV-IR Survey Findings

Table 36 – 114: Span K4, Traditional Inspection versus Thermal Data

Traditional Inspection Deficiency Number*	Type of Deficiency	Delamination Identified with Thermal?	Thermal Sketch Number**	IR Image #	Comment(s)
1	HSA	Partially	15	676	
2	HSA	No	None	-	
3	Spall	Misidentified	16	680	Spall misidentified as delamination
4	HSA	Yes	19	694	
5	HSA	Yes	18	694	
6	HSA	Partially	13	696	
7	HSA & Spall	Yes	12	696	
8	HSA	Yes	11	696	
9	HSA	Yes	9	682	
10	HSA	Yes	8	682	
11	Spall	n/a	-	-	
12	HSA	Yes	7	674	
13	Spall	n/a	-	-	
14	HSA	No	None	-	
15	HSA	Yes	4	696	
16	HSA	Yes	6	696	
17	HSA	Yes	5	696	
18	Spall	n/a	-	-	
19	Spall	n/a	-	-	
20	HSA	Yes	3	684	
21	Spall	n/a	-	-	
22	Spall	n/a	-	-	
23	HSA	No	None	-	
24	HSA & Spall	Yes	2	684	
25	HSA	Yes	1	682	
26	HSA	No	None	-	
27	HSA	Yes	22	688	
28	HSA	Yes	23	688	
29	HSA	No	None	-	
None	-	False Positive	17	680	Paint overspray
None	-	False Positive	10	686	Paint overspray
None	-	False Positive	14	700	Discoloration of deck
None	-	False Positive	20	702	Discoloration of deck
None	-	False Positive	21	678	Paint overspray, discoloration of deck
None	-	False Positive	24	692	Discoloration of deck
None	-	False Positive	25	704	

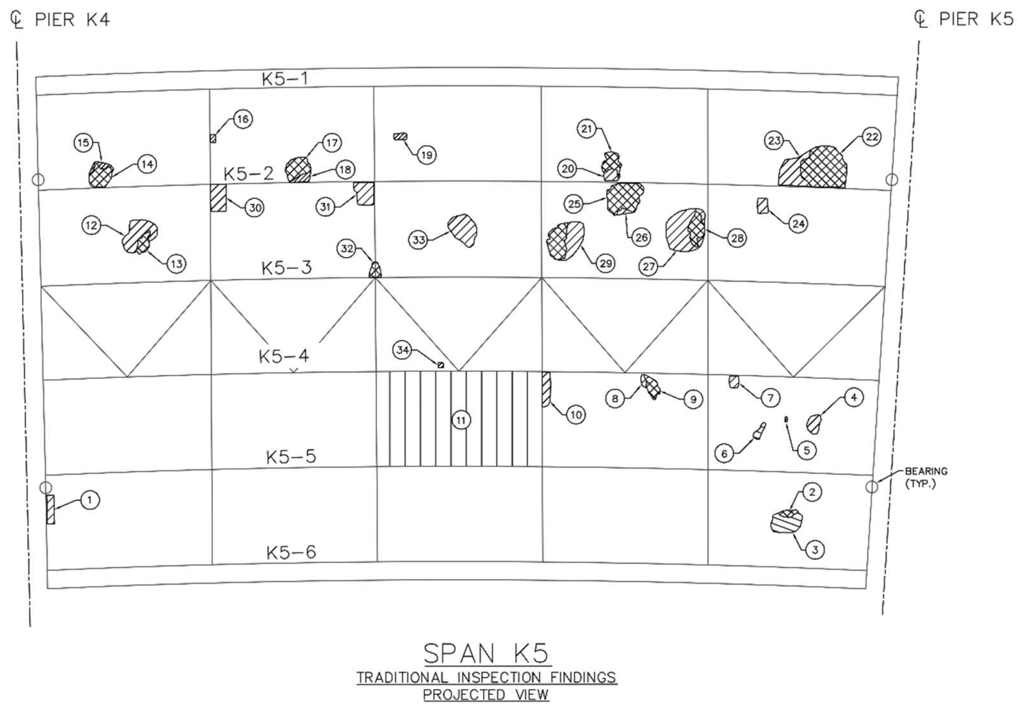


Figure 84 - Span K5 Traditional Inspection Findings

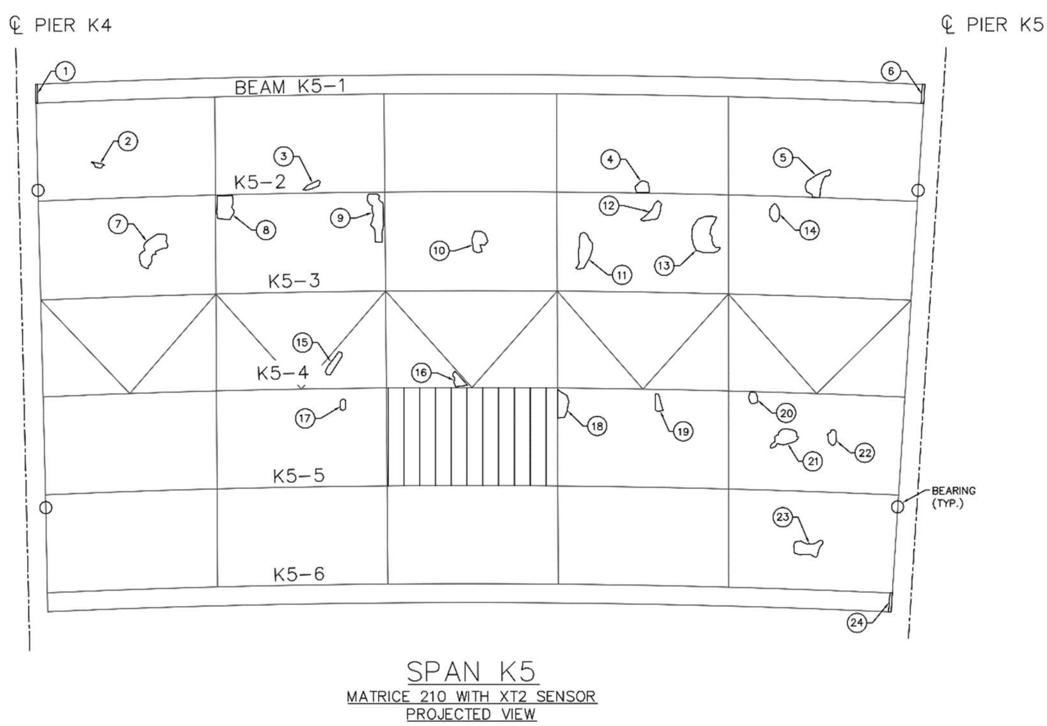


Figure 83 - Span K5 UAV-IR Survey Findings

Table 37 – 114: Span K5, Traditional Inspection versus Thermal Data

Traditional Inspection Deficiency Number*	Type of Deficiency	Delamination Identified with Thermal?	Thermal Sketch Number**	IR Image #	Comment(s)
1	HSA	No	None	-	
2	Spall	n/a	-	-	
3	HSA	Yes	23	163	
4	HSA	Yes	22	161	
5	HSA	Partially	21	161	Thermal shows 5 & 6 as one larger combined area
6	HSA	Partially	21	161	Thermal shows 5 & 6 as one larger combined area
7	HSA	Yes	20	161	
8	HSA	Yes	19	167	
9	Spall	n/a	-	-	
10	HSA	Partially	18	167	
11	n/a	n/a	-	-	
12	HSA	Yes	7	189	
13	Spall	n/a	-	-	
14	Spall	n/a	-	-	
15	HSA	Yes	2	187	
16	HSA	No	None	-	
17	Spall	n/a	-	-	
18	HSA	Yes	3	183	
19	HSA	No	None	-	
20	HSA	Yes	4	171	
21	Spall	n/a	-	-	
22	Spall	n/a	-	-	
23	HSA	Yes	5	157	
24	HSA	Yes	14	159	
25	Spall	n/a	-	-	
26	HSA	Yes	12	169	Thermal area is larger than actual
27	HSA	Yes	13	169	
28	Spall	n/a	-	-	
29	HSA & Spall	Yes	11	169	
30	HSA	Yes	8	181	
31	HSA	Yes	9	181	Thermal area is larger than actual
32	Spall	n/a	-	-	
33	HSA	Partially	10	173	
34	HSA	Yes	16	175	
None	-	False Positive	1	185	
None	-	False Positive	6	155	
None	-	False Positive	15	179	Paint overspray
None	-	False Positive	17	177	
None	-	False Positive	24	165	

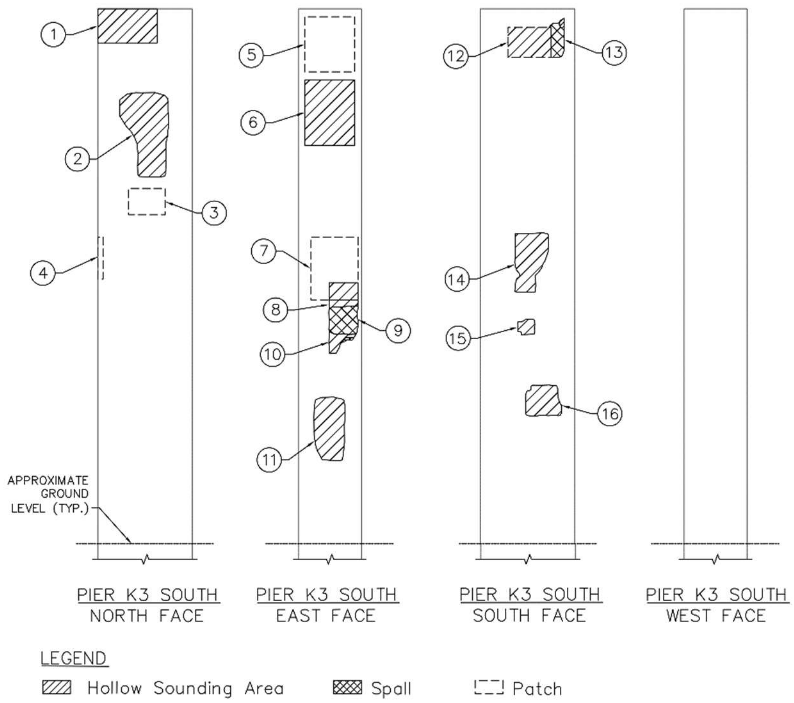


Figure 85 - Pier K3 South Column Traditional Inspection Findings

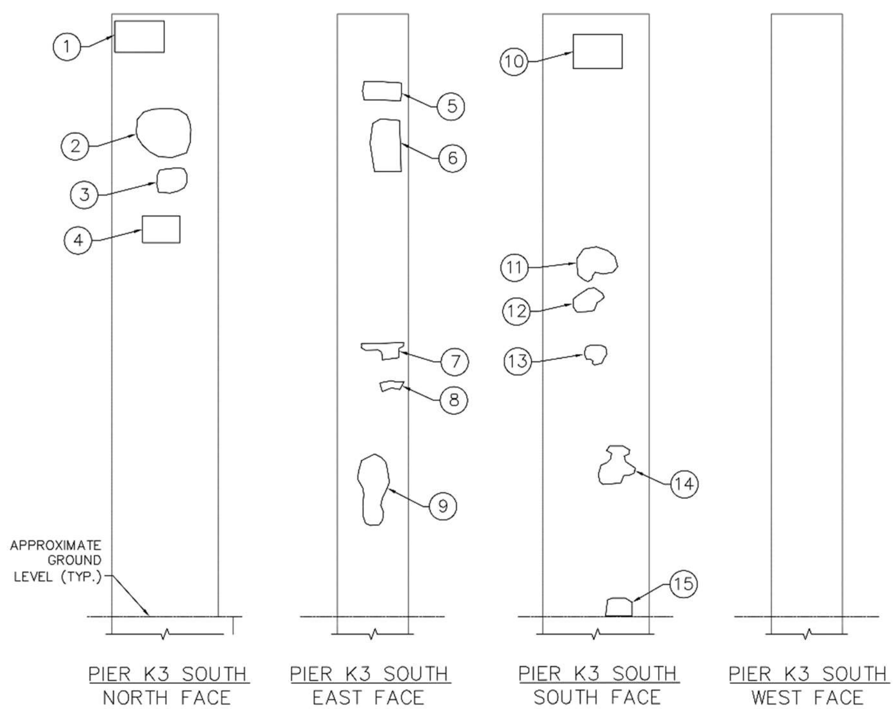


Figure 86 - Pier K3 South Column UAV-IR Survey Findings

Table 38 – 114: Pier K3 South Column, Traditional Inspection versus Thermal Data

Traditional Inspection Deficiency Number*	Type of Deficiency	Delamination Identified with Thermal?	Thermal Sketch Number**	IR Image #	Comment(s)
1	HS Patch	Yes	1	736	
2	HSA	Yes	2, 3	736	
3	Sound patch	Misidentified	4	736	Patch at location
4	Sound patch	n/a	-	736	
5	Sound patch	Misidentified	5	730	Patch at location
6	HS Patch	Partially	6	730	
7	HS Patch	No	None	732	
8	HSA	Yes	7	732	
9	Spall	n/a	-	732	
10	HSA & Spall	Partially	8	8	
11	HSA	Yes	9	734	
12	HS Patch	Yes	10	722	
13	HSA & Spall	No	None	722	
14	HSA	Yes	11, 12	724	
15	HSA	Yes	13	724, 726	
16	HSA	Yes	14	726	
None	-	False Positive	15	728	

Table 39 – 114: Summary of Findings by Field Test Location

Span / Pier	Span K4	Span K5	Pier K3 South
# Delamination	22	23	14
# Detected	15	16	8
% Detected	68.18	69.57	57.14
# Partially Detected	2	4	2
% Partially Detected	9.09	17.39	14.29
# Not Detected	5	3	2
% Not Detected	22.73	13.04	14.29
# Misidentified	1	0	2
% Misidentified	4.55	0.00	14.29
# False Positives	7	5	1
% False Positives	31.82	21.74	7.14

Based on the summary of findings, the mean percentages for detection and partial detection follow:

- Full Detection = 64.96%
- Partial Detection = 13.59%
- Combined Full and Partial Detection = 78.55%

Despite the large temperature swing, thermal imaging was unable to identify all of the delaminations along the portions of the bridge selected for field testing. However, it did identify more locations of delamination than were specifically identified in the most recent National Bridge Inspection Standards (NBIS) Routine inspection. It should be noted that Routine Inspection aren't intended to capture every specific deficiency but rather focus on the more severe deficiencies. Table 40 provides the number of identified deficiencies (spalls and delaminations) and delaminations for each inspection.

Table 40 – 114: Identified Deficiencies during Inspections

Inspection	Component	Total # of Deficiencies Noted	Deficiencies with Delamination
2021 NBIS Routine Inspection	Span 4	9	7
	Span 5	13	8
	K3 South	8	8
NETC Traditional Cross Check Inspection	Span 4	29	22
	Span 5	34	22
	K3 South	16	14
NETC UAV-IR Survey	Span 4	-	17
	Span 5	-	19
	K3 South	-	12

False positives were still present, even with staff experienced in interpreting thermal imagery. A visual cross check of the thermal data will help reduce the number of false positives. However, in some cases, the visual cross check imagery is limited due to various conditions such as sun glare, large contrast due to shadows, or low light levels reducing visibility.

Review of Weather Conditions and Temperatures

The temperature for these data sets had an approximately 20-degree increase starting 6 hours before data collection which provided a large temperature differential which resulted in approximately 80% of the delaminations being either fully or partially identified using thermal imagery. Table 41 provides the Time, Temperature, and Atmospheric Conditions during Data Collection.

Table 41 – 114: Time, Temperature, and Atmospheric Conditions during Data Collection

Date	10/20/2021	10/21/2021
Span / Pier	Span K4, K3 South	Span K5
Start Time	10:58 AM	12:12 PM
End Time	12:01 PM	12:29 PM
Temp at Start (°F)	71	74
Temp at End (°F)	74	74
Avg. Temp. (°F)	72.5	74
Temp 6 Hr Prior (°F)	52	53
Δ Temp 6 Hr (°F)	20.5	21
Temp 3 Hr Prior (°F)	61	64
Δ Temp 3 Hr (°F)	11.5	10
Temp 2 Hr Prior (°F)	63	70
Δ Temp 2 Hr (°F)	9.5	4
Temp 1 Hr Prior (°F)	67	73
Δ Temp 1 Hr (°F)	5.5	1
Dew Point (°F)	51	50
Humidity (%)	49	43
Wind Speed (mph)	5	12
Date of Last Rainfall	10/17/2021	10/17/2021

Figure 87 - Layout of BIN 4RT

Bridge B-16-369 (BIN 4RT)

B-16-369 (BIN 4RT) carries Interstate I-90 Eastbound off- ramp B (Exit 131) over I-90 westbound, a MassDOT yard, and Ramps F, D, and L in the City of Boston (Figure 87). The bridge is a fourteen-span structure consisting of steel girders supporting a composite reinforced concrete deck with an integral concrete wearing surface.

The bridge was originally built in 1964 and has not been rehabilitated. Several of the bridge piers had concrete repairs performed in 2020. According to the August 2020 Routine Inspection report, the deck condition was rated 4 – Poor. The NBE quantities within the report indicated that Element 12 – Reinforced Concrete Deck had 5,194 square feet rated as Condition State 2 and 1,345 square feet rated as Condition State 3 for the defect "Delamination/Spall/Patched Area."

This bridge was selected based on the amount of concrete deterioration to the deck, vertical clearance of the bridge (approximately 20 feet for the selected span), and ease of access since portions of the bridge span a mostly unused MassDOT lot.

The approach for this bridge follows:

1. Perform multiple UAV-IR surveys to identify delaminations along the underside of the deck for one span with no pre-existing deficiency locations for comparison with traditional inspection findings.
2. Capture multiple sets of IR imagery of all the delaminations identified during the traditional inspection for comparison.
3. Review weather conditions and temperatures against the effectiveness of the thermal data.

Figure 88 - BIN 4RT Traditional Inspection

The traditional inspection was performed on 9/21/21. Two trained bridge inspectors performed an inspection of the underside of the deck with a bucket truck (Figure 88). The inspectors boomed up to each diaphragm bay and sounded the deck with emphasis on areas suspected of being delaminated (i.e. areas with efflorescence, rust staining, or adjacent to cracking). The inspectors marked identified delaminations with an outline and hatch marks with lumber crayon. The traditional inspection for the underside of the span took approximately 1 1/2 hours. The full traditional inspection findings can be found in Appendix E-1.

The traditional inspection was performed prior to data collection with UAV mounted thermal cameras so that the inspectors would be able to capture thermal imagery of each delamination. The UAV-IR data collection was performed on 10/19/21, 10/22/21, and 1/19/22.

Field testing on 10/19/21 and 10/22/21 was performed by AECOM staff using a DJI Matrice 210 and Zenmuse XT2 thermal camera. The field team for these two dates was comprised of one non-destructive evaluation (NDE) specialist with extensive experience analyzing top of bridge deck thermal imagery, one NBIS qualified Team Leader / Part 107 commercial UAS pilot, and one bridge inspection team member /

Part 107 commercial UAS pilot. The data collection was performed using dual flight controllers; one dedicated to flying the drone and the other functioning as the sensor operator. The third staff member was present in order to take the field notes which were transcribed onto blank framing plan sketches for the bridge spans. The determination of delaminations from the visible temperature differential was made by AECOM's NDE specialist.


Figure 89 - Data Collection with MassDOT

Field testing on 1/19/22 was performed by AECOM staff and MassDOT Aeronautics staff using MassDOT's DJI Matrice 300 and Zenmuse XT2 thermal camera. The data collection was performed similar to the previous field testing with two MassDOT UAS pilots functioning as the pilot and sensor operator. An AECOM bridge inspector served as the third staff member for note taking (Figure 89). The determination of delaminations from the visible temperature differential was made by one of AECOM's bridge inspectors that has been involved in this research project.

UAV-IR Surveys with No Pre-Existing Deficiency Locations

For the underside of the spans, the drone was incrementally flown along the diaphragm bays, momentarily stopping at each bay to allow the field staff to identify any delaminations. Due to the height of the bridge, the sensor was angled upward between +45 and +75 degrees to capture the full length of a diaphragm bay rather than perpendicular to the deck. For the data collection, the drone control settings were adjusted to show the thermal image and visual image side-by-side. This allowed the team to cross check the visual data during collection to help identify any false positive identifications of delamination.

When a delamination was identified, the rough shape and approximate location of the delamination were hand drawn onto the framing plan sketches. The thermal image and visual image from the XT2 sensor were captured and also noted on the field sketches. The field sketches were drawn up in AutoCAD with the captured imagery being used to refine the information from the field sketches. In some instances, the limits of the delaminations were traced from the captured imagery. These sketches were drawn up from the original raw thermal imagery and not with post processed imagery (although imagery was post processed for reference). The sketches from the thermal survey as well as the associated thermal imagery are included in Appendices E-2.

The traditional inspection findings were compared against the thermal data that was collected. Figures 90 through 93 on the following pages provide the UAV-IR Survey Finding Sketches and abridged Traditional Inspection Sketches. It should be noted that the traditional inspection sketches include locations of spalling, which were not captured as part of the UAV-IR surveys.

The traditional inspection and UAV-IR survey finding sketches were compared to identify the amount of delaminations that were properly identified. As part of this, each location of delamination was categorized as either identified, partially identified, misidentified, not identified or false positive. The definitions for these terms can be found in the discussion for Bridge S-24-083 (BIN 114). This information was compiled in Table 42. The summary of findings is presented in Table 43.

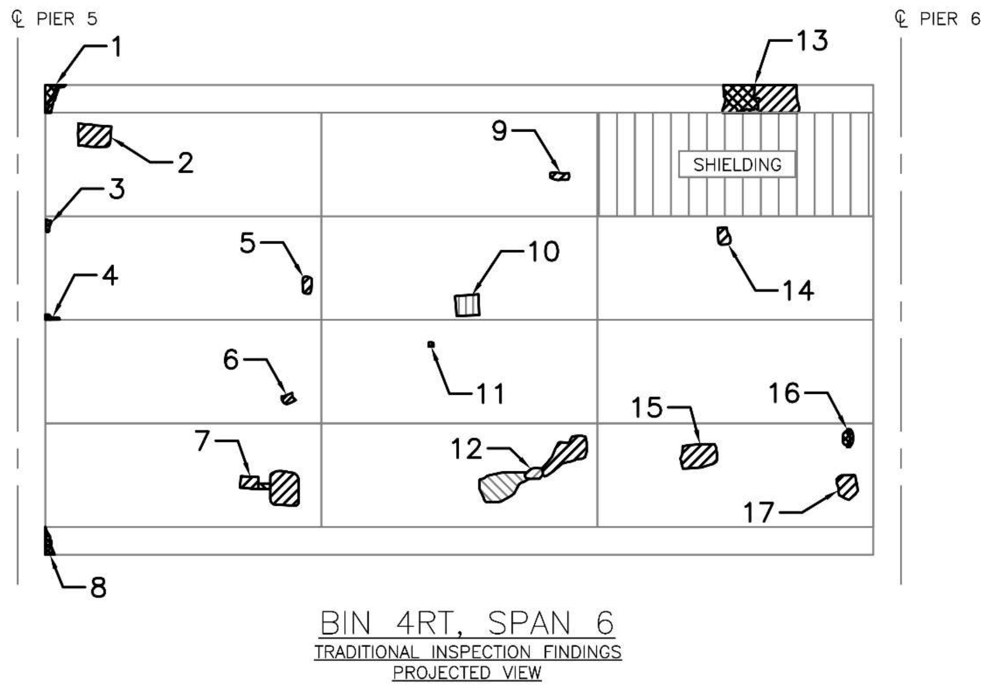


Figure 90 - BIN 4RT, Span 6, Traditional Inspection Findings

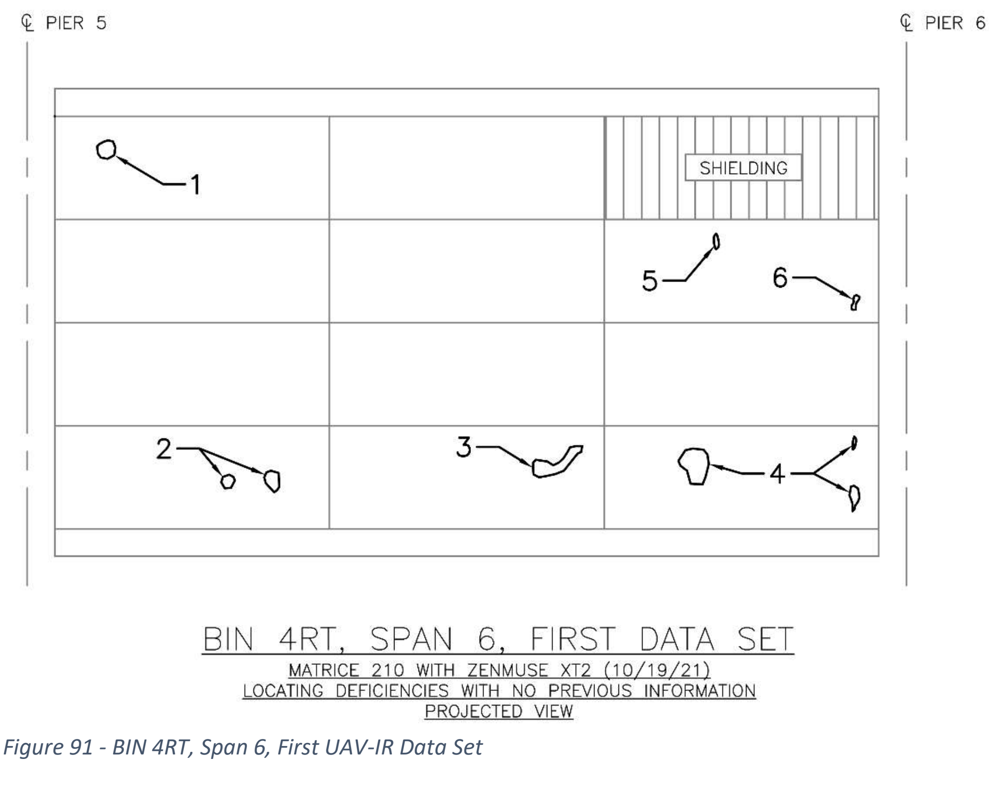


Figure 91 - BIN 4RT, Span 6, First UAV-IR Data Set

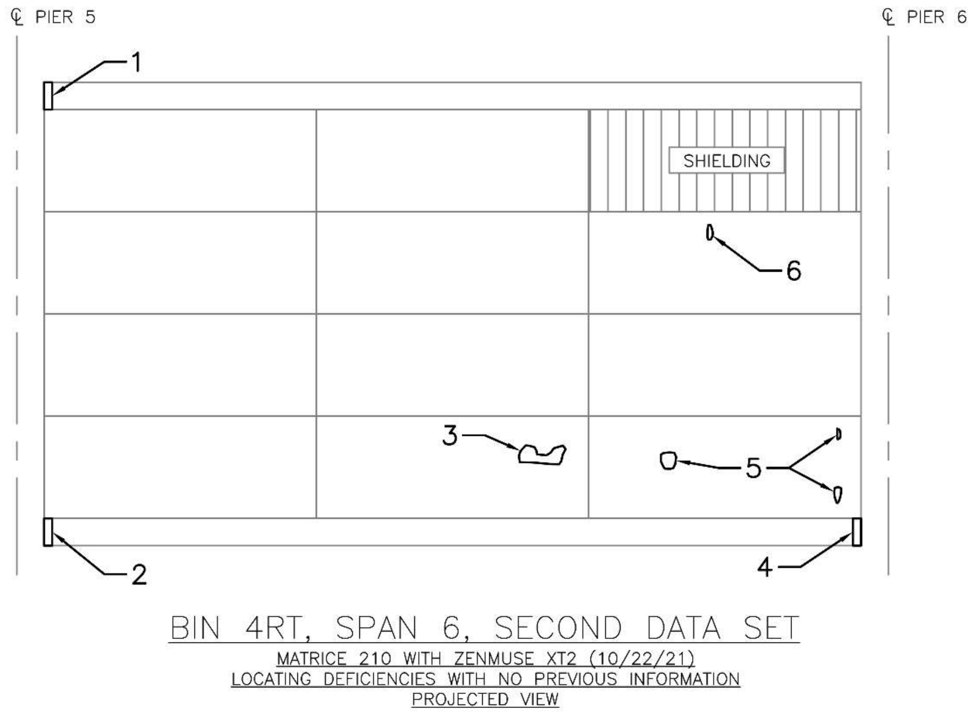


Figure 92 - BIN 4RT, Span 6, Second UAV-IR Data Set

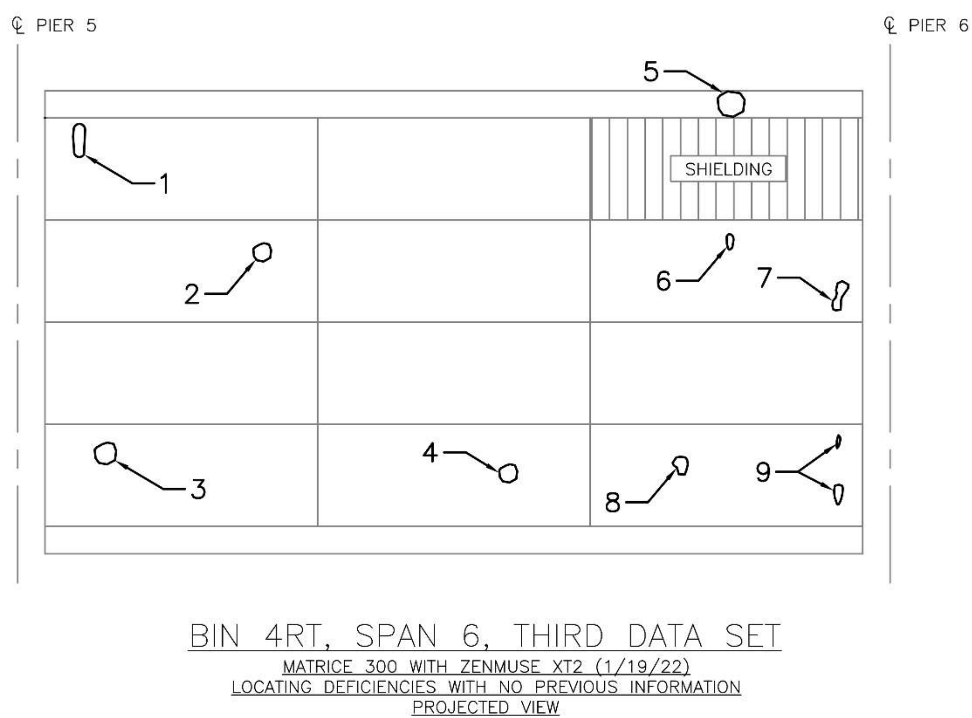


Figure 93 - BIN 4RT, Span 6, Third UAV-IR Data Set

Table 42 – 4RT: Span 6, Comparison of Traditional Inspection versus Thermal Data

Traditional Inspection Deficiency Number*	Type of Deficiency	First Data Set (10/19/2021)			Second Data Set (10/22/2021)			Third Data Set (1/19/2022)		
		Delam. Identified with Thermal?	Thermal Sketch Number **	Comment(s)	Delam. Identified with Thermal?	Thermal Sketch Number **	Comment(s)	Delam. Identified with Thermal?	Thermal Sketch Number **	Comment(s)
1	HSA & Spall	No	-		Yes	1		No	-	
2	HSA	Yes	1		No	-		Partial	1	
3	Spall	n/a	-		n/a	-		n/a	-	
4	Spall	n/a	-		n/a	-		n/a	-	
5	HSA	No	-		No	-		No	-	
6	HSA	No	-		No	-		No	-	
7	HSA	Partial	2		No	-		No	-	
8	Spall	n/a	-		Mis-identified	2	Spall identified as delam	No	-	
9	HSA	No	-		No	-		No	-	
10	n/a	n/a	-		n/a	-		n/a	-	
11	HSA	No	-		No	-		No	-	
12	HSA	Partial	3		Yes	3		Partial	4	
13	HSA & Spall	No	-		No	-		Yes	5	
14	HSA	Yes	5		Yes	6		Yes	6	
15	HSA	Yes	4		Yes	5		Partial	8	
16	HSA & Spall	Yes	4		Yes	5		Yes	9	
17	HSA	Yes	4		Yes	5		Yes	9	
None	-	False Positive	2		False Positive	4		False Positive	2	
None	-	False Positive	6		-	-		False Positive	3	
-	-	-	-		-	-		False Positive	7	

** Deficiency number corresponds to the traditional inspection findings sketch.*
*** Thermal sketch number corresponds to the UAV-IR data set sketches.*

Table 43 – 4RT: Span 6, Summary of Findings

Data Set	First (10/29/21)	Second (10/22/21)	Third (1/19/22)
# Detected	5	6	4
% Detected	38.46%	46.15%	30.77%
# Partially Detected	2	0	3
% Partially Detected	15.38%	0.00%	23.08%
# Not Detected	6	7	7
% Not Detected	46.15%	53.85%	53.85%
# Misidentified	0	1	0
% Misidentified	0.00%	7.69%	0.00%
# False Positives	2	1	3
% False Positives	15.38%	7.69%	23.08%

Based on the summary of findings, the mean percentages for detection and partial detection follow:

- Full Detection = 38.46%
- Partial Detection = 12.82%
- Combined Full and Partial Detection = 51.28%

It should be noted that the majority of the delaminations along the span that was field tested were relatively minor and small which may have contributed to the limited detection. While thermal imaging was unable to identify all of the delaminations along the portions of the bridge selected for field testing, it did identify more locations of delamination than were specifically identified in the most recent NBIS Routine inspection. However, the Routine Inspection general deficiency description for the deck indicated that that area numerous delaminations throughout the bridge. Table 44 provides the number of identified deficiencies (spalls and delaminations) and delaminations for each inspection.

Table 44 – 4RT: Identified Deficiencies during Inspections

Inspection	Total # of Deficiencies Noted	Deficiencies with Delamination
2020 NBIS Routine Inspection	4	1
NETC Traditional Cross Check	16	13
NETC UAV-IR Survey, First Data Set	-	7
NETC UAV-IR Survey, Second Data Set	-	6
NETC UAV-IR Survey, Third Data Set	-	7

Thermal Data of Delaminations Identified during Traditional Inspection Findings

As part of the data collection, thermal imagery of each delamination identified during the traditional inspection was captured with the thermal camera. The thermal imagery was compiled into sketches which are included as Appendix E-3. The thermal imagery was reviewed to identify the amount of delaminations that could be identified. This includes the original raw thermal imagery as well as thermal imagery post processed in Flir Tools. Each location of delamination was categorized as either identified, partially identified, or not identified. This information was compiled in Table 45. The summary of findings is presented in Table 46.

Table 45 – 4RT: Identification Based on Thermal Data of Delaminations

Deficiency Number*	First Data Set (10/19/2021)		Second Data Set (10/22/2021)		Third Data Set (1/19/2022)	
	Original Image	Post Processed	Original Image	Post Processed	Original Image	Post Processed
	Delamination Identified?	Delamination Identified?	Delamination Identified?	Delamination Identified?	Delamination Identified?	Delamination Identified?
1	No	Partial	No	Partial	No	Partial
2	No	Yes	partial	Partial	No	Partial
3	n/a	n/a	n/a	n/a	n/a	n/a
4	n/a	n/a	n/a	n/a	n/a	n/a
5	No	No	No	No	No	No
6	No	Partial	No	Partial	No	No
7	Partial	Yes	partial	Yes	No	Yes
8	n/a	n/a	n/a	n/a	n/a	n/a
9	No	Partial	No	Partial	No	No
10	n/a	n/a	n/a	n/a	n/a	n/a
11	No	No	No	No	No	No
12	Partial	Partial	Partial	Partial	Partial	Partial
13	No	Partial	Partial	Partial	Partial	Yes
14	Yes	Yes	Yes	Yes	Yes	Yes
15	Partial	Yes	Partial	Yes	Partial	Partial
16	Yes	Yes	Yes	Yes	Partial	Partial
17	Partial	Yes	Yes	Yes	Yes	Yes

** Deficiency number corresponds to the traditional inspection findings sketch*

Table 46 – 4RT: Summary of Findings for Thermal Data of Delaminations

Data Set	First (10/29/21)		Second (10/22/21)		Third (1/19/22)	
	Original Image	Post Processed	Original Image	Post Processed	Original Image	Post Processed
# Detected	2	6	3	5	2	4
% Detected	15.38%	46.15%	23.08%	38.46%	15.38%	30.77%
# Partially Detected	4	5	5	6	4	5
% Partially Detected	30.77%	38.46%	38.46%	46.15%	30.77%	38.46%
# Not Detected	7	2	5	2	7	4
% Not Detected	53.85%	15.38%	38.46%	15.38%	53.85%	30.77%

Based on the summary of findings, the mean percentages for detection and partial detection follow:

- Full Detection = 17.95% with original imagery; 38.46% with post processing
- Partial Detection = 33.33% with original imagery; 41.03% with post processing
- Combined Full and Partial Detection = 51.28% with original imagery; 79.49% with post processing

In general, the detection rate for delaminations increased when the imagery was post processed. The post processing generally focused on manually adjusting the temperature span to be a smaller range (typically around 10 degrees). None of the drones tested provided full manual control of the temperature span. However, the field tested Flir thermal cameras were able to set the temperature span manually during data collection which could potentially eliminate the need for post processing of the data.

Review of Weather Conditions and Temperatures

The temperature changes for these data sets varied between 7 and 14.5 degrees in the 6 hours before data collection. This resulted in approximately 50% of delaminations being identified either fully or partially for both identification of delamination without any pre-existing deficiency locations and for thermal imagery of all pre-identified delaminations. The detection rate was likely impacted by the relatively minor nature of most of the delaminations that were present. Table 47 provides the Time, Temperature, and Atmospheric Conditions during Data Collection.

Table 47 - 4RT: Time, Temperature, and Atmospheric Conditions during Data Collection

Date	10/19/2021	10/22/2021	1/19/2022
Start Time	10:36 AM	11:39 AM	10:23 AM
End Time	11:26 AM	12:00 PM	10:40 AM
Temp at Start (°F)	55	70	35
Temp at End (°F)	57	70	36
Avg. Temp. (°F)	56	70	35.5
Temp 6 Hr Prior (°F)	47	63	21
Δ Temp 6 Hr (°F)	9	7	14.5
Temp 3 Hr Prior (°F)	49	67	24
Δ Temp 3 Hr (°F)	7	3	11.5
Temp 2 Hr Prior (°F)	51	69	27
Δ Temp 2 Hr (°F)	5	1	8.5
Temp 1 Hr Prior (°F)	55	70	33
Δ Temp 1 Hr (°F)	1	0	2.5
Dew Point (°F)	36	49	23
Humidity (%)	47	47	57
Wind Speed (mph)	17	15	17
Date of Last Rainfall	10/5/2021	10/5/2021	1/18/2022

The thermal imagery for the third data set on 1/19/22 could have been affected by the recent rainfall the day before. However, the results seem in line with previous data sets so that affect was likely minimal.

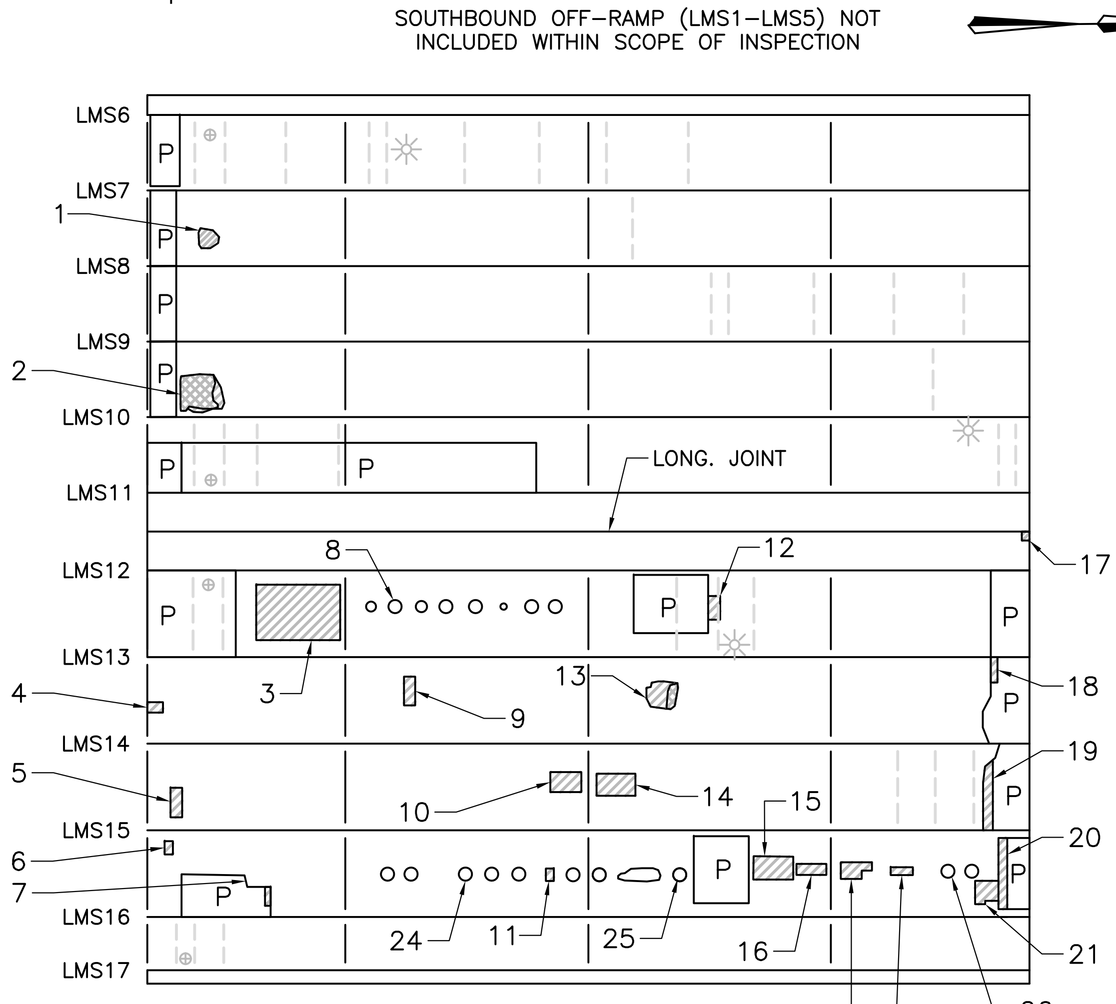
Conclusions

The field testing of commercially available handheld and UAV-mounted thermal cameras was performed at five bridge sites in Massachusetts and Rhode Island. Varying approaches for data collection and analysis were utilized at each bridge in order to establish different experiences to use as a basis for guidelines and protocols for the implementation of these technologies, which will be developed as part of Task 3 of this research project. Some key takeaways from the data collection and analysis task include:

- Handheld thermal cameras offer much more control of data collection settings than drone mounted thermal cameras thus reducing the need for post processing and increasing the likelihood of correct defect detection in the field.
- Temperature differentials in thermal imagery caused by delaminations do not always line up with the limits as determined by manual sounding.
- Experience with interpreting thermal imagery is important to reduce the likelihood of false positive identification of defects. False positives can be easily triggered by a variety of factors causing temperature differentials in thermal imagery.
- Thermal imagery should be cross checked with visual imagery whenever possible to reduce the likelihood of false positive identification. However, visual cross check can be limited based on sun glare, contrast caused by shadows, and overall lighting conditions.
- Even under ideal conditions, it is possible that not all delaminations along the underside of bridge decks will be detected by thermal imaging. Delaminations that are minor, small in size, or deeper within the deck may not be detected. However, the thermal data for BINs 114 and 4RT identified more areas of delamination than were noted as part of the most recent bridge inspection reports.

Appendix A

Bridge S-17-039 (BIN 4E5)



SPAN L–M

Traditional Inspection

LEGEND:

- Hollow Area
- Spall
- Patch
- Diaphragm
- Utility Bracket
- Overhead Light
- Drain

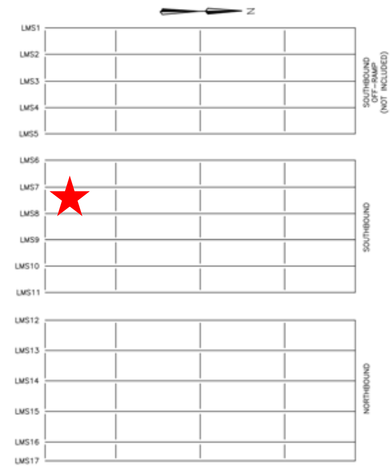
NOTES:

1. This inspection was limited to the mainline portion of Span L–M. The off–ramp portion (LMS1–LSM5) was omitted as the ramp deck separate from the mainline.
2. Diaphragm, Utility Bracket, Drain and Overhead Light locations are approximate.
3. The sketch shows the results of the initial traditional inspection using hammer sounding along the underside of the deck.

DEFICIENCIES:

1. 16" long x up to 19" wide hollow area (18" wide at south end, 8" wide at north end).
2. 2'–1" long (avg.) x 2'–9" wide spall exposed rebar and adjacent up to 10" long (6" avg) x 18" wide hollow area and 14" long x 4" wide hollow area.
3. Hollow sounding area with moderate efflorescence, honey combing, cracking, and discoloration.
4. Two hollow areas in sloped portion; 7" long x 3" wide and 14" long x up to 5" wide (3" wide avg).
5. 10½" long x 2'–2½" wide minor hollow area.
6. 7½" long x 12" wide hollow area.
7. Patched area with 5" long x 17" wide hollow area due to void.
8. Eight up to 12"ø patches within bay.
9. Up to 10" long x 2'–2" wide hollow area.
10. 2'–4" long x up to 18" wide hollow area.
11. 6" long x 9" wide hollow sounding patch.
12. 2" long x 6" wide hollow area.
13. 10" long x 23" wide spall with exposed rebar and adjacent 20" long x 18" wide hollow area.
14. 2'–11" long x 20" wide hollow area.
15. 3'–0" long x 21" wide hollow area.
16. 2'–3" long x 10" wide hollow area.
17. 4" long x 6" wide hollow area in haunch.
18. 5" long x 23" wide hollow area/void in patch due to void with adjacent 8" long x 7" wide hollow area in the haunch.
19. 8" long x 3'–3" wide hollow area/void in patch. The west edge of the patch has a spall/void extending behind the patch.
20. 8" long x 4'–2" wide hollow area/void in patch.
21. 21" long x 18" wide hollow area (up to 21" wide for 9" length).
22. 2'–4" long x 15" wide minor hollow area.
23. 20" long x 7" wide hollow area.
24. Three patches up to 12"ø. Sound unless otherwise noted.
25. Seven patches up to 12"ø within bay. Sound unless otherwise noted.
26. Seven patches up to 12"ø within bay. Sound unless otherwise noted.

4E5, Location 1

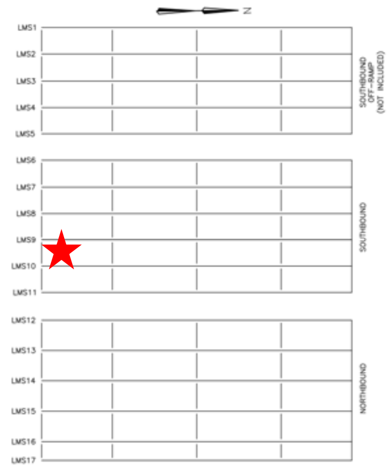


Key Plan for Span L-M

Deficiency Description:
Hollow sounding area measuring 16” long by up to 19” wide (8” wide at north end, 19” wide near middle, 18” wide near south end)

Visually Identifiable as Delamination?
No, the crack could suggest delamination but hammer sounding was necessary to confirm.

4E5, Location 2

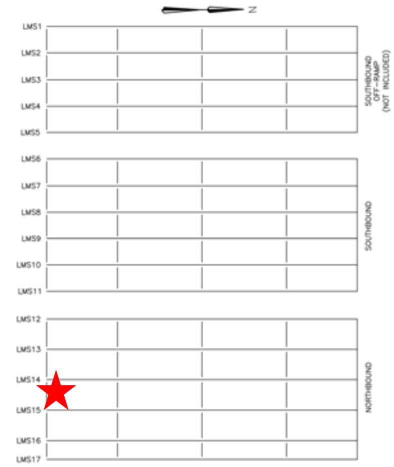


Key Plan for Span L-M

Deficiency Description:
Spall measuring 2’-1” long (average) x 2’-9” wide with two adjacent hollow sounding areas measuring up to 10” long (6” long average) x 18” wide and 14” long x 4” wide.

Visually Identifiable as Delamination?
No, adjacent spalling suggested delamination but hammer sounding was necessary to confirm.

4E5, Location 3



Key Plan for Span L-M

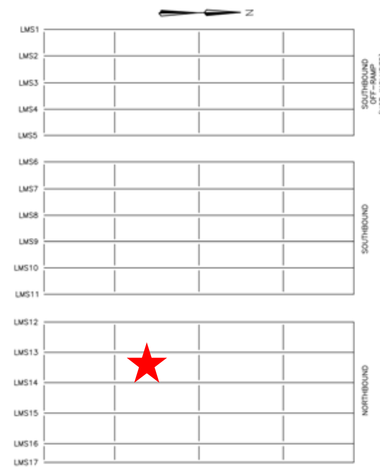
Deficiency Description:
Minor hollow sounding area measuring 10 ½" long x 26 ½" wide

Visually Identifiable as Delamination?
No, this location was only identified through random hammer sounding of the deck.

4E5, Location 4

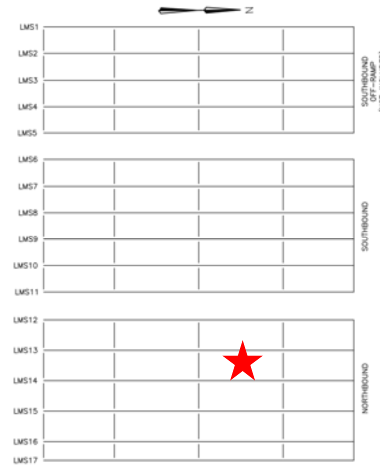
Deficiency Description:
Hollow sounding area measuring up to 10” long x 26” wide

Visually Identifiable as Delamination?
No, the crack could suggest delamination but hammer sounding is necessary to confirm.



Key Plan for Span L-M

4E5, Location 5



Key Plan for Span L-M

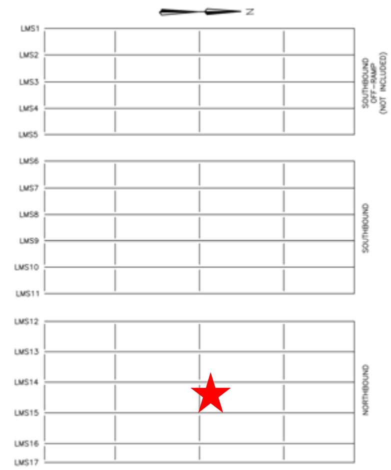
Deficiency Description:
Spall measuring 10” long x 23” wide with adjacent hollow sounding area measuring 20” long x 18” wide

Visually Identifiable as Delamination?
Yes, there is separation cracking that is visible although the limits of the delamination required hammer sounding to determine.

4E5, Location 6

<u>Deficiency Description:</u>
Minor hollow sounding area measuring 2’-11” long x 1’-8” wide

<u>Visually Identifiable as Delamination?</u>
No, cracking and poor consolidation can suggest delamination but hammer sounding was necessary to confirm. Additionally, the delamination was very minor and might not be noted by all inspectors due to the atypical tone produced when sounding.

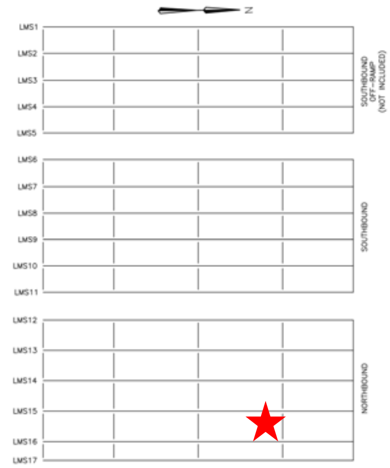


<u>Key Plan for Span L-M</u>

4E5, Location 7

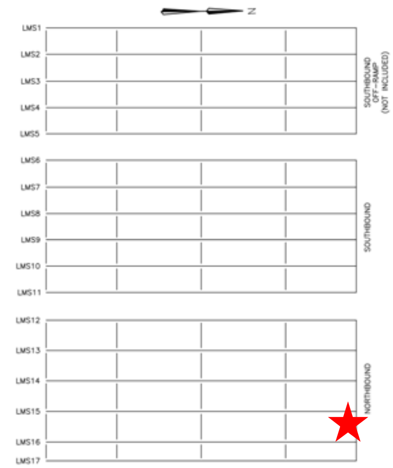
<u>Deficiency Description:</u>
Two adjacent hollow sounding areas. South area (orange outline): hollow sounding area measuring 3’-0” long x 21” wide containing two hollow sounding patches. North area (red outline): hollow sounding area measuring 2’-3” long x 10” wide containing hollow sounding patch

<u>Visually Identifiable as Delamination?</u>
No, rust staining, cracking, and patches suggest possible delamination but hammer sounding was necessary to confirm.



Key Plan for Span L-M

4E5, Location 8

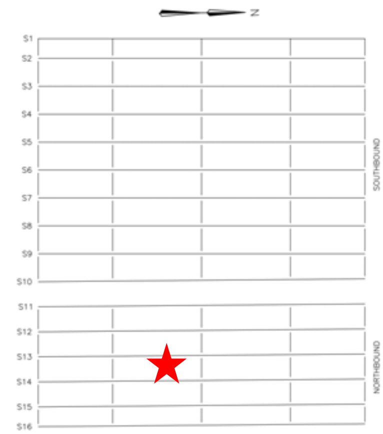


Key Plan for Span L-M

Deficiency Description:
Previous repair has hollow sounding area/void measuring 8” long x 4’-2” wide. Deck has hollow sounding area measuring 21” long x 18” wide (up to 21” wide).

Visually Identifiable as Delamination?
No, rust staining and cracking suggest delamination but hammer sounding is necessary to confirm.

4E5, Location 9



Key Plan for Span P-R

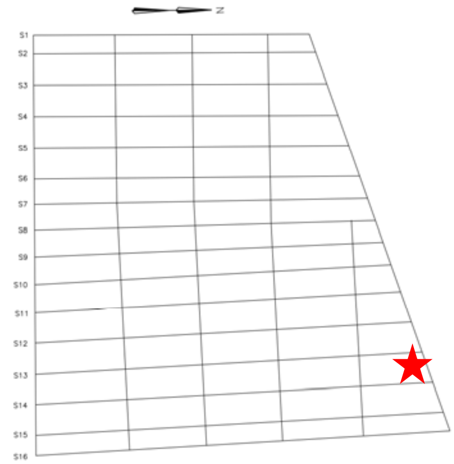
Deficiency Description:
Hollow sounding area measuring up to 30” long x 42” wide containing spalling 16” long x 3” deep

Visually Identifiable as Delamination?
Yes, there is separation cracking that is visible although the limits of the delamination required hammer sounding to determine.

4E5, Location 10

<u>Deficiency Description:</u>
Hollow sounding area measuring 64” long x up to 48” wide

<u>Visually Identifiable as Delamination?</u>
No, discoloration and efflorescence could suggest delamination but hammer sounding was necessary to confirm.

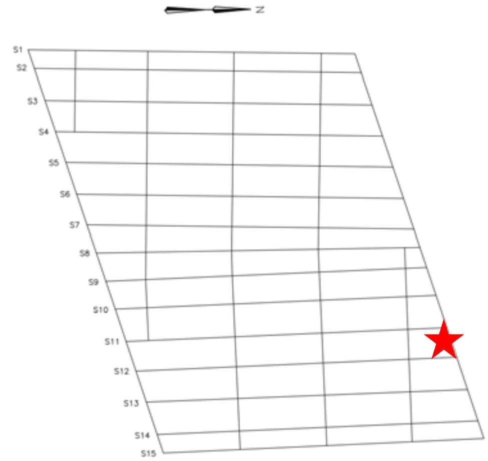


Key Plan for Span R-S

4E5, Location 11

Deficiency Description:
Hollow sounding area measuring up to 60” long x 48” wide with adjacent spalling measuring up to 6” wide x 25” long and dampness

Visually Identifiable as Delamination?
No, discoloration and efflorescence could suggest delamination but hammer sounding was necessary to confirm.



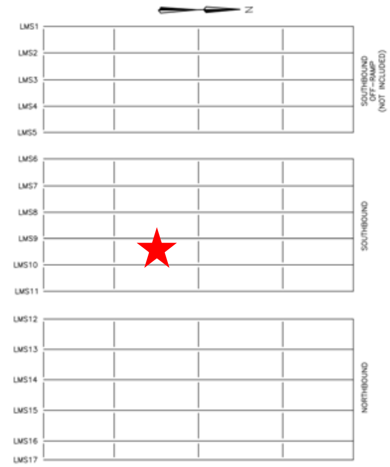
Key Plan for Span S-T

4E5, Location 12

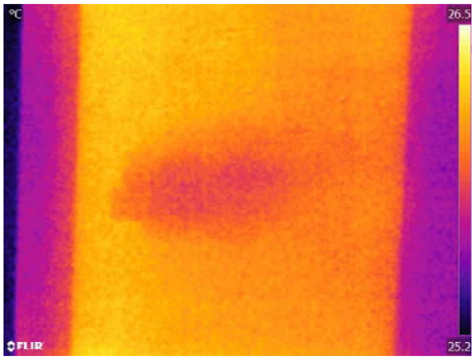
<u>Deficiency Description:</u>
None

<u>Visually Identifiable as Delamination?</u>
No delamination present.

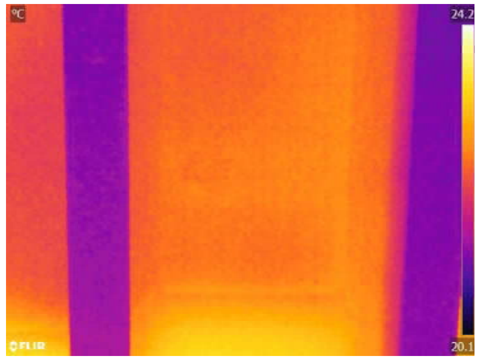
<u>Note:</u>
This location is intended to serve as a control for thermal imagery at a location with no delamination that was detected by hammer sounding.



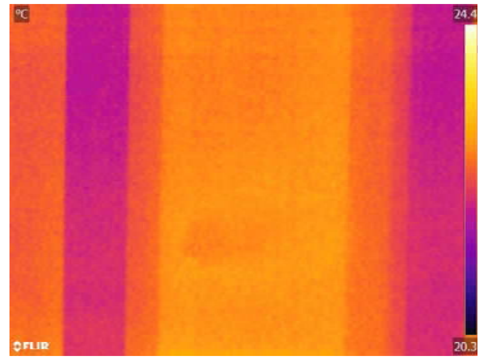
<u>Key Plan for Span L-M</u>



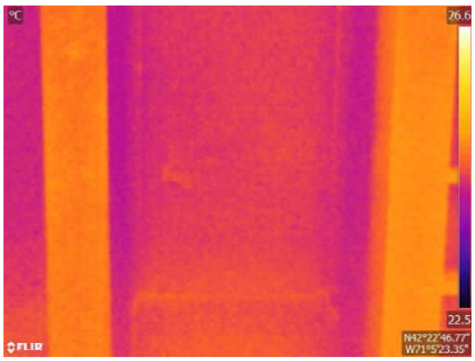
E96_Loc1_01_FLIR0011



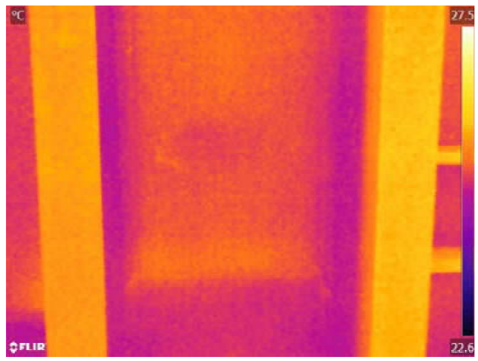
E96_Loc1_02_FLIR0079



E96_Loc1_03_FLIR0213



E96_Loc1_04_FLIR0267



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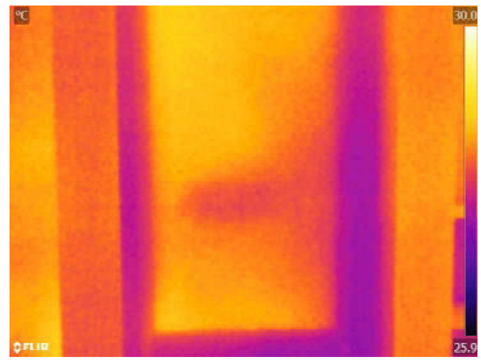

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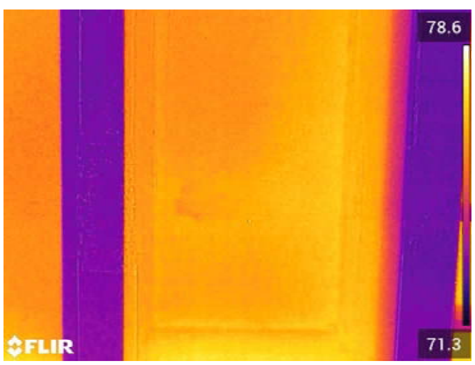

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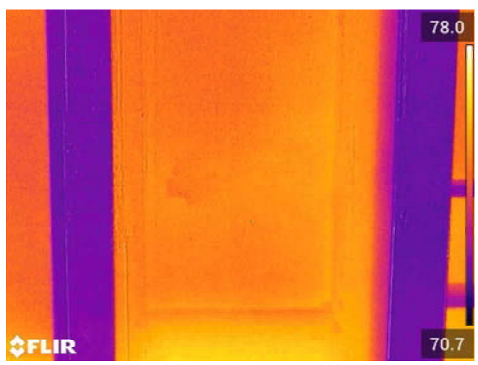

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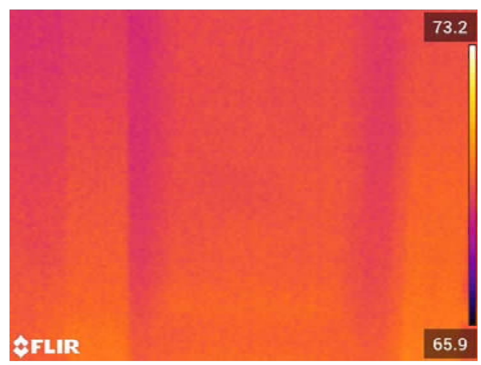

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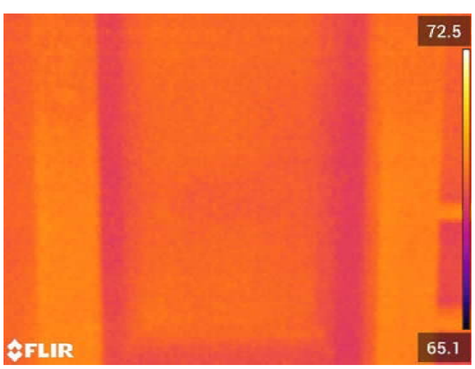

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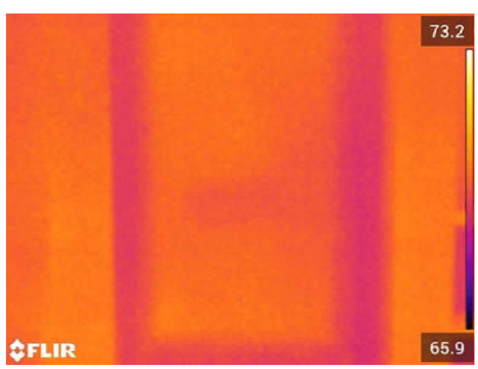

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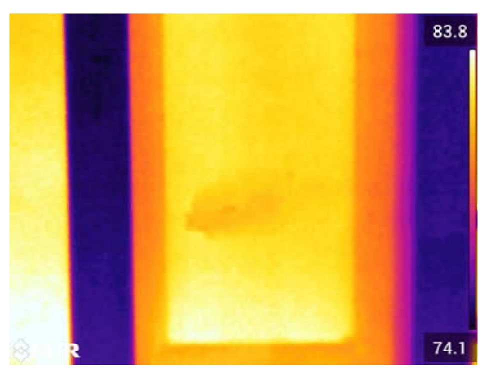

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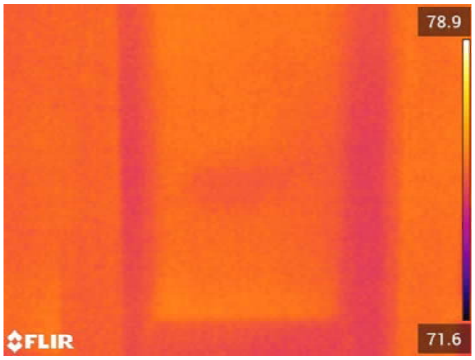

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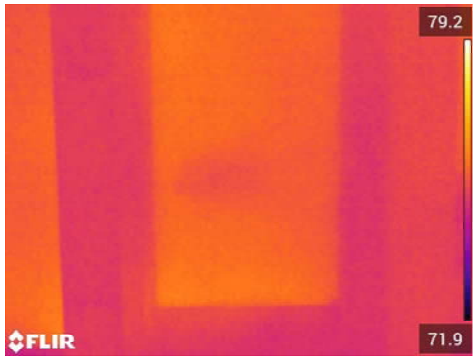

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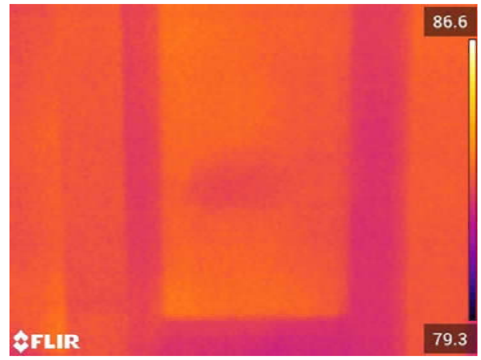

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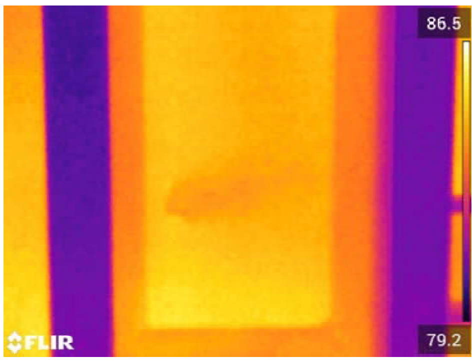

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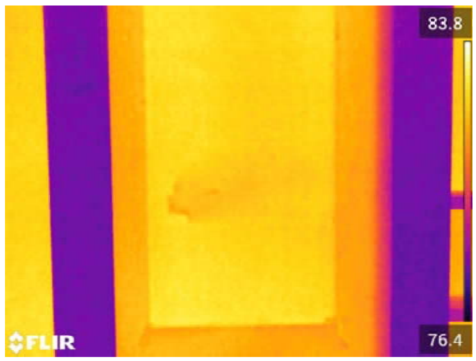

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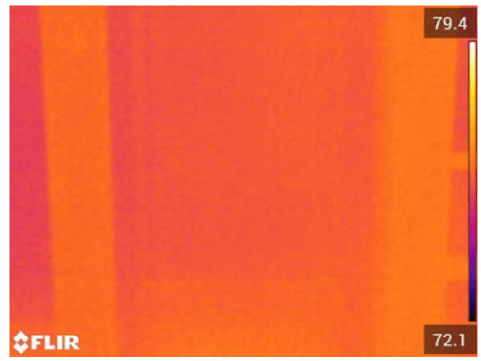

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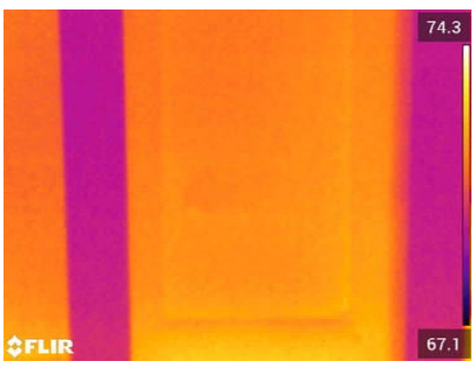

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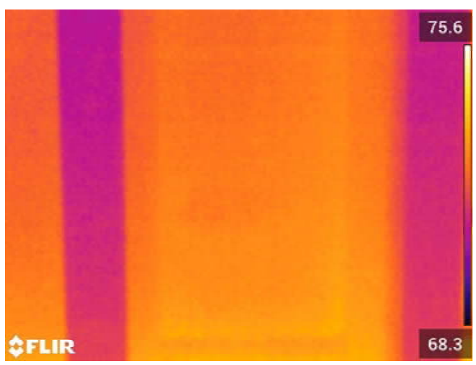

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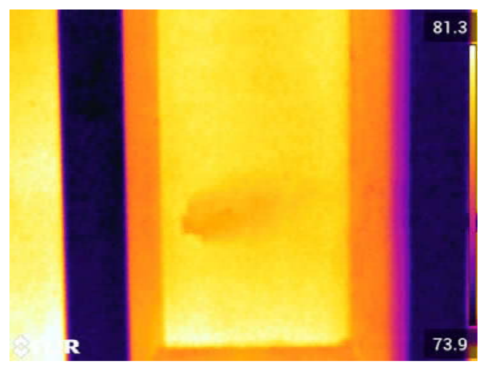

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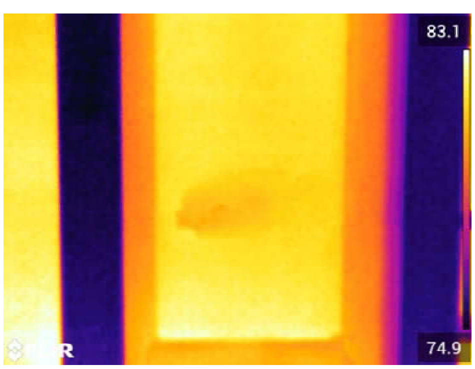

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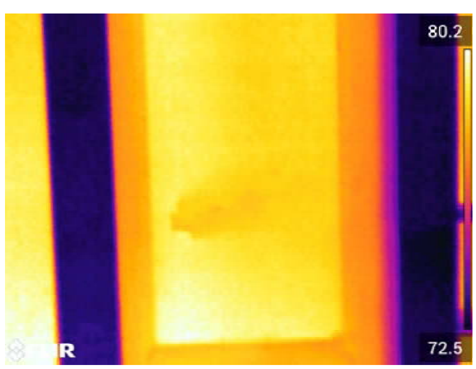

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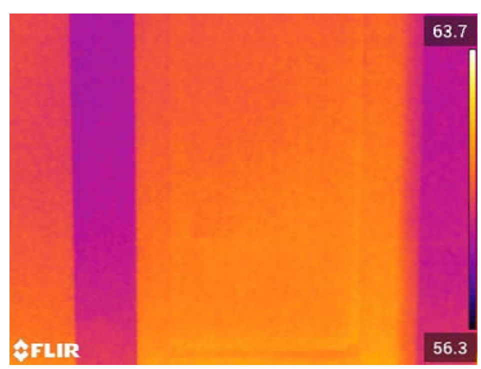

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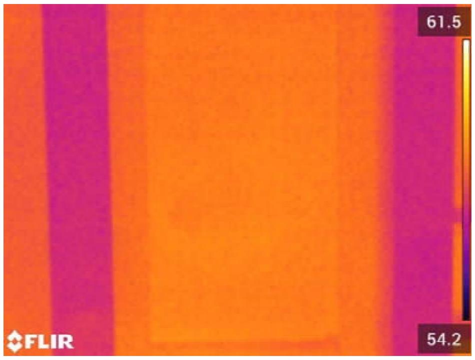

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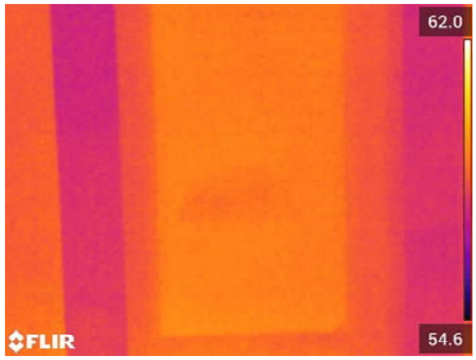

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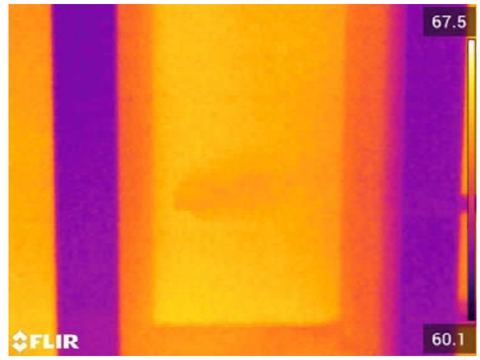

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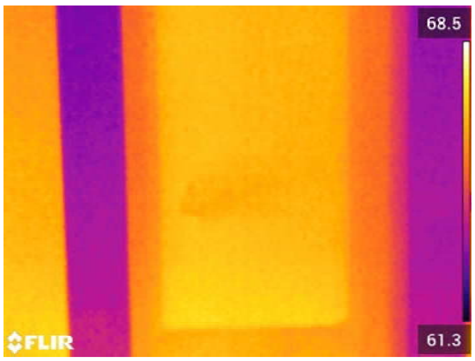

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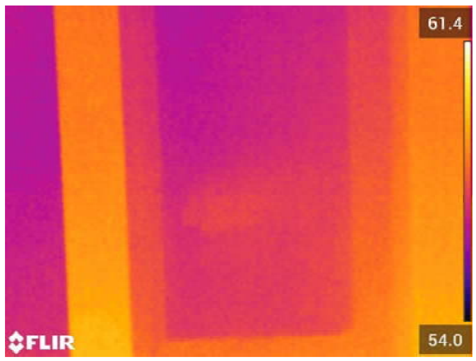

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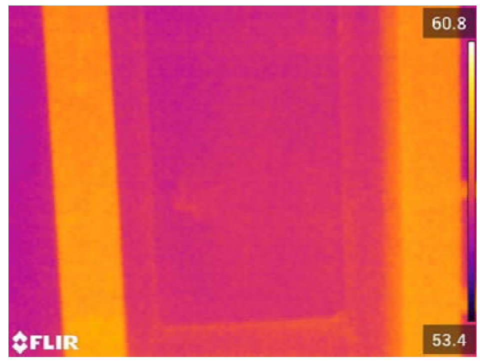

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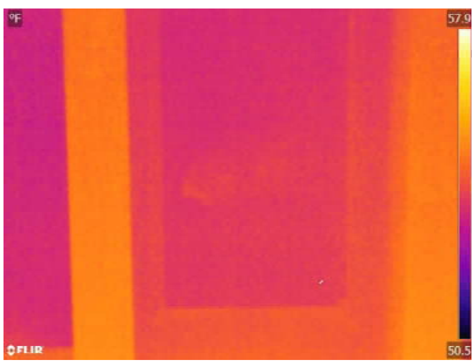

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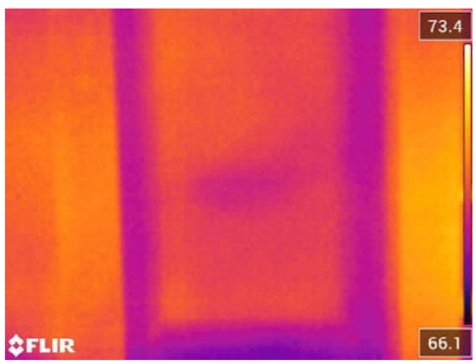

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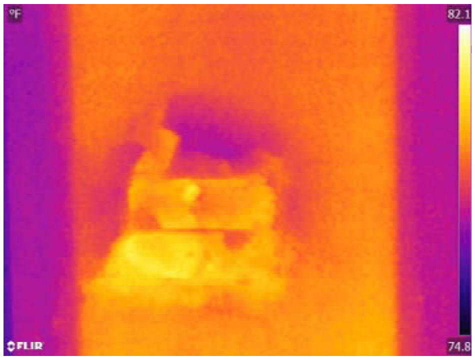

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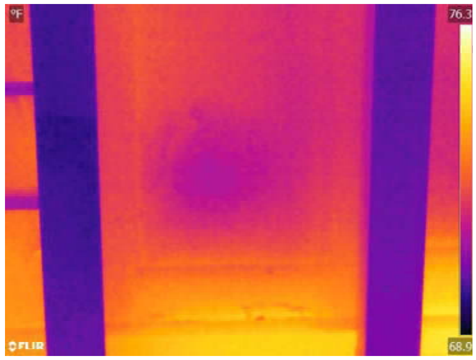

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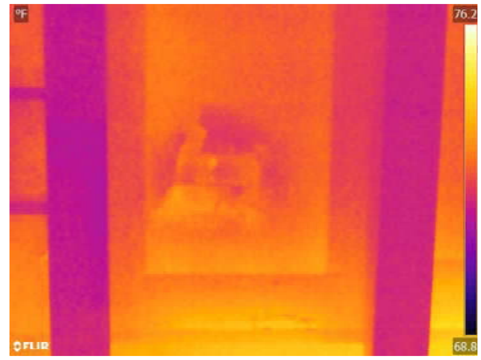

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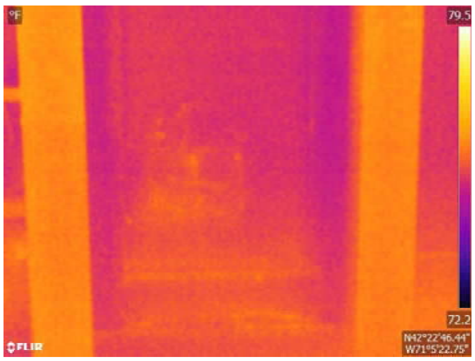

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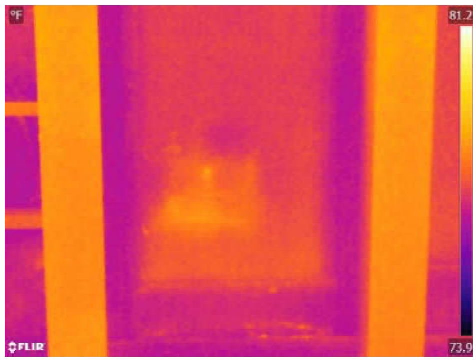

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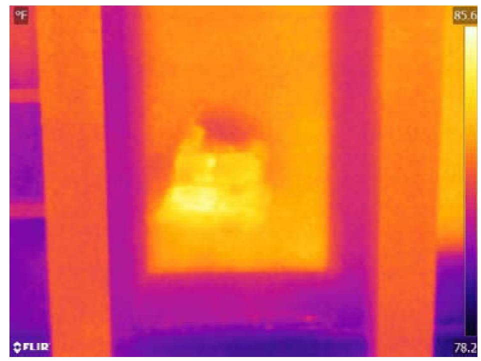

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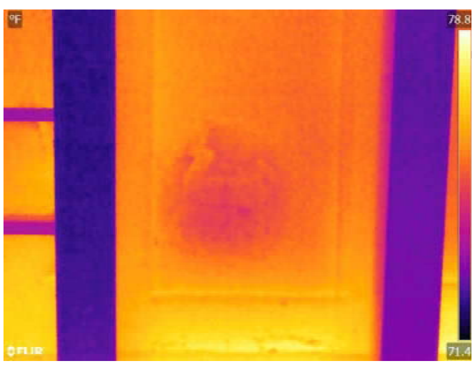

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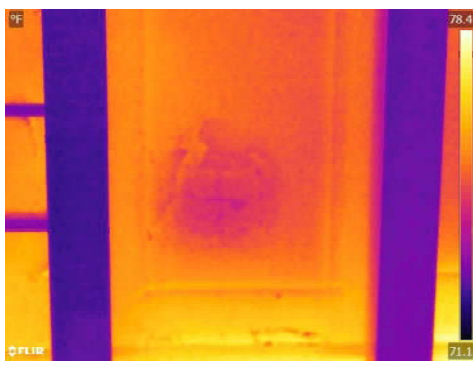

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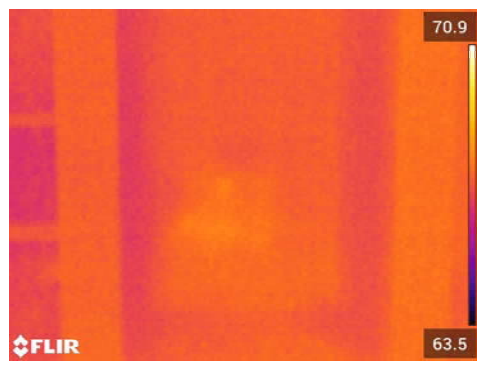

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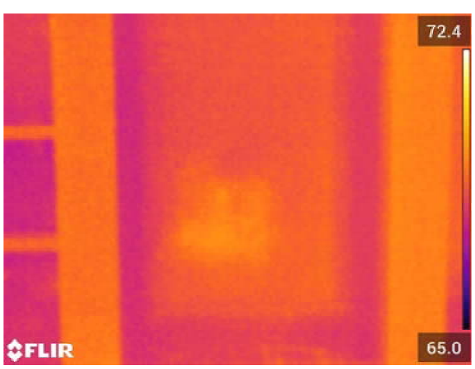

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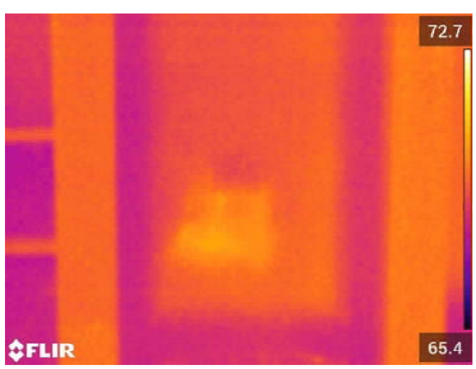

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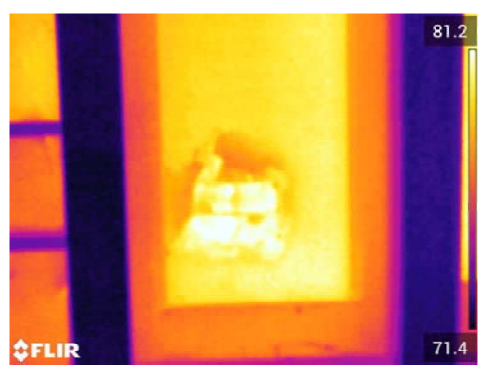

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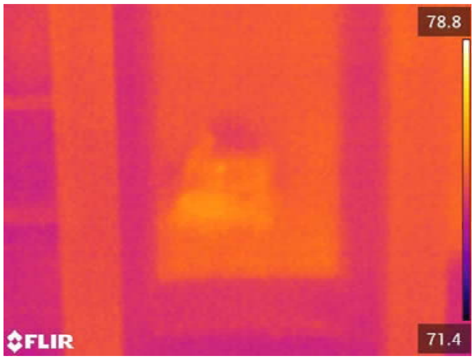

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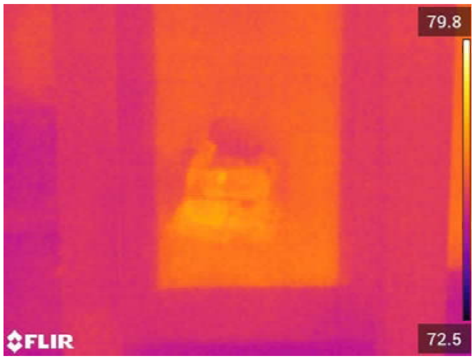

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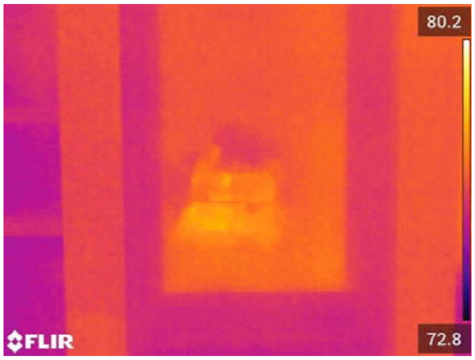

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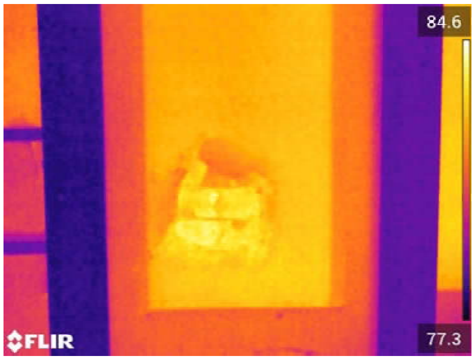

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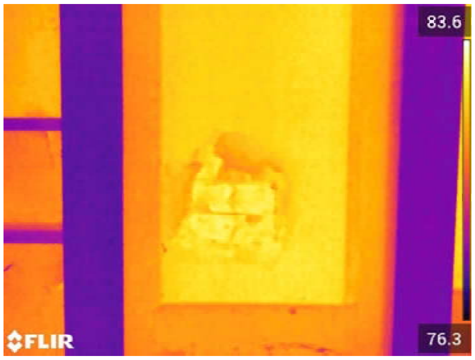

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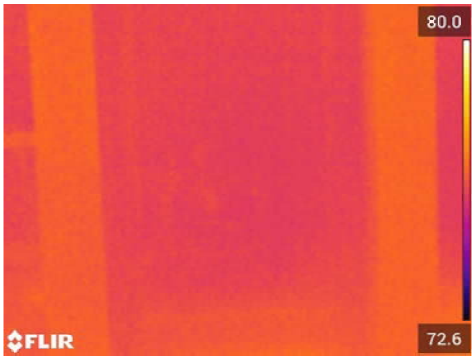

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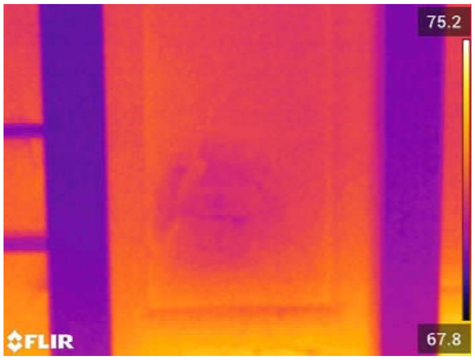

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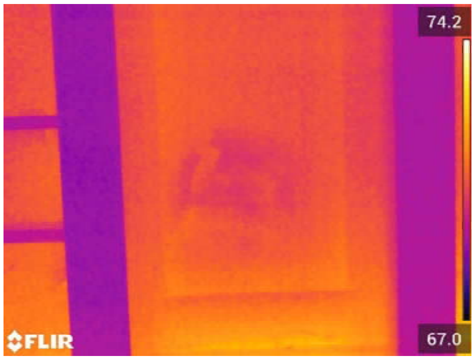

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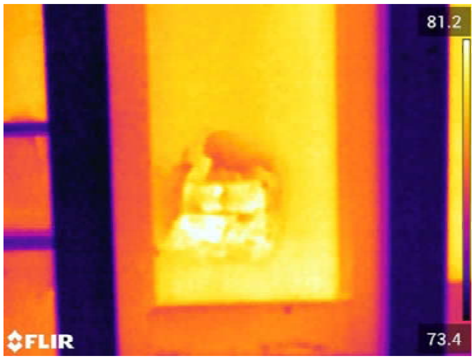

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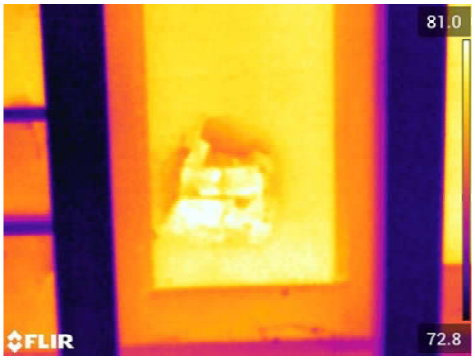

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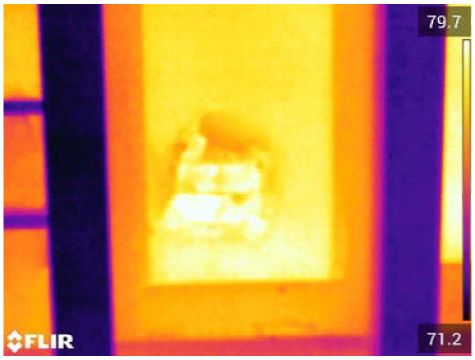

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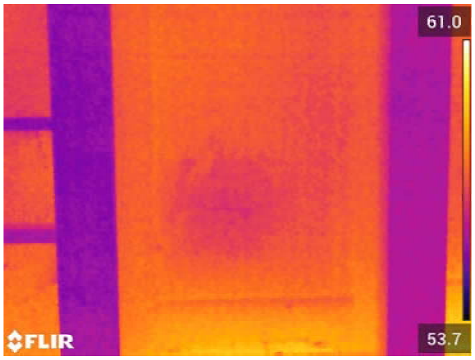

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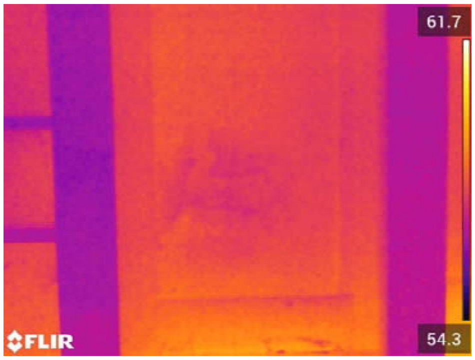

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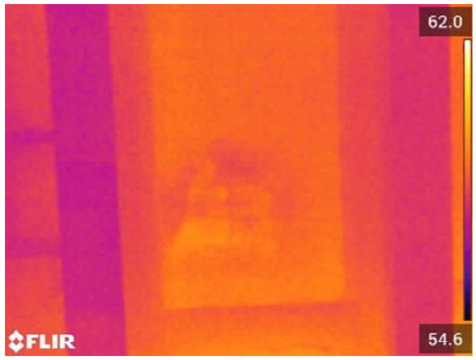

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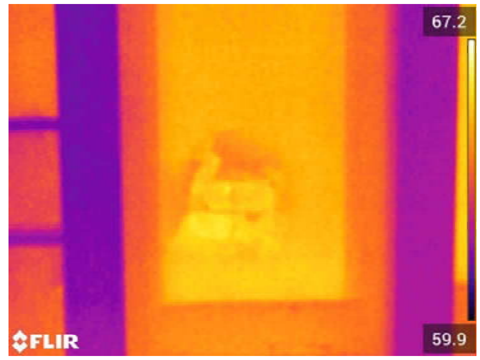

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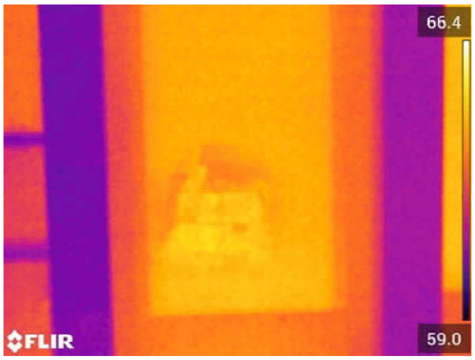

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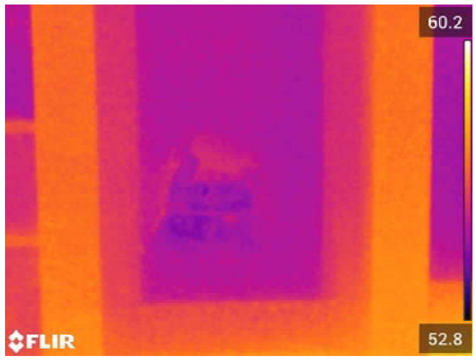

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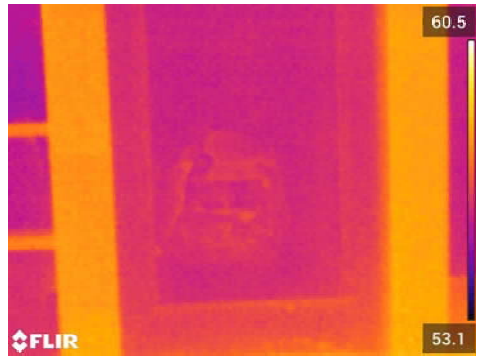

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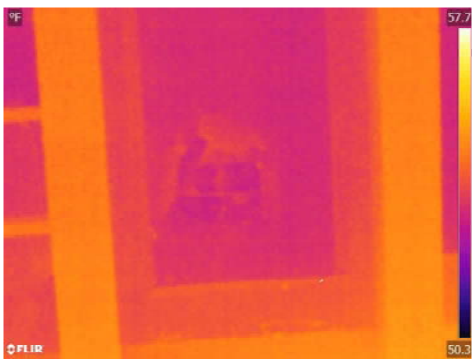

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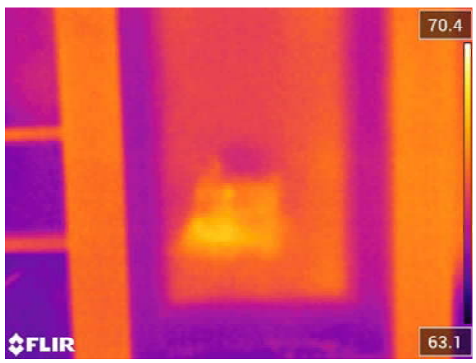

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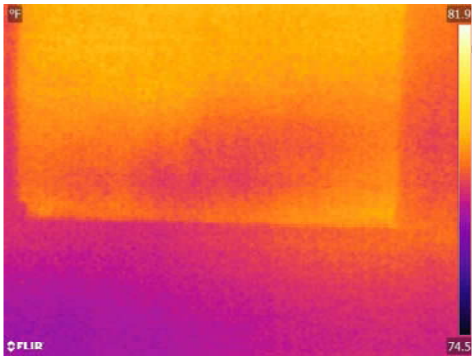

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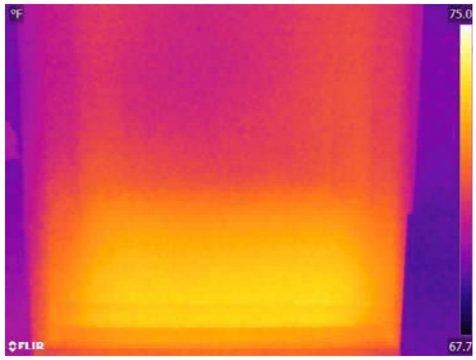

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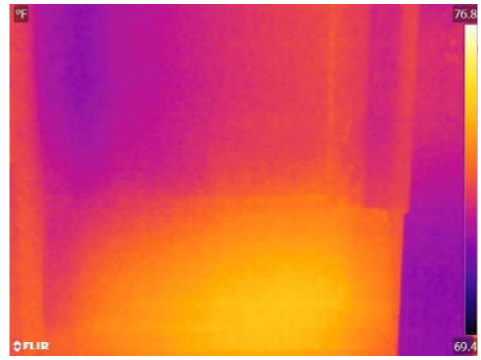

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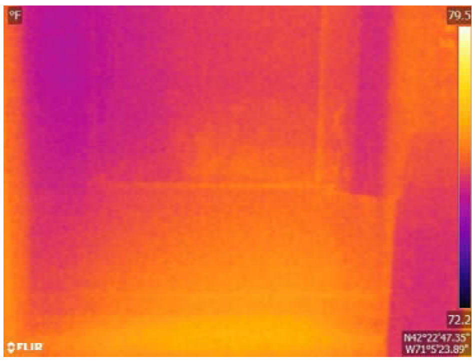

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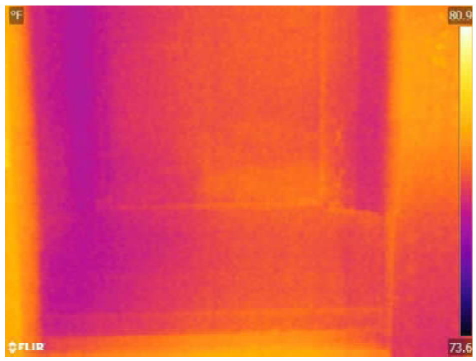

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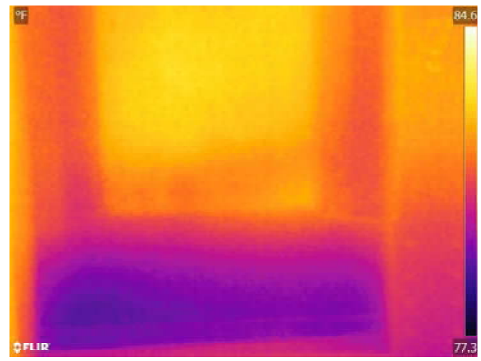

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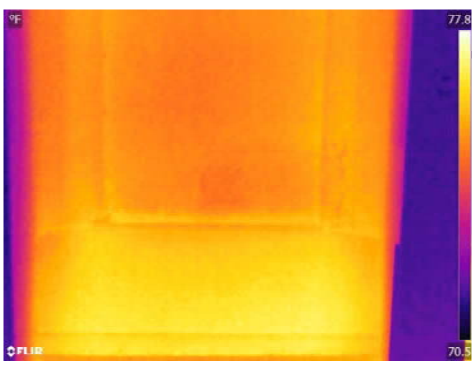

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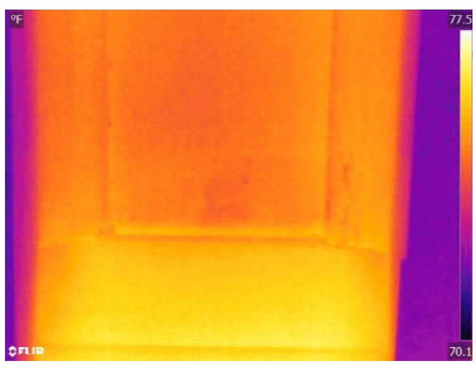

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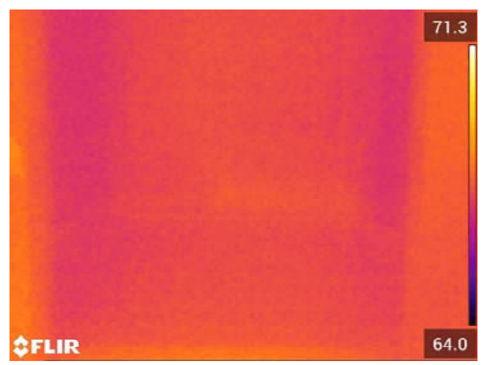

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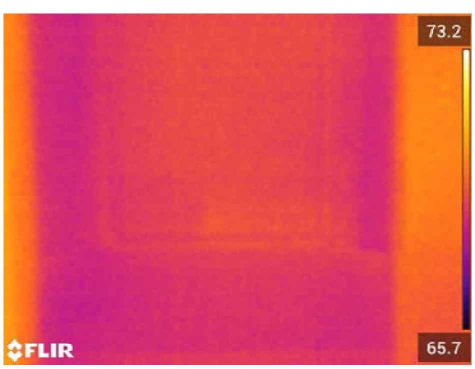

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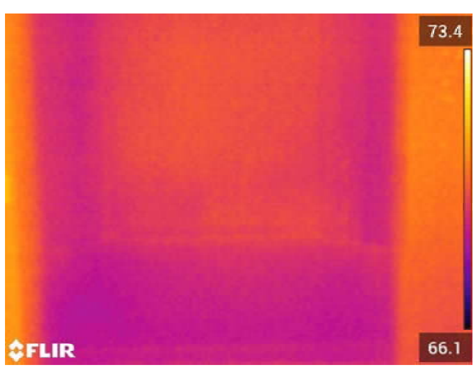

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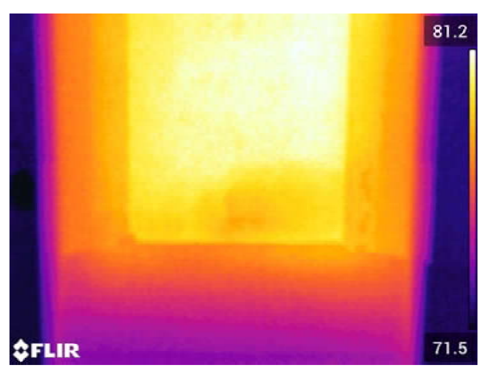

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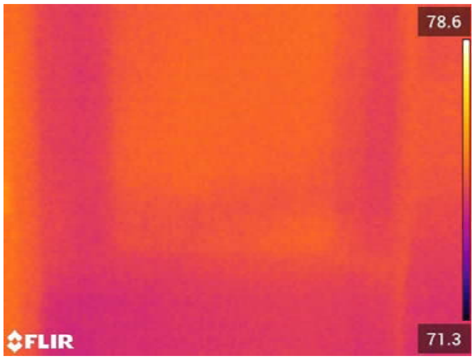

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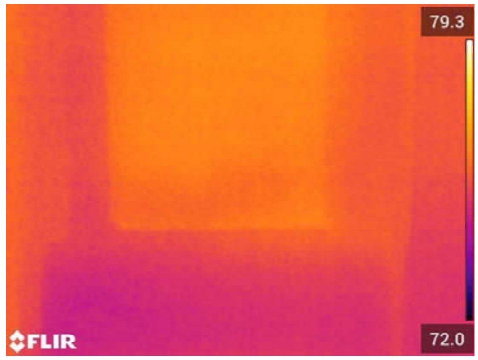

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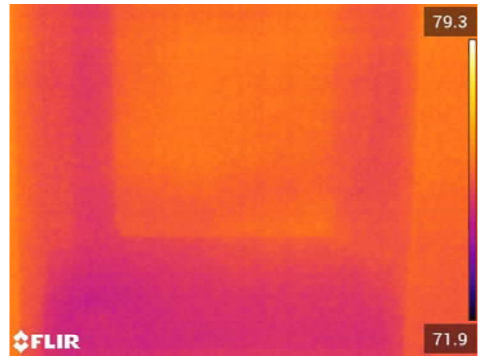

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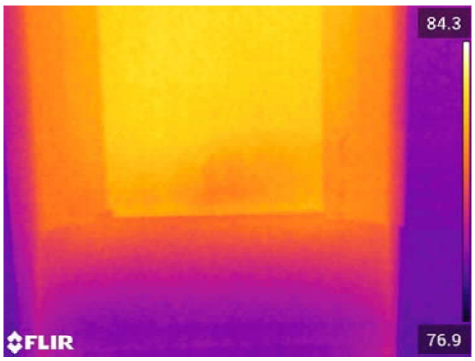

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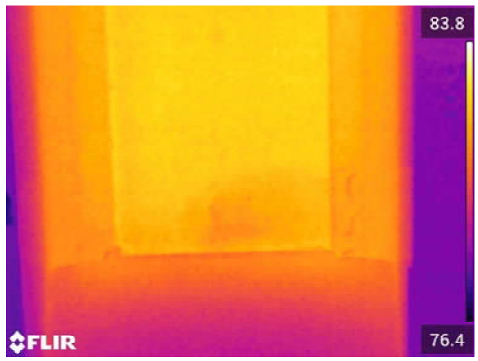

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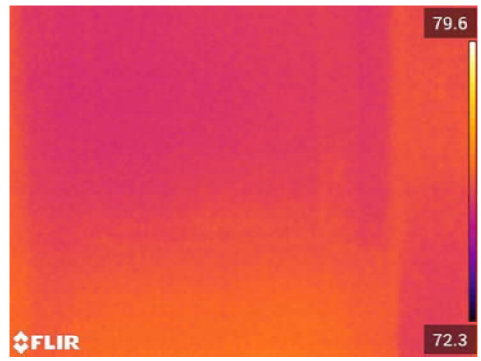

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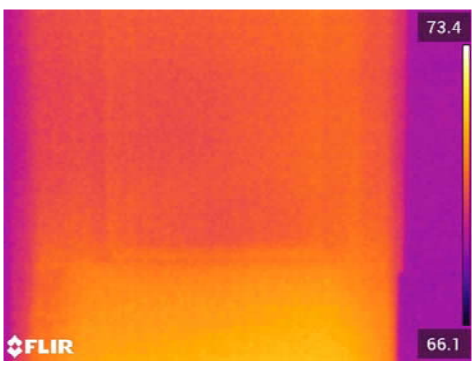

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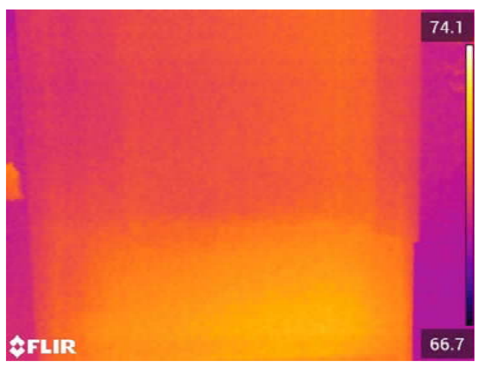

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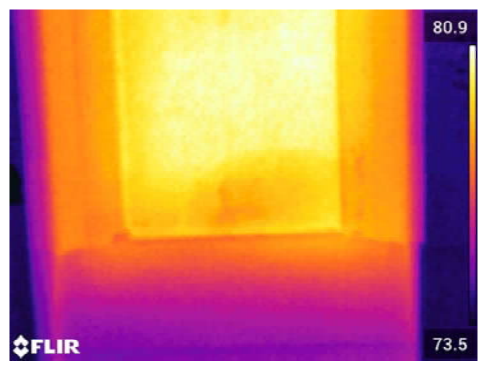

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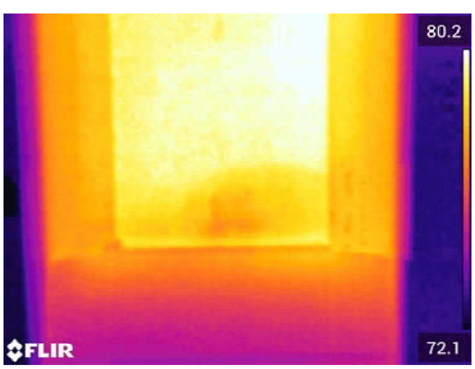

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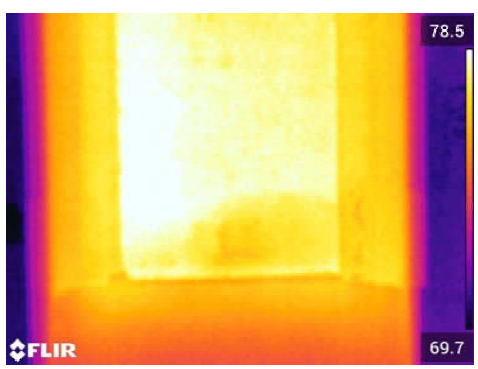

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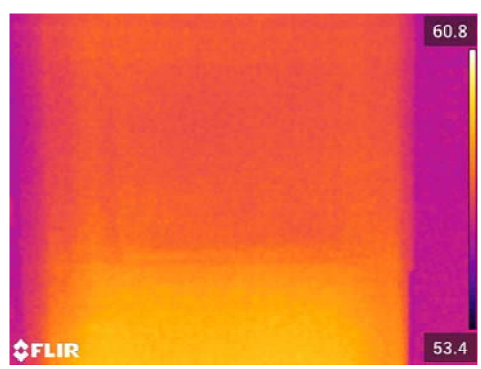

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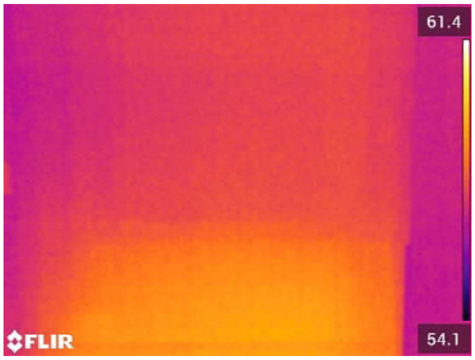

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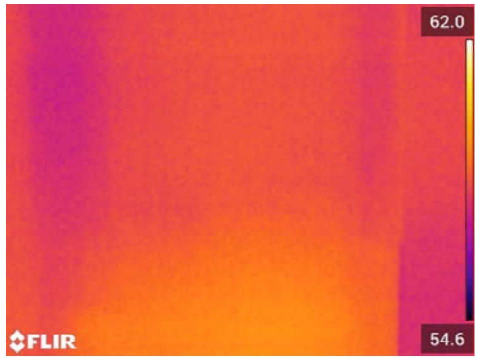

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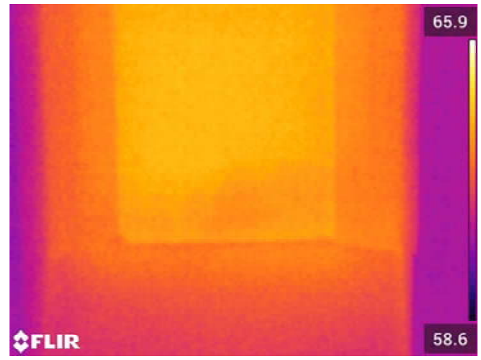

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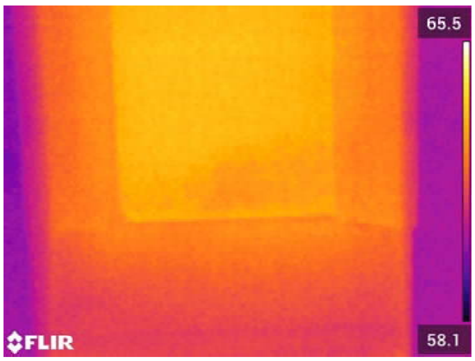

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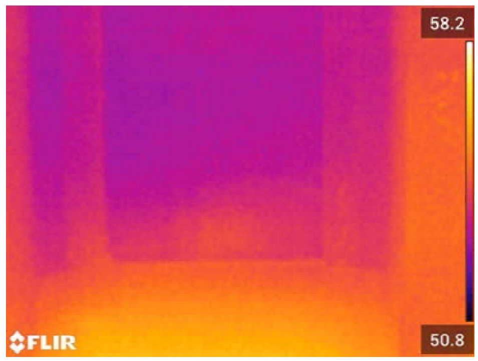

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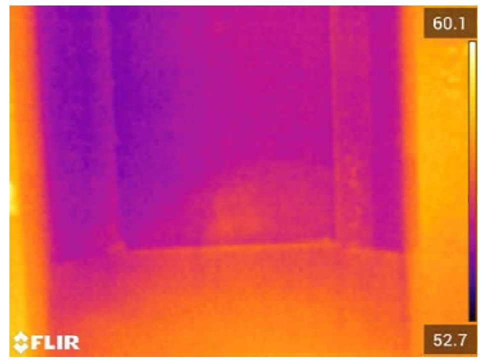

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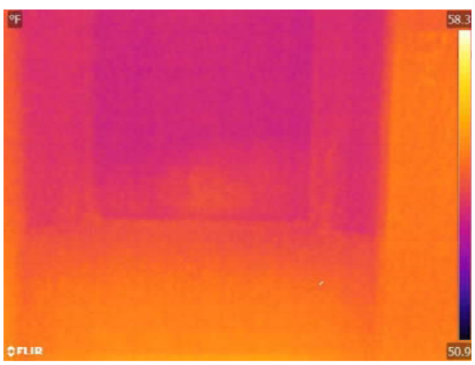

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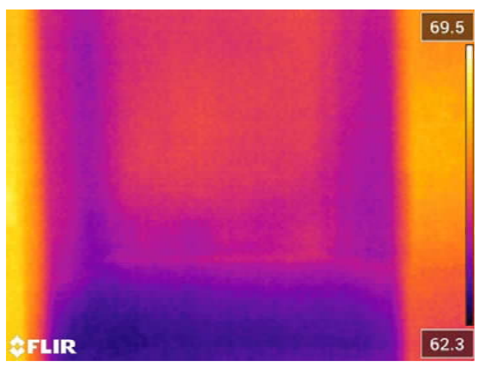

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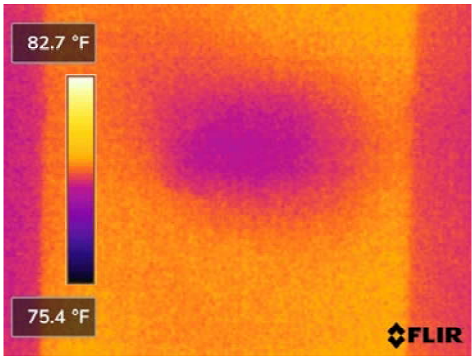

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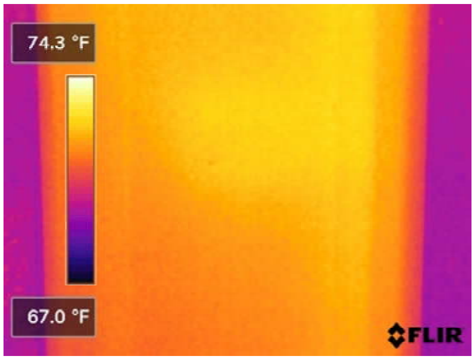

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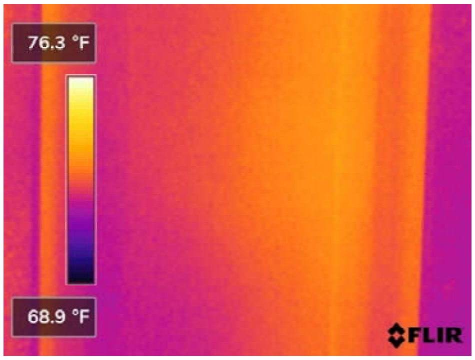

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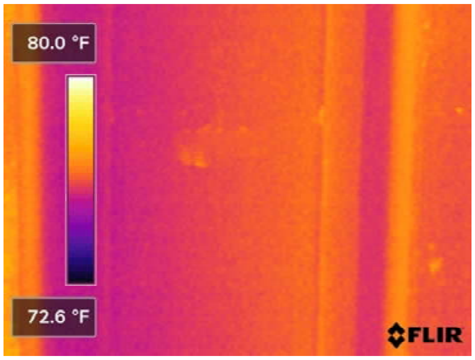

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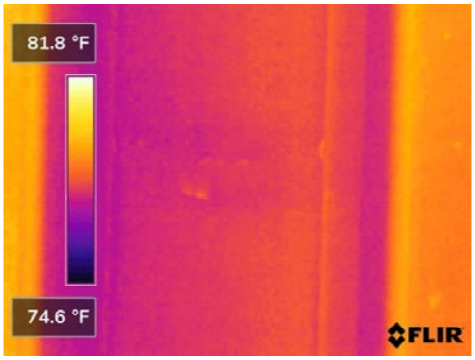

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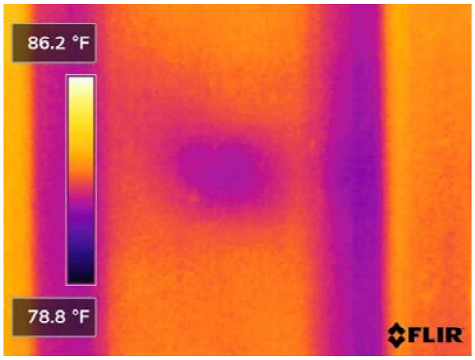

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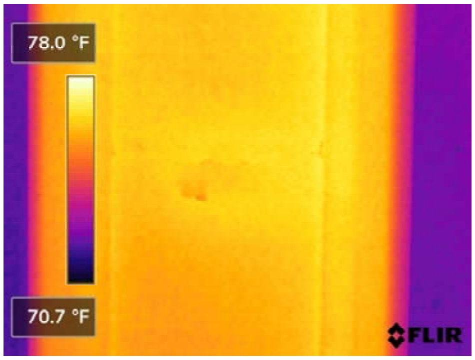

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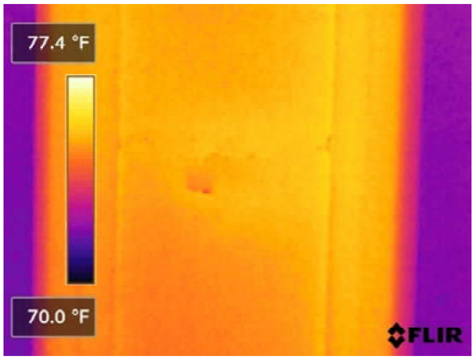

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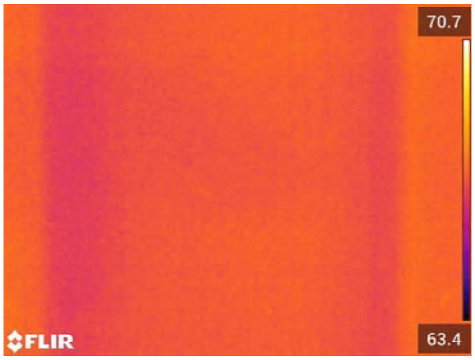

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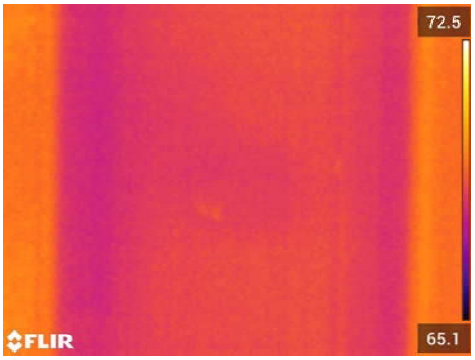

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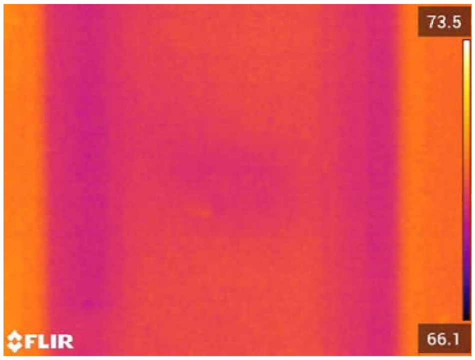

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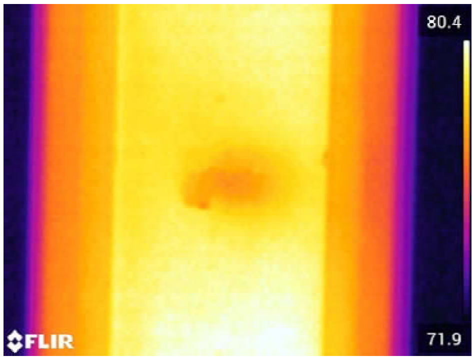

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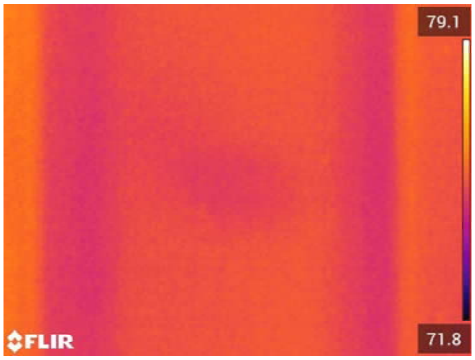

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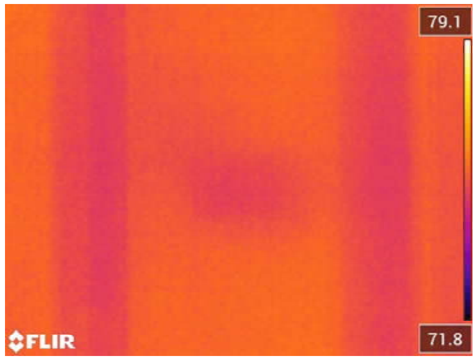

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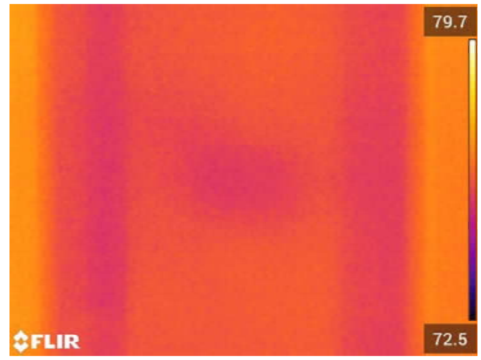

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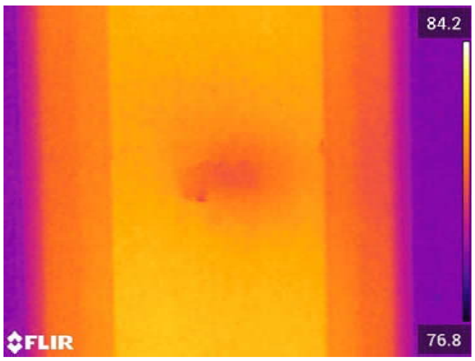

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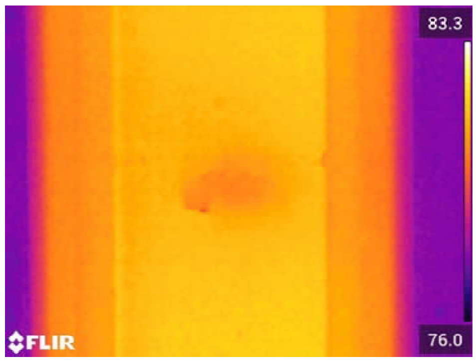

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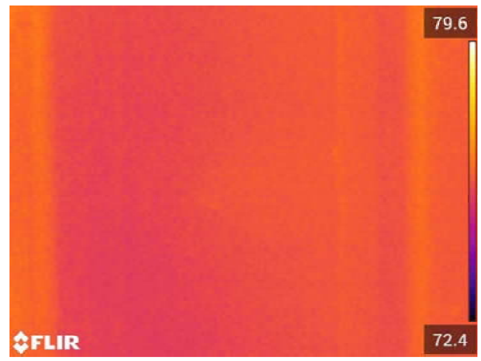

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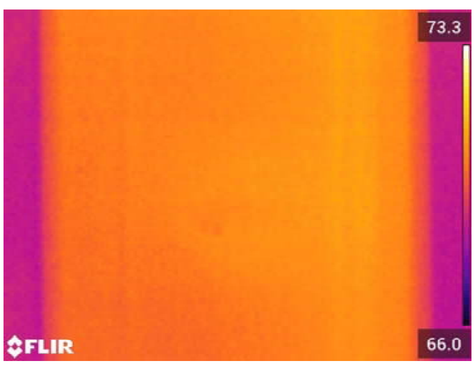

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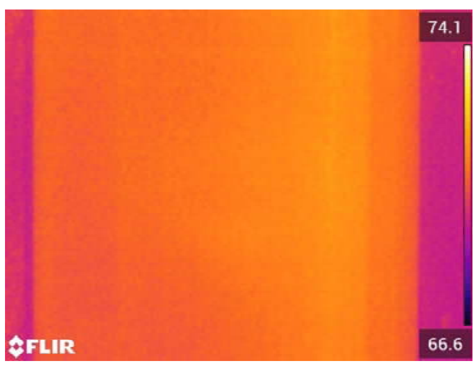

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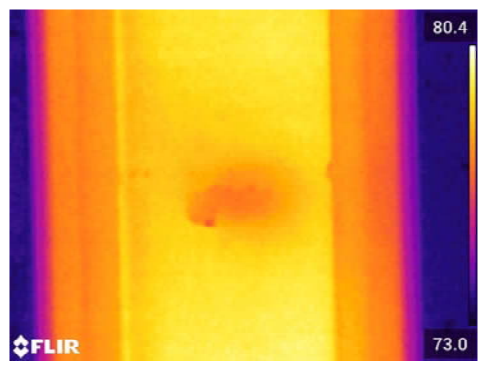

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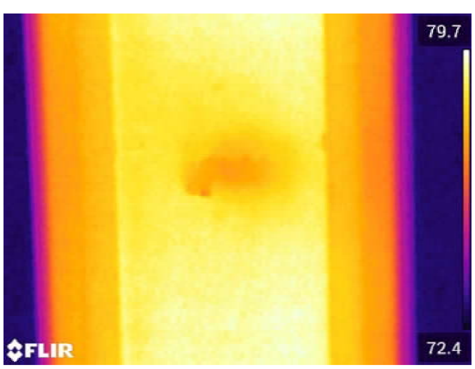

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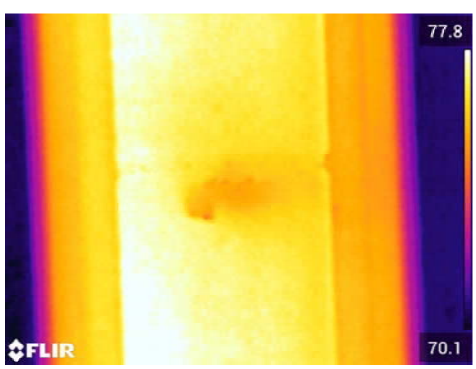

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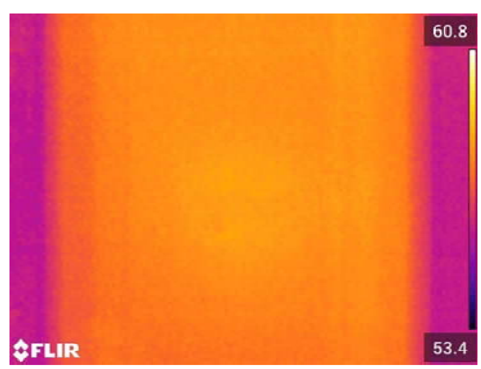

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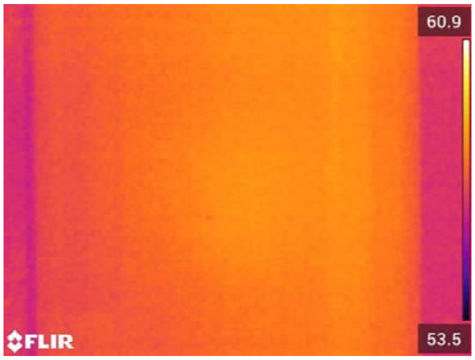

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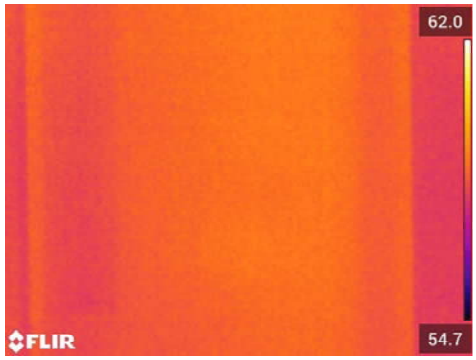

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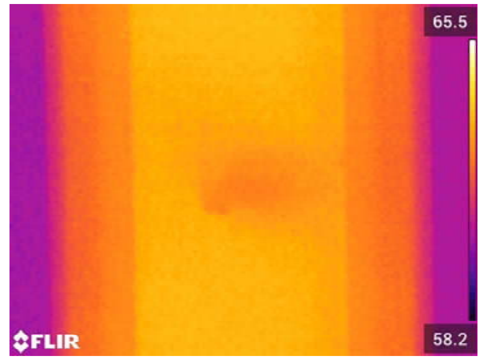

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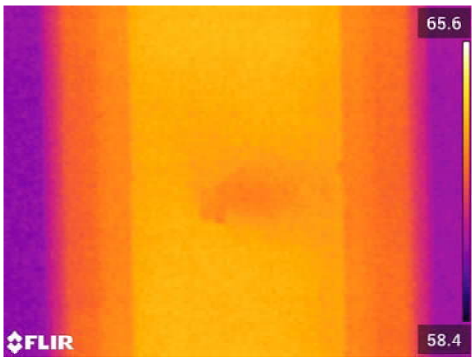

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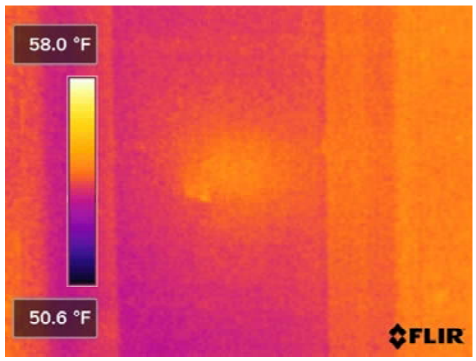

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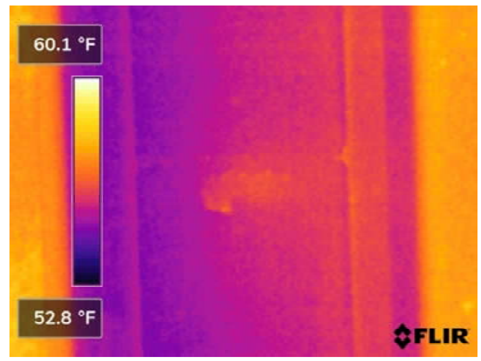

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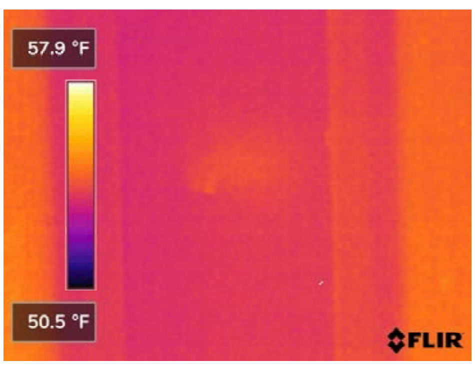

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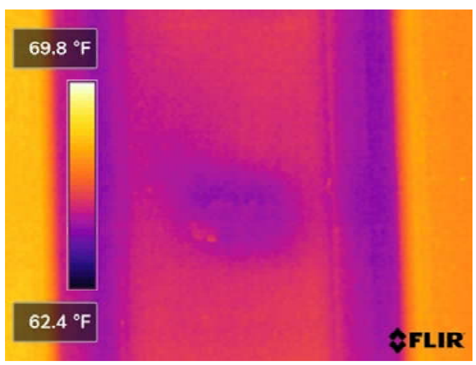

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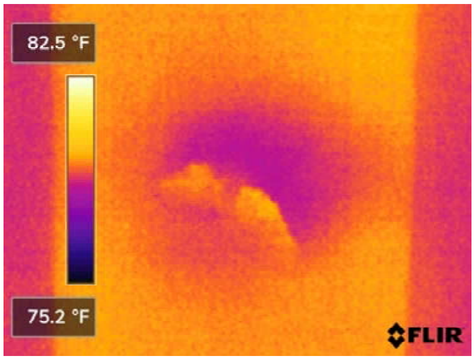

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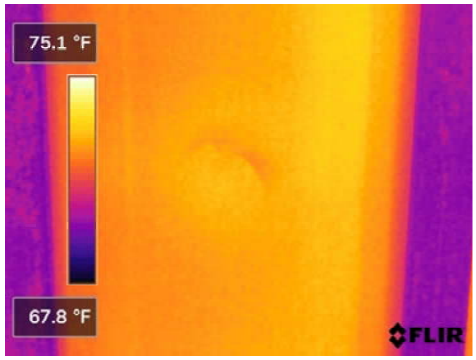

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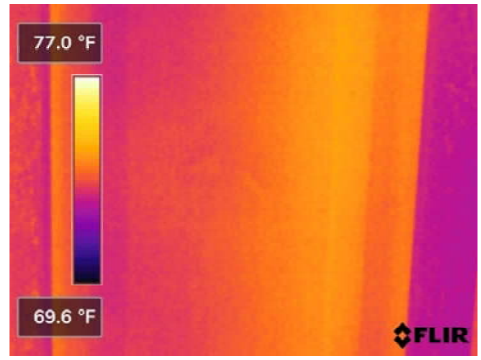

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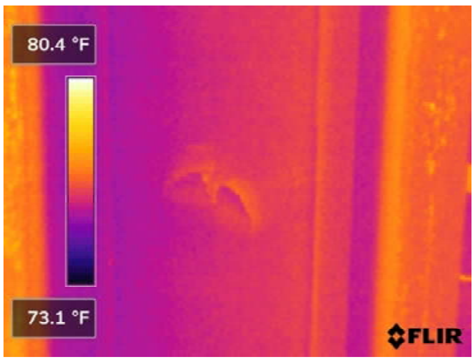

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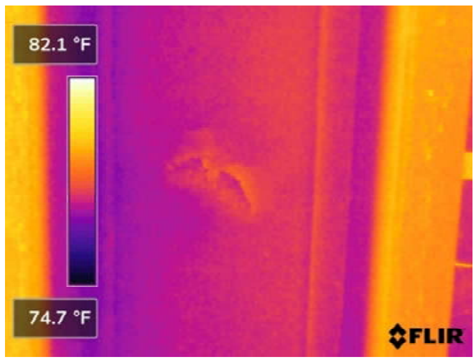

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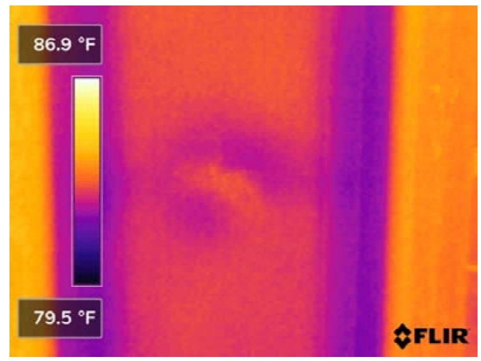

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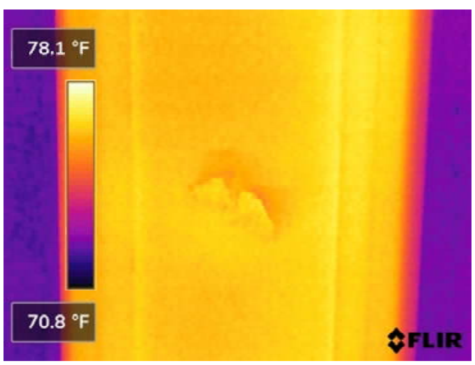

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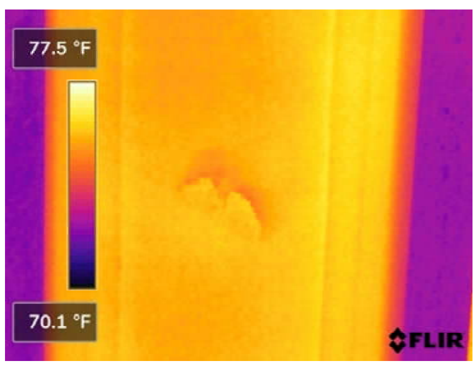

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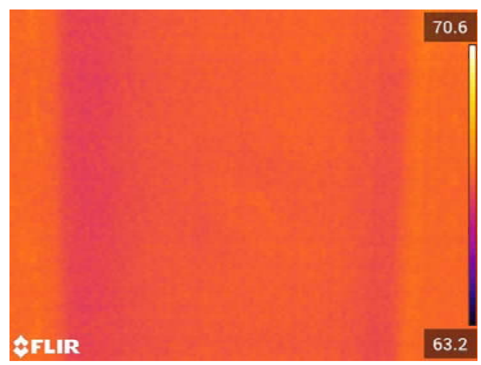

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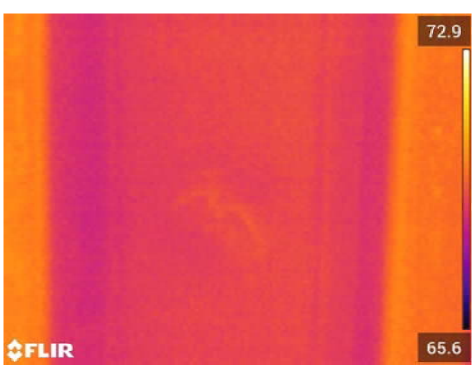

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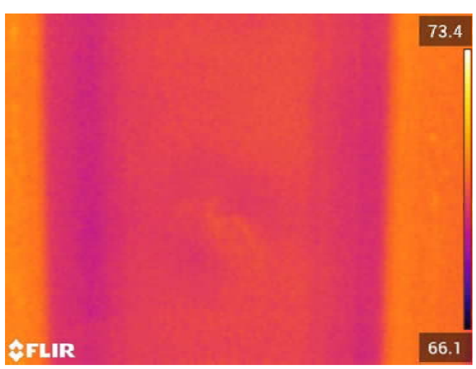

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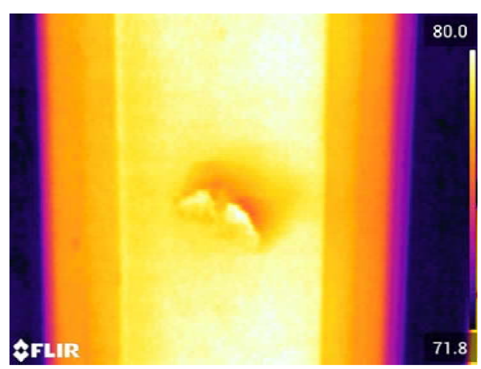
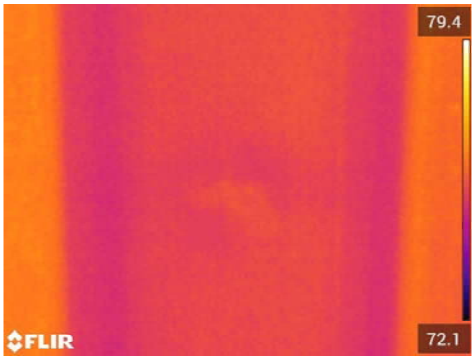


E96_Loc5_12_FLIR1101



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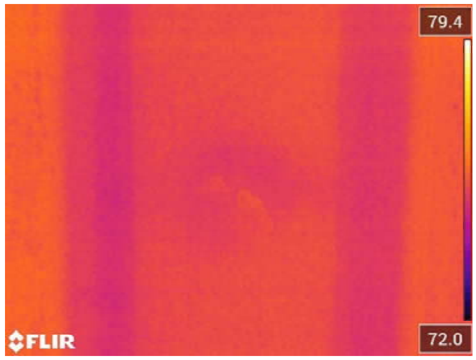

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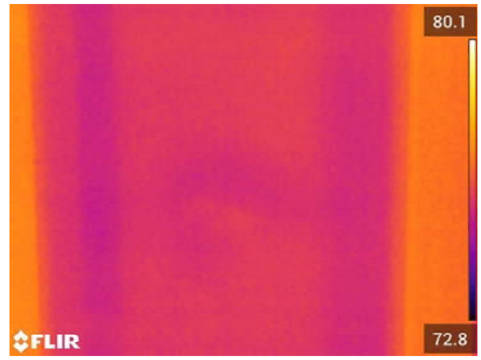

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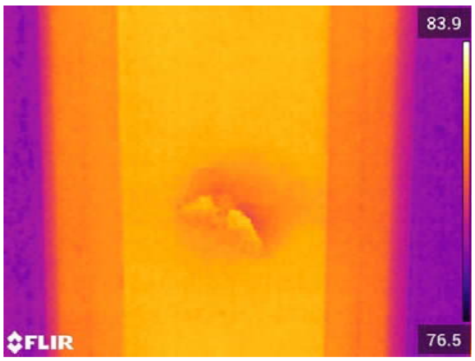

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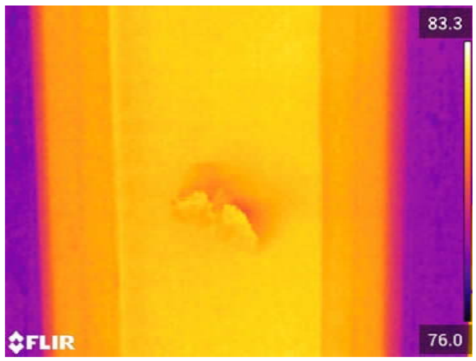

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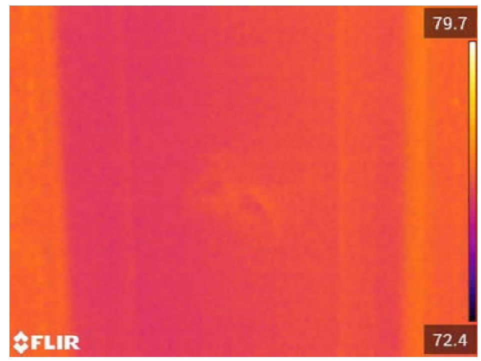

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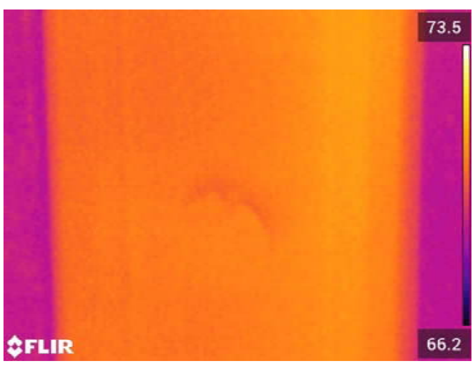

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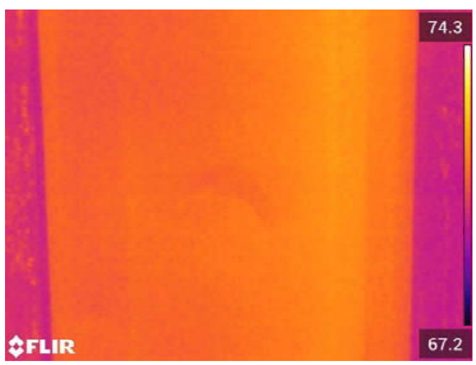

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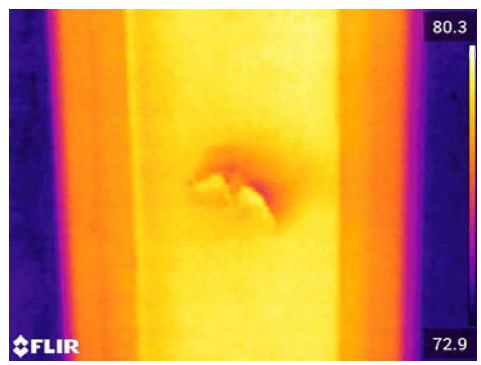

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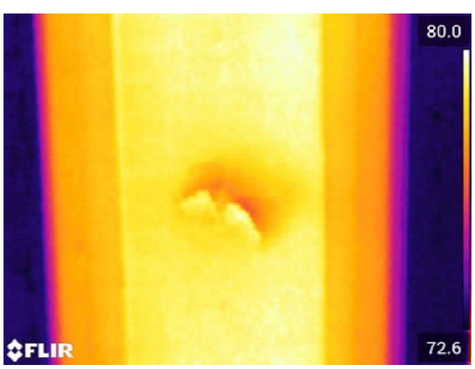

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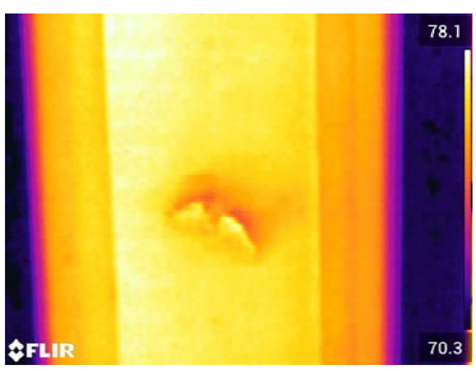

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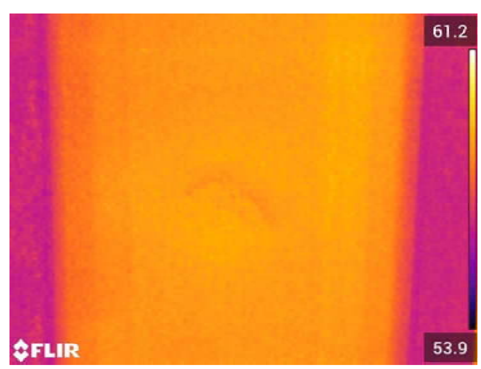

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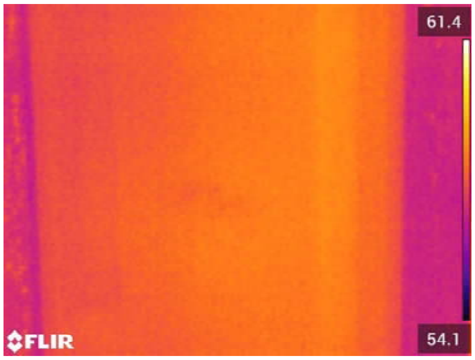

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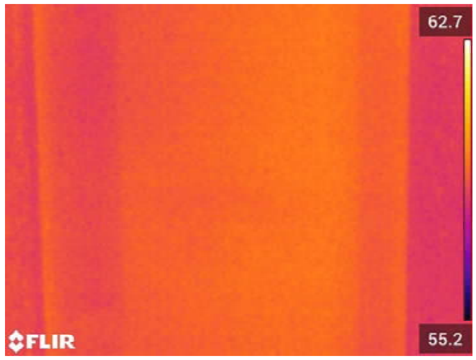

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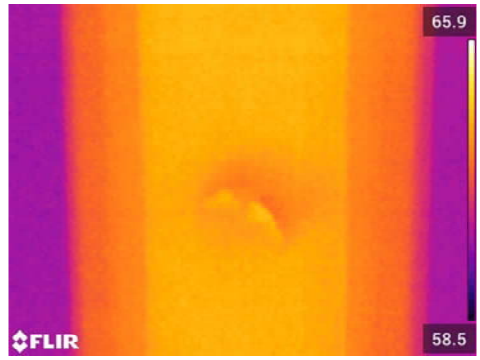

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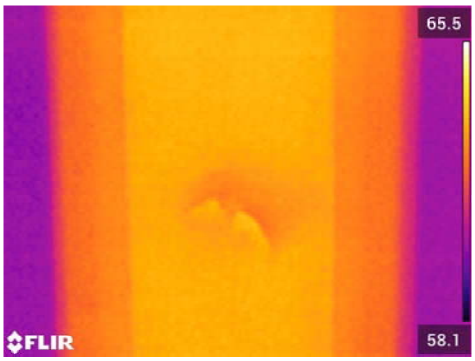

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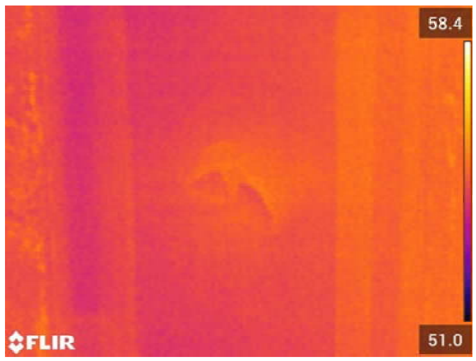

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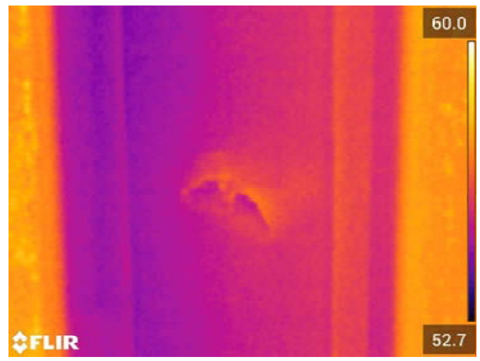

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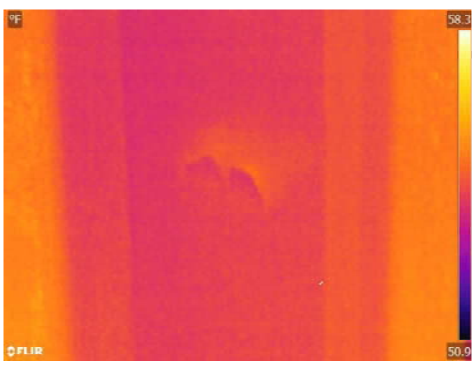

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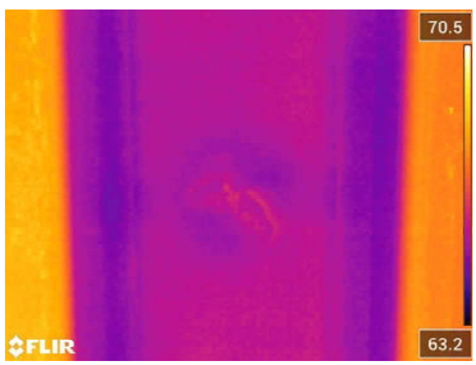

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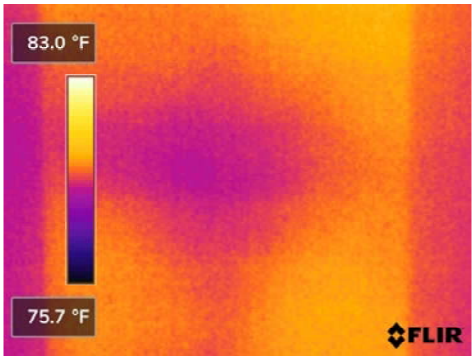

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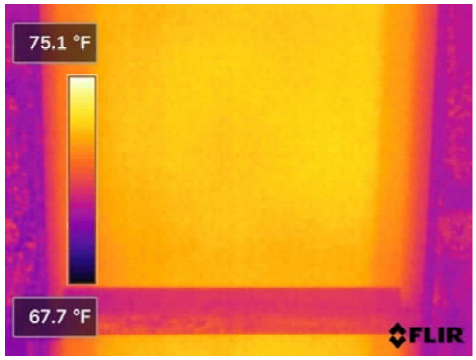

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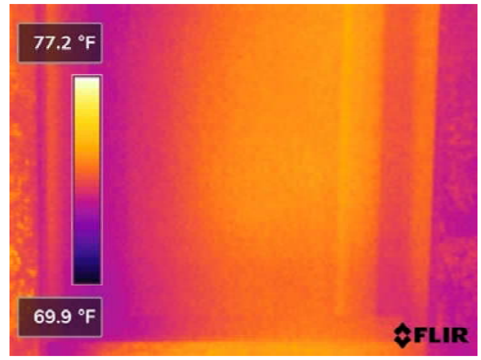

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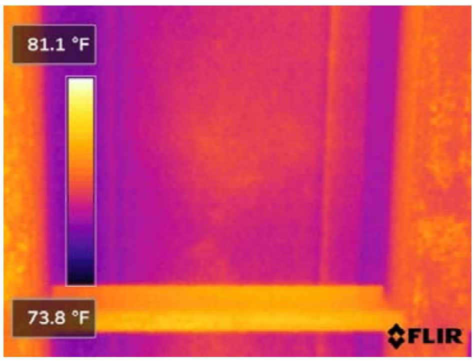

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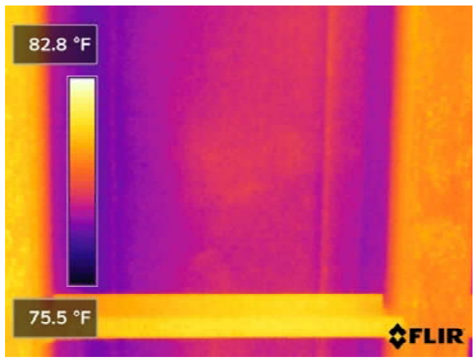

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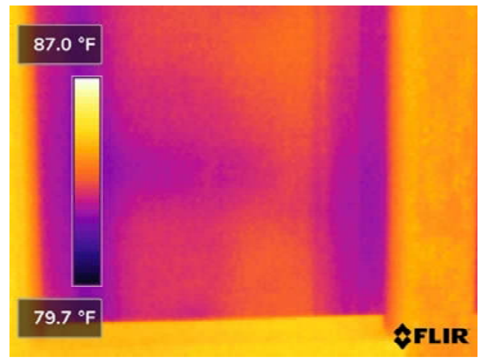

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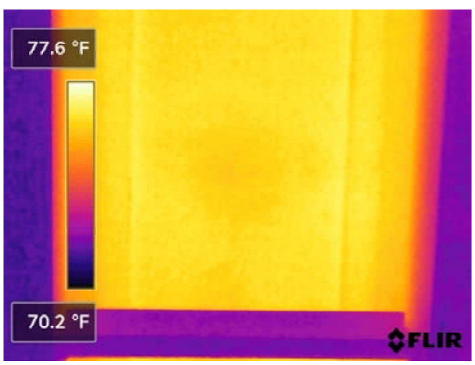

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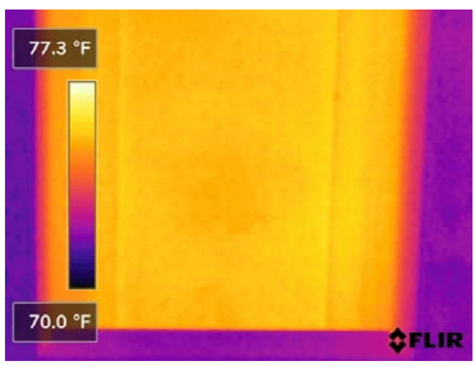

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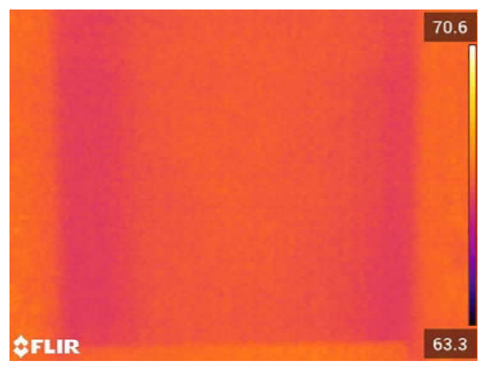

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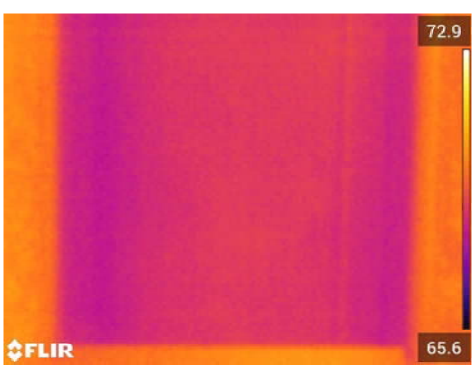

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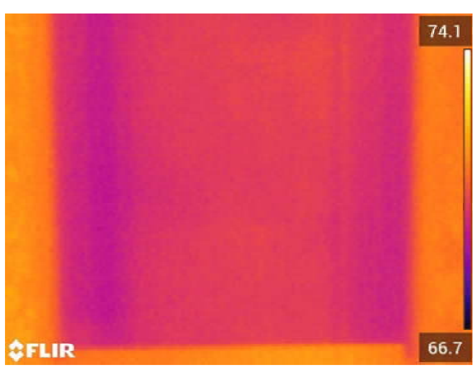

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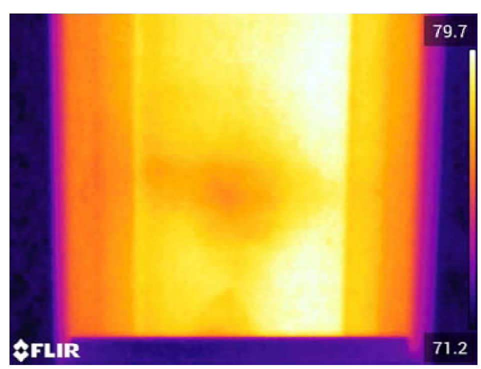

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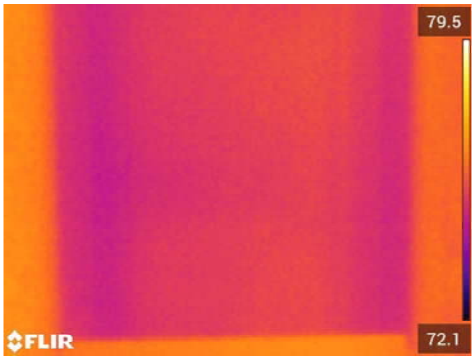

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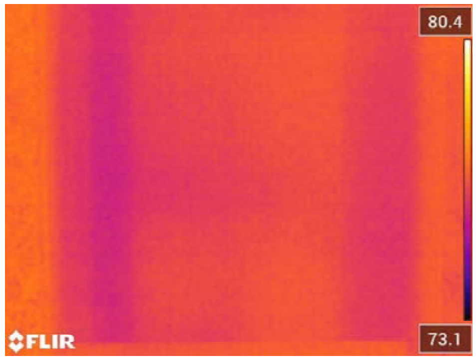

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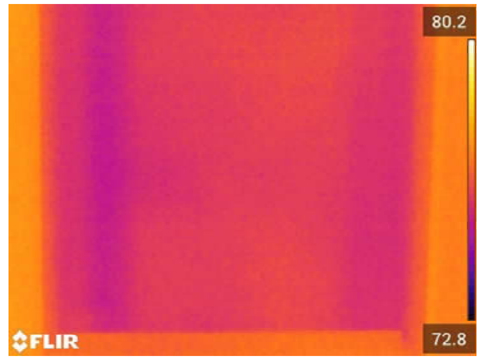

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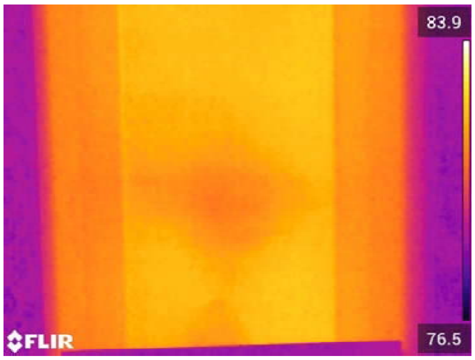

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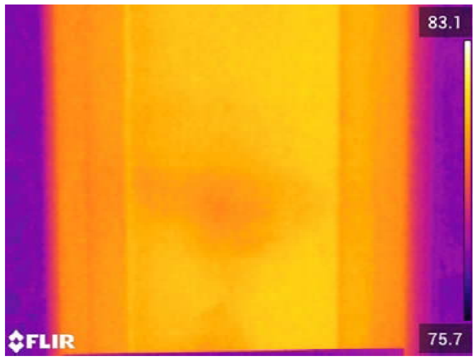

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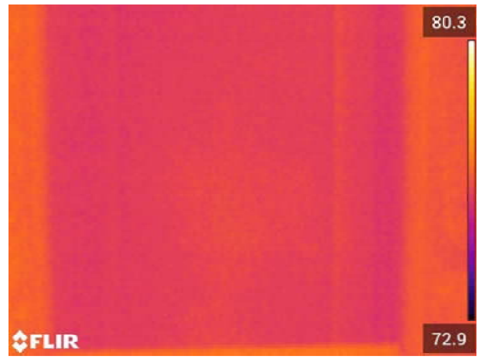

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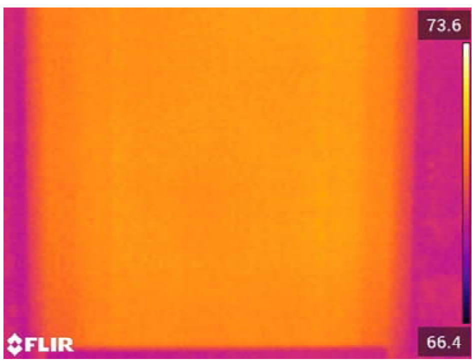

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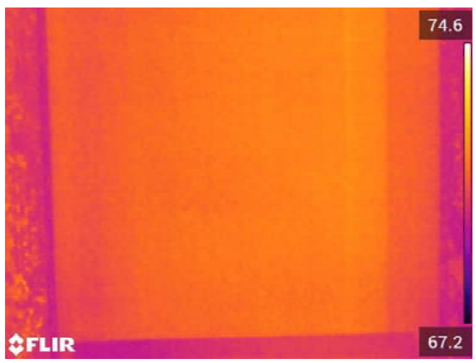

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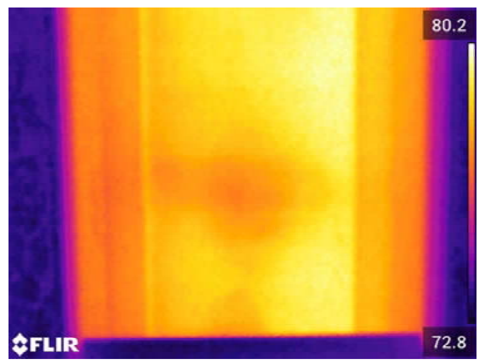

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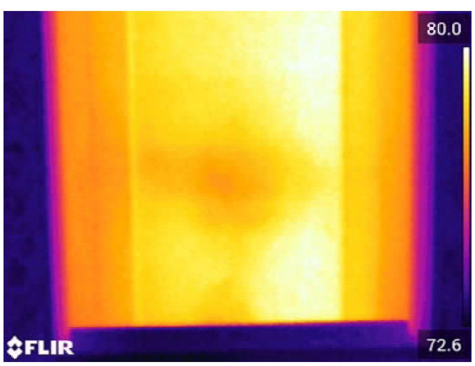

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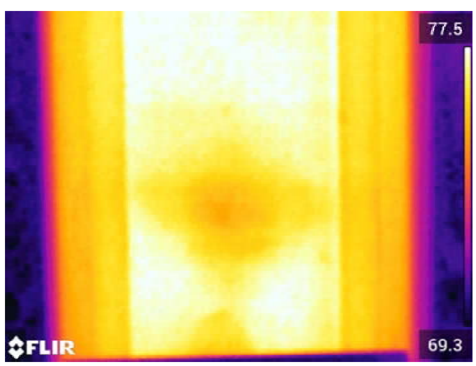

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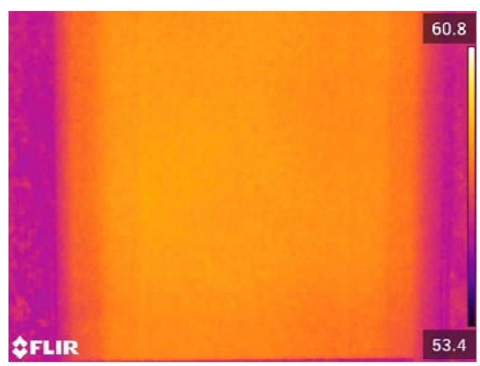

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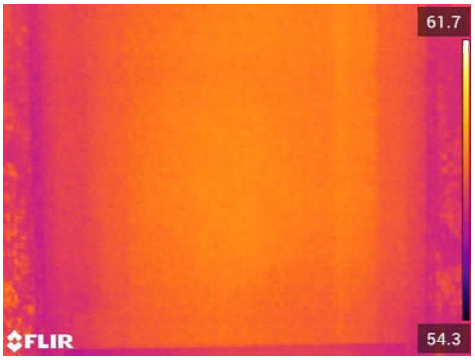

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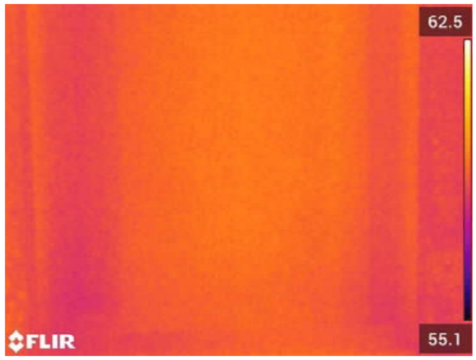

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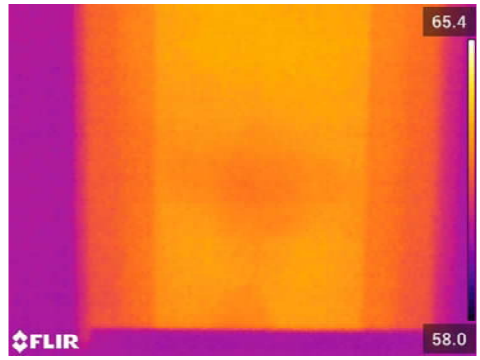

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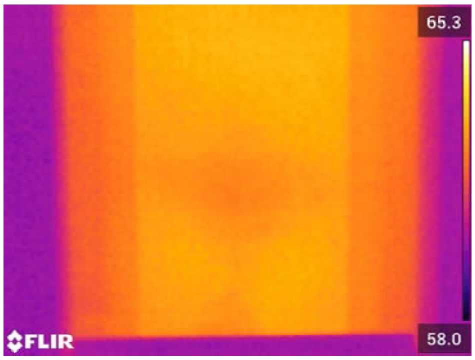

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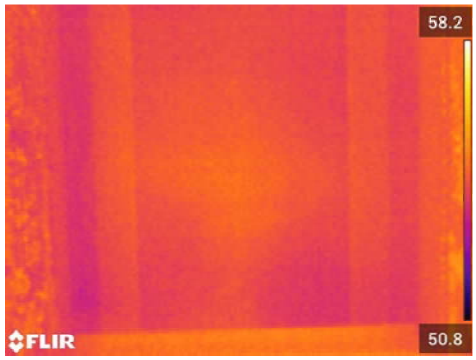

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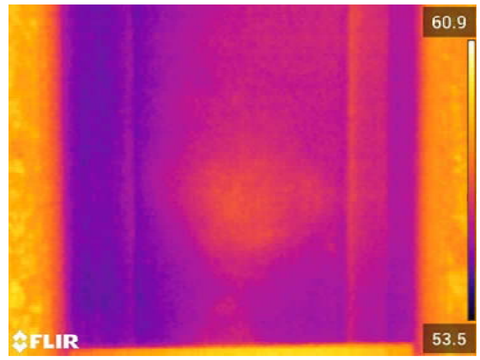

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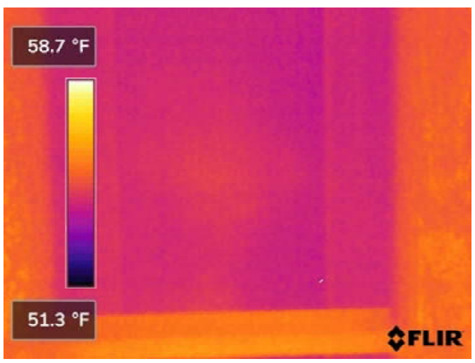

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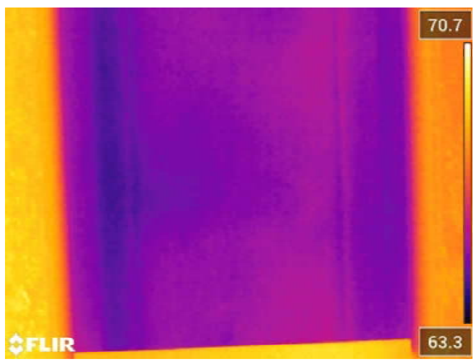

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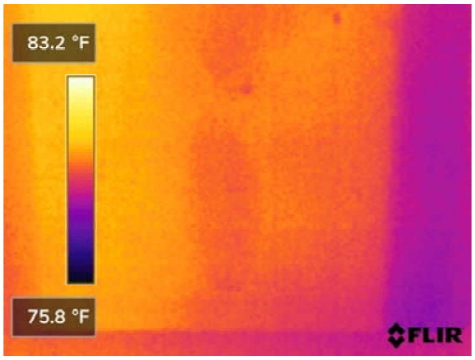

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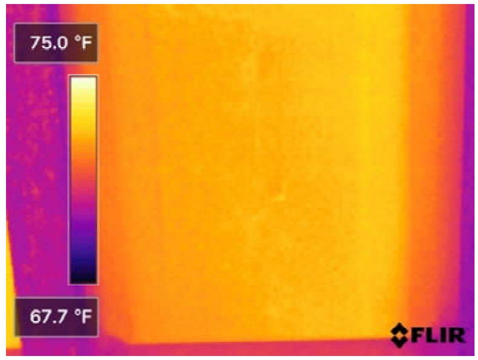

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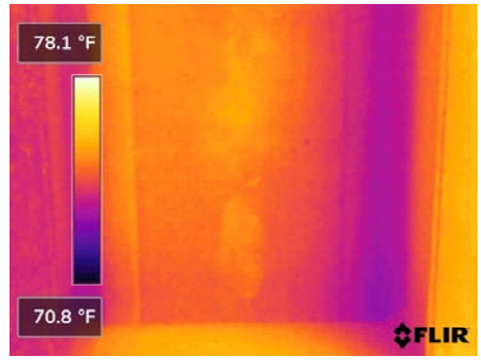

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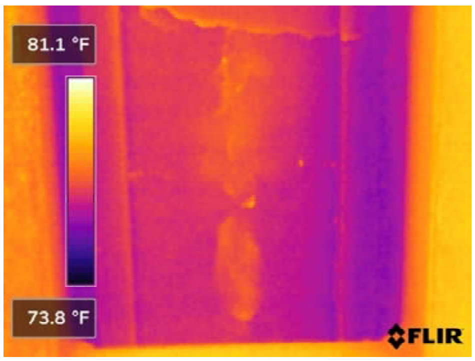

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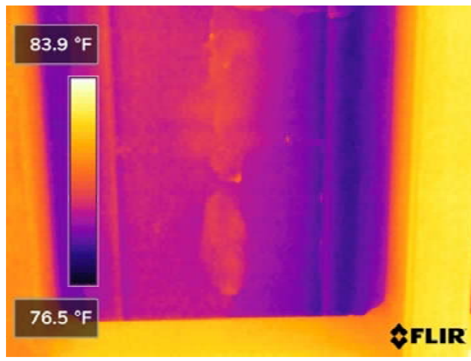

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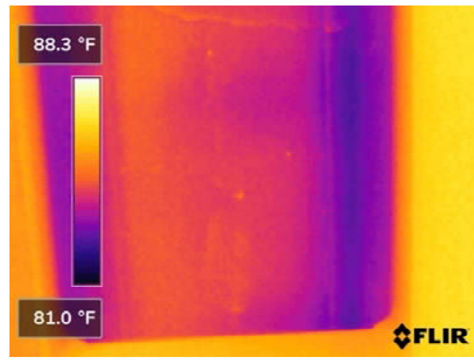

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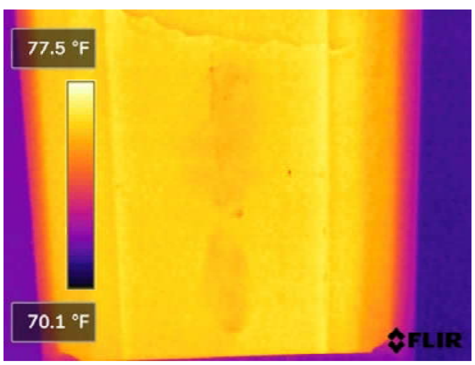

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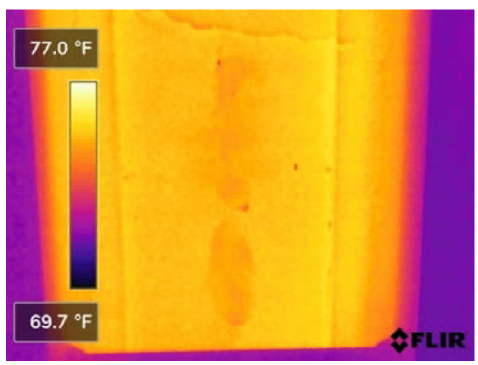

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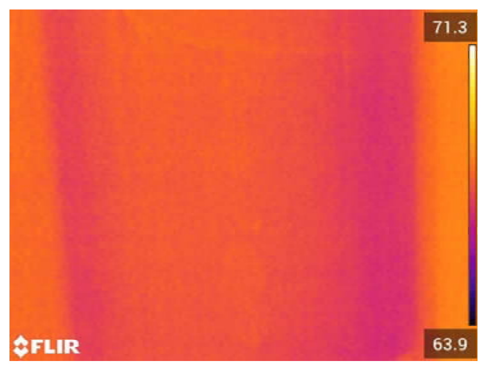

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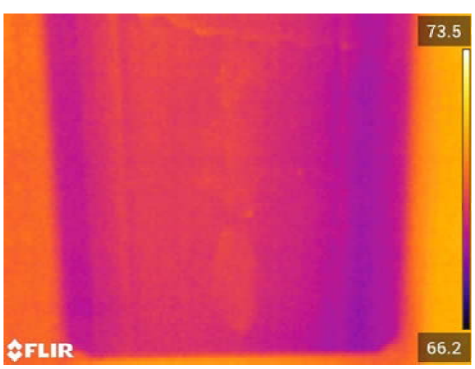

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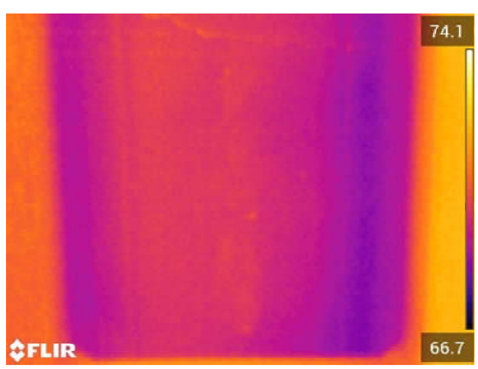

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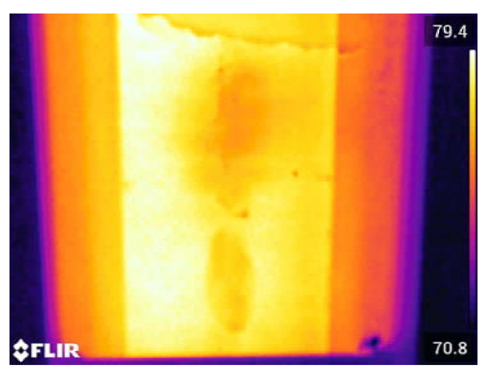

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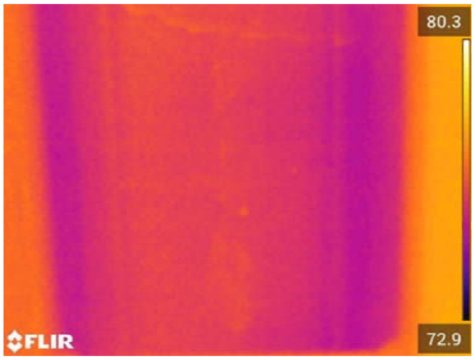

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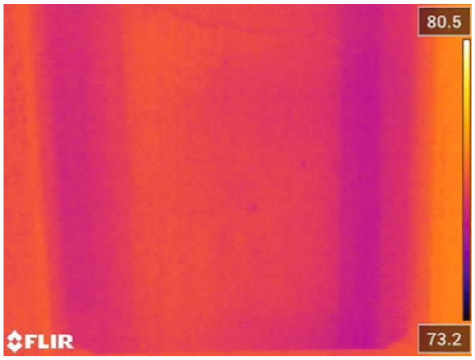

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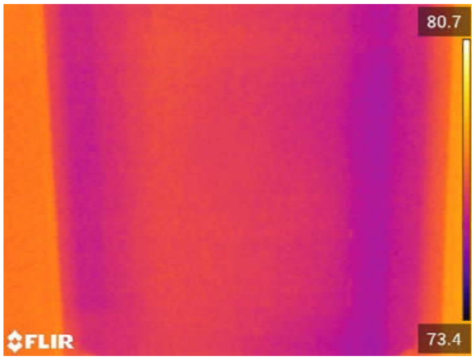

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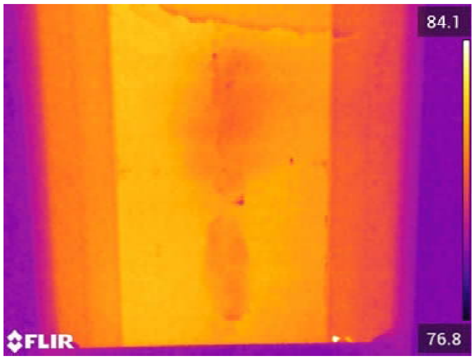

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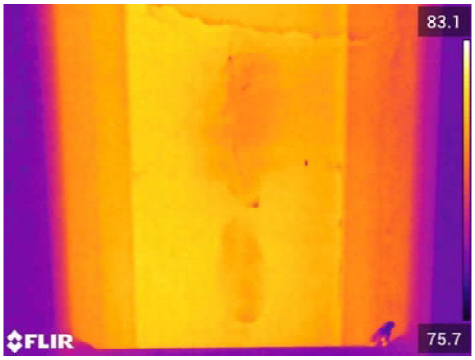

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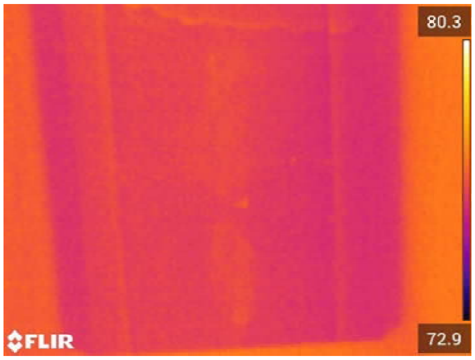

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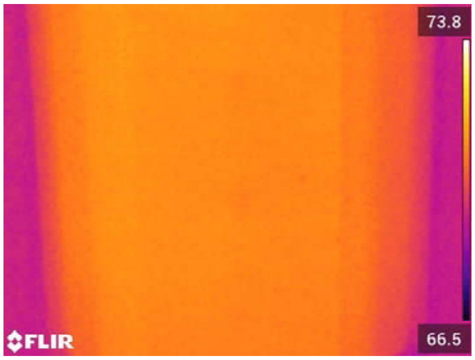

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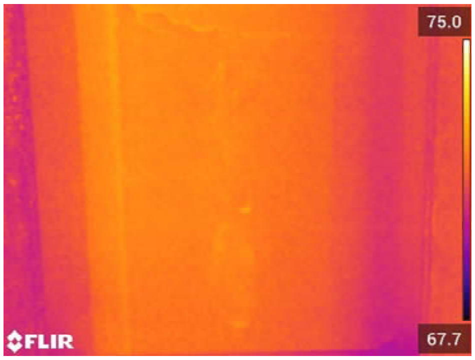

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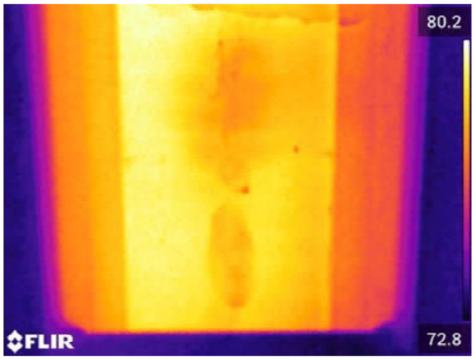

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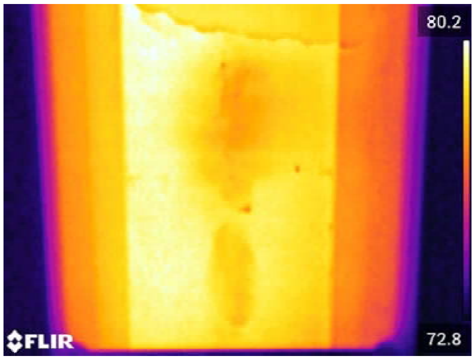

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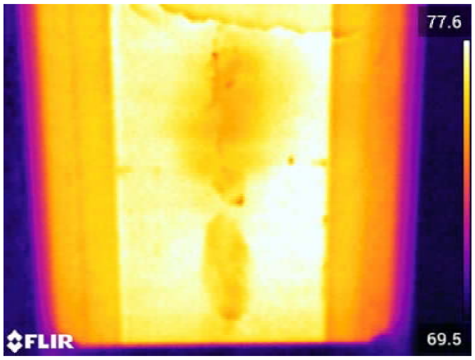

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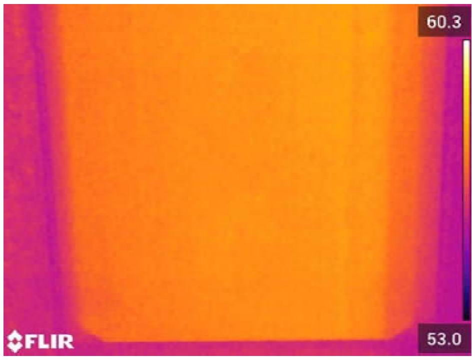

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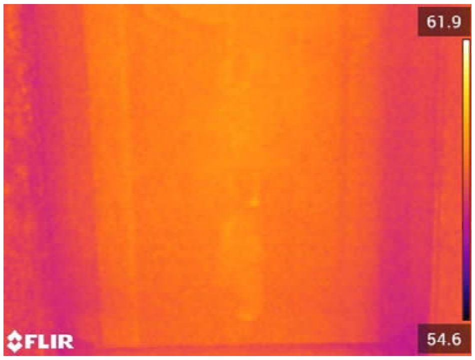

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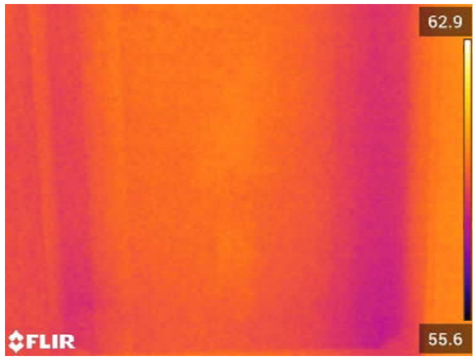

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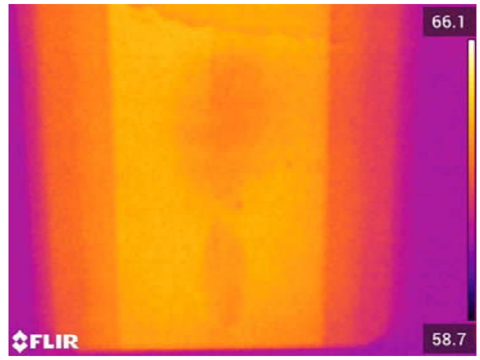

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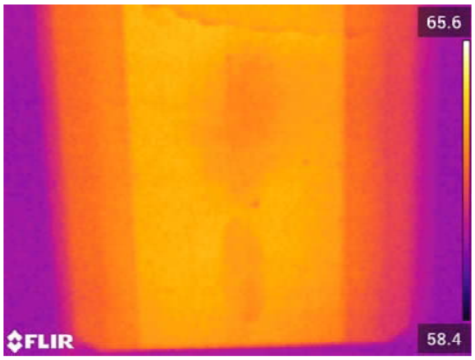

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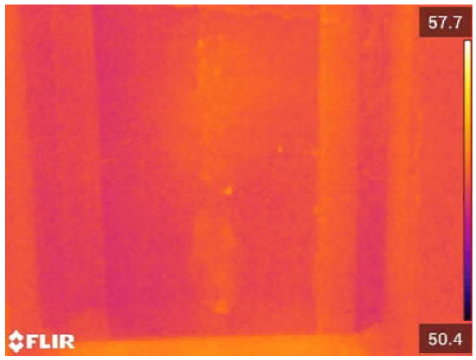

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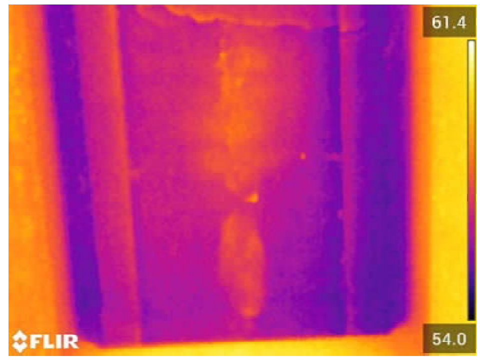

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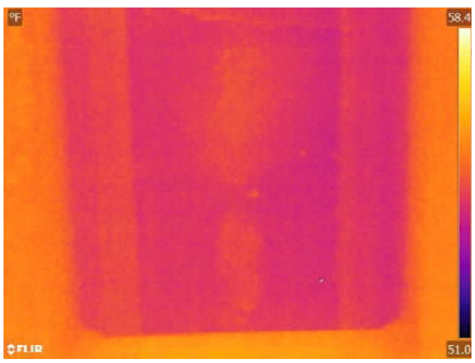

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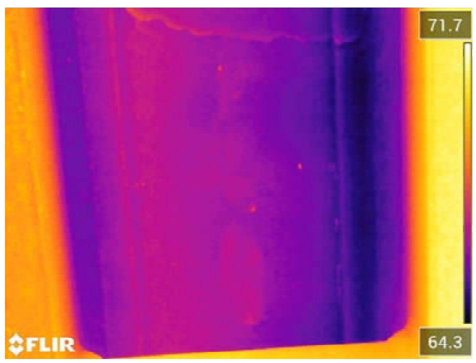

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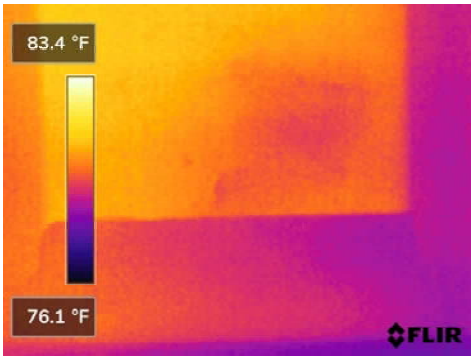

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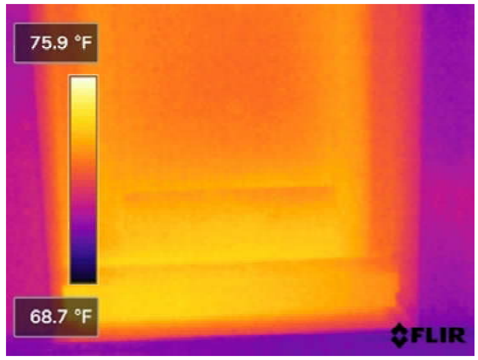

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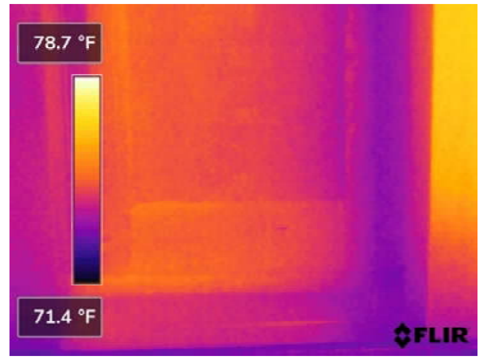

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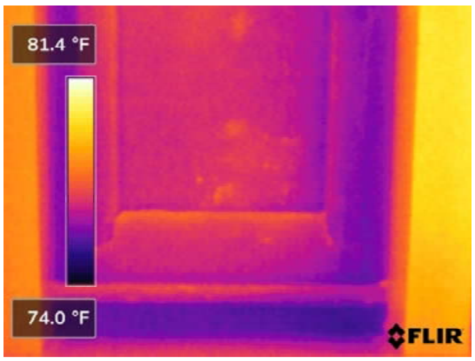

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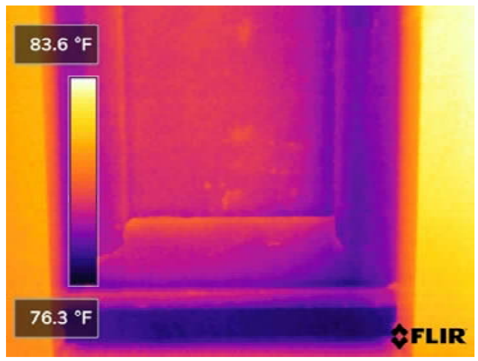

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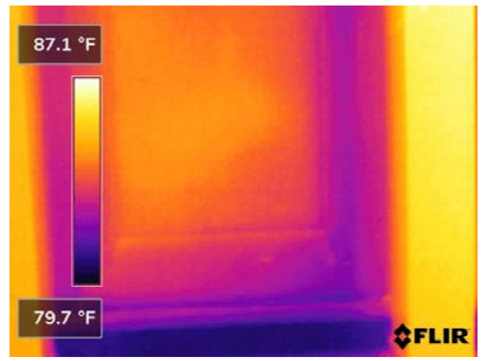

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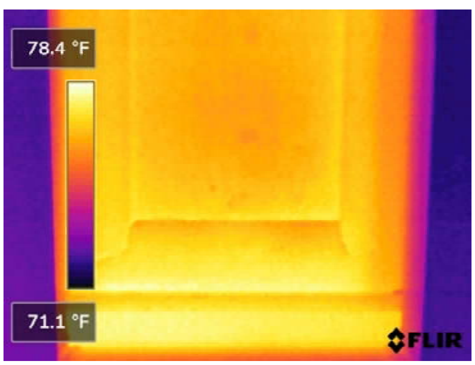

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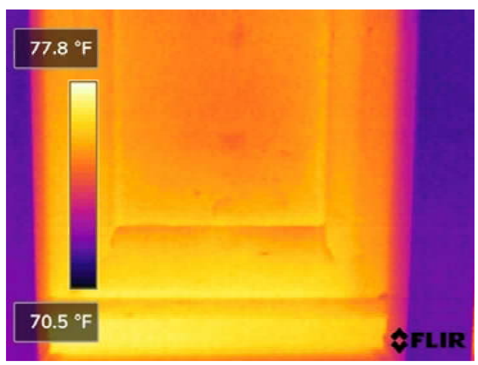

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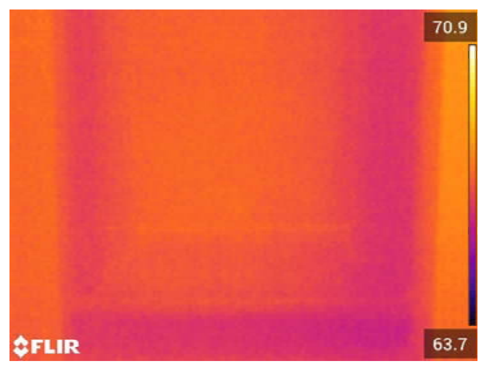

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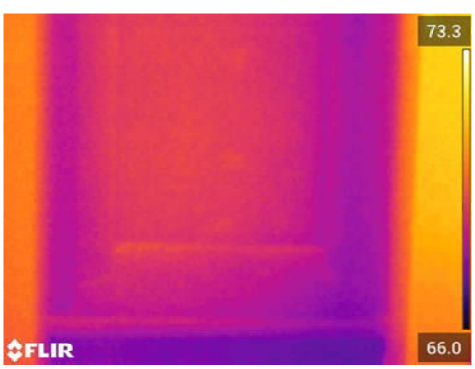

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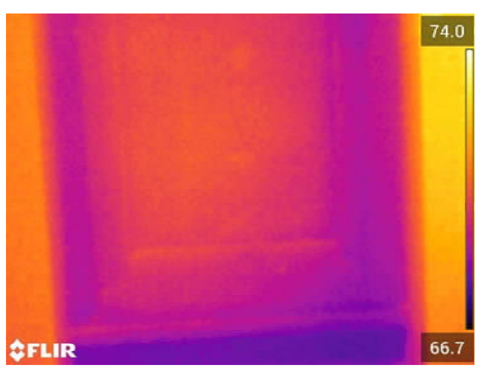

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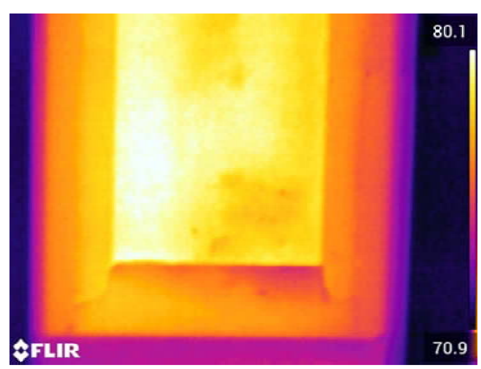

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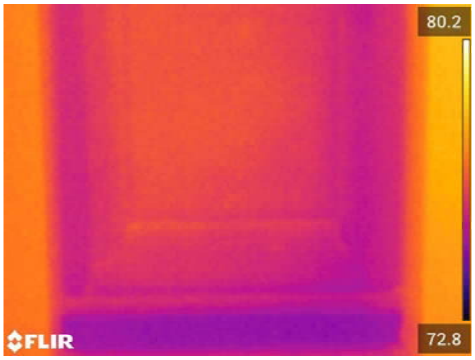

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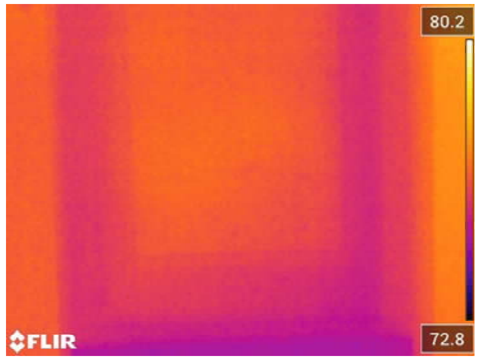

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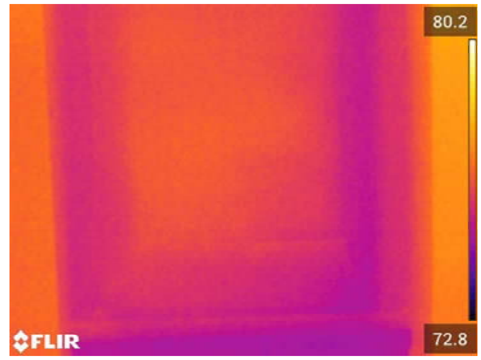

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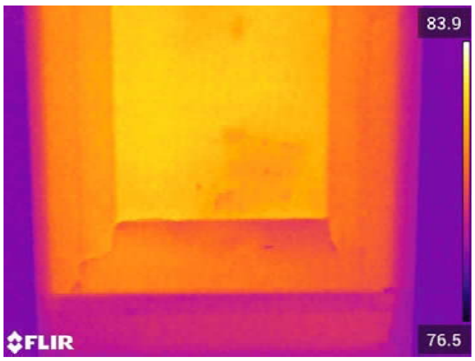

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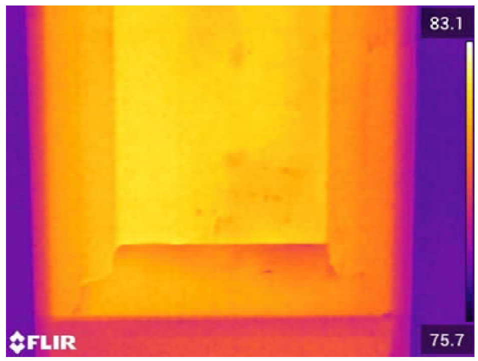

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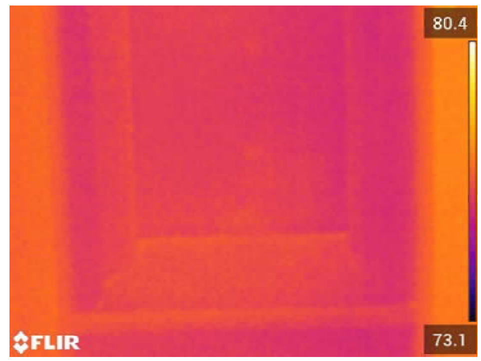

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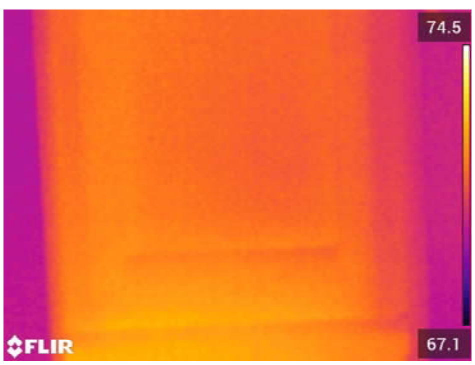

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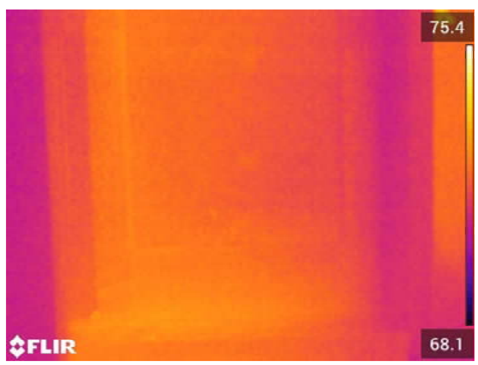

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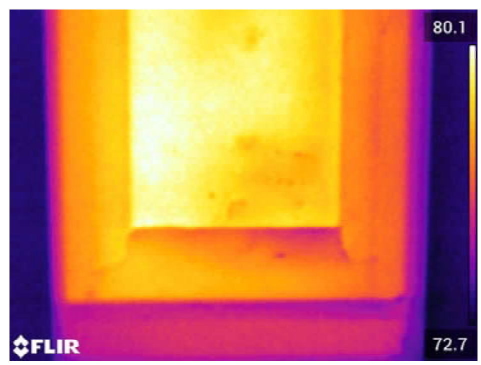

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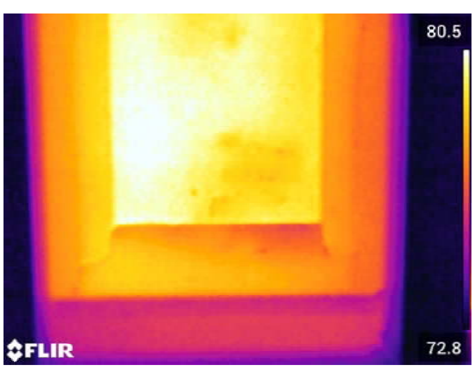

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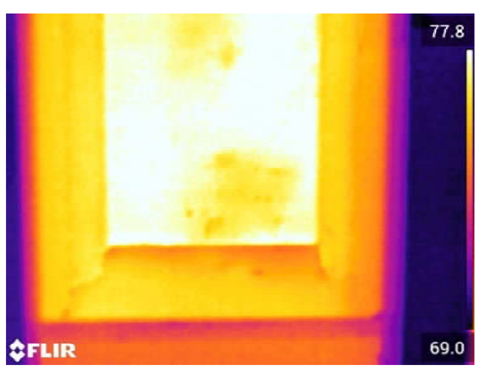

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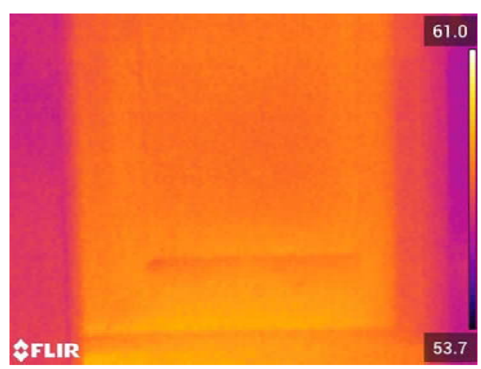

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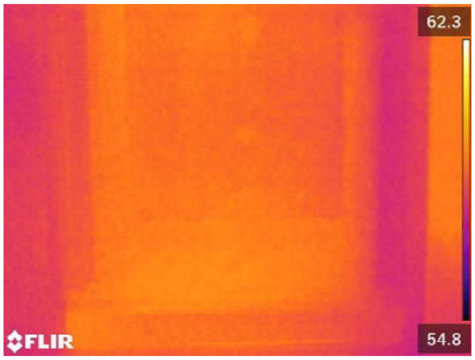

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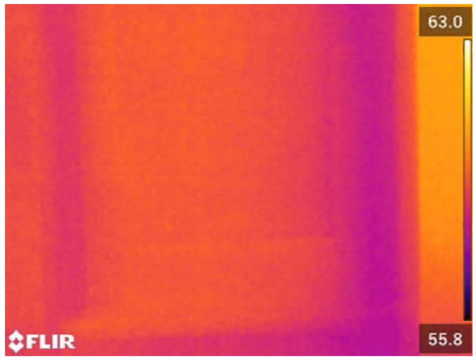

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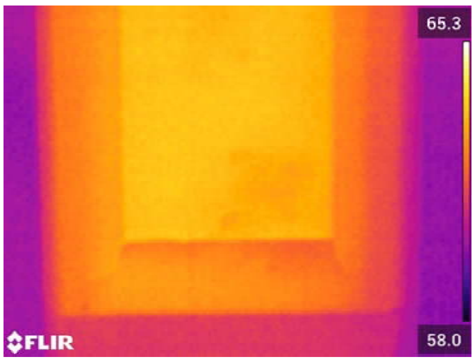

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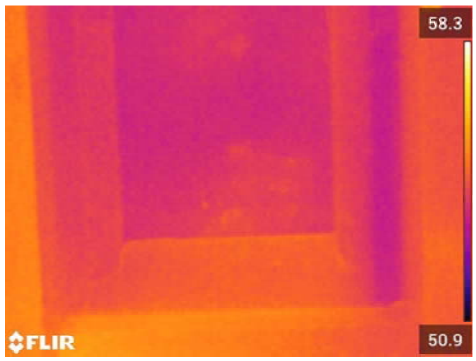

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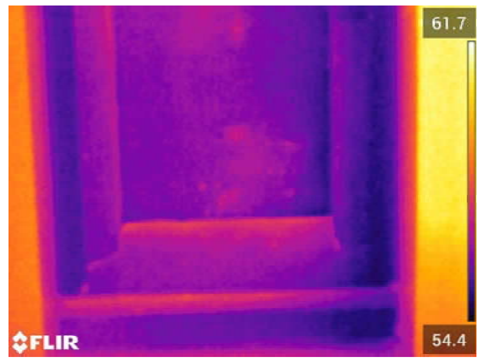

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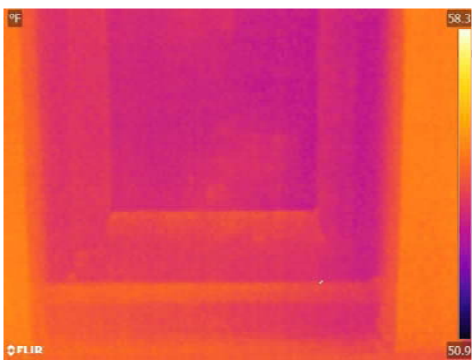

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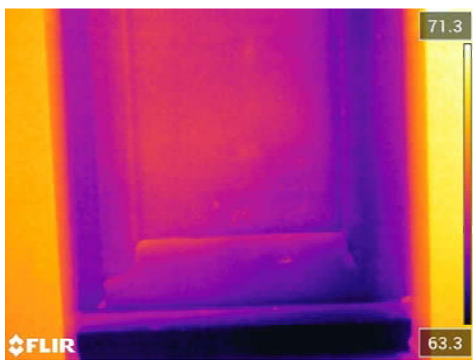

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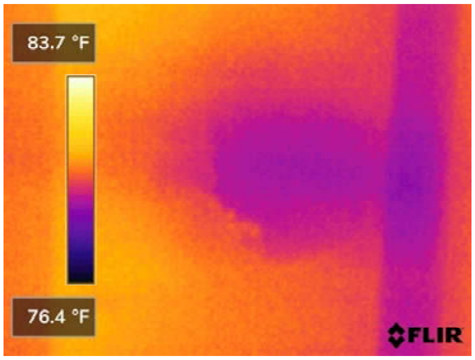

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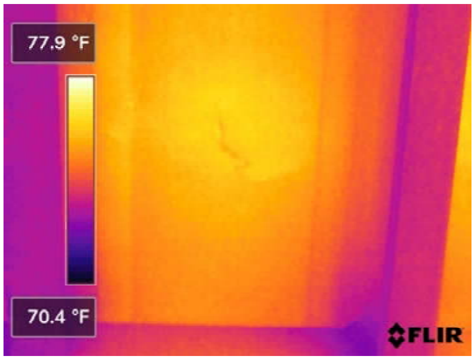

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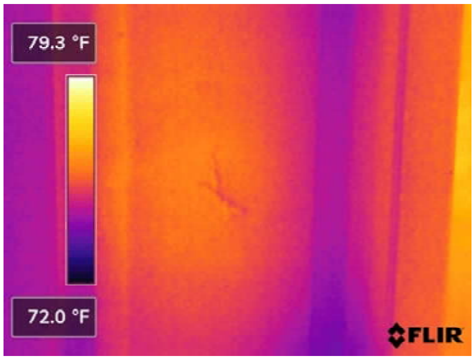

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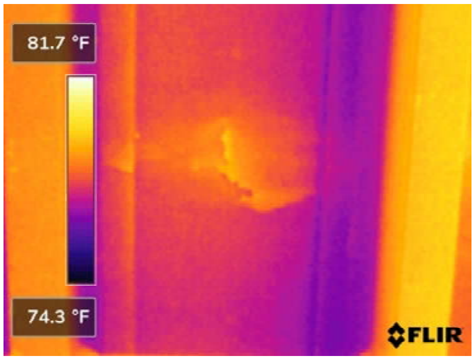

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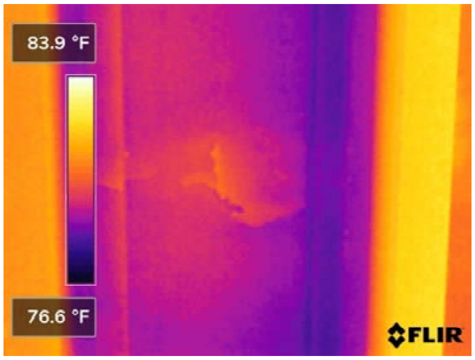

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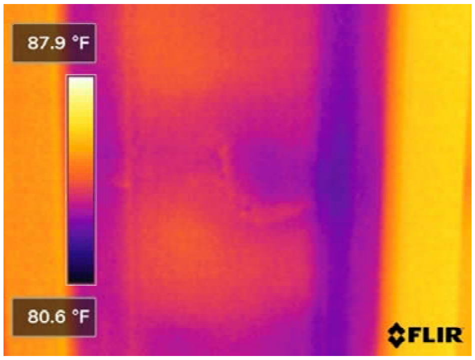

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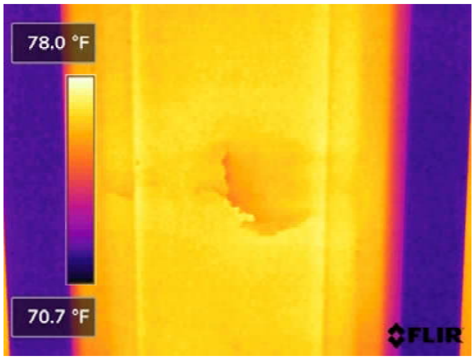

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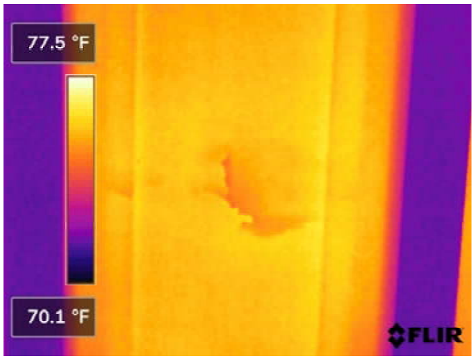

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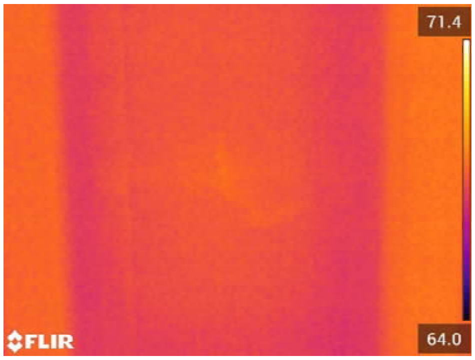

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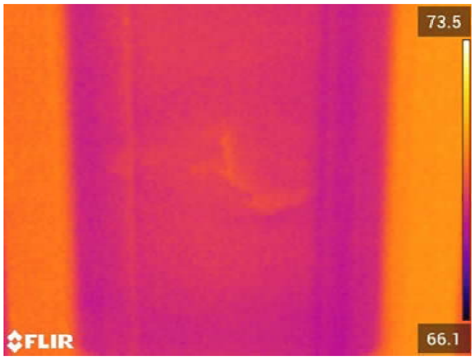

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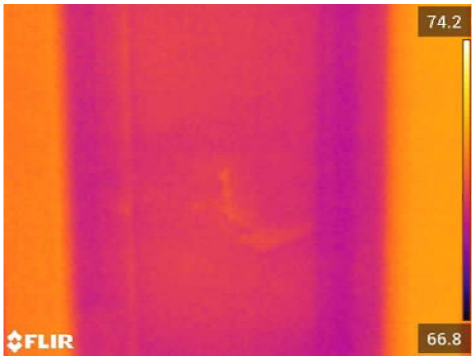

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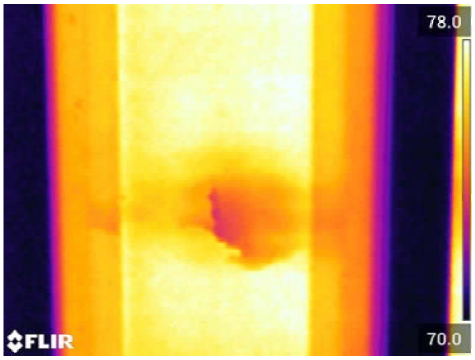

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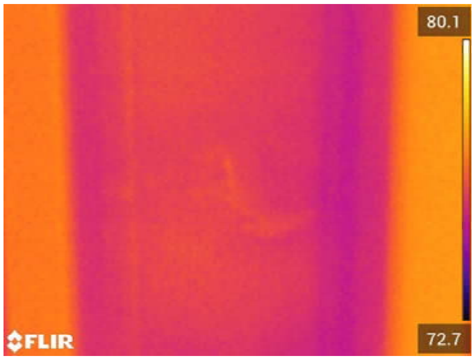

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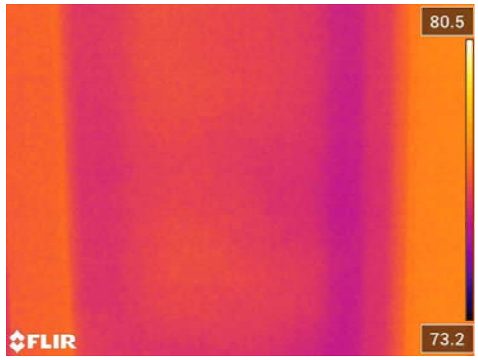

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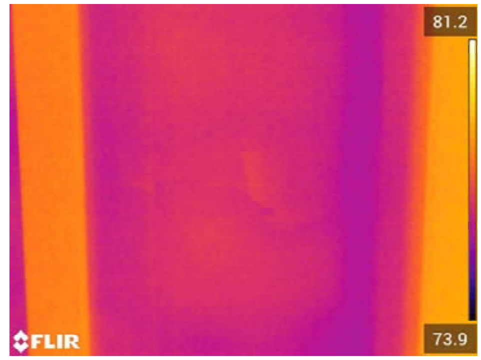

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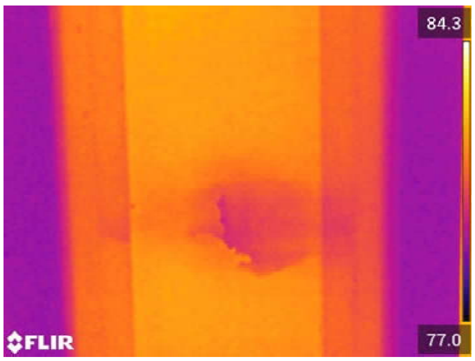

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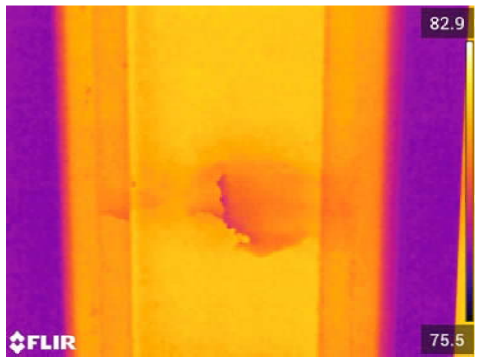

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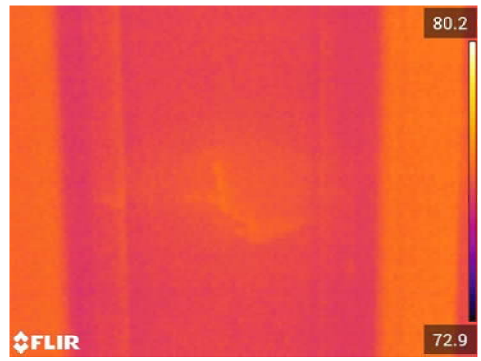

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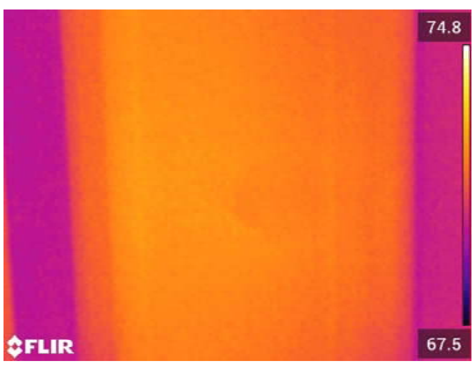

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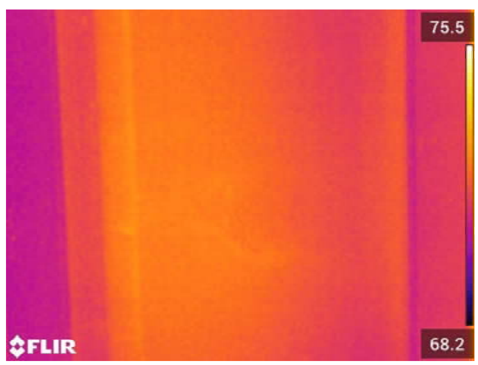

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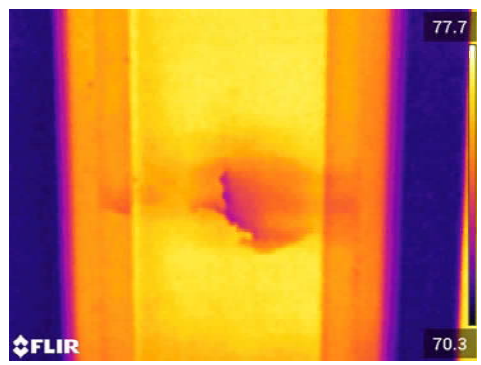

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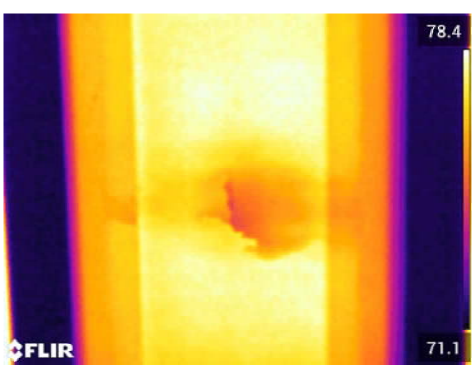

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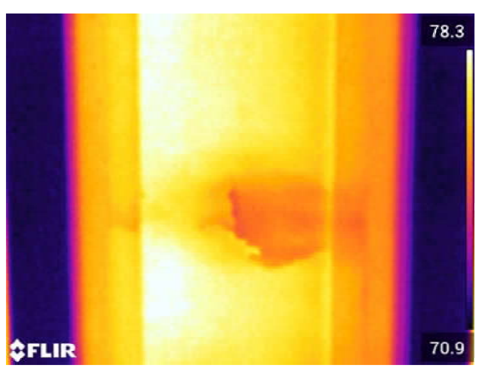

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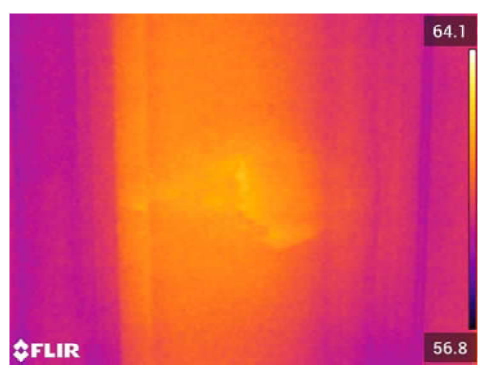

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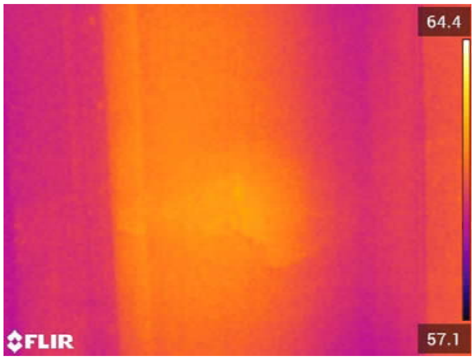

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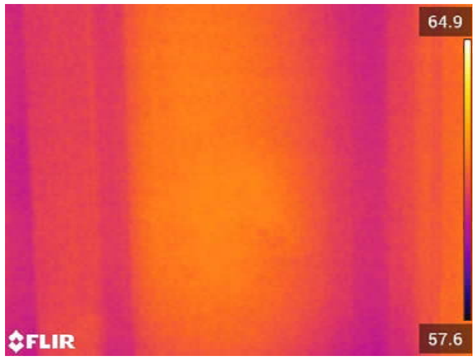

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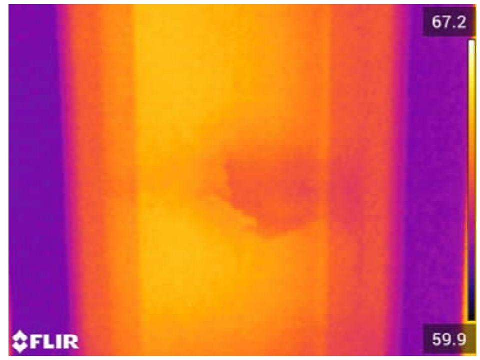

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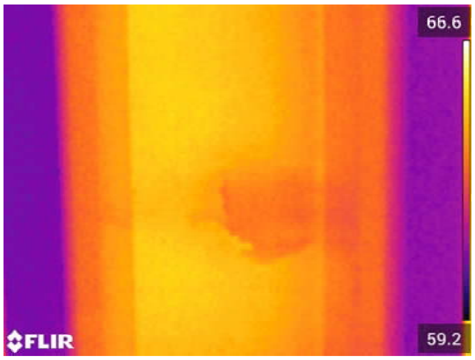

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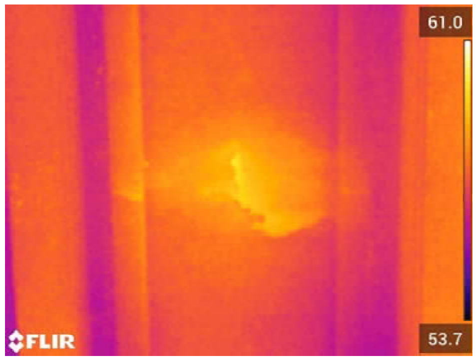

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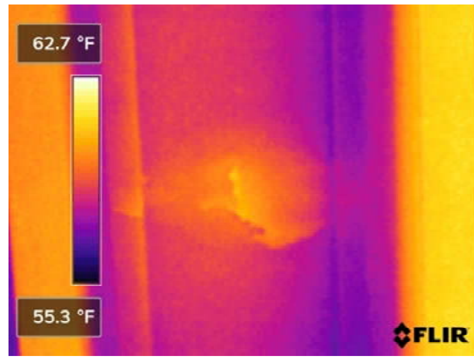

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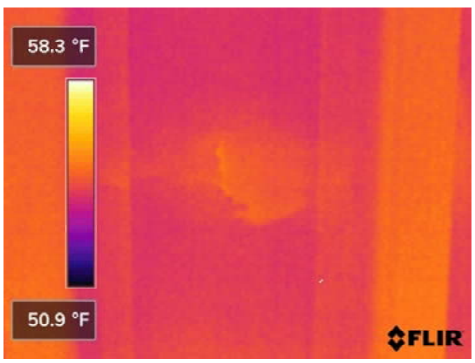

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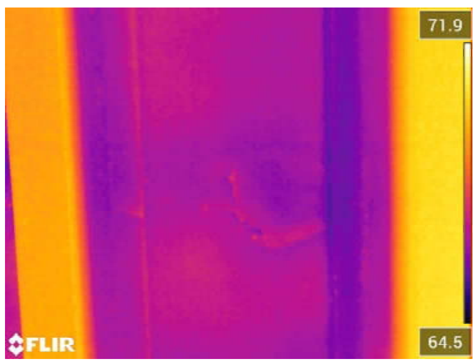

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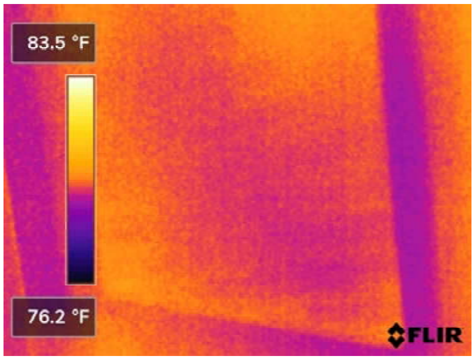

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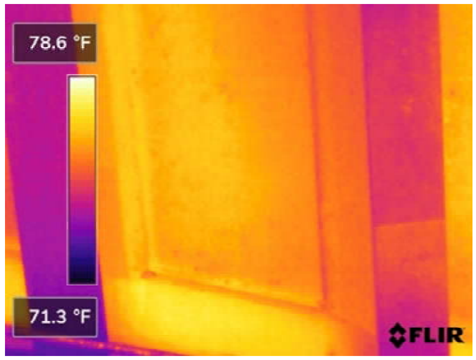

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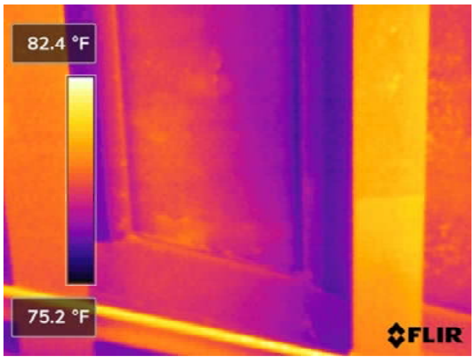

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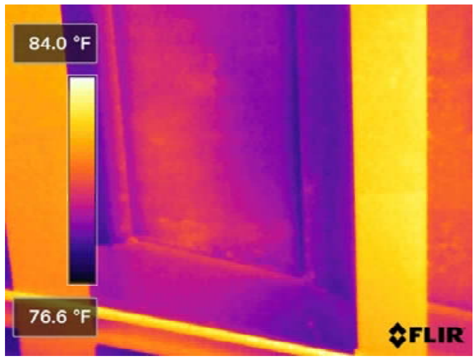

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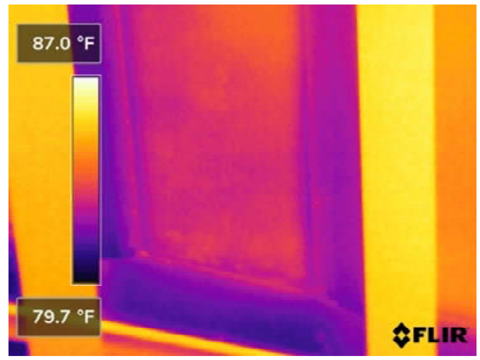

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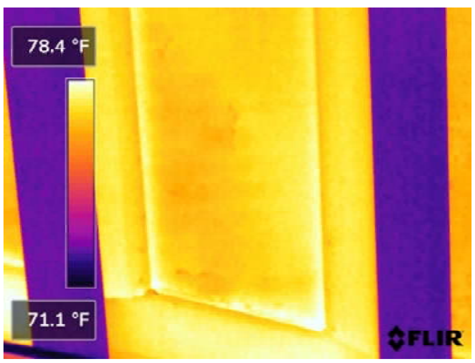

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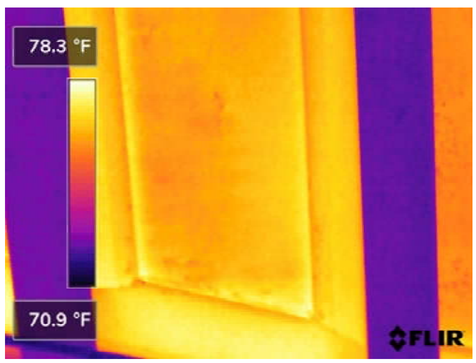

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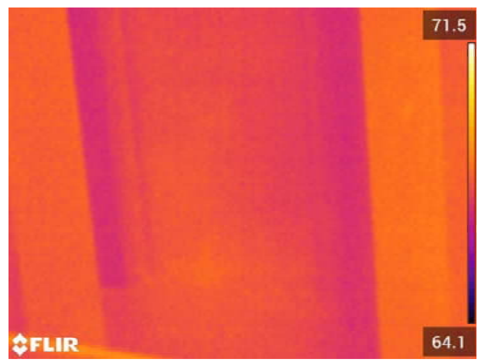

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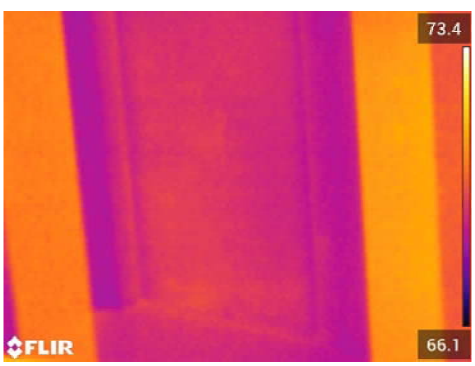

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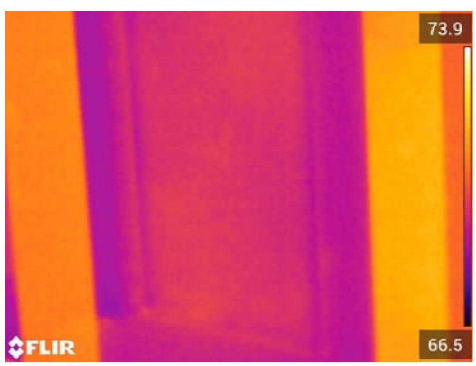

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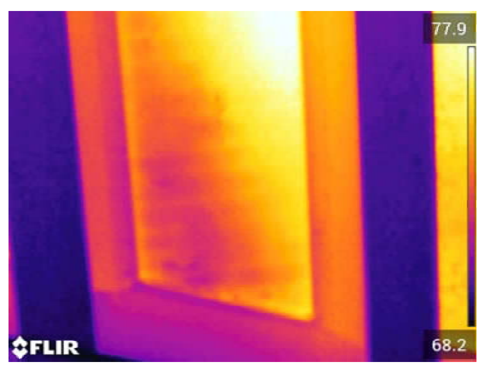

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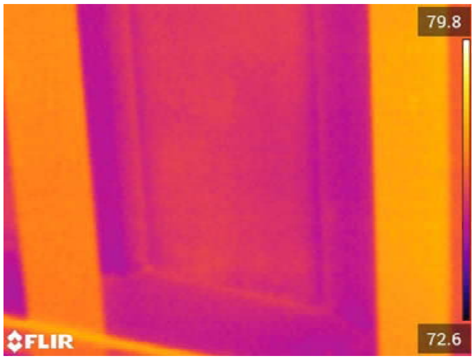

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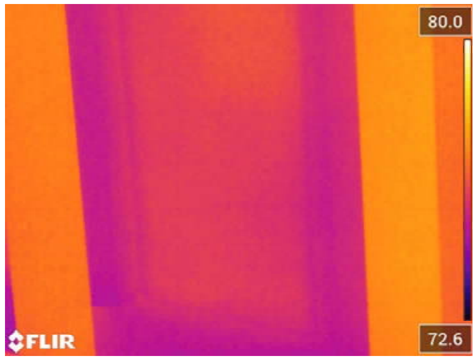

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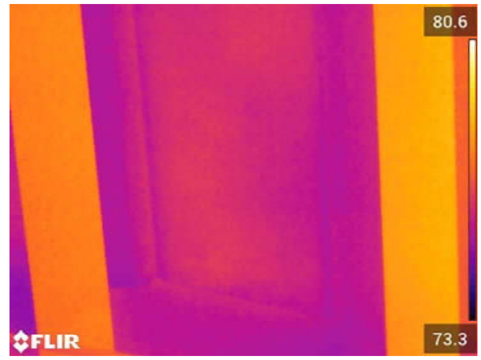

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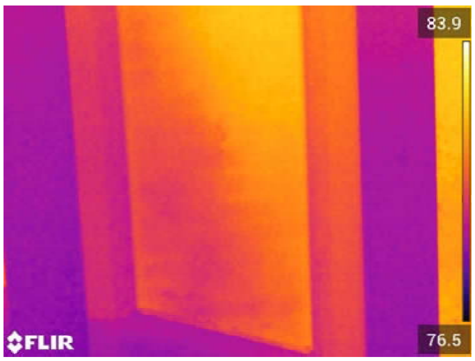

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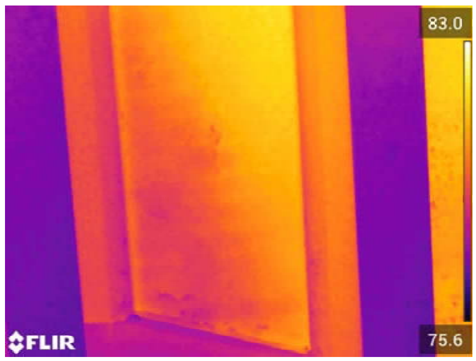

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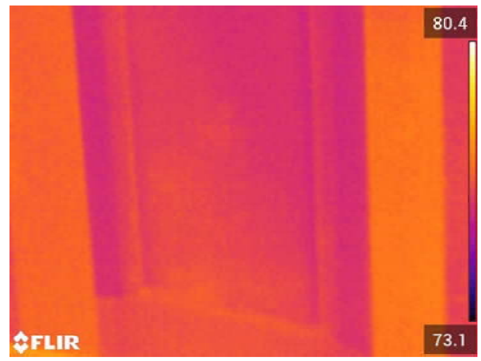

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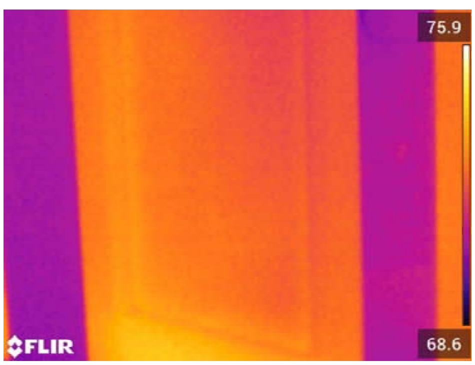

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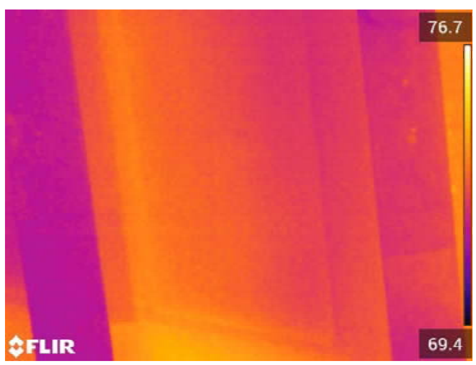

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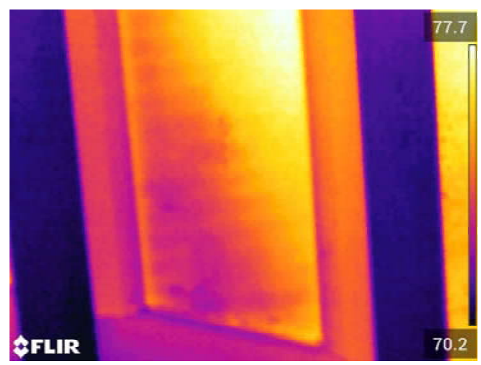

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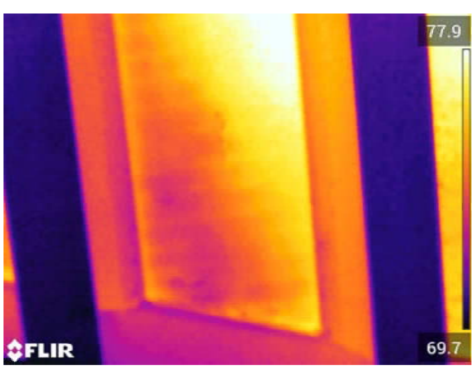

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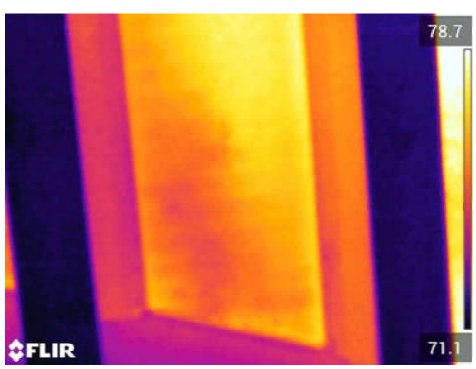

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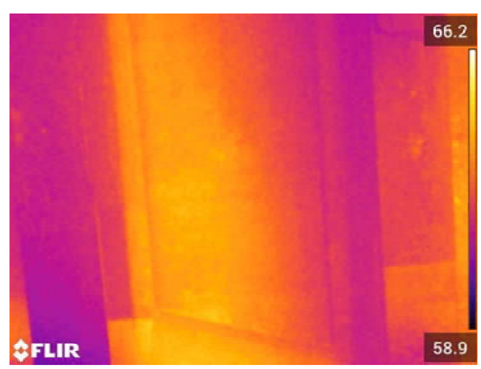

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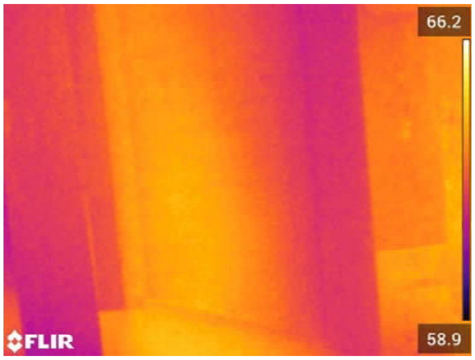

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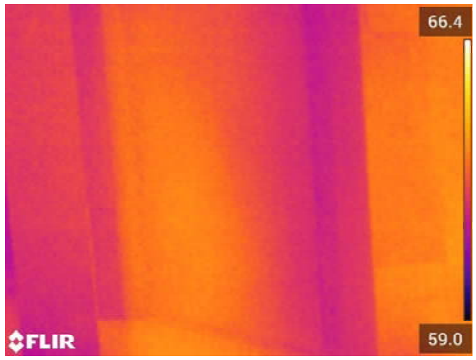

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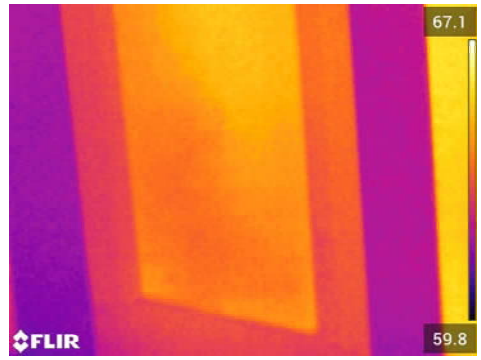

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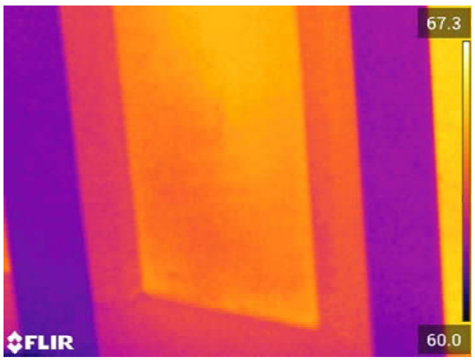

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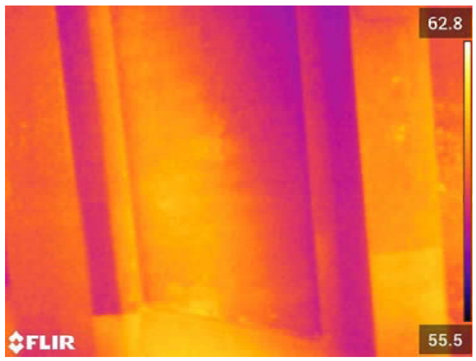

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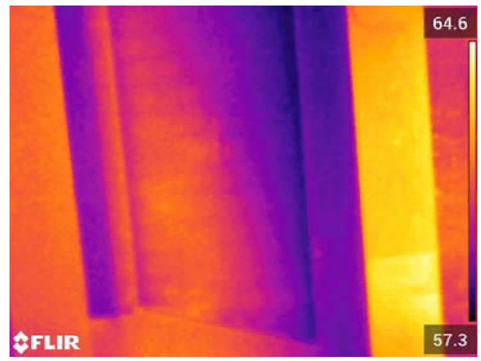

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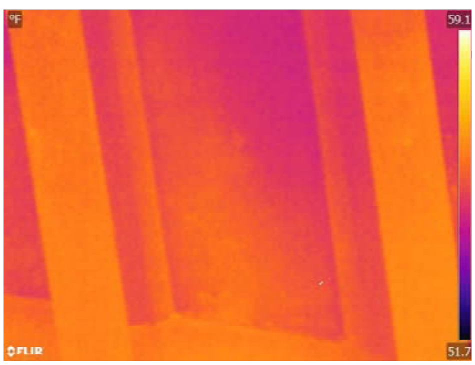

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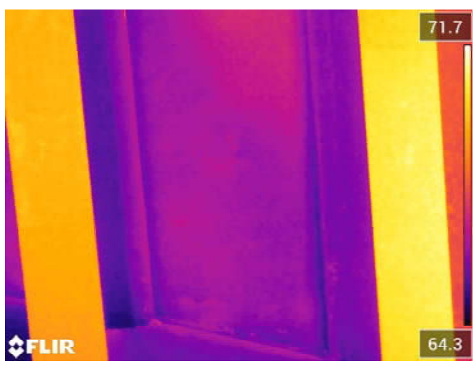

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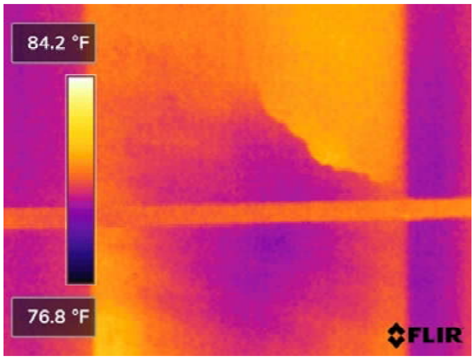

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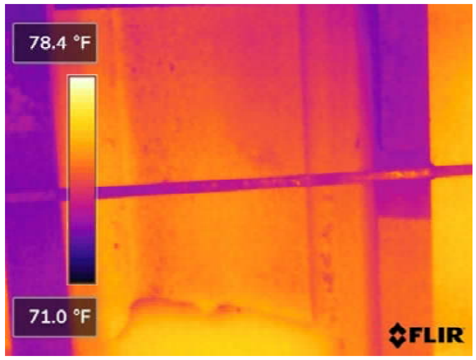

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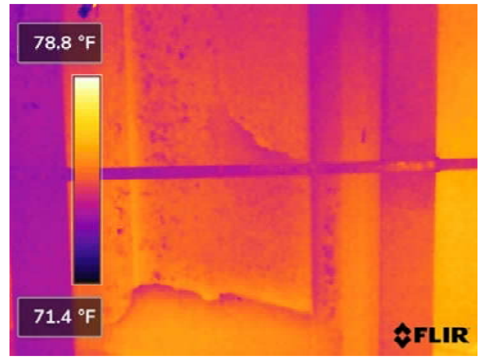

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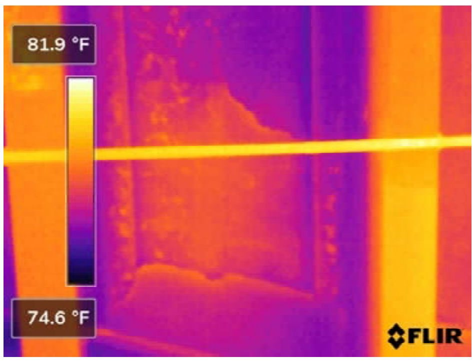

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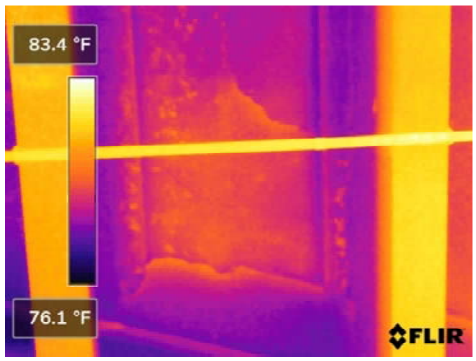

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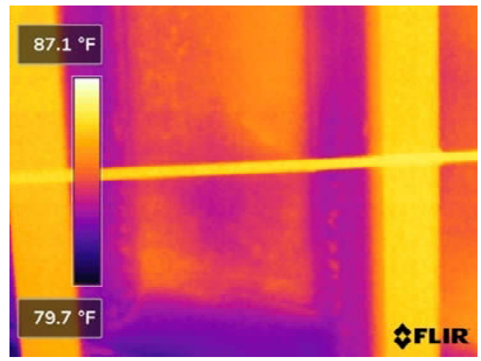

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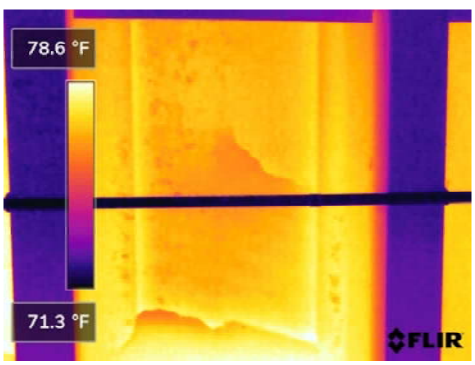

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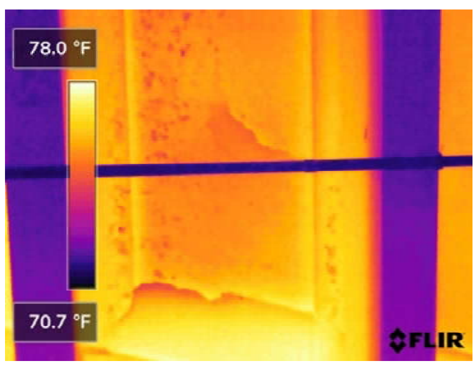

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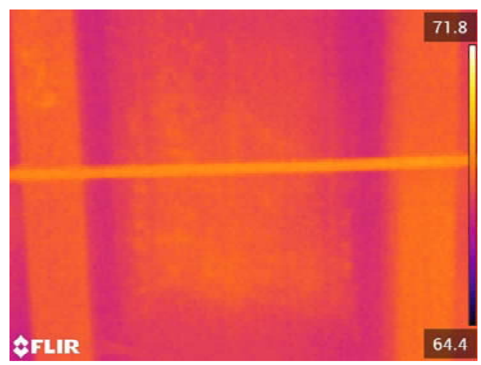

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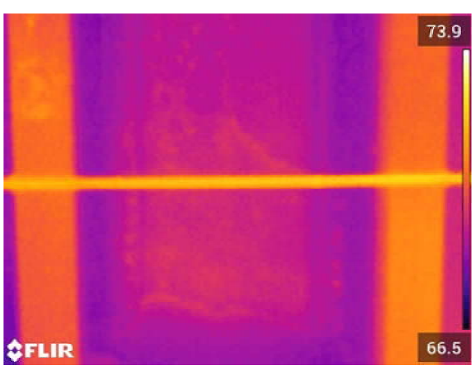

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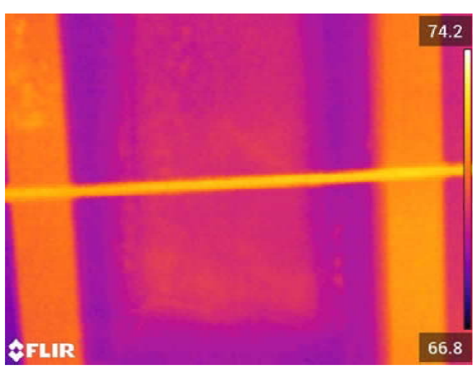

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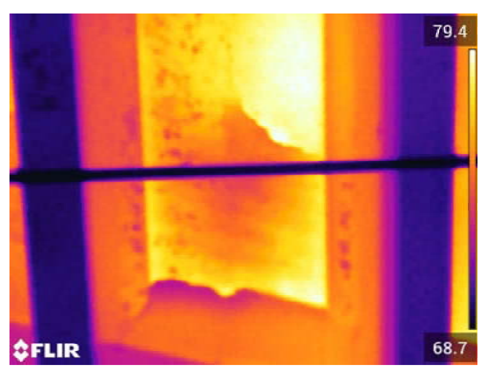

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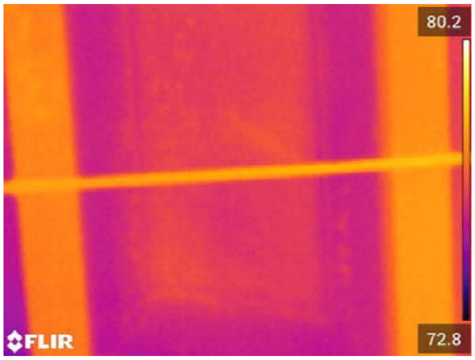

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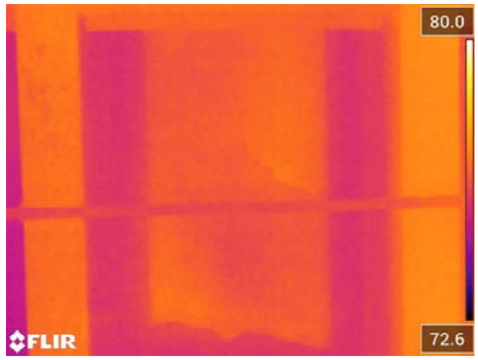

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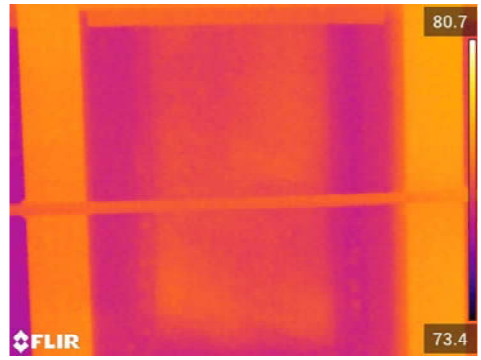

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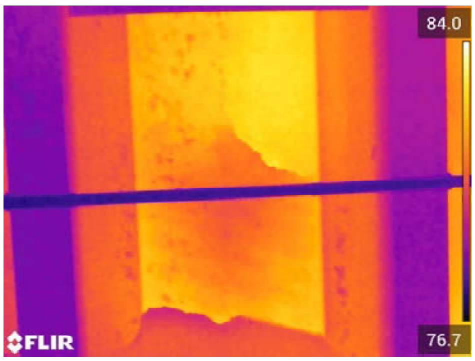

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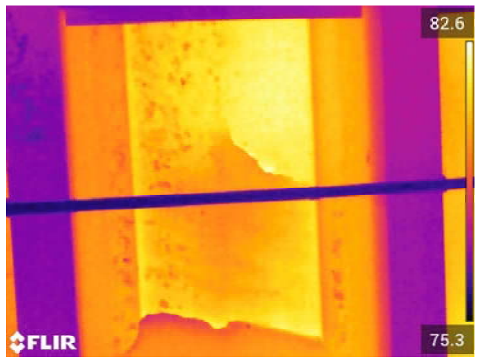

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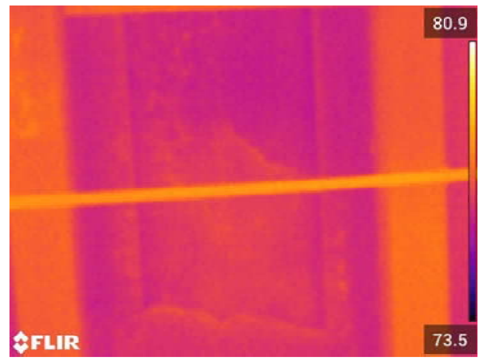

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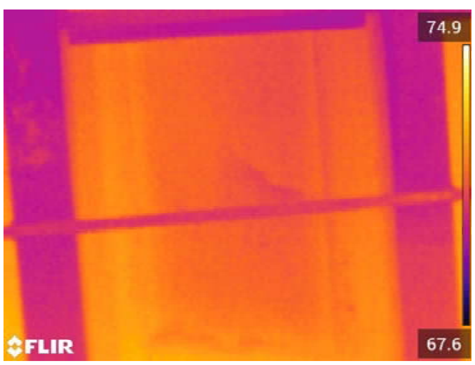

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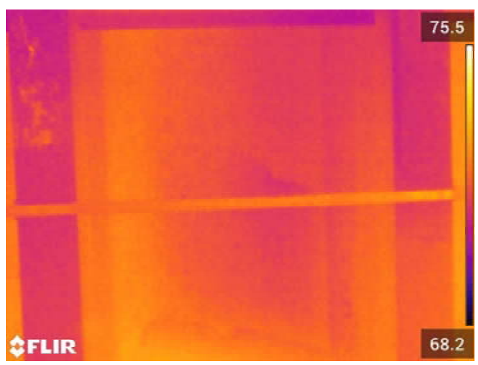

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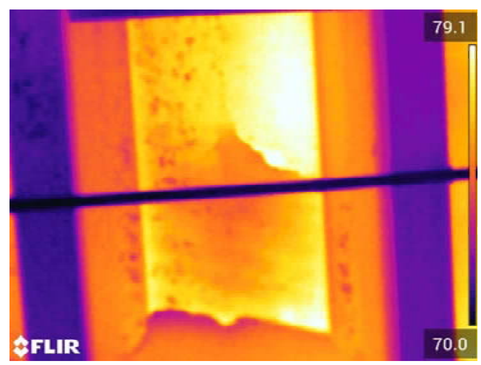

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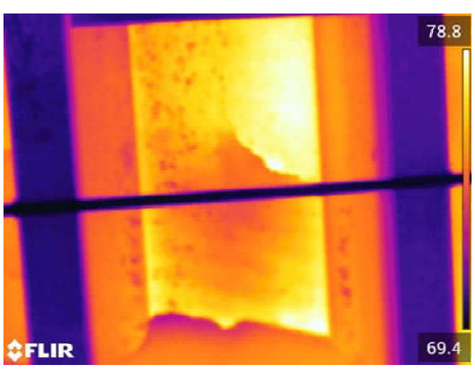

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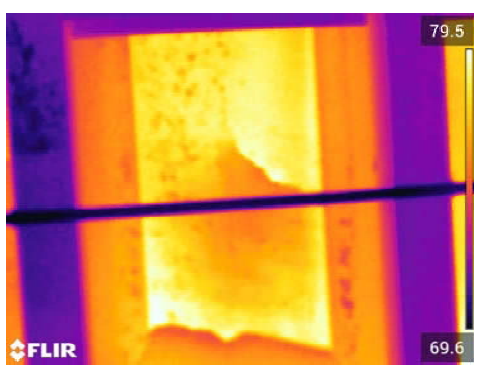

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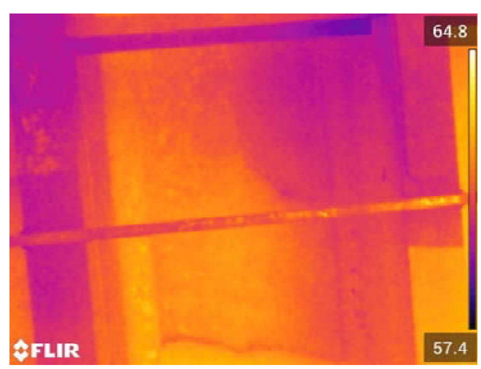

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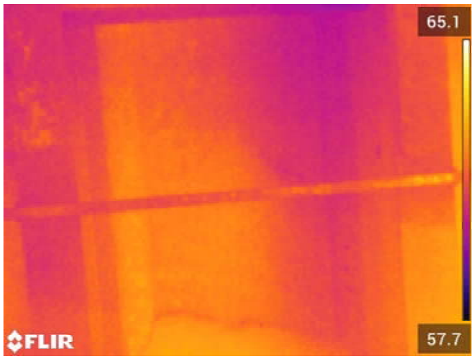

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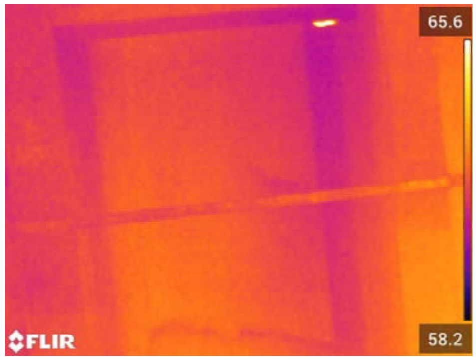

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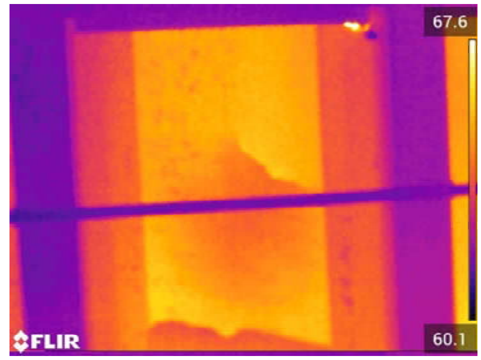

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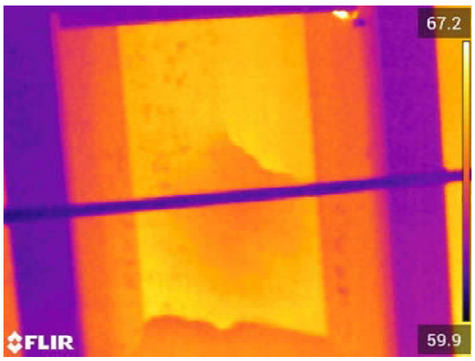

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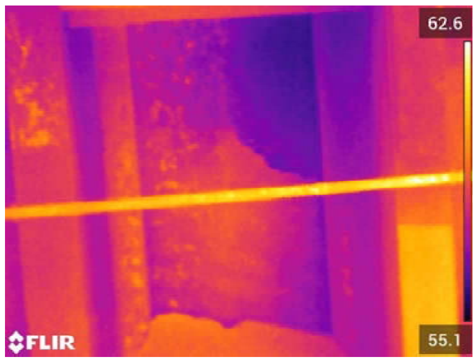

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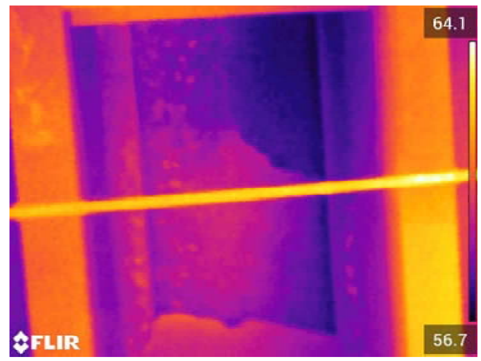

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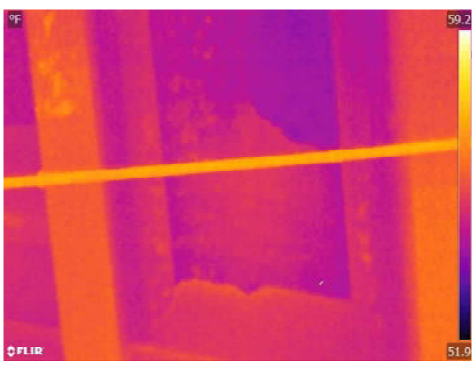

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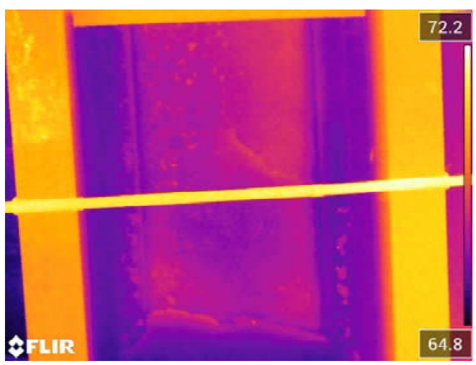

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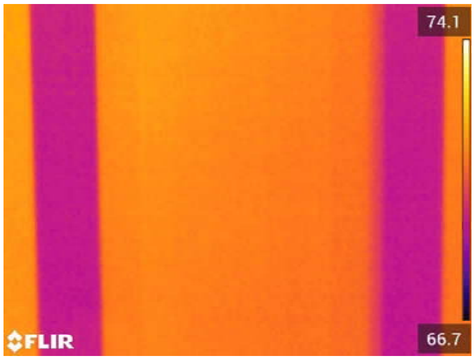

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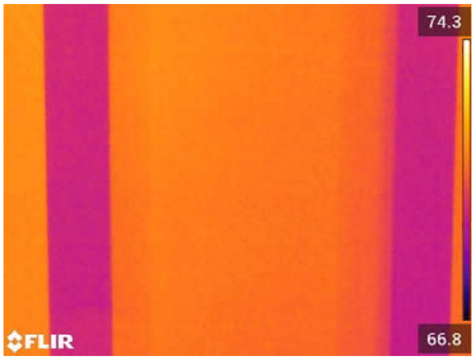

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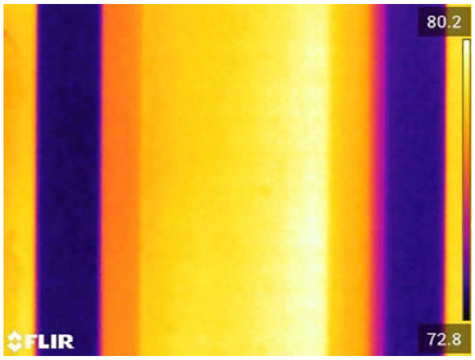

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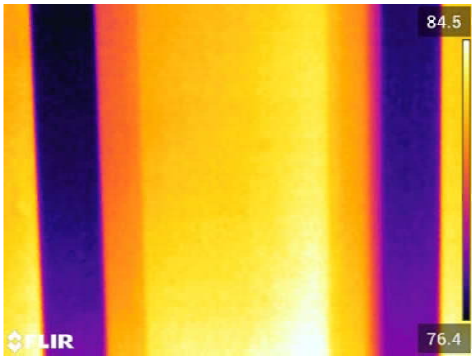

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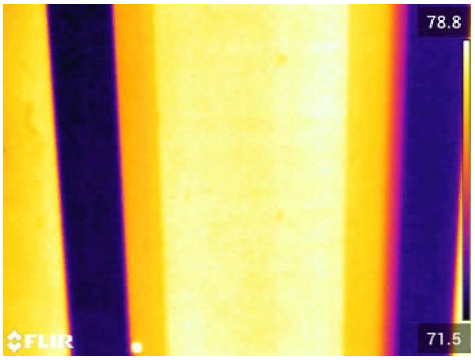

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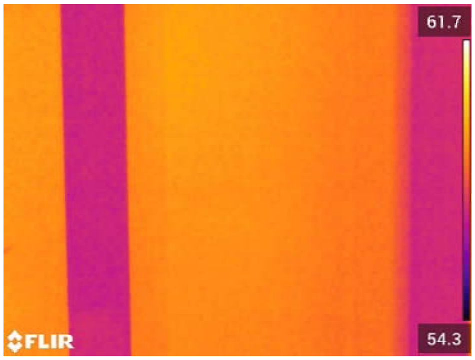

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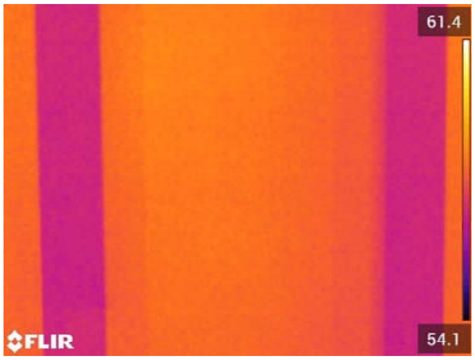

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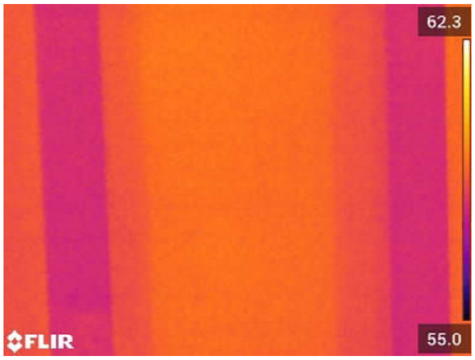

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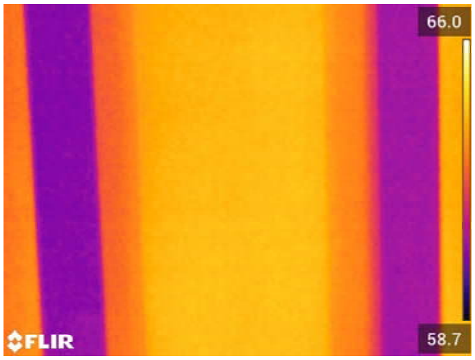

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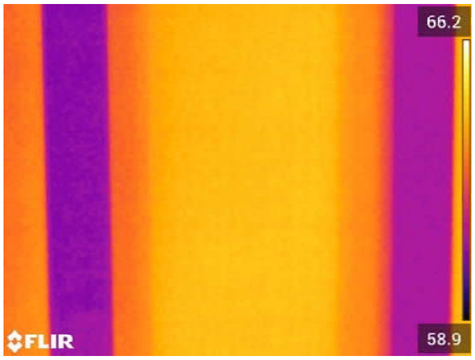

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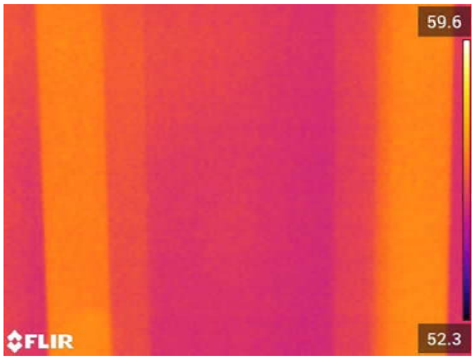

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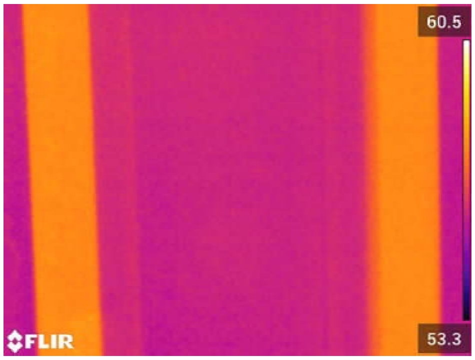

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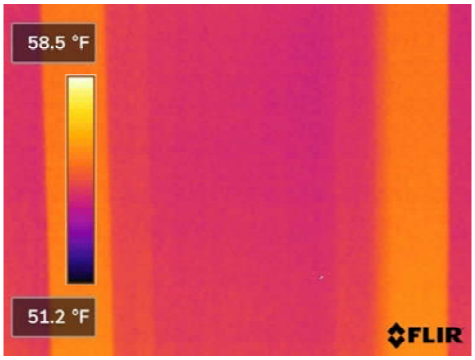

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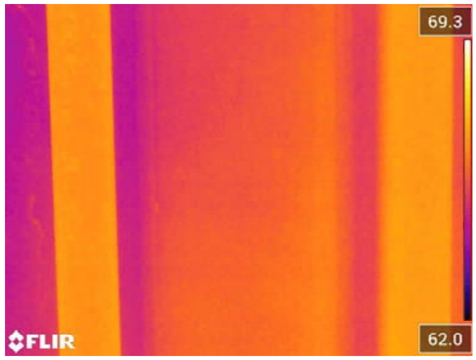

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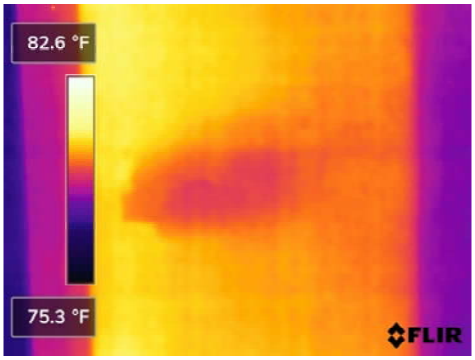

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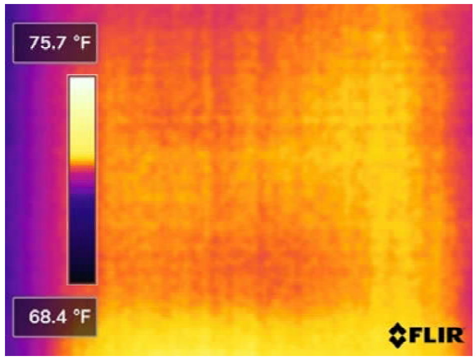

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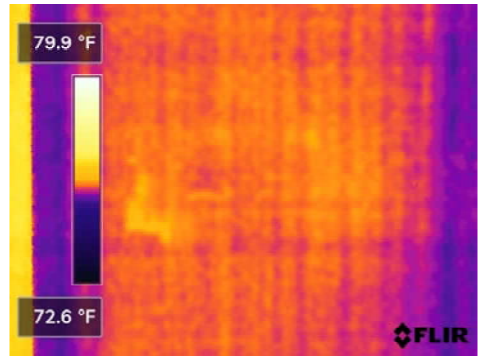

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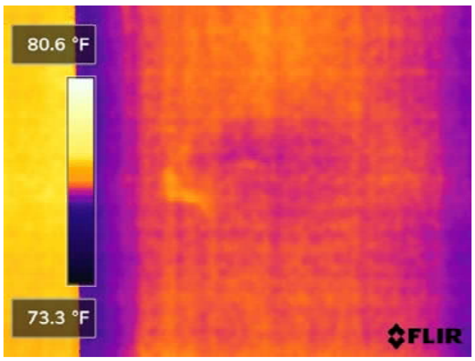

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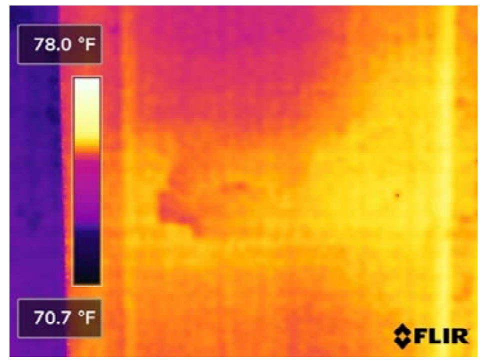

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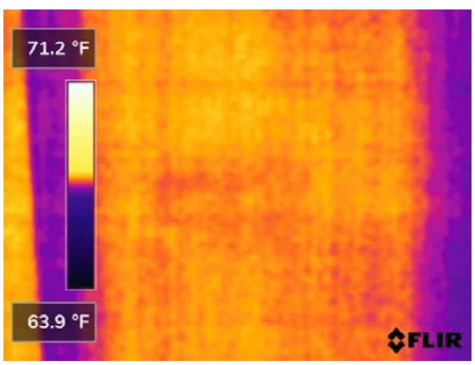

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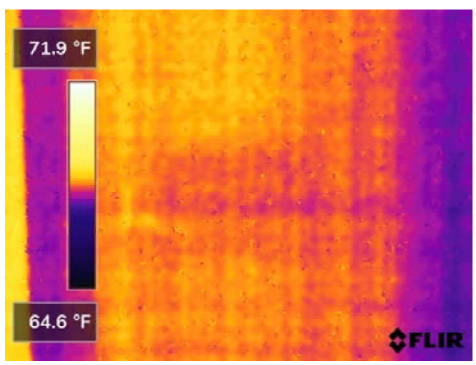

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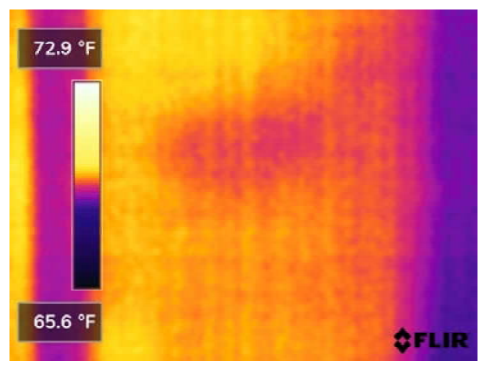

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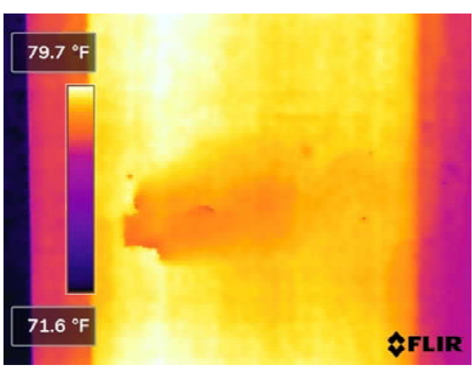

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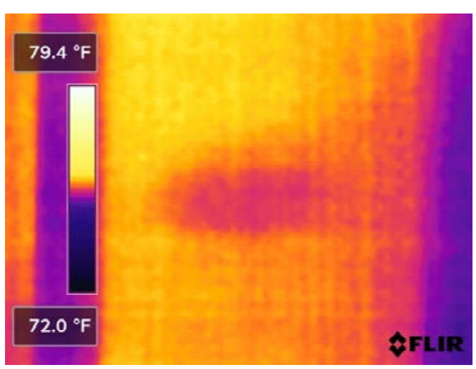

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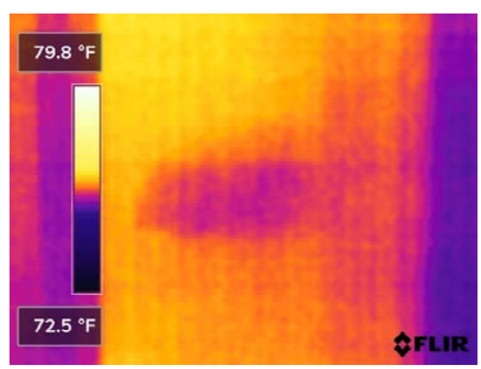

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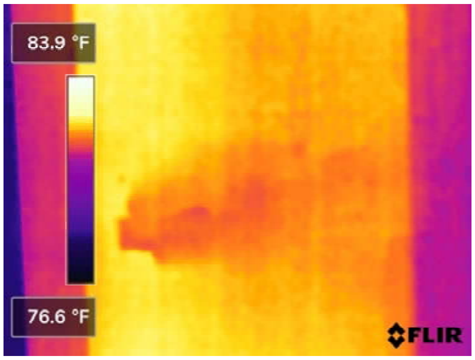

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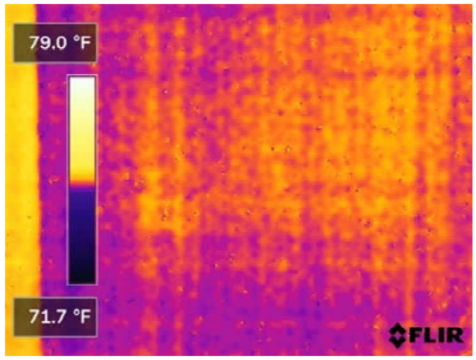

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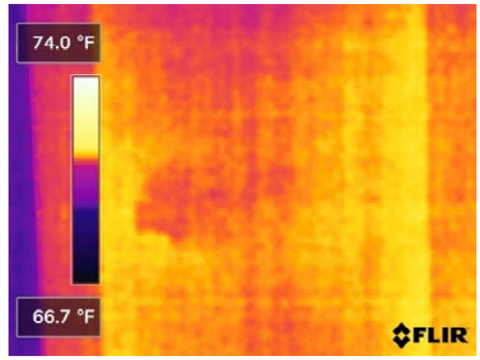

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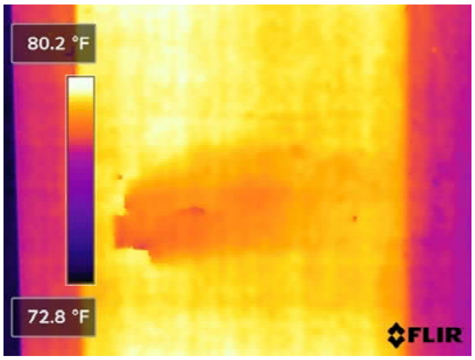

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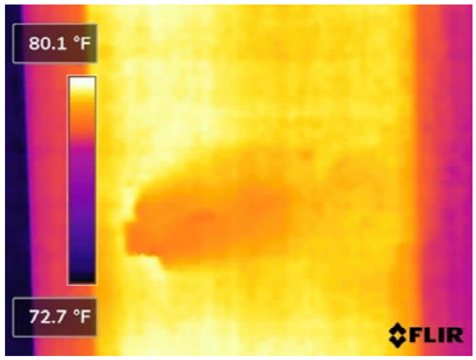

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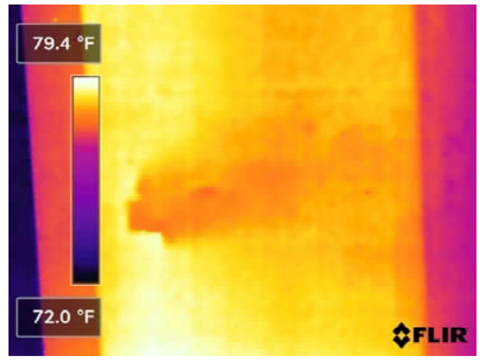

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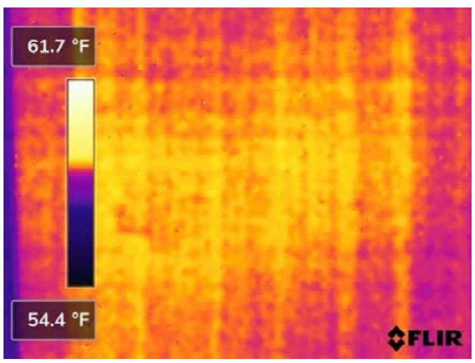

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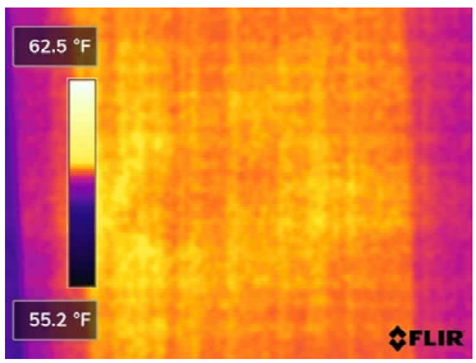

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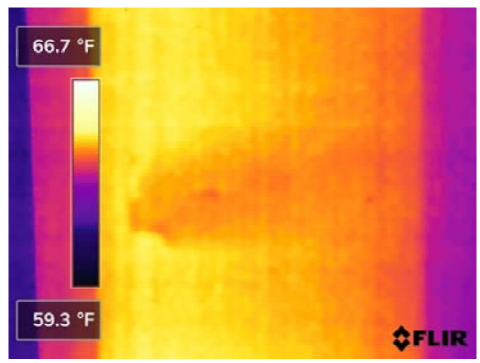

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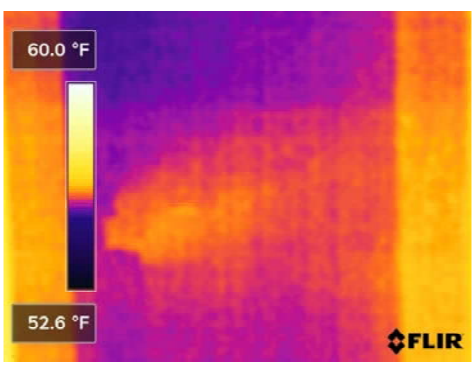

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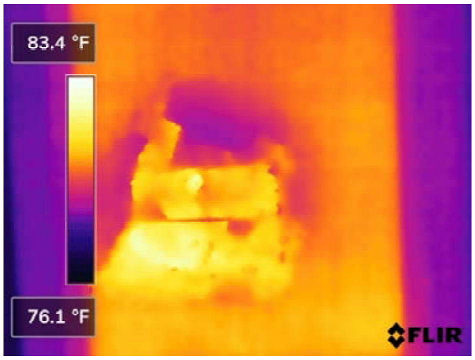

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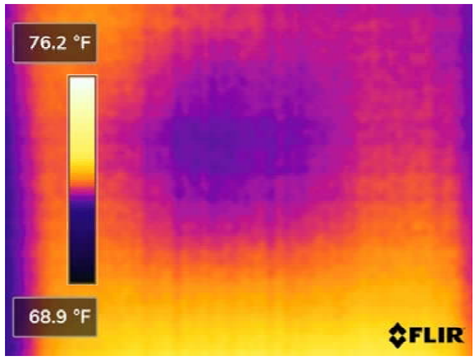

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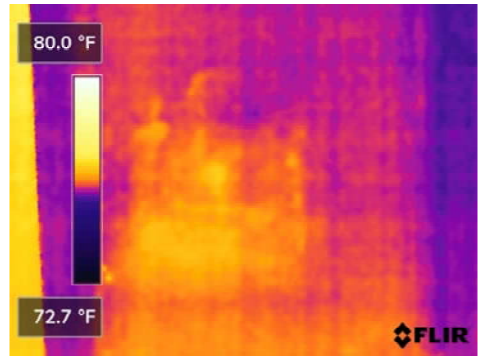

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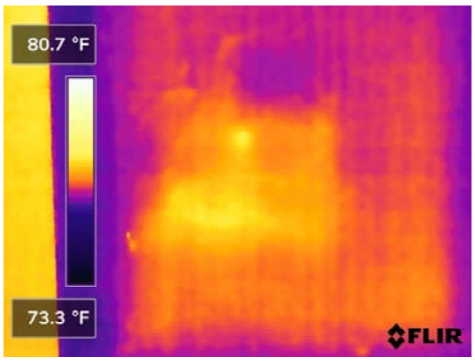

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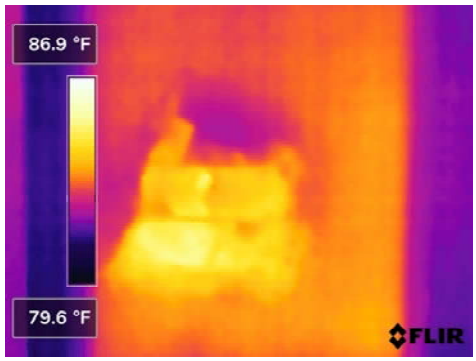

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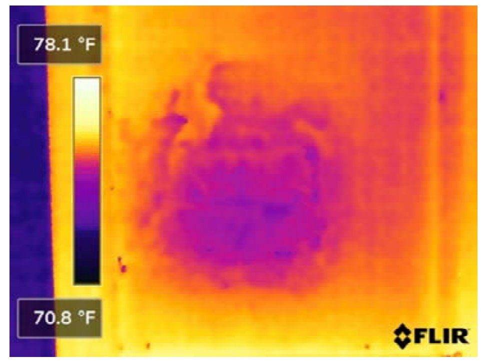

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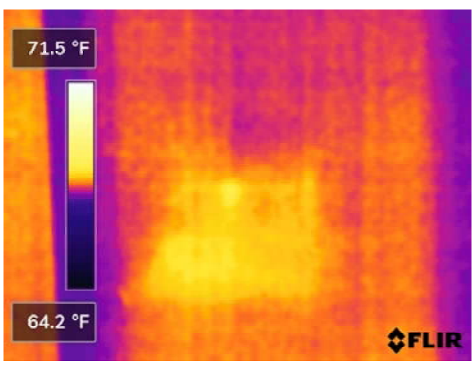

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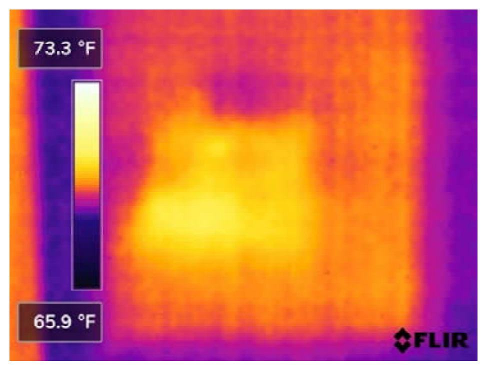

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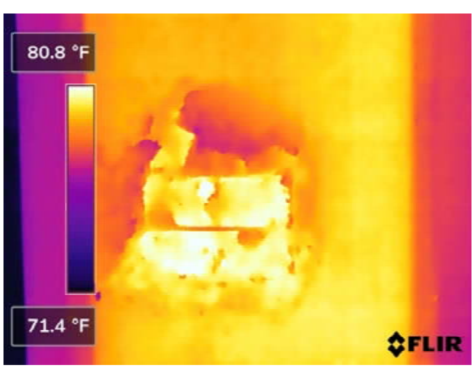

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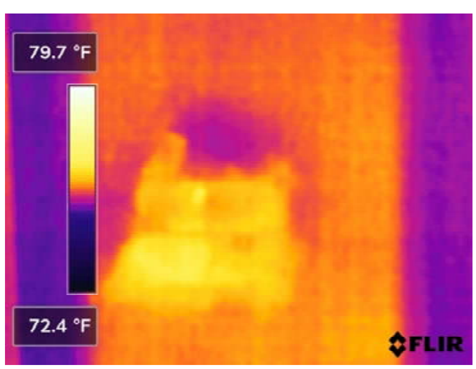

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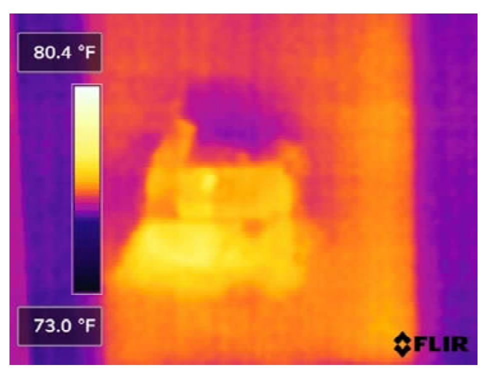

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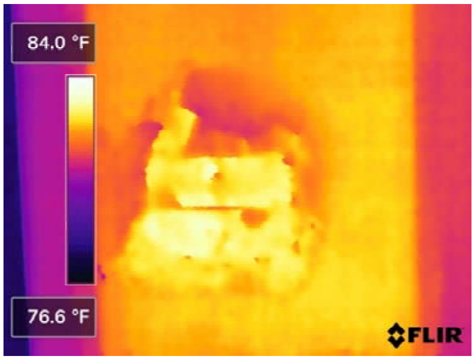

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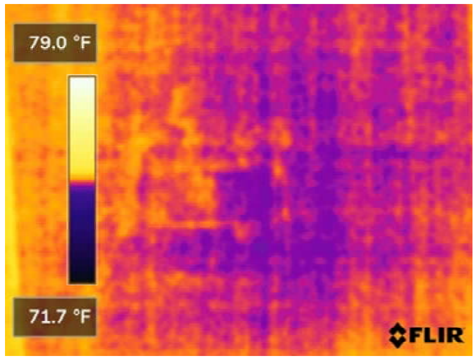

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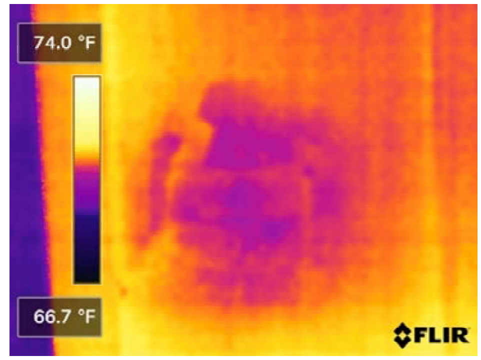

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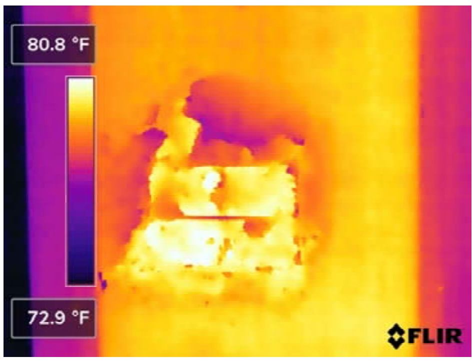

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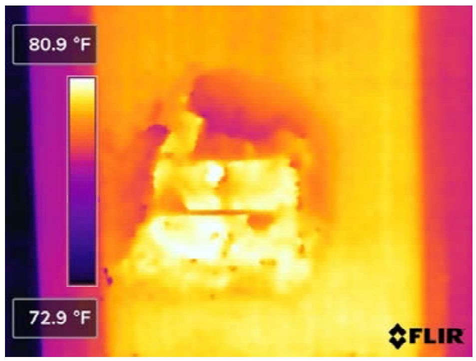

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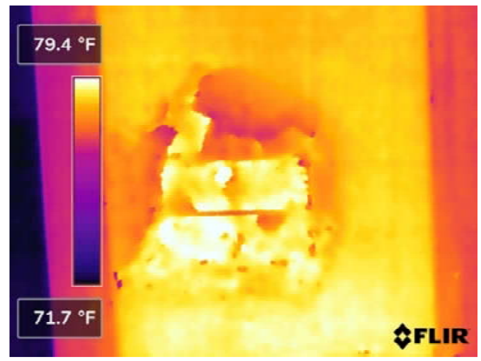

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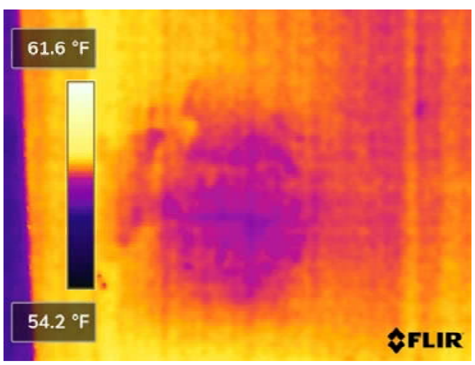

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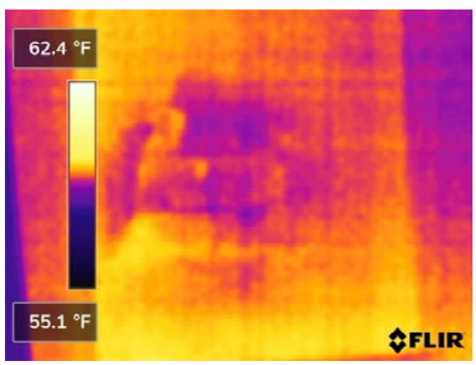

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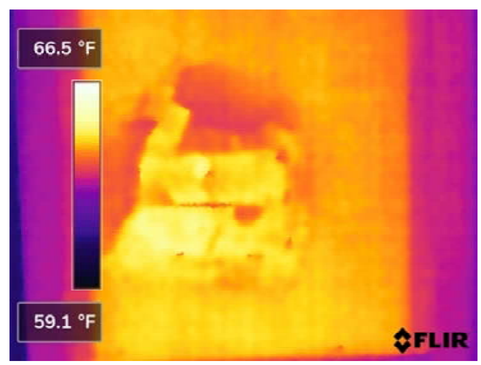

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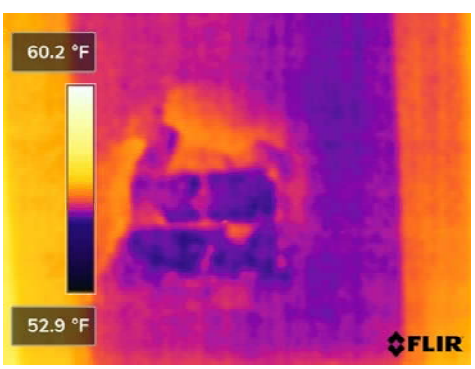

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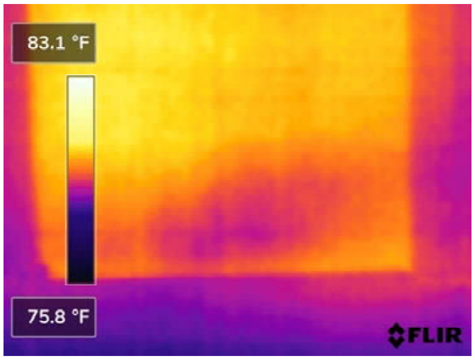

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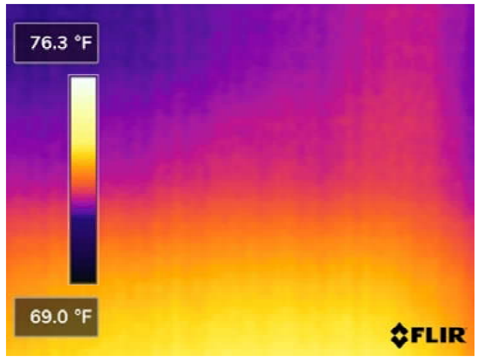

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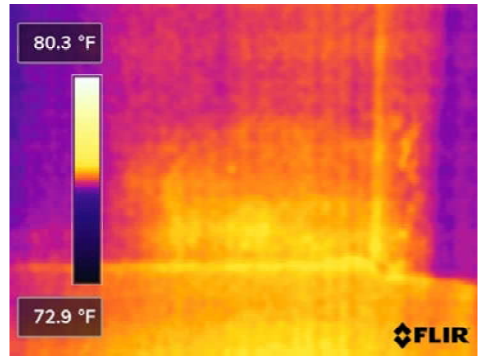

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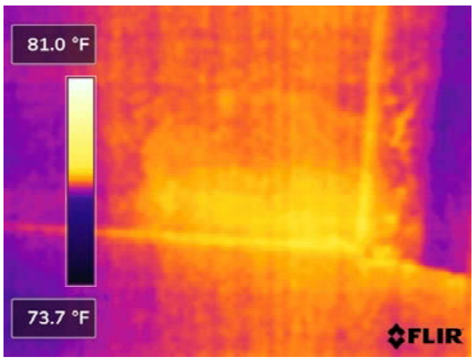

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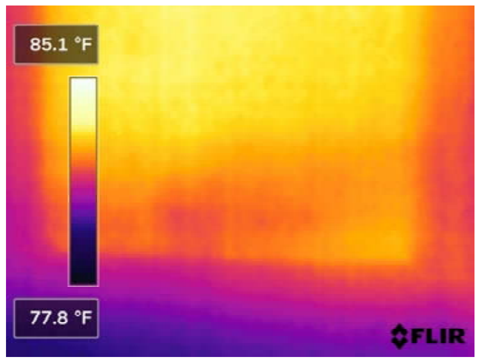

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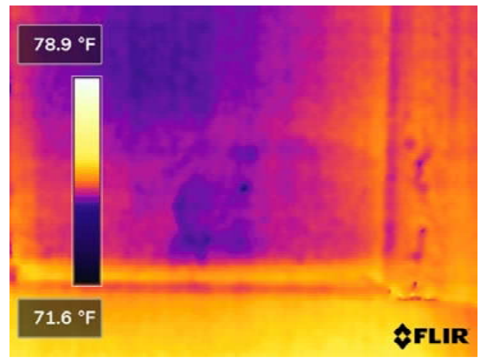

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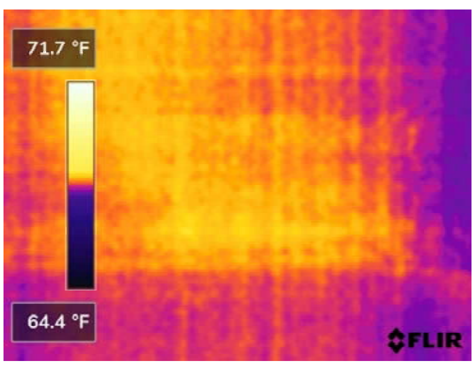

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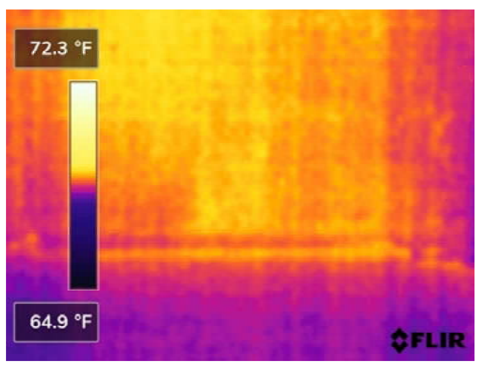

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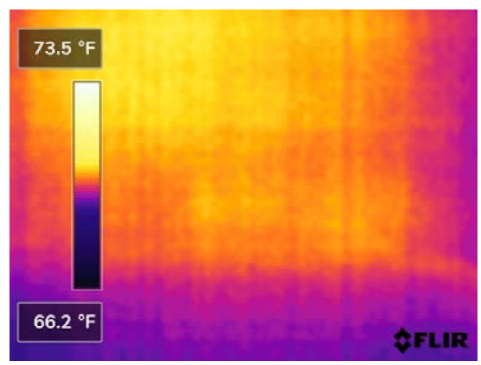

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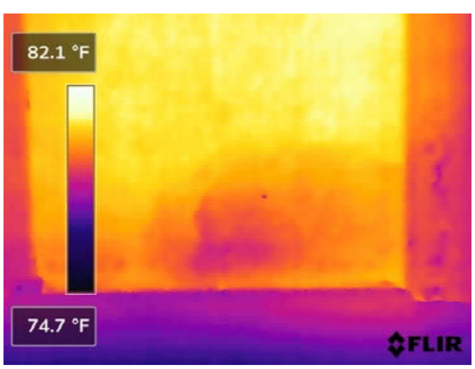

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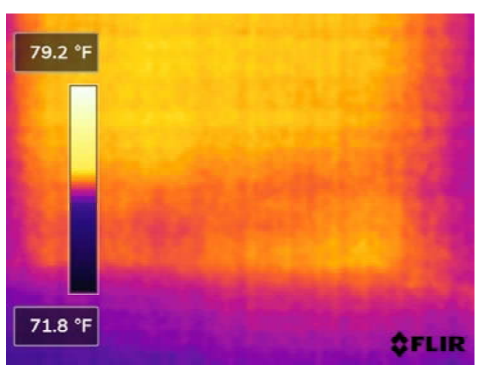

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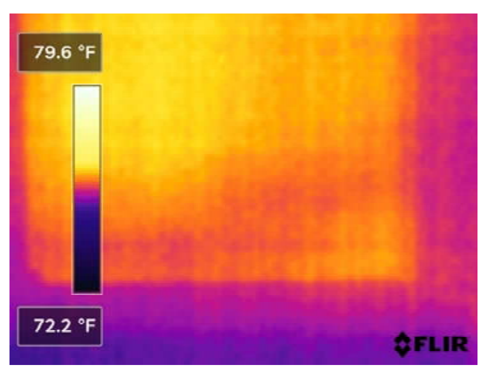

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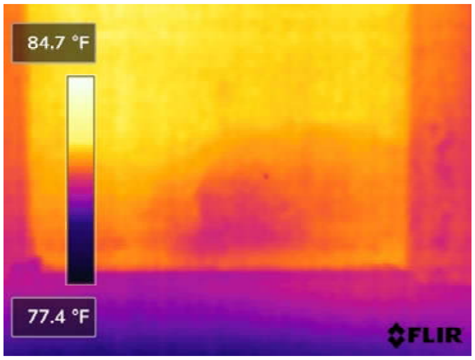

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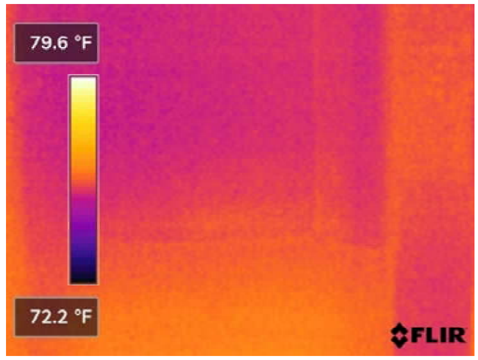

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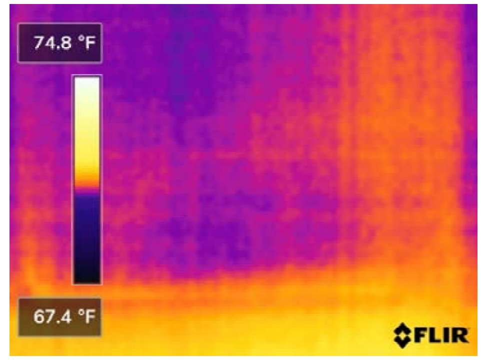

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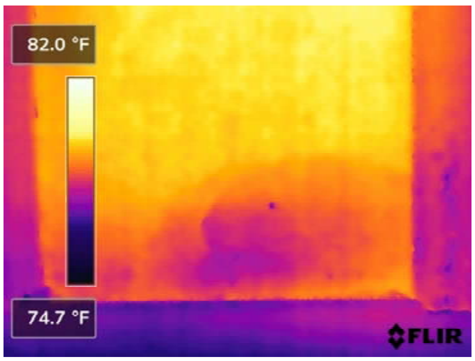

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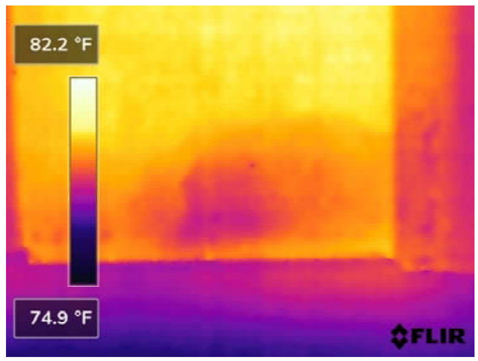

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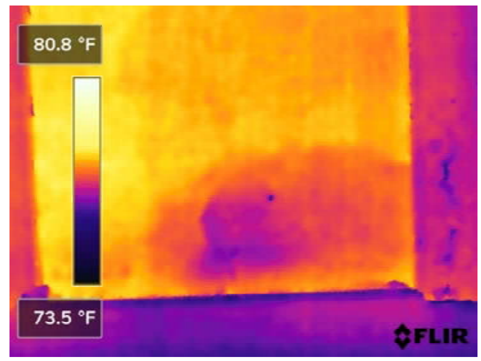

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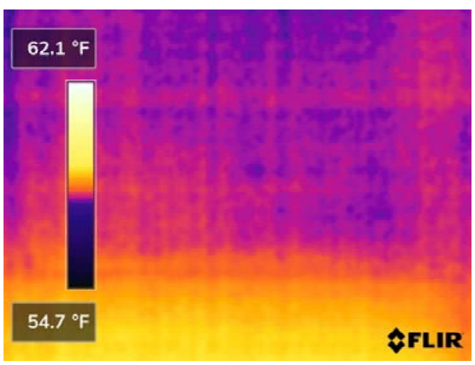

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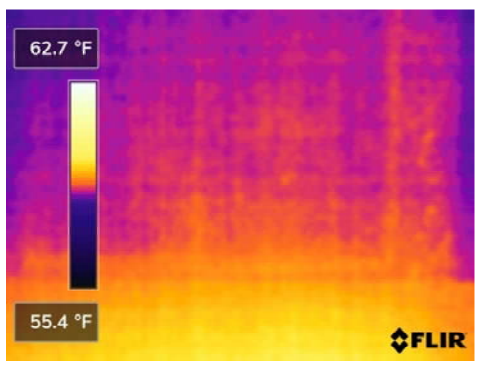

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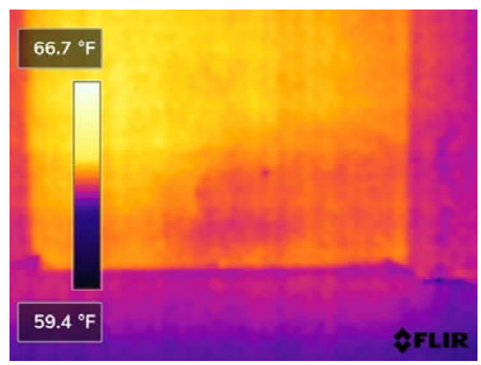

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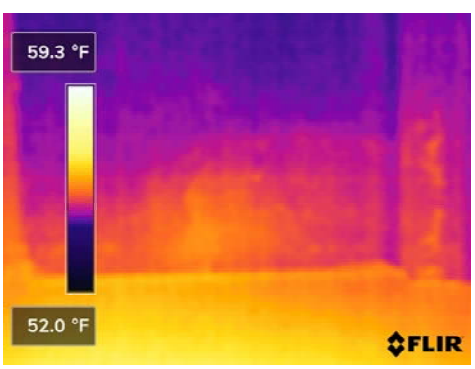

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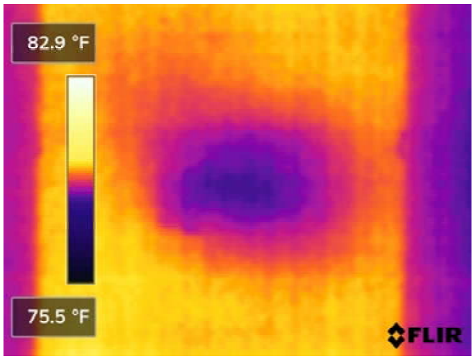

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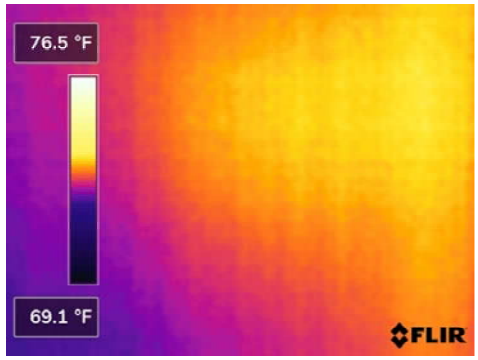

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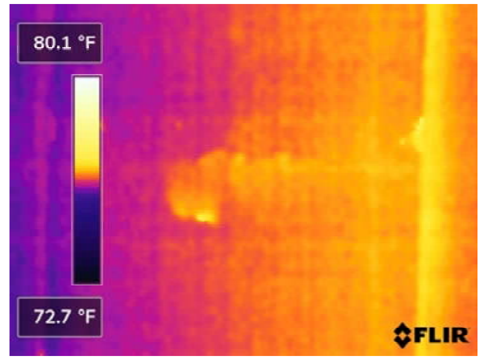

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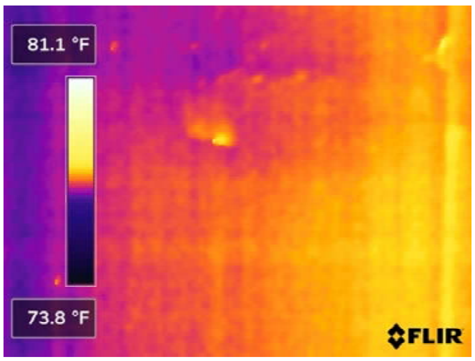

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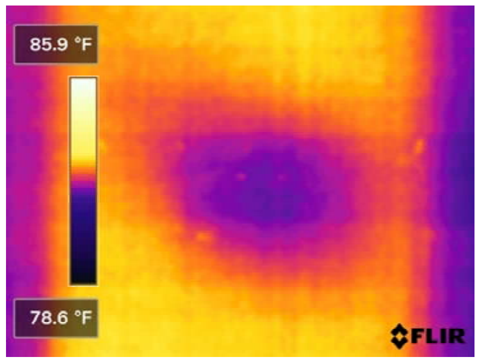

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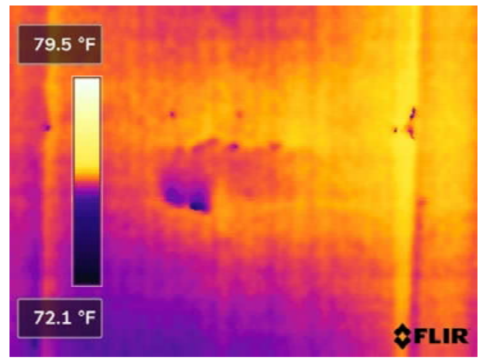

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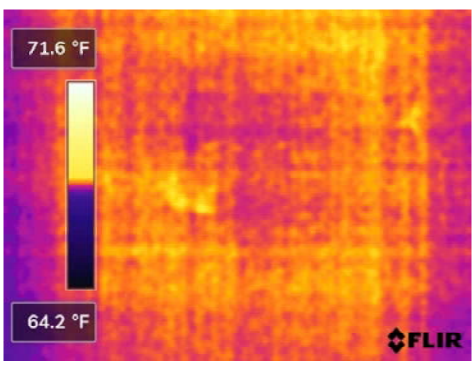

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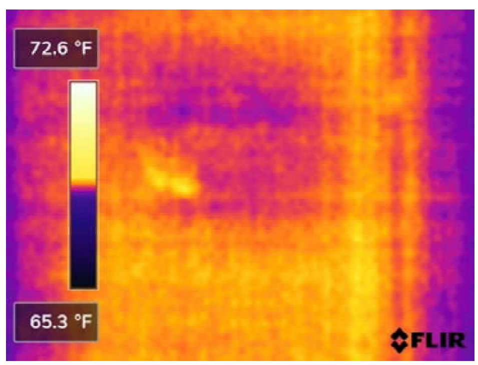

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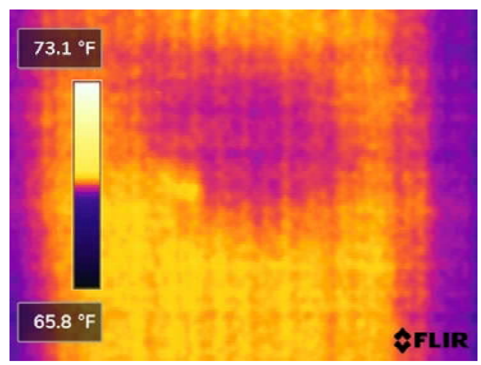

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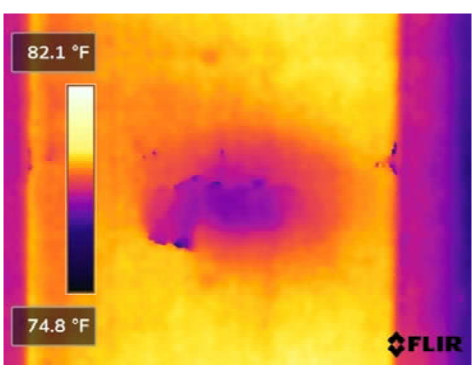

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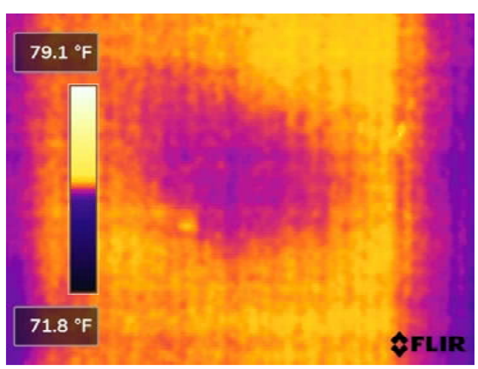

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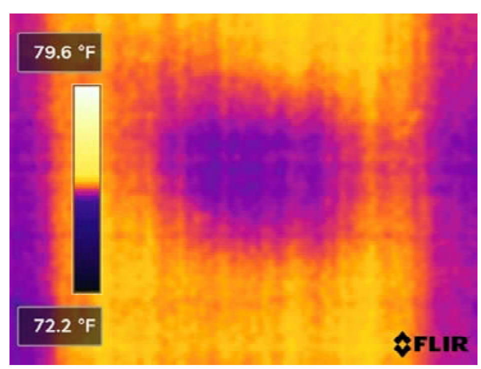

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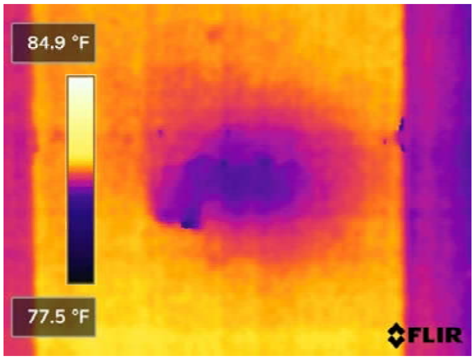

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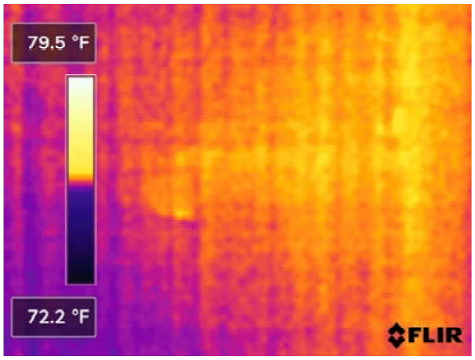

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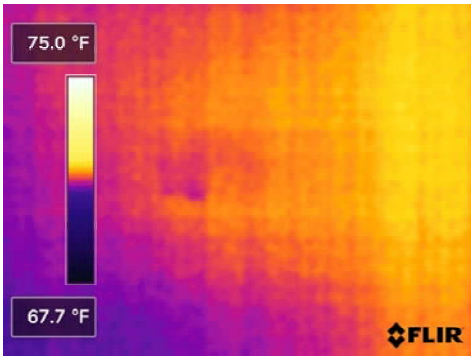

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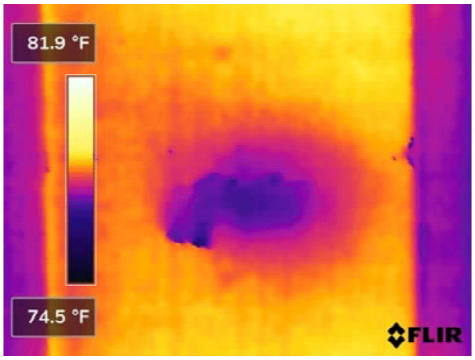

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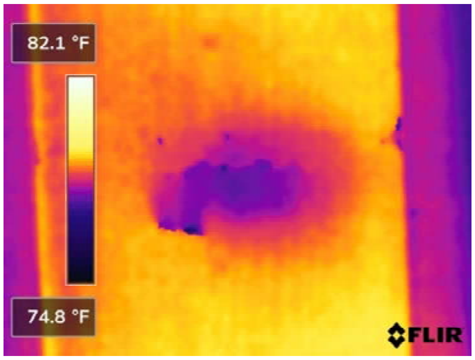

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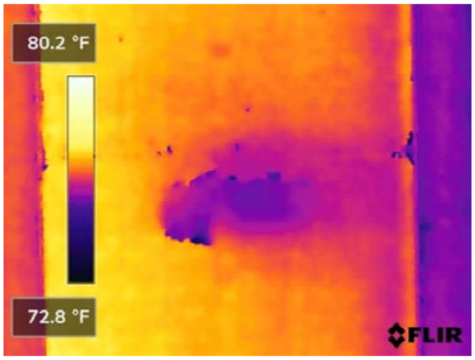

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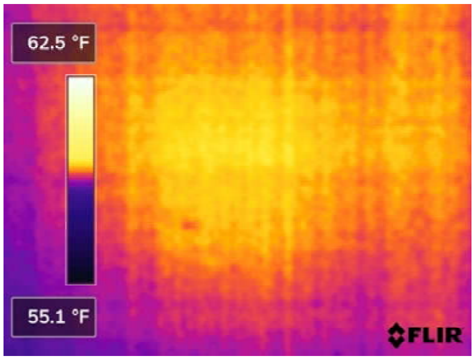

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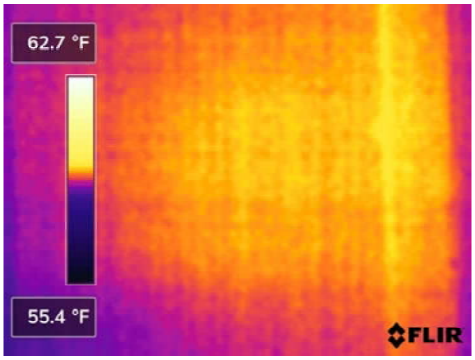

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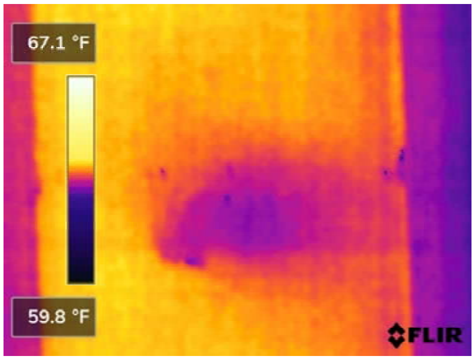

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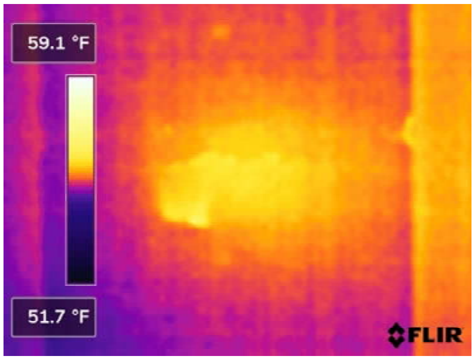

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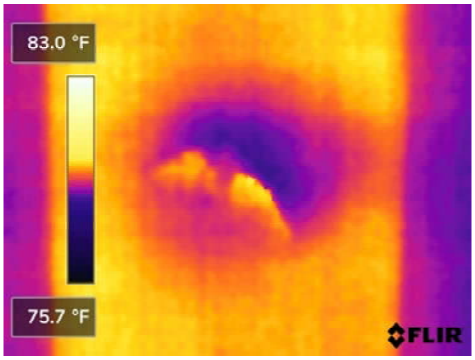

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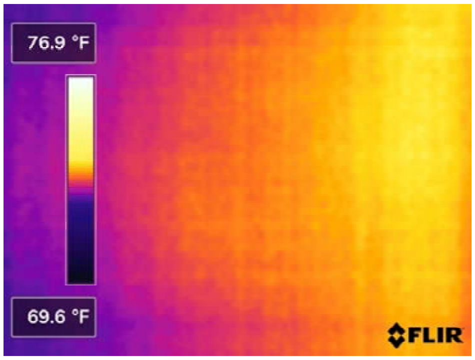

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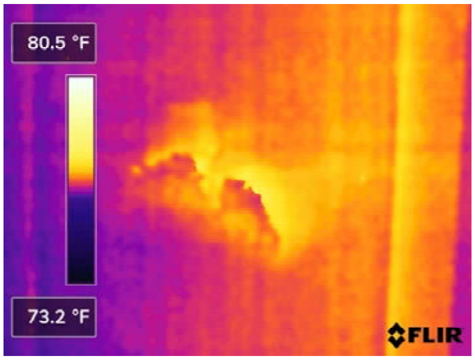

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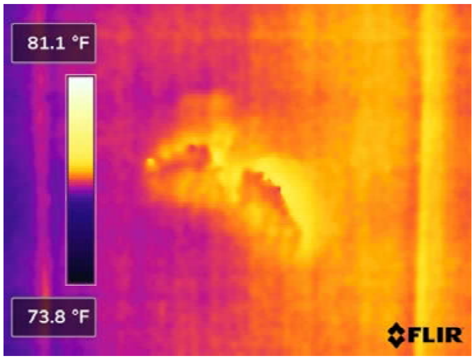

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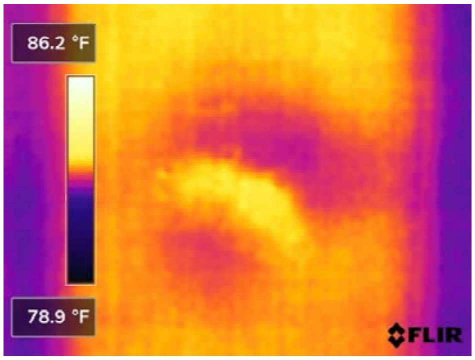

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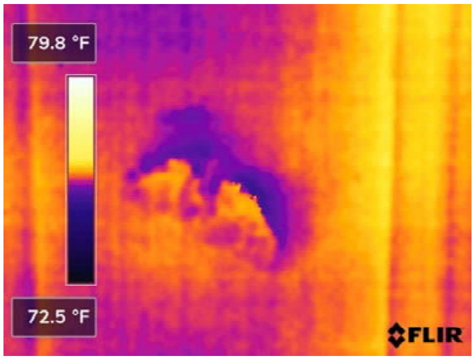

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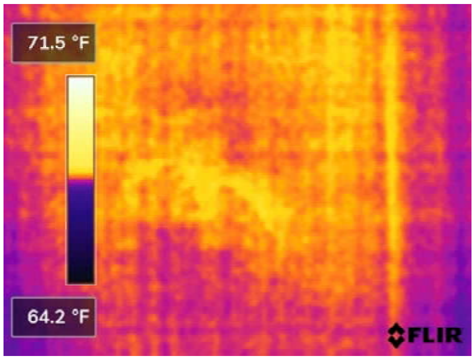

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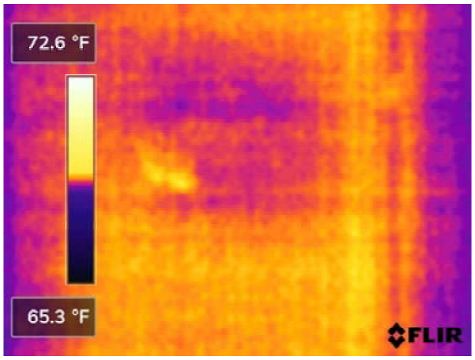

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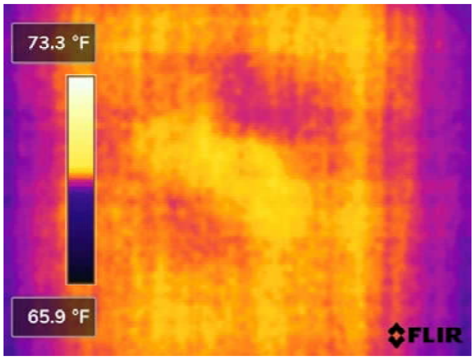

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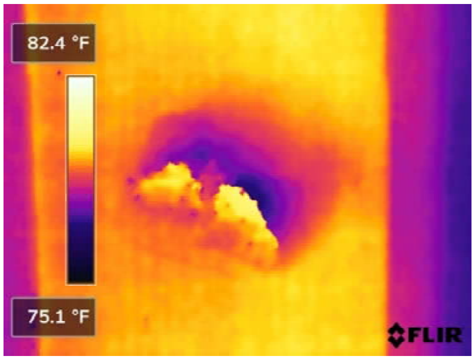

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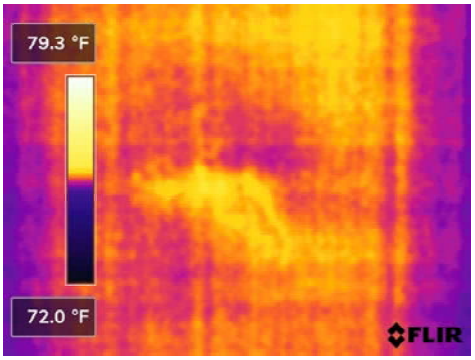

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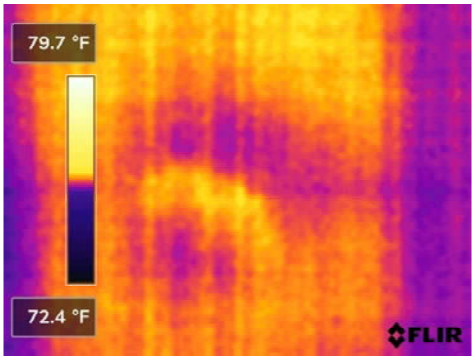

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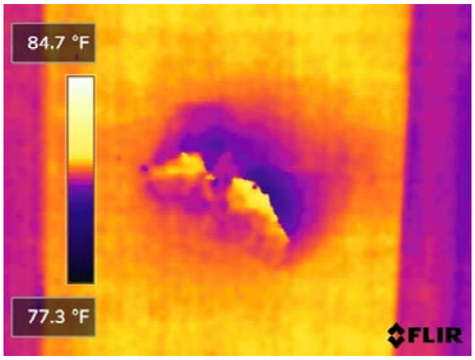

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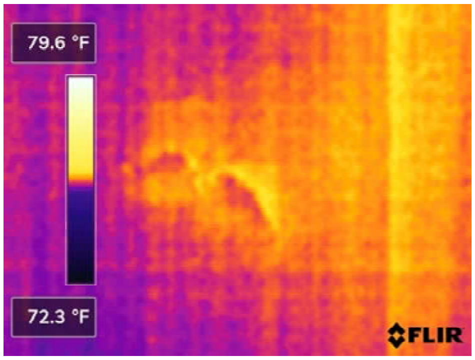

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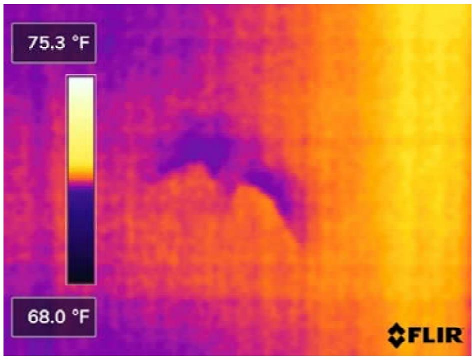

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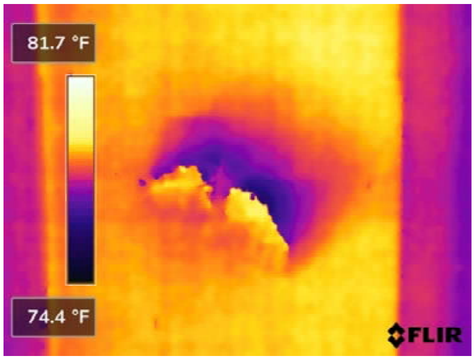

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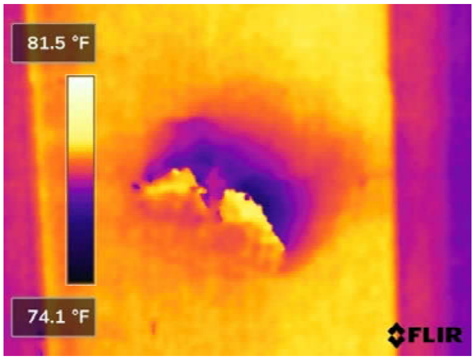

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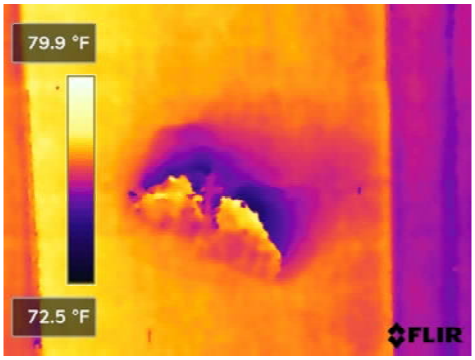

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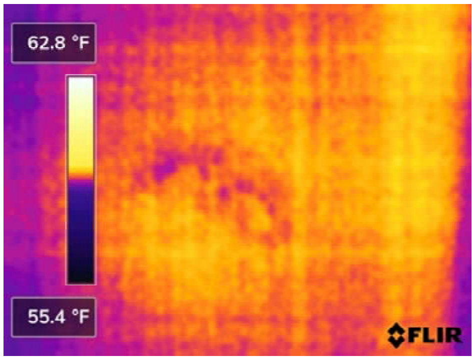

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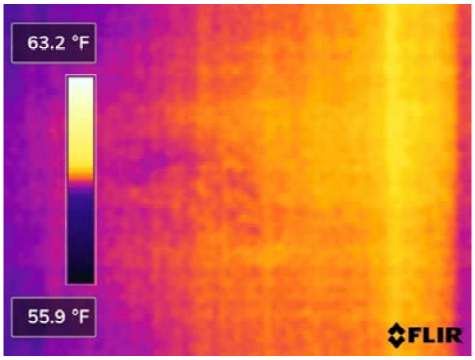

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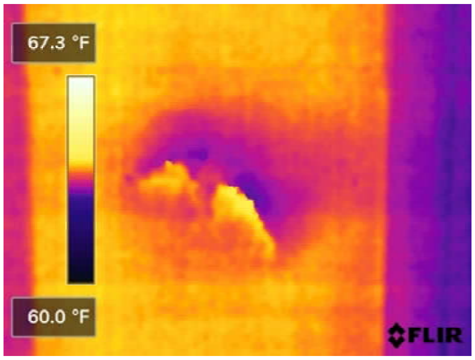

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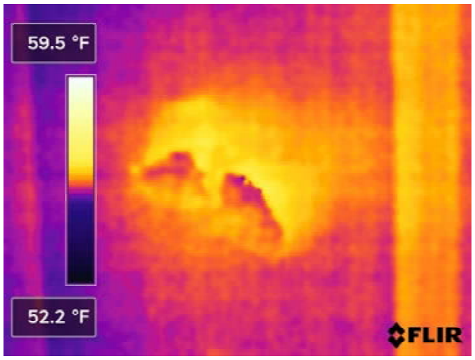

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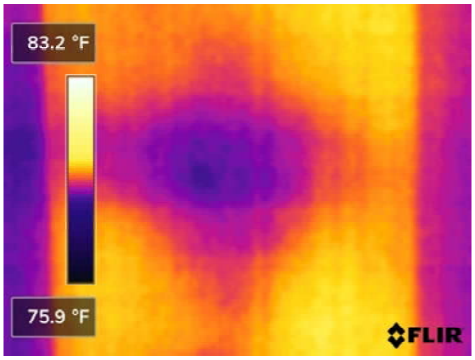

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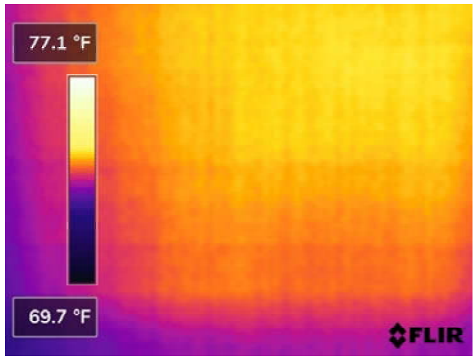

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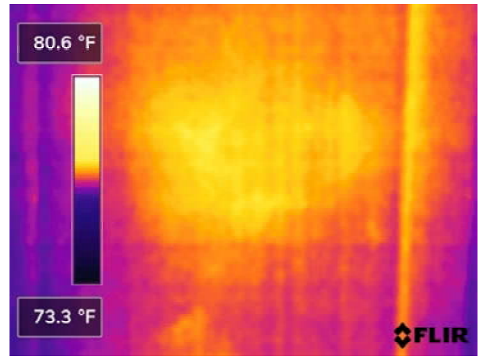

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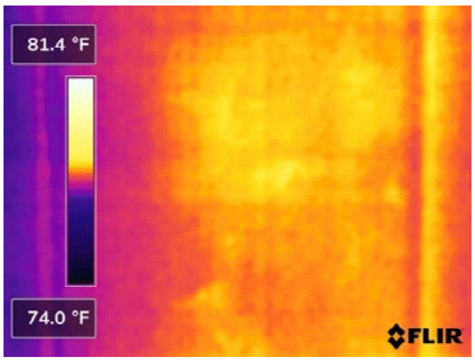

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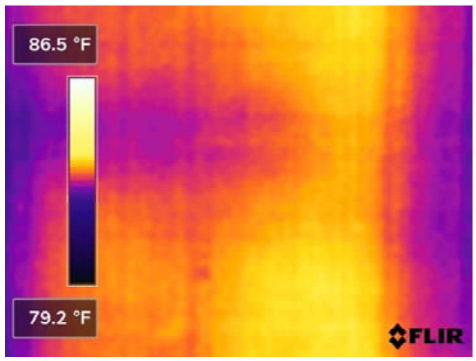

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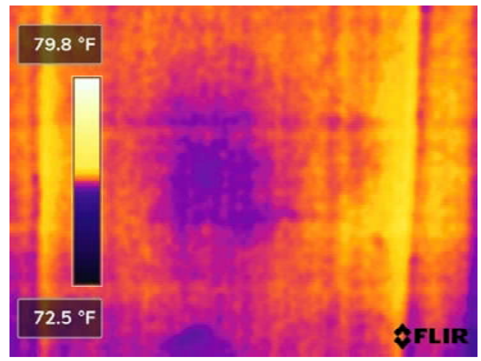

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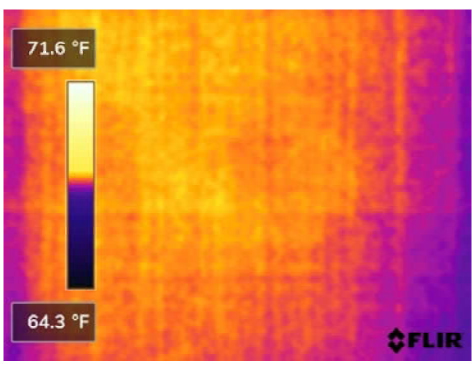

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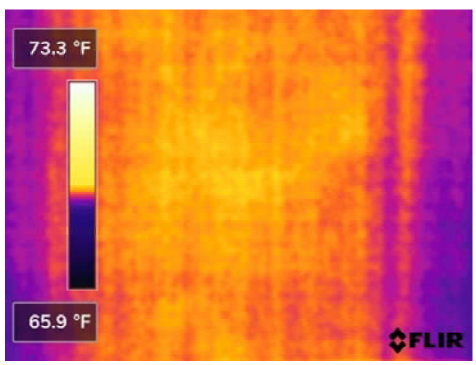

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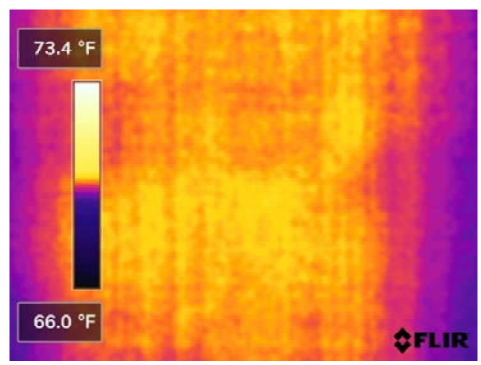

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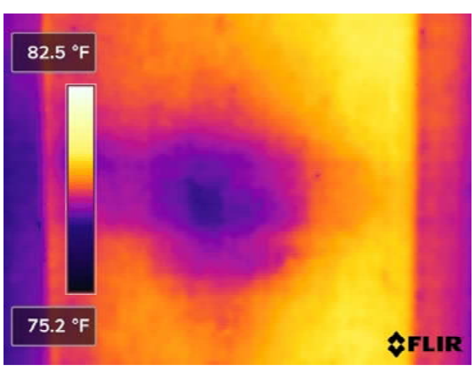

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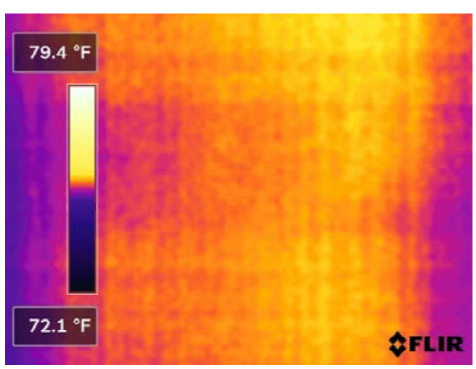

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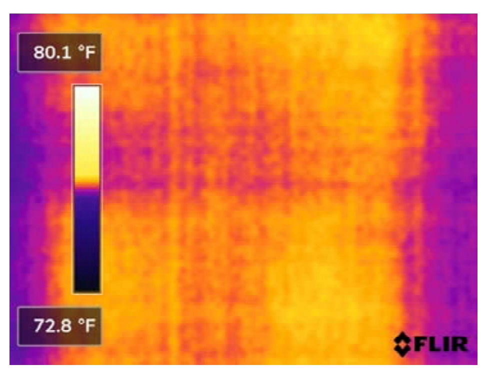

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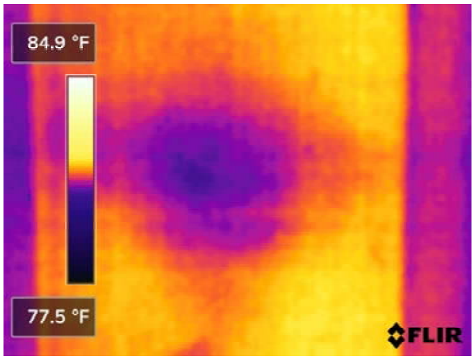

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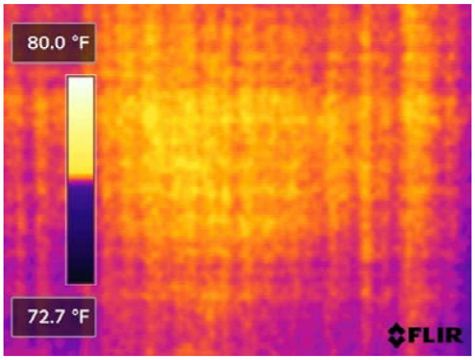

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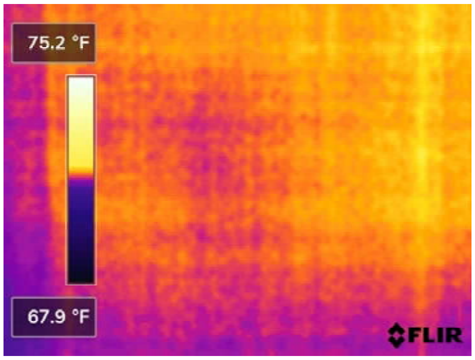

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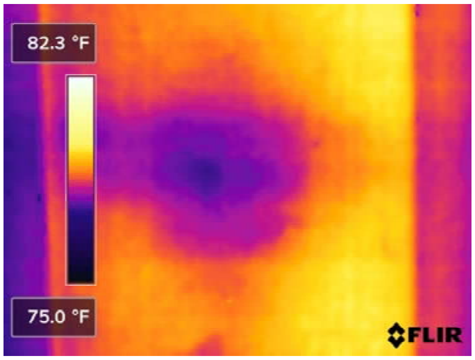

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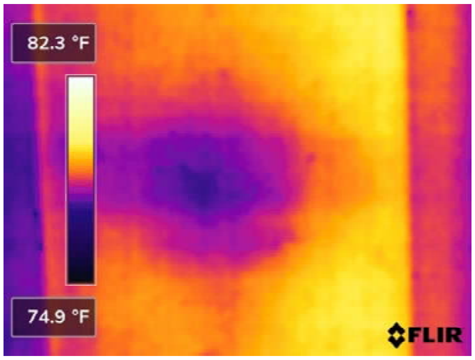

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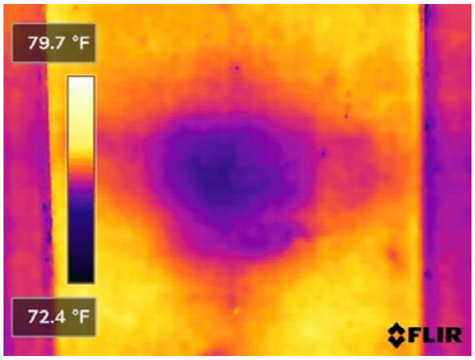

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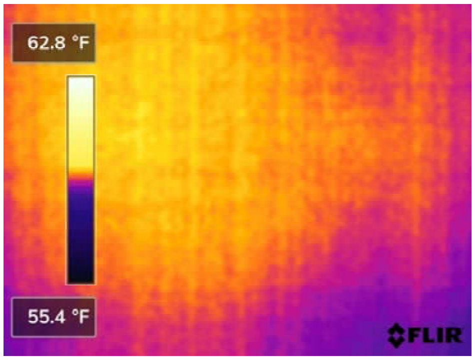

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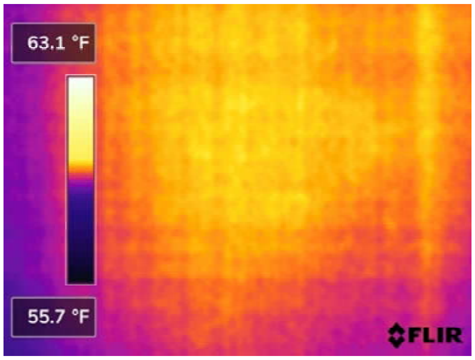

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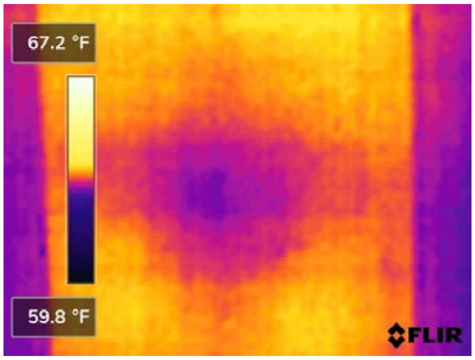

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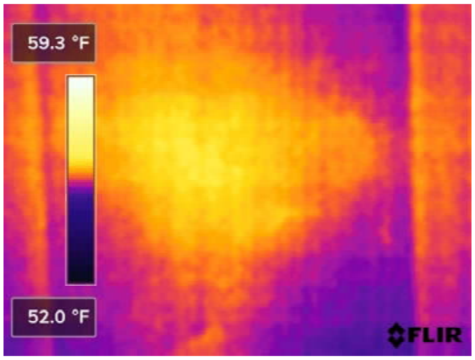

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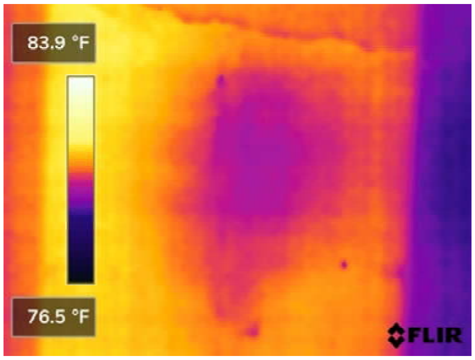

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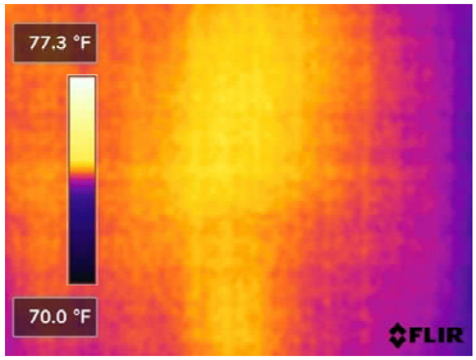

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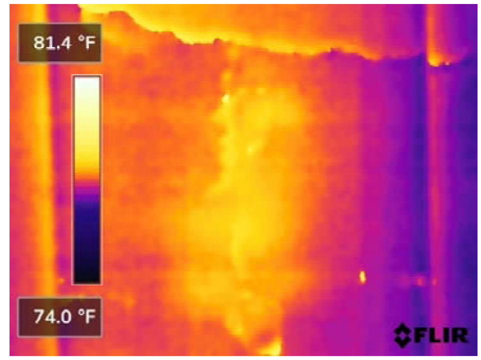

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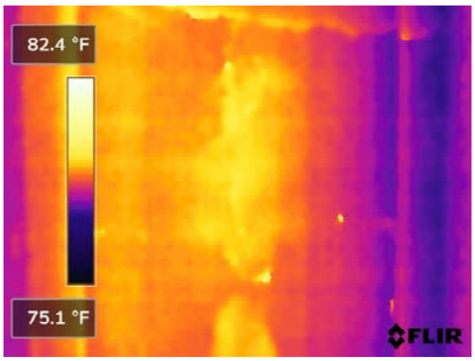

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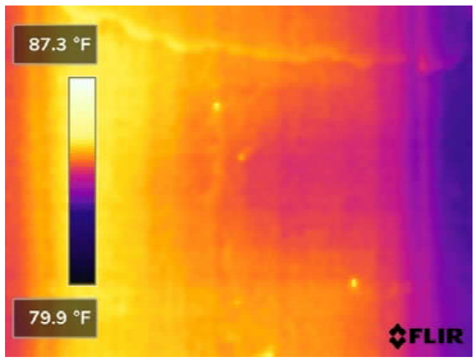

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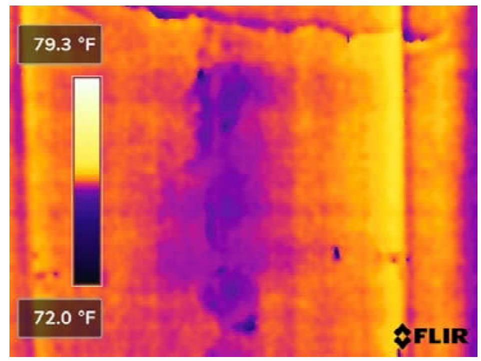

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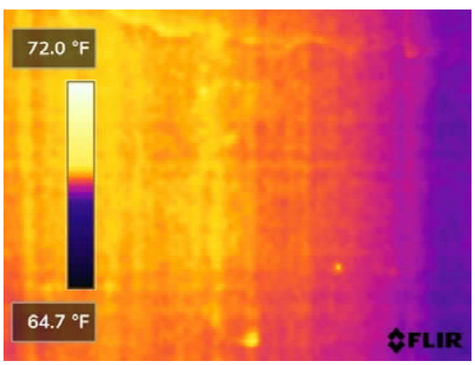

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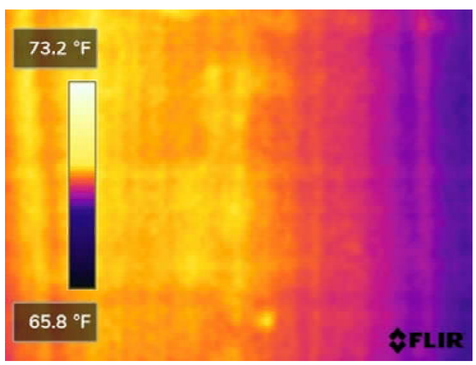

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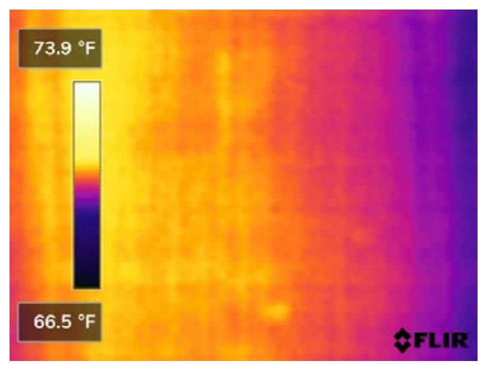

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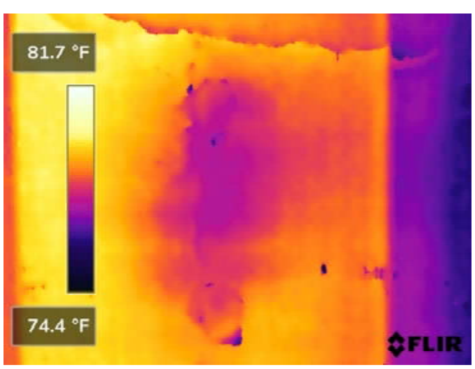

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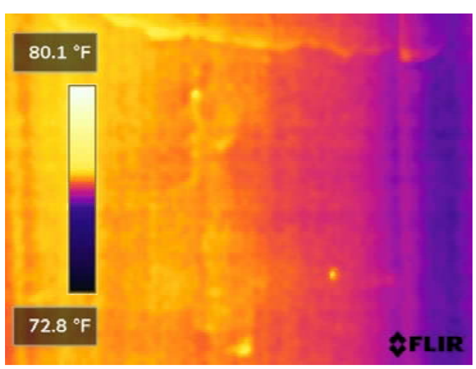

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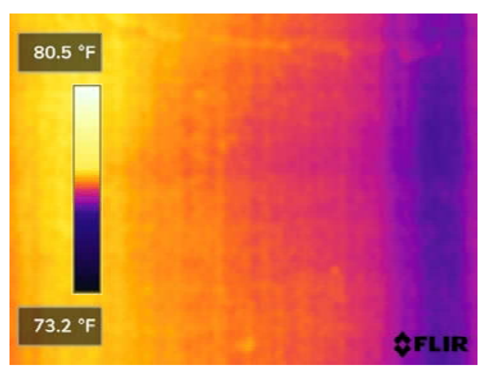

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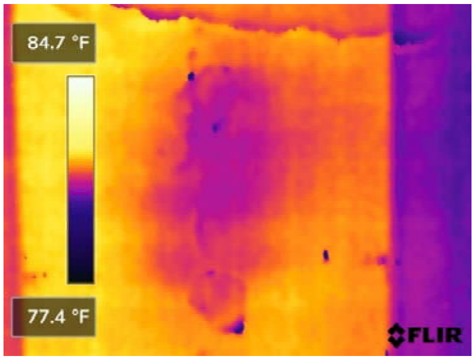

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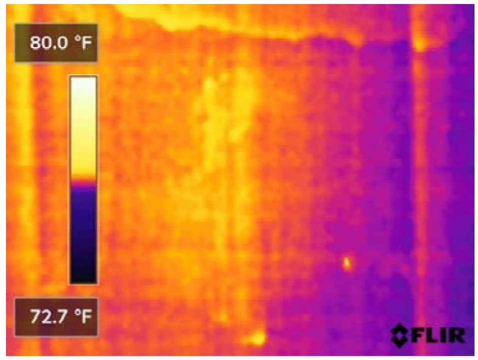

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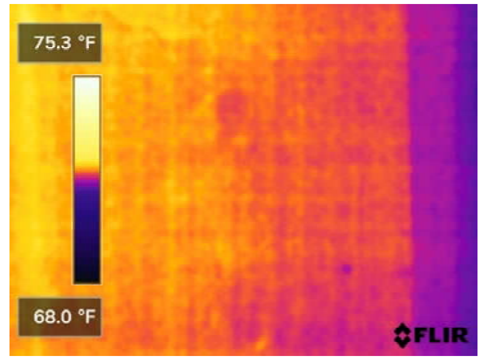

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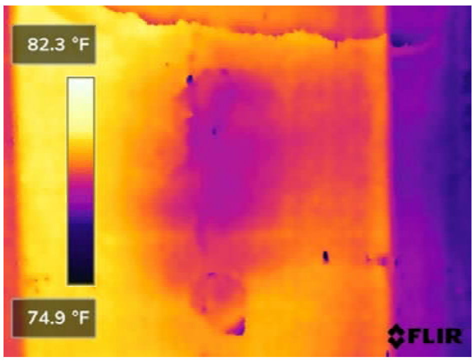

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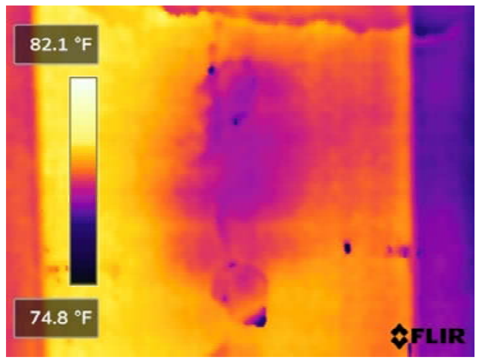

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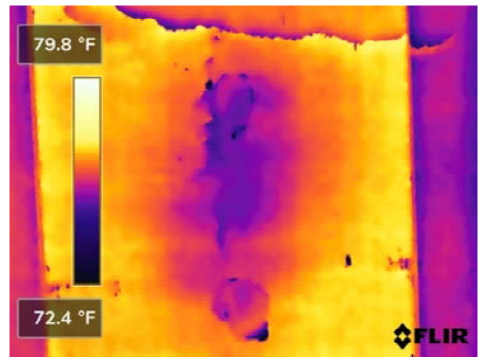

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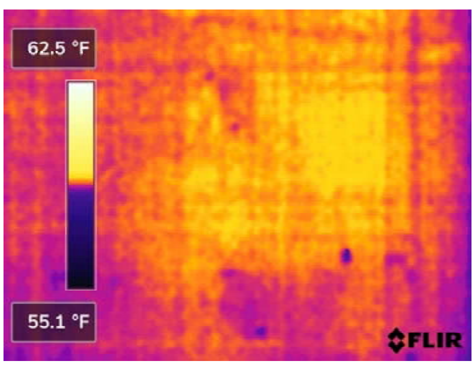

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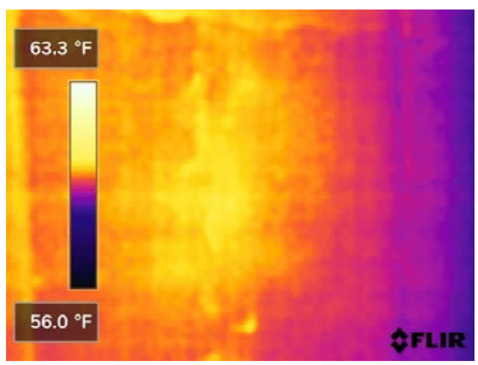

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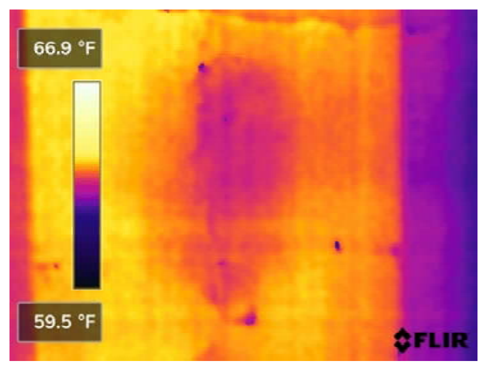

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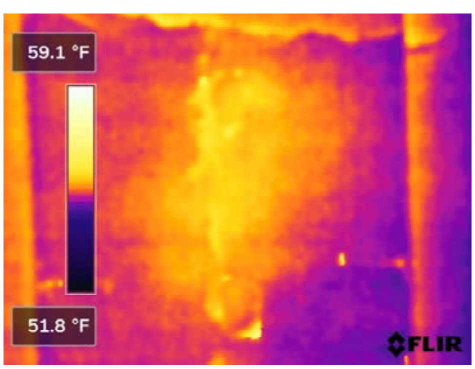

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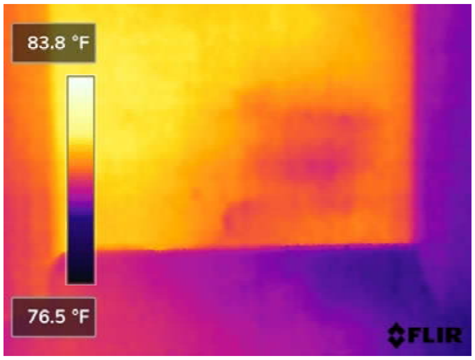

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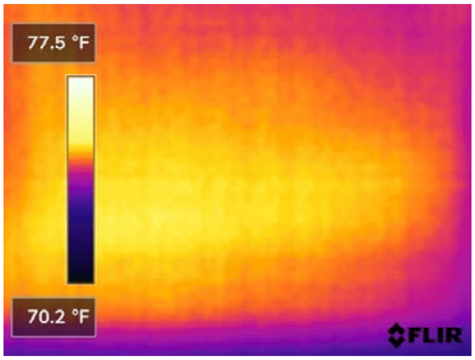

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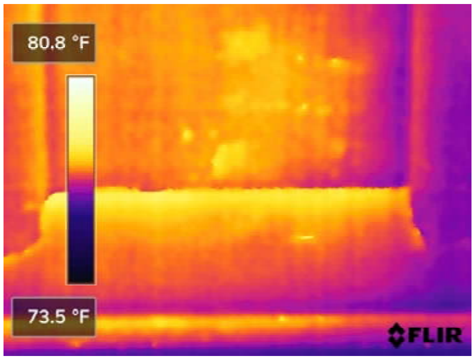

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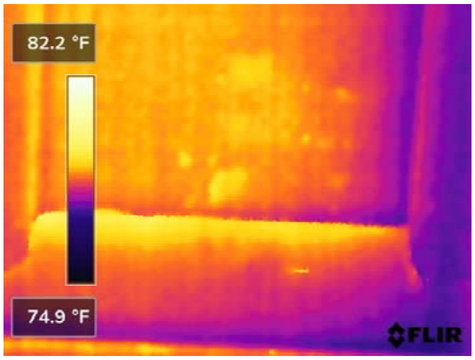

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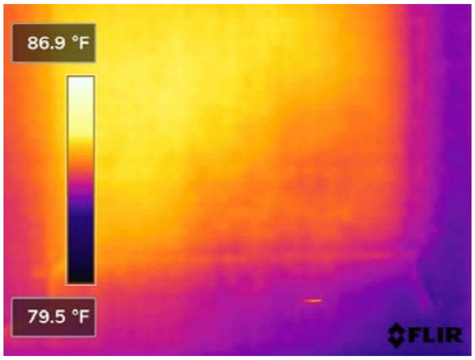

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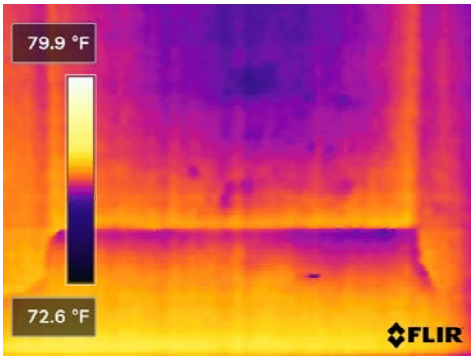

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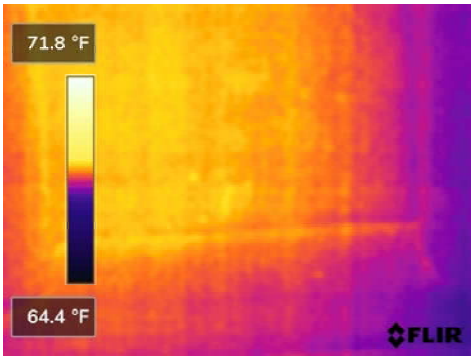

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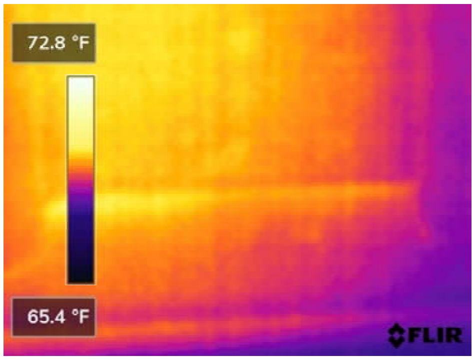

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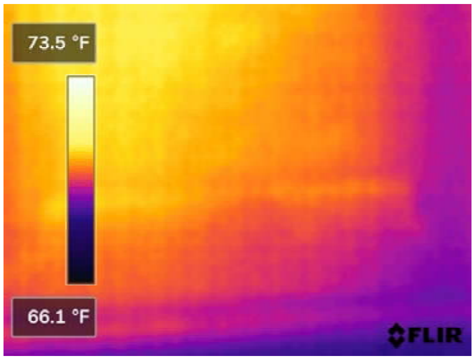

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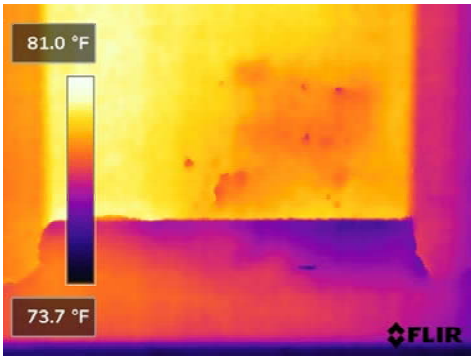

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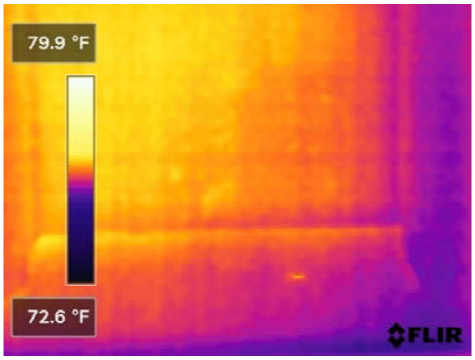

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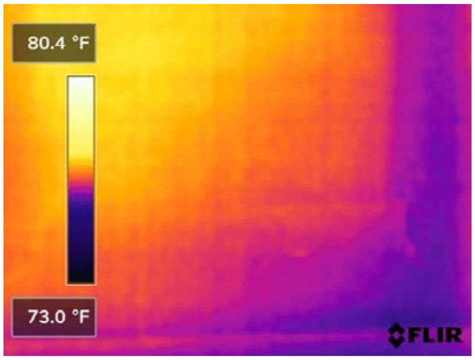

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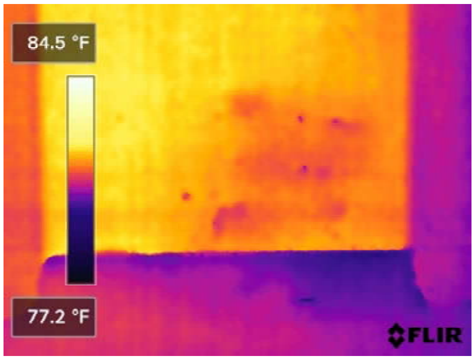

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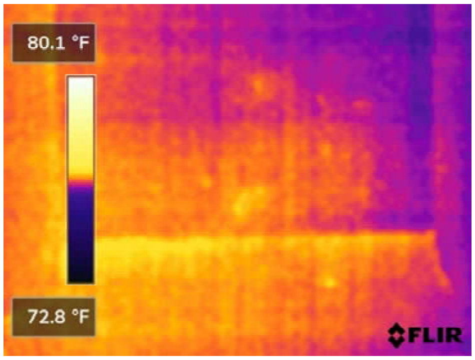

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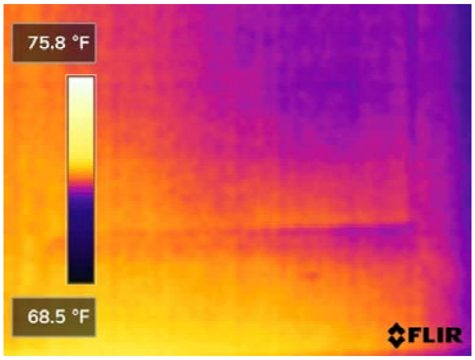

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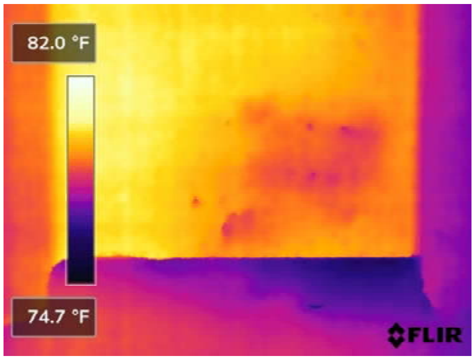

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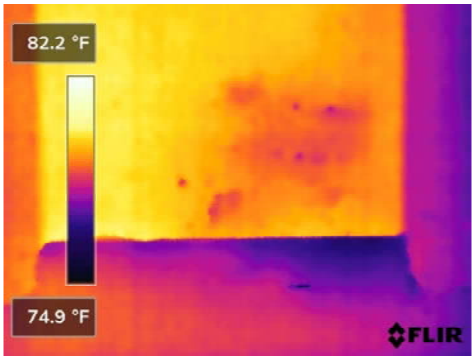

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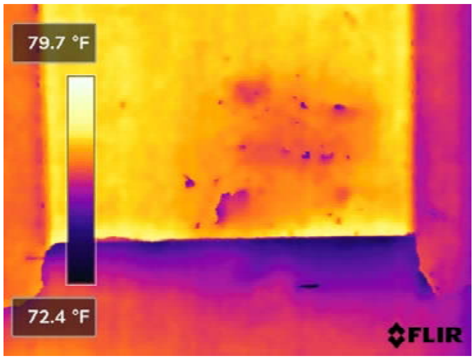

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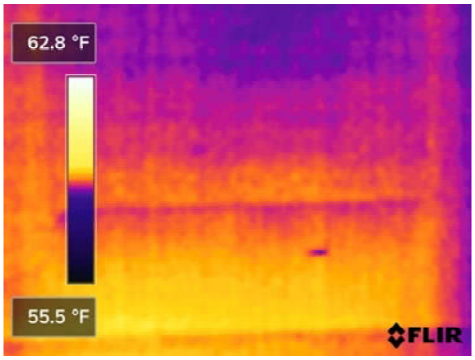

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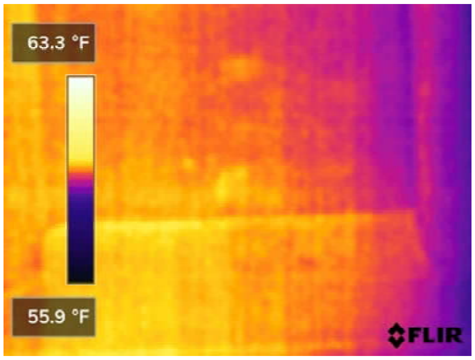

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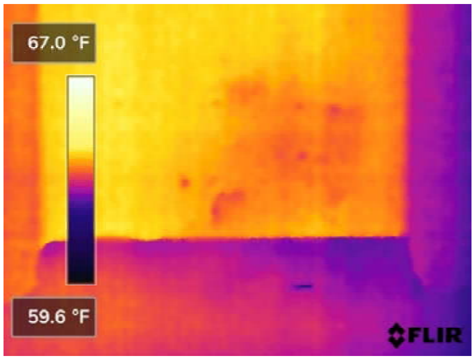

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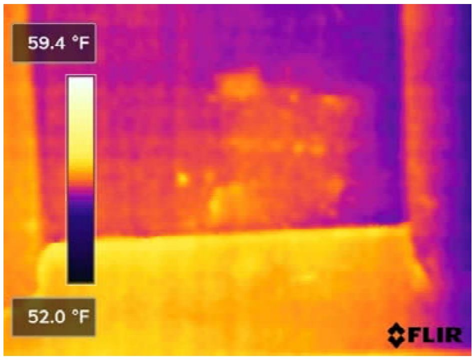

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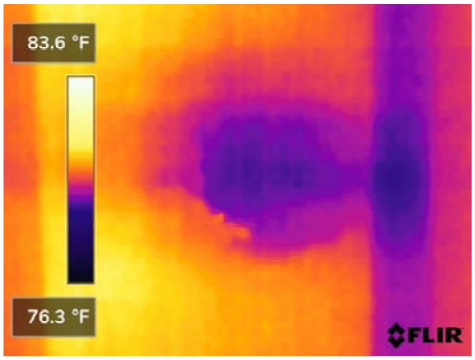

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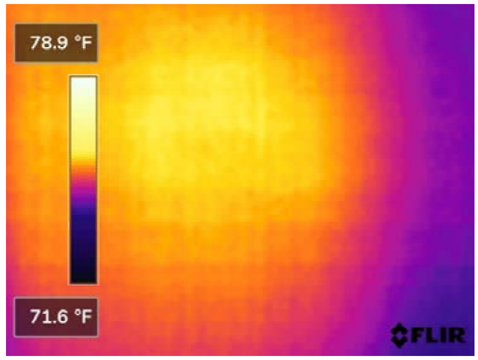

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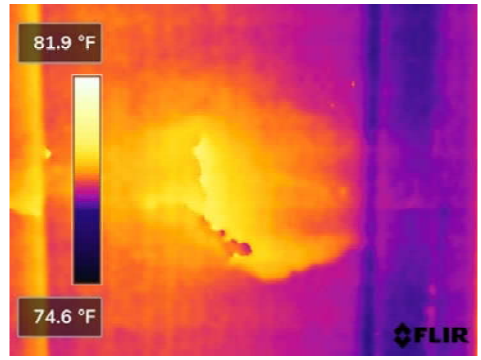

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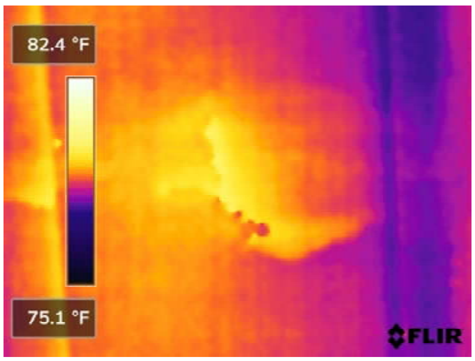

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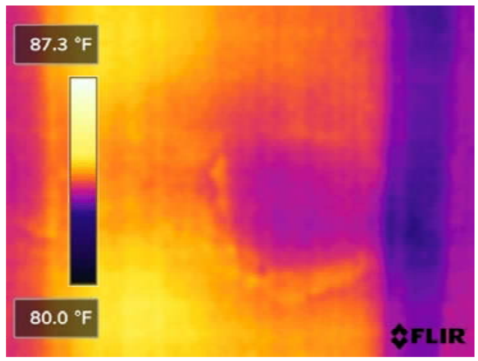

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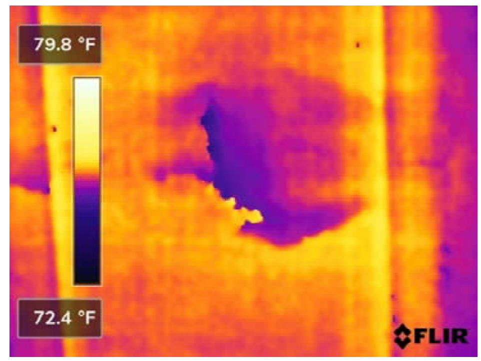

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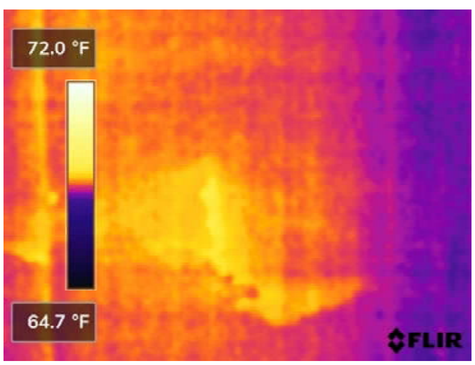

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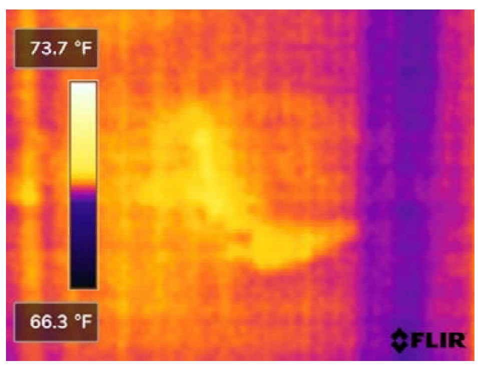

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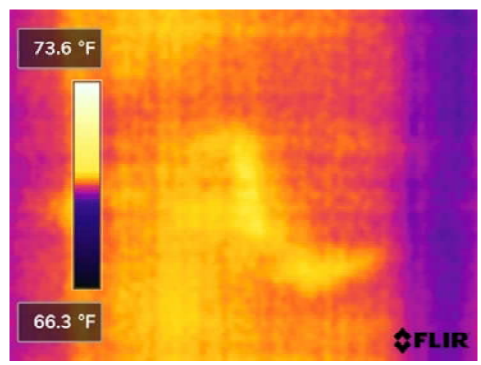

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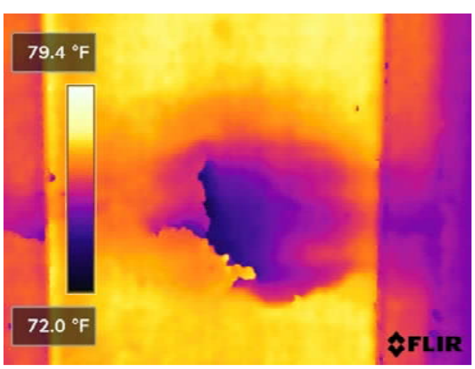

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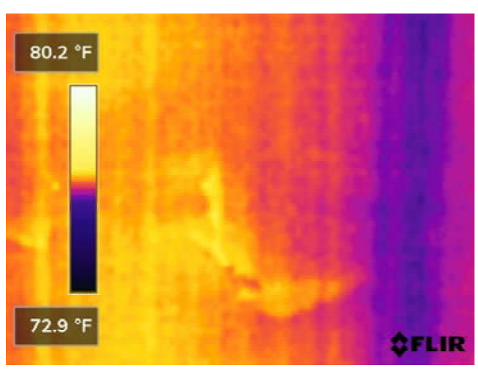

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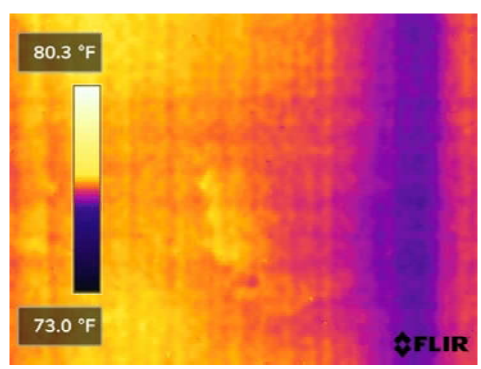

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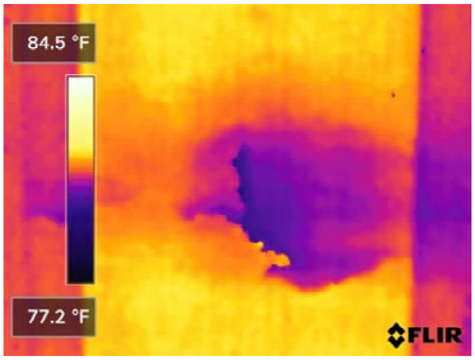

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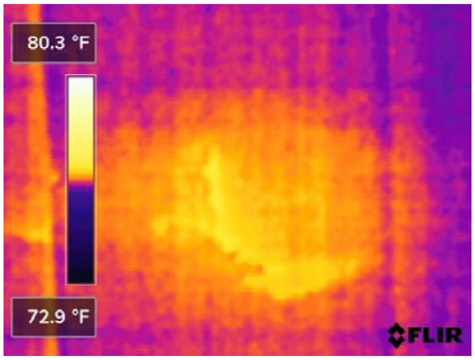

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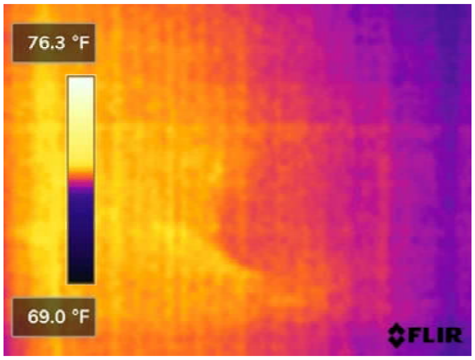

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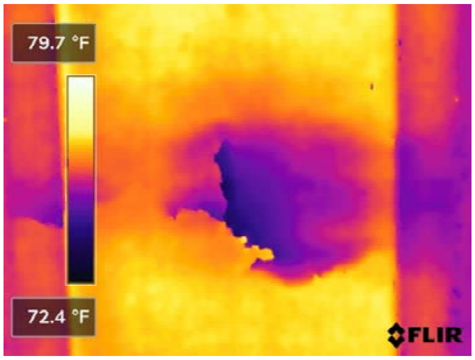

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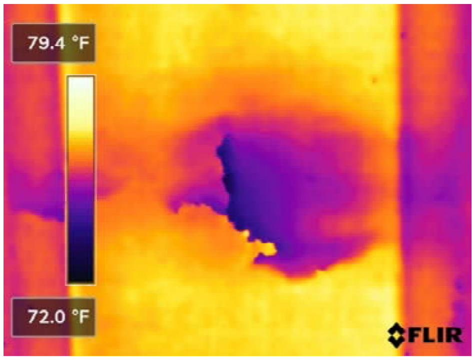

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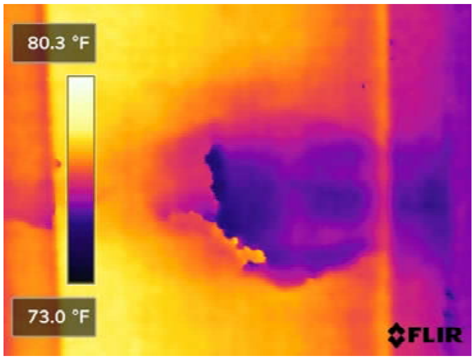

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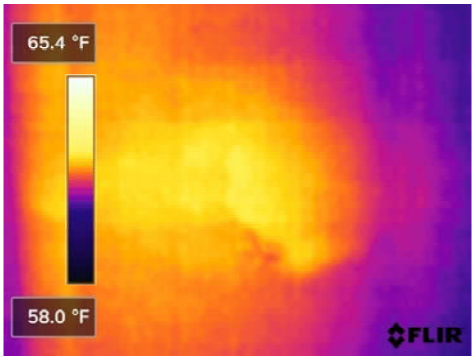

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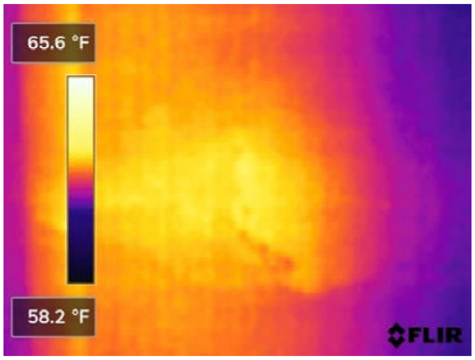

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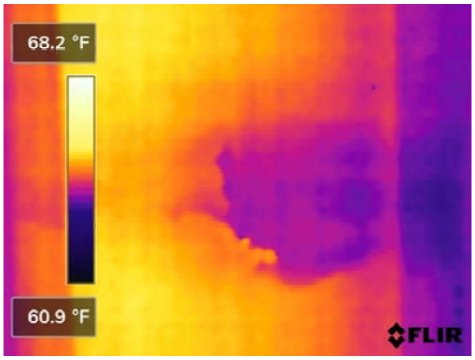

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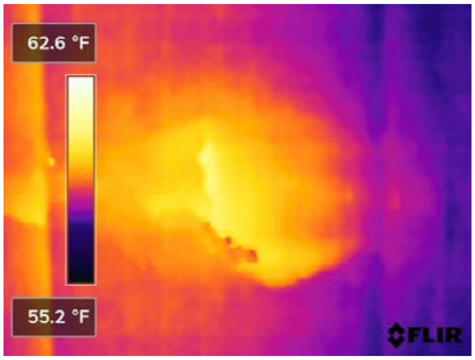

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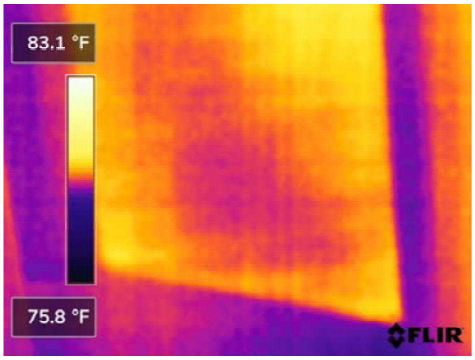

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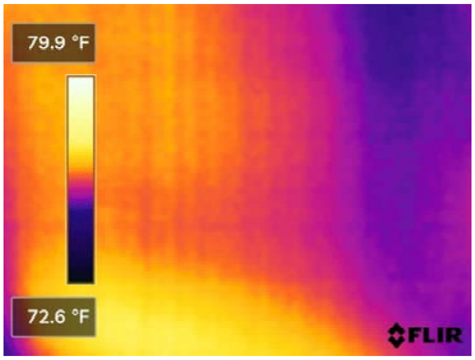

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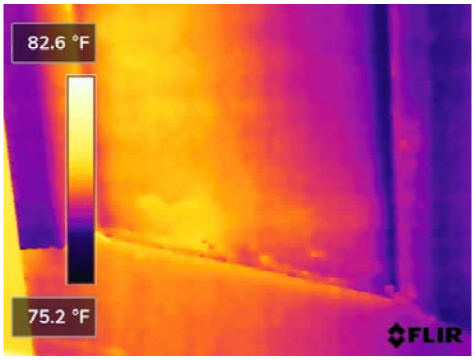

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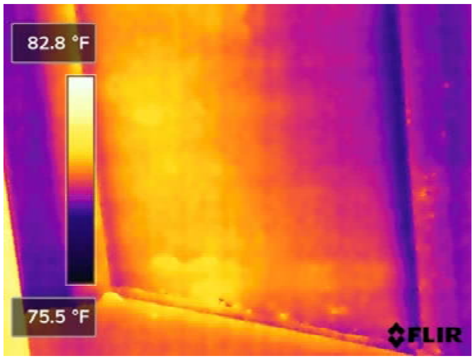

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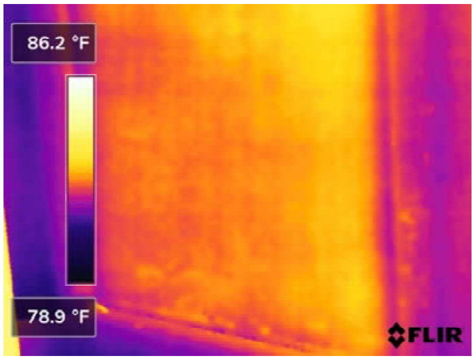

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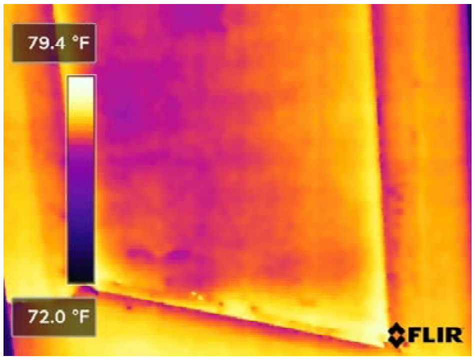

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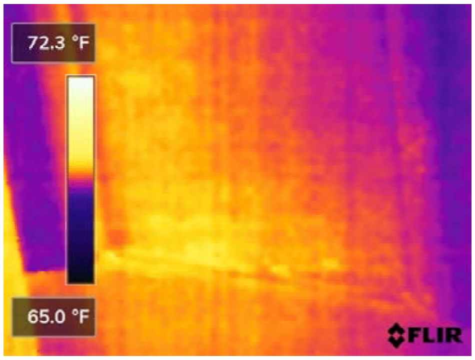

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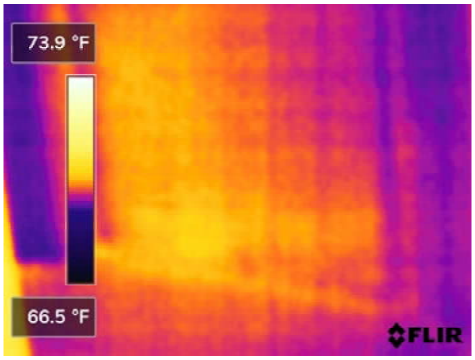

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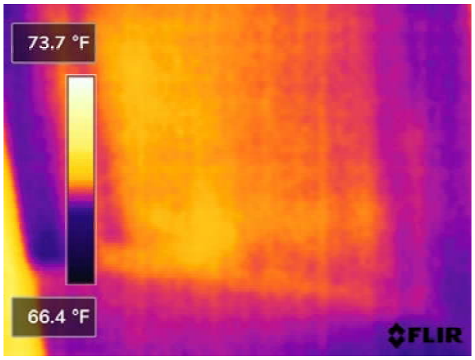

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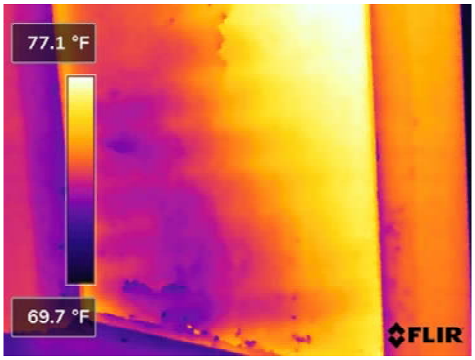

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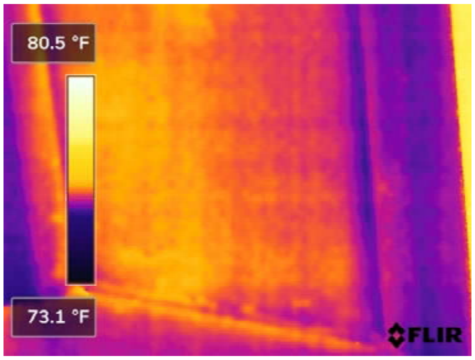

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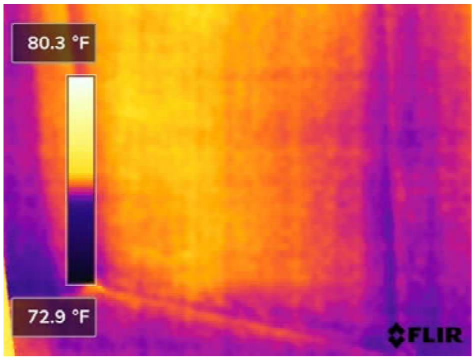

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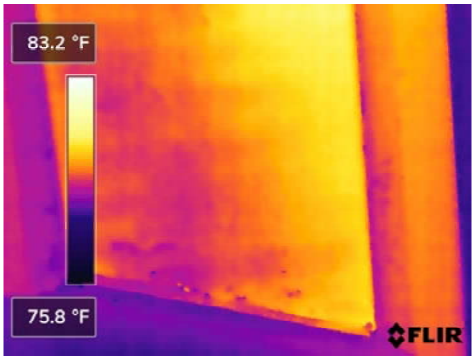

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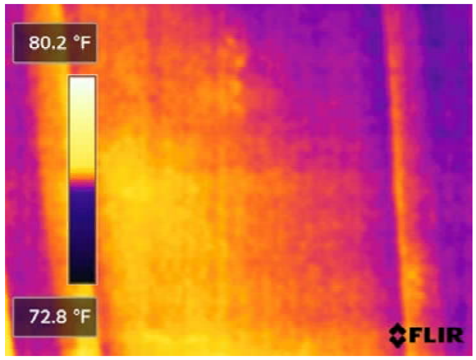

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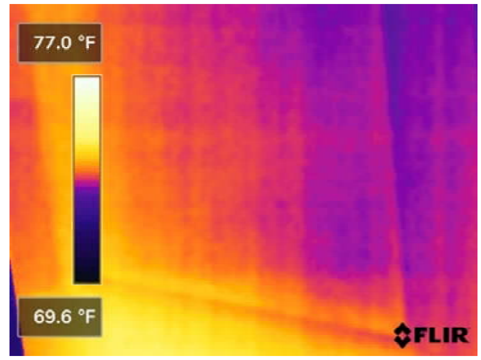

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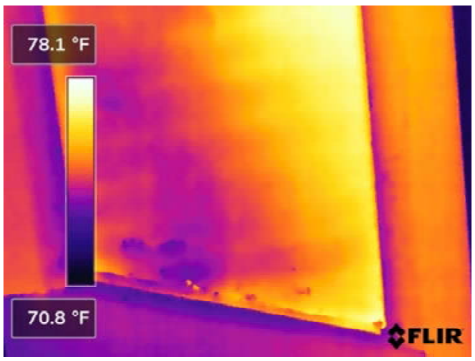

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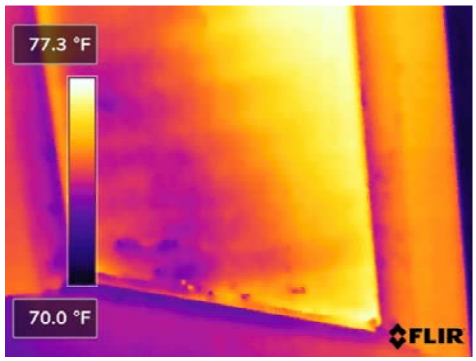

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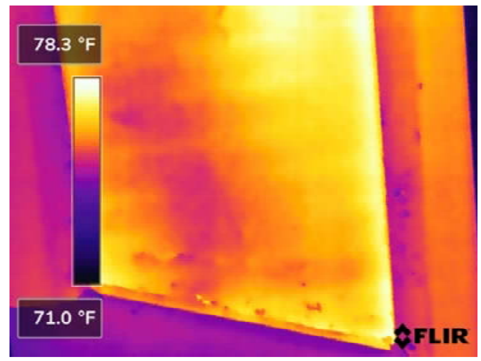

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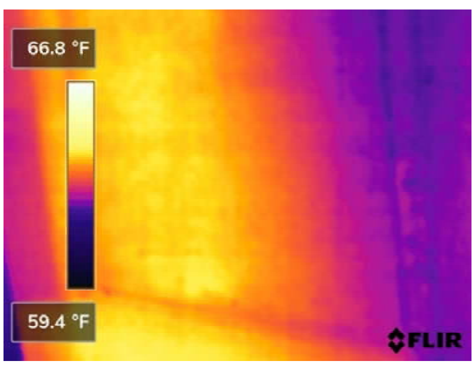

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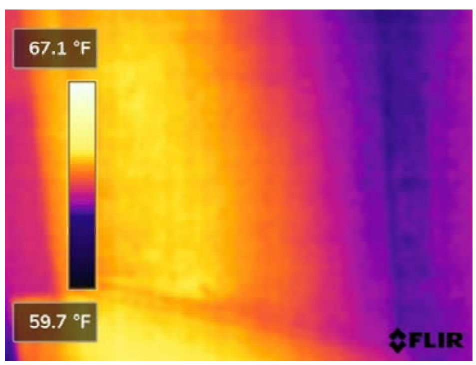

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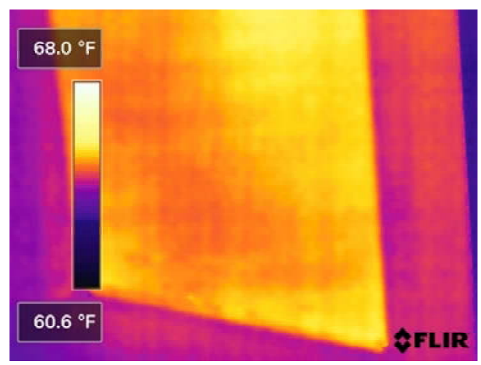

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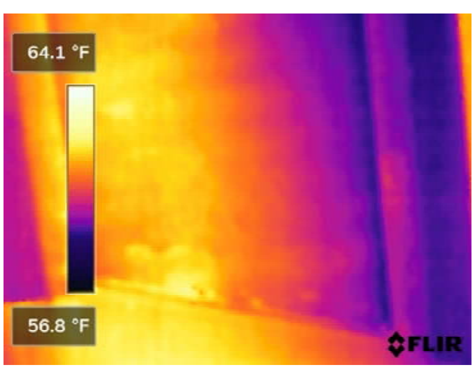

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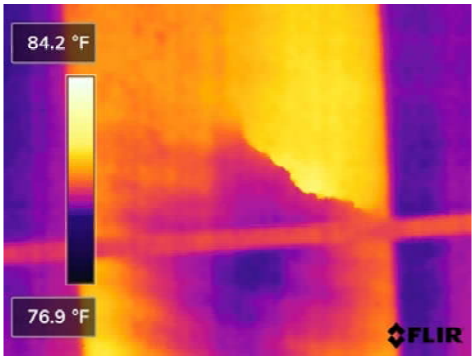

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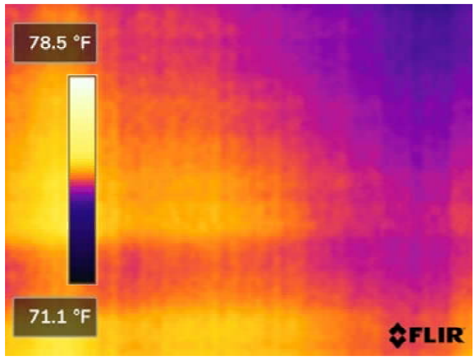

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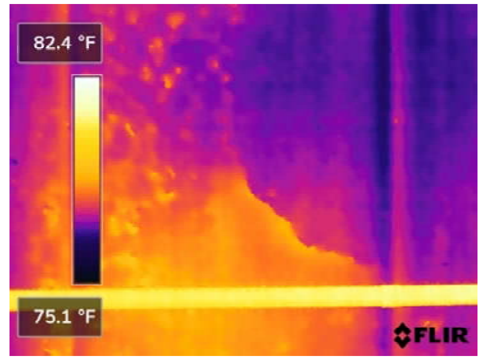

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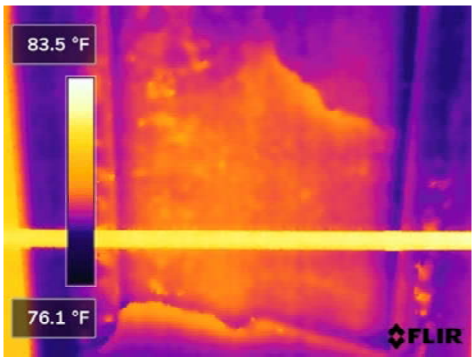

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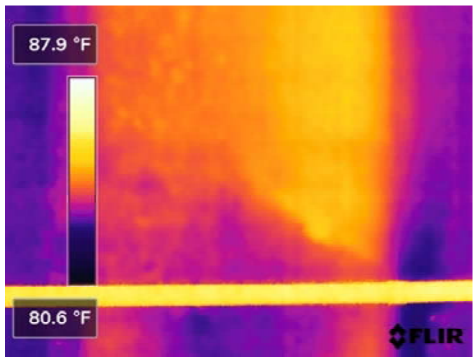

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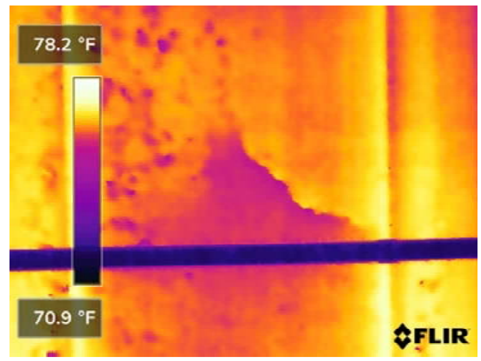

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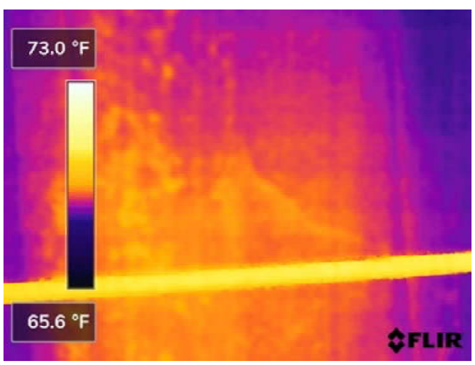

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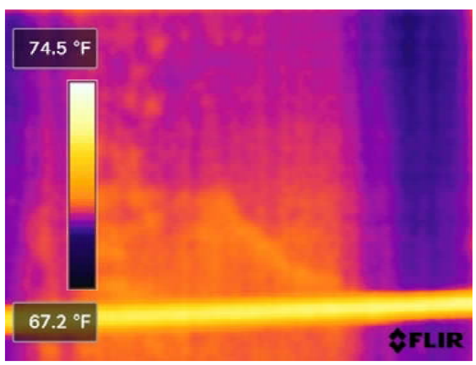

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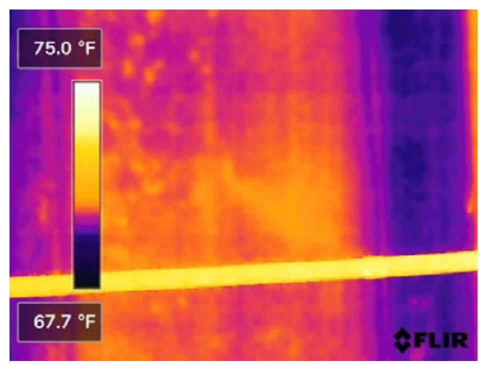

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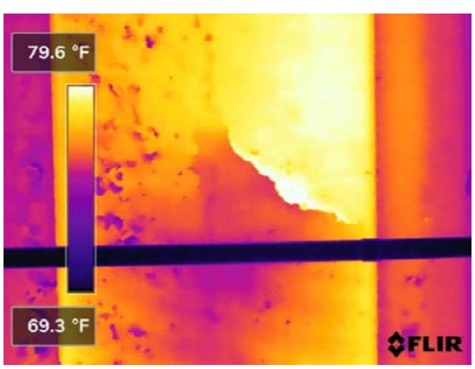

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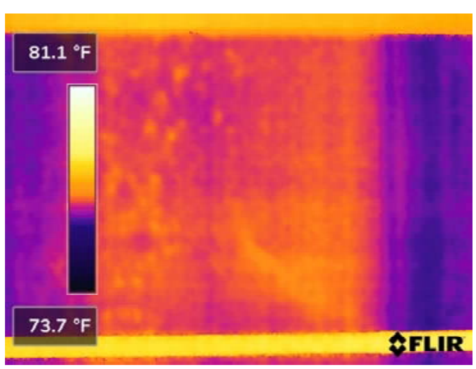

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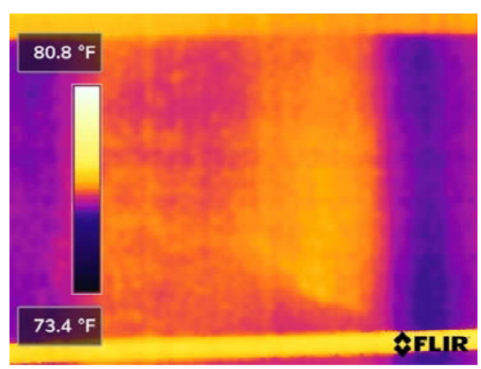

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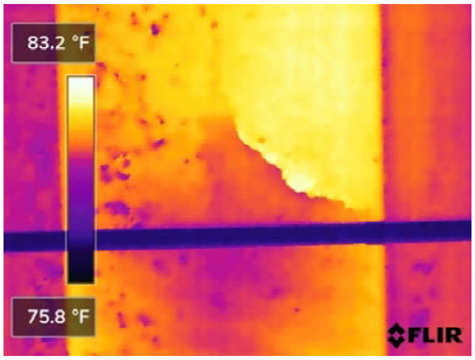

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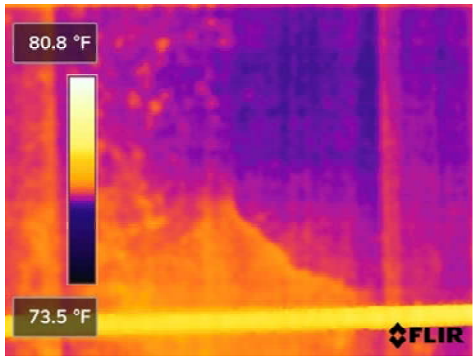

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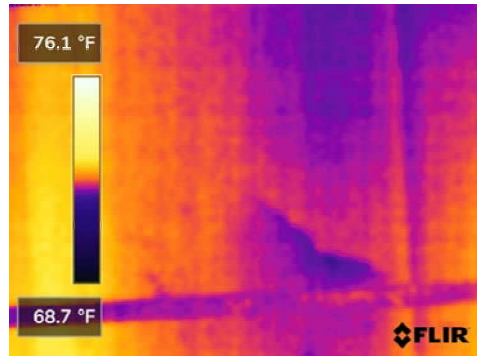

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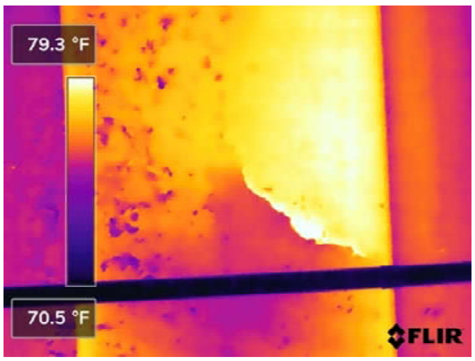

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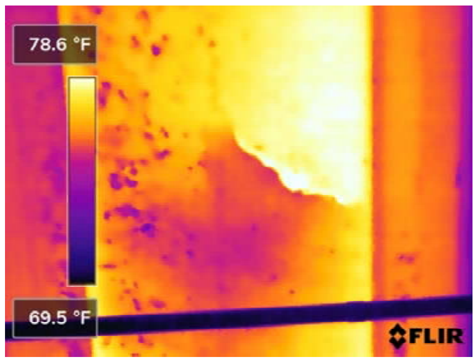

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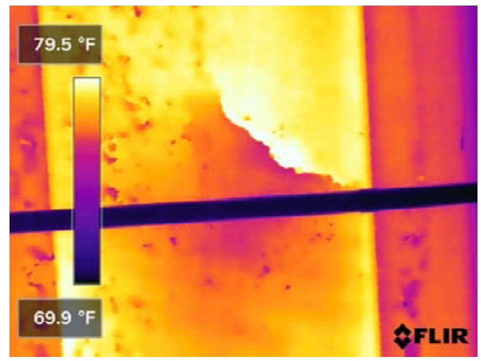

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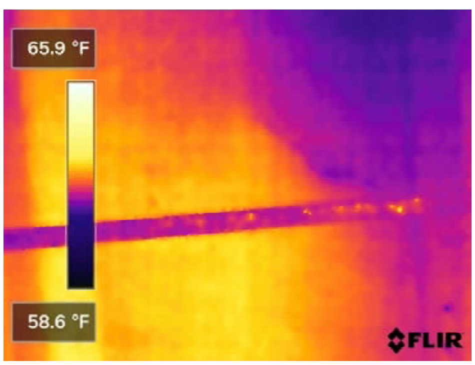

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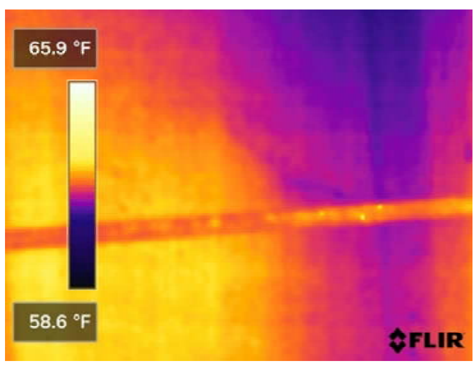

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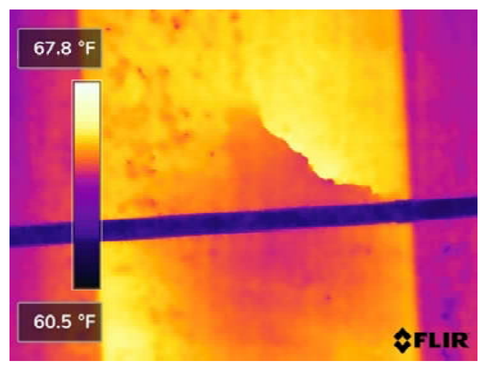

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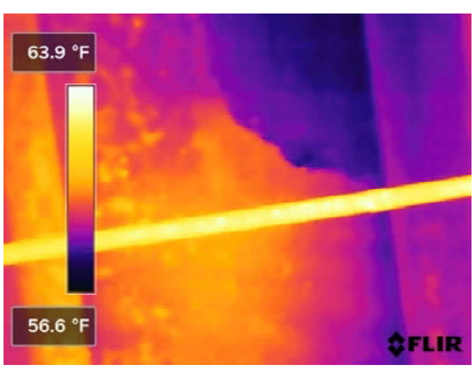

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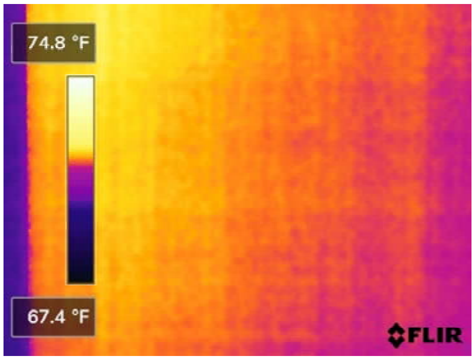

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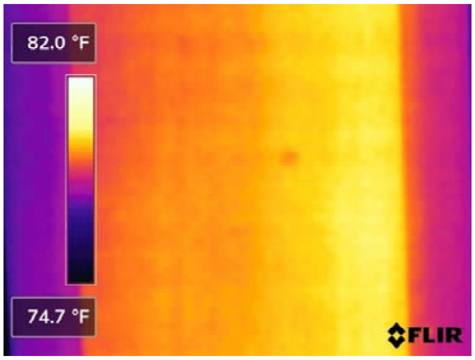

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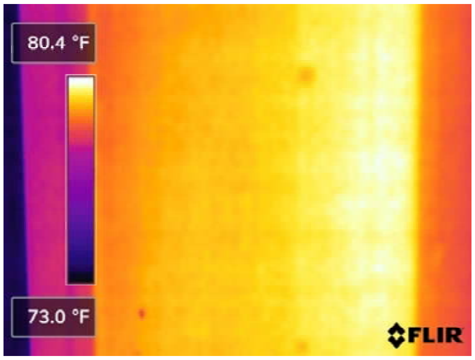

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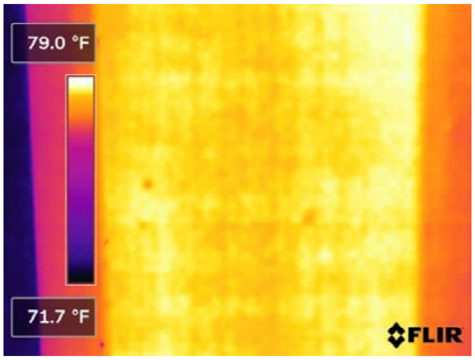

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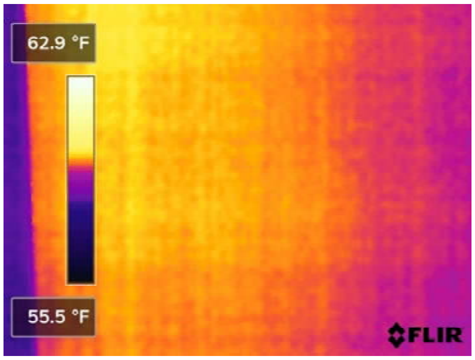

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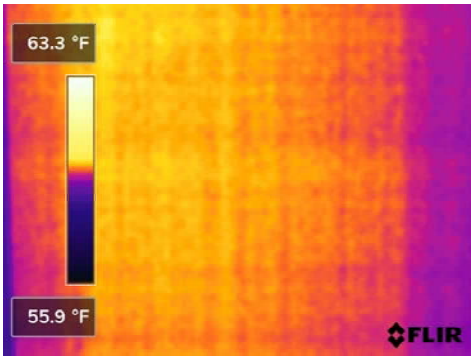

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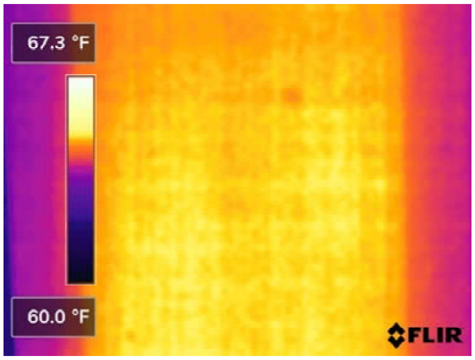

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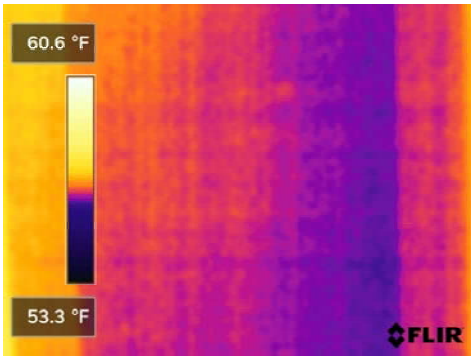

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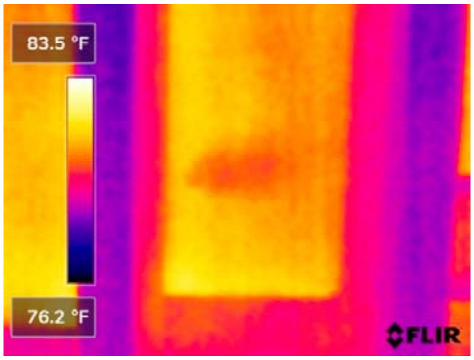

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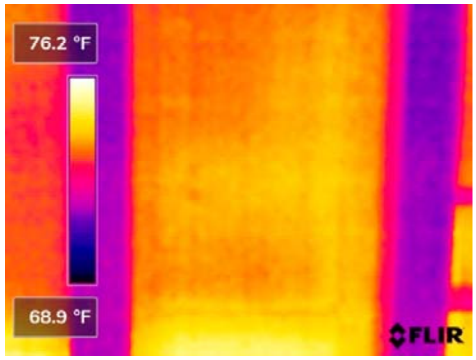

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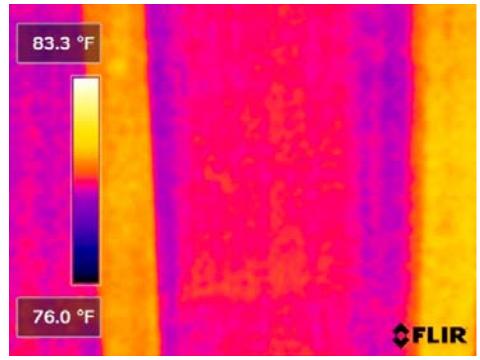

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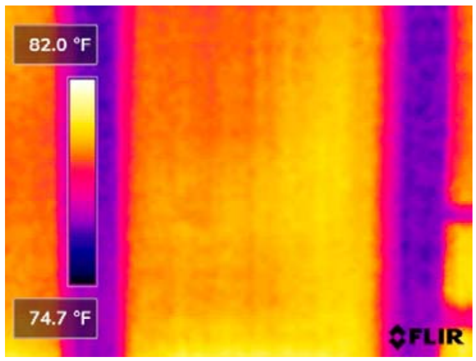
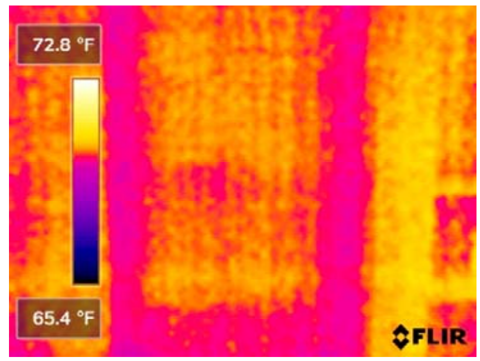


E8_Loc01_05_FLIR0468



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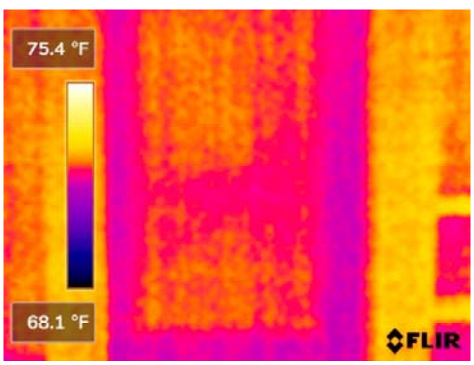

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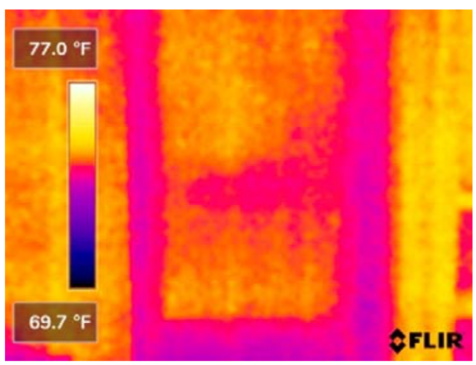

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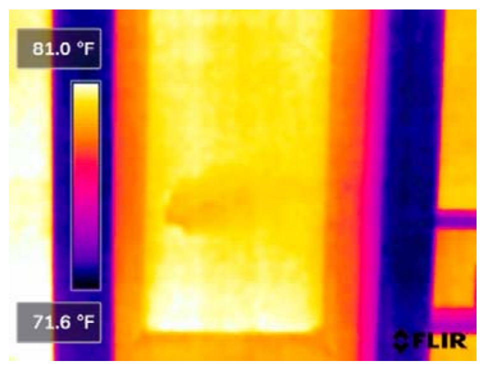

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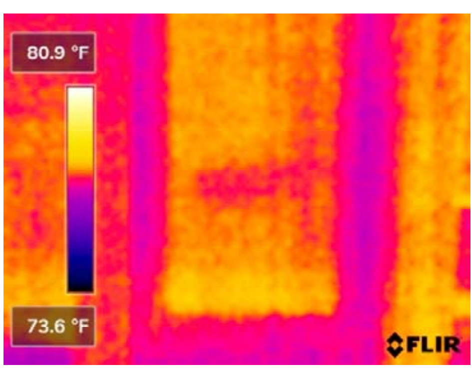

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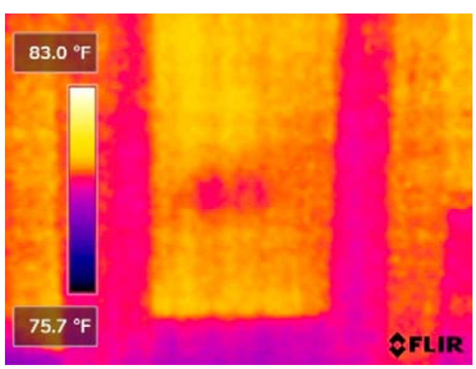

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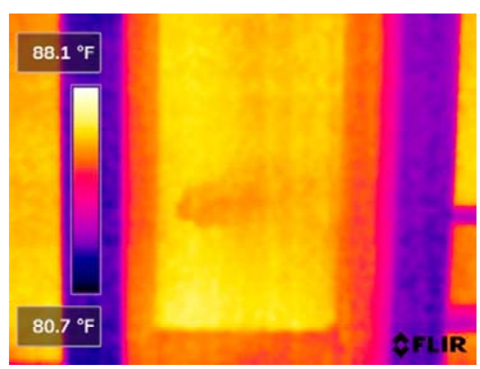

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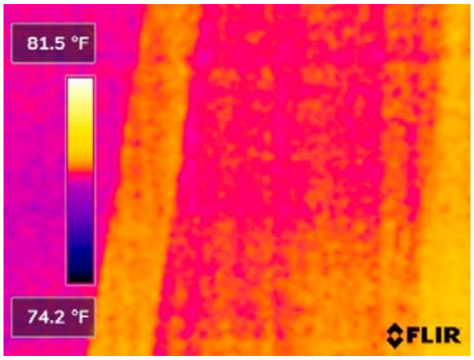

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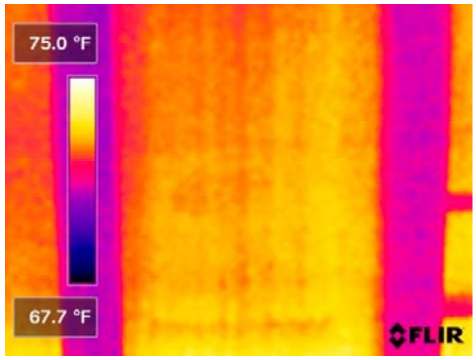

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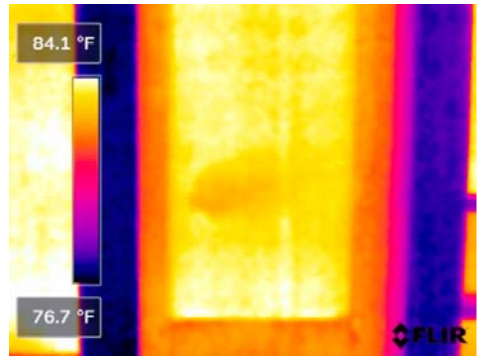

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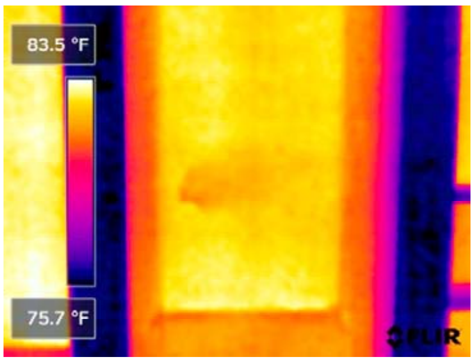

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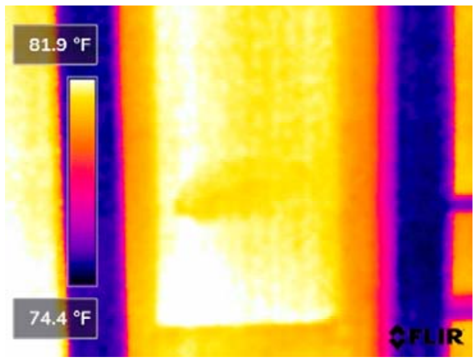

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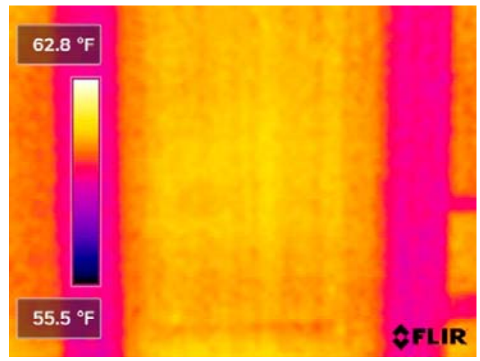

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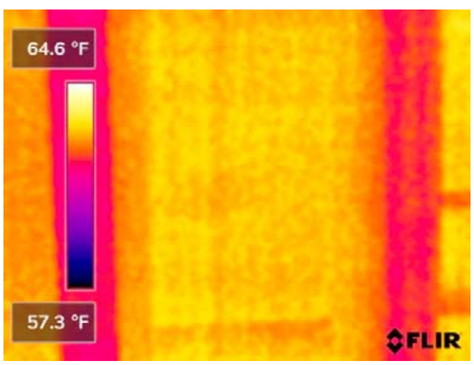

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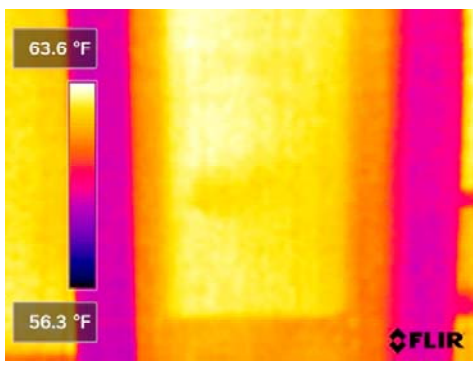

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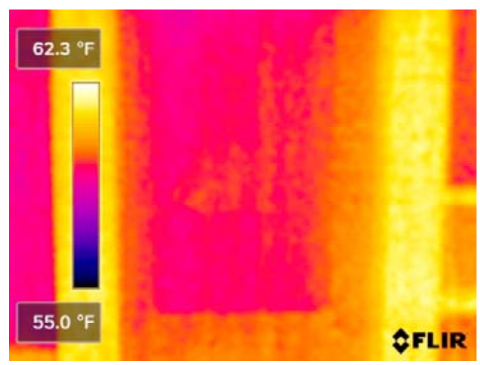

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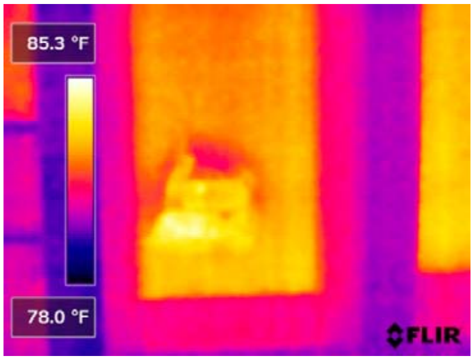

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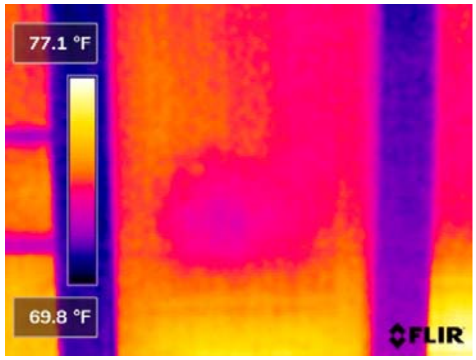

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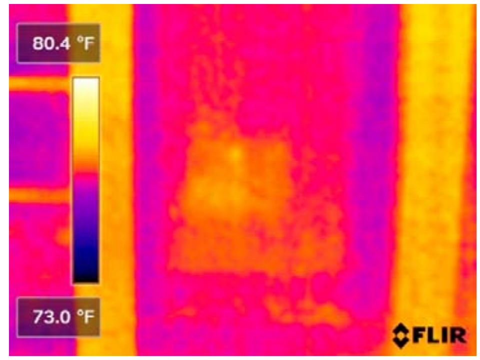

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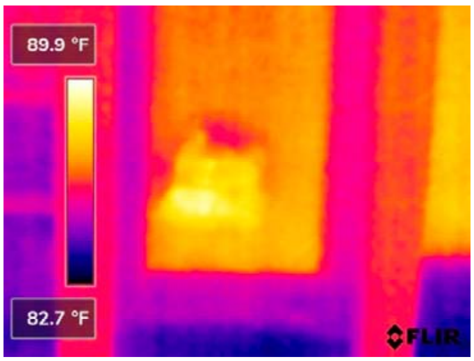

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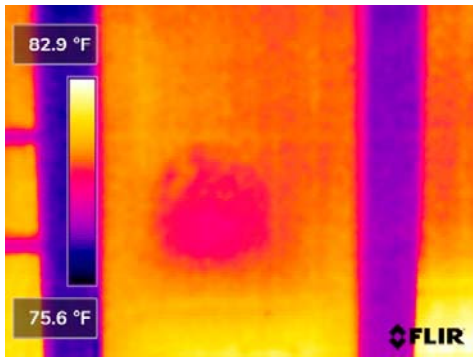

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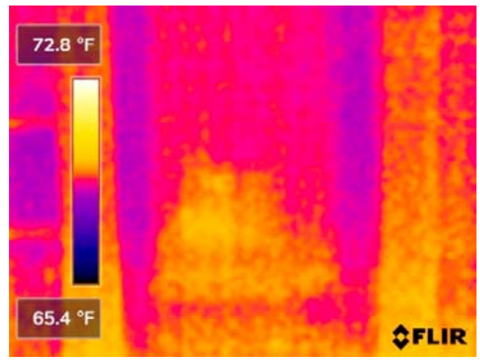

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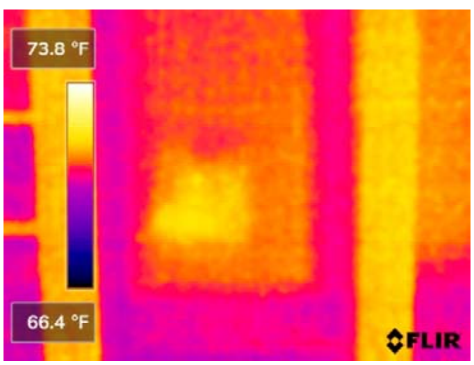

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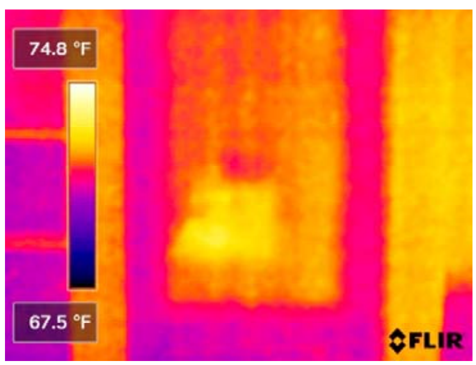

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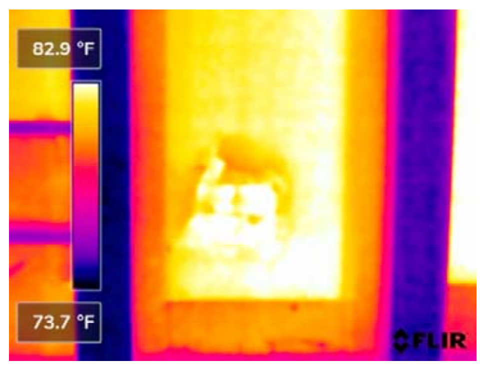

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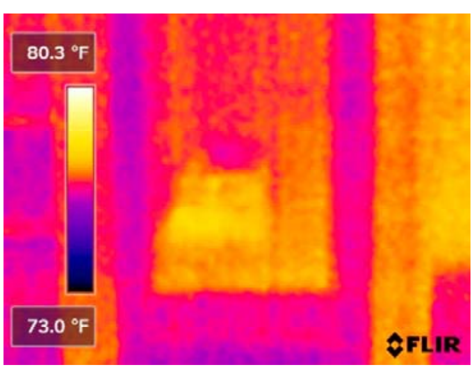

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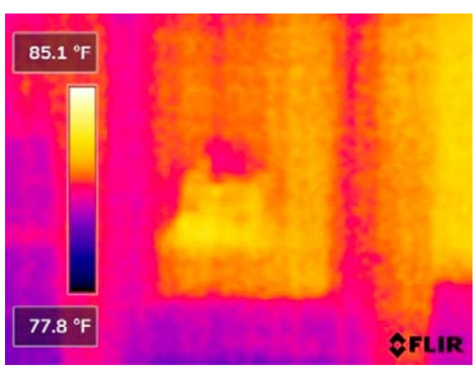

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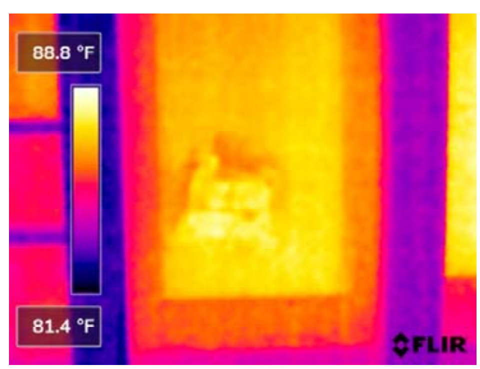

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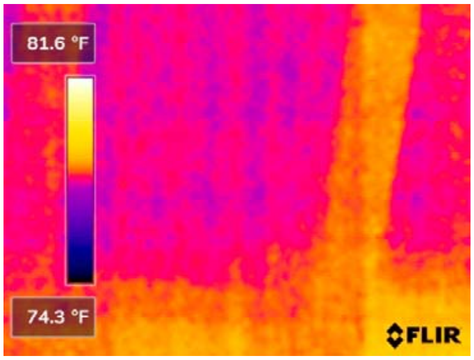

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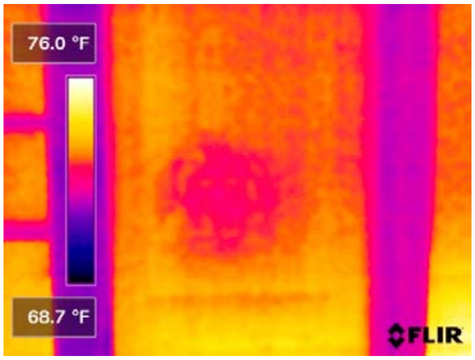

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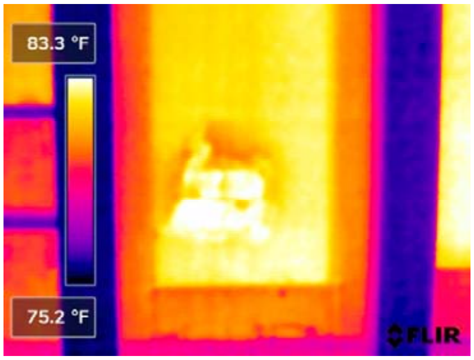

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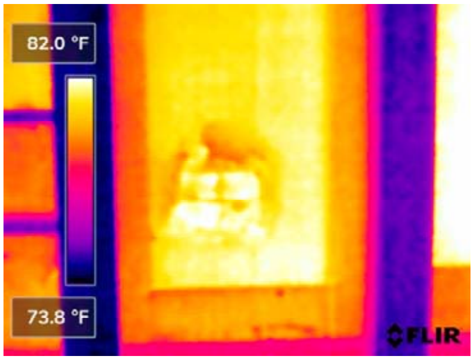

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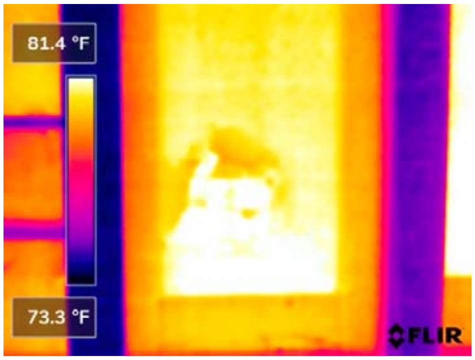

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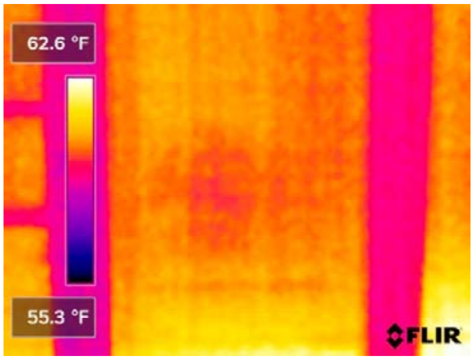

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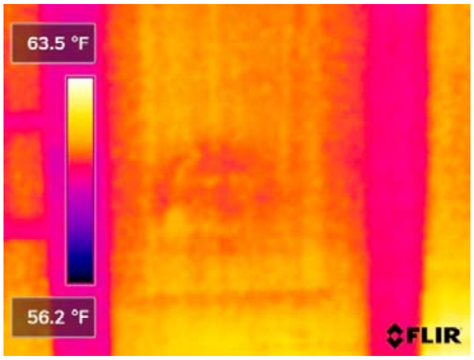

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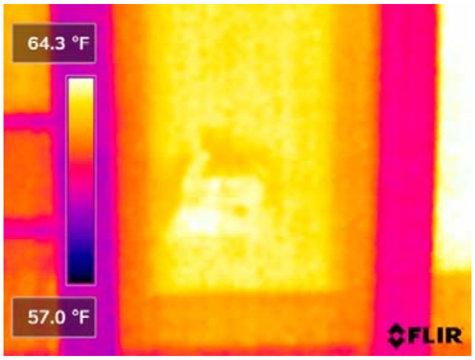

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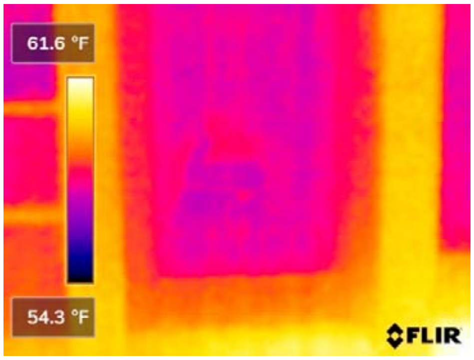

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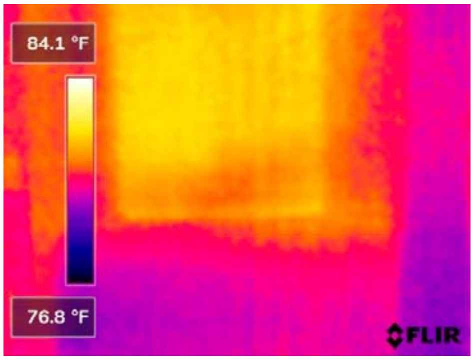

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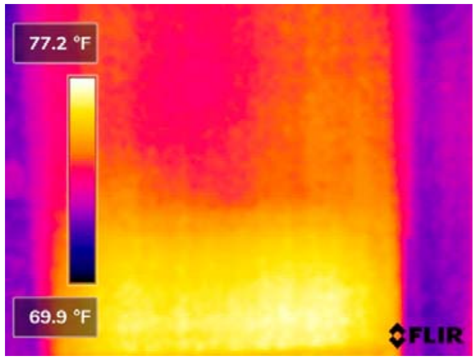

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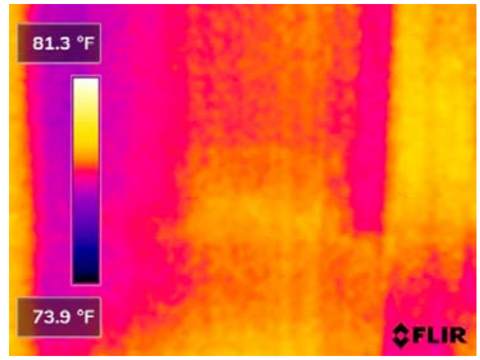

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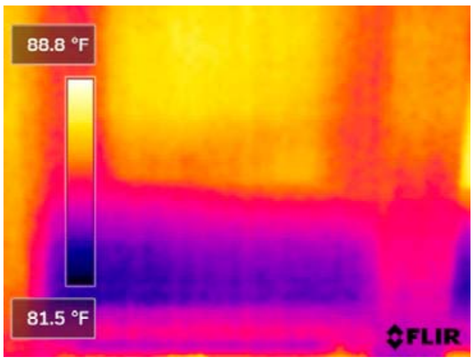

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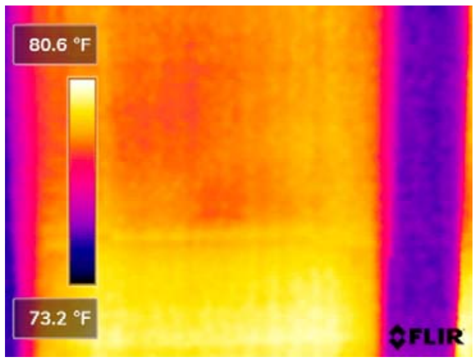

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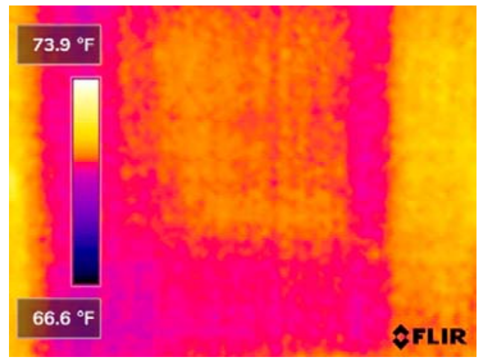

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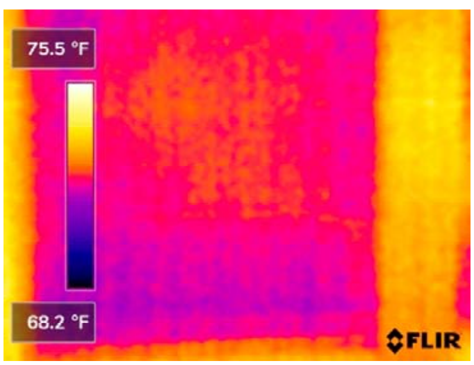

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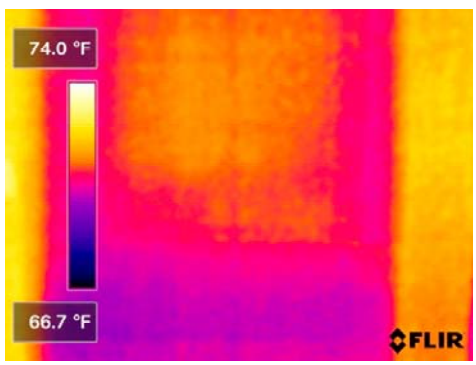

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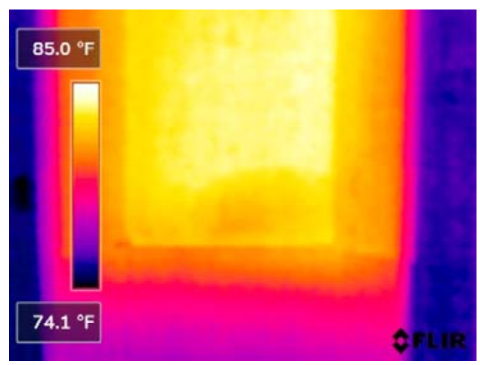

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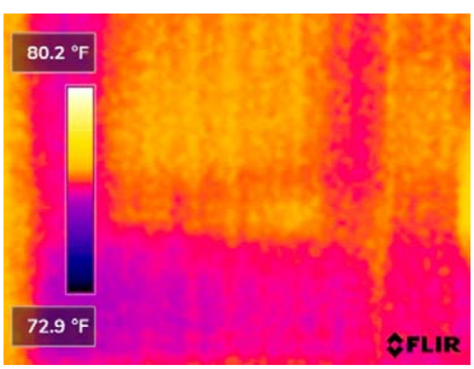

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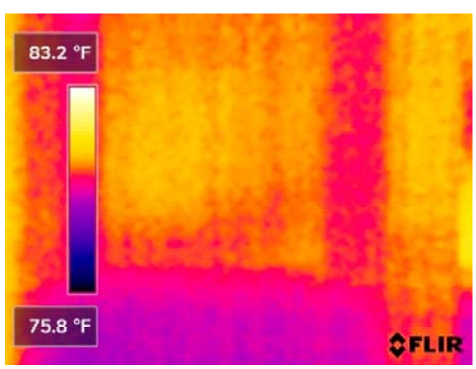

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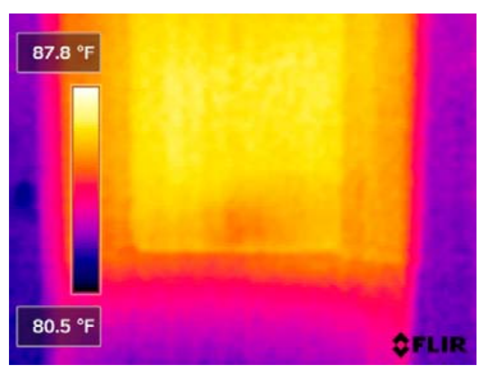

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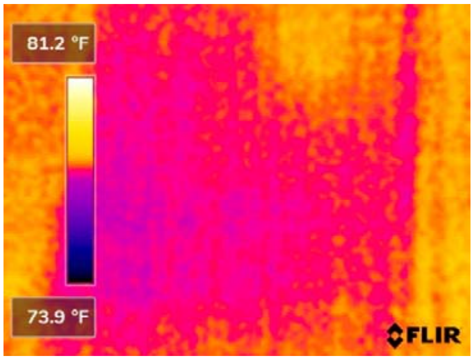

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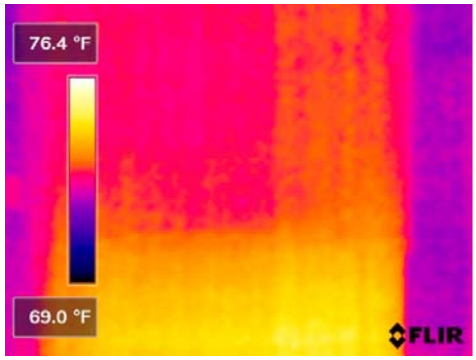

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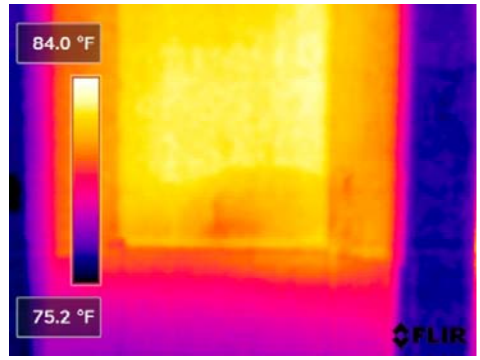

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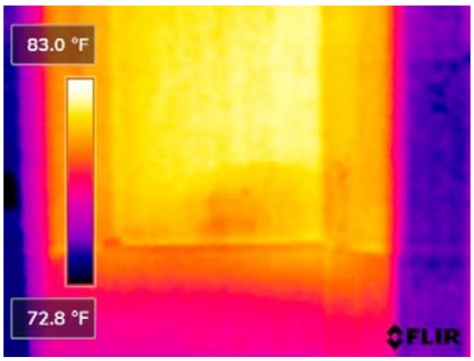

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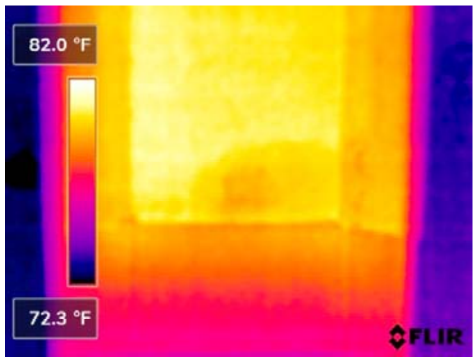

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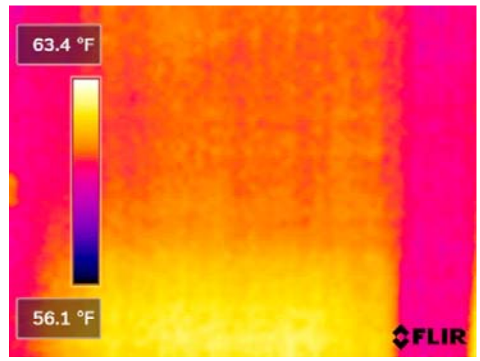

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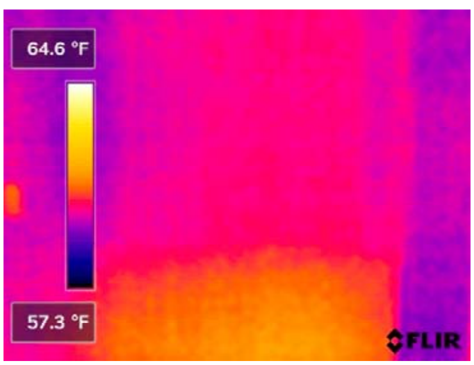

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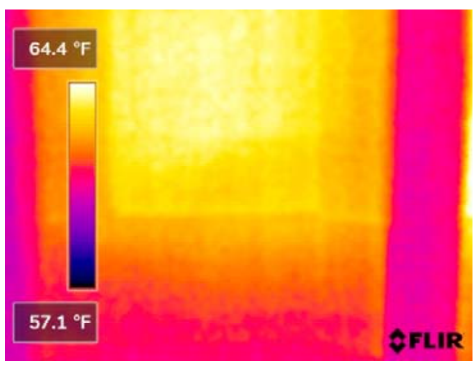

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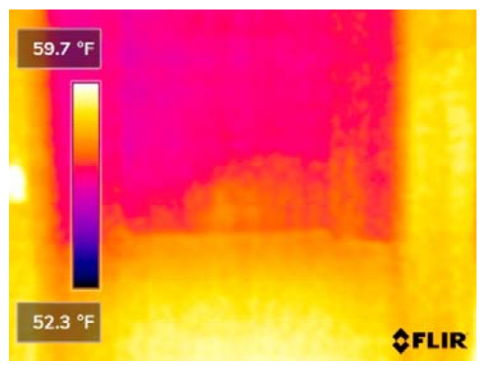

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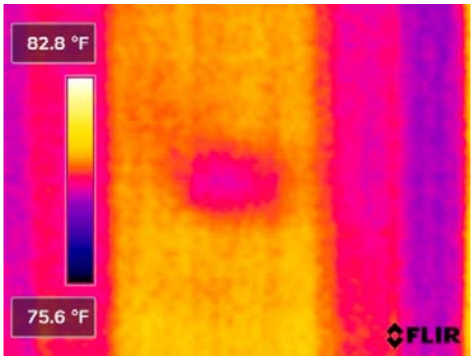

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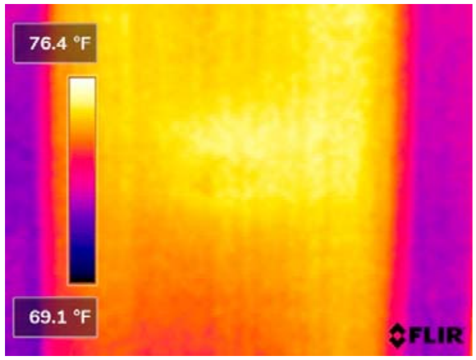

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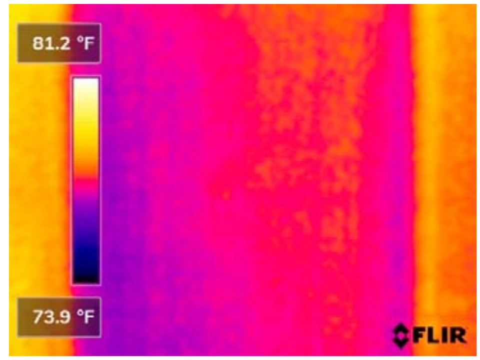

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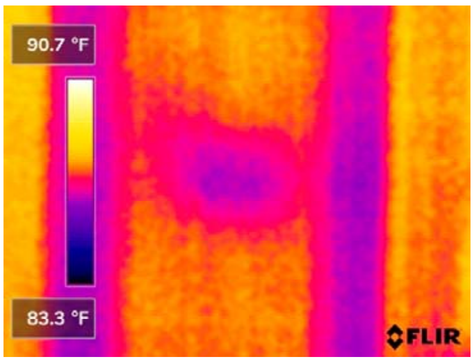

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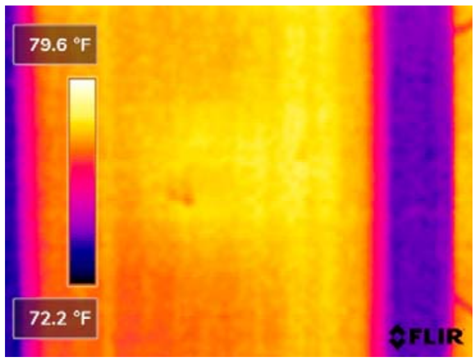

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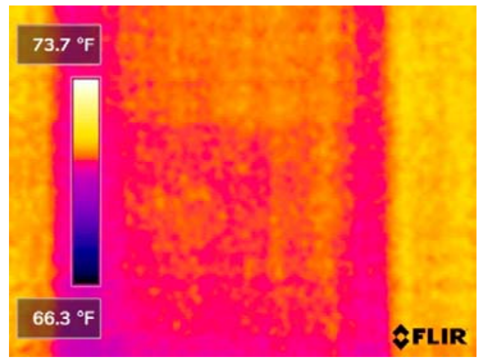

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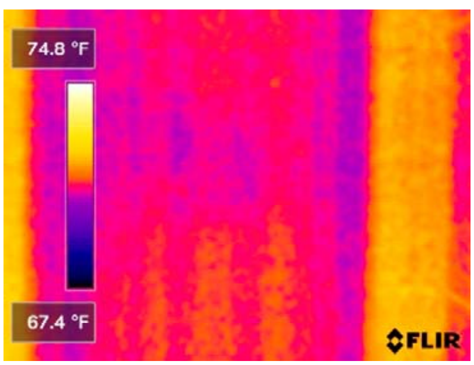

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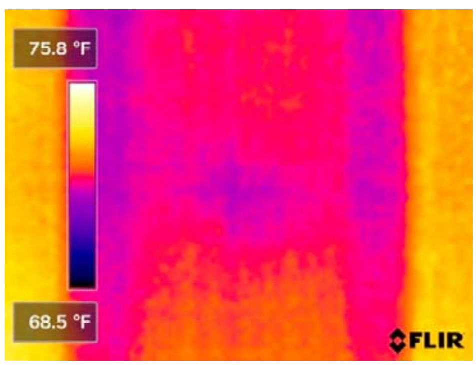

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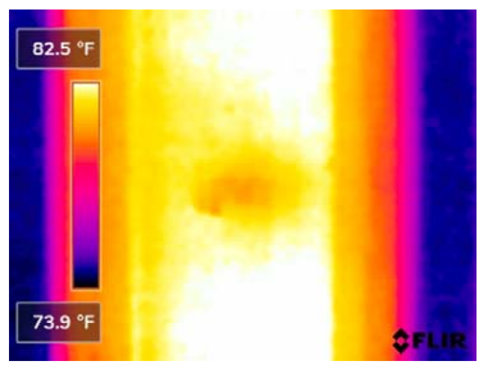

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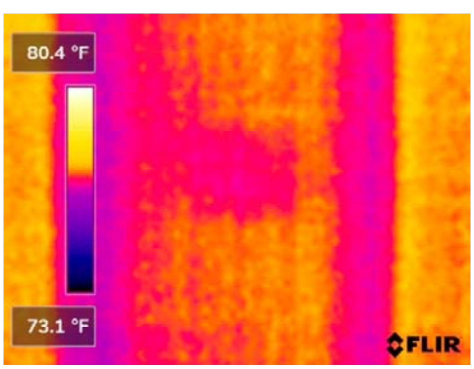

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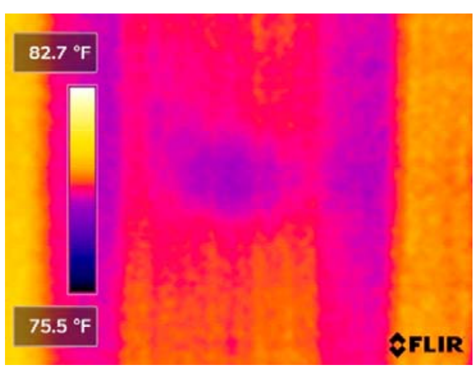

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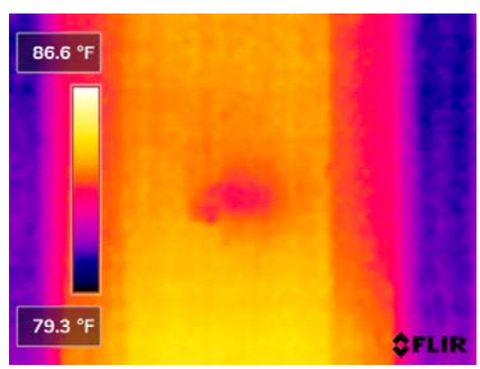

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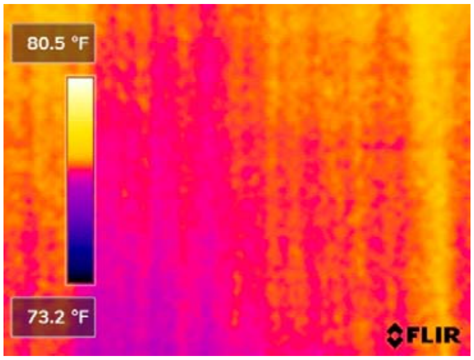

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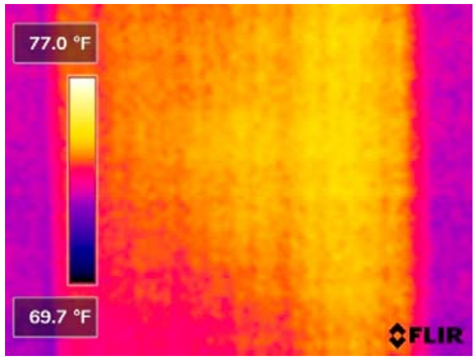

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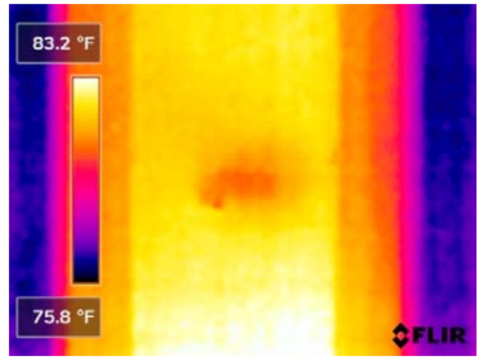

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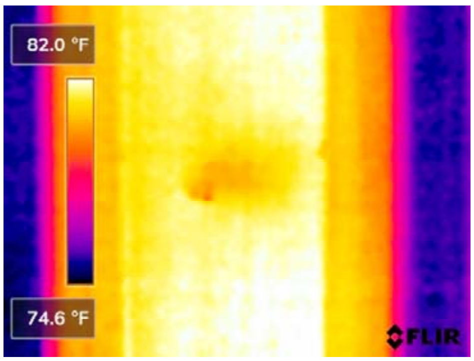

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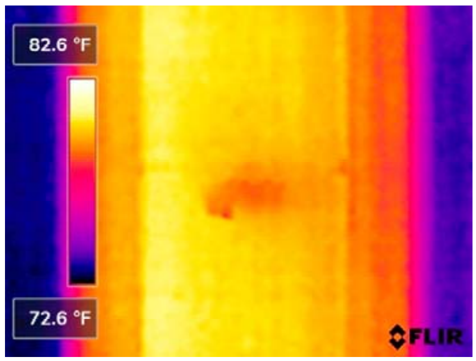

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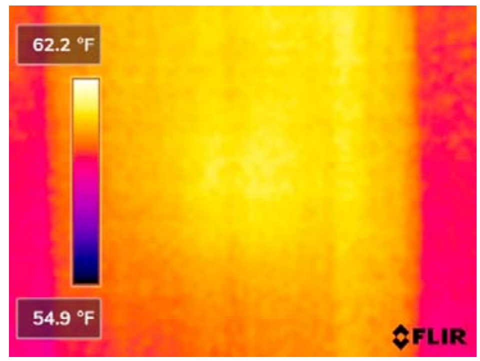

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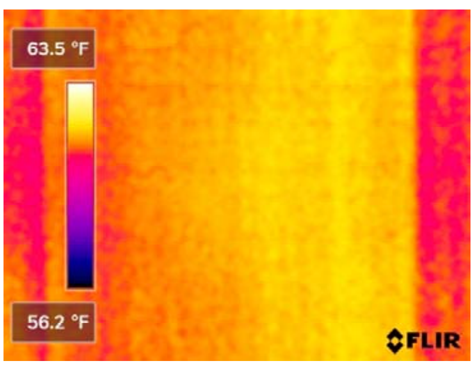

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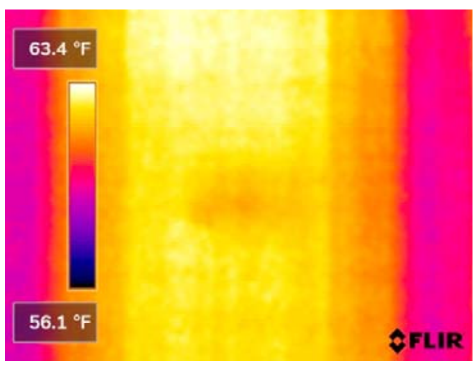

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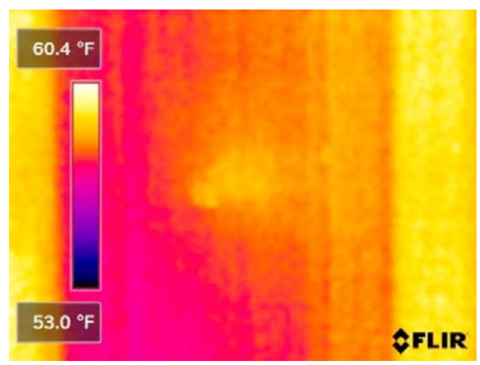

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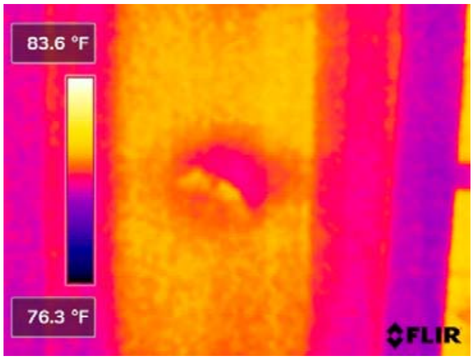

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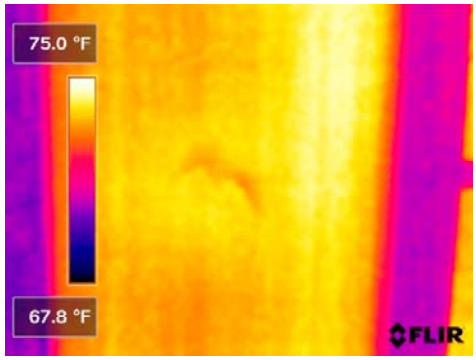

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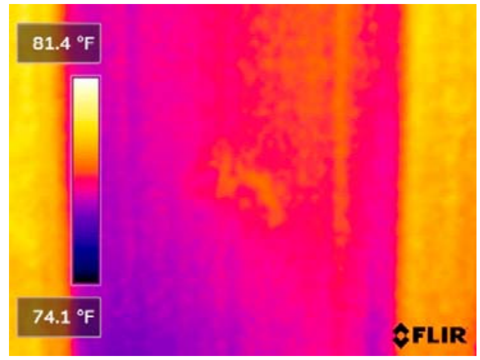

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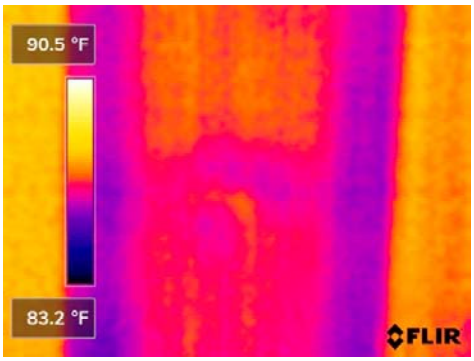

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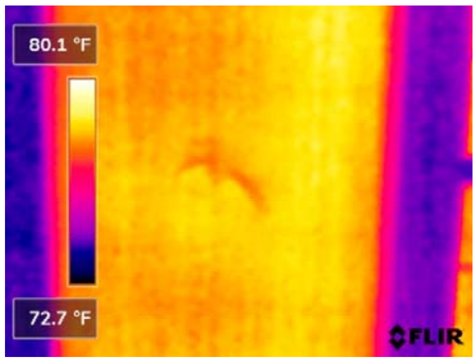

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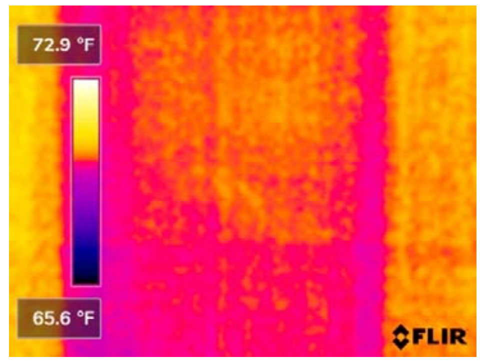

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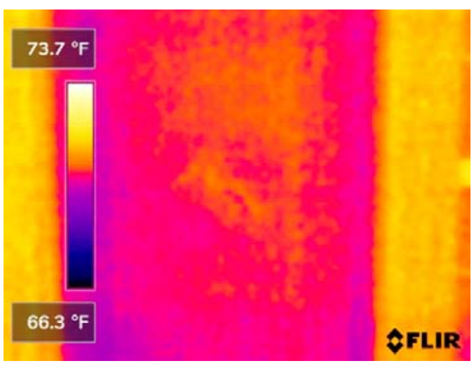

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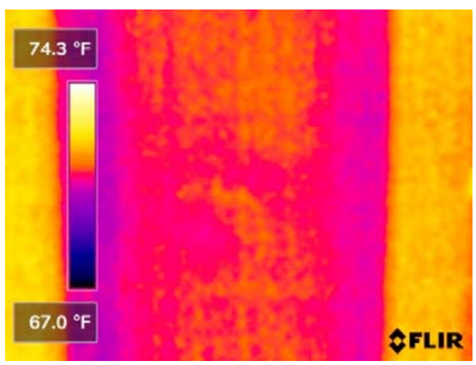

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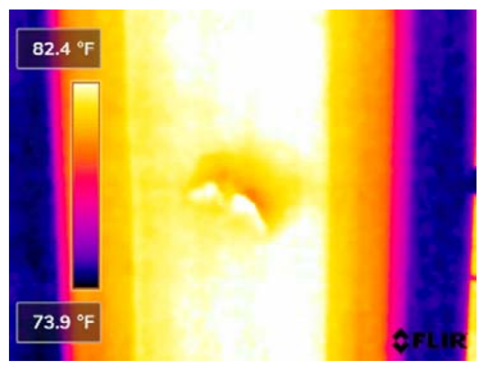

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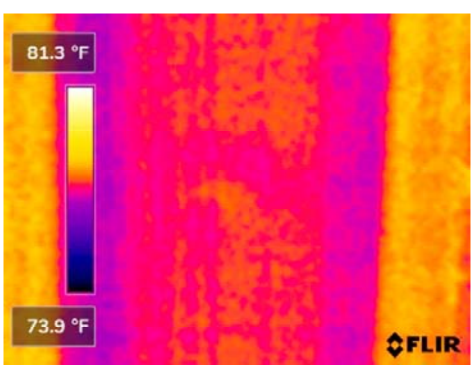

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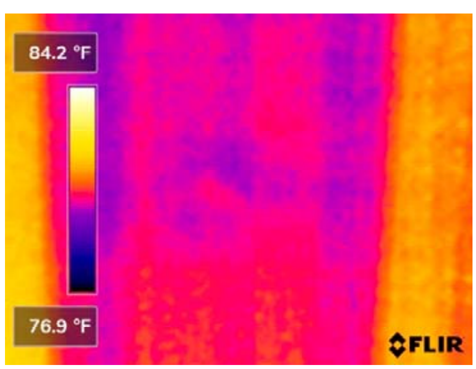

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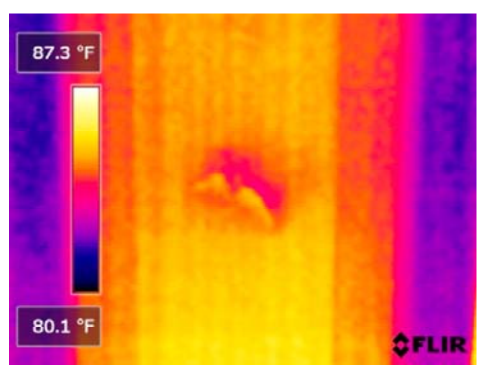

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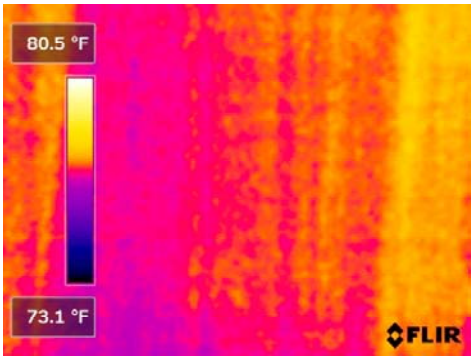

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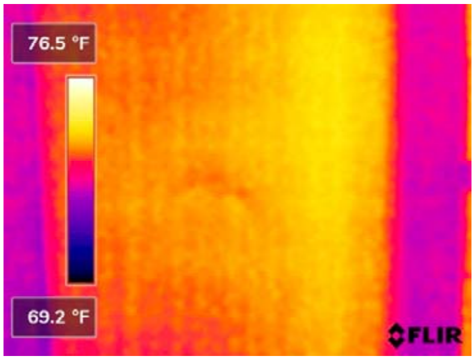

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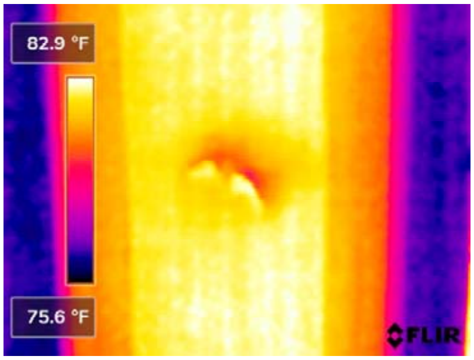

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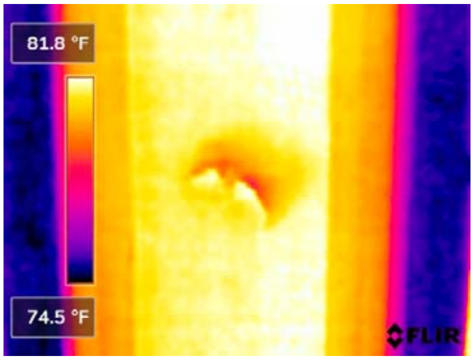

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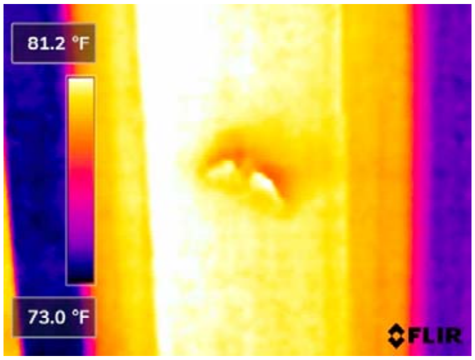

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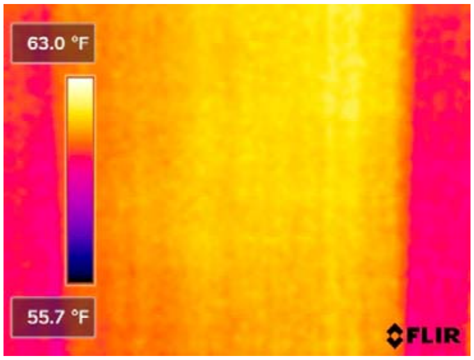

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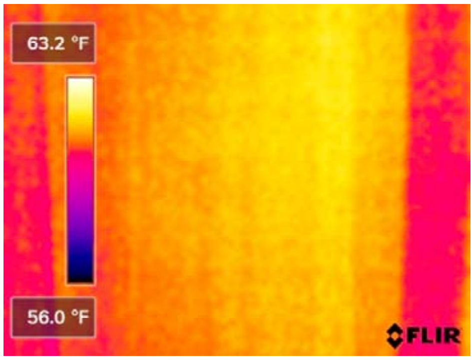

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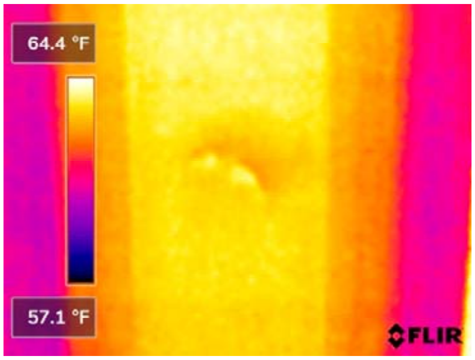

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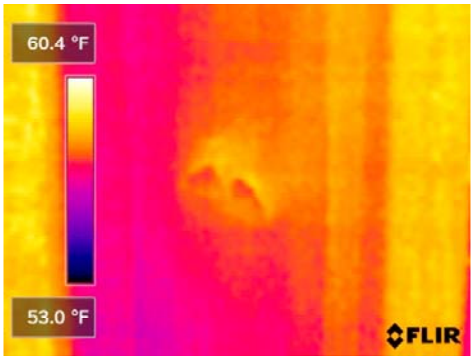

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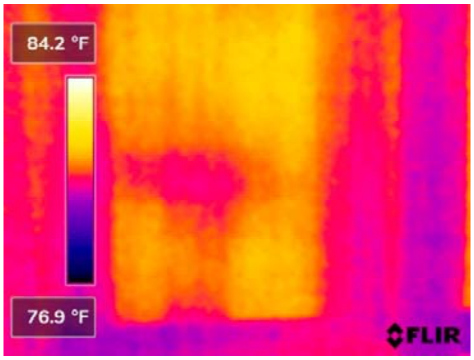

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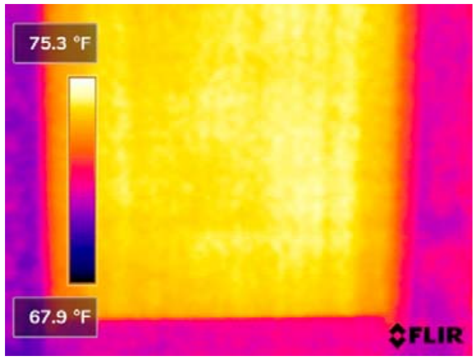

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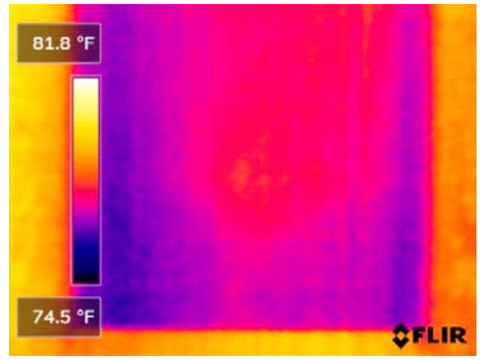

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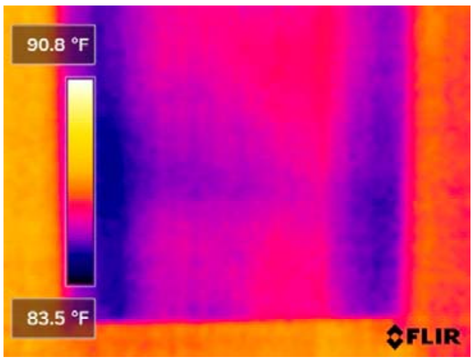

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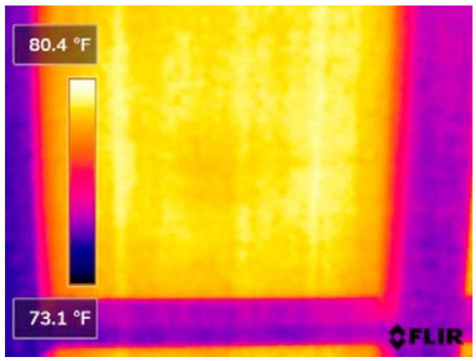

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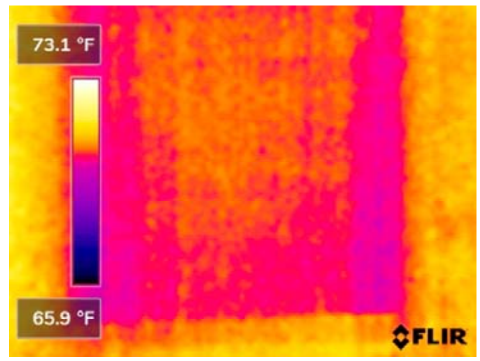

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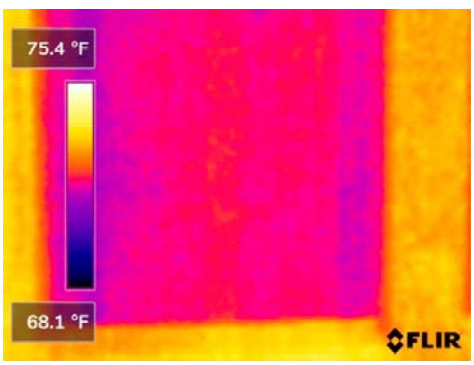

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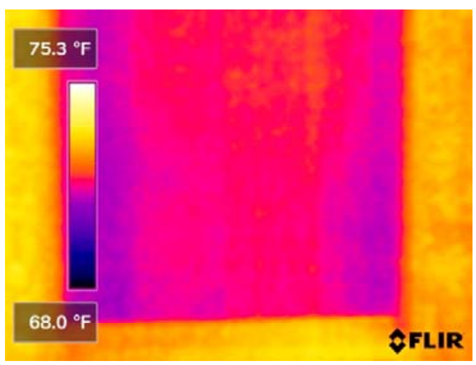

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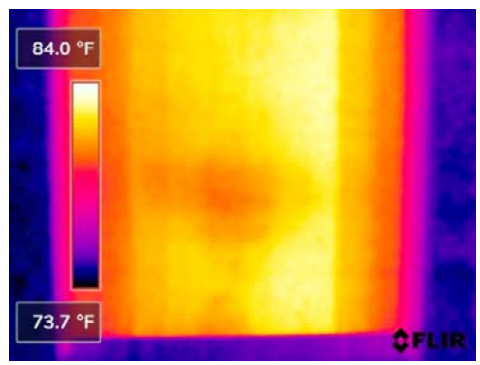

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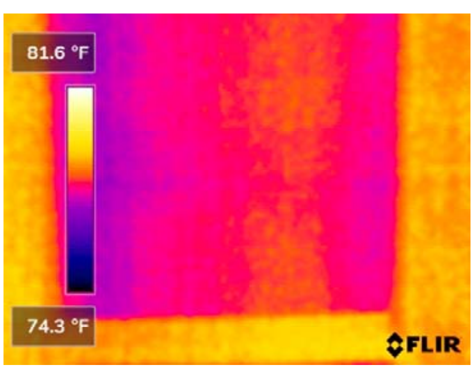

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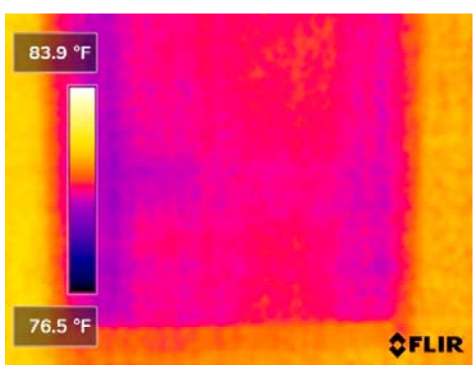

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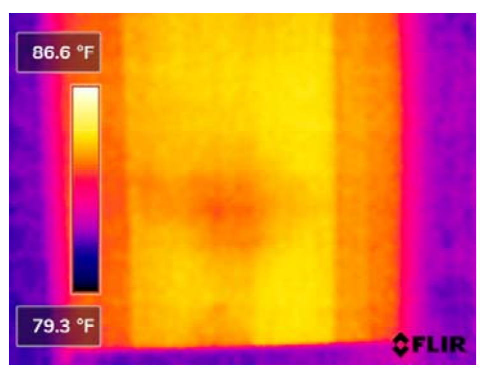

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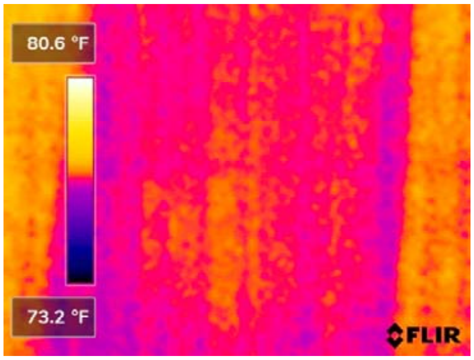

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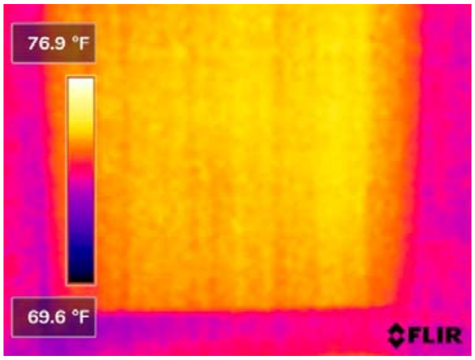

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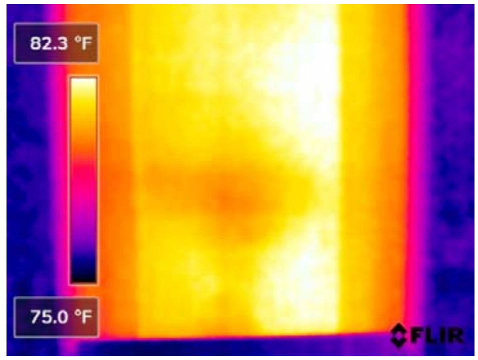

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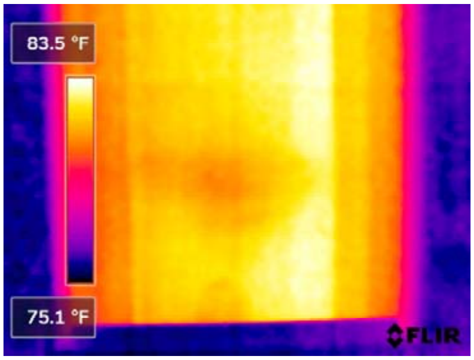

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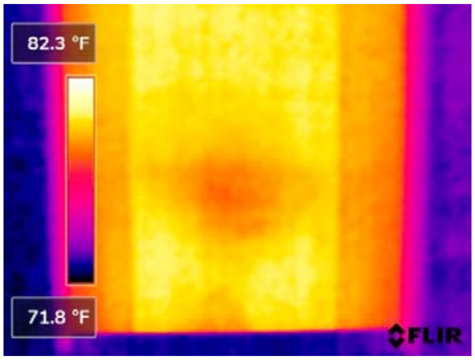

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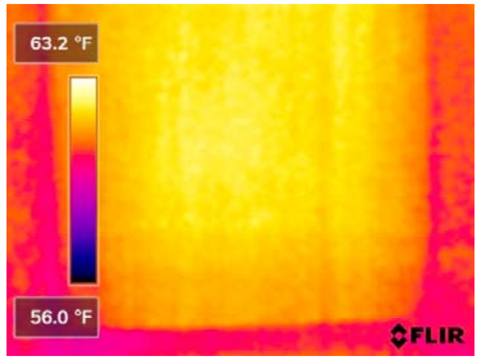

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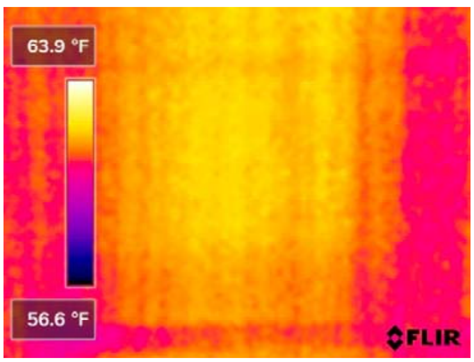

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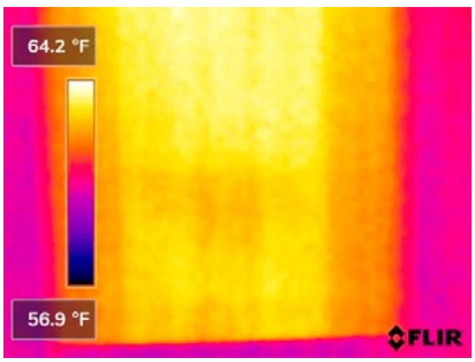

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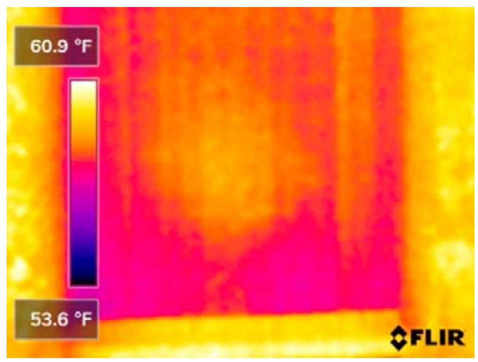

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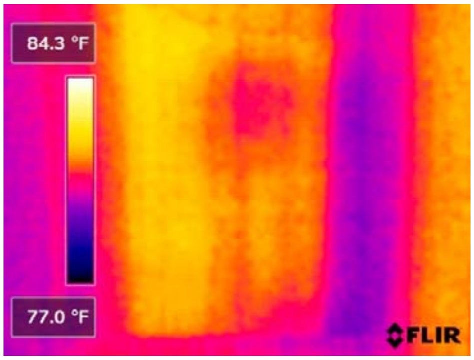

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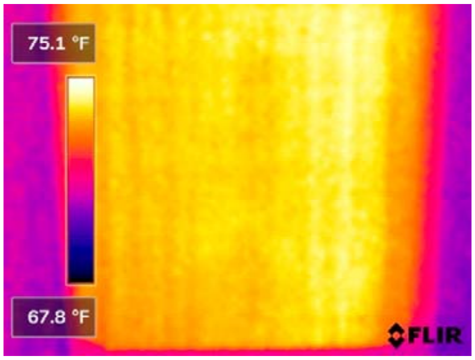

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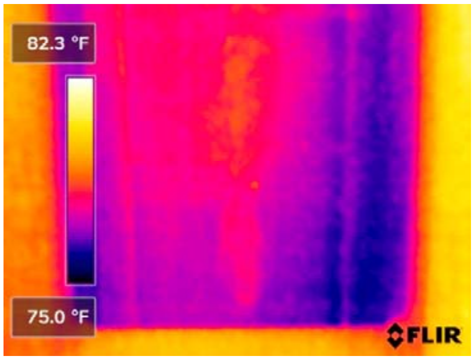

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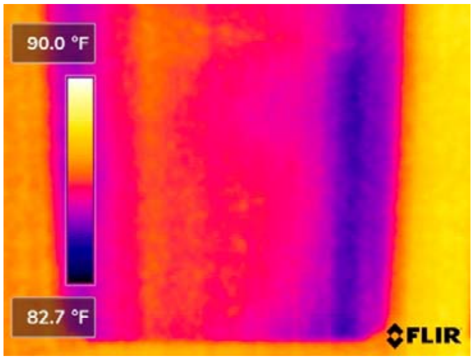

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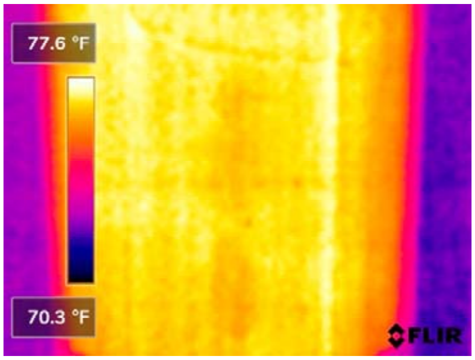

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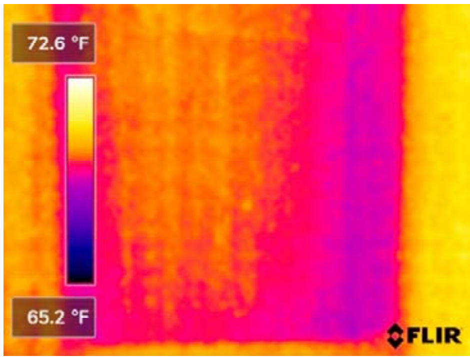

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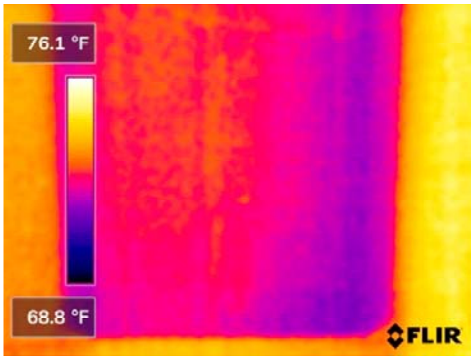

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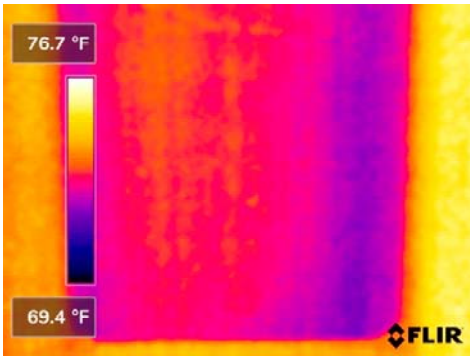

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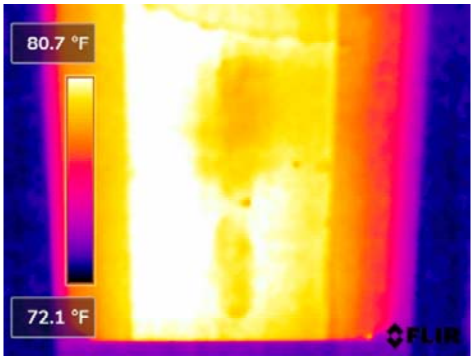

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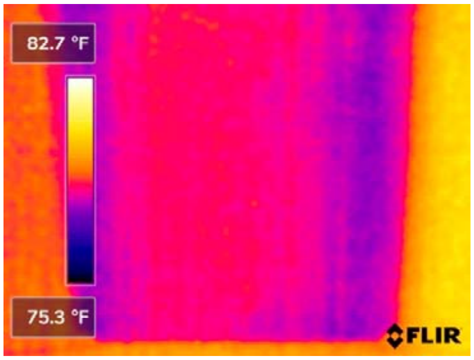

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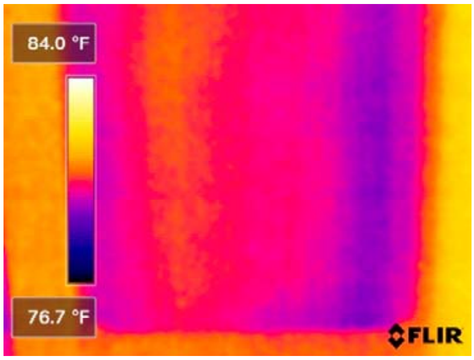

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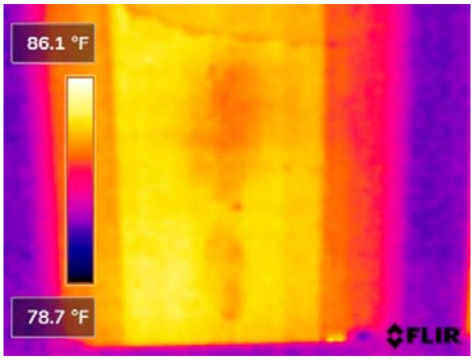

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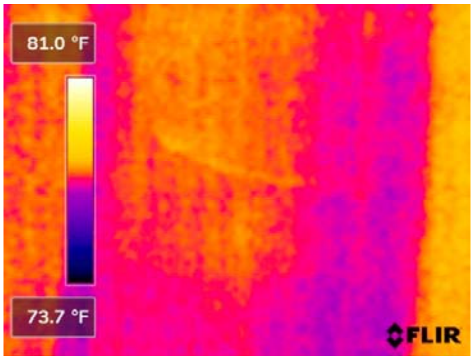

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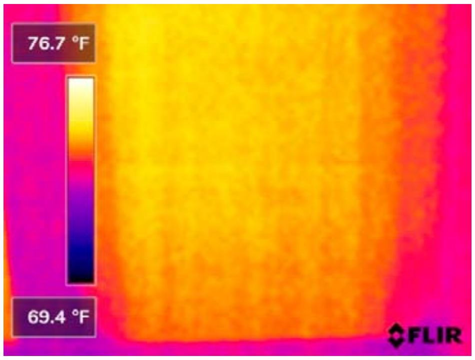

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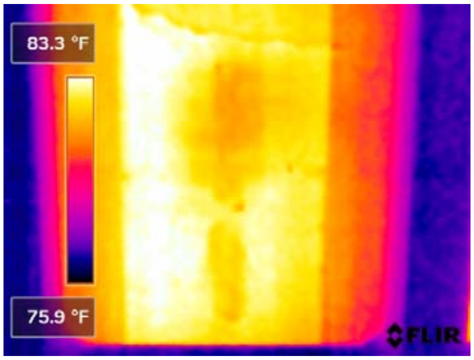
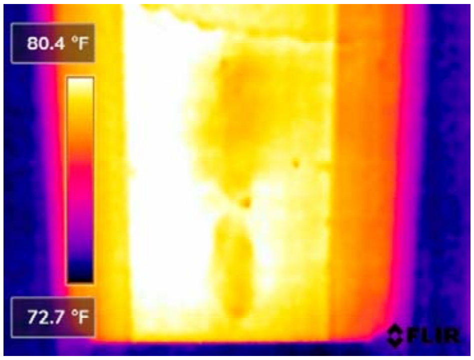


E8_Loc07_15_FLIR1780



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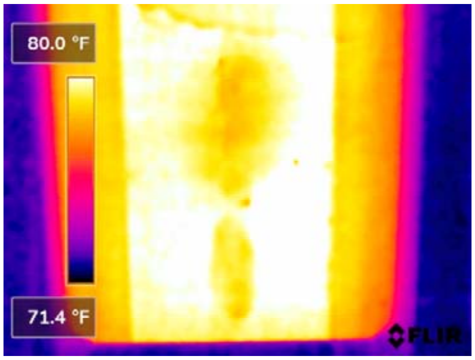

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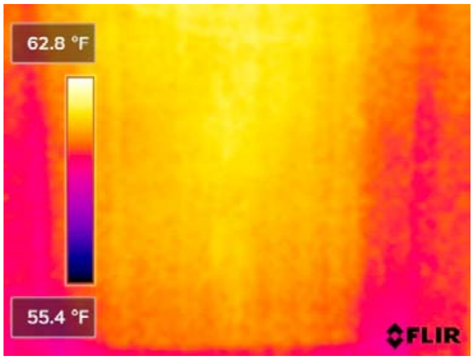

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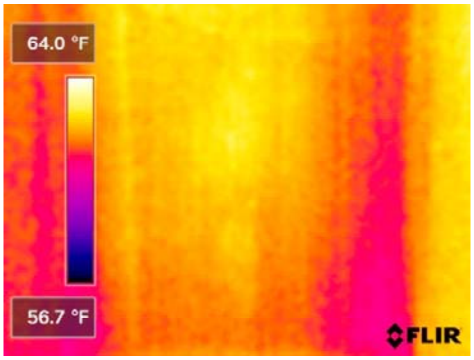

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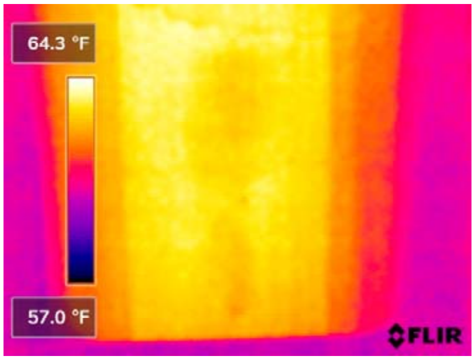
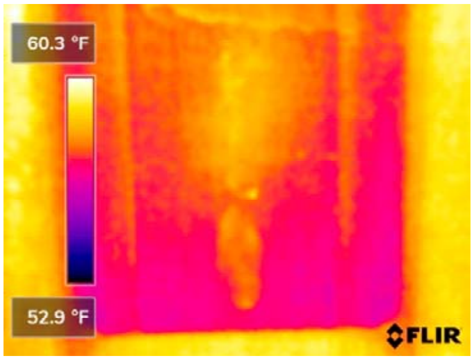


E8_Loc07_20_FLIR2230



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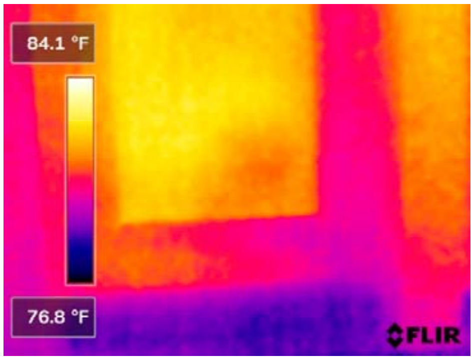

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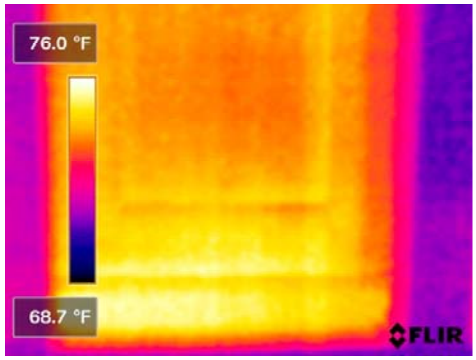

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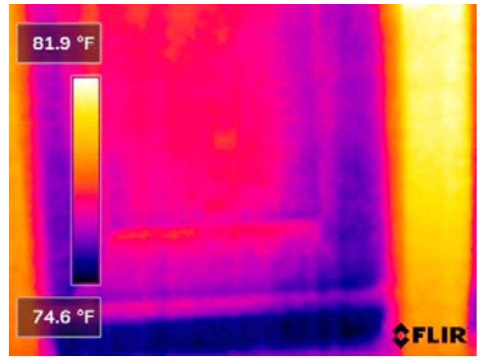

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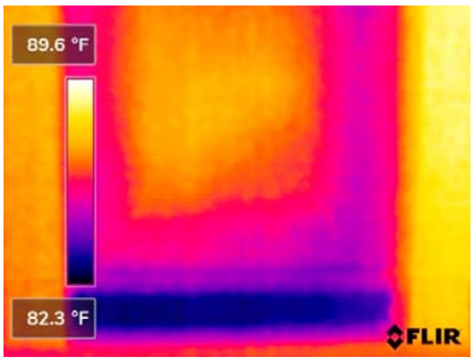

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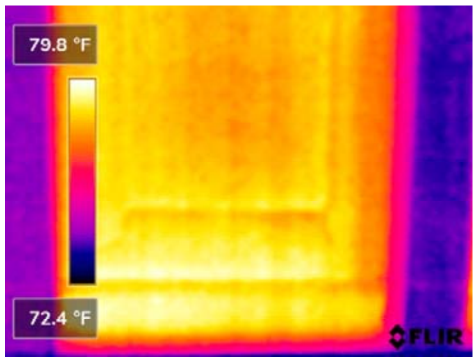

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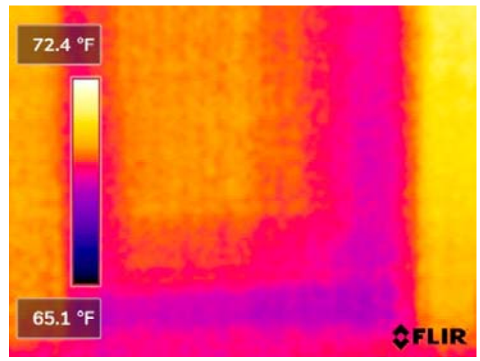

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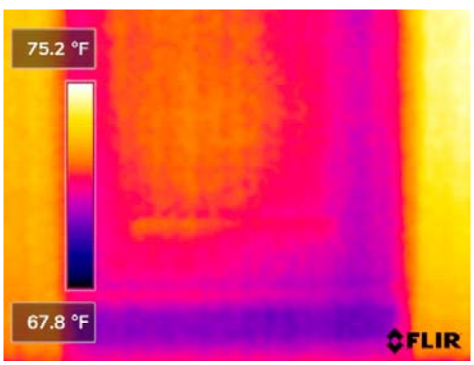

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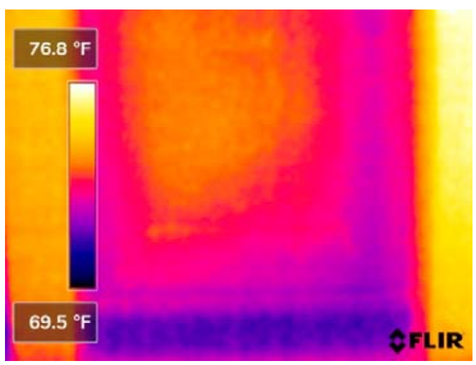

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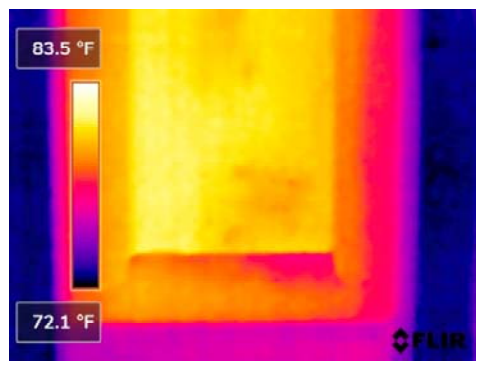

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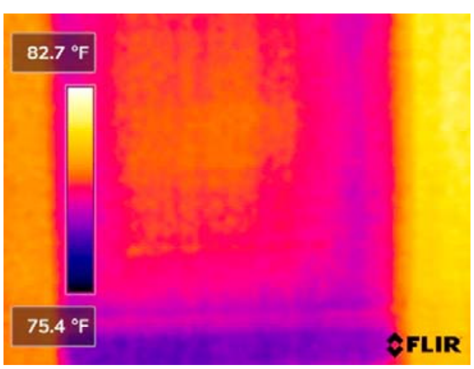

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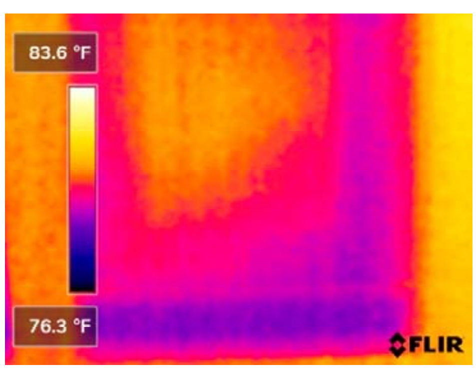

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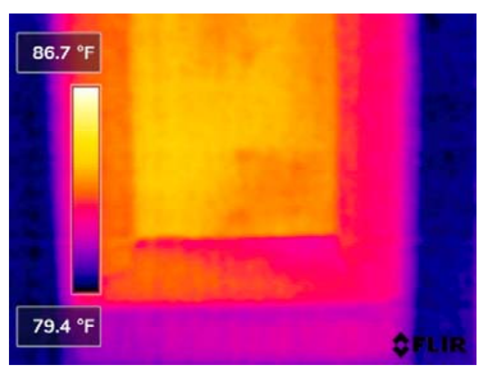

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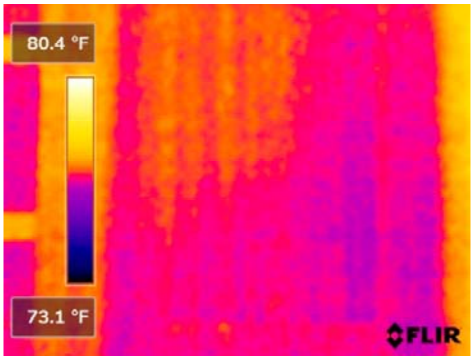

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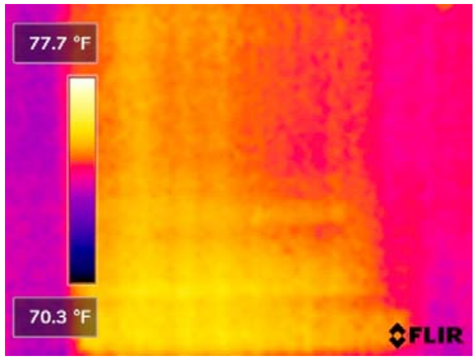

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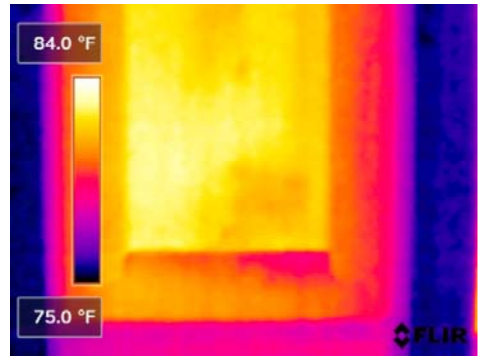

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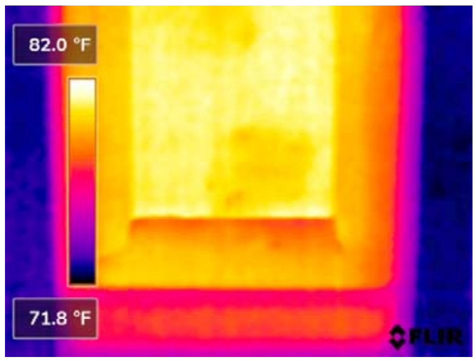
E8_Loc08_16_Skipped



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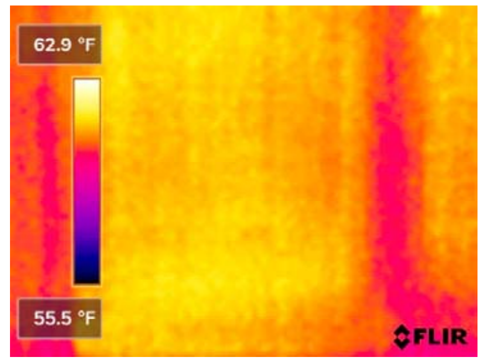

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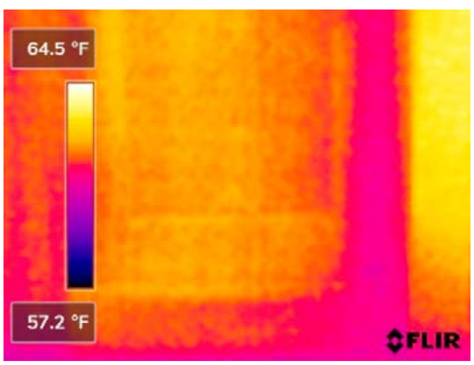

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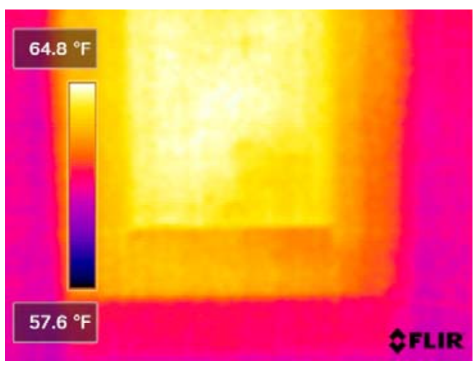

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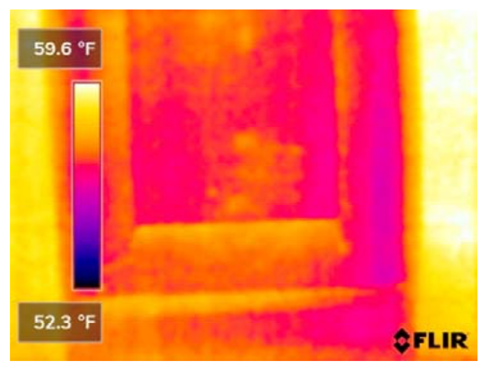

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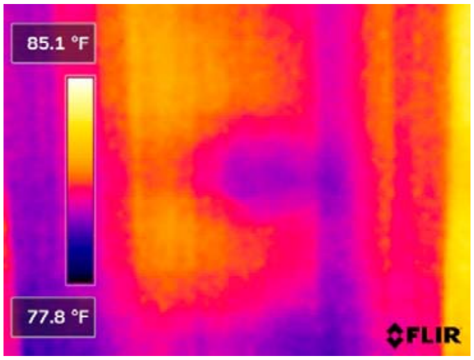

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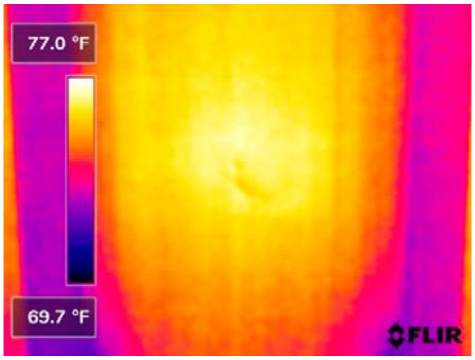

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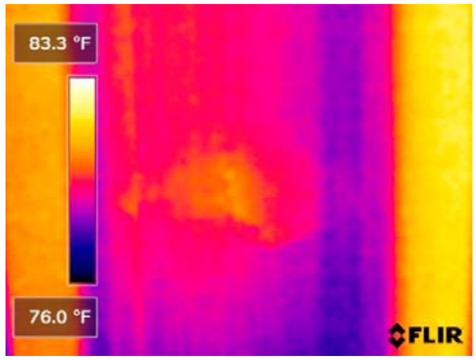

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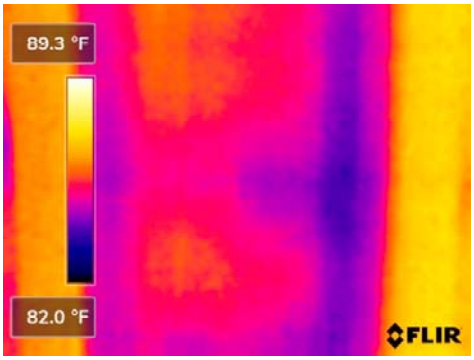

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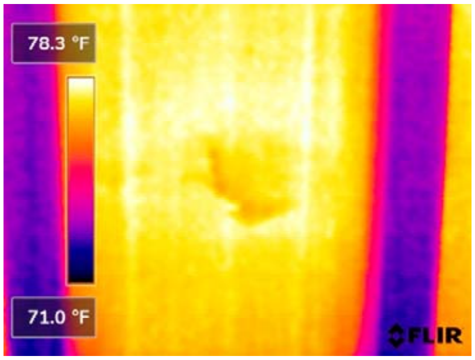

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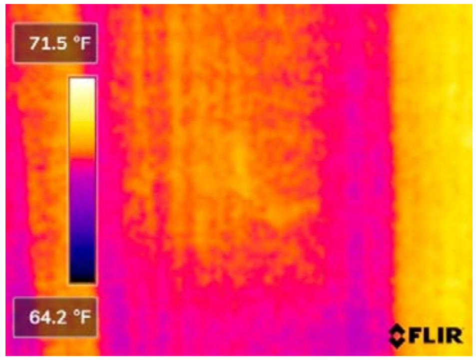

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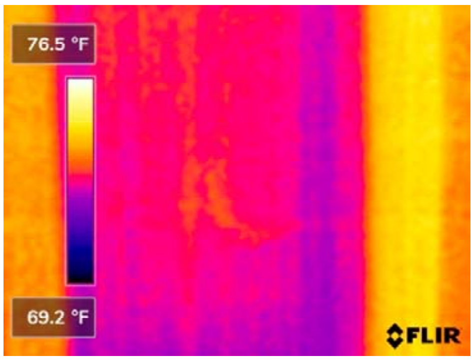

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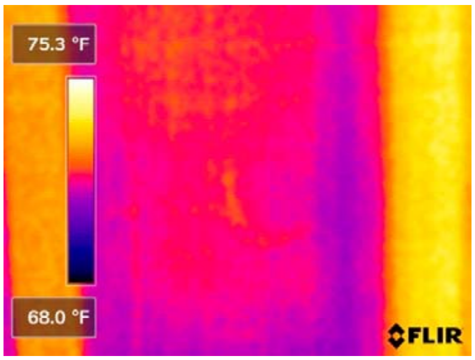

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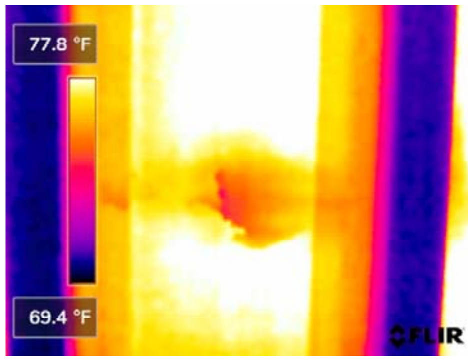

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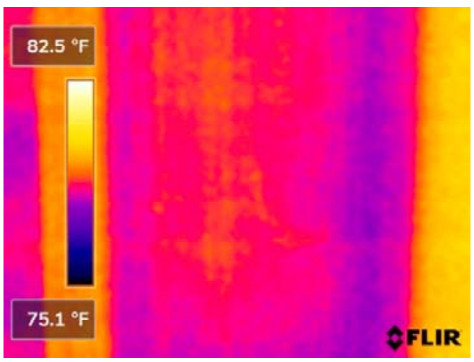

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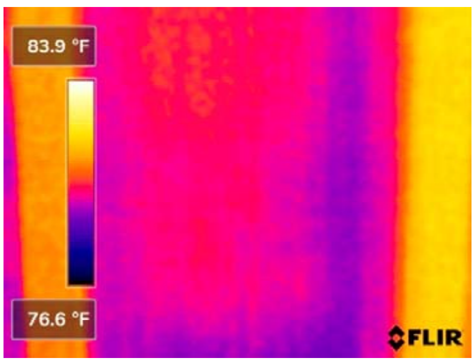

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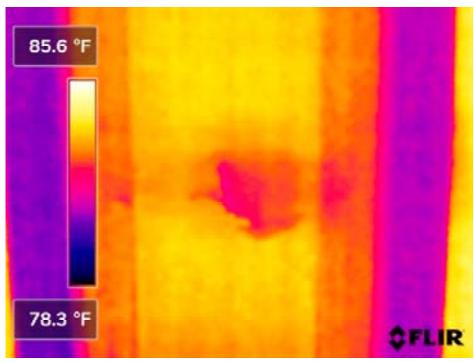

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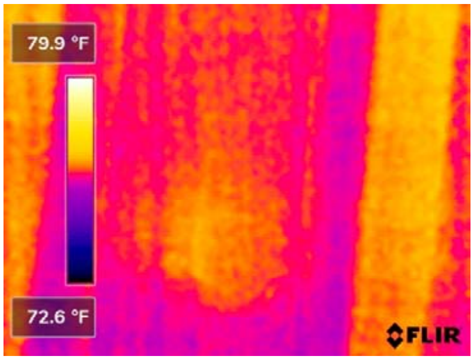

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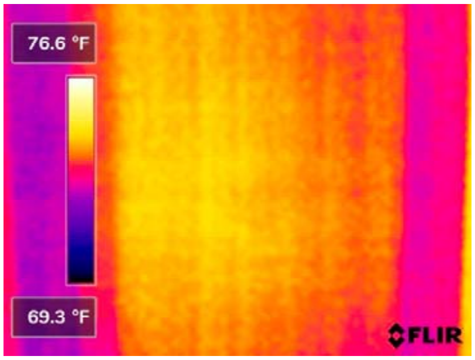

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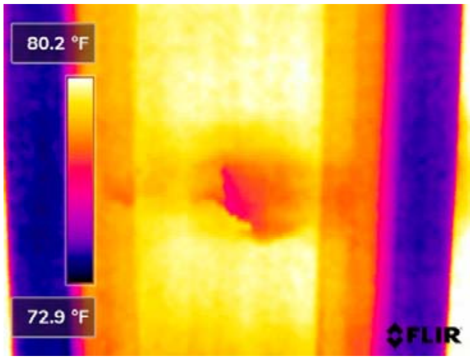

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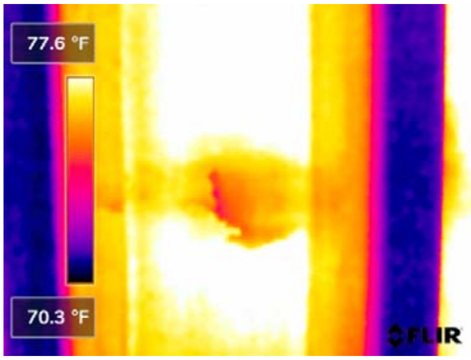

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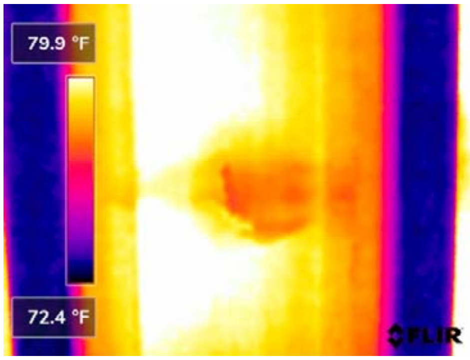

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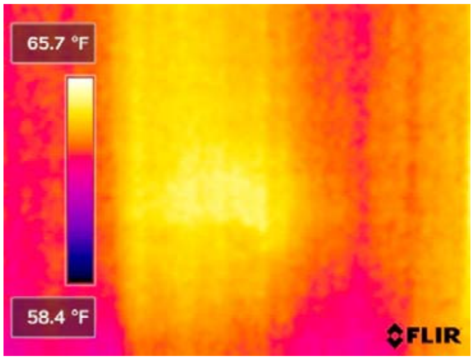

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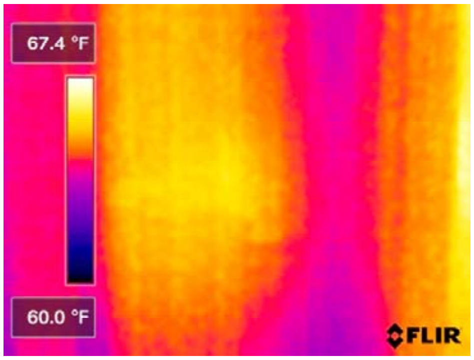

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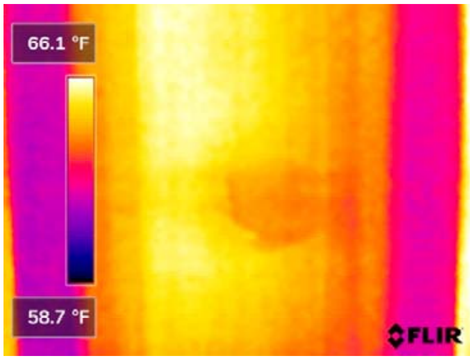

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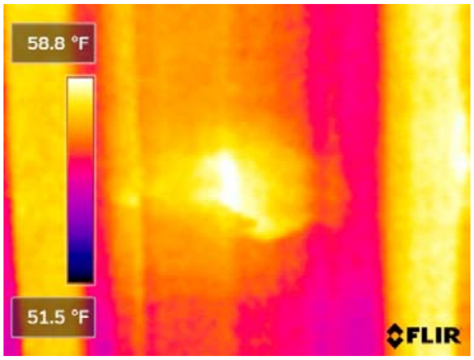

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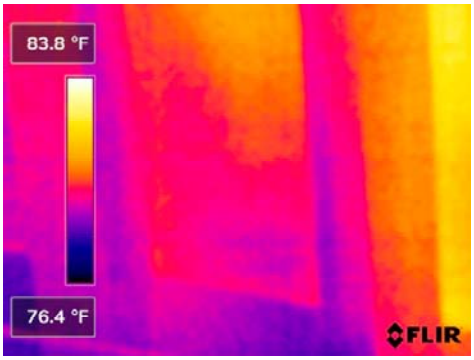

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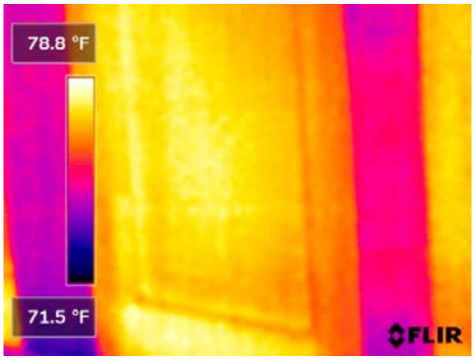

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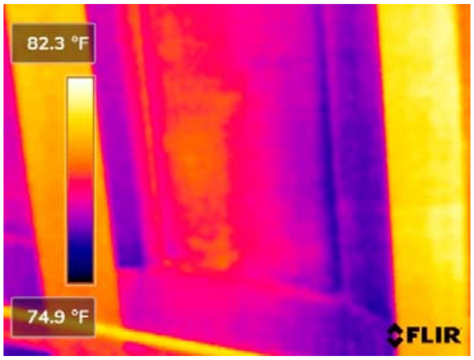

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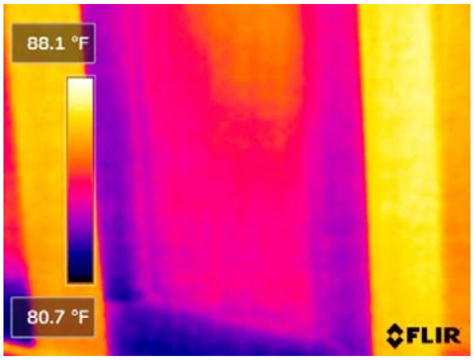

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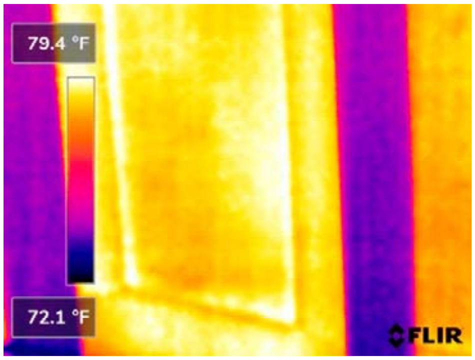

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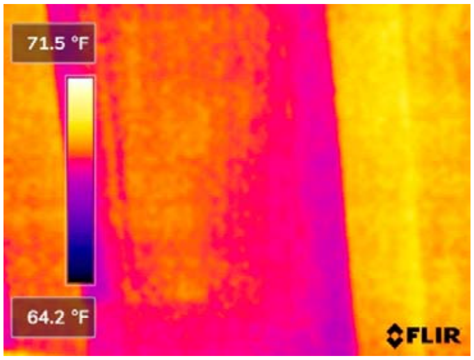

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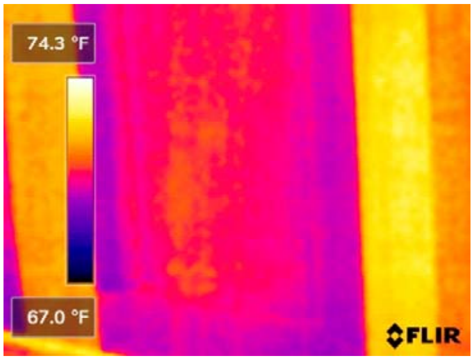

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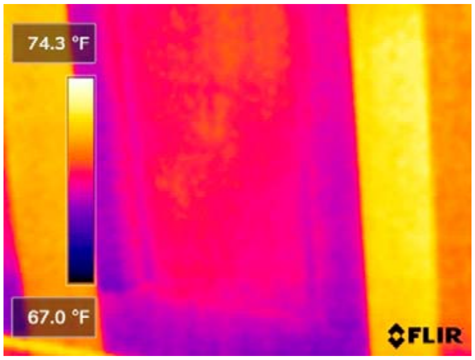

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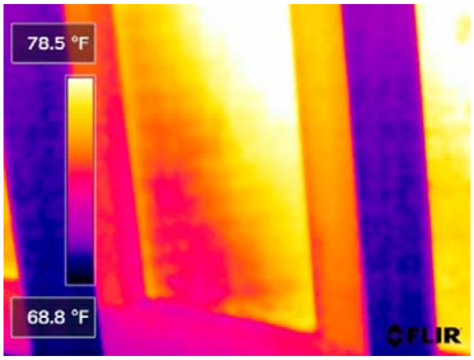

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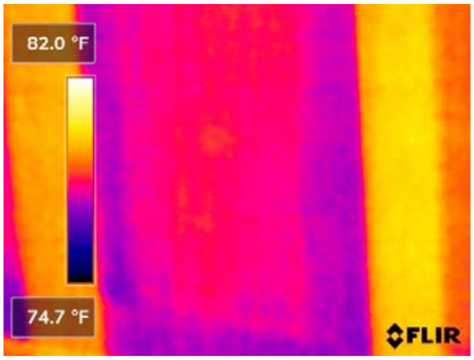

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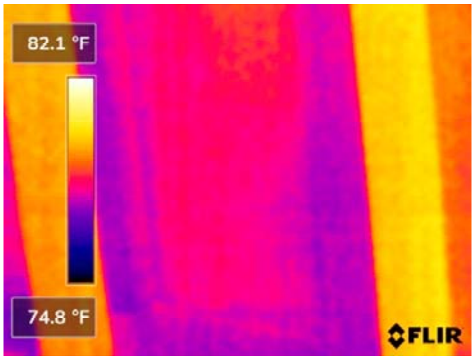

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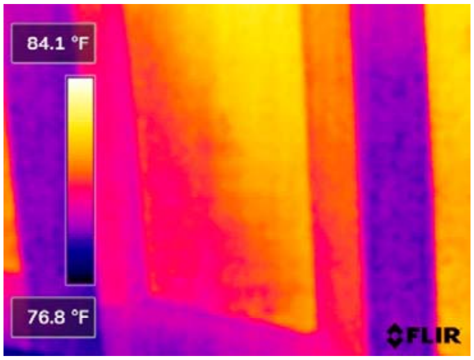

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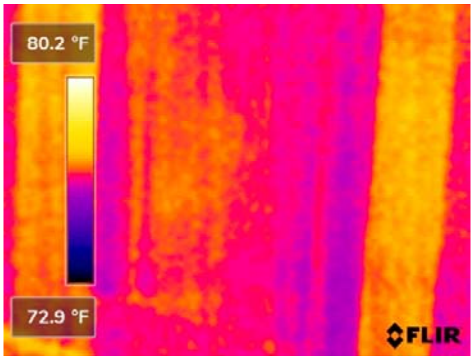

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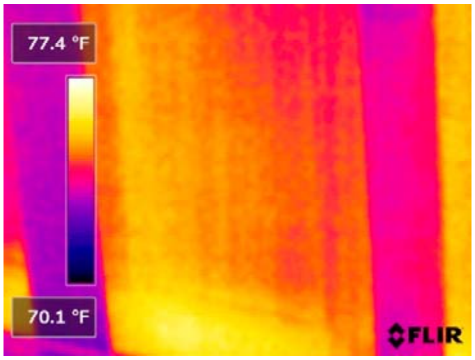

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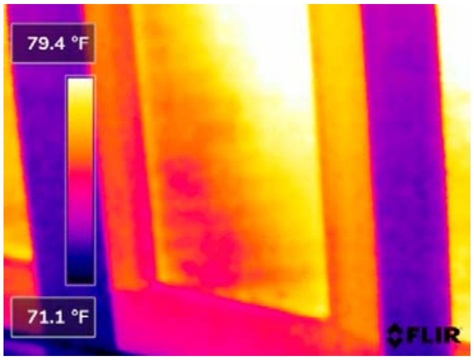

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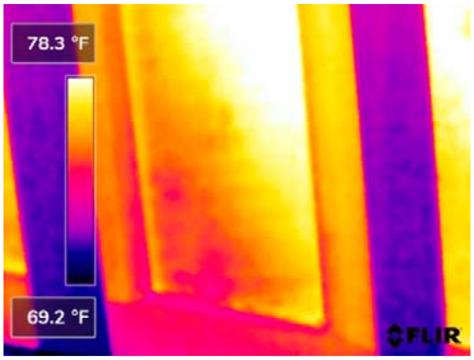

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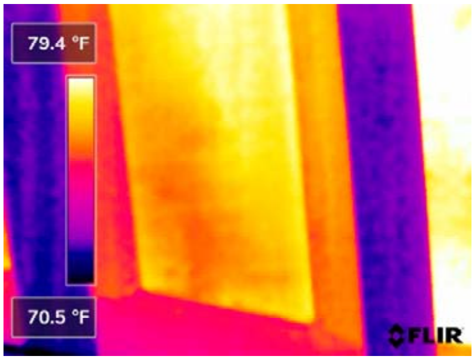

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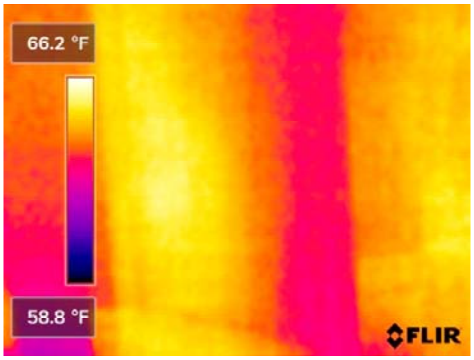

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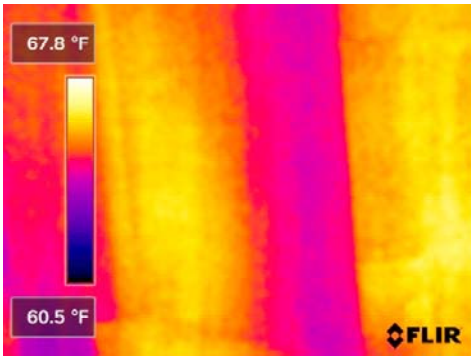

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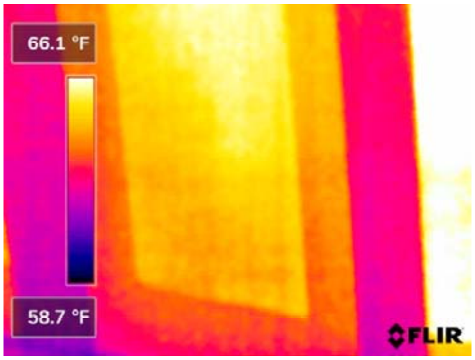

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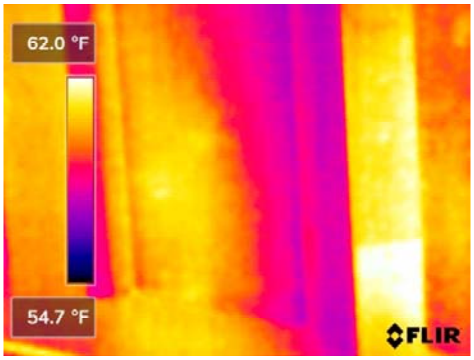
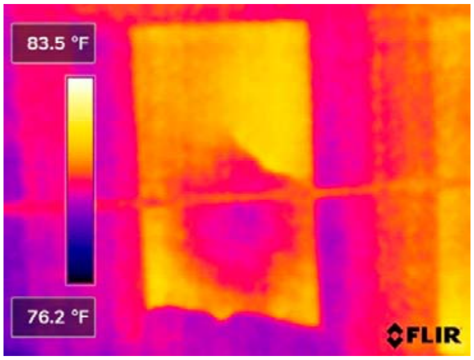


E8_Loc10_21_FLIR2374



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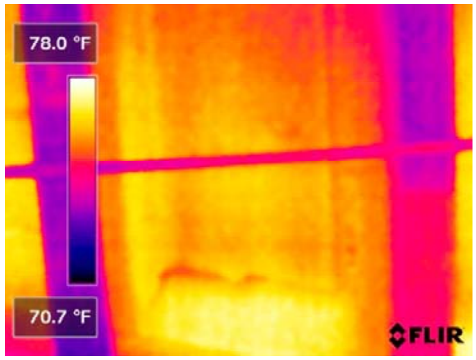

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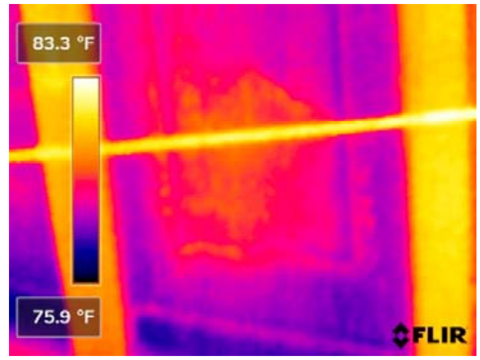

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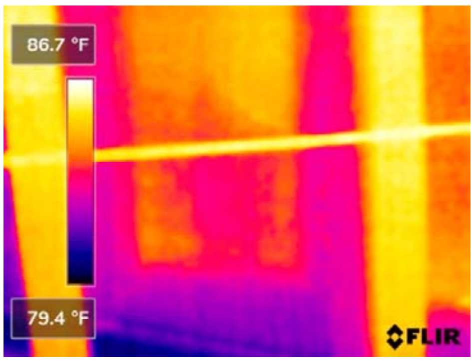

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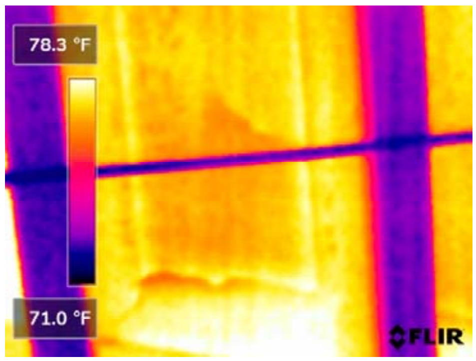

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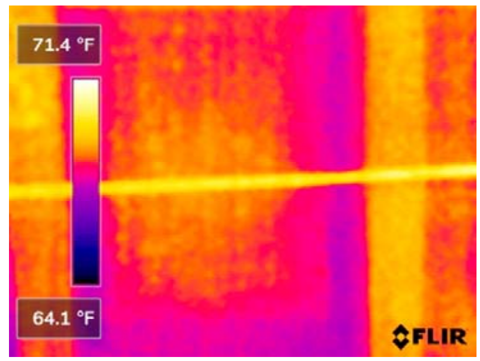

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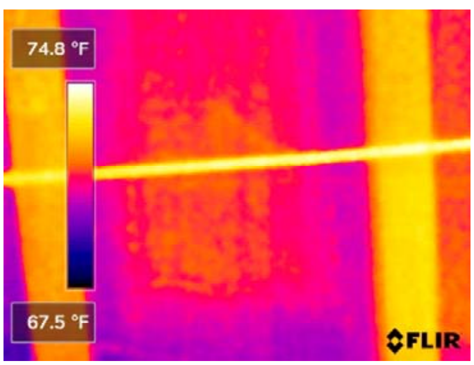

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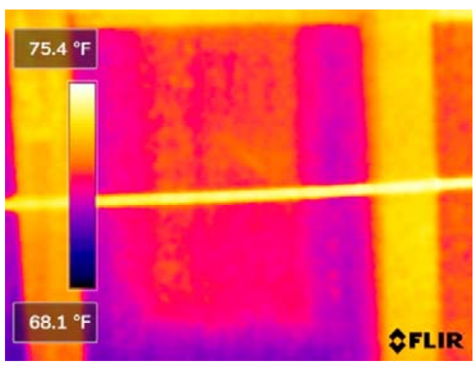

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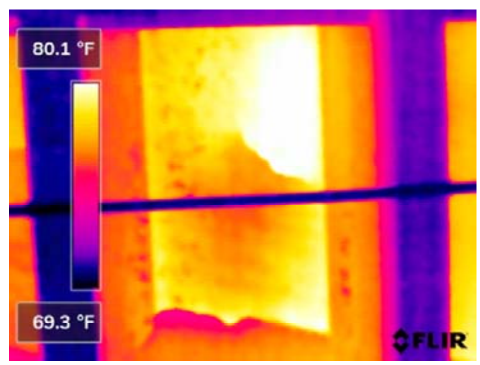

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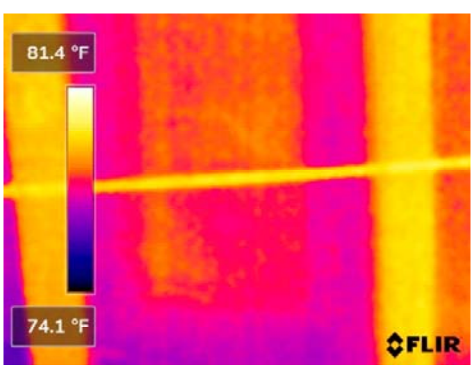

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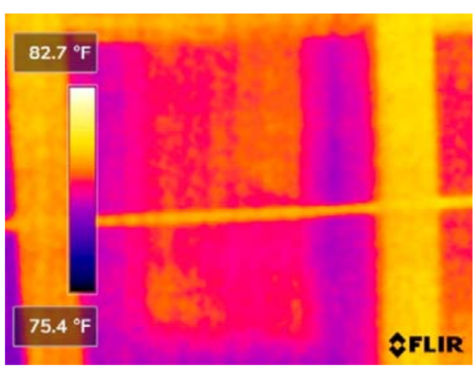

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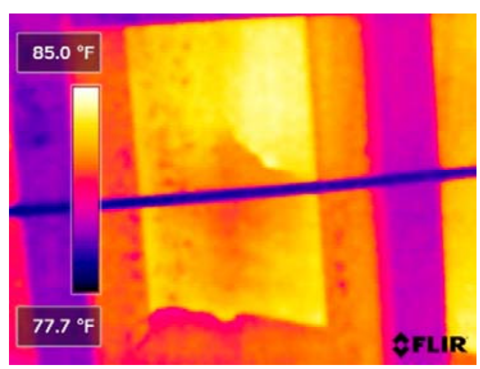

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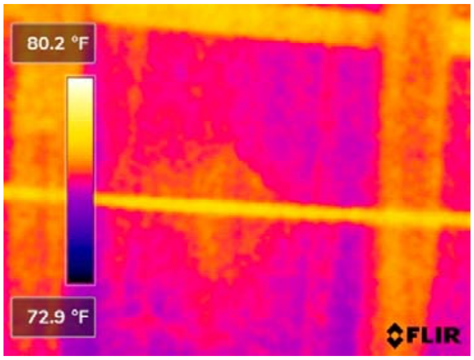
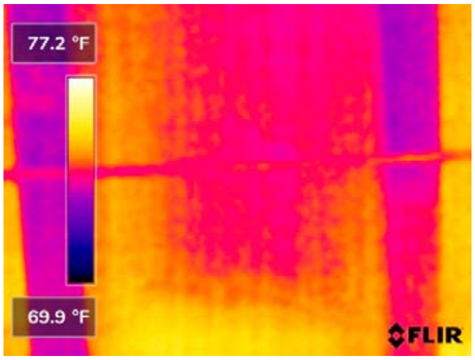


E8_Loc11_13_FLIR1700



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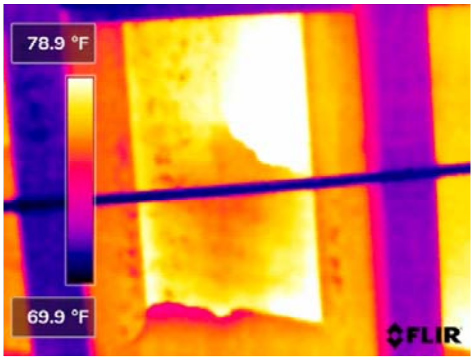

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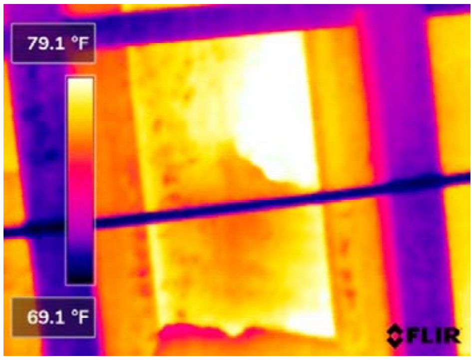

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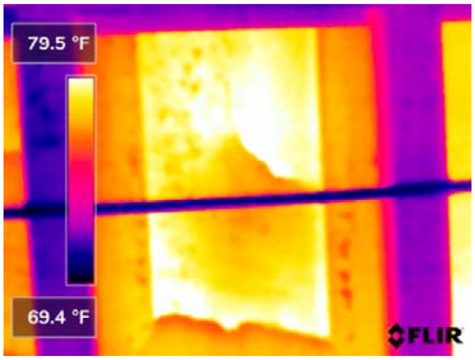
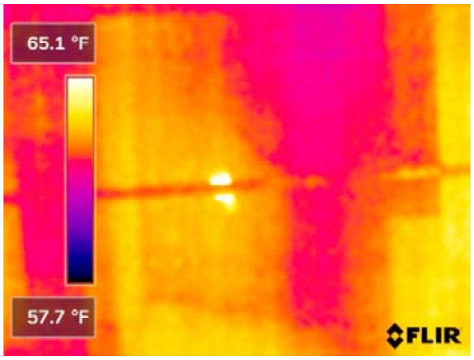


E8_Loc11_17_FLIR2010



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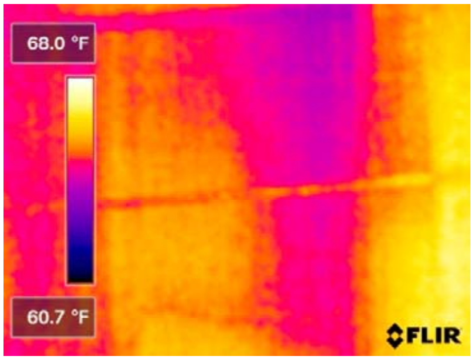
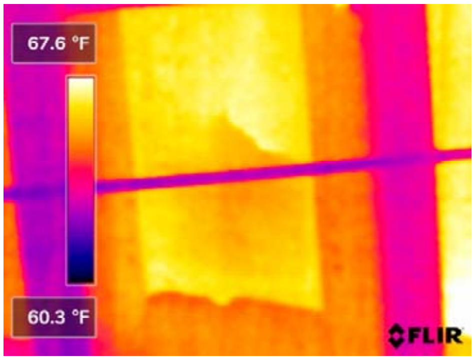


E8_Loc11_19_FLIR2192



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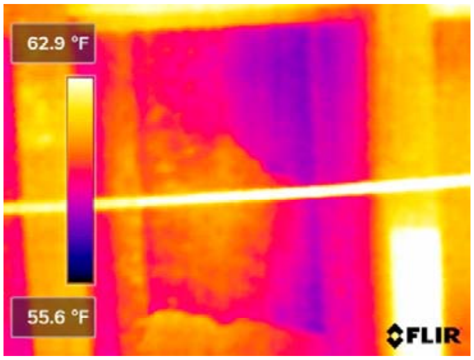

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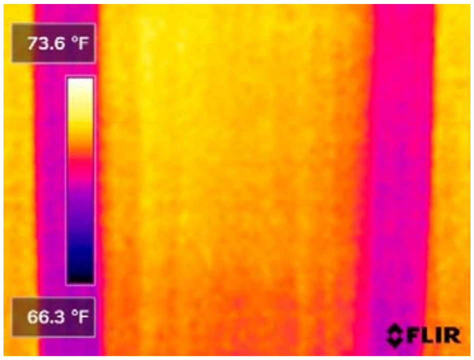

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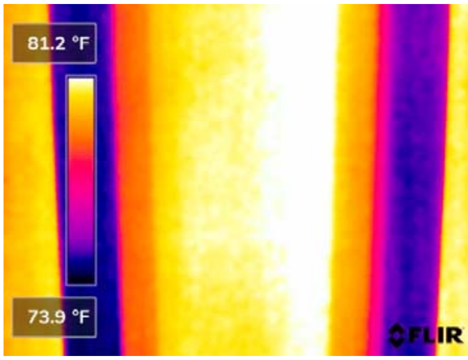

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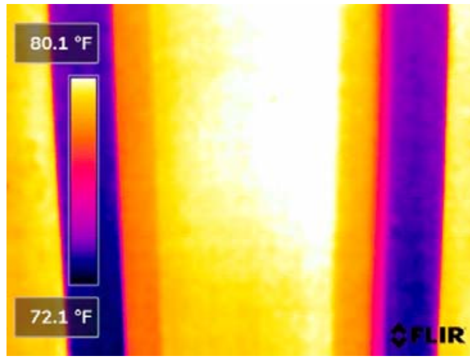

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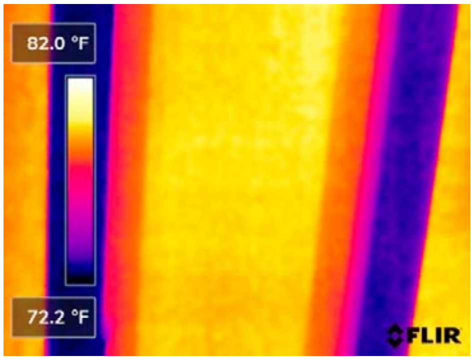

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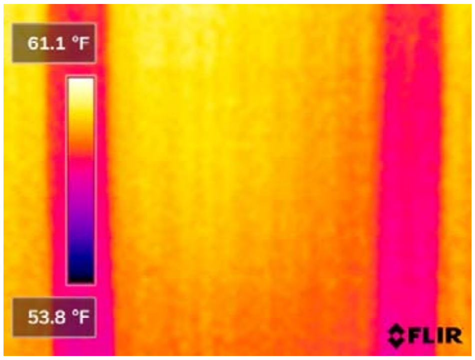

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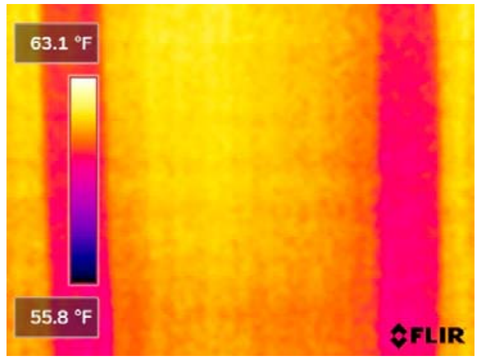

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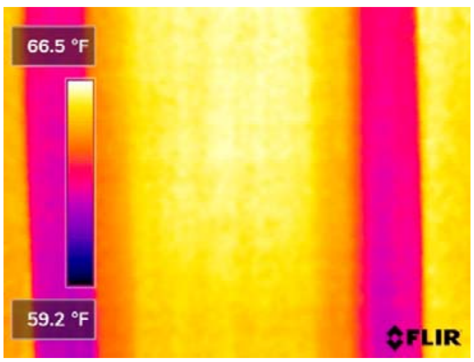

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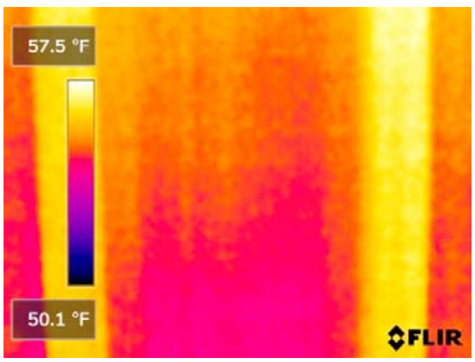

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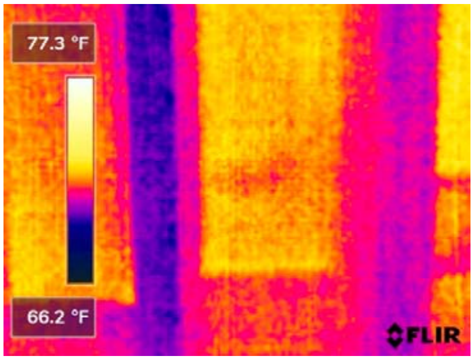
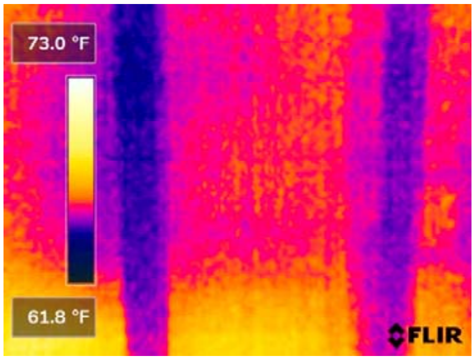


C5_Loc01_01_FLIR0005



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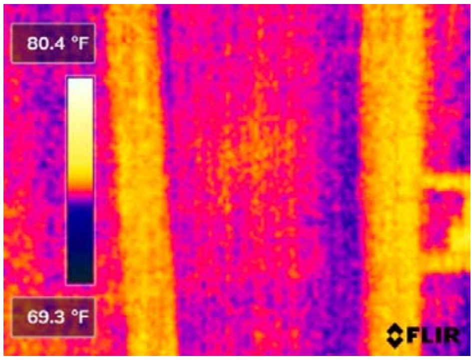

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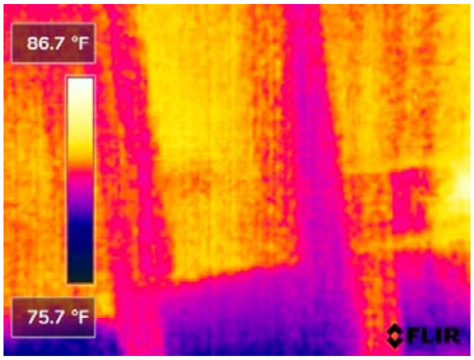

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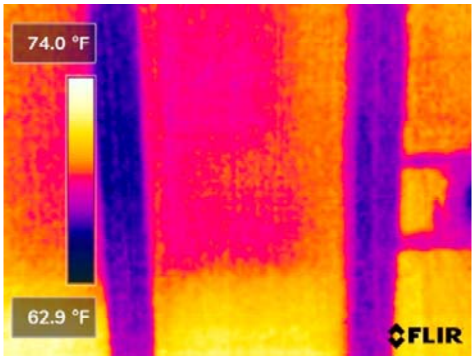

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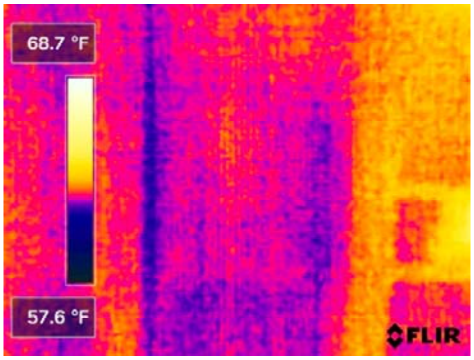

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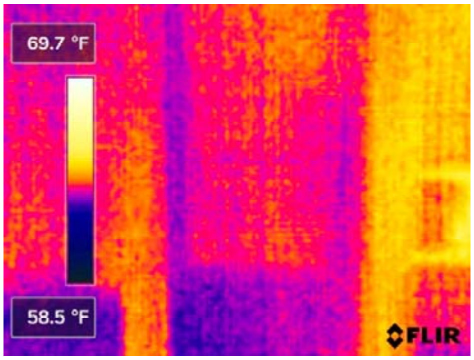

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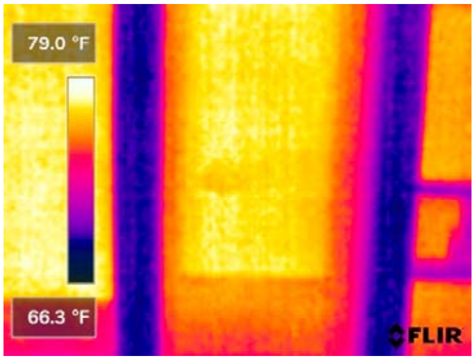

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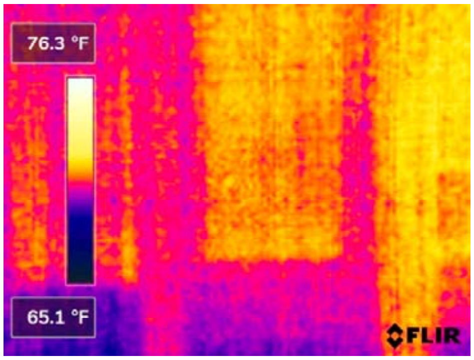

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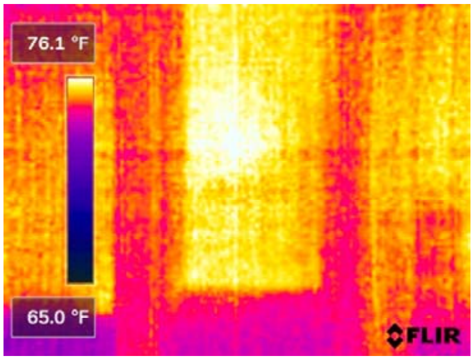

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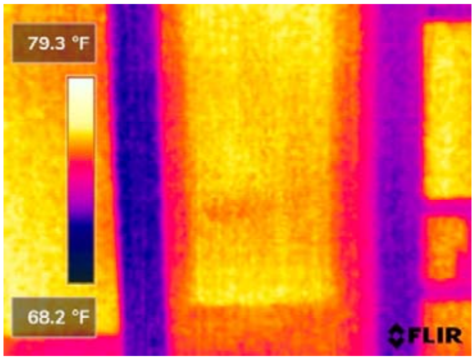

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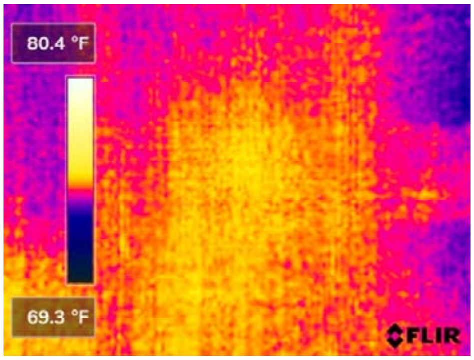

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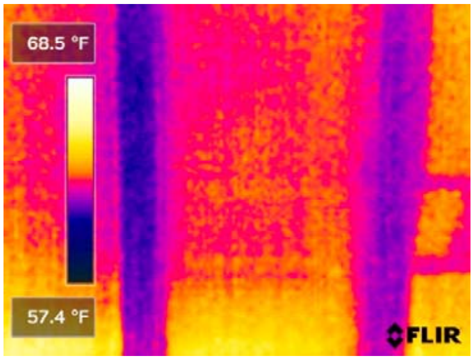

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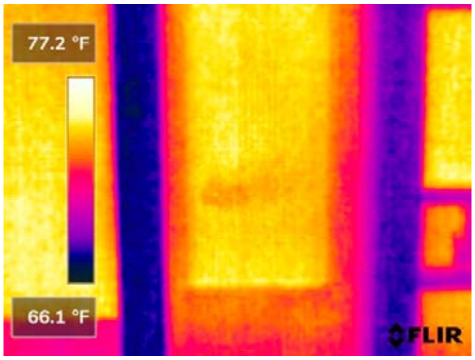

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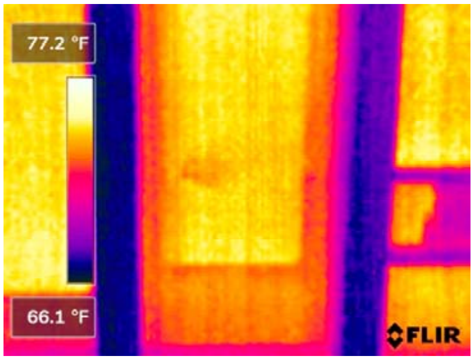

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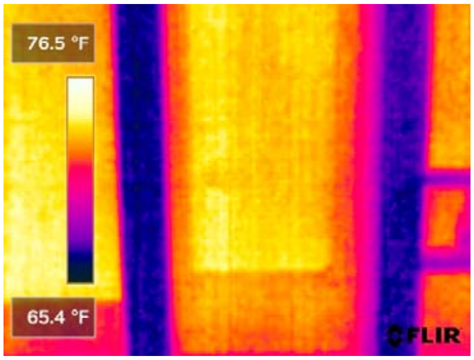

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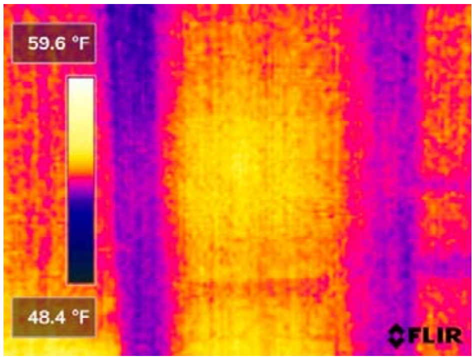

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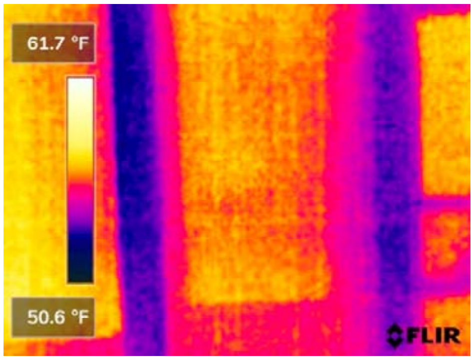

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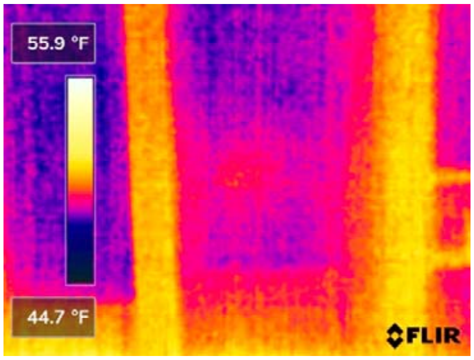

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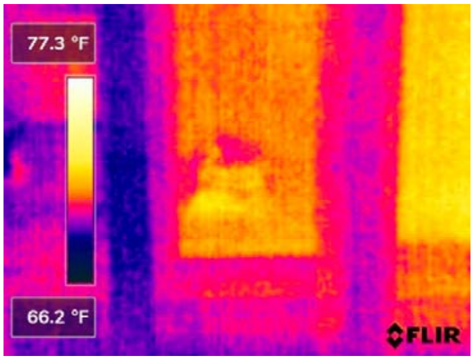

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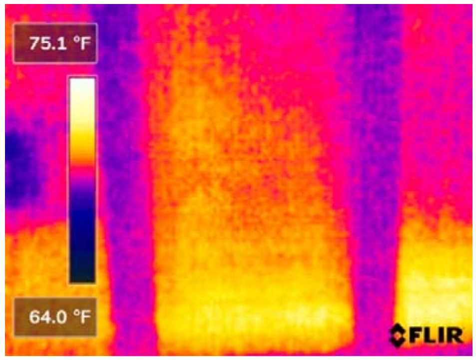

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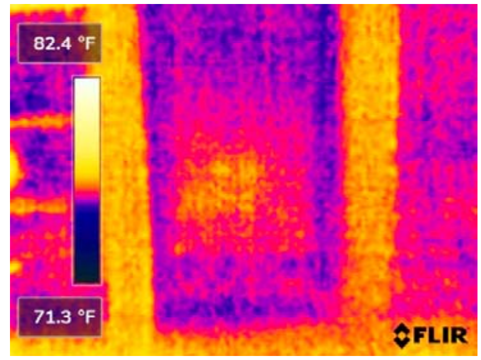

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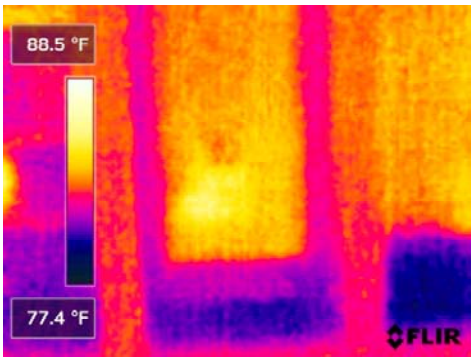

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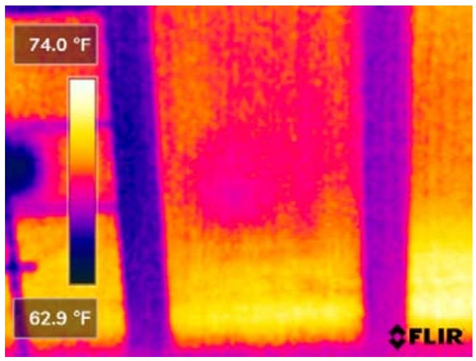

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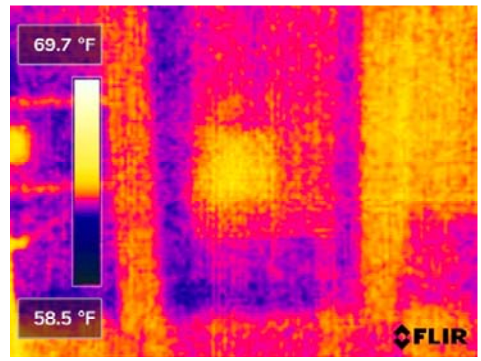

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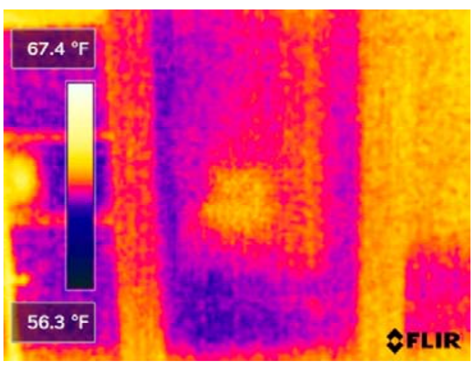

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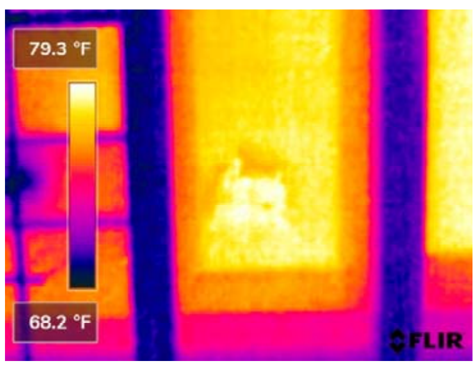

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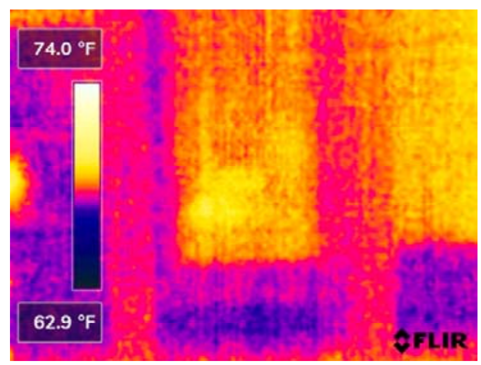

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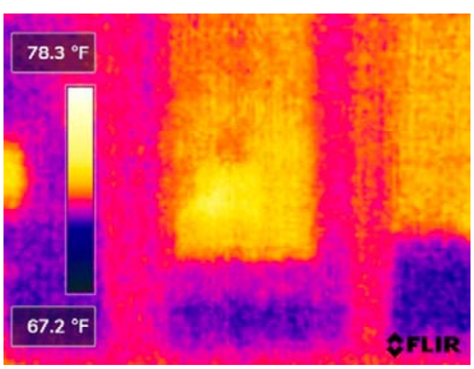

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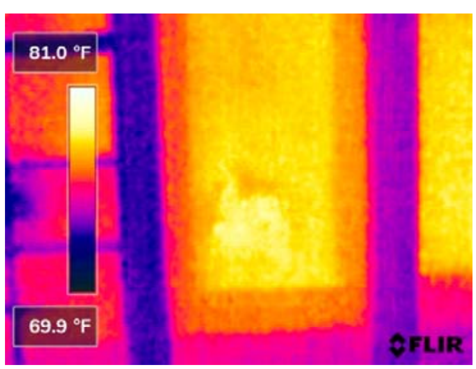

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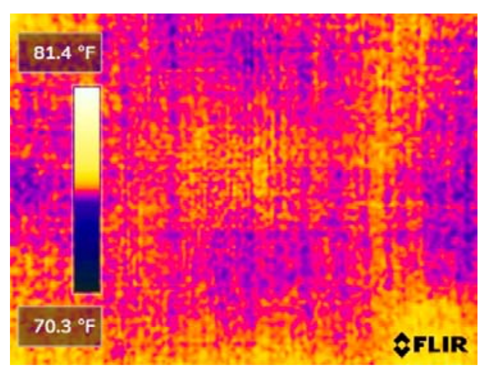

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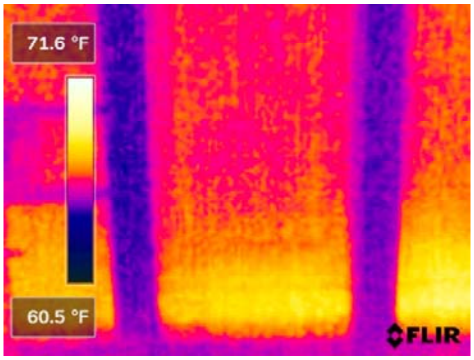

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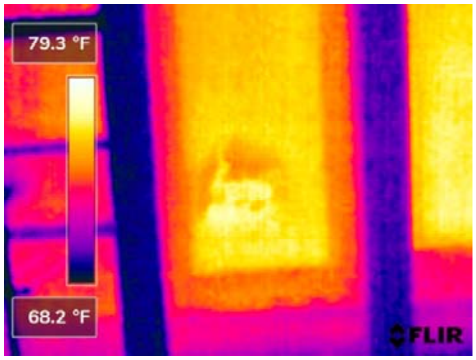

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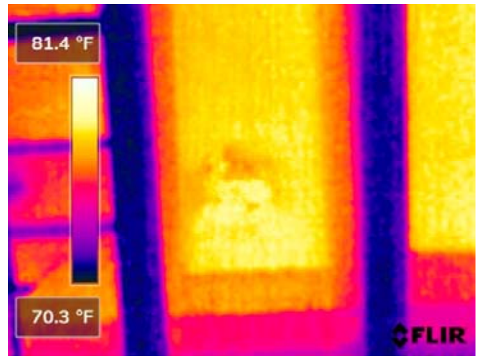

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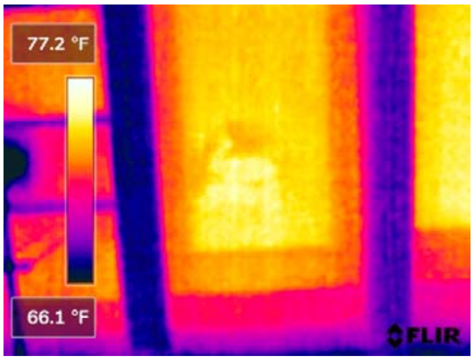

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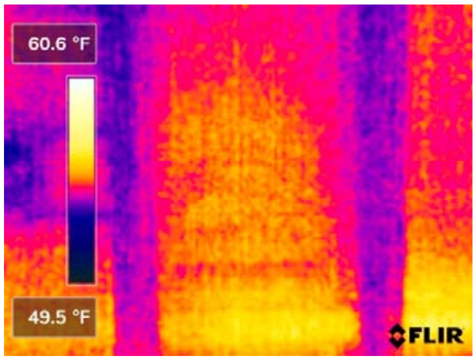

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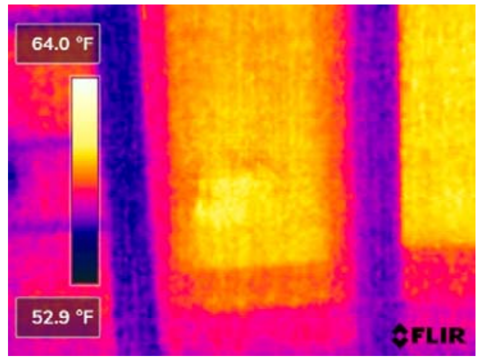

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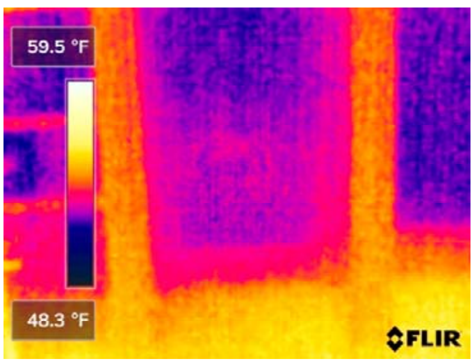

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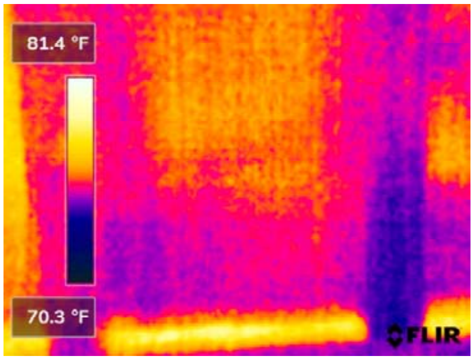

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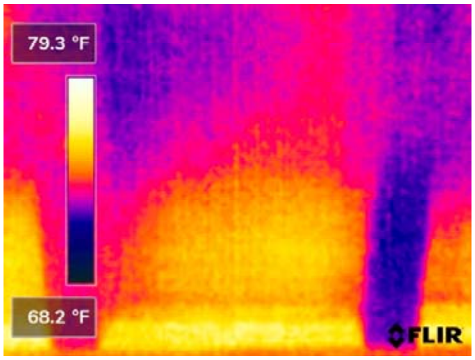

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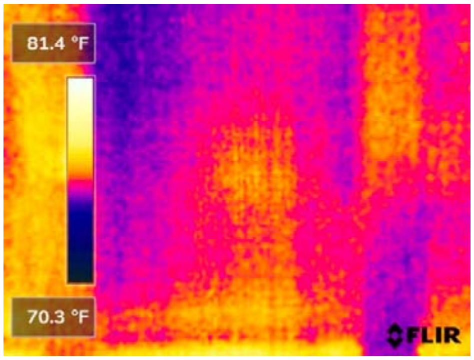

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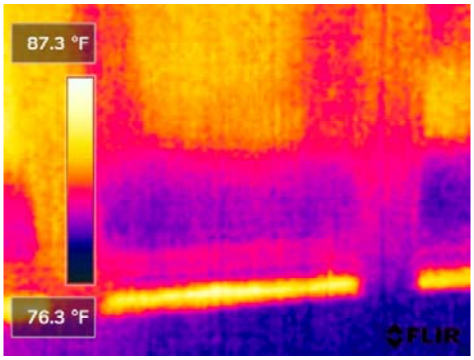

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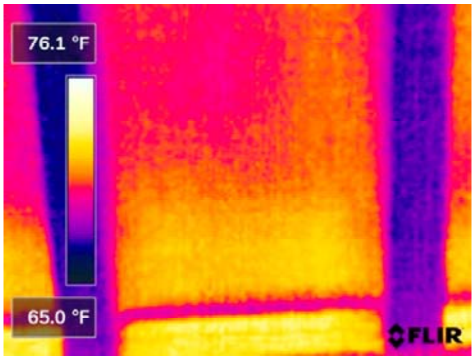

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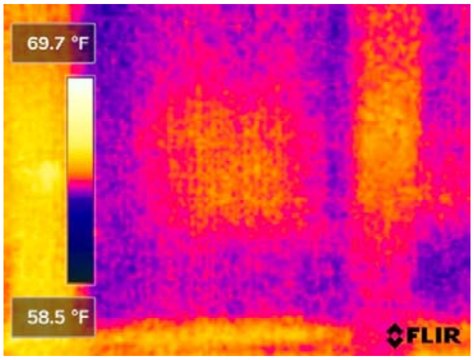

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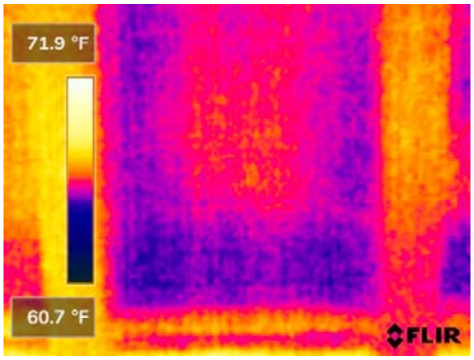

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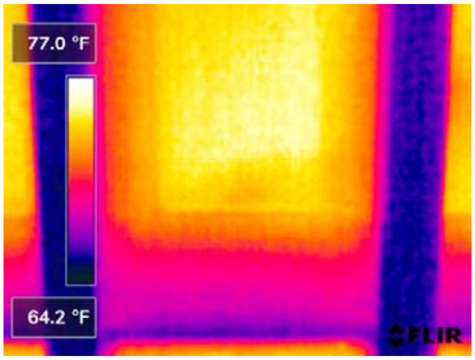

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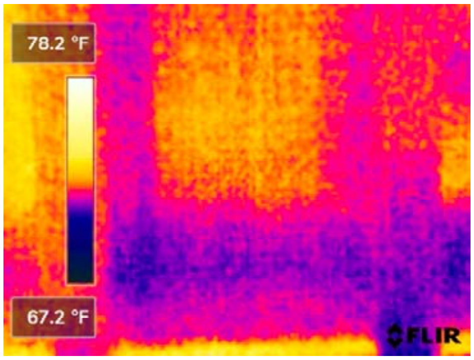

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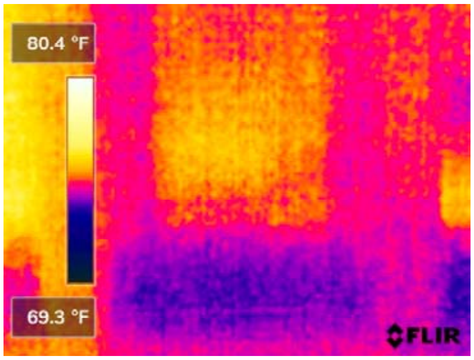

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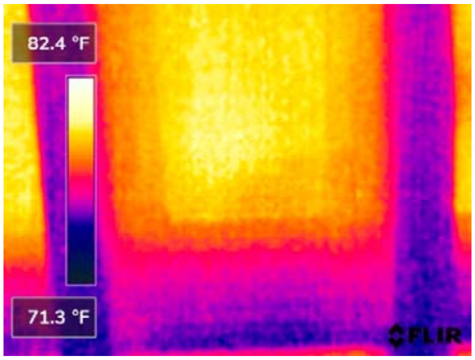

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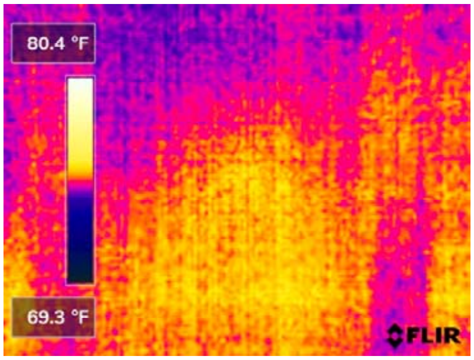

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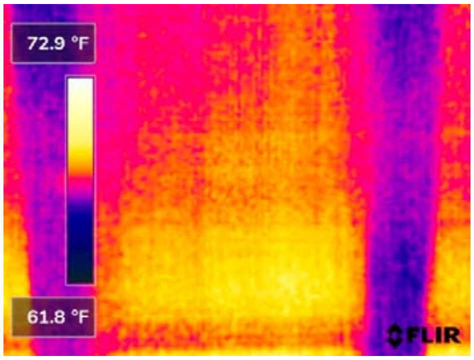

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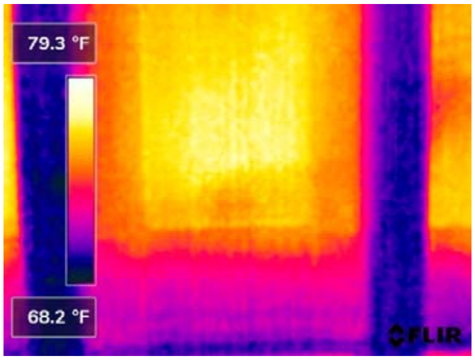

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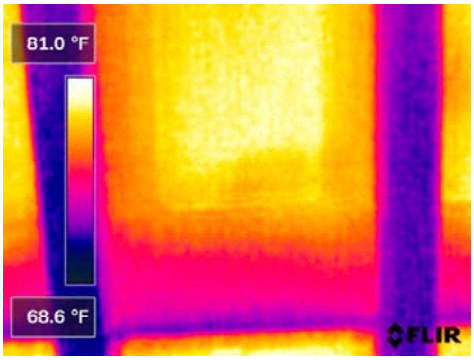

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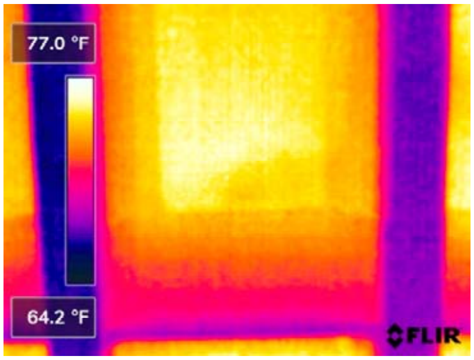

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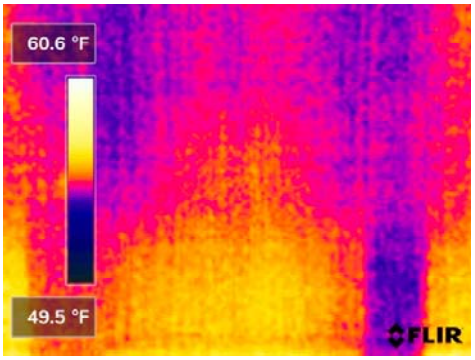

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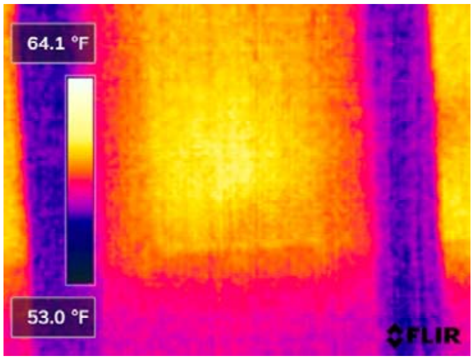

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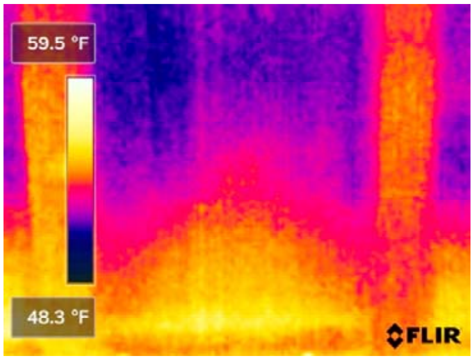

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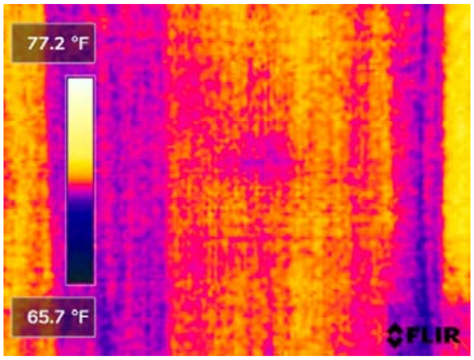

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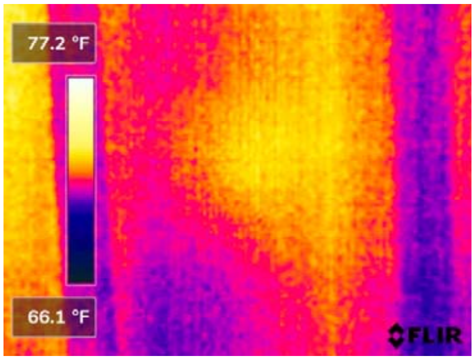

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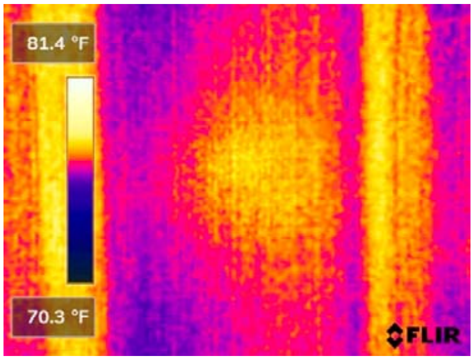

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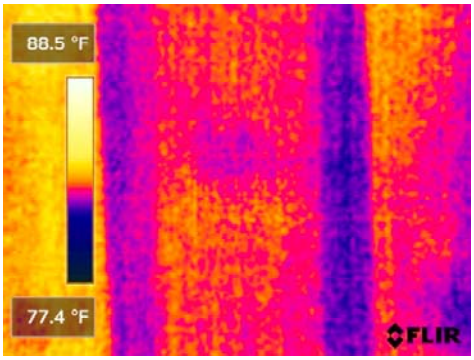

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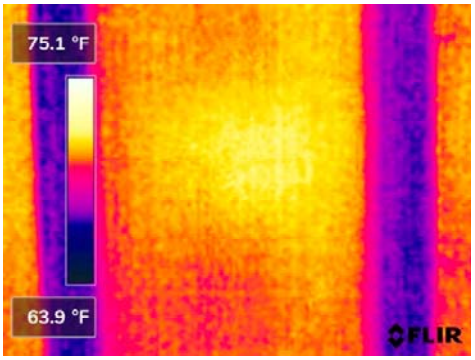

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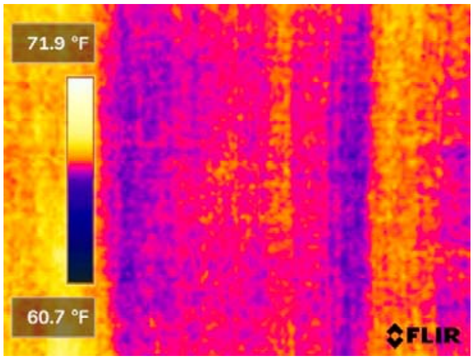

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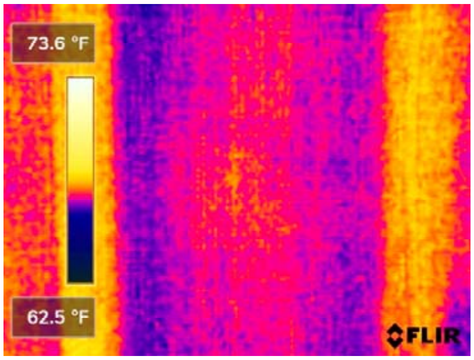

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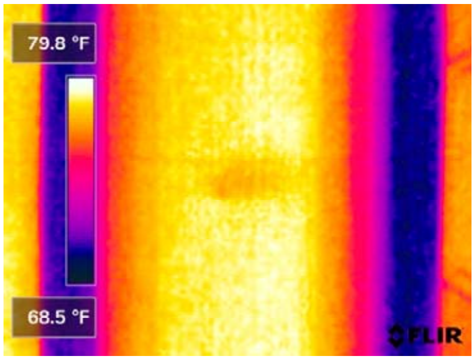

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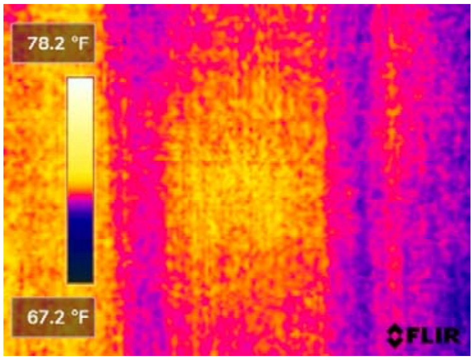

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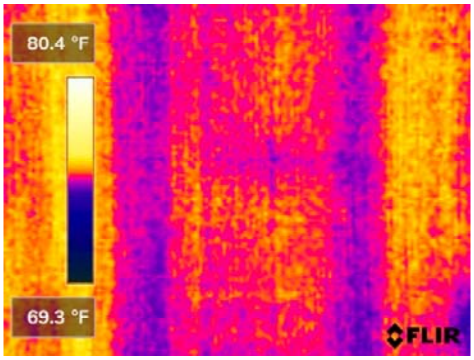

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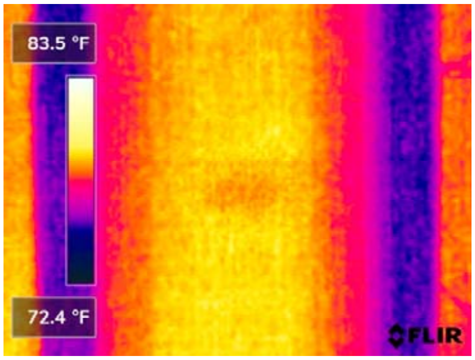

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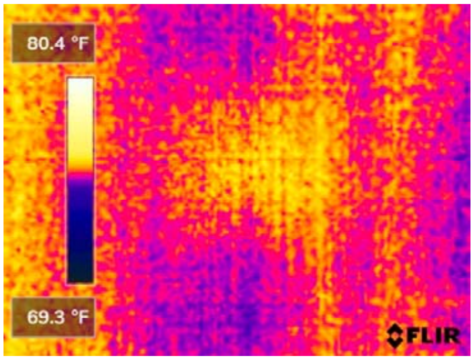

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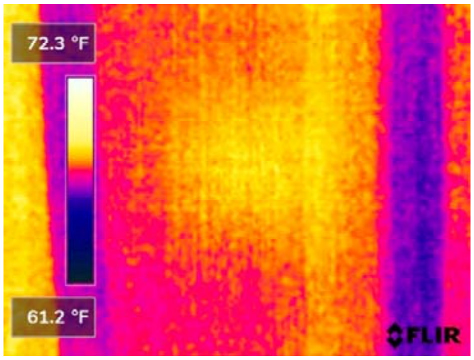

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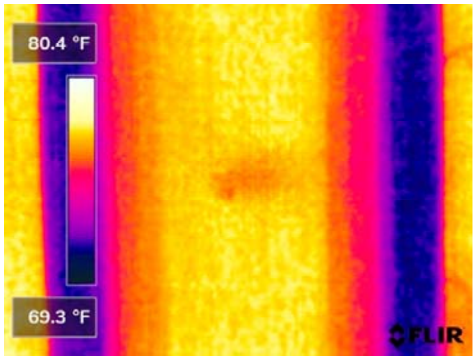

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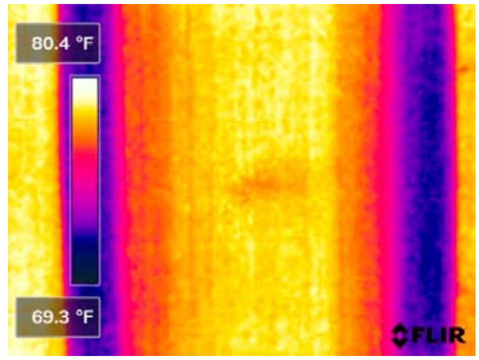

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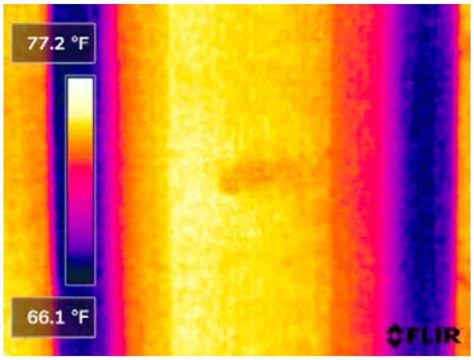

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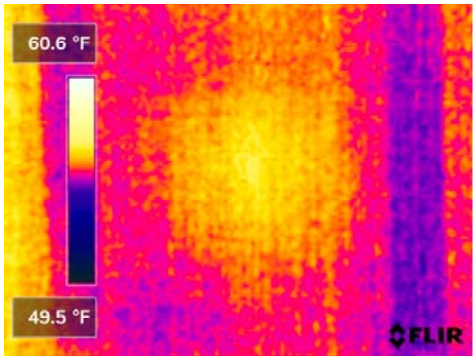

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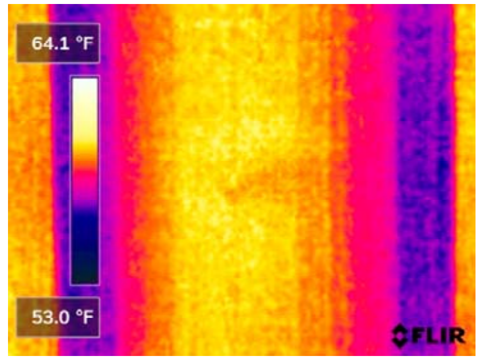

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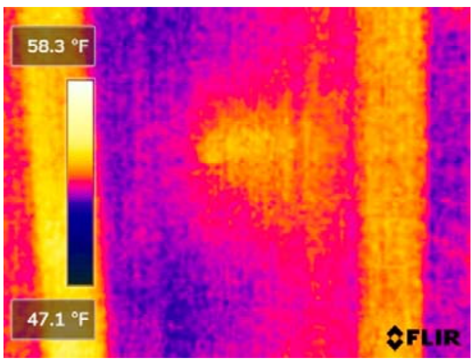

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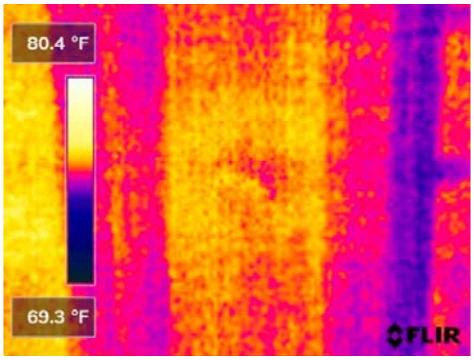

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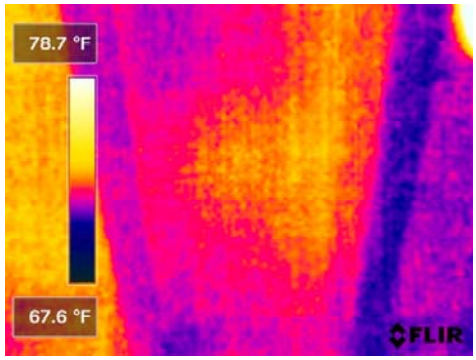

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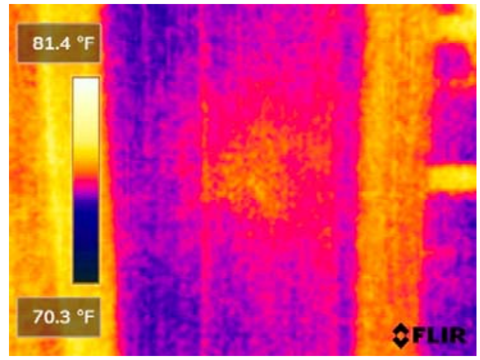

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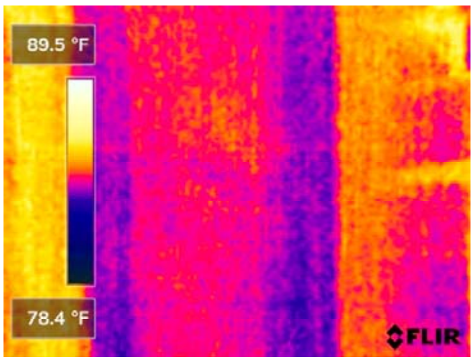

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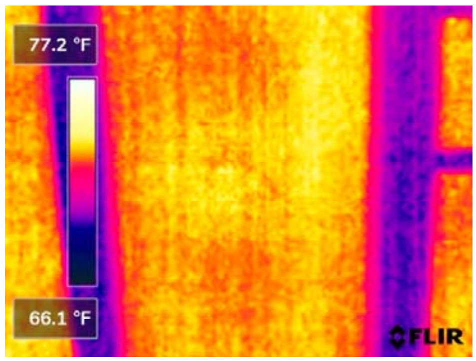

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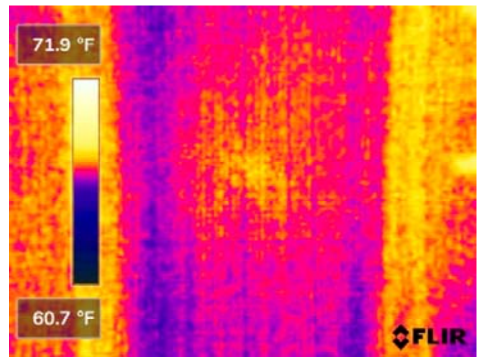

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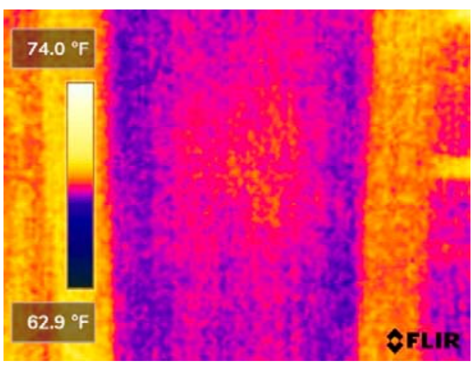

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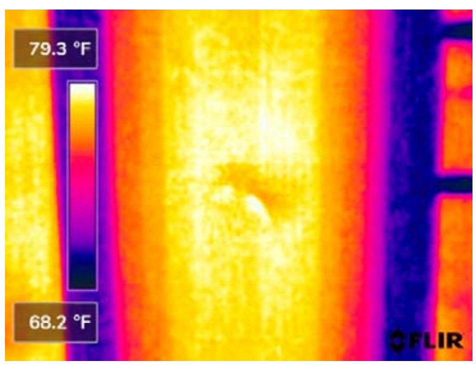

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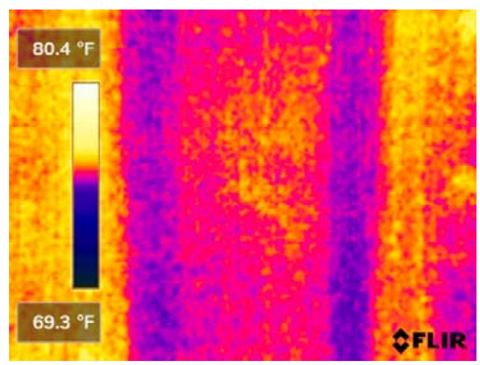

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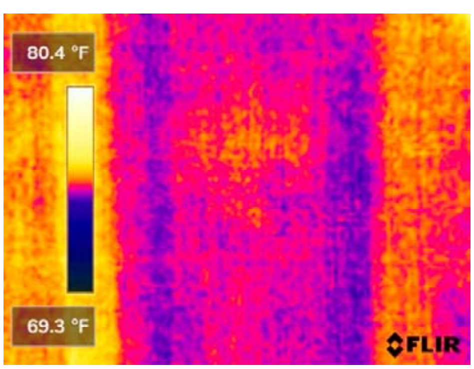

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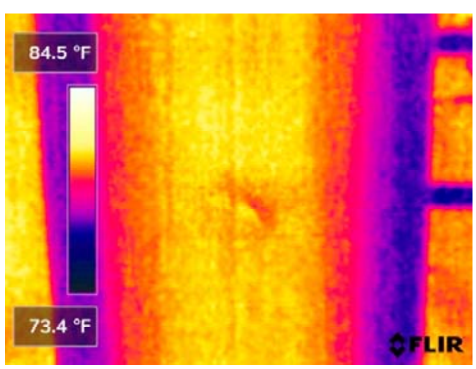

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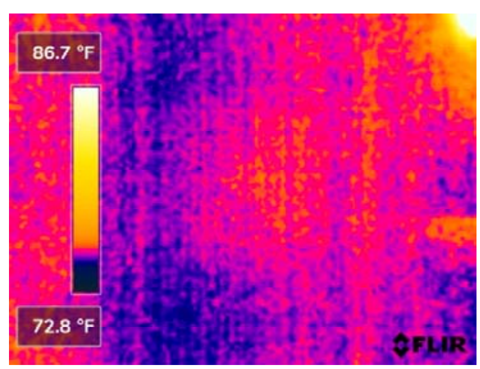

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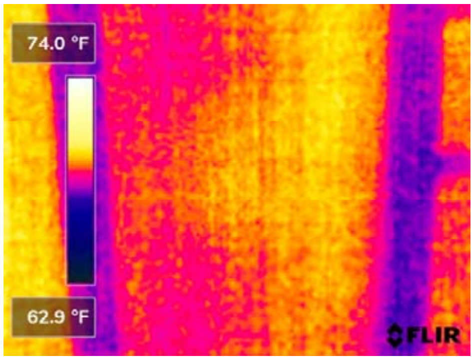

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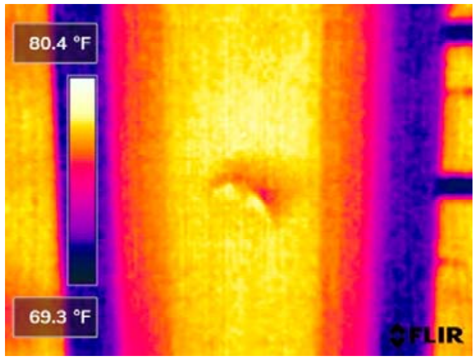

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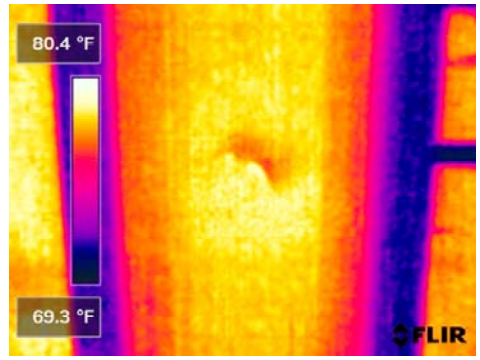

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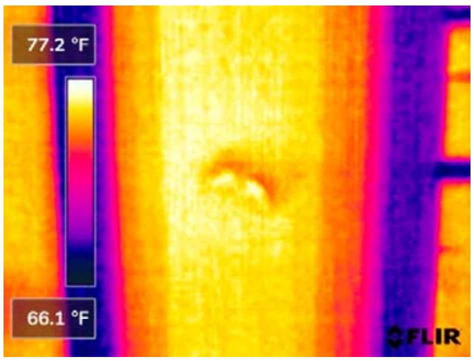

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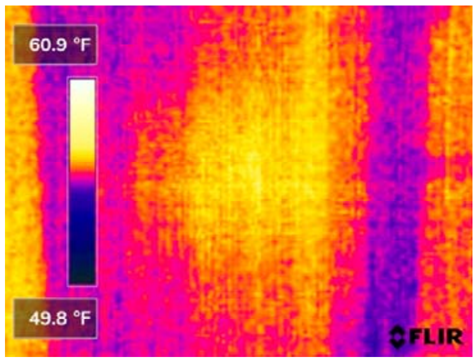

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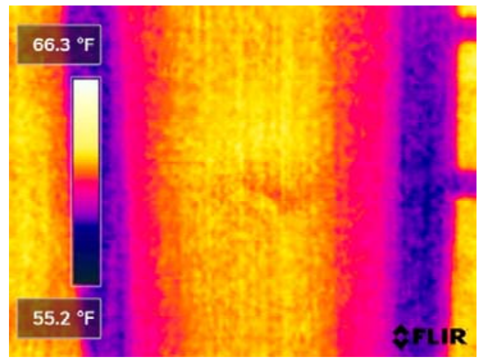

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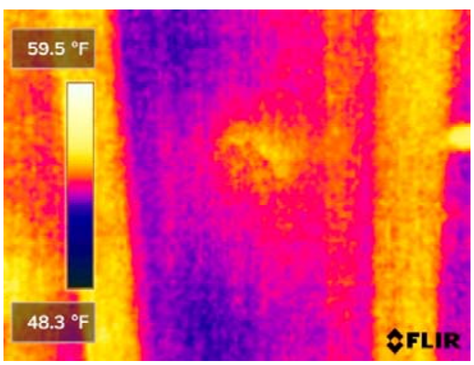

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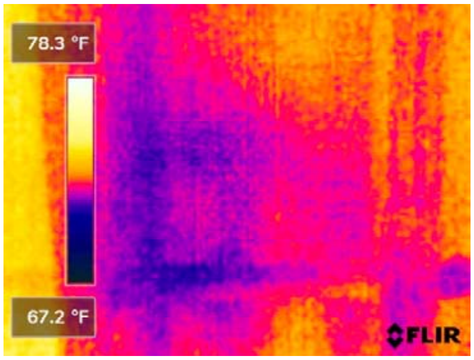

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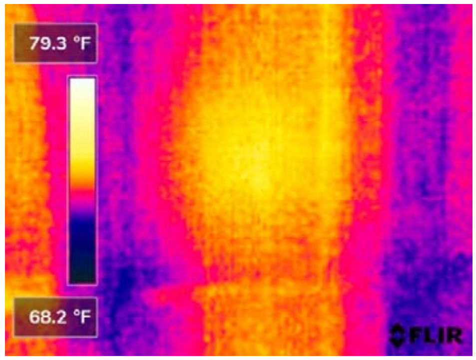

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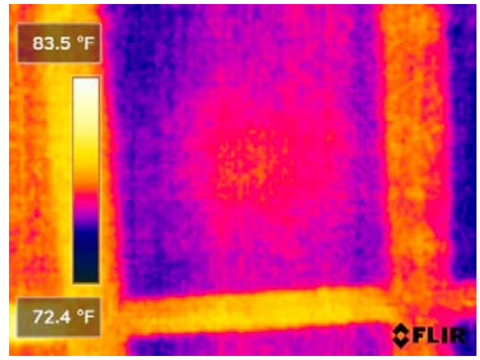

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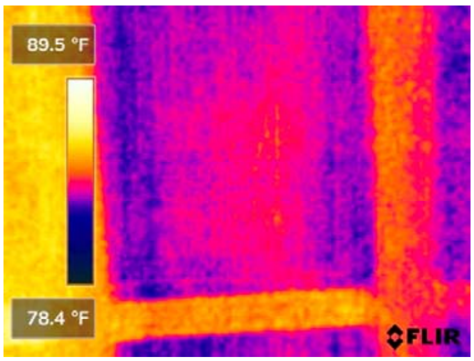

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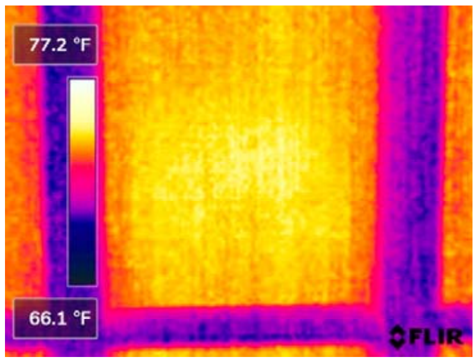

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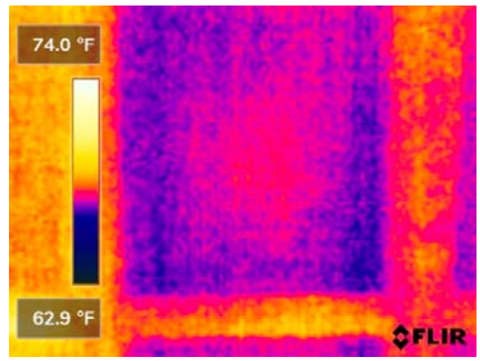

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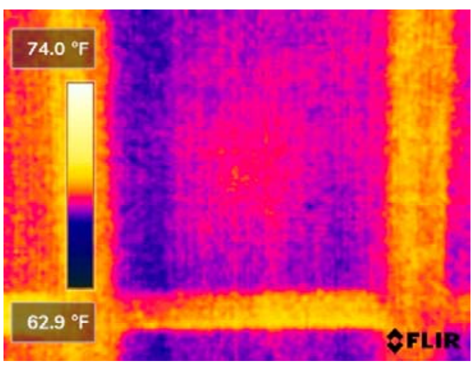

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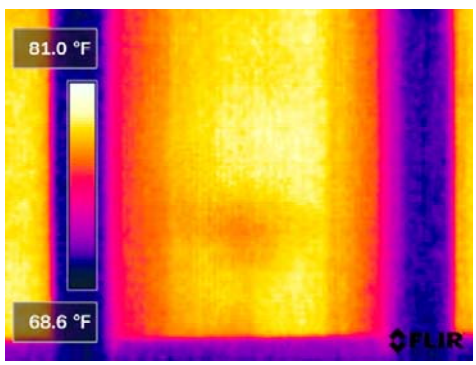

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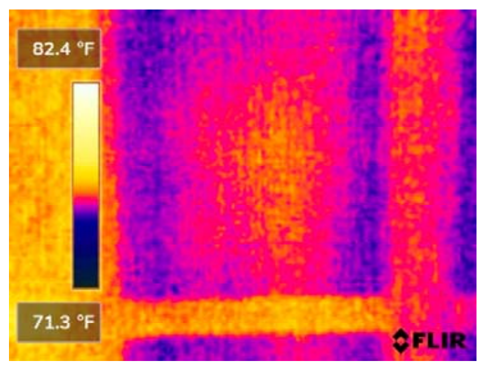

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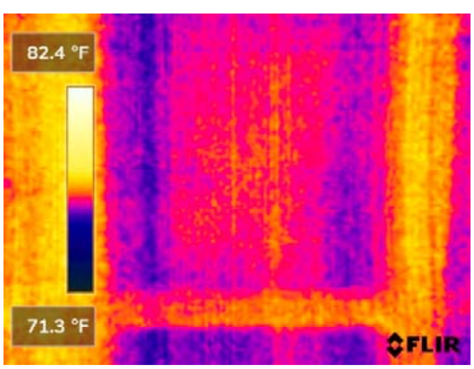

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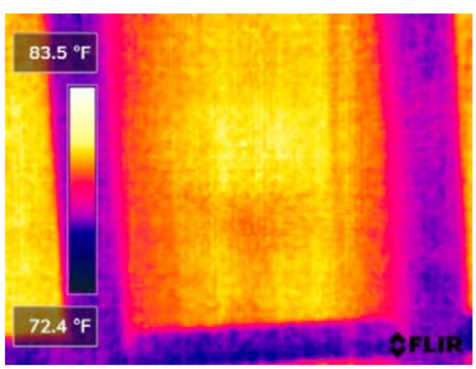

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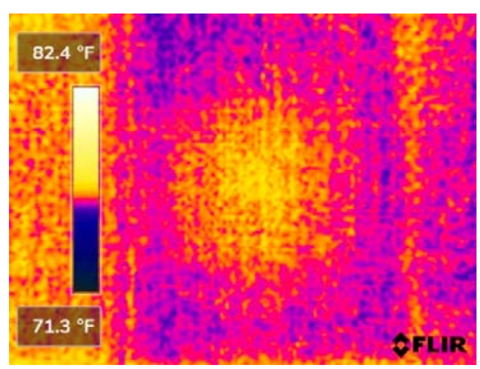

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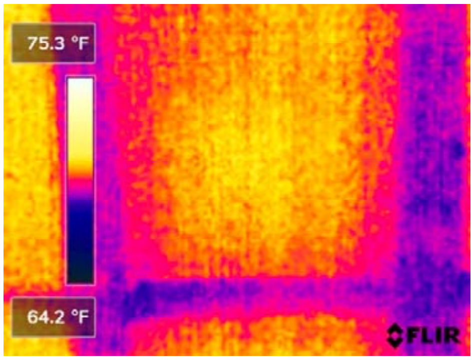

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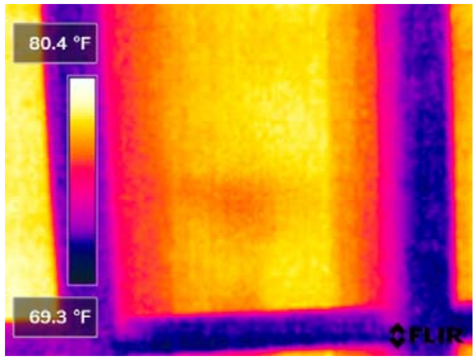

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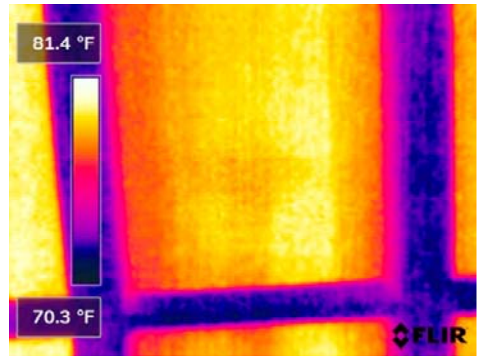

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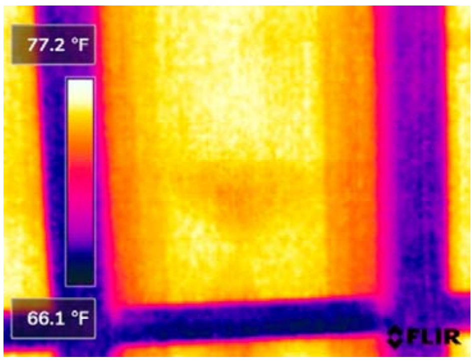

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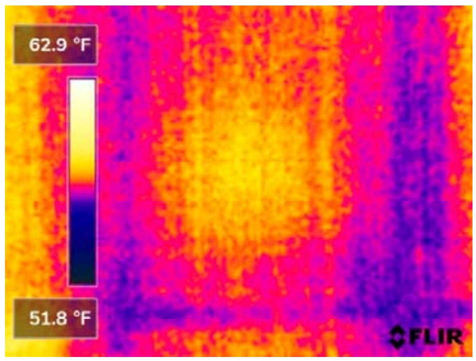

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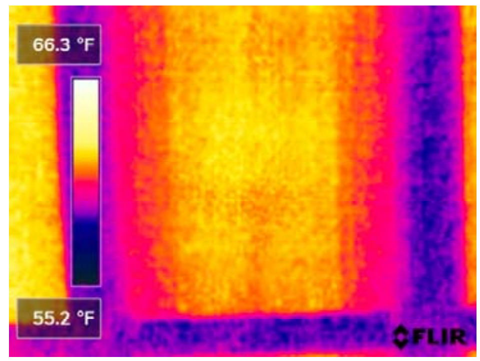

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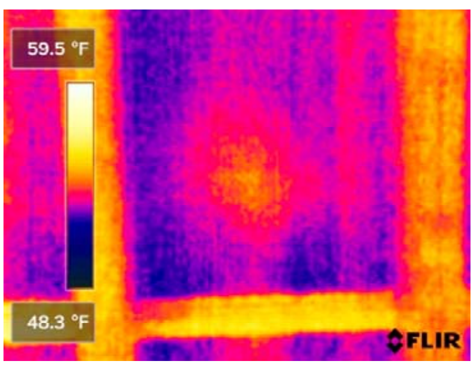

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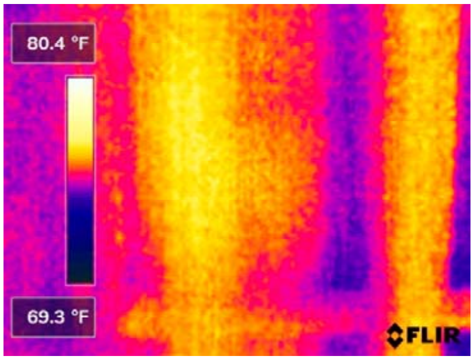

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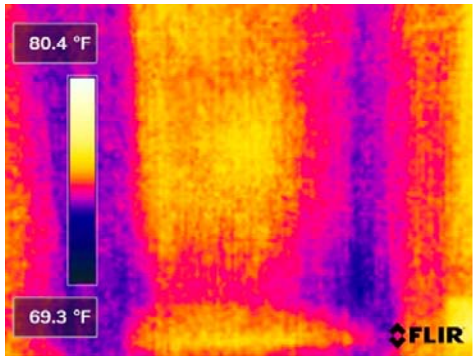

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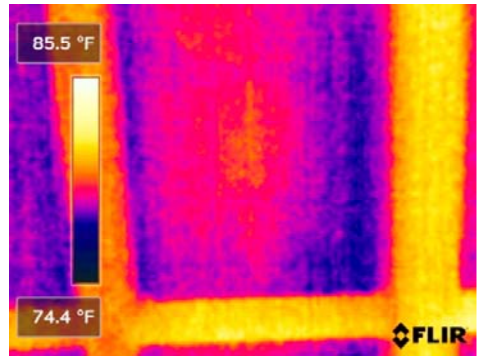

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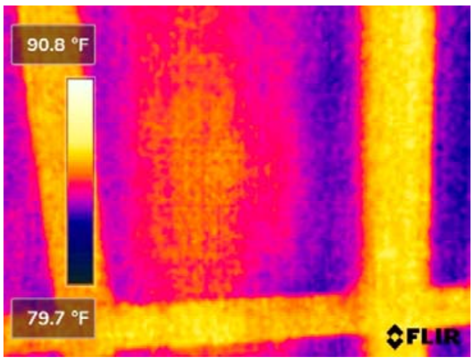

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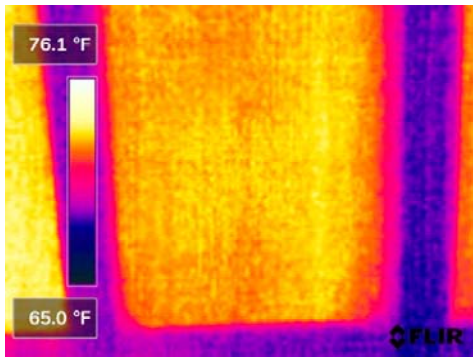

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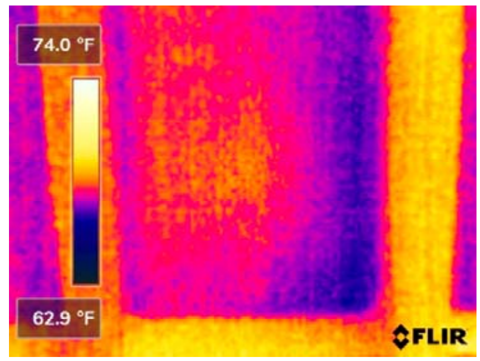

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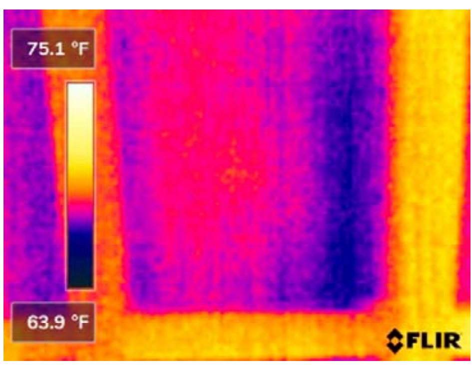

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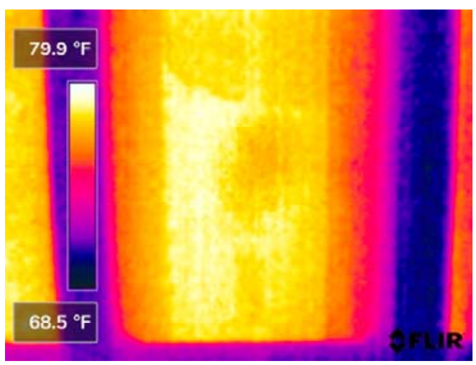

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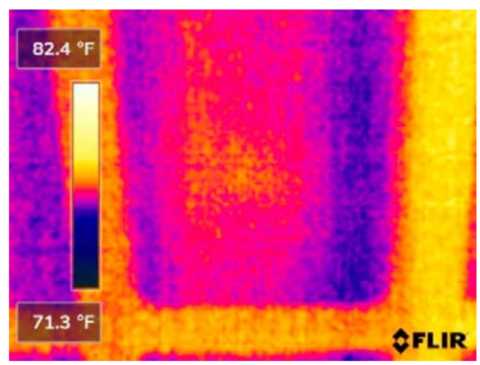

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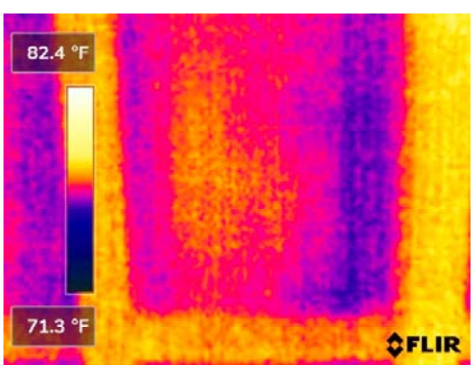

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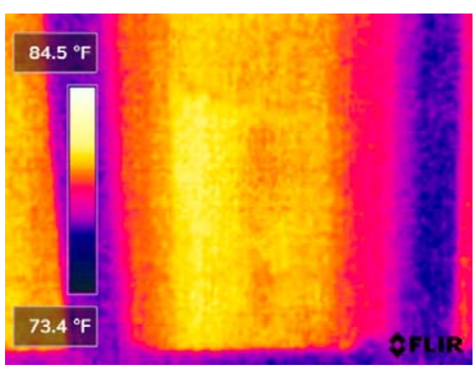

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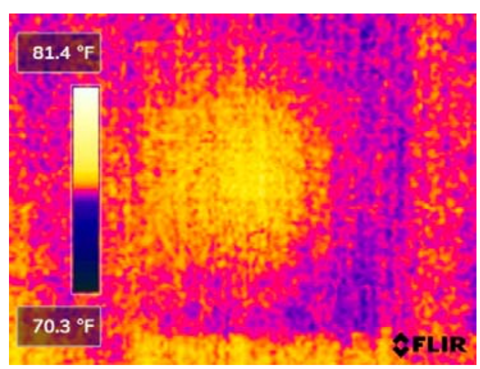

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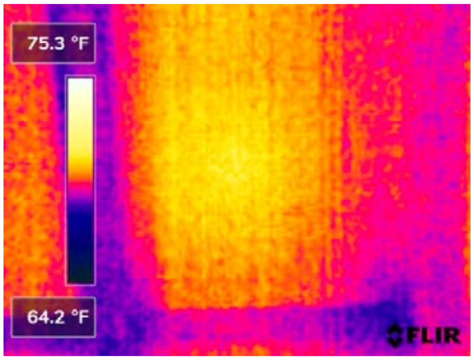

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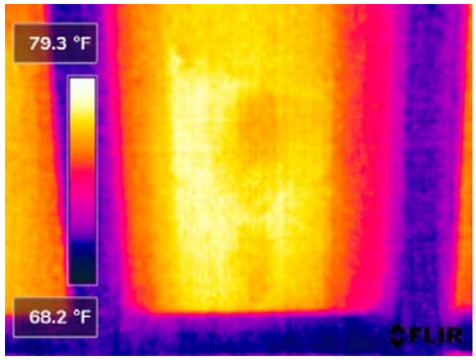

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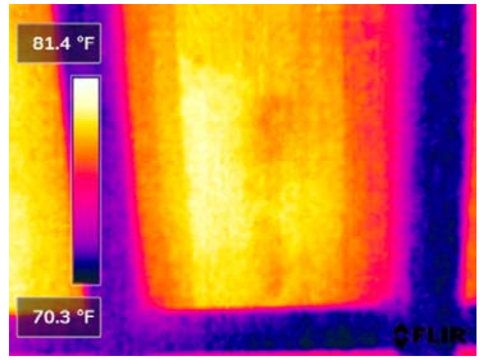

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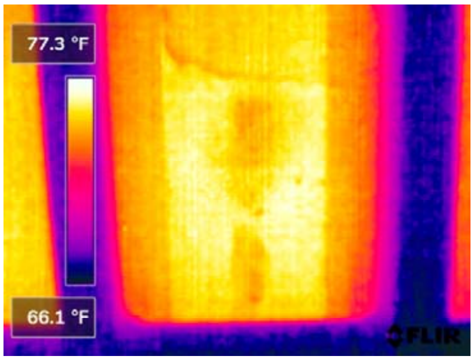

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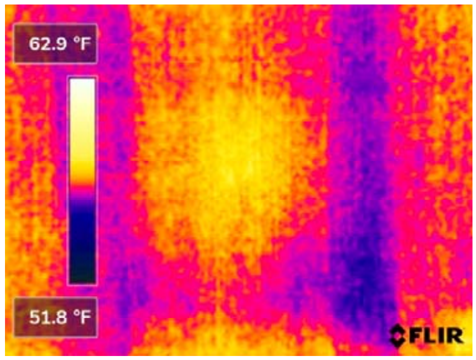

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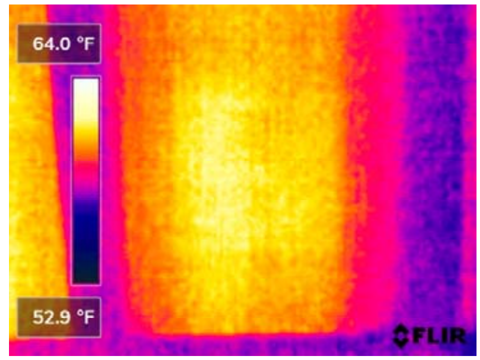

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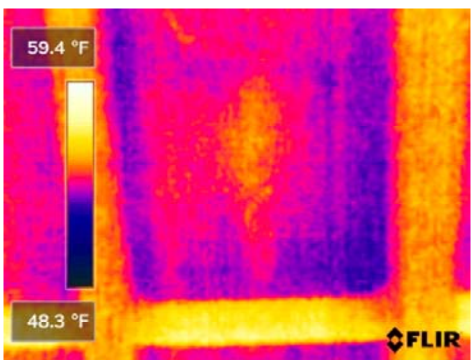

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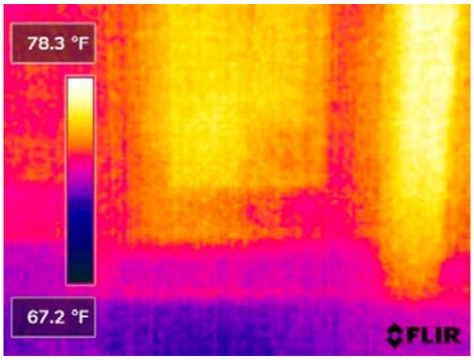

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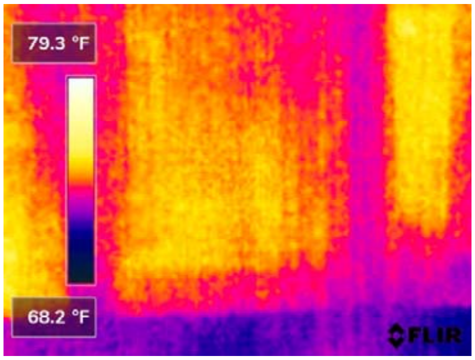

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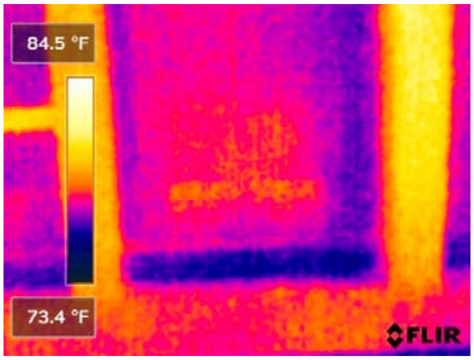

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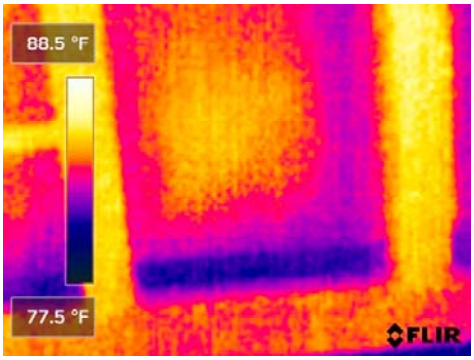

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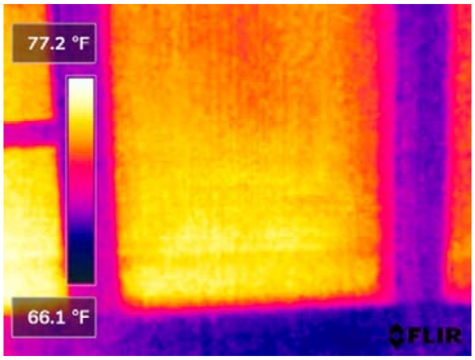

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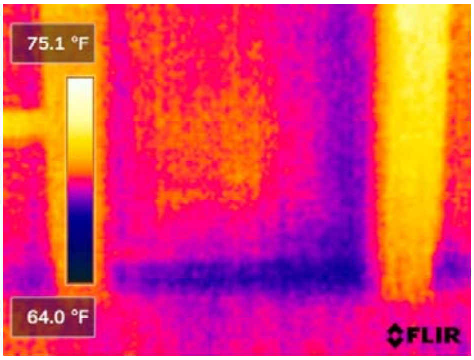

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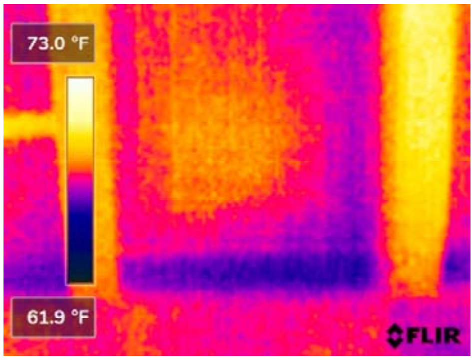

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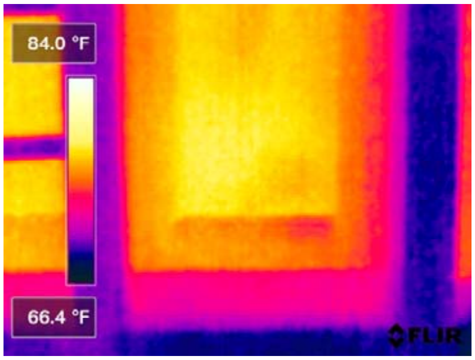

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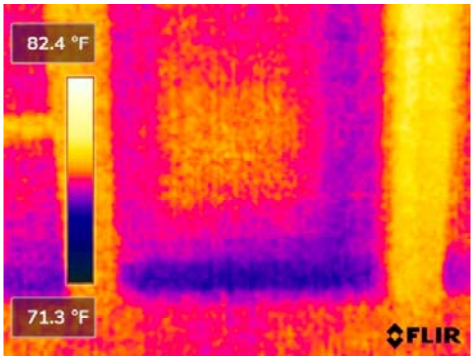

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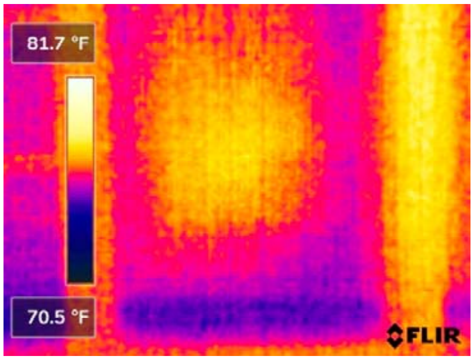

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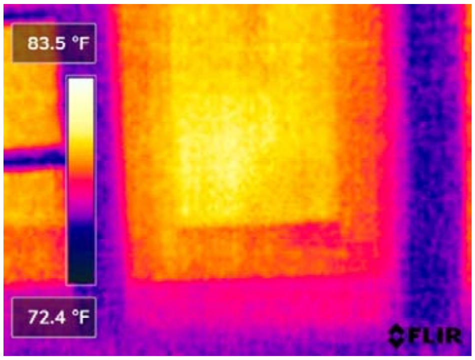

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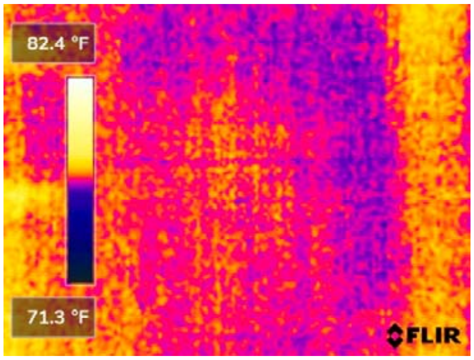

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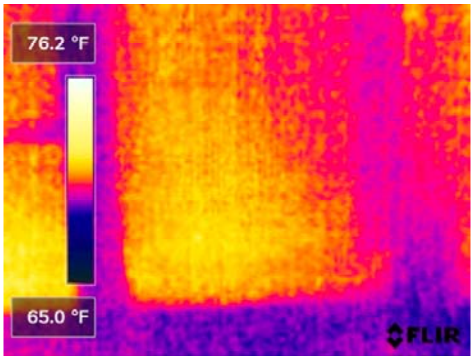

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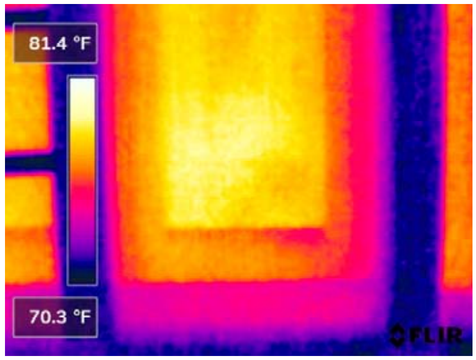

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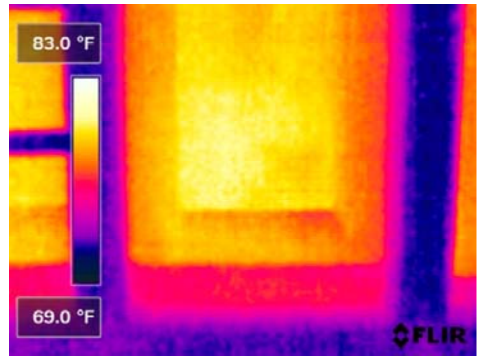

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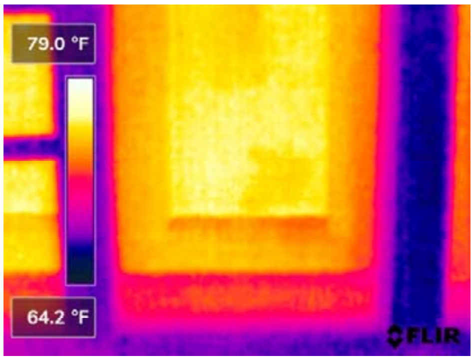

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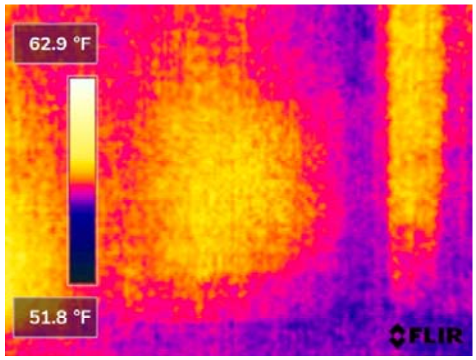

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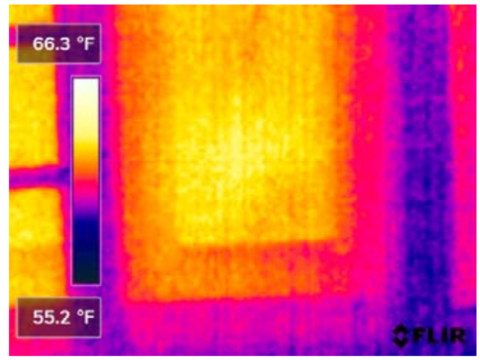

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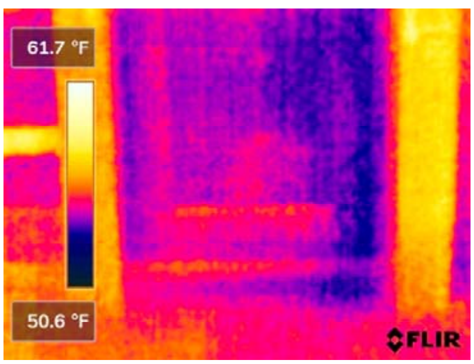

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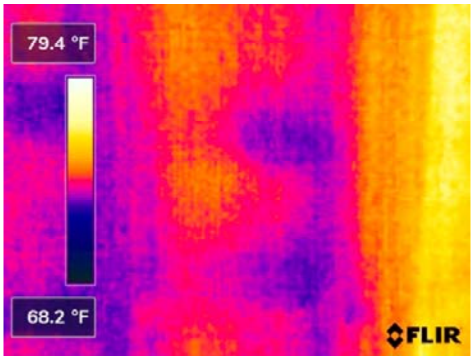

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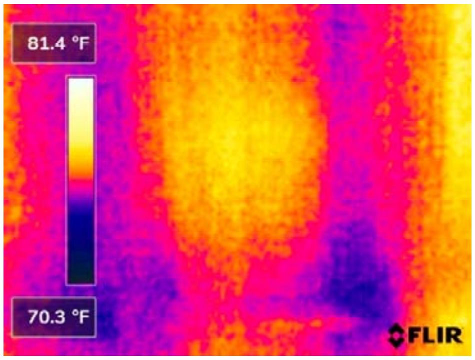

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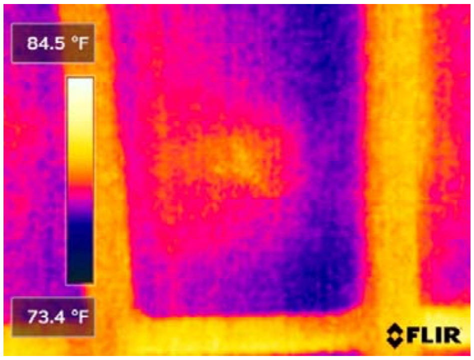

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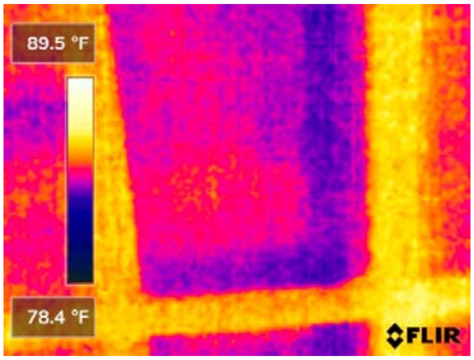

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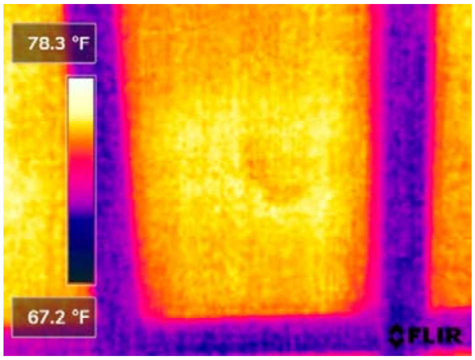

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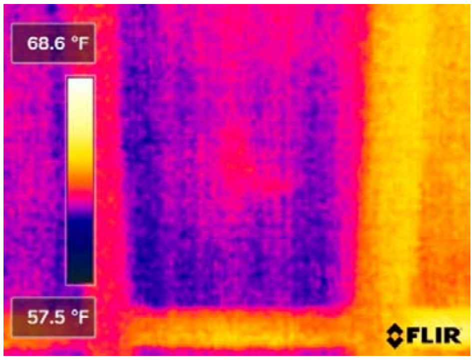

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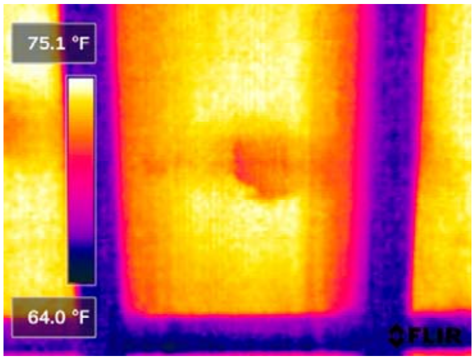

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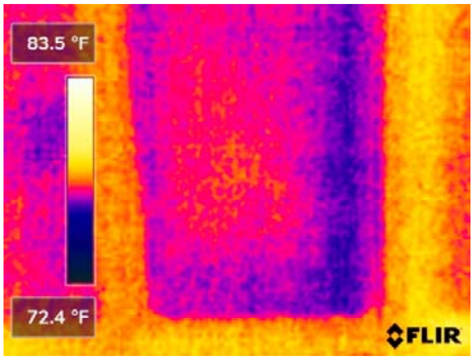

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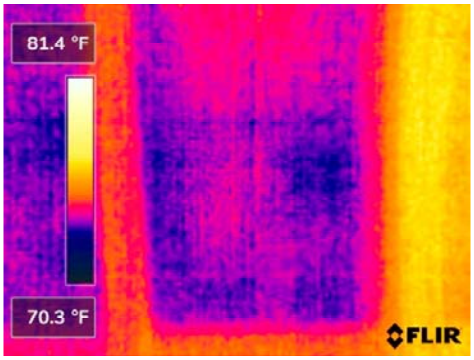

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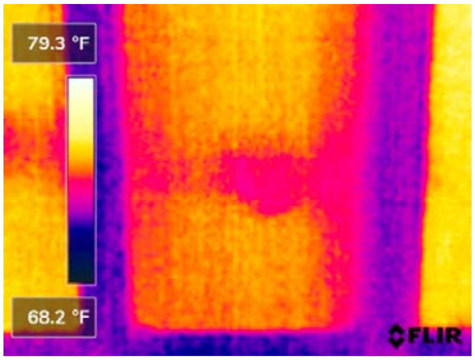

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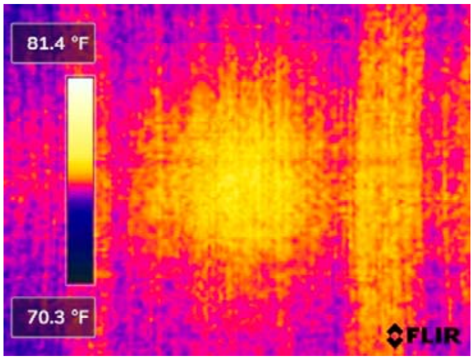

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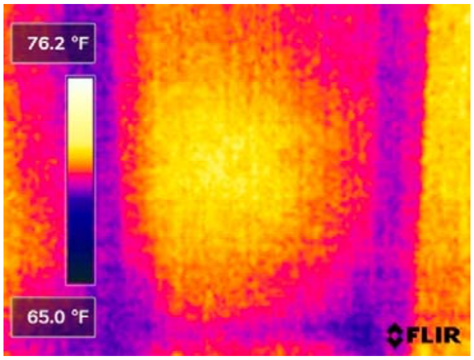

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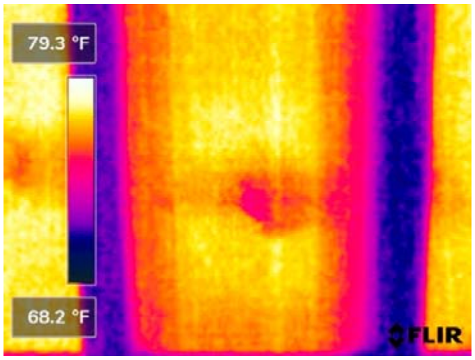

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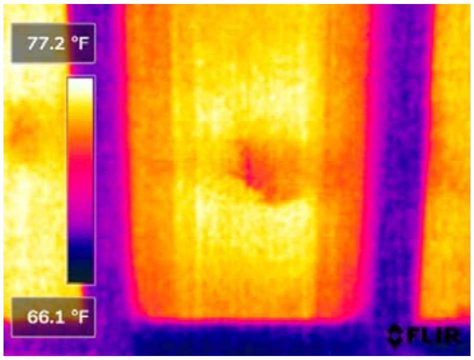

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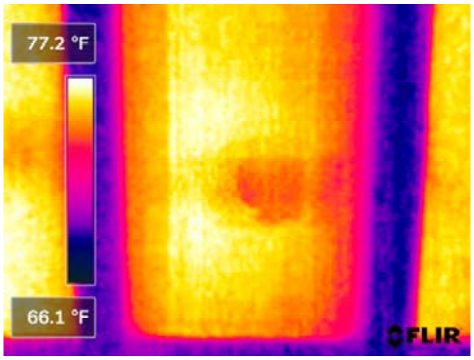

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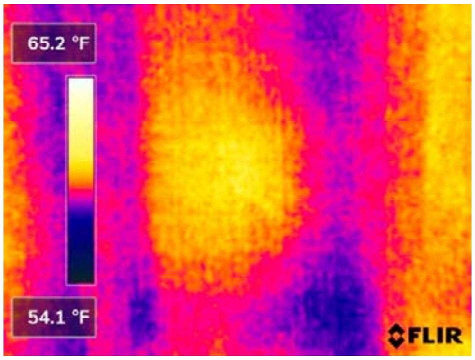

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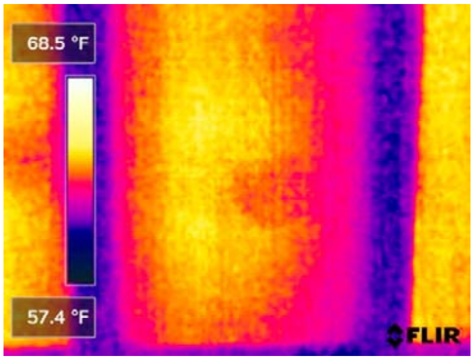

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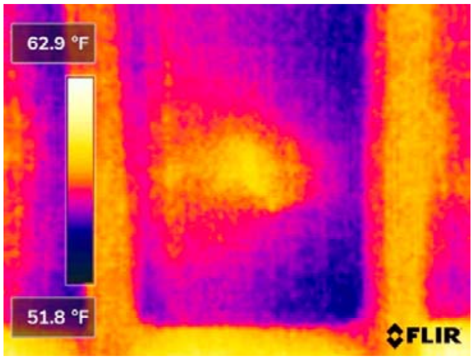

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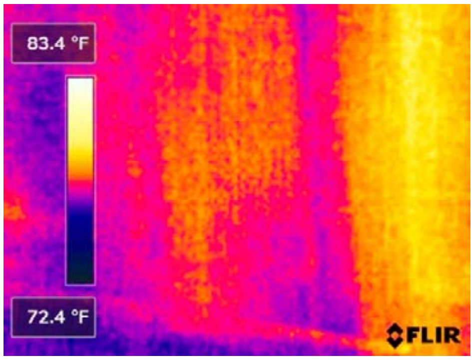

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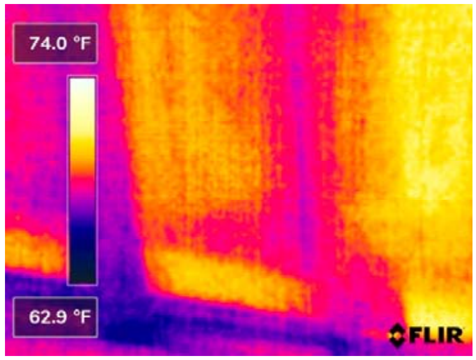

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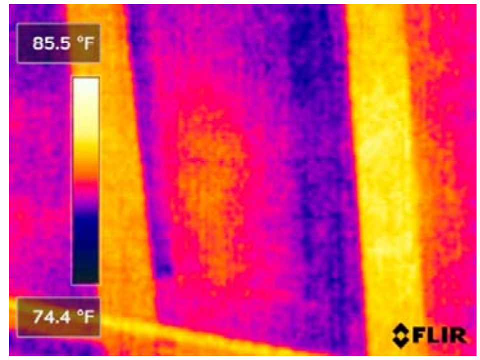

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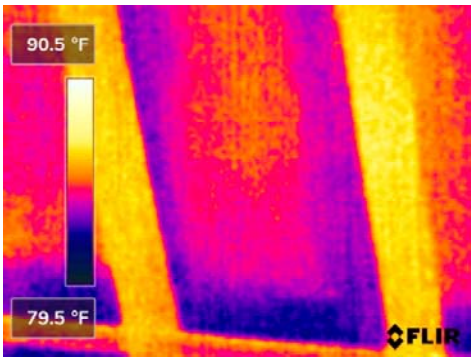

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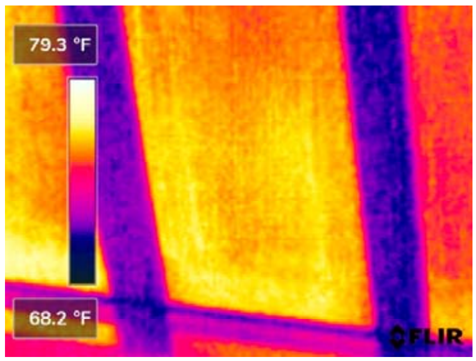

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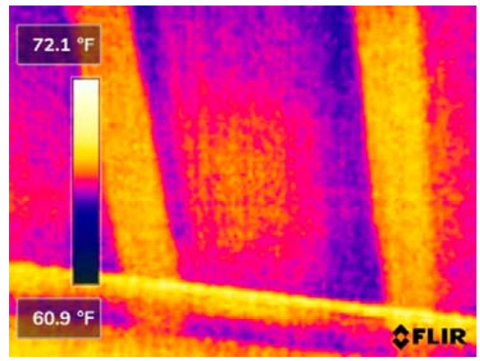

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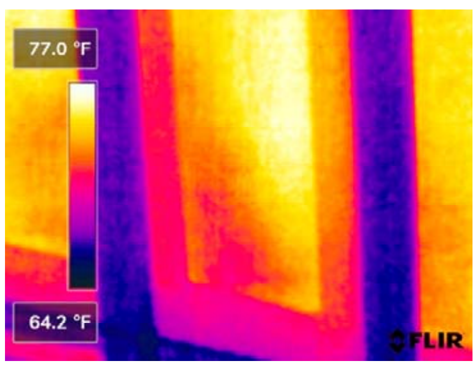

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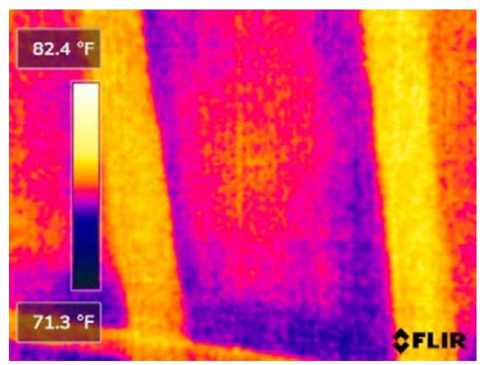

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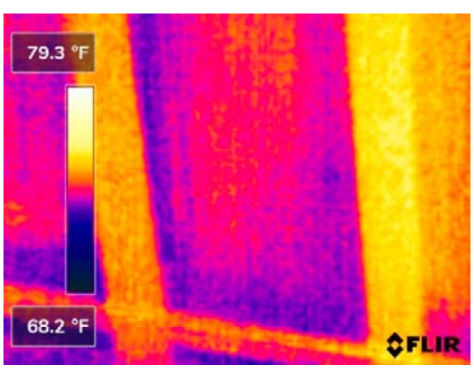

C5_Loc10_10_FLIR1303

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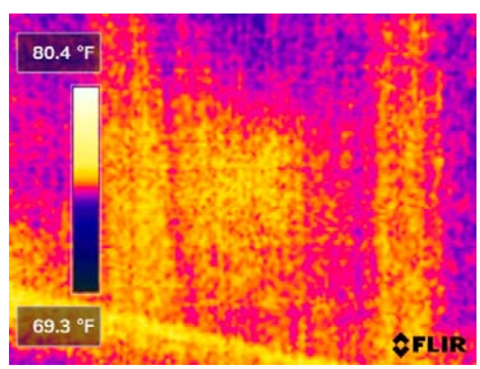

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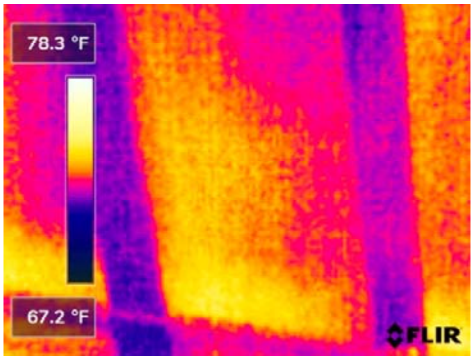

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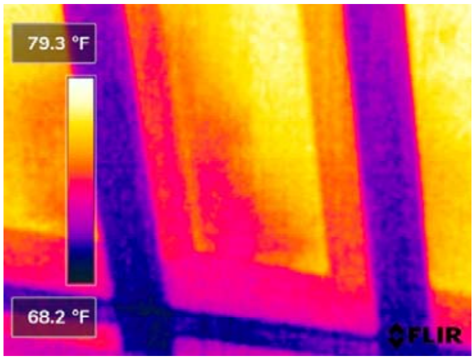

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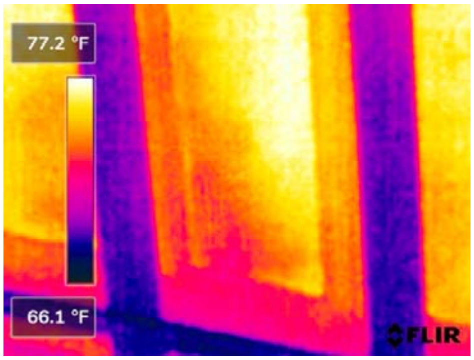

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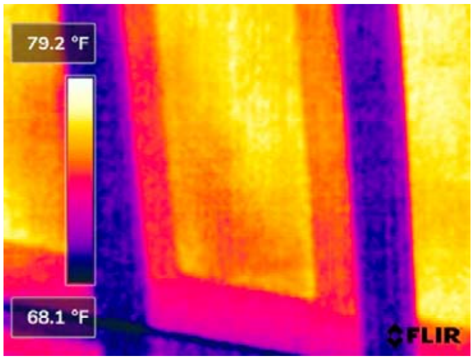

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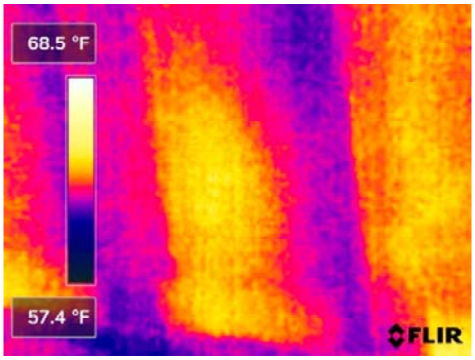

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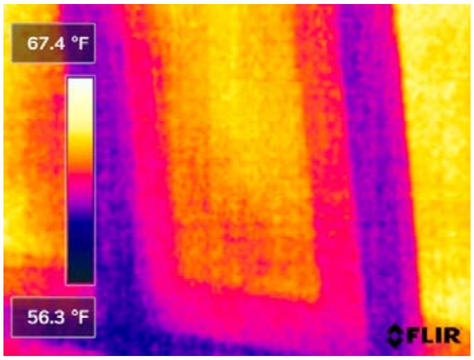

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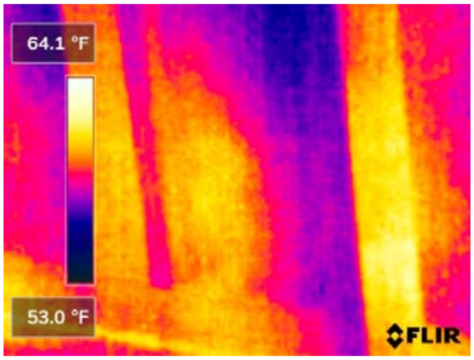

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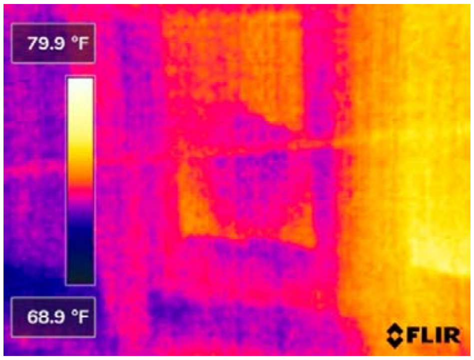

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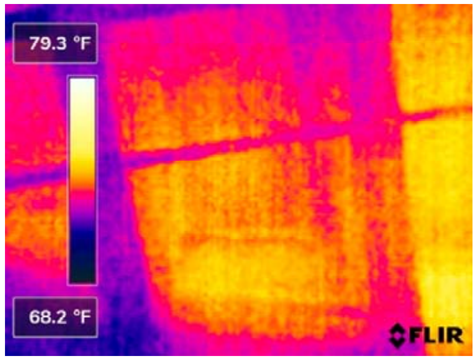

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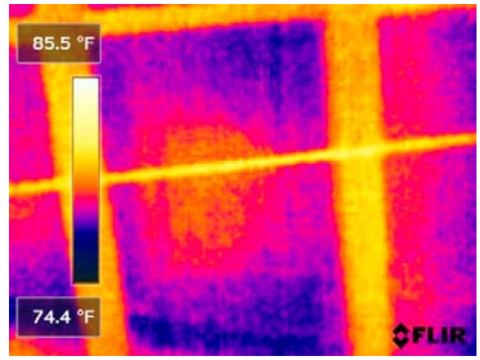

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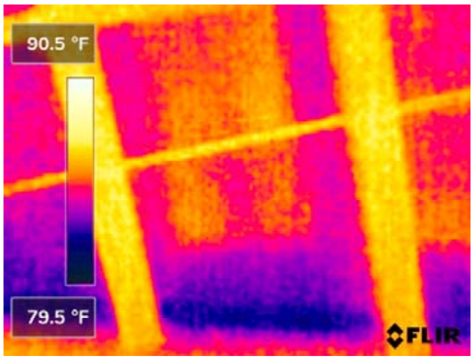

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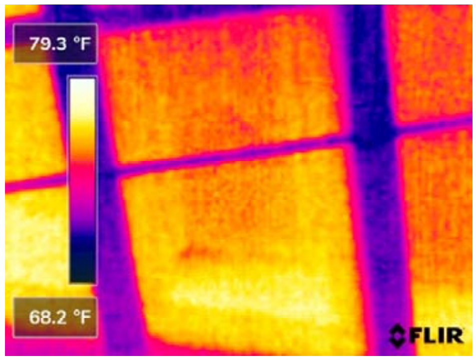

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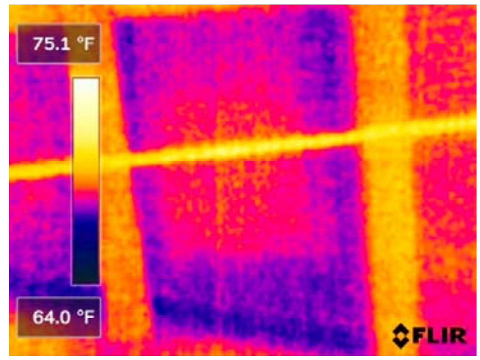

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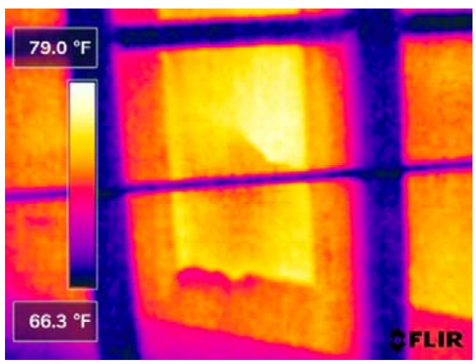

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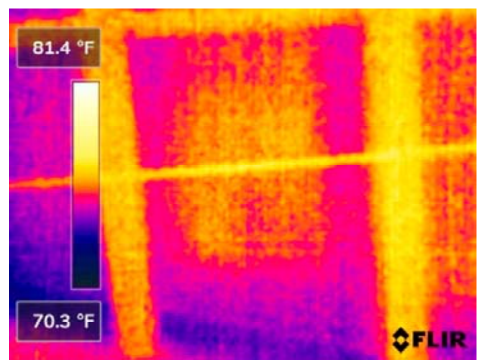

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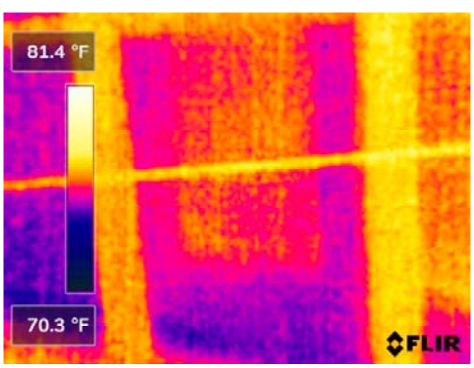

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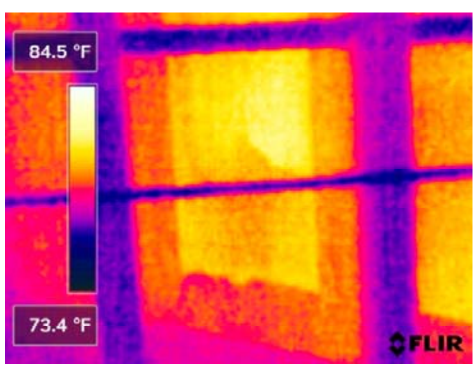

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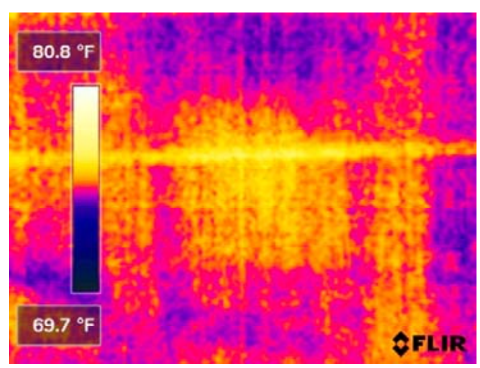

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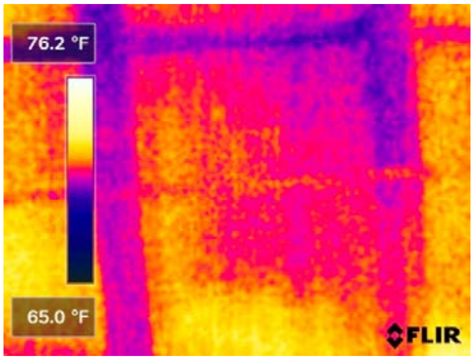

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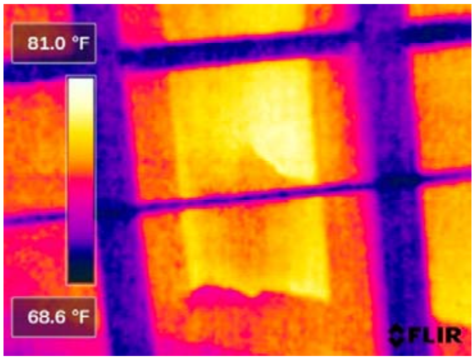

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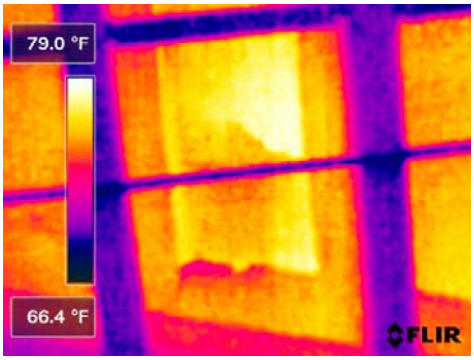

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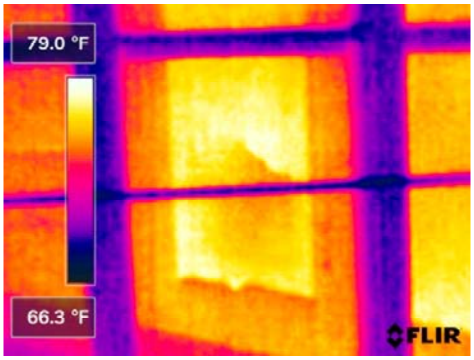

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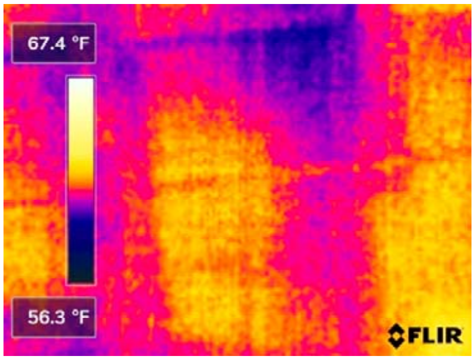

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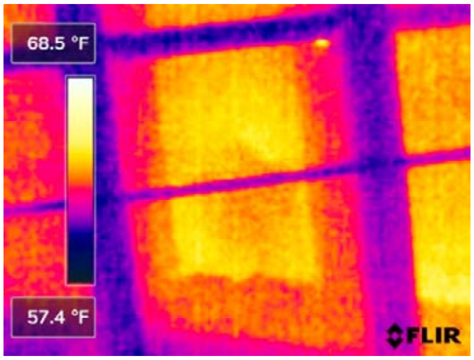

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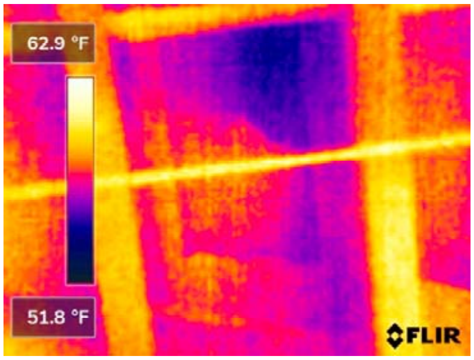

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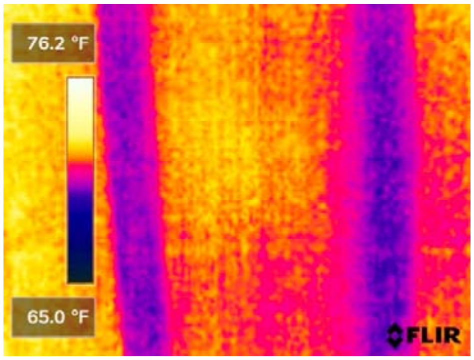

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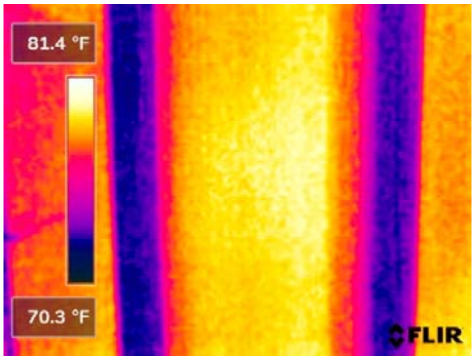

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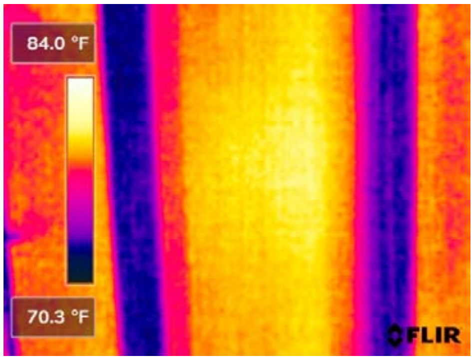

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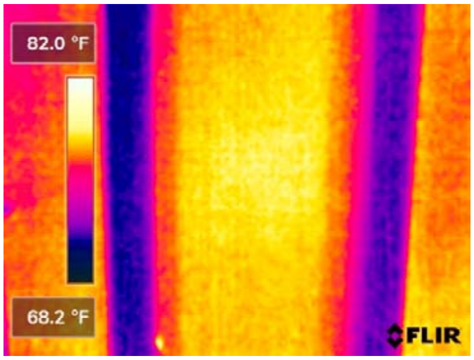

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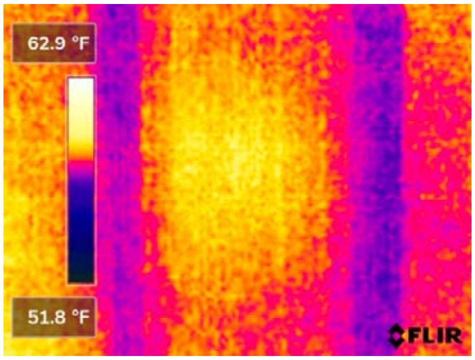

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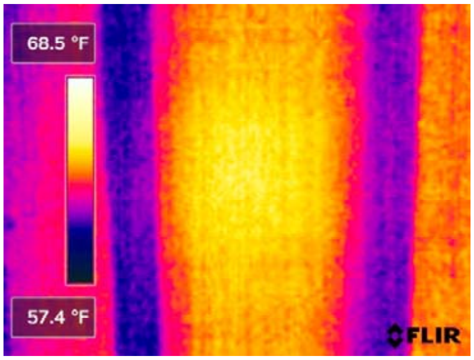

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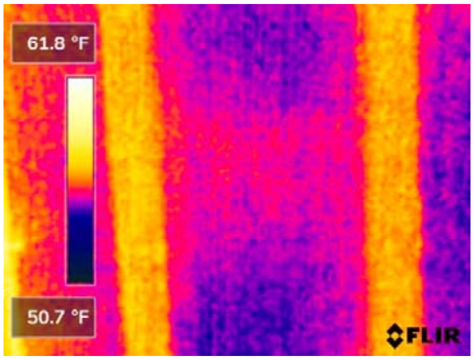

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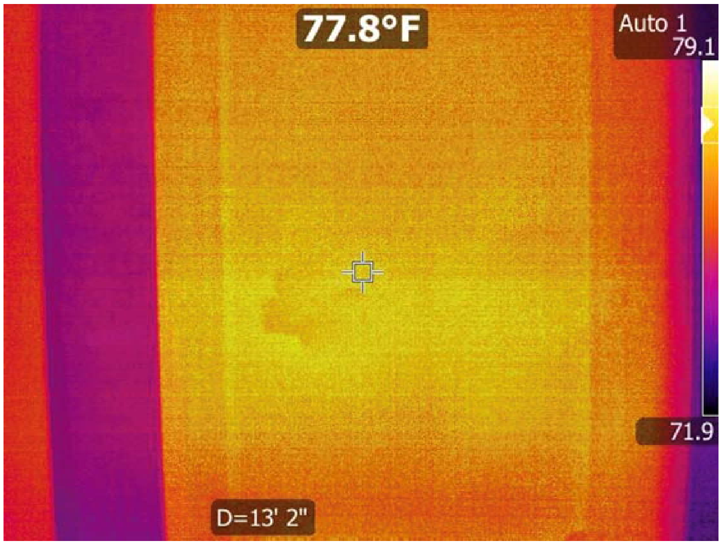

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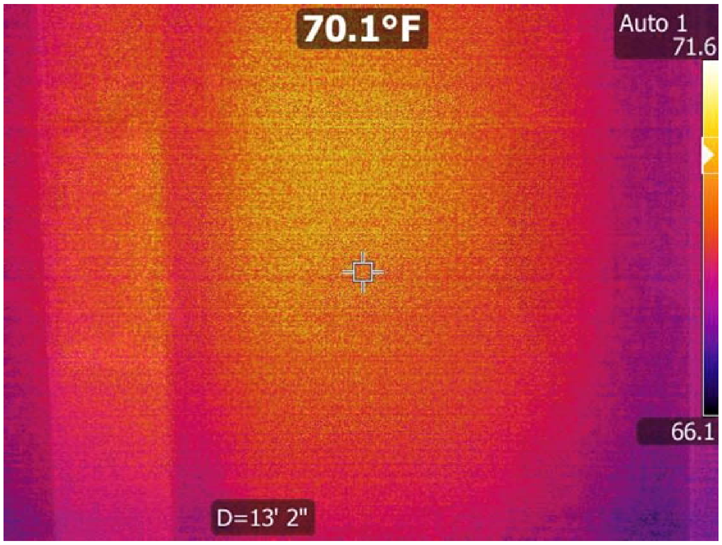

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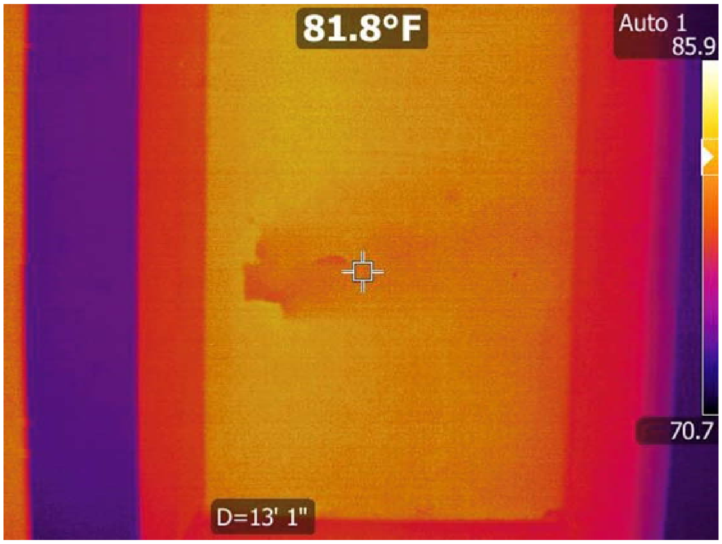

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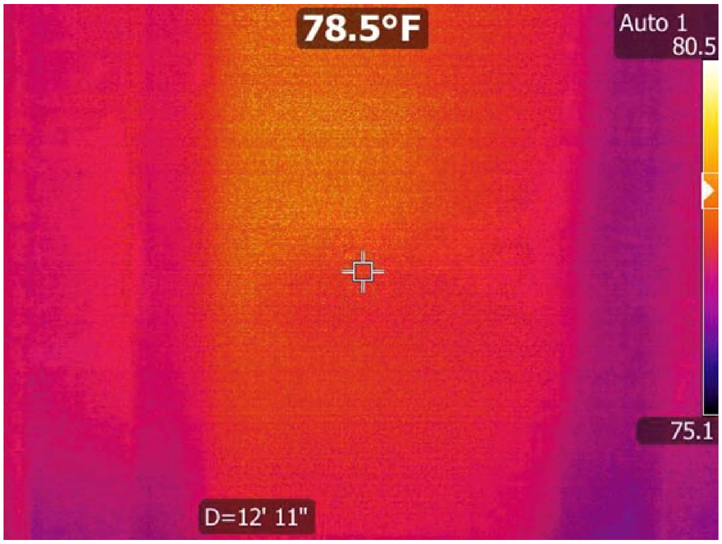

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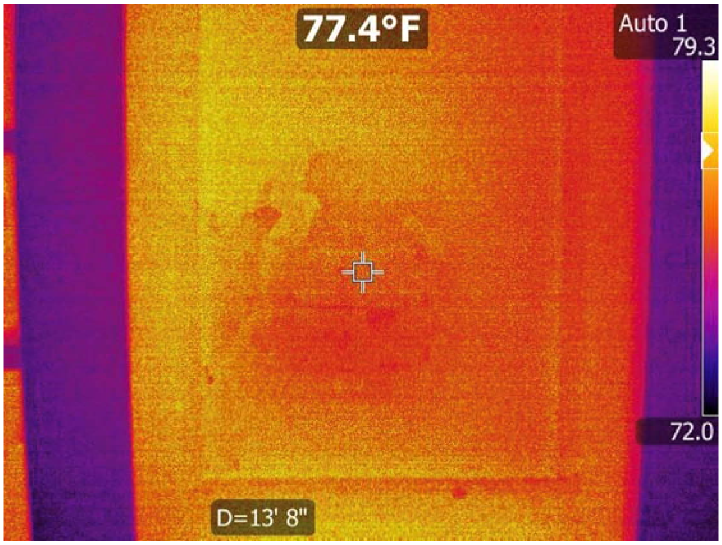

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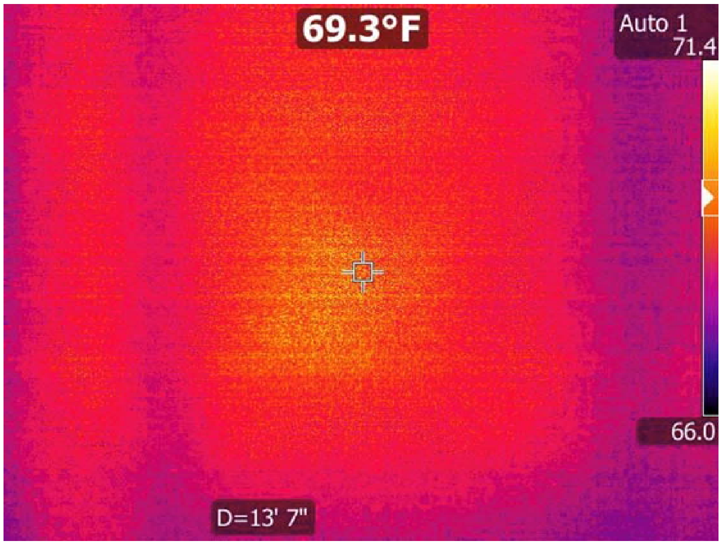

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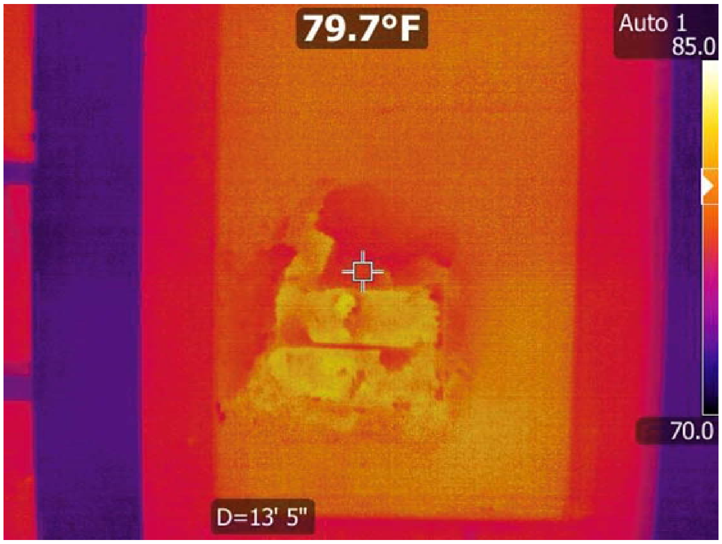

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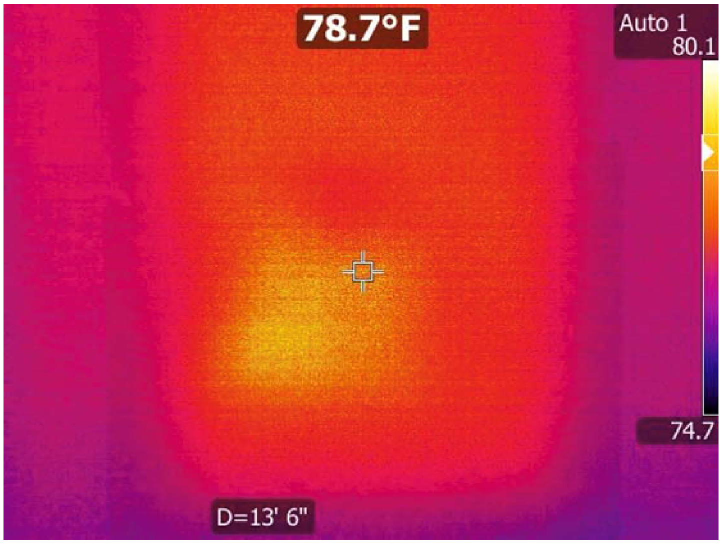

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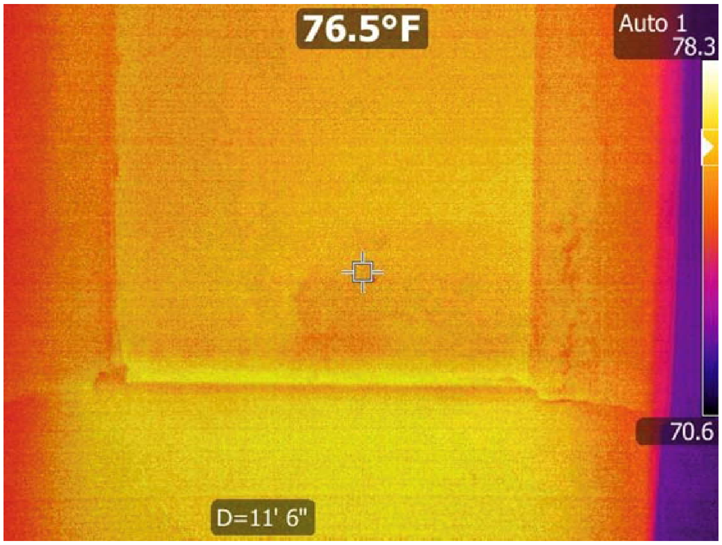

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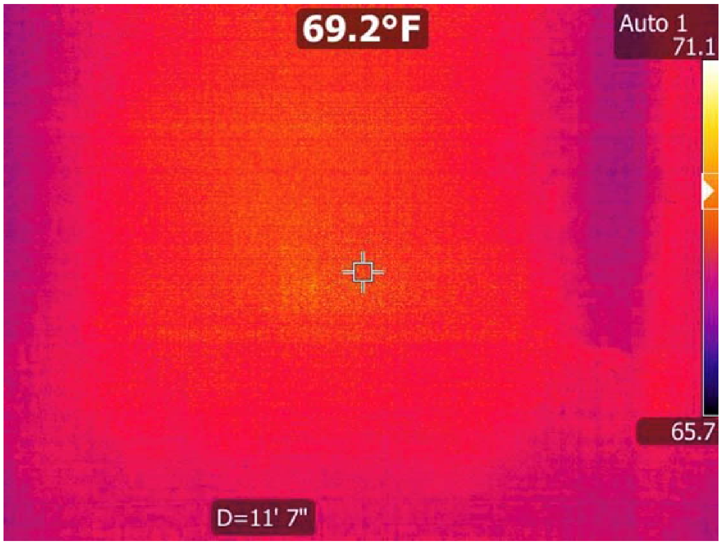

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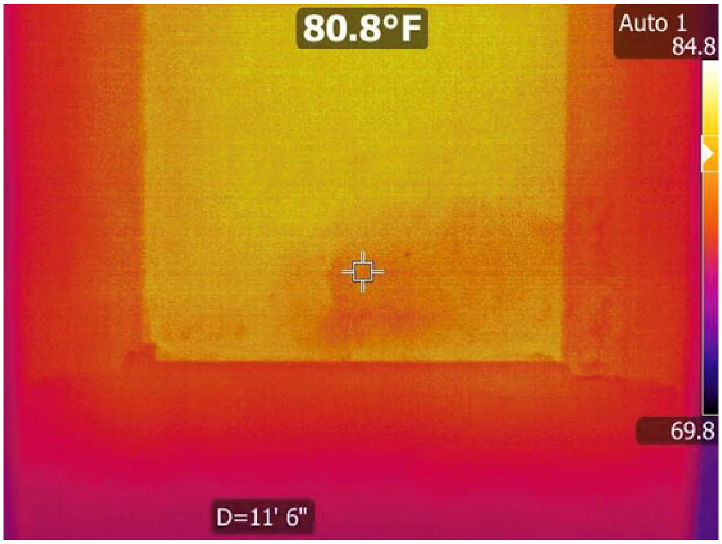

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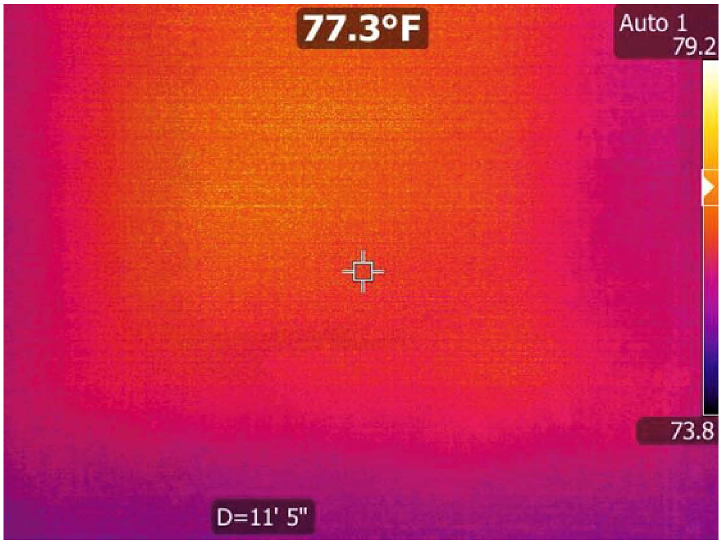

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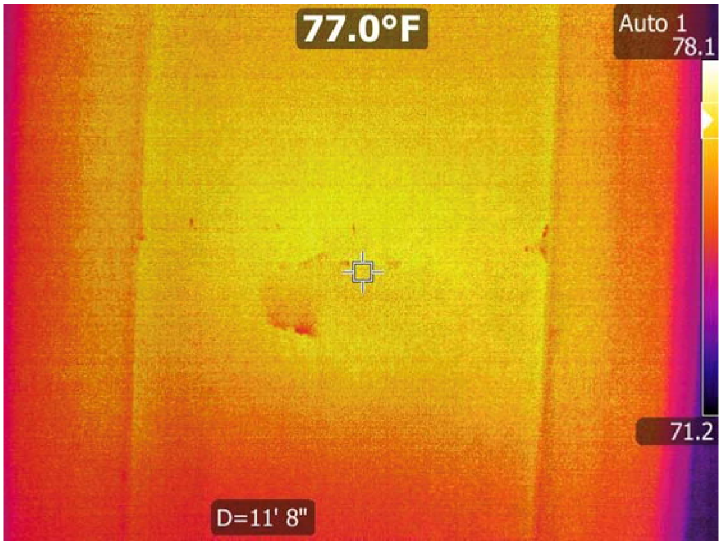

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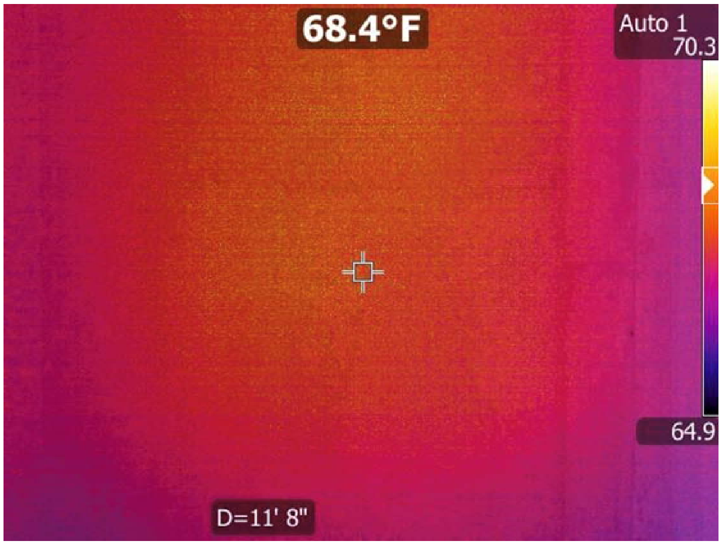

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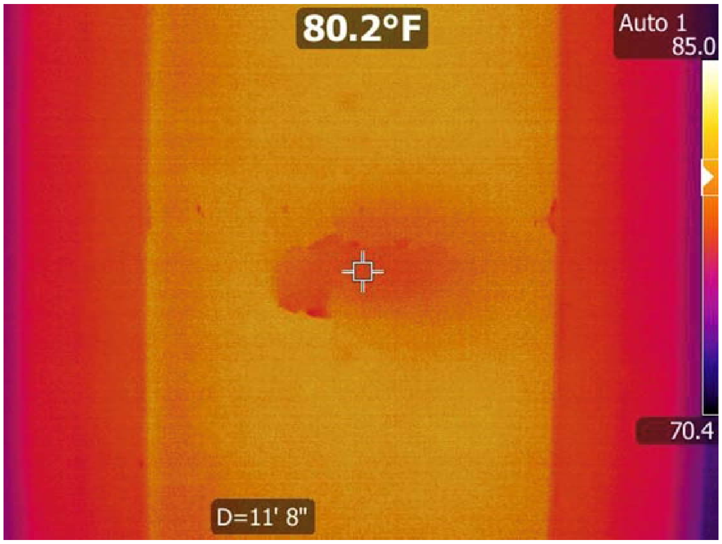

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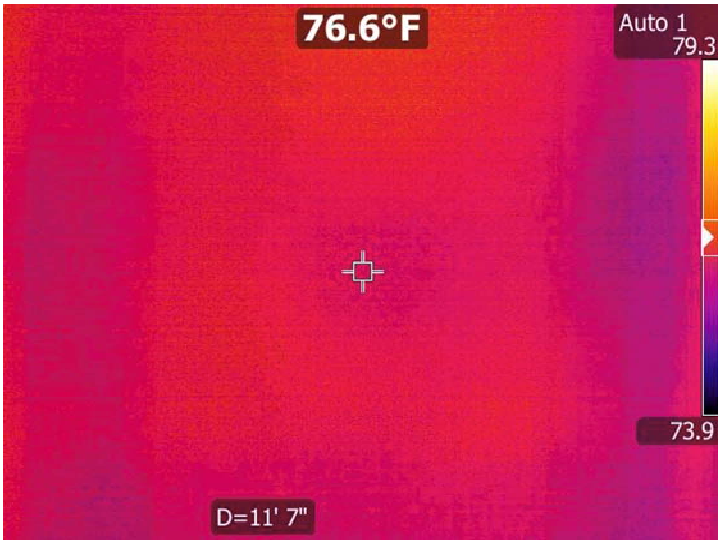

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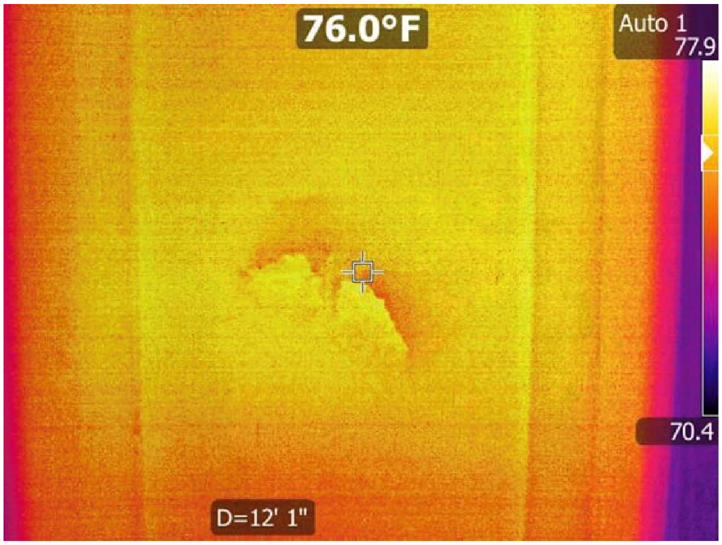

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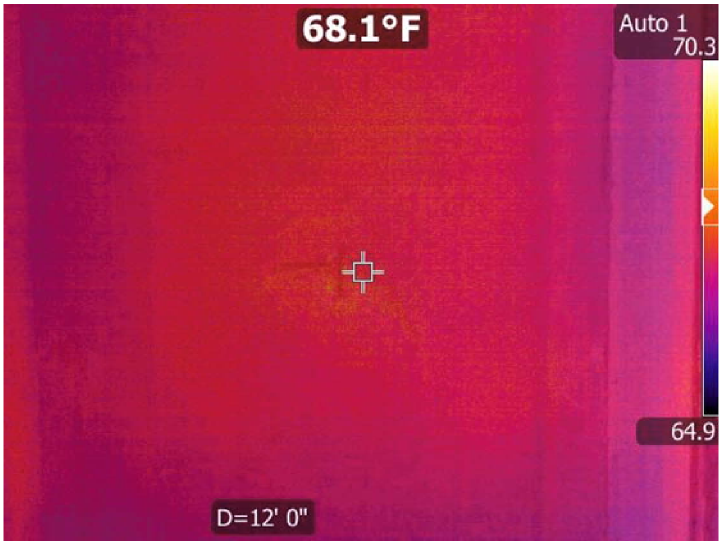

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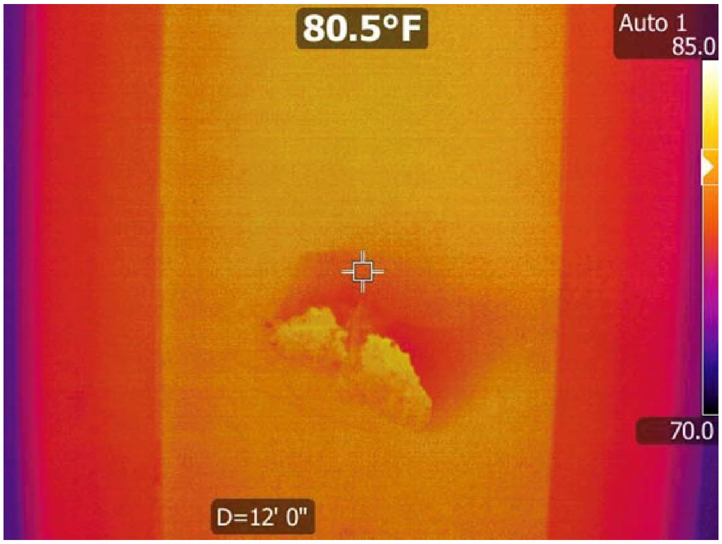

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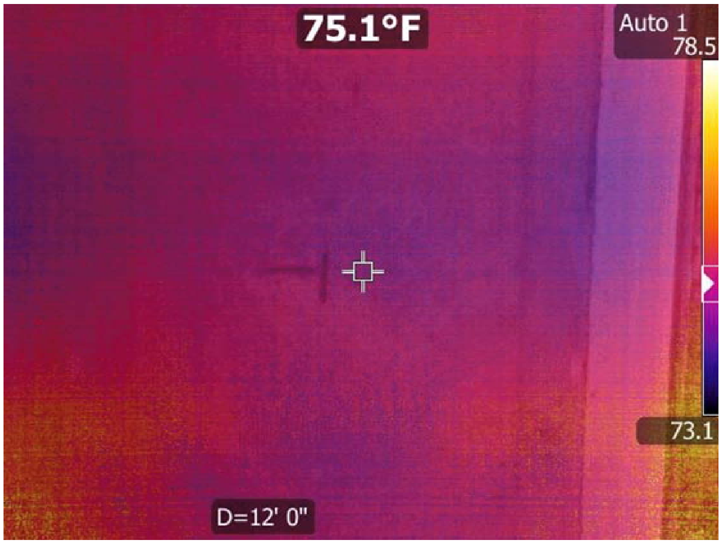

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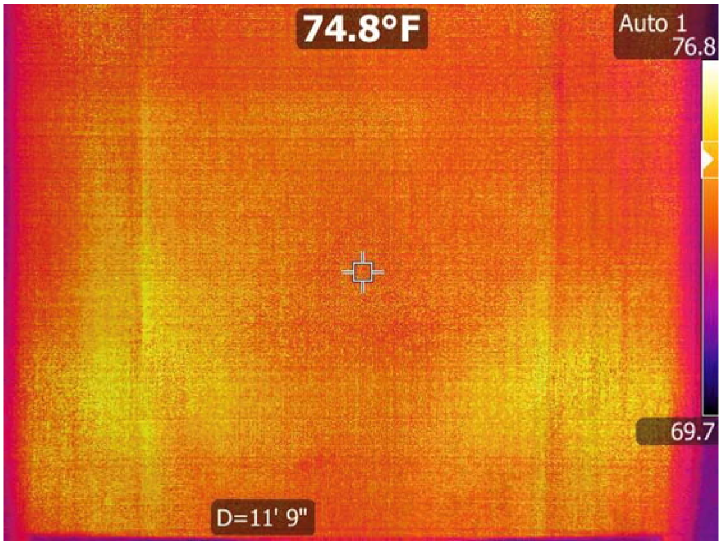

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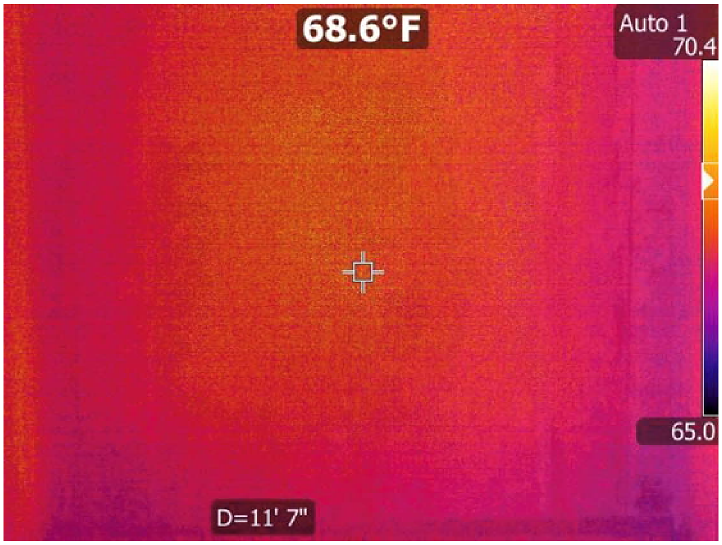

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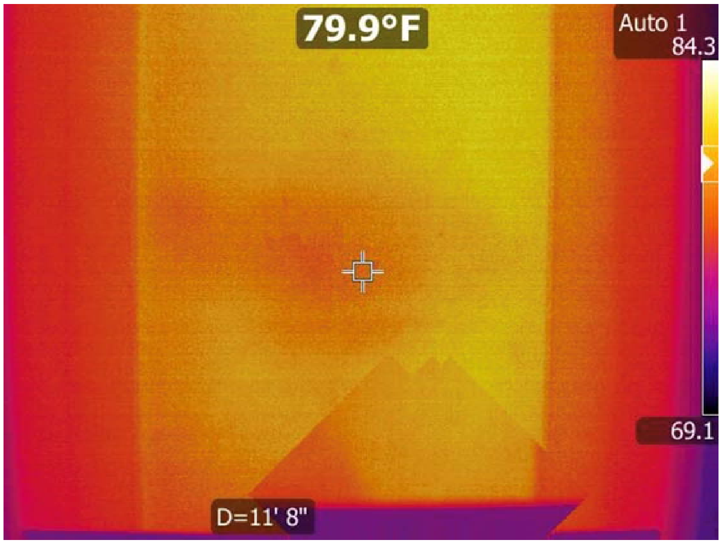

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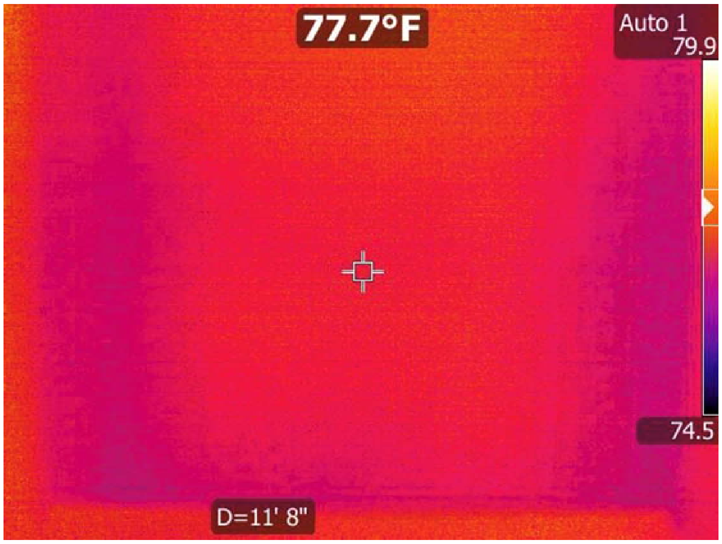

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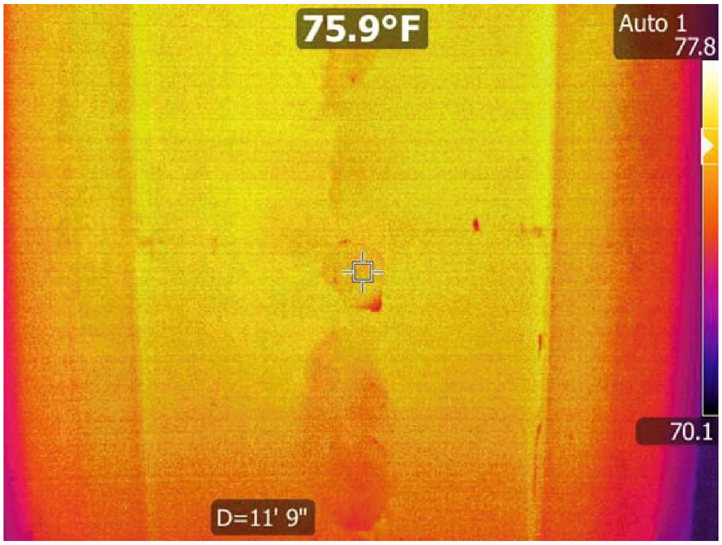

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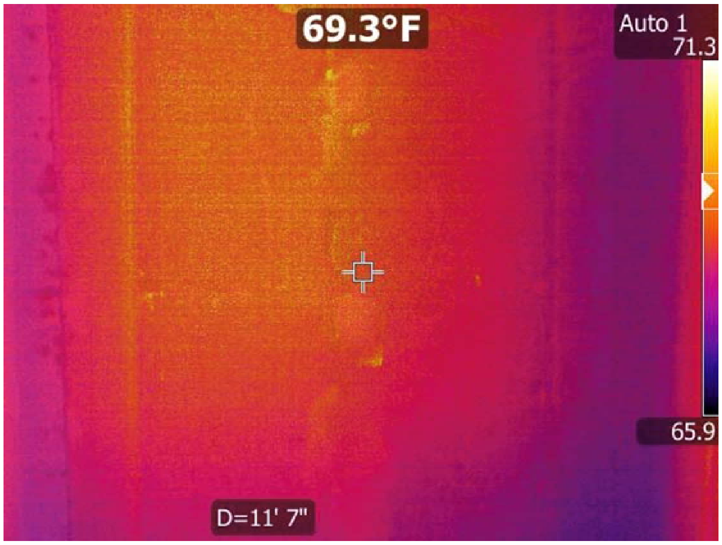

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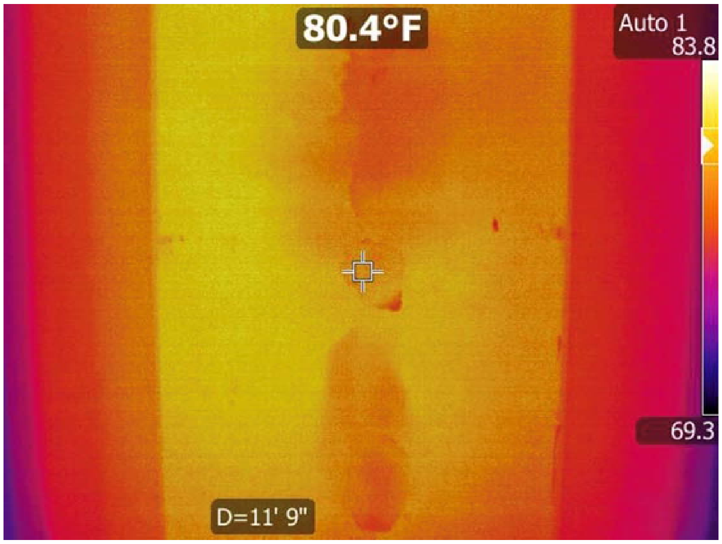

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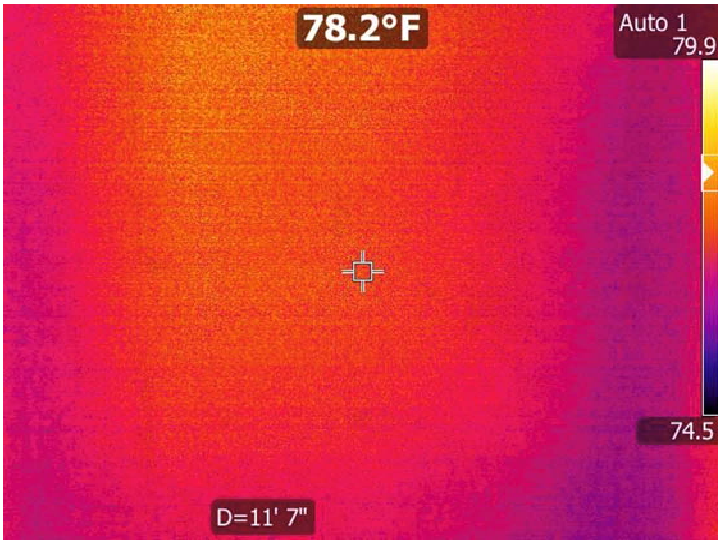

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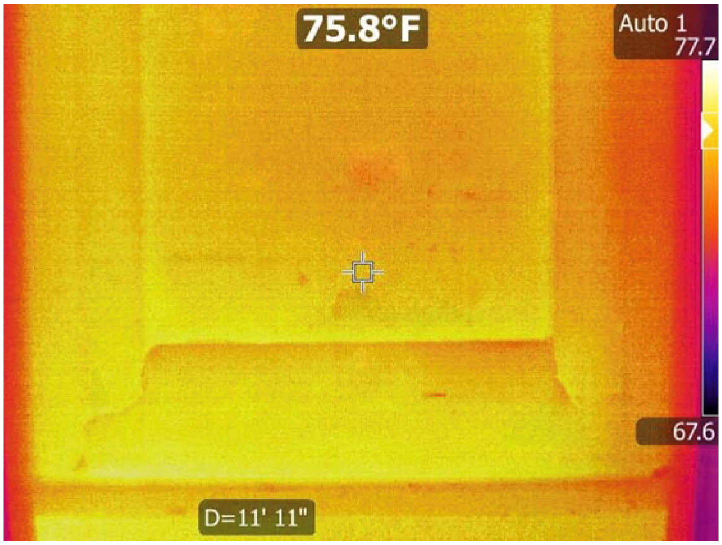

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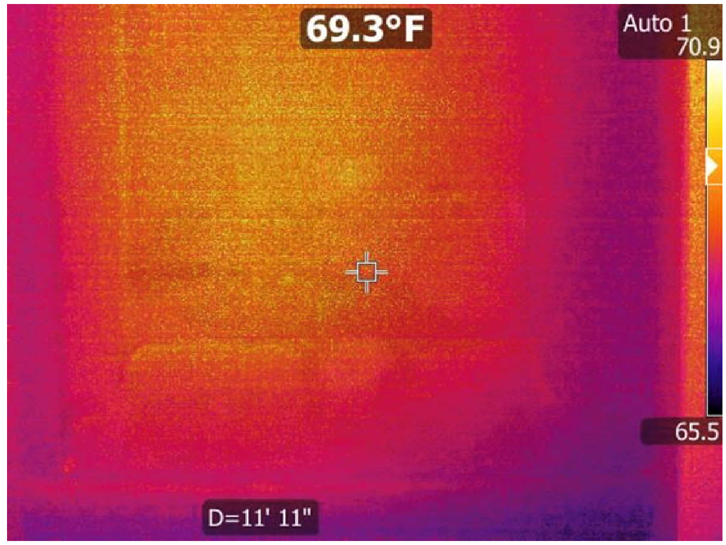

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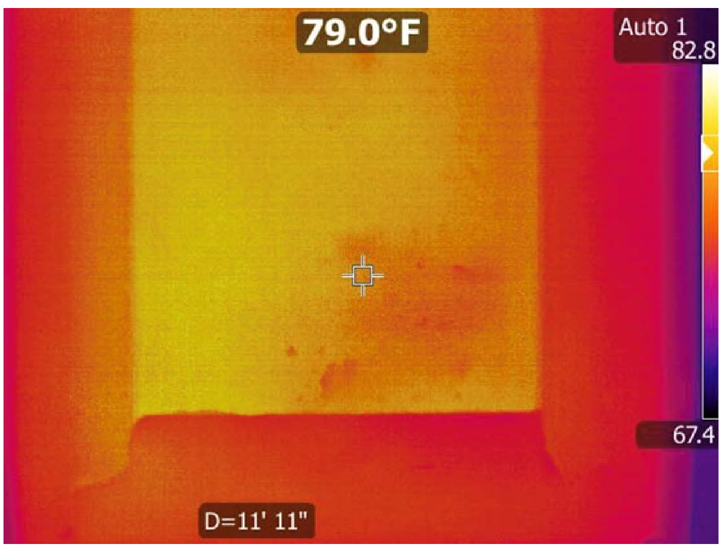

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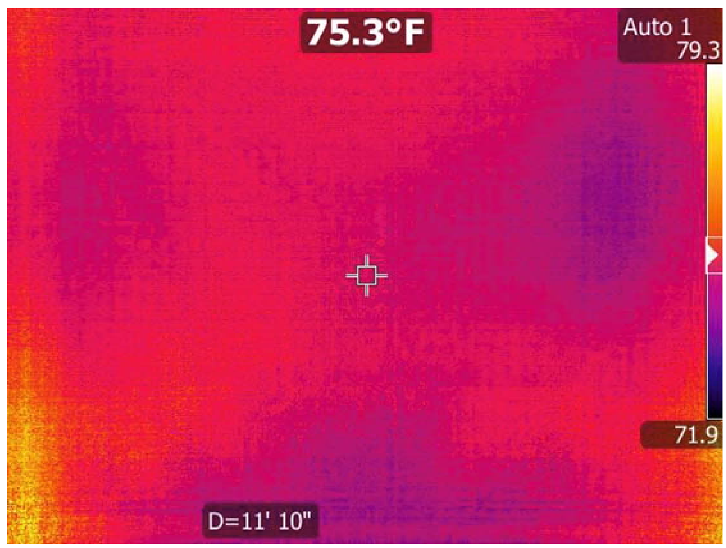

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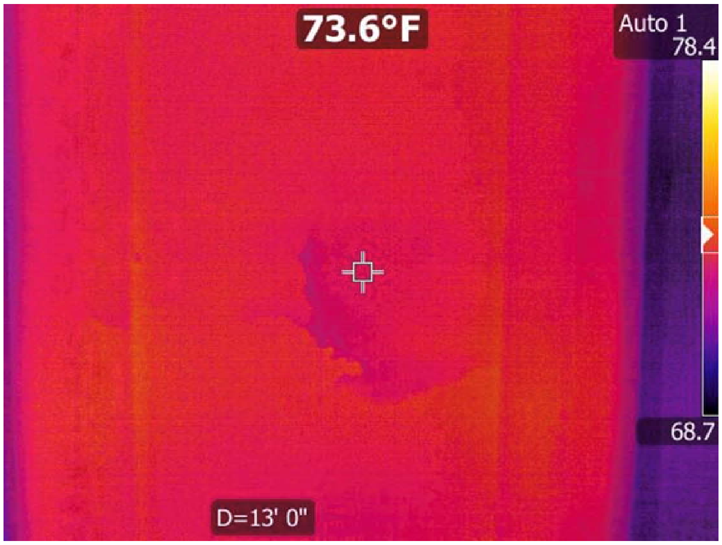

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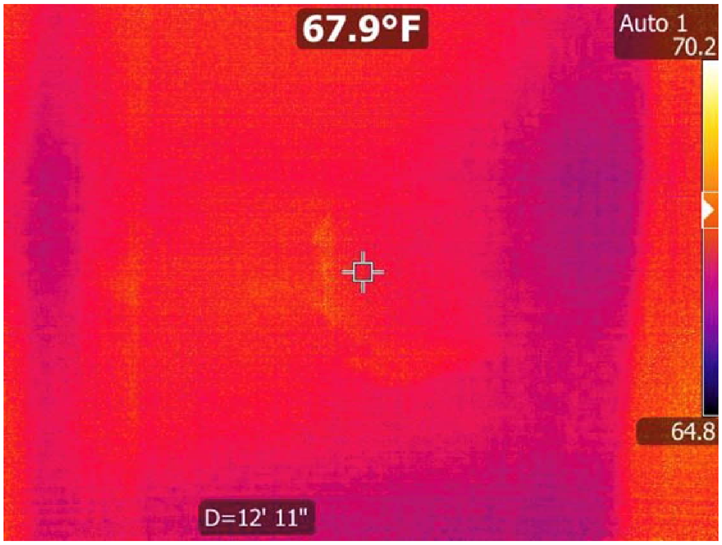

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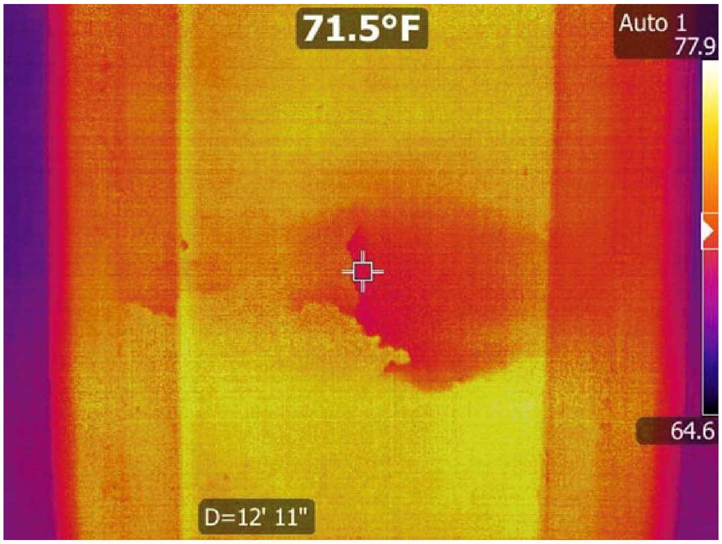

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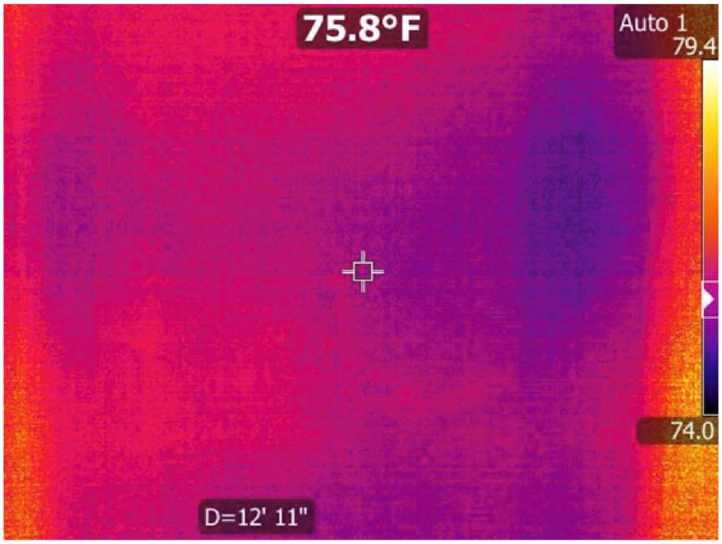

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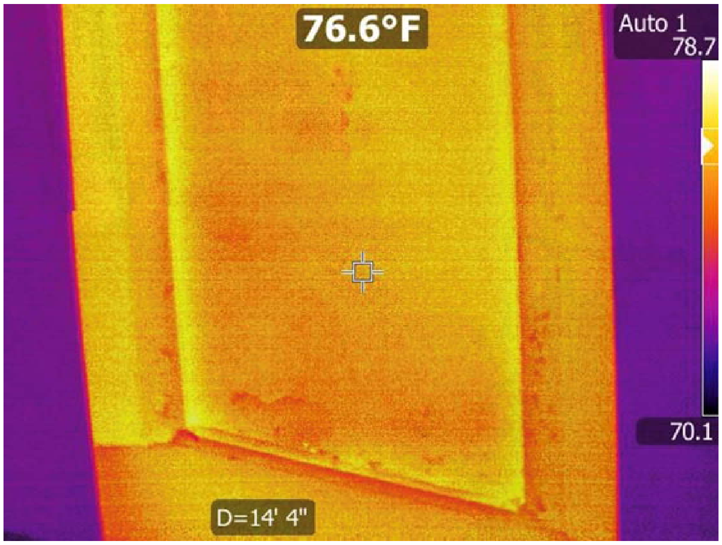

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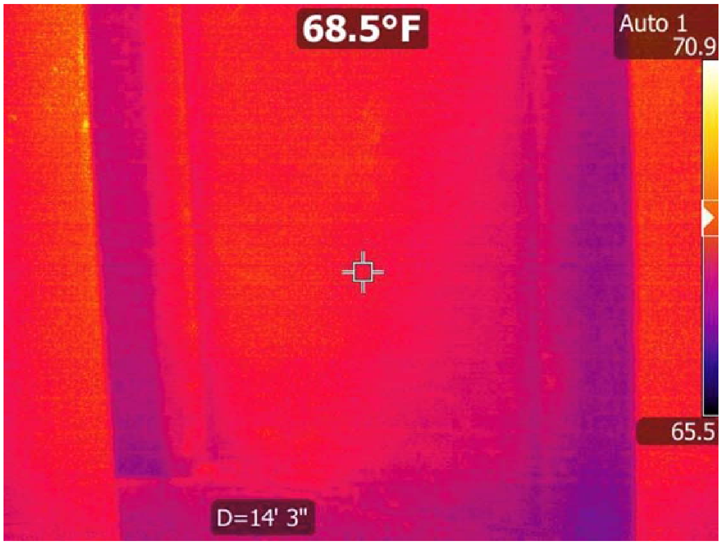

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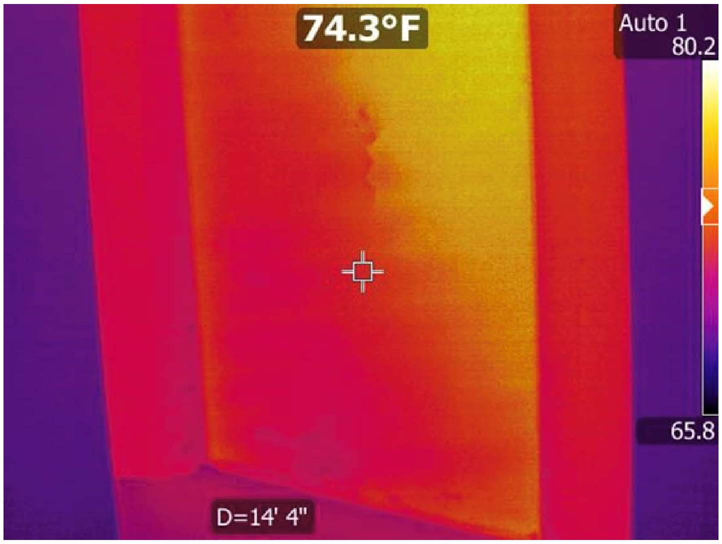

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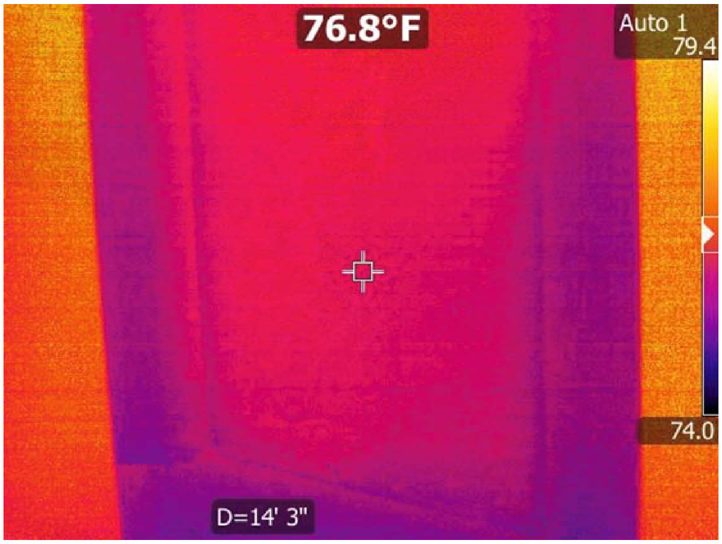

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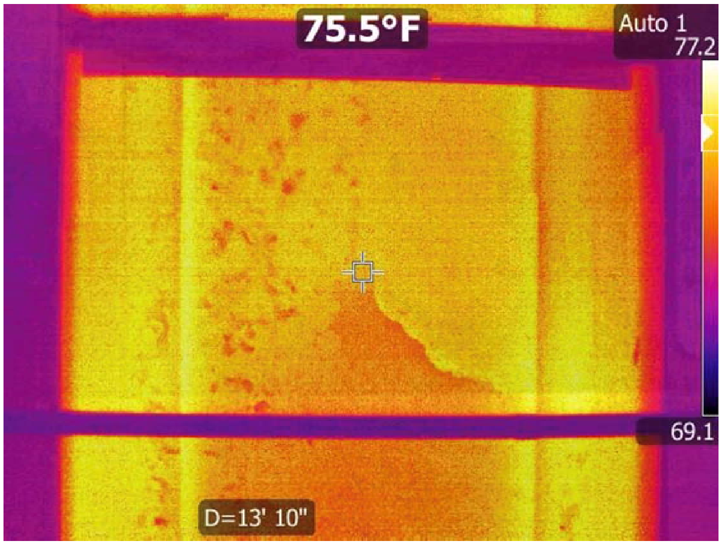

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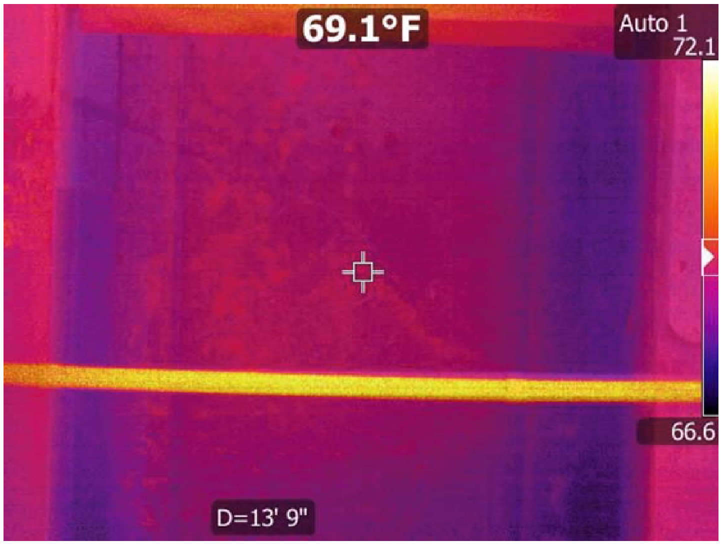

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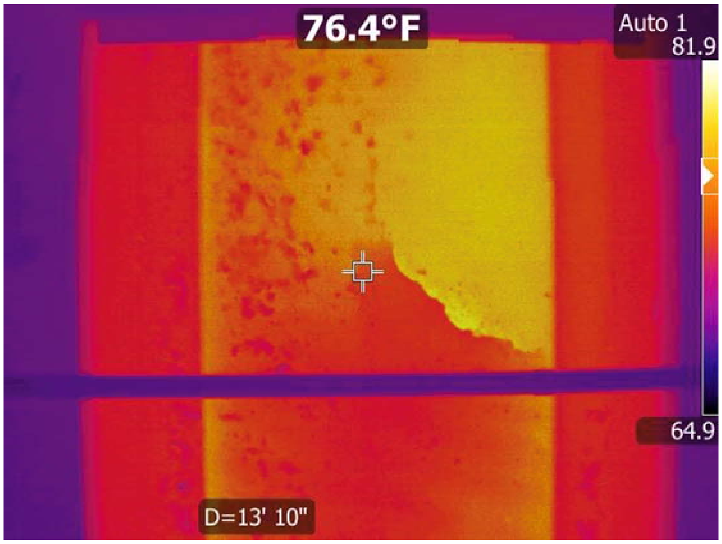

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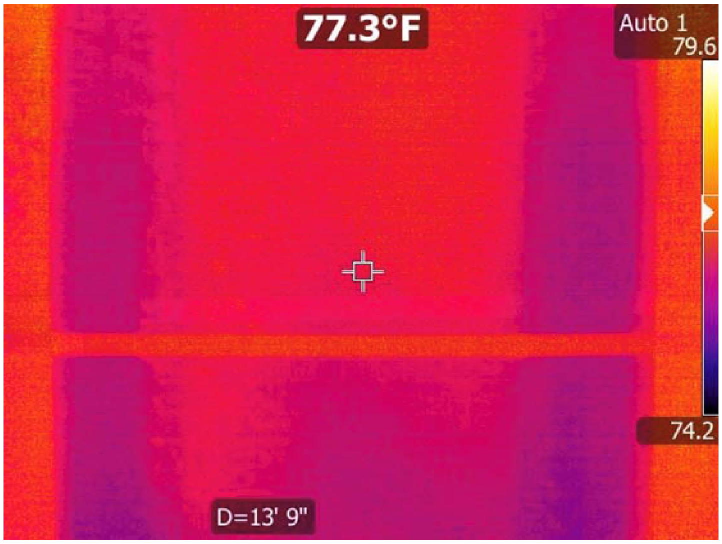

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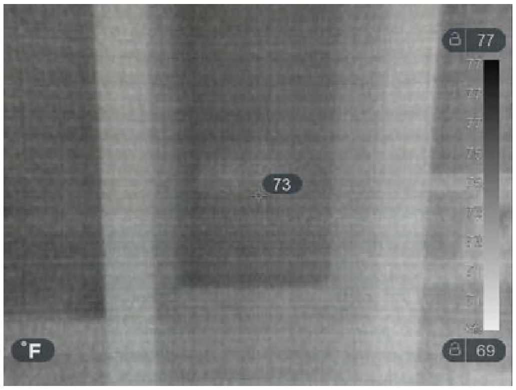

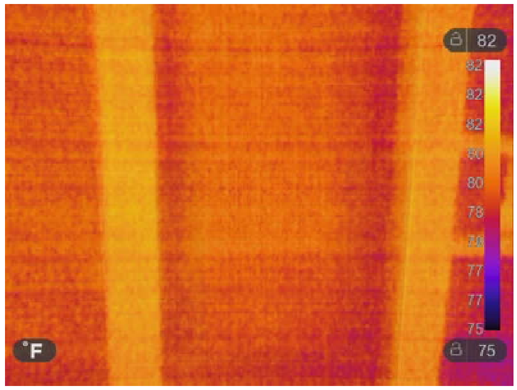

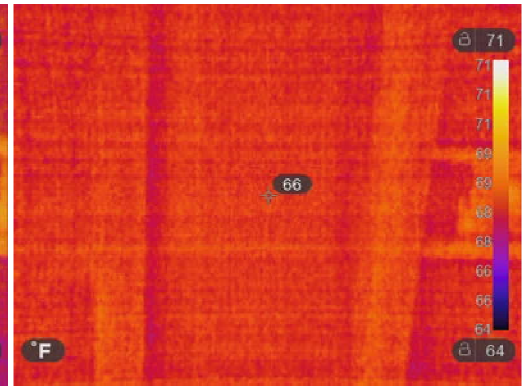

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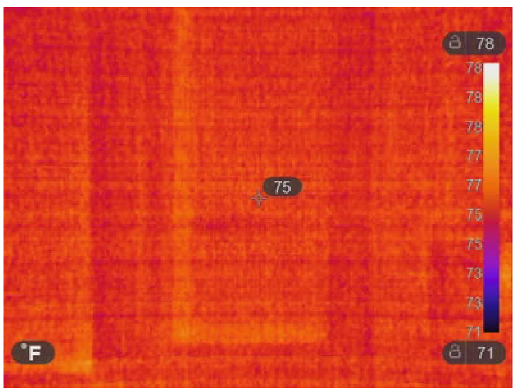

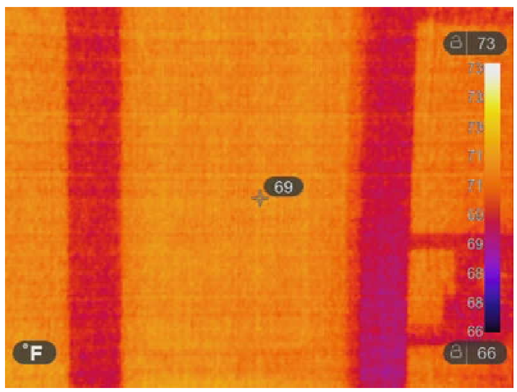

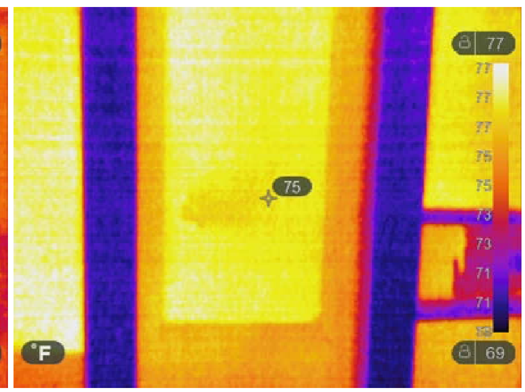

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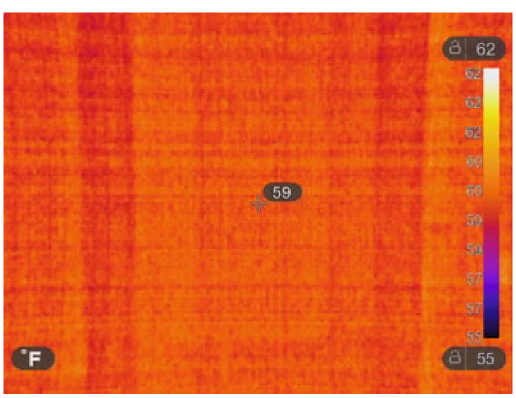

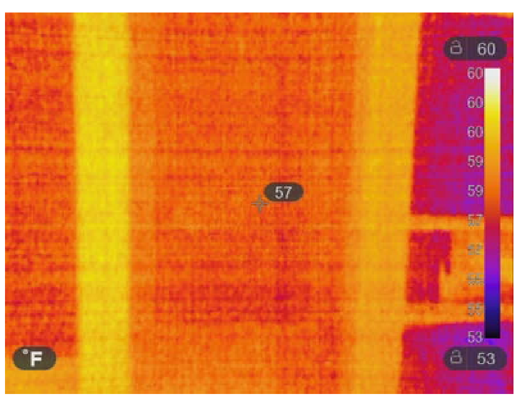

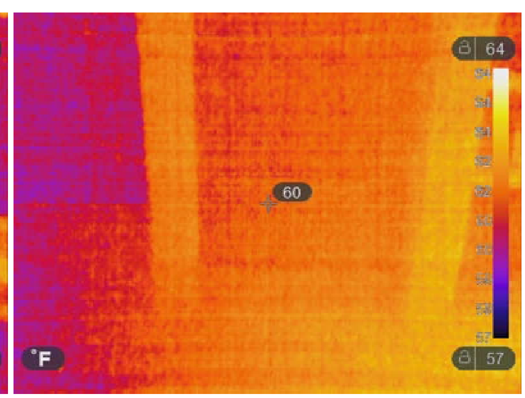

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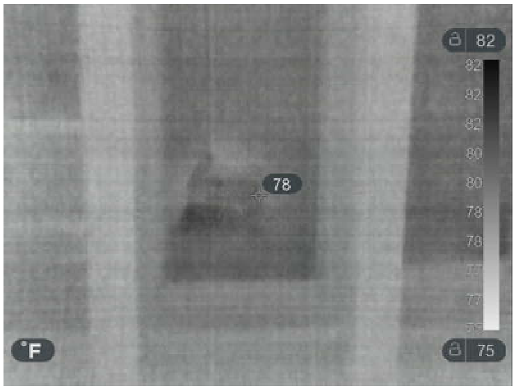

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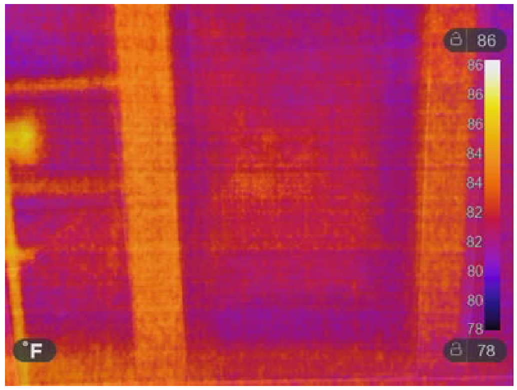

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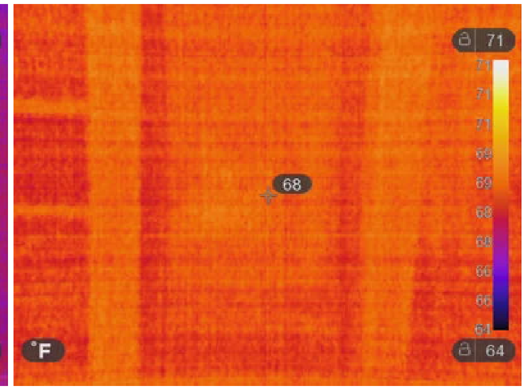

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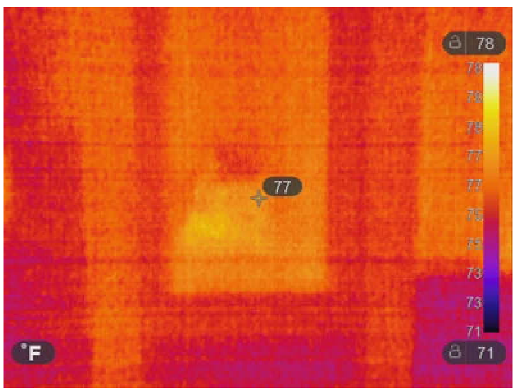

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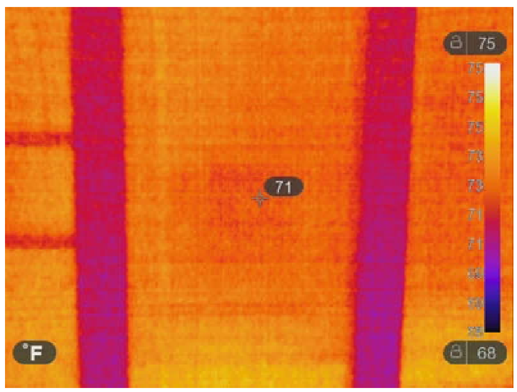

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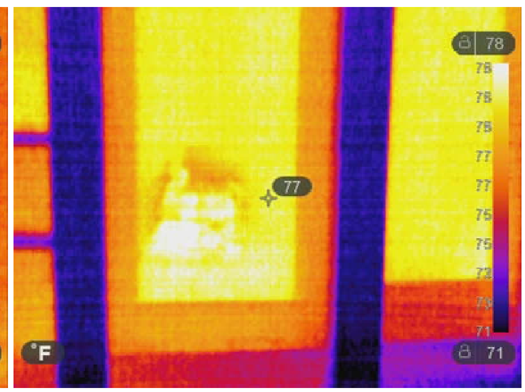

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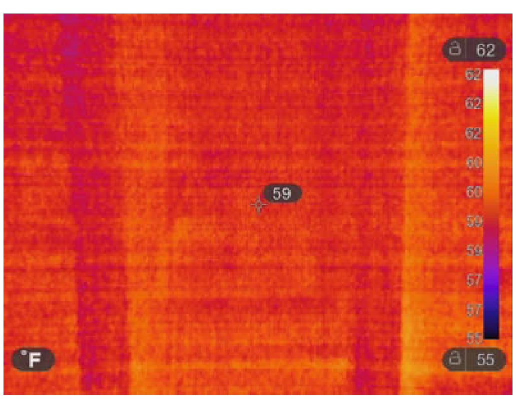

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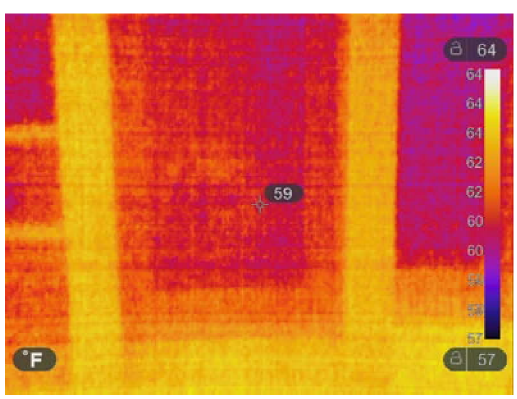

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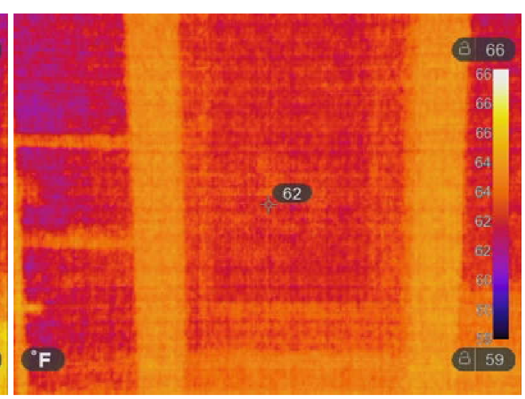

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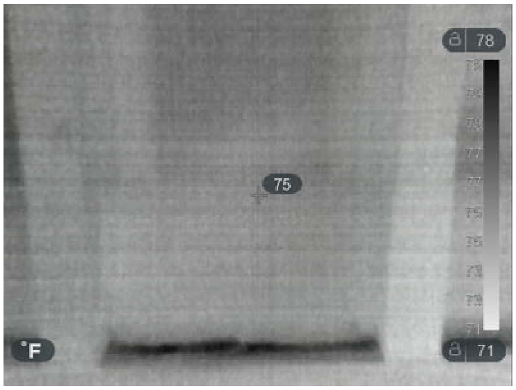

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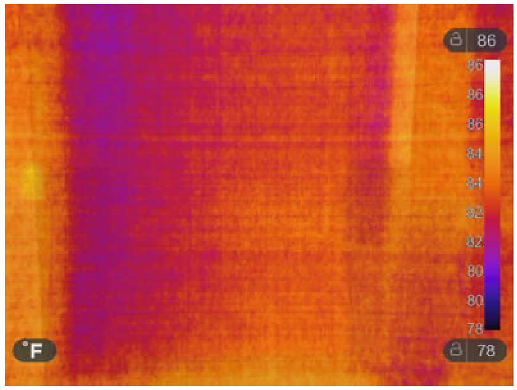

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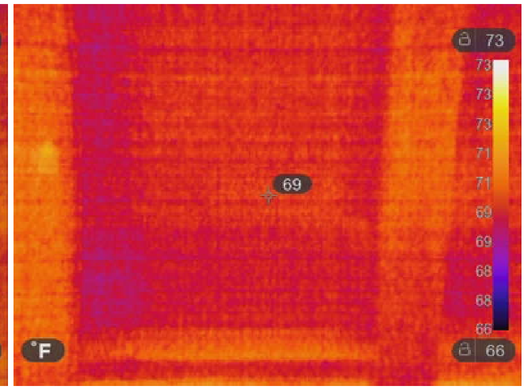

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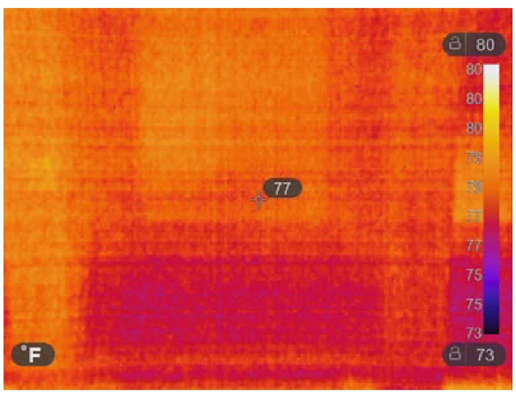

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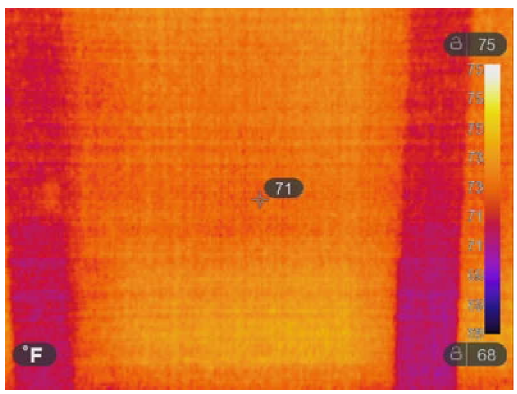

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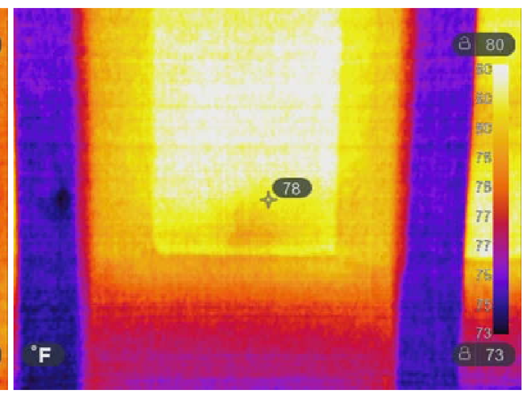

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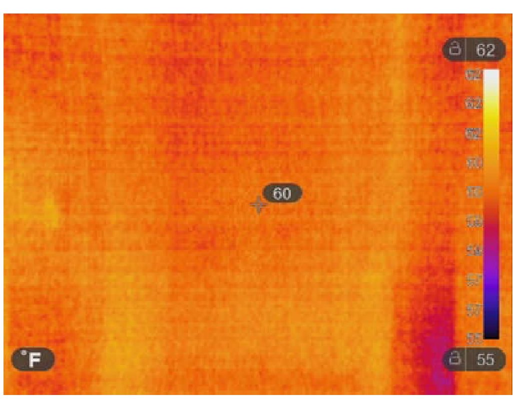

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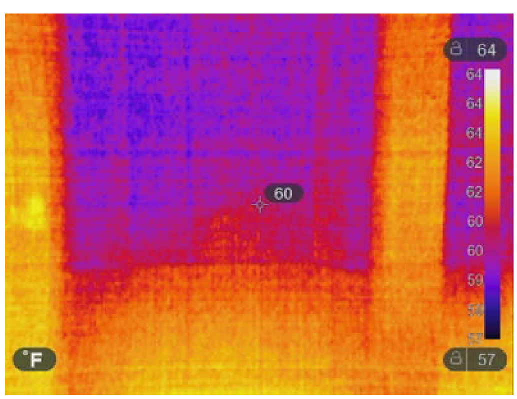

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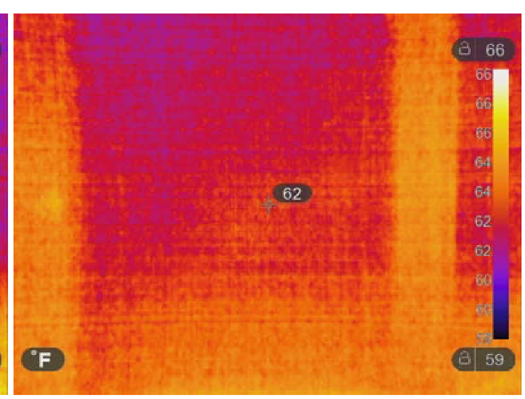

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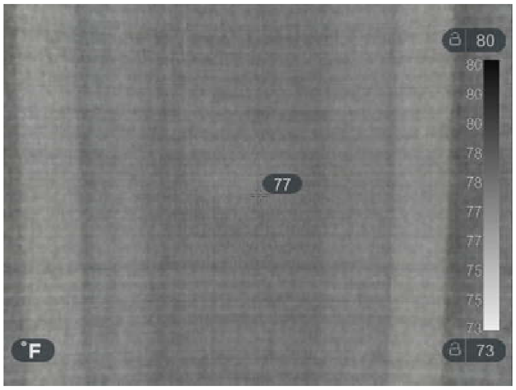

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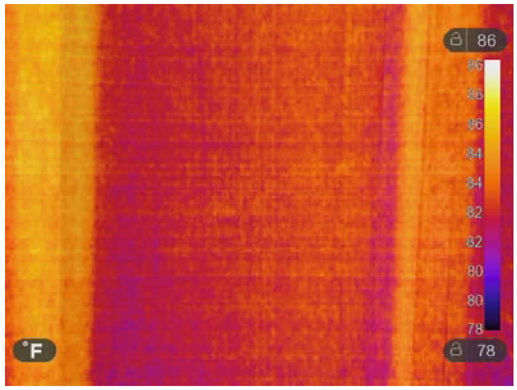

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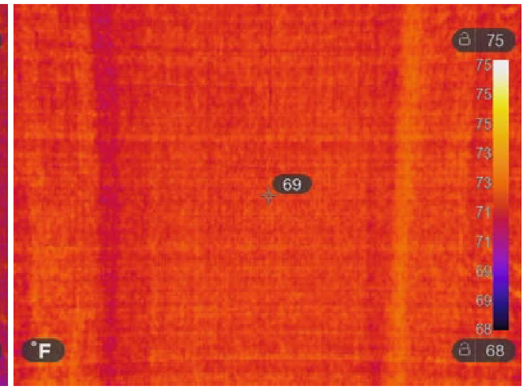

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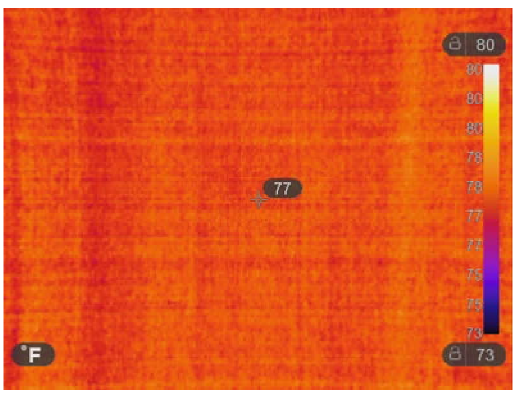

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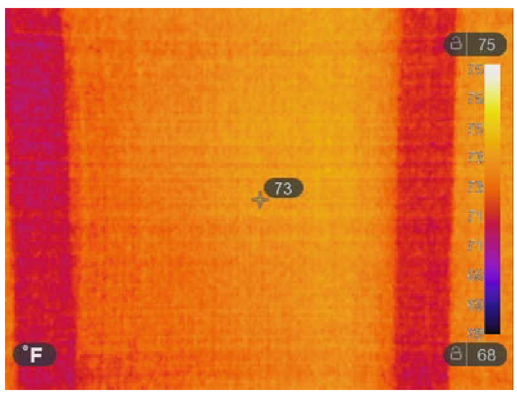

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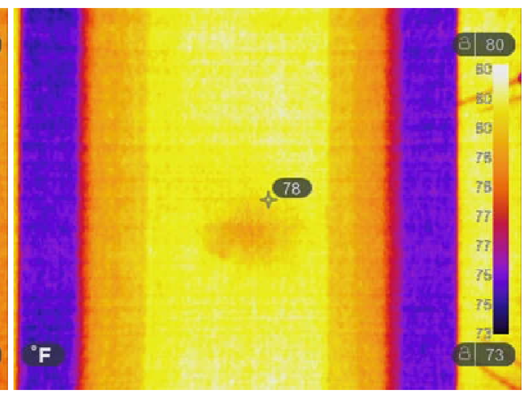

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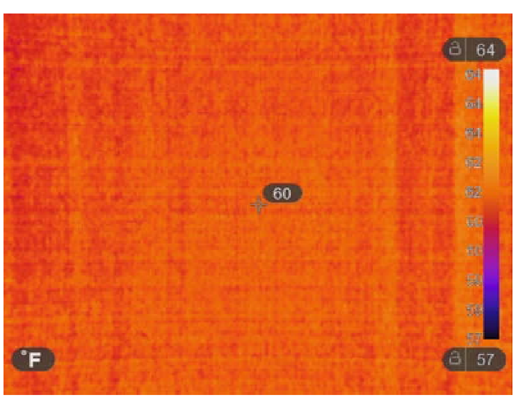

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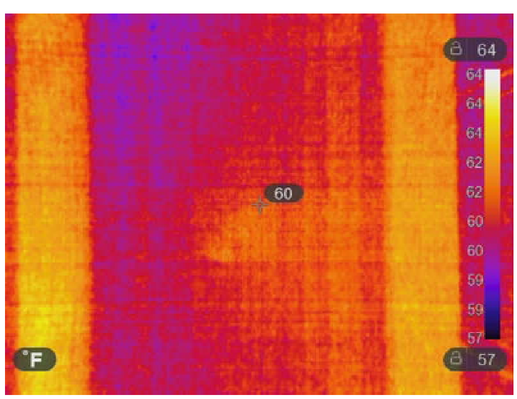

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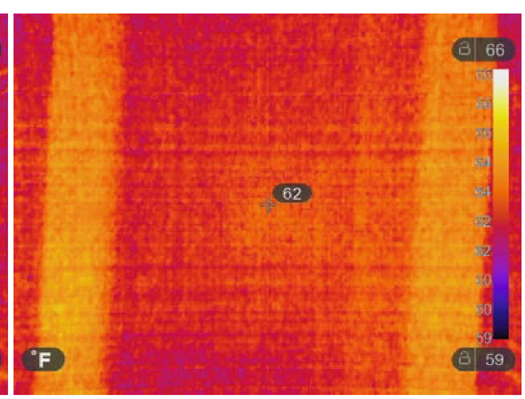

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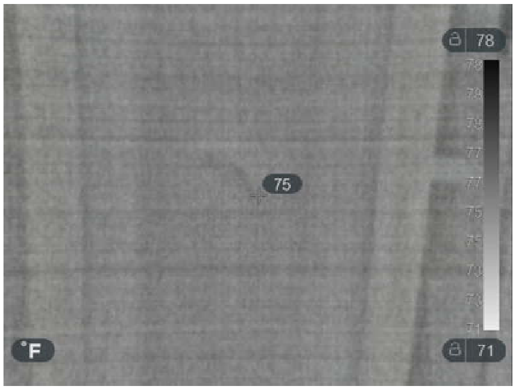

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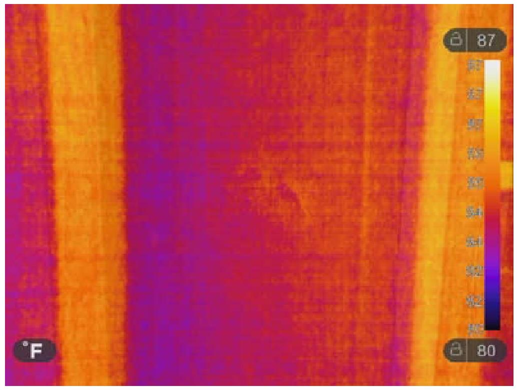

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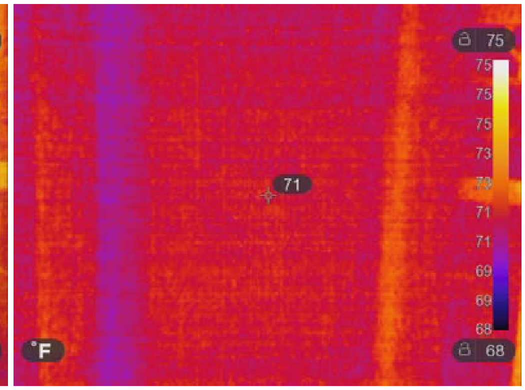

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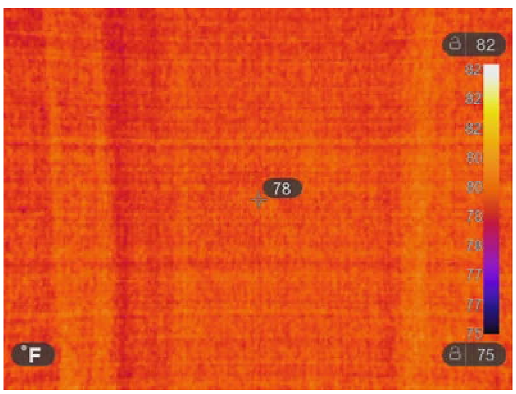

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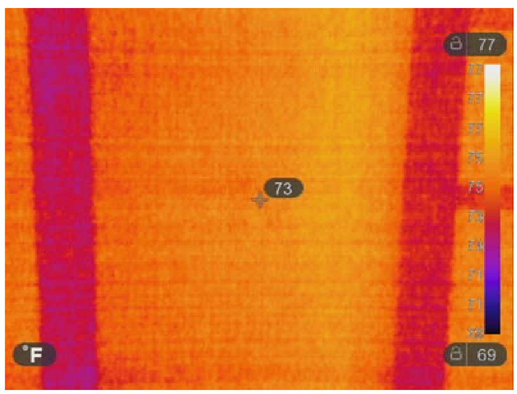

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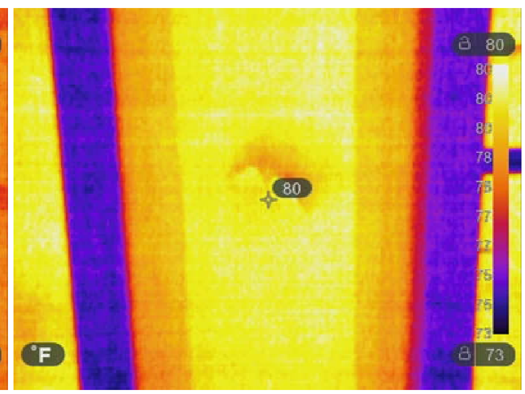

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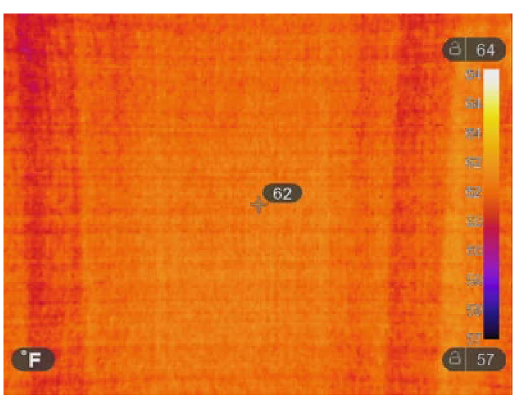

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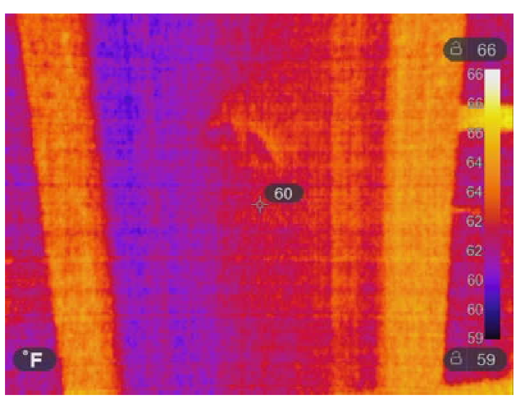

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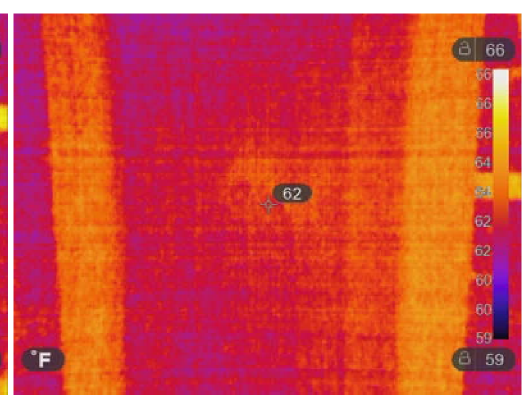

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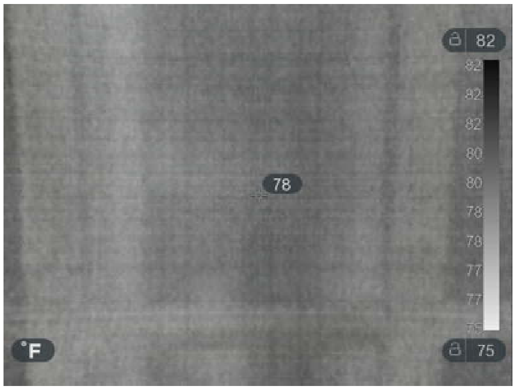

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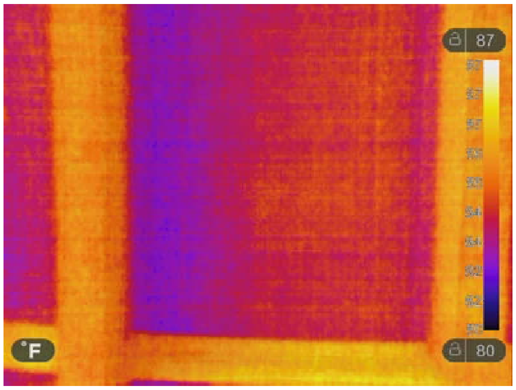

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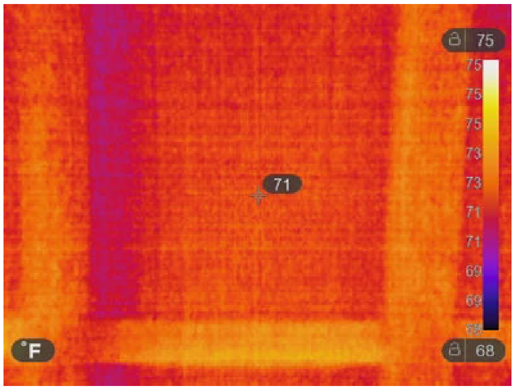

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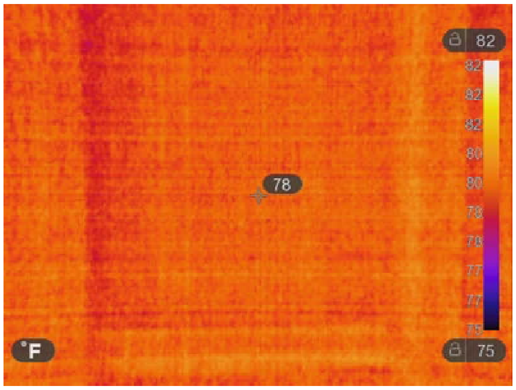

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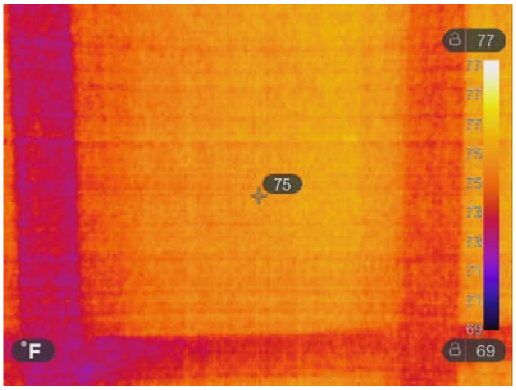

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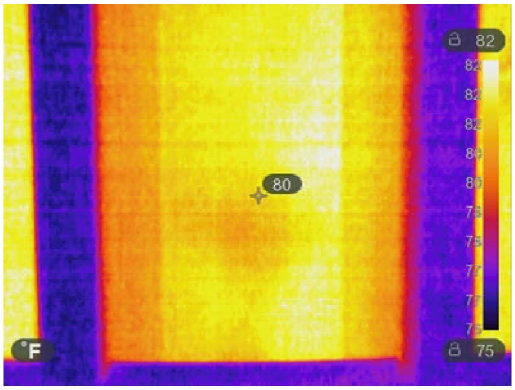

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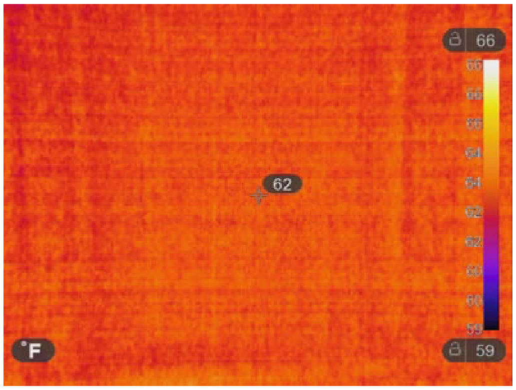

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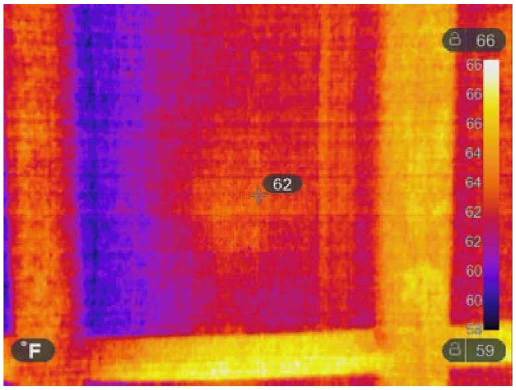

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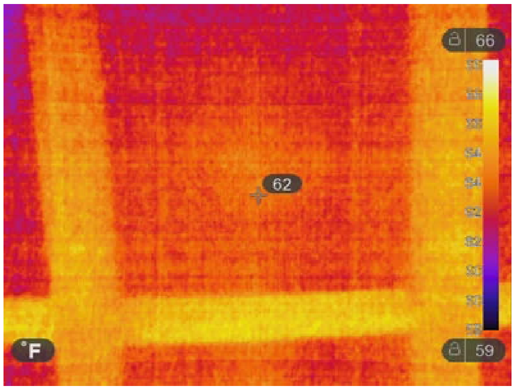

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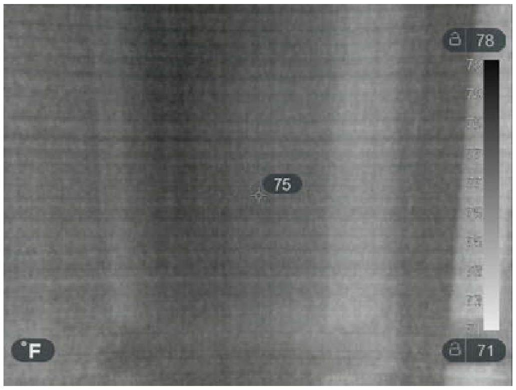

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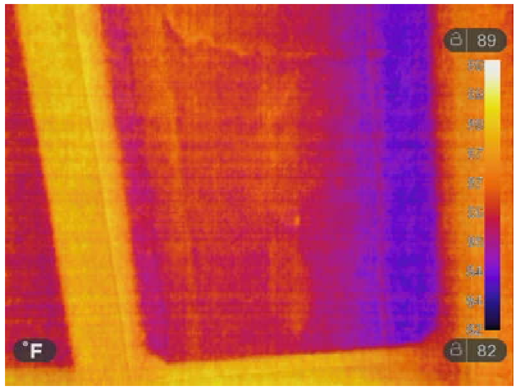
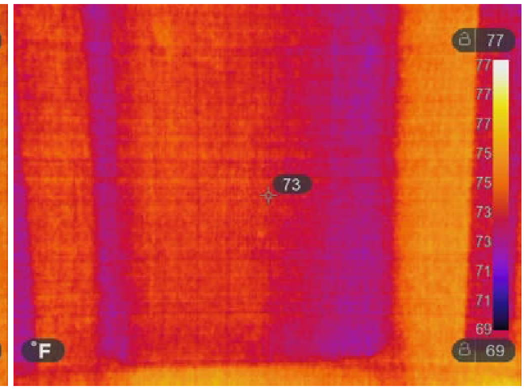
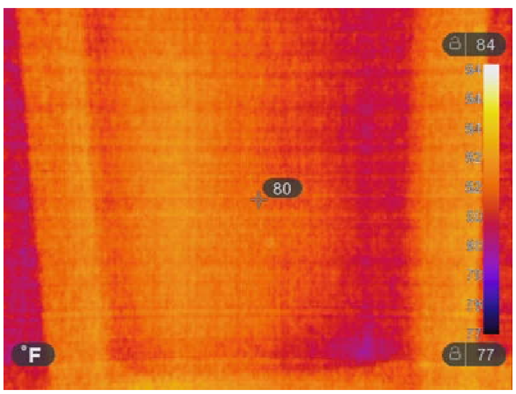


Seek_Loc07_02_20210915_113442_A



Seek_Loc07_03_20210918_131213_A



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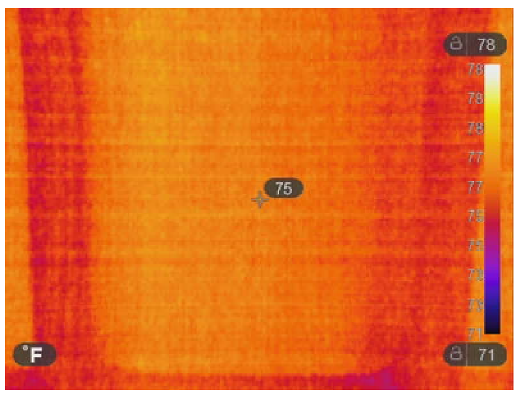

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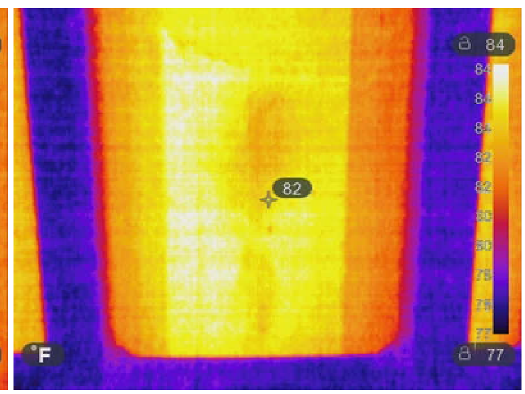

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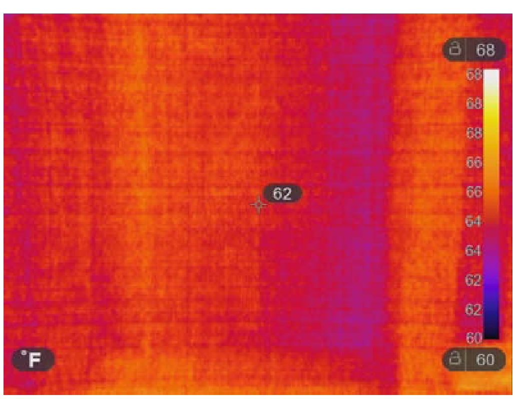

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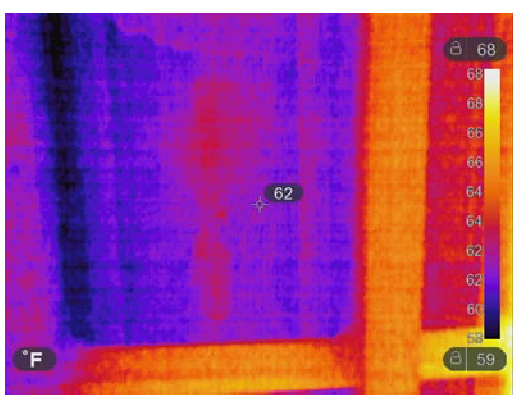

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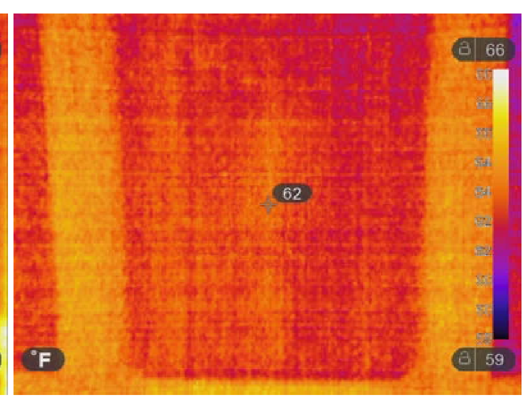

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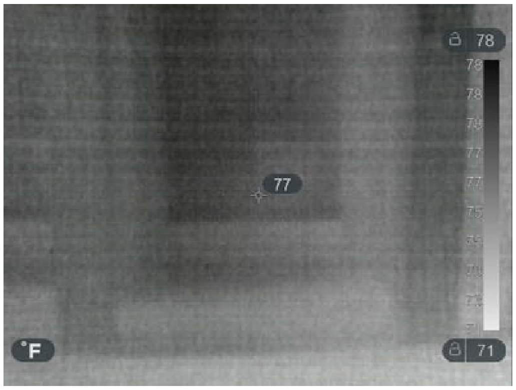

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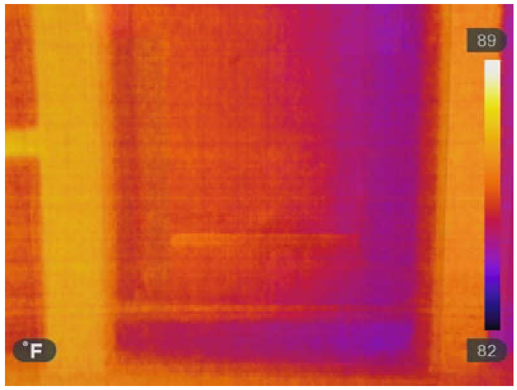

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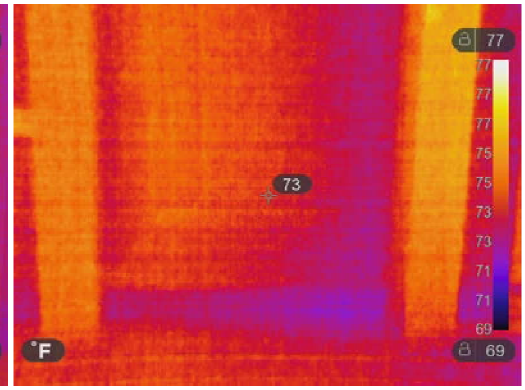

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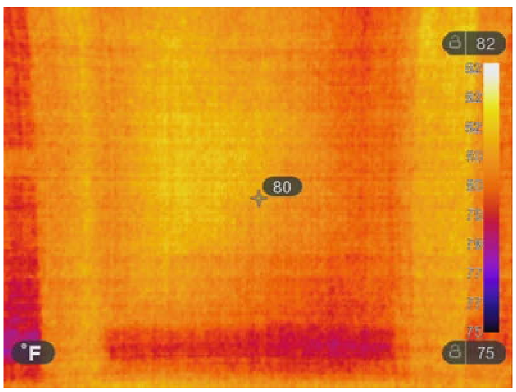

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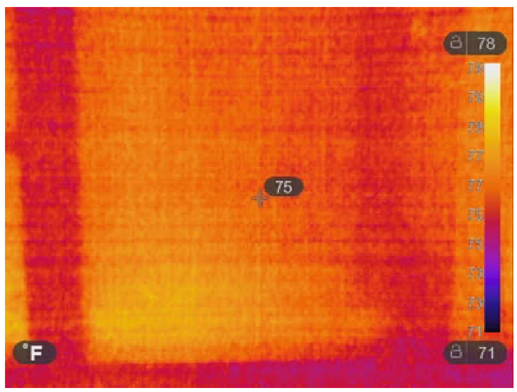

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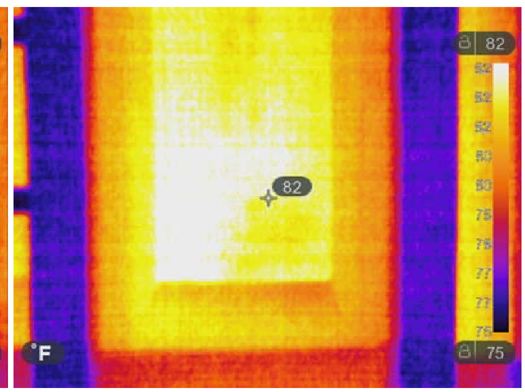

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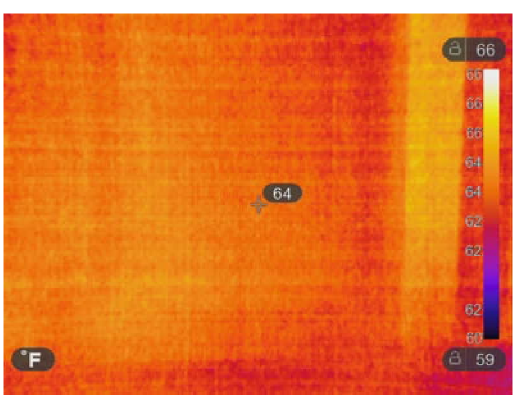

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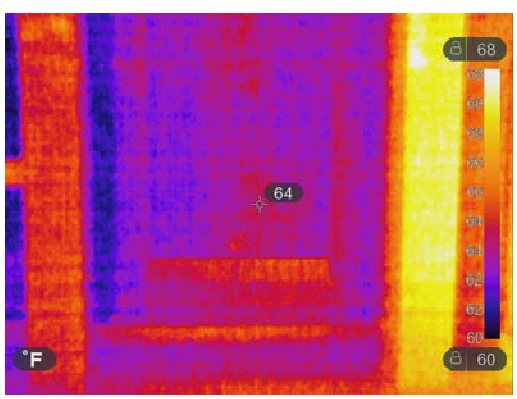

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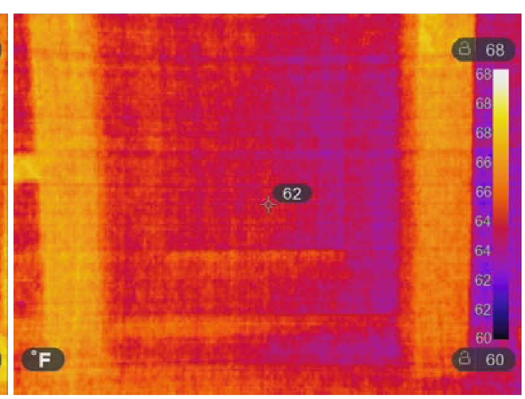

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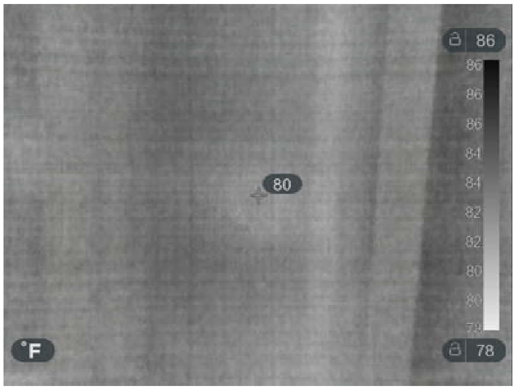

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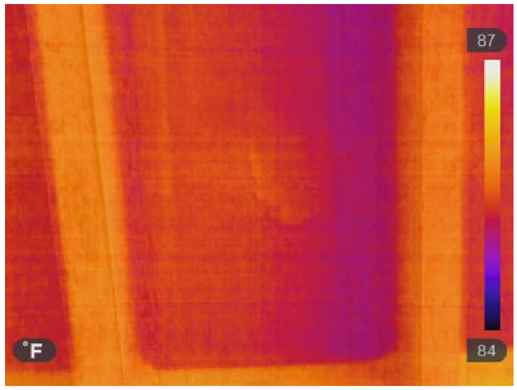

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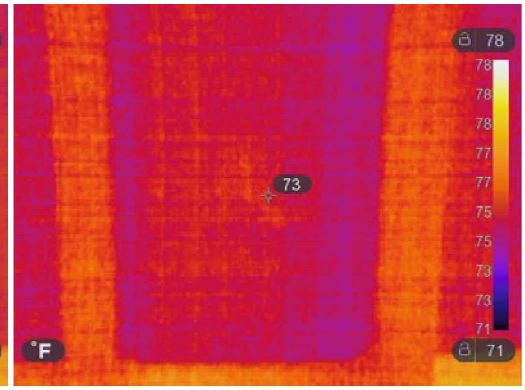

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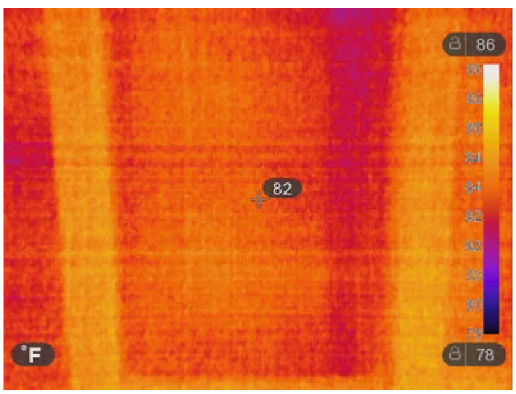

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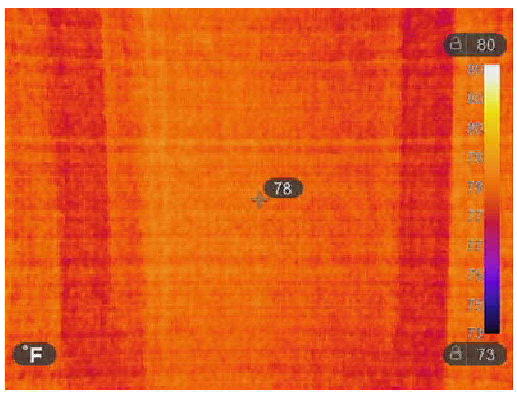

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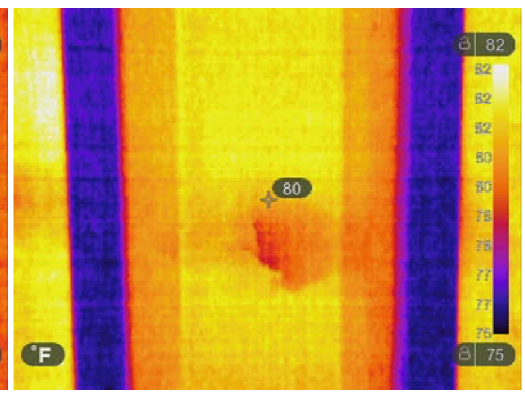

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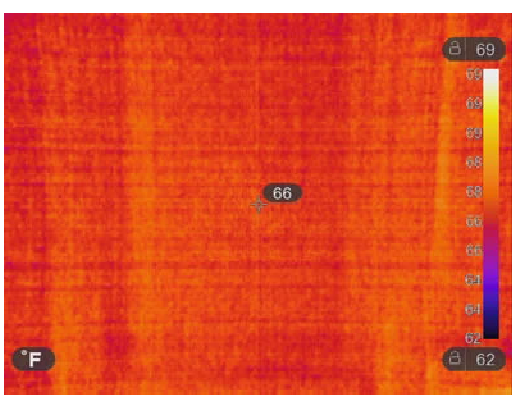

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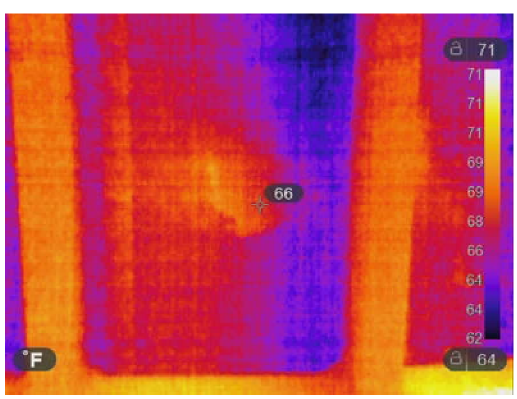

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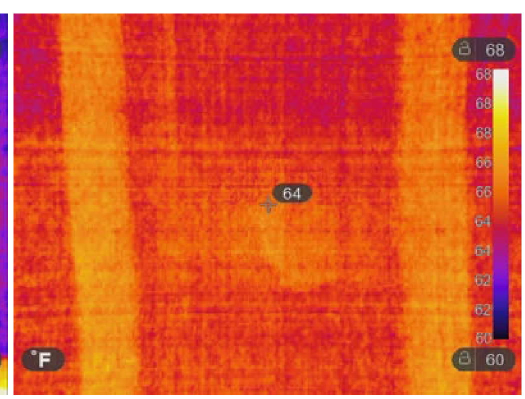

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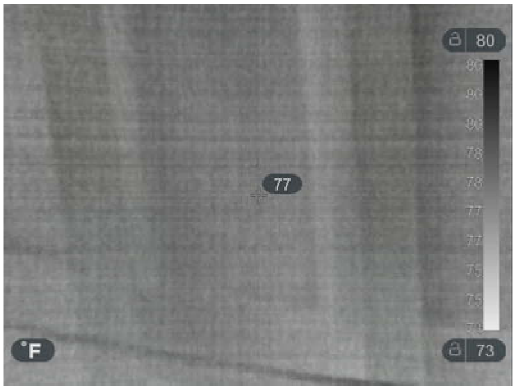

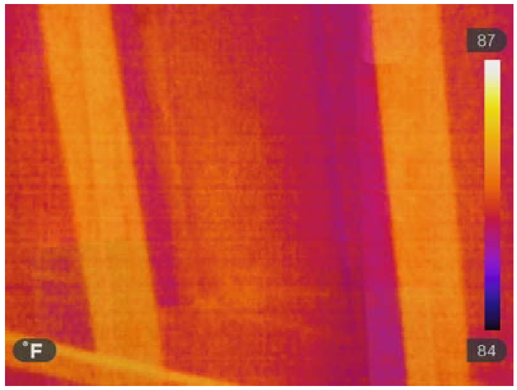

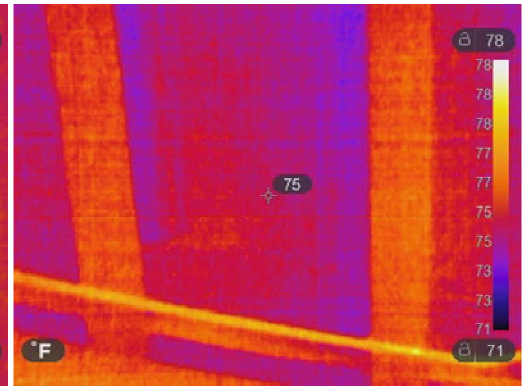

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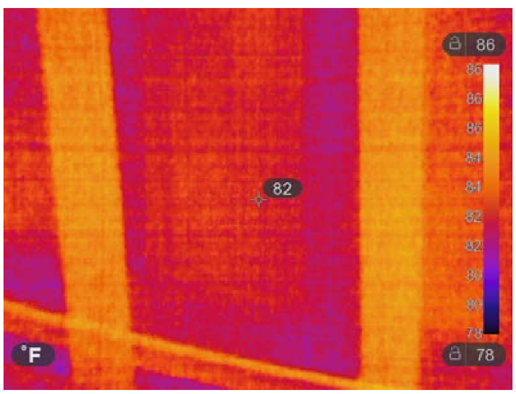
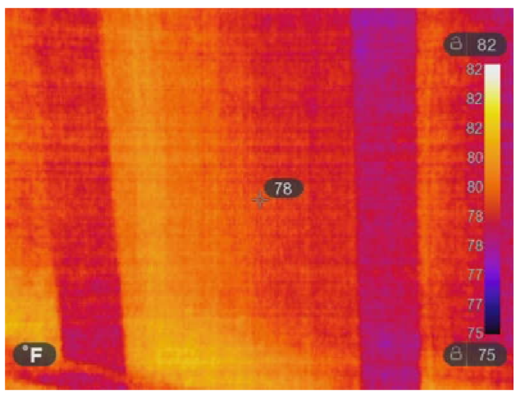
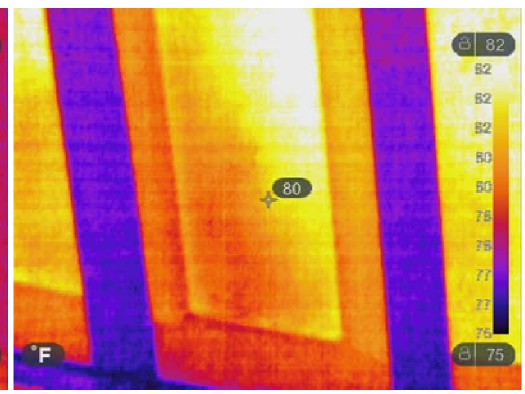
Seek_Loc10_02_20210915_113851_A

Seek_Loc10_03_20210918_131458_A



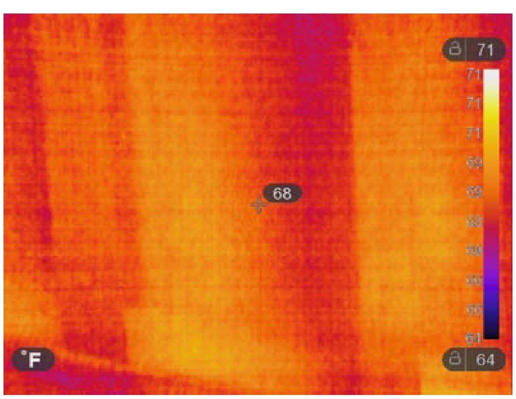


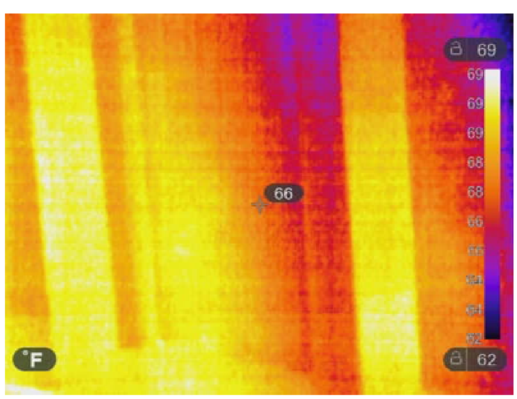


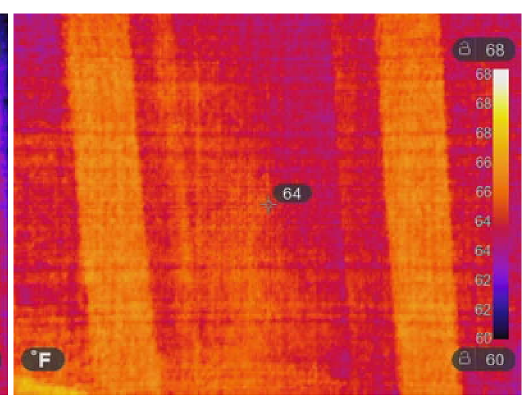
Seek_Loc10_04_20210923_133759_A

Seek_Loc10_05_20210925_110139_A

Seek_Loc10_06_20210925_192849_A







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Seek_Loc10_08_20211001_104149_A

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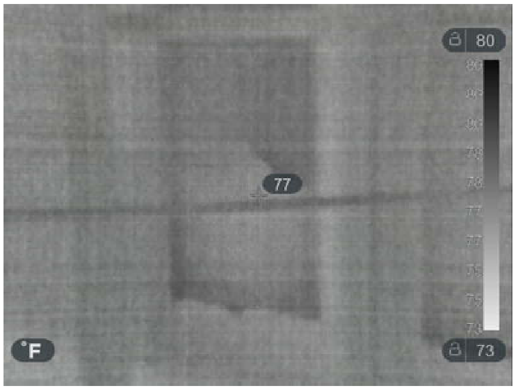

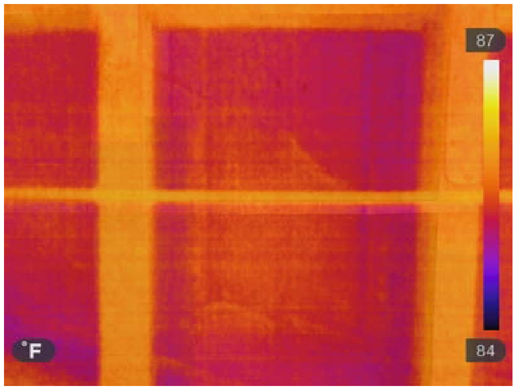

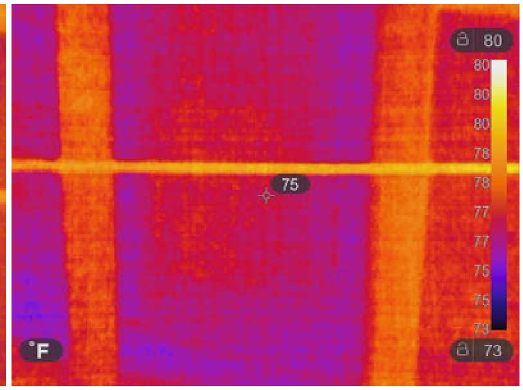

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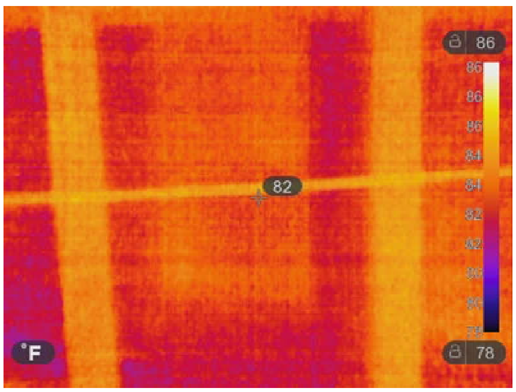
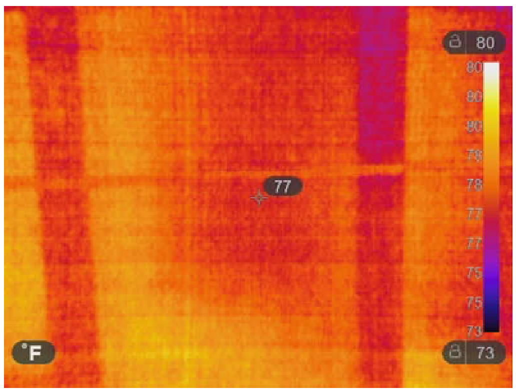
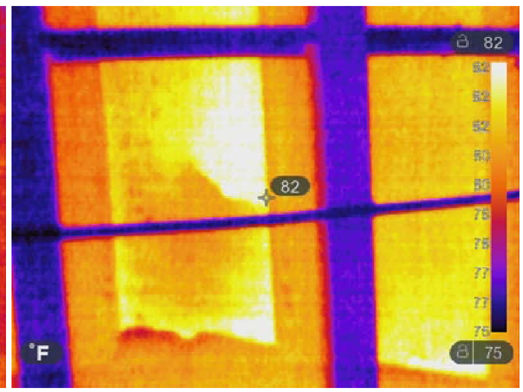
Seek_Loc11_02_20210915_114003_A

Seek_Loc11_03_20210918_131607_A







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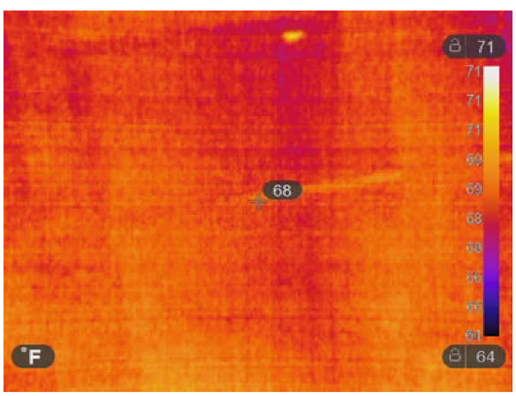
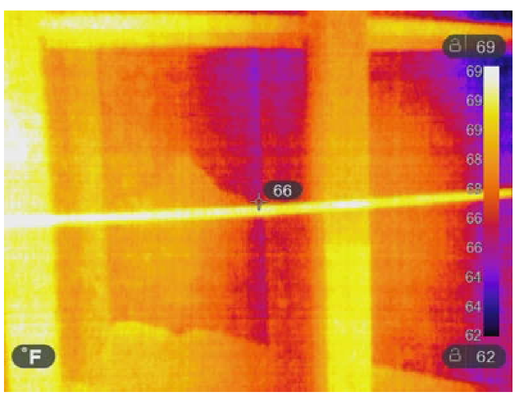
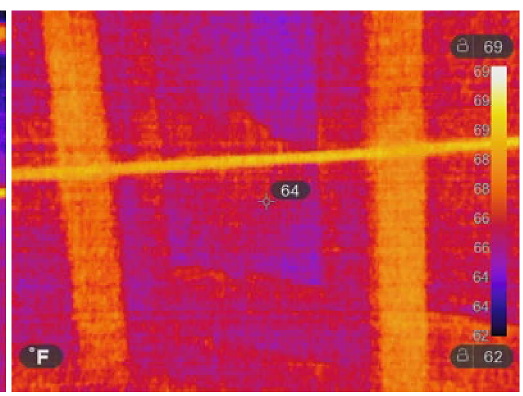
Seek_Loc11_05_20210925_110206_A

Seek_Loc11_06_20210925_192918_A



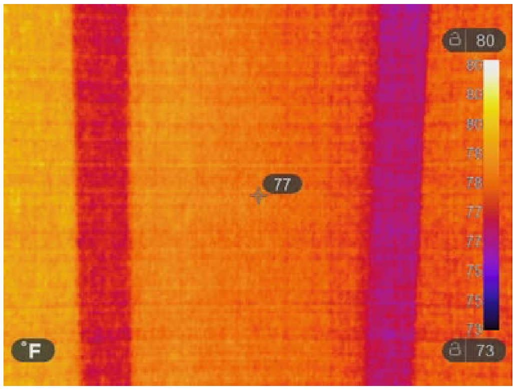




Seek_Loc11_07_20210930_112822_A

Seek_Loc11_08_20211001_104235_A

Seek_Loc11_09_20211006_095939_A



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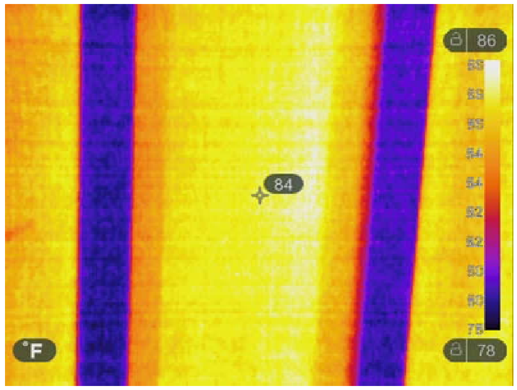

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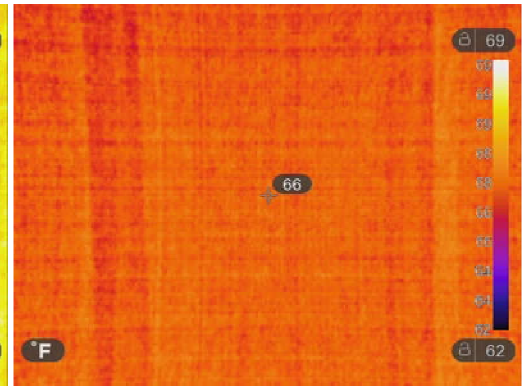

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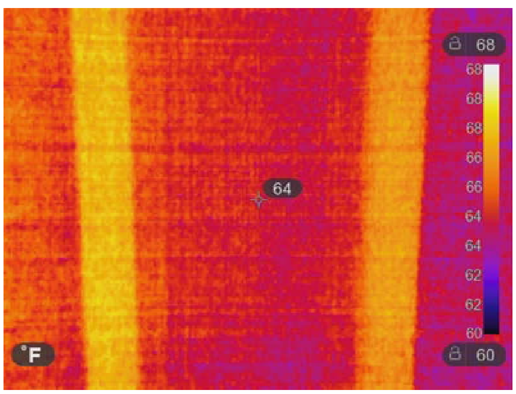

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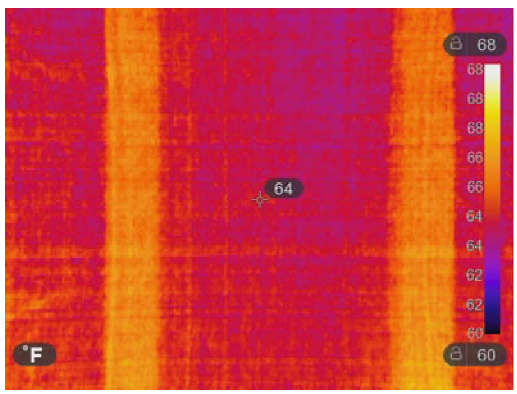


Seek_Loc12_09_20211006_100138_A

BIN 4E5 - Flir E96 - Time, Temperature, and Atmospheric Conditions during Data Collection																	
Date and Time				Temperature Changes									Atmospheric Conditions				
Data Set	Date	Start Time	End Time	Temp at Time of Testing (°F)	Temp 6 Hrs Prior (°F)	Δ Temp 6 Hrs (°F)	Temp 3 Hrs Prior (°F)	Δ Temp 3 Hrs (°F)	Temp 2 Hr Prior (°F)	Δ Temp 2 Hrs (°F)	Temp 1 Hr Prior (°F)	Δ Temp 1 Hr (°F)	Dew Point (°F)	Humidity (%)	Wind Speed (mph)	Last Rainfall
1	9/13/2021	1:40 PM	2:02 PM	82	70	12	78	4	78	4	79	3	57	45	9	6 hours prior
2	9/14/2021	9:47 AM	10:05 AM	72	65	7	68	4	70	2	70	2	55	55	8	26 hours prior
3	9/14/2021	11:23 AM	11:33 AM	72	66	6	70	2	72	0	72	0	55	53	9	30 hours prior
4	9/15/2021	10:38 AM	10:46 AM	83	71	12	76	7	80	3	82	1	71	67	13	2 days prior
5	9/15/2021	11:49 AM	12:11 PM	84	71	13	76	8	80	4	82	2	71	67	13	2 days prior
6	9/15/2021	2:43 PM	3:03 PM	84	80	4	84	0	85	-1	85	-1	69	61	18	2 days prior
7	9/16/2021	8:55 AM	9:03 AM	70	74	-4	68	2	68	2	68	2	64	81	7	1 hour prior
8	9/16/2021	10:13 AM	10:20 AM	65	70	-5	64	1	69	-4	70	-5	65	84	7	2 hours prior
9	9/18/2021	12:10 PM	12:19 PM	72	66	6	69	3	70	2	72	0	65	78	5	2 days prior
10	9/18/2021	1:32 PM	1:41 PM	72	66	6	70	2	72	0	72	0	65	79	6	2 days prior
11	9/18/2021	2:16 PM	2:23 PM	72	68	4	73	-1	72	0	72	0	65	78	8	2 days prior
12	9/19/2021	7:49 PM	7:55 PM	64	71	-7	67	-3	65	-1	64	0	55	72	5	16 hours prior
13	9/22/2021	1:02 PM	1:10 PM	76	70	6	77	-1	76	0	78	-2	67	74	20	3 days prior
14	9/22/2021	2:08 PM	2:14 PM	77	72	5	76	1	80	-3	76	1	68	74	9	3 days prior
15	9/23/2021	1:02 PM	1:09 PM	76	70	6	80	-4	80	-4	77	-1	67	74	7	Rain during data collection
16	9/23/2021	7:47 PM	7:55 PM	70	81	-11	76	-6	72	-2	72	-2	66	87	13	7 hours prior
17	9/23/2021	8:45 PM	8:50 PM	70	80	-10	72	-2	72	-2	70	0	66	87	10	8 hours prior
18	9/24/2021	9:52 AM	10:04 AM	78	71	7	75	3	76	2	78	0	69	74	14	20 hours prior
19	9/25/2021	10:24 AM	10:32 AM	73	67	6	66	7	66	7	69	4	52	48	5	2 days prior
20	9/25/2021	11:06 AM	11:12 AM	73	66	7	66	7	69	4	73	0	50	44	8	2 days prior
21	9/25/2021	6:52 PM	6:59 PM	65	73	-8	68	-3	66	-1	65	0	61	87	7	Rain during data collection
22	9/25/2021	7:34 PM	7:51 PM	65	72	-7	68	-3	66	-1	65	0	61	87	7	Rain during data collection
23	9/26/2021	7:59 PM	8:06 AM	67	75	-8	71	-4	69	-2	68	-1	46	47	13	13 hours prior
24	9/30/2021	9:45 AM	9:51 AM	60	55	5	55	5	58	2	60	0	43	53	12	2 days prior
25	9/30/2021	10:38 AM	10:45 AM	61	55	6	58	3	60	1	60	1	42	50	10	2 days prior
26	9/30/2021	11:43 AM	11:49 AM	61	55	6	60	1	60	1	61	0	42	50	8	2 days prior
27	9/30/2021	6:20 PM	6:27 PM	60	62	-2	61	-1	61	-1	61	-1	43	55	10	2 days prior
28	9/30/2021	7:06 PM	7:14 PM	58	62	-4	61	-3	61	-3	60	-2	44	59	9	2 days prior
29	10/1/2021	9:36 AM	9:51 AM	63	51	11.5	52	10.5	55	7.5	59	3.5	45	50	15	3 days prior
30	10/1/2021	10:59 AM	11:05 AM	66	51	15	57	9	61	5	64	2	44	45	10	3 days prior
31	10/6/2021	9:24 AM	9:45 AM	64	56	8	59	5.5	62	2	63	1	52	64	0	30 hours prior

Weather data taken from Weather Underground - General Edward Lawrence Logan International Airport Weather Station

Reviewer: Tony Tieso
Role: Non-destructive Evaluation Technician

E96 - Identification of Delamination												
Data Set	**Location**											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1	y	y	y	y	y	y	y	y	y	n	y	n/a
2	n	y	n	n	y	n	n	n	y	y	n	n/a
3	y	y	n	n	n	n	y	n	n	n	y	n/a
4	n	n	y	y	y	y	y	y	y	y	y	n/a
5	y	n	y	y	y	n	y	y	y	y	y	n/a
6	y	y	y	y	y	n	y	n	y	n	y	n/a
7	n	y	n	y	y	n	y	n	y	y	y	n/a
8	n	n	n	y	y	n	y	n	y	y	y	n/a
9	n	n	n	n	n	n	n	n	y	n	n	n/a
10	n	y	n	n	y	n	y	n	y	y	y	n/a
11	y	y	n	n	n	n	y	n	y	n	n	n/a
12	y	y	y	y	y	y	y	y	y	y	y	n/a
13	y	y	n	n	y	n	y	n	y	n	n	n/a
14	y	y	n	y	y	n	n	n	n	n	y	n/a
15	y	y	n	n	n	n	n	n	y	n	n	n/a
16	y	y	y	y	y	y	y	y	y	y	y	n/a
17	y	y	y	y	y	y	y	y	y	y	y	n/a
18	n	n	n	n	y	n	y	n	y	n	y	n/a
19	n	y	n	n	y	n	n	n	n	n	y	n
20	n	y	n	n	n	n	y	n	n	n	y	n
21	y	y	y	y	y	y	y	y	y	y	y	n
22	y	y	y	y	y	y	y	y	y	y	y	n
23	y	y	y	y	y	y	y	y	y	y	y	n
24	n	n	n	n	y	n	n	n	y	y	y	n
25	n	n	n	n	n	n	y	n	y	n	n	n
26	y	y	n	n	n	n	y	n	n	n	y	n
27	y	y	y	y	y	n	y	n/a	y	n	y	n
28	y	y	y	y	y	n	y	n	y	n	y	n
29	y	y	y	y	y	y	y	y	y	y	y	n
30	n	y	y	y	y	y	y	y	y	y	y	n
31	y	y	y	y	y	n	y	n	y	n	y	n
32	y	y	n	y	y	n	y	n	y	y	y	n

n/a = Image was not captured

Reviewer: Kevin Ahearn
Role: Structural Engineer, Bridge Inspector

E96 - Identification of Delamination												
Data Set	**Location**											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	n/a
2	No	No	No	No	Yes	No	No	No	No	No	No	n/a
3	No	Yes	No	No	No	No	Yes	No	No	No	Yes	n/a
4	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	n/a
5	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	n/a
6	Yes	Yes	No	Yes	No	Yes	Yes	No	No	No	Yes	n/a
7	Yes	No	No	Yes	Yes	No	Yes	No	Yes	Yes	Yes	n/a
8	Yes	No	No	Yes	Yes	No	Yes	No	Yes	No	Yes	n/a
9	No	No	No	No	No	No	No	No	No	No	No	n/a
10	No	No	No	No	Yes	No	Yes	No	Yes	Yes	No	n/a
11	No	Yes	No	No	No	No	Yes	No	Yes	No	No	n/a
12	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	n/a
13	No	Yes	No	Yes	No	No	Yes	No	Yes	No	No	n/a
14	Yes	Yes	No	Yes	No	No	No	No	No	No	No	n/a
15	Yes	Yes	No	Yes	No	No	No	No	Yes	Yes	No	n/a
16	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	n/a
17	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	n/a
18	No	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes	n/a
19	No	No	No	No	No	No	No	No	No	No	No	No
20	No	No	No	No	No	No	No	No	No	No	No	No
21	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
22	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
23	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
24	No	No	No	No	No	No	No	No	Yes	Yes	Yes	No
25	No	No	No	No	No	No	Yes	No	No	Yes	Yes	No
26	Yes	Yes	No	No	No	No	No	No	No	Yes	No	No
27	Yes	Yes	Yes	Yes	Yes	Yes	Yes	n/a	Yes	Yes	Yes	No
28	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
29	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
30	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
31	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
32	Yes	No	No	No	No	No	Yes	No	Yes	No	No	No

n/a = Image was not captured

Reviewer: Kevin Ahearn
Role: Structural Engineer, Bridge Inspector

E96 - Identification of Delamination												
Data Set	**Location**											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	n/a
2	No	No	No	No	Yes	No	No	No	No	No	No	n/a
3	No	Yes	No	No	No	No	Yes	No	No	No	Yes	n/a
4	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	n/a
5	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	n/a
6	Yes	Yes	No	Yes	No	Yes	Yes	No	No	No	Yes	n/a
7	Yes	No	No	Yes	Yes	No	Yes	No	Yes	Yes	Yes	n/a
8	Yes	No	No	Yes	Yes	No	Yes	No	Yes	No	Yes	n/a
9	No	No	No	No	No	No	No	No	No	No	No	n/a
10	No	No	No	No	Yes	No	Yes	No	Yes	Yes	No	n/a
11	No	Yes	No	No	No	No	Yes	No	Yes	No	No	n/a
12	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	n/a
13	No	Yes	No	Yes	No	No	Yes	No	Yes	No	No	n/a
14	Yes	Yes	No	Yes	No	No	No	No	No	No	No	n/a
15	Yes	Yes	No	Yes	No	No	No	No	Yes	Yes	No	n/a
16	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	n/a
17	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	n/a
18	No	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes	n/a
19	No	No	No	No	No	No	No	No	No	No	No	No
20	No	No	No	No	No	No	No	No	No	No	No	No
21	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
22	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
23	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
24	No	No	No	No	No	No	No	No	Yes	Yes	Yes	No
25	No	No	No	No	No	No	Yes	No	No	Yes	Yes	No
26	Yes	Yes	No	No	No	No	No	No	No	Yes	No	No
27	Yes	Yes	Yes	Yes	Yes	Yes	Yes	n/a	Yes	Yes	Yes	No
28	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
29	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
30	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
31	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
32	Yes	No	No	No	No	No	Yes	No	Yes	No	No	No

n/a = Image was not captured

Reviewer: Kevin Ahearn
Role: Structural Engineer, Bridge Inspector

E86 - Identification of Delamination												
Data Set	**Location**											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	n/a
2	No	No	No	No	No	No	No	No	No	No	Yes	n/a
3	No	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	n/a
4	No	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	n/a
5	n/a	Yes	No	Yes	Yes	Yes	No	Yes	No	Yes	Yes	n/a
6	No	No	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	n/a
7	No	No	No	No	No	No	No	No	Yes	Yes	Yes	n/a
8	No	n/a	No	No	No	No	No	No	Yes	Yes	Yes	n/a
9	Yes	Yes	No	Yes	No	No	No	No	No	No	No	n/a
10	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	n/a
11	Yes	Yes	No	Yes	No	No	No	No	No	Yes	No	n/a
12	Yes	Yes	No	Yes	Yes	No	No	No	No	No	No	n/a
13	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	n/a
14	No	No	No	No	Yes	No	Yes	No	Yes	Yes	Yes	n/a
15	No	No	No	No	Yes	No	No	No	No	No	No	No
16	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
17	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
18	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No
19	No	No	No	No	No	Yes	No	No	Yes	Yes	Yes	No
20	No	No	No	No	No	No	Yes	No	Yes	Yes	Yes	No
21	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
22	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No

n/a = Image was not captured

Reviewer: Kevin Ahearn
Role: Structural Engineer, Bridge Inspector

E8 - Identification of Delamination												
Data Set	Location											
	1	2	3	4	5	6	7	8	9	10	11	12
1	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	n/a
2	No	No	No	No	Yes	Yes	No	No	No	No	Yes	n/a
3	No	No	No	No	Yes	No	Yes	No	Yes	Yes	Yes	n/a
4	n/a	Yes	No	Yes	No	No	No	No	No	Yes	Yes	n/a
5	No	No	No	No	Yes	No	Yes	No	Yes	Yes	Yes	n/a
6	No	No	No	No	No	No	No	No	No	No	No	n/a
7	No	Yes	No	No	No	No	No	No	No	No	No	n/a
8	Yes	No	No	Yes	No	No	No	No	No	No	No	n/a
9	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	n/a
10	Yes	Yes	No	Yes	No	No	No	No	No	No	No	n/a
11	Yes	Yes	No	Yes	No	No	No	No	No	No	No	n/a
12	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	n/a
13	No	No	No	No	No	No	No	No	No	Yes	Yes	n/a
14	No	No	No	No	No	No	No	No	No	No	No	No
15	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
16	Yes	Yes	Yes	Yes	Yes	Yes	Yes	n/a	Yes	Yes	Yes	No
17	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
18	No	No	No	No	No	No	No	No	No	Yes	Yes	No
19	No	No	No	No	No	No	Yes	No	No	Yes	Yes	No
20	No	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No
21	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No

n/a = Image was not captured

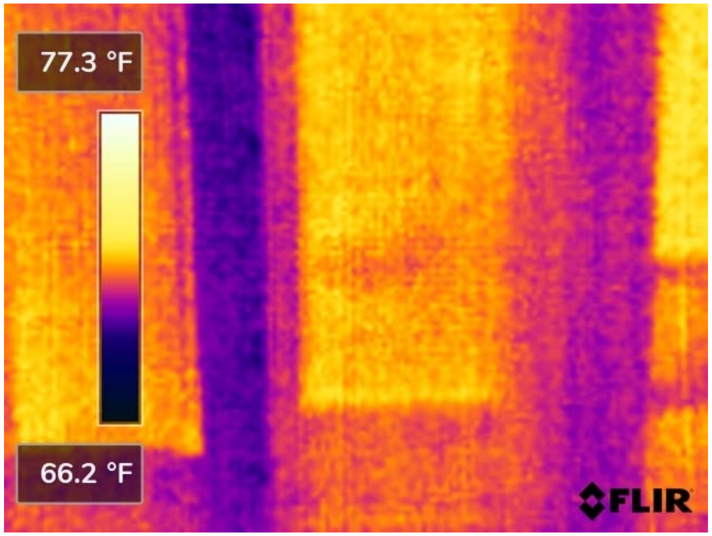
Reviewer: Kevin Ahearn
Role: Structural Engineer, Bridge Inspector

C5 - Identification of Delamination												
Data Set	Location											
	1	2	3	4	5	6	7	8	9	10	11	12
1	Yes	Yes	No	No	Yes	No	No	Yes	No	No	Yes	n/a
2	No	No	No	No	No	No	No	No	No	No	No	n/a
3	No	No	No	No	Yes	Yes	No	No	Yes	Yes	Yes	n/a
4	No	No	No	Yes	No	No	No	No	No	No	No	n/a
5	No	No	No	No	No	No	No	No	Yes	No	No	n/a
6	No	No	No	No	Yes	Yes	No	No	Yes	No	No	n/a
7	No	No	No	No	No	No	No	No	n/a	n/a	n/a	n/a
8	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	n/a
9	No	No	No	No	No	No	No	No	No	No	No	n/a
10	No	No	No	No	No	No	No	No	No	No	No	n/a
11	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	n/a
12	No	No	No	No	No	No	No	No	No	No	No	n/a
13	No	No	No	No	No	No	No	No	No	Yes	No	n/a
14	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
15	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
16	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
17	No	No	No	No	No	No	No	No	No	Yes	Yes	No
18	No	No	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	No
19	Yes	No	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No

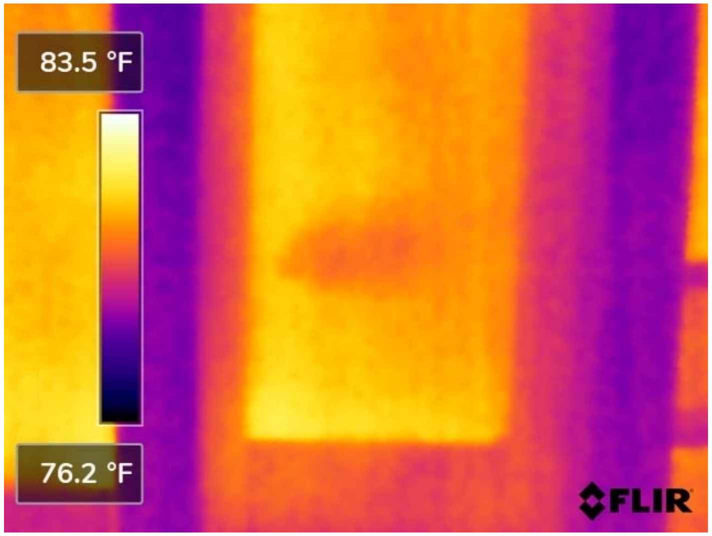
n/a = Image was not captured

4E5, Location 1 – Comparison of Camera Imagery

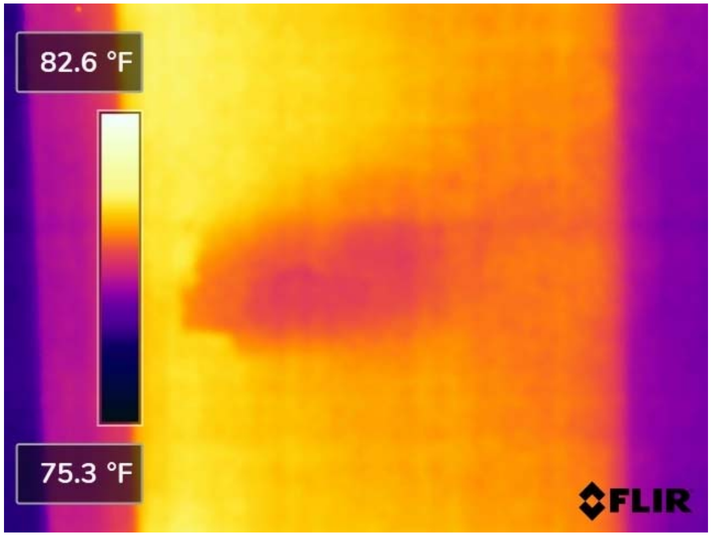
Ironbow Palette, Automatic Settings



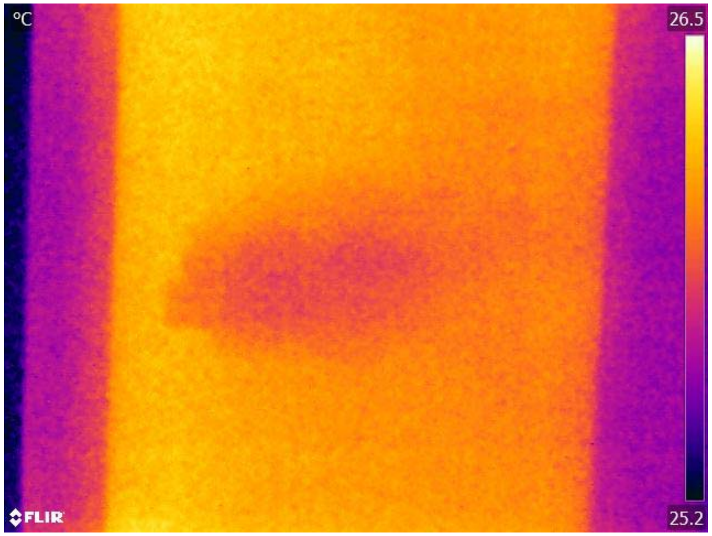
C5_Loc01_01_FLIR0005



E8_Loc01_01_FLIR0022



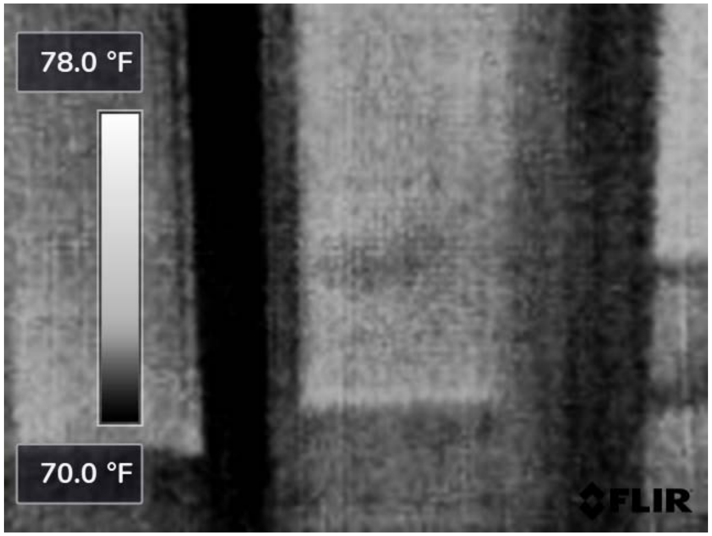
E86_Loc01_01_FLIR0027



E96_Loc1_01_FLIR0011

4E5, Location 1 – Comparison of Camera Imagery

Grayscale Palette, Manual Settings



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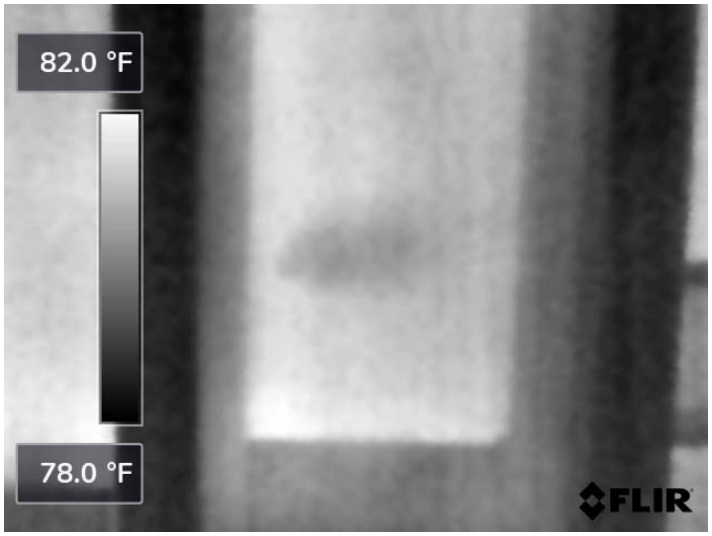
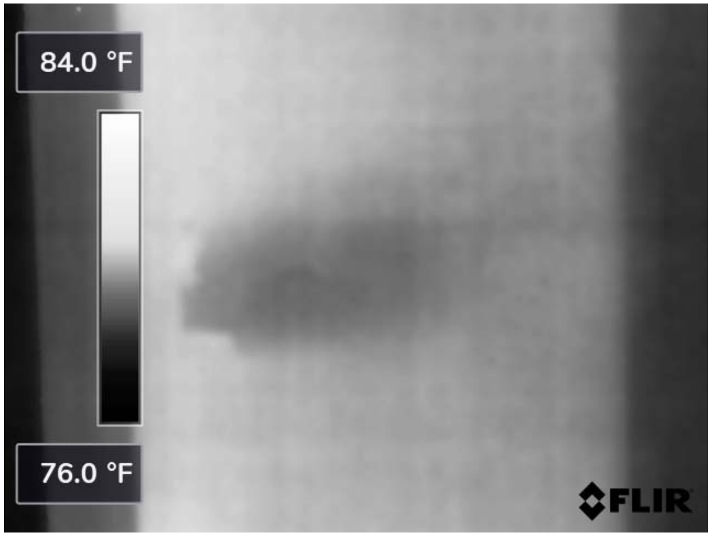
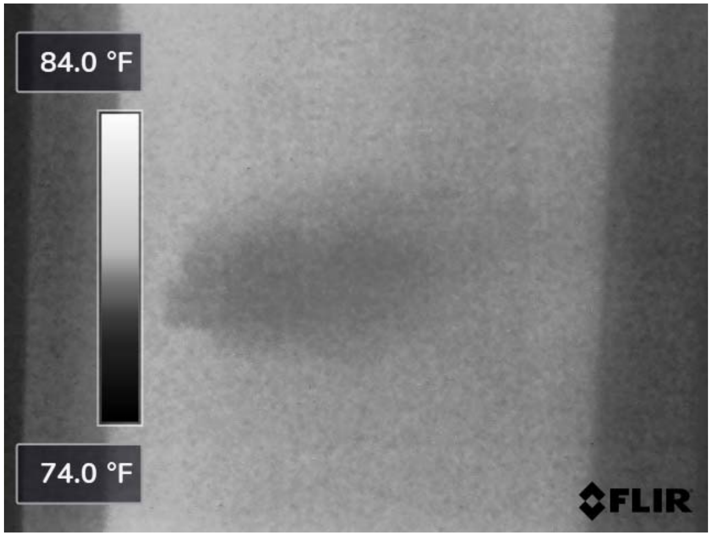


E8_Loc01_01_FLIR0022



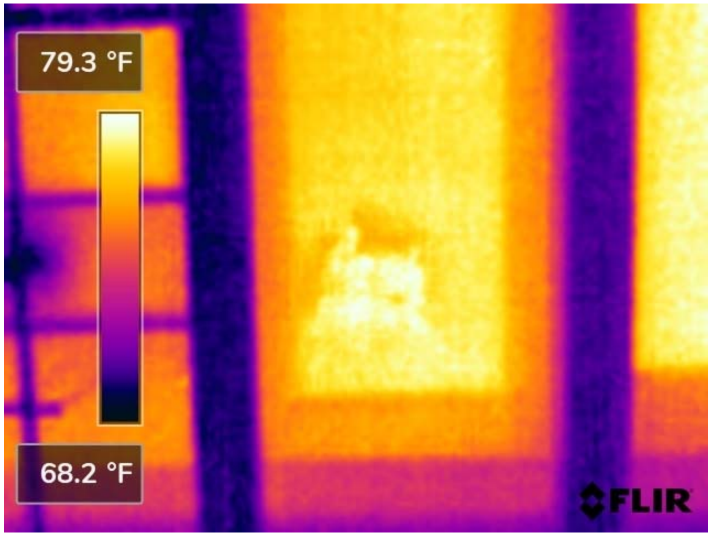
E86_Loc01_01_FLIR0027



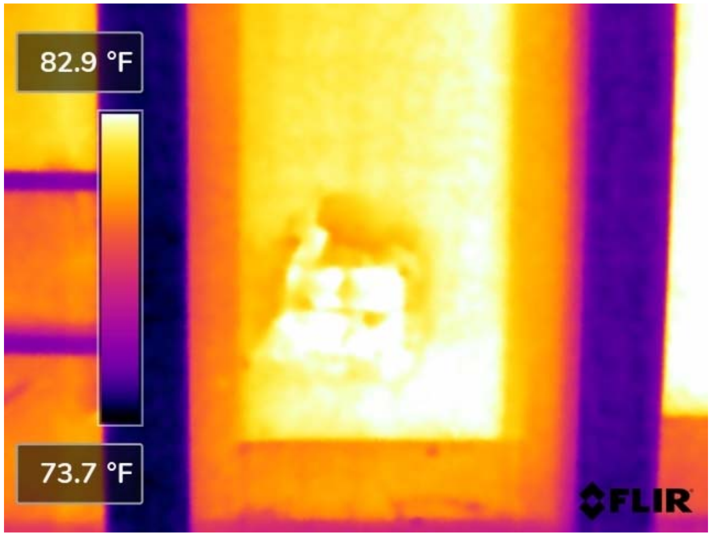
E96_Loc1_01_FLIR0011

4E5, Location 2 – Comparison of Camera Imagery

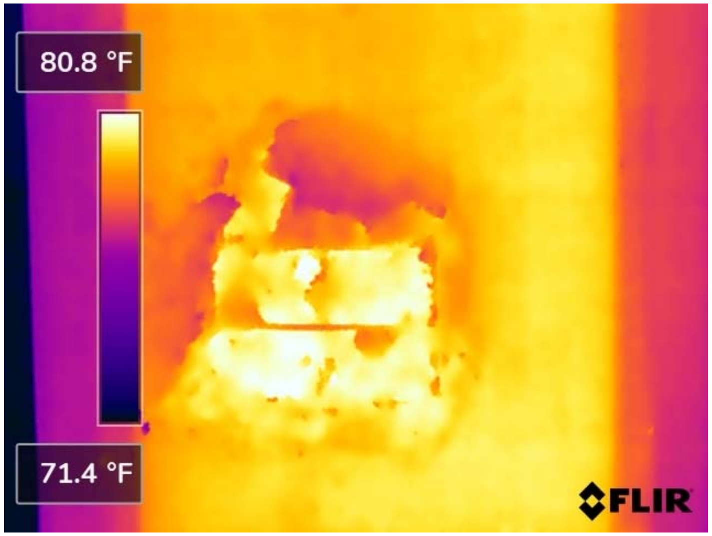
Ironbow Palette, Automatic Settings



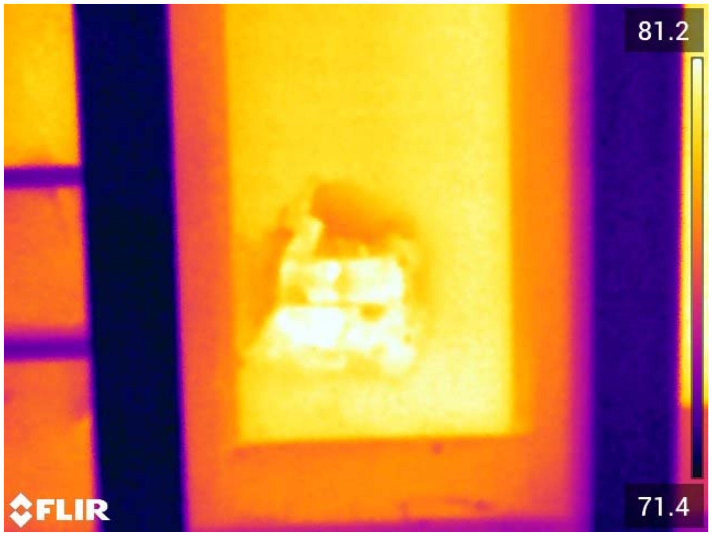
C5_Loc02_08_FLIR0953



E8_Loc02_09_FLIR1046



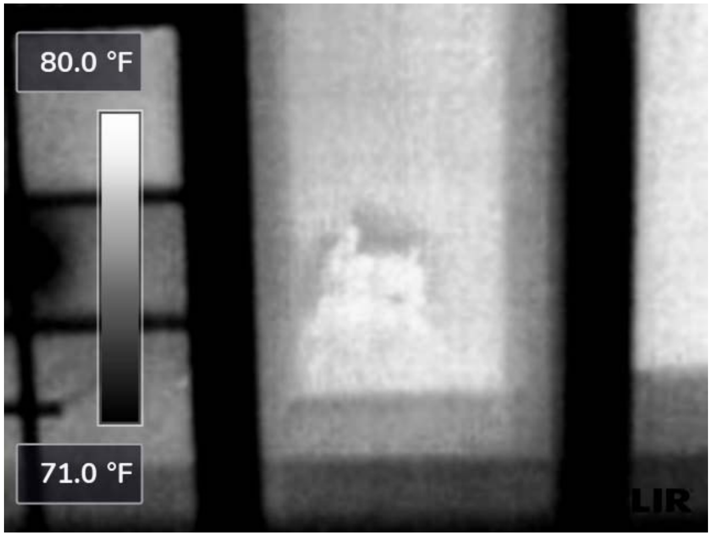
E86_Loc02_10_FLIR0983



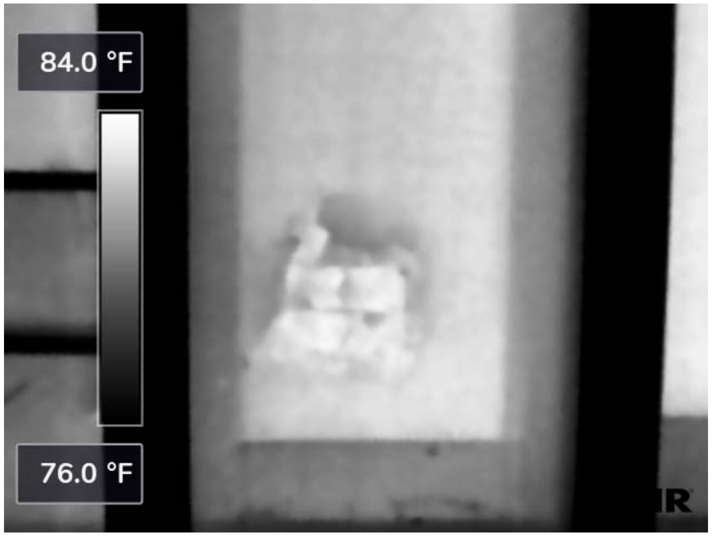
E96_Loc2_12_FLIR1089

4E5, Location 2 – Comparison of Camera Imagery

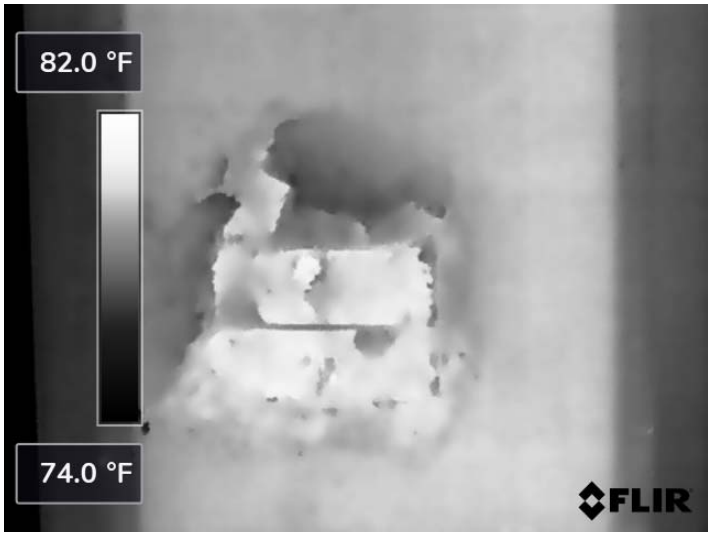
Grayscale Palette, Manual Settings



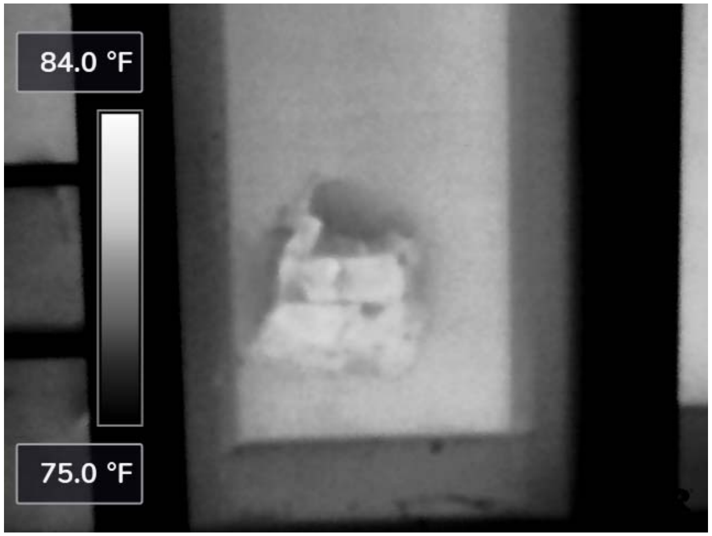
C5_Loc02_08_FLIR0953



E8_Loc02_09_FLIR1046



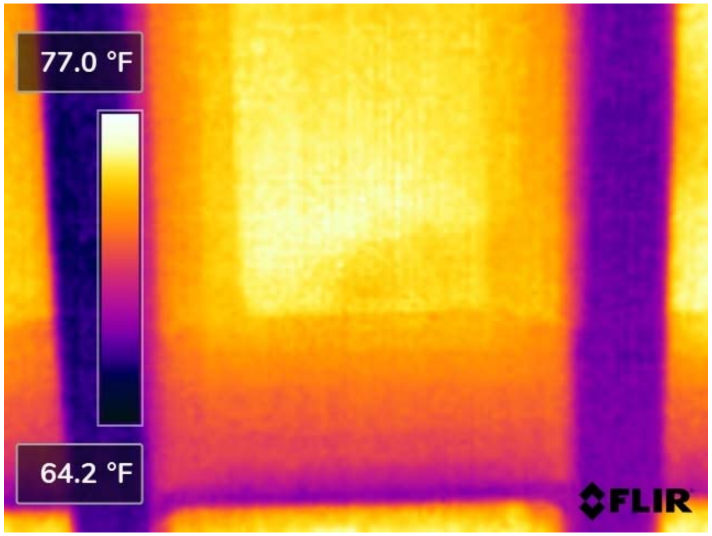
E86_Loc02_10_FLIR0983



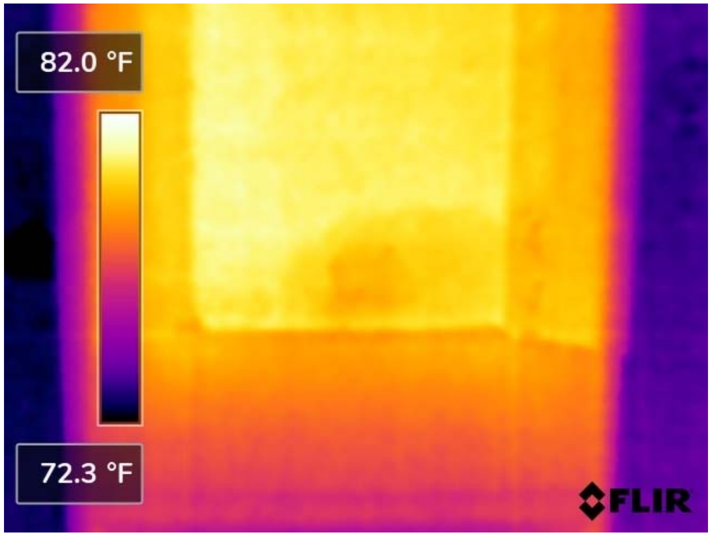
E96_Loc2_12_FLIR1089

4E5, Location 3 – Comparison of Camera Imagery

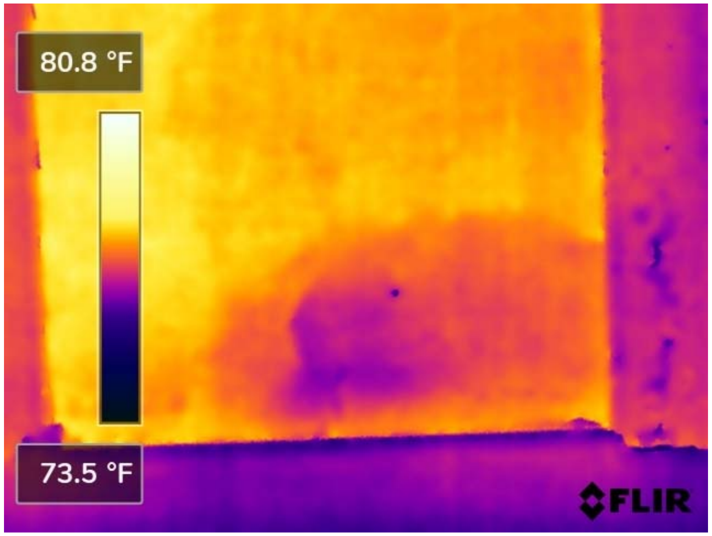
Ironbow Palette, Automatic Settings



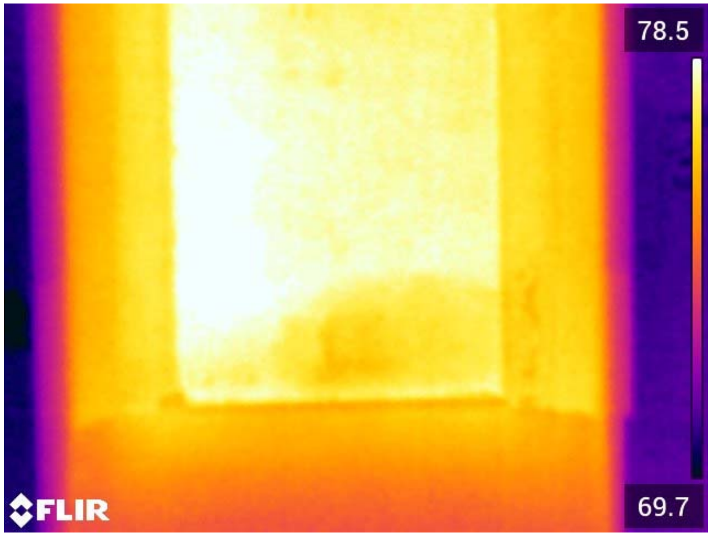
C5_Loc03_16_FLIR1815



E8_Loc03_17_FLIR1978



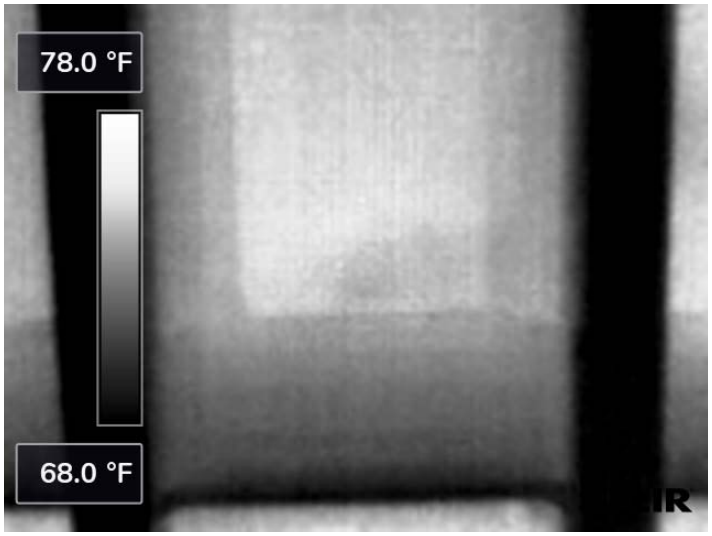
E86_Loc03_18_FLIR1717



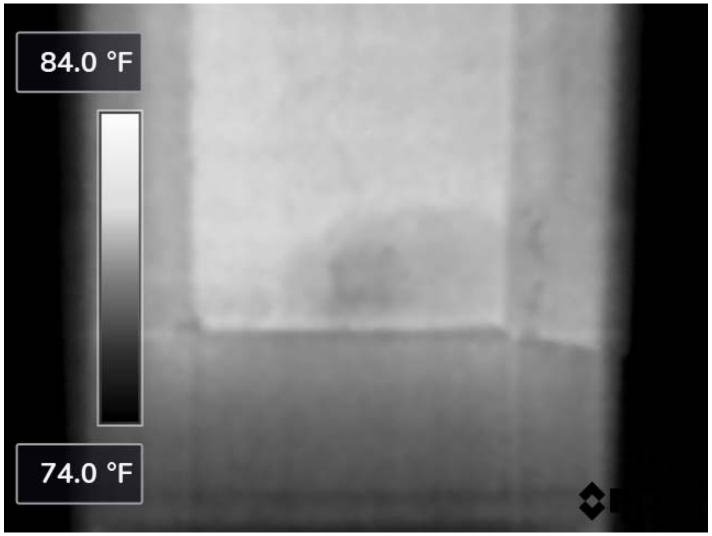
E96_Loc3_23_FLIR2683

4E5, Location 3 – Comparison of Camera Imagery

Grayscale Palette, Manual Settings



C5_Loc03_16_FLIR1815



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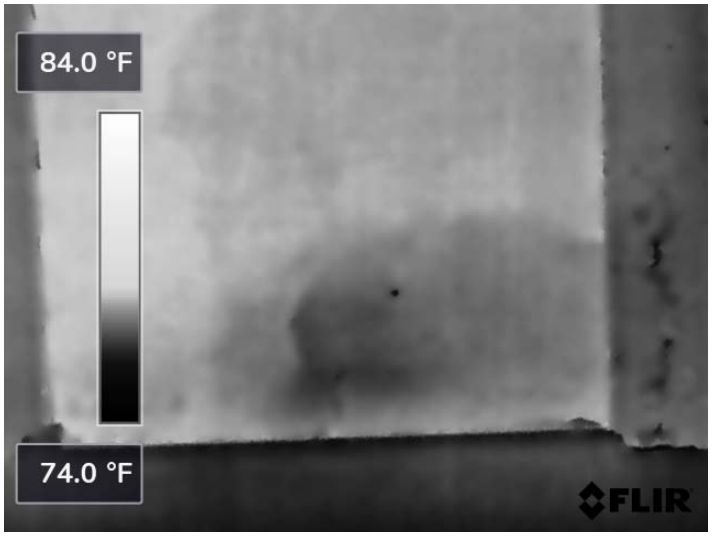

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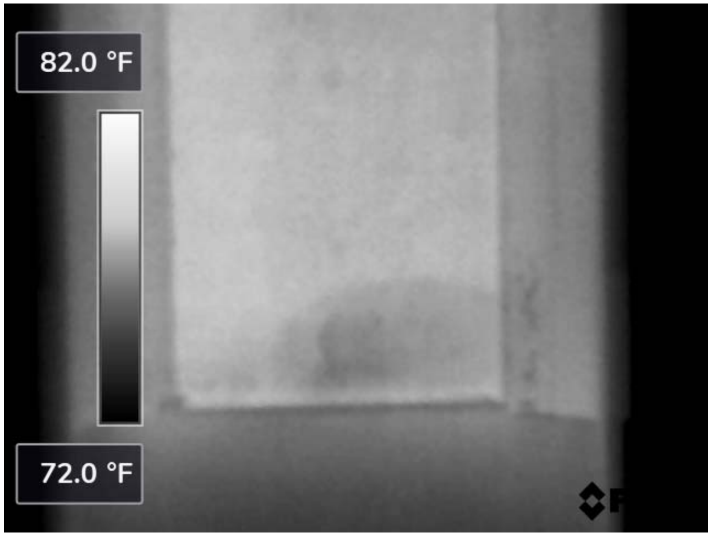
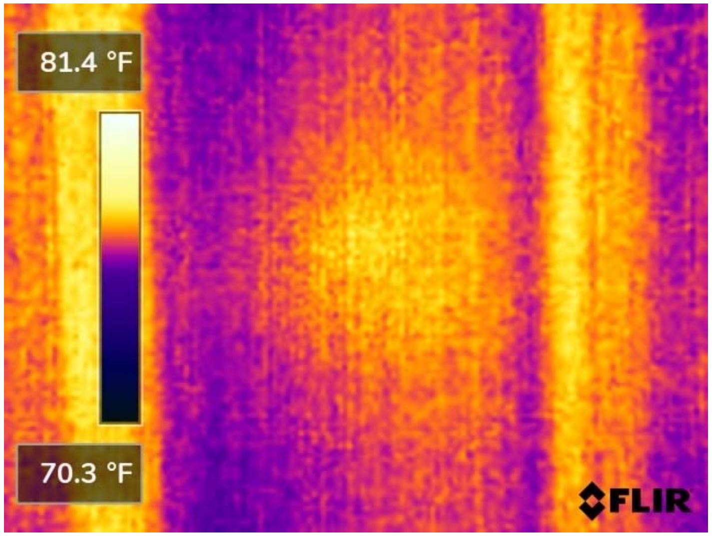


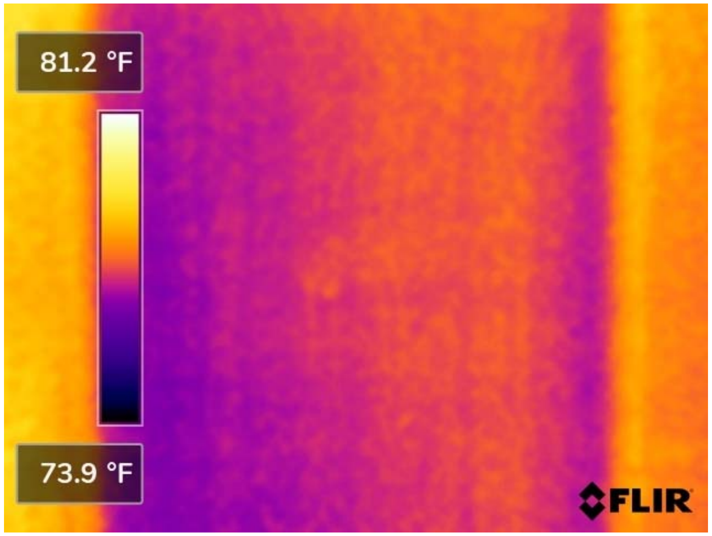
E96_Loc3_23_FLIR2683

4E5, Location 4 – Comparison of Camera Imagery

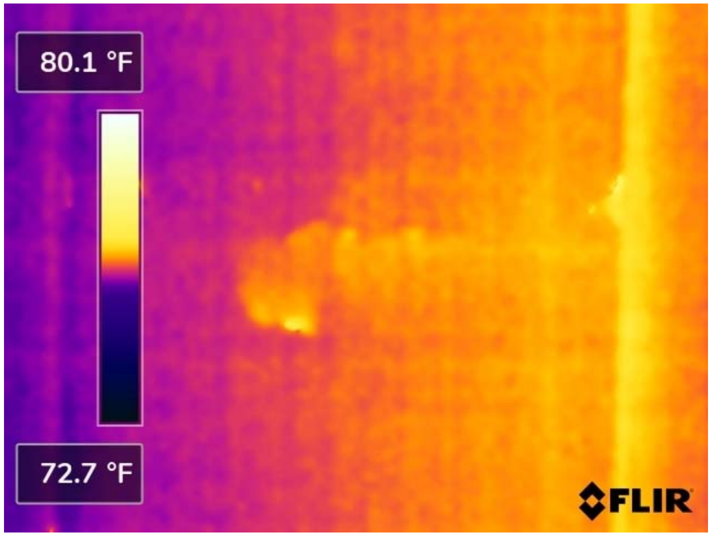
Ironbow Palette, Automatic Settings



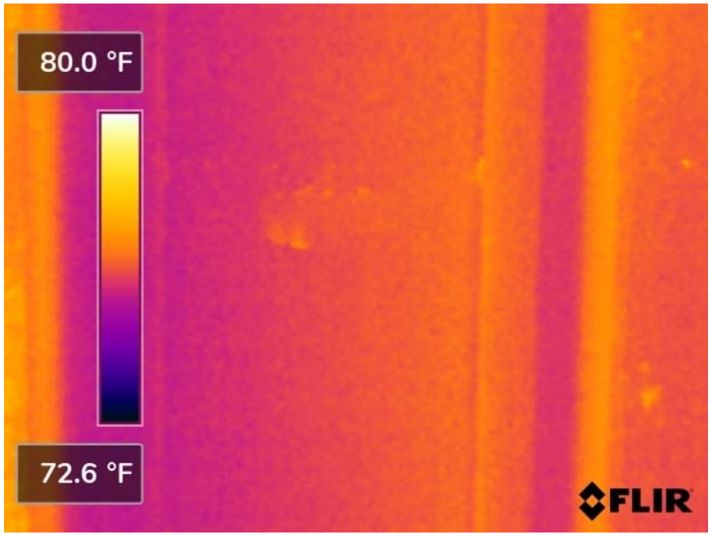
C5_Loc04_03_FLIR0275



E8_Loc04_03_FLIR0278



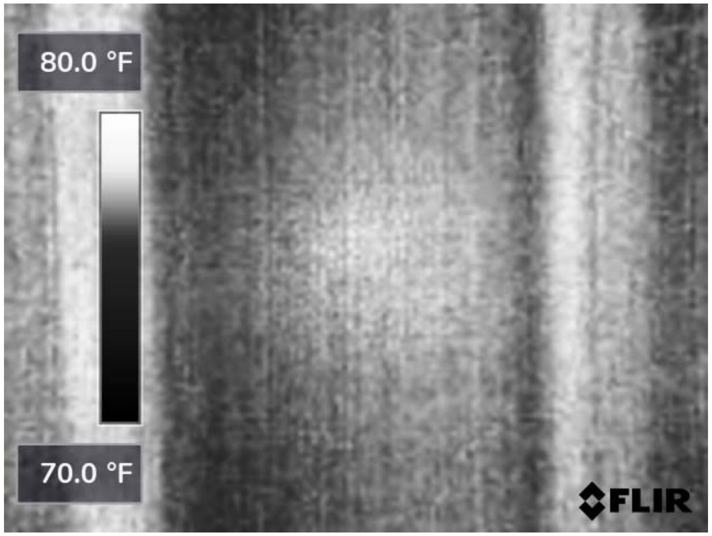
E86_Loc04_03_FLIR0309



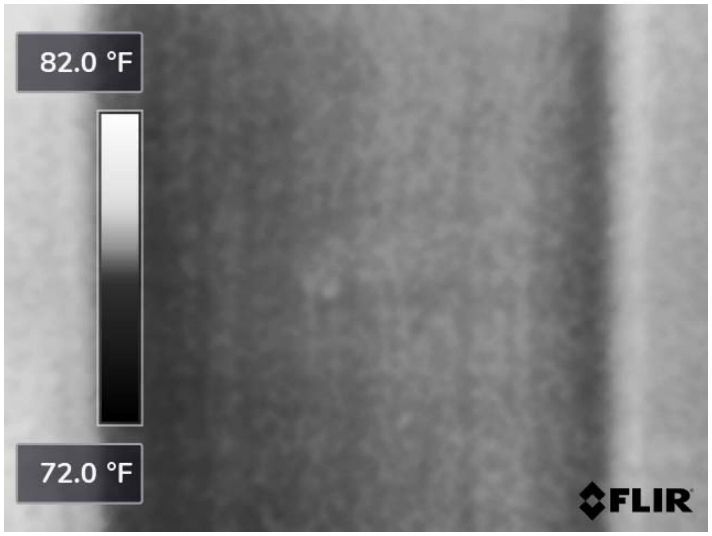
E96_Loc4_04_FLIR0279

4E5, Location 4 – Comparison of Camera Imagery

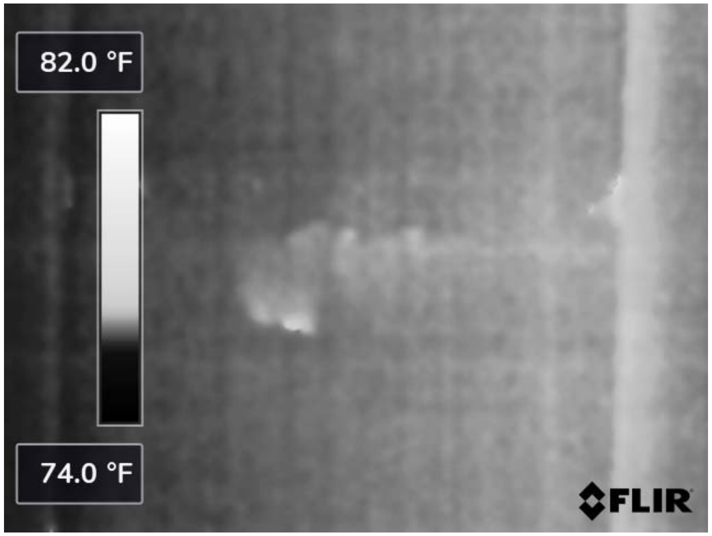
Grayscale Palette, Manual Settings



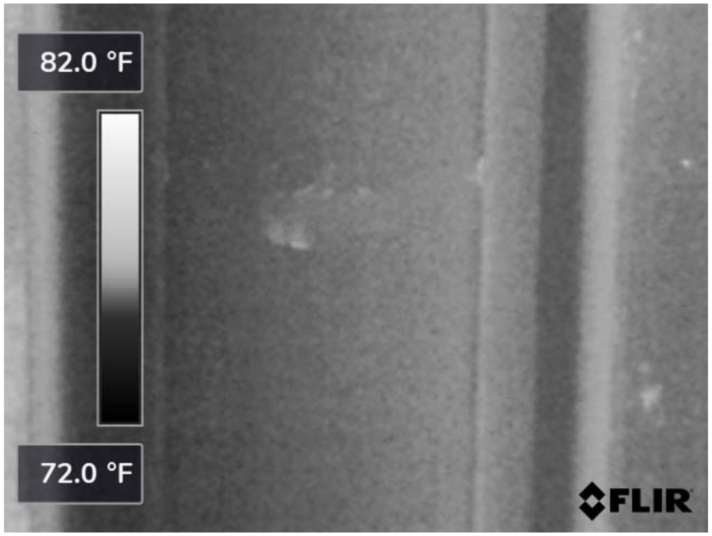
C5_Loc04_03_FLIR0275



E8_Loc04_03_FLIR0278



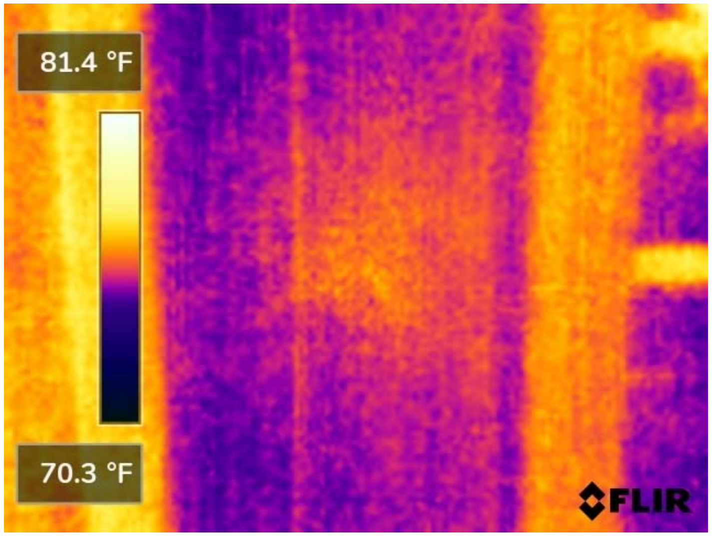
E86_Loc04_03_FLIR0309



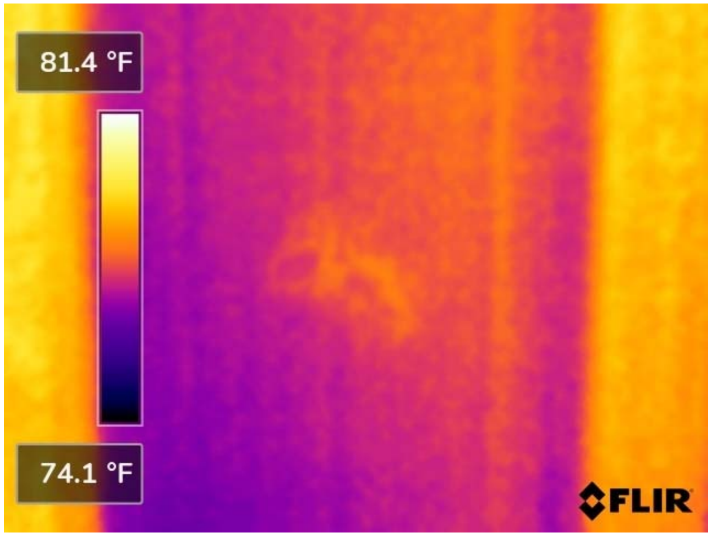
E96_Loc4_04_FLIR0279

4E5, Location 5 – Comparison of Camera Imagery

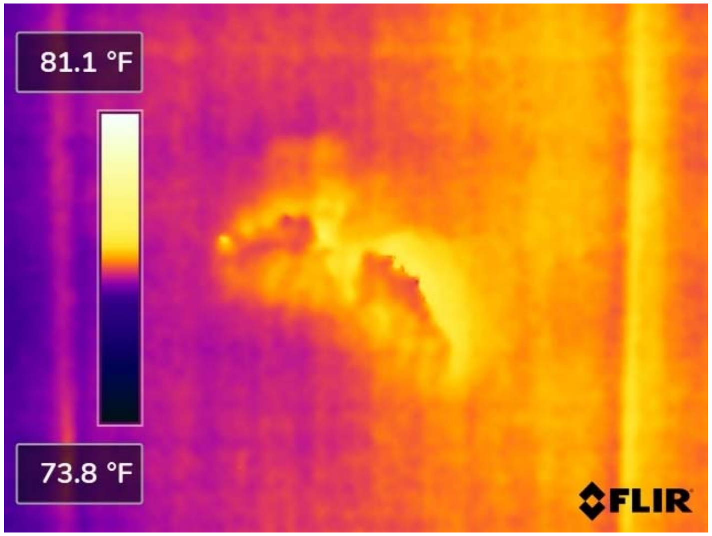
Ironbow Palette, Automatic Settings



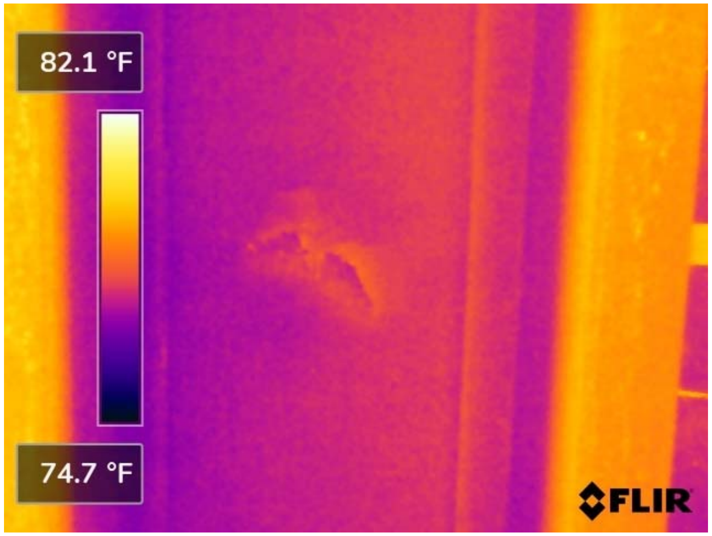
C5_Loc05_03_FLIR0285



E8_Loc05_03_FLIR0288



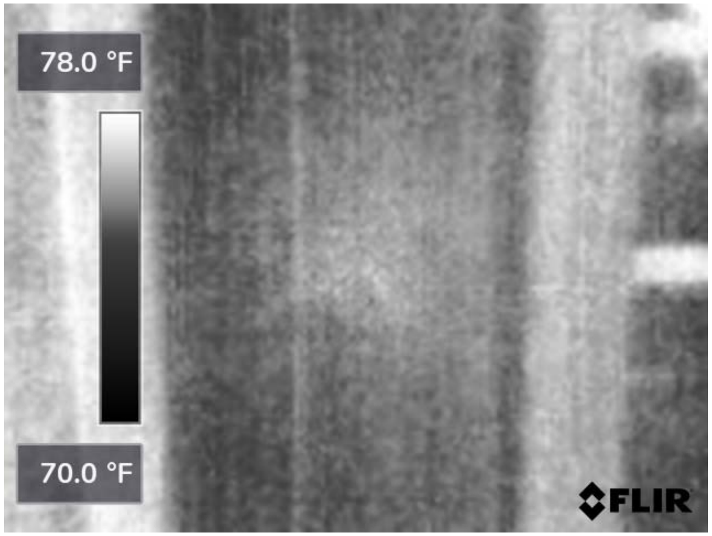
E86_Loc05_04_FLIR0399



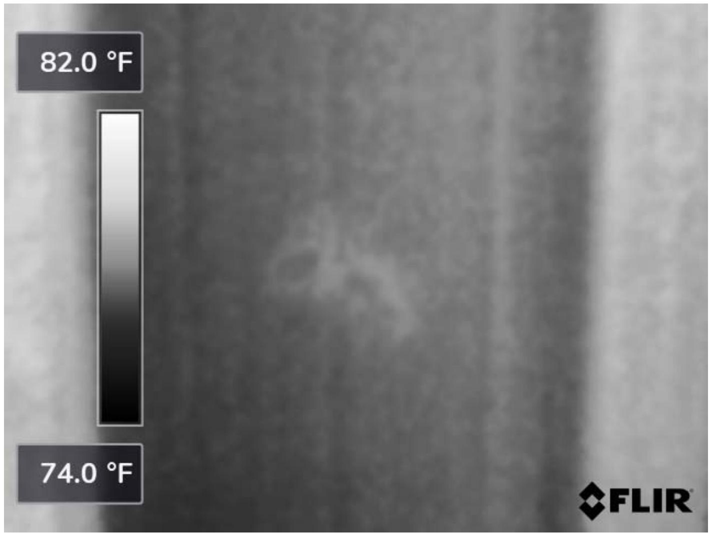
E96_Loc5_05_FLIR0353

4E5, Location 5 – Comparison of Camera Imagery

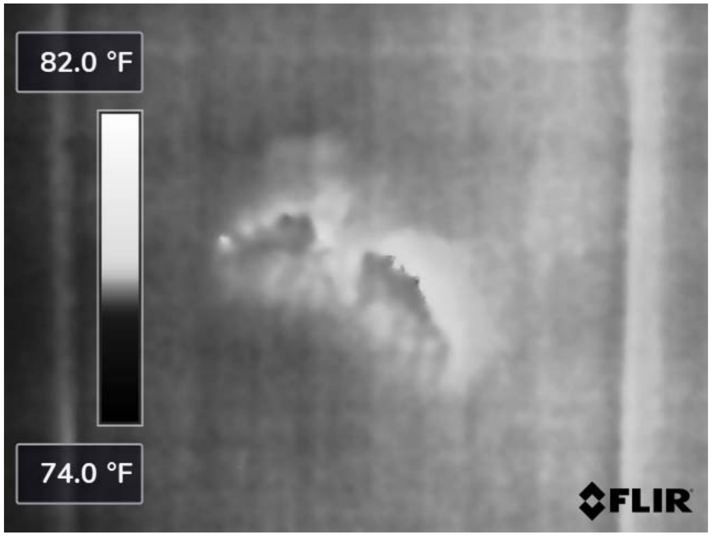
Grayscale Palette, Manual Settings



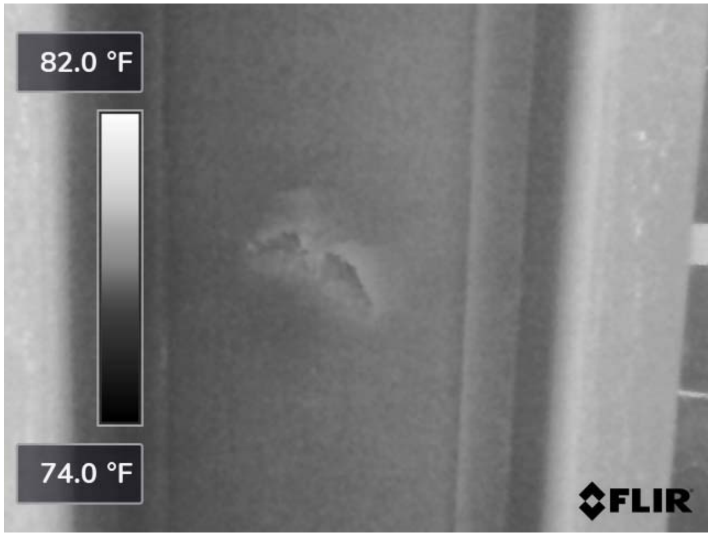
C5_Loc05_03_FLIR0285



E8_Loc05_03_FLIR0288



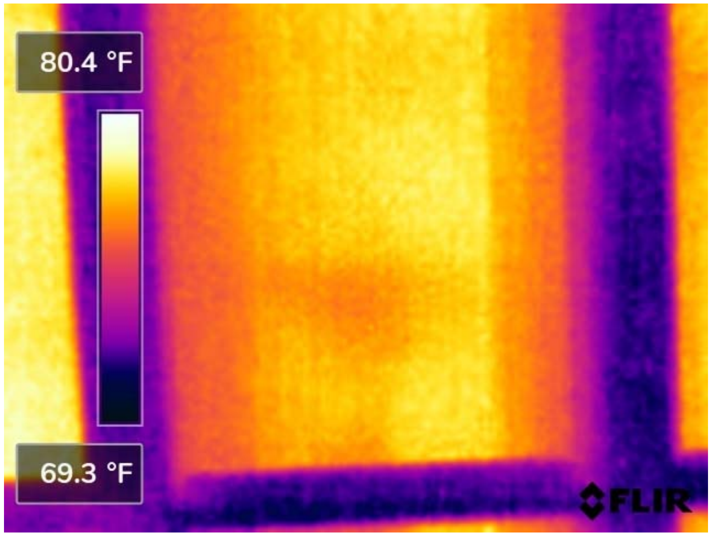
E86_Loc05_04_FLIR0399



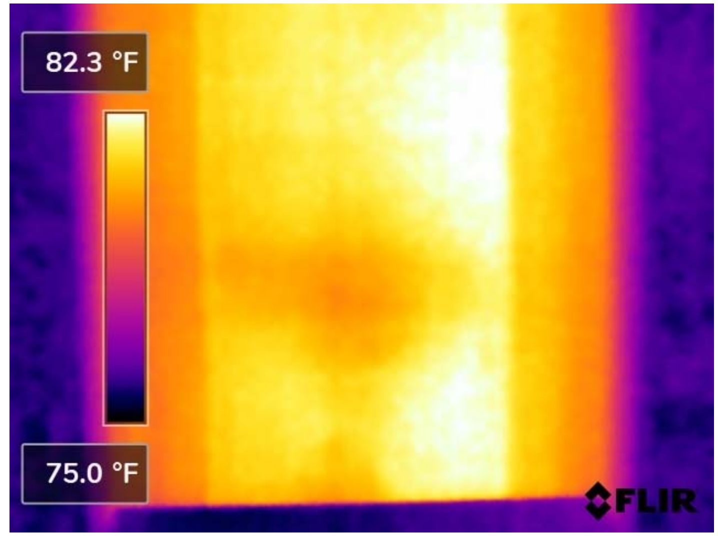
E96_Loc5_05_FLIR0353

4E5, Location 6 – Comparison of Camera Imagery

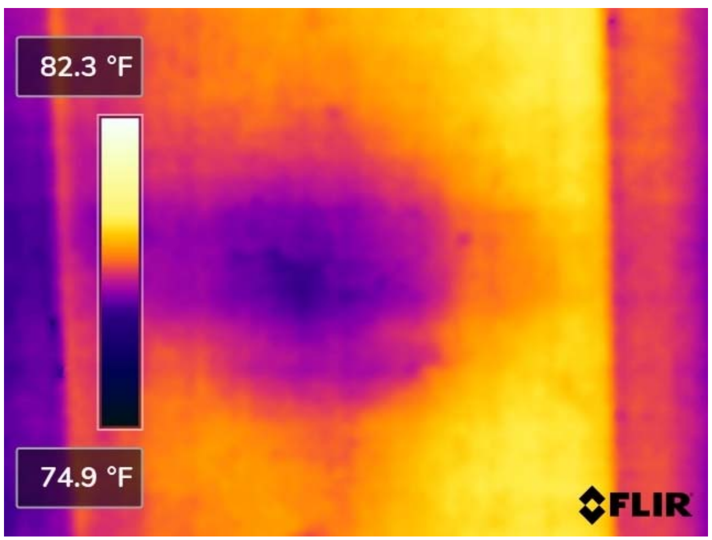
Ironbow Palette, Automatic Settings



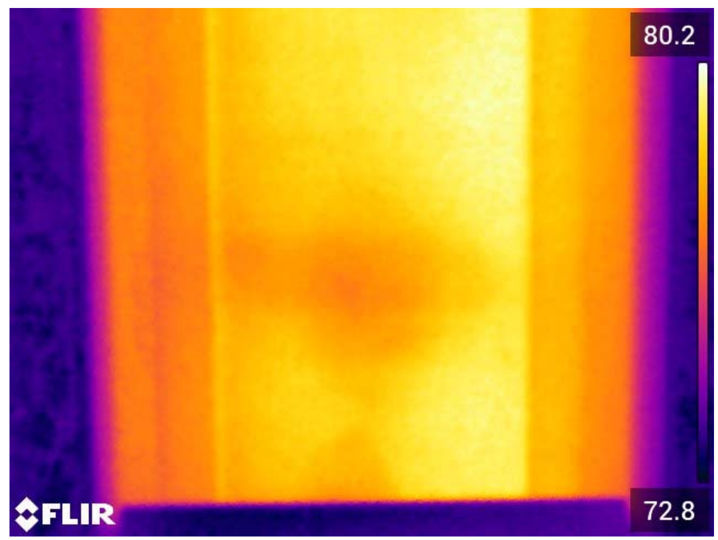
C5_Loc06_14_FLIR1477



E8_Loc06_15_FLIR1776



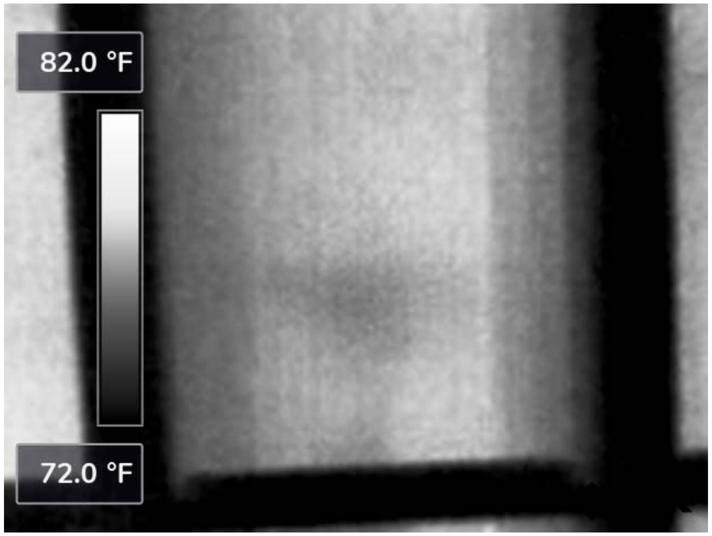
E86_Loc06_17_FLIR1625



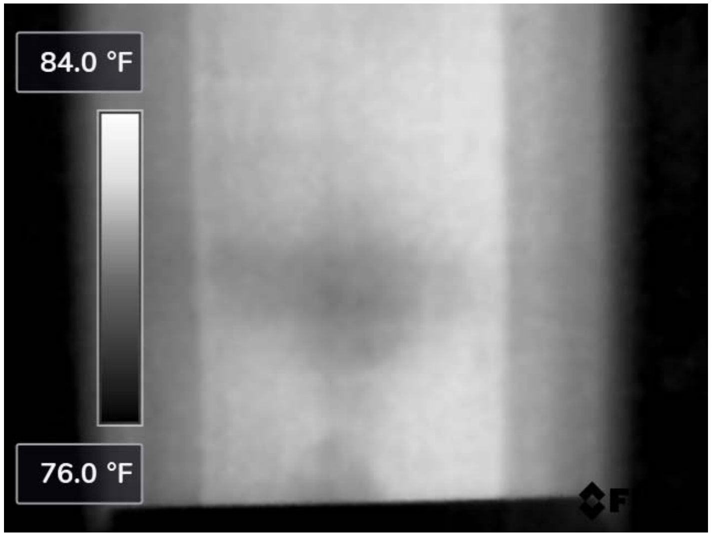
E96_Loc6_21_FLIR2333

4E5, Location 6 – Comparison of Camera Imagery

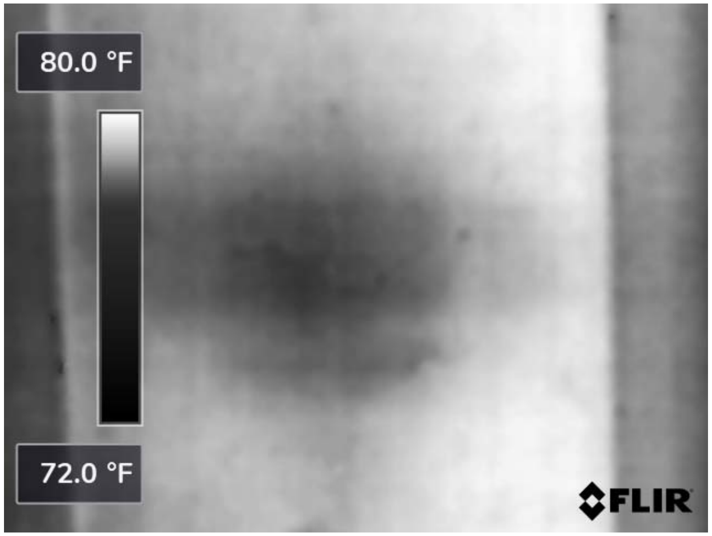
Grayscale Palette, Manual Settings



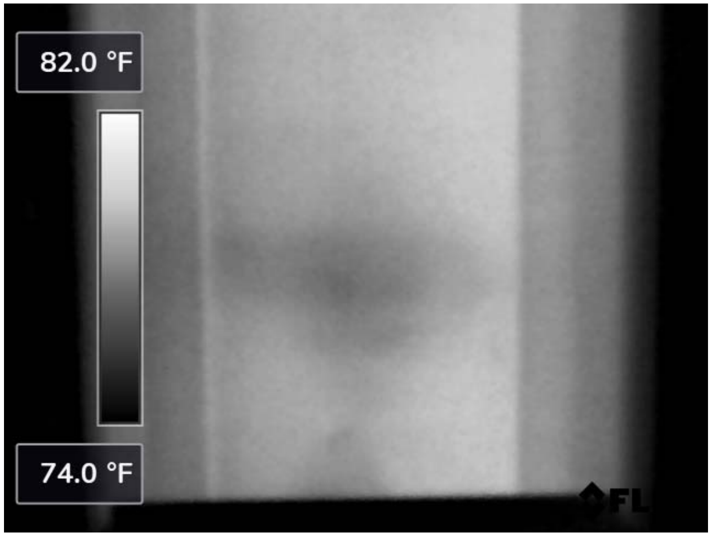
C5_Loc06_14_FLIR1477



E8_Loc06_15_FLIR1776



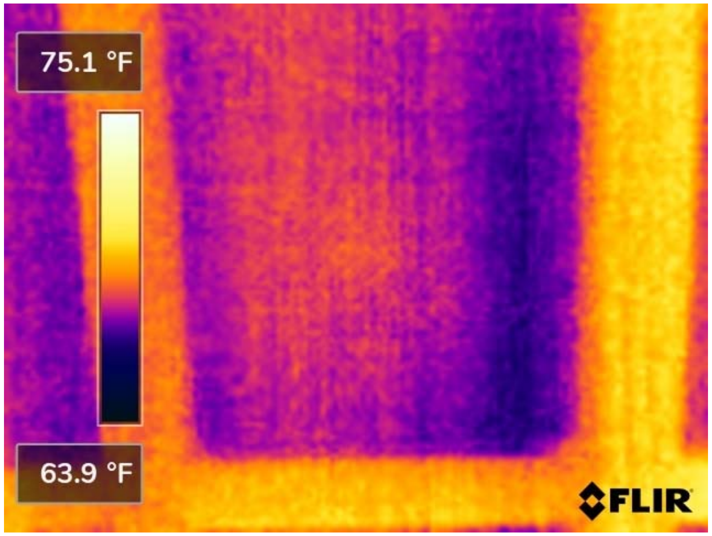
E86_Loc06_17_FLIR1625



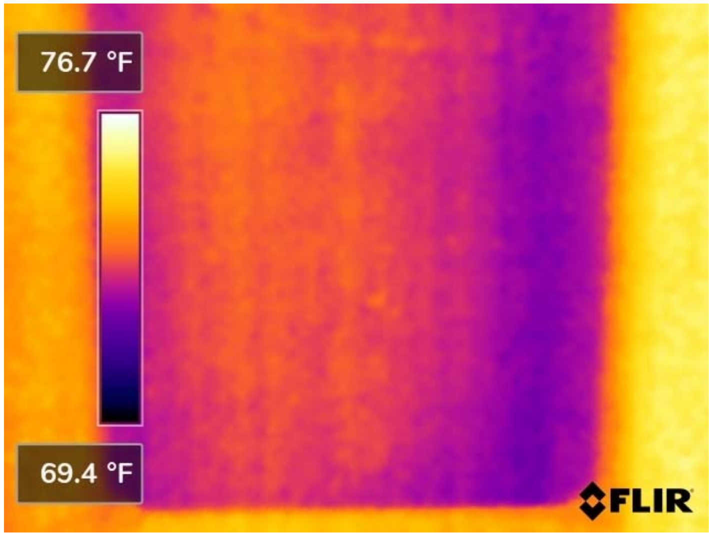
E96_Loc6_21_FLIR2333

4E5, Location 7 – Comparison of Camera Imagery

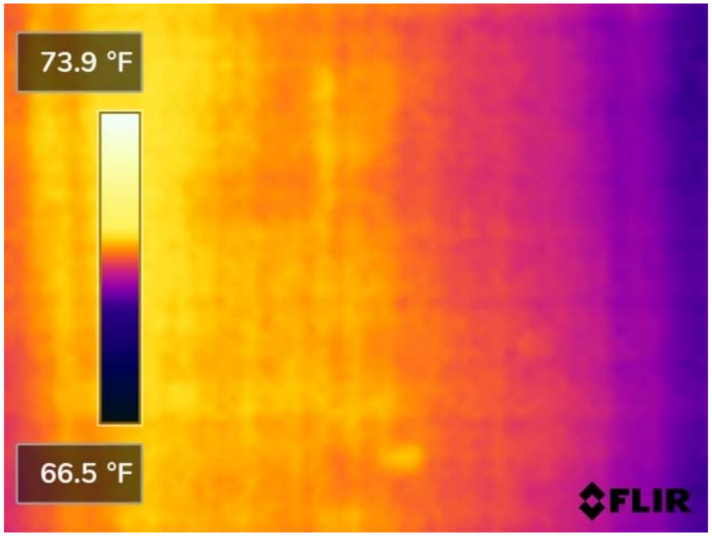
Ironbow Palette, Automatic Settings



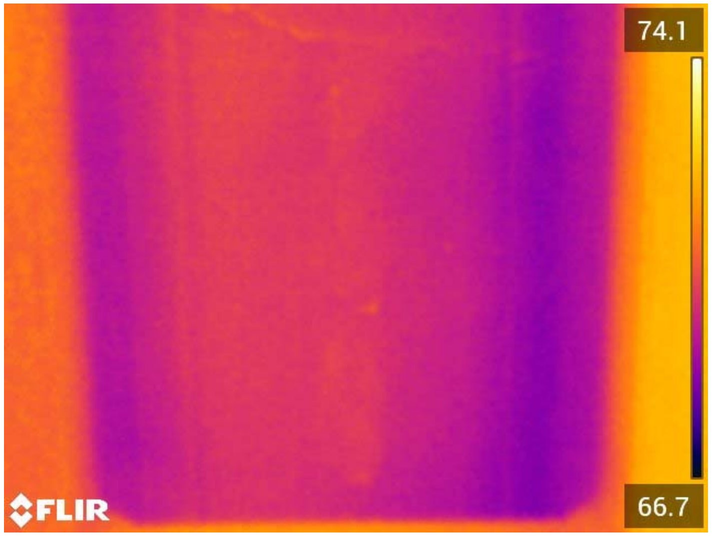
C5_Loc07_07_FLIR0819



E8_Loc07_08_FLIR1018



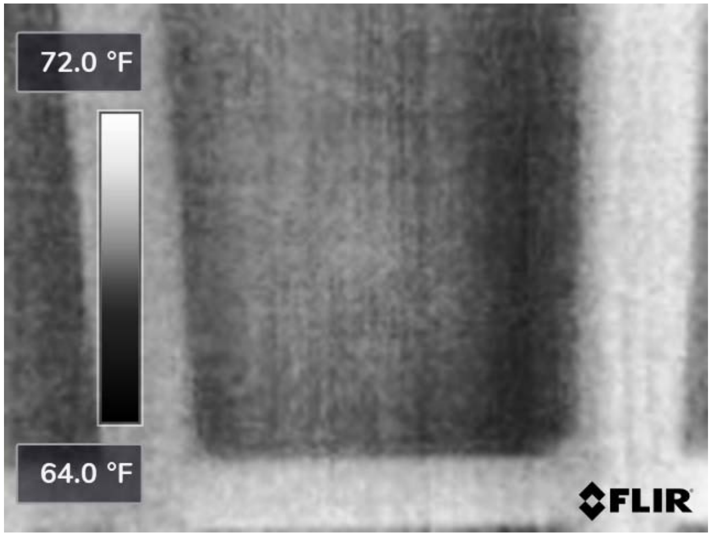
E86_Loc07_09_FLIR0949



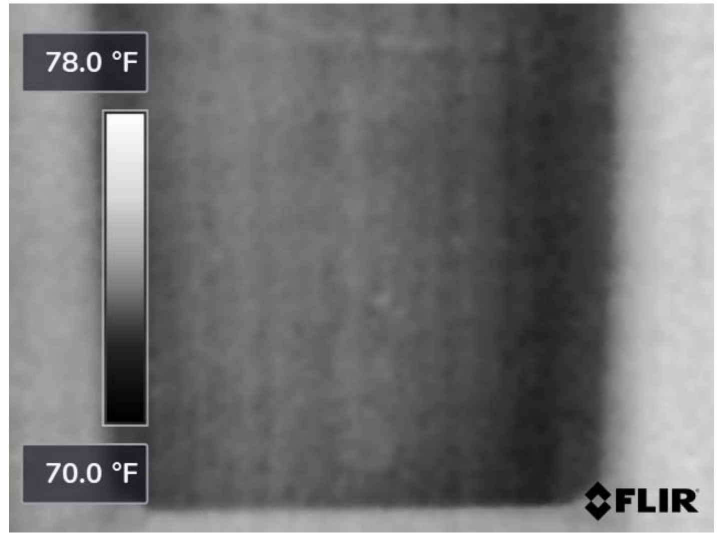
E96_Loc7_11_FLIR1039

4E5, Location 7 – Comparison of Camera Imagery

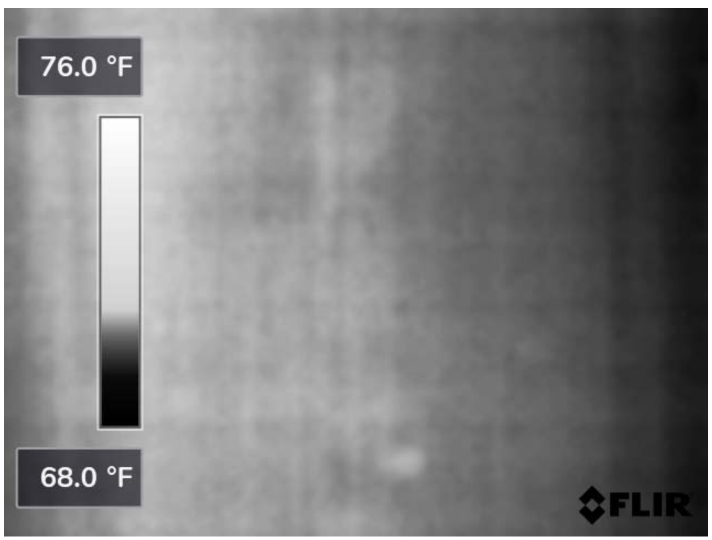
Grayscale Palette, Manual Settings



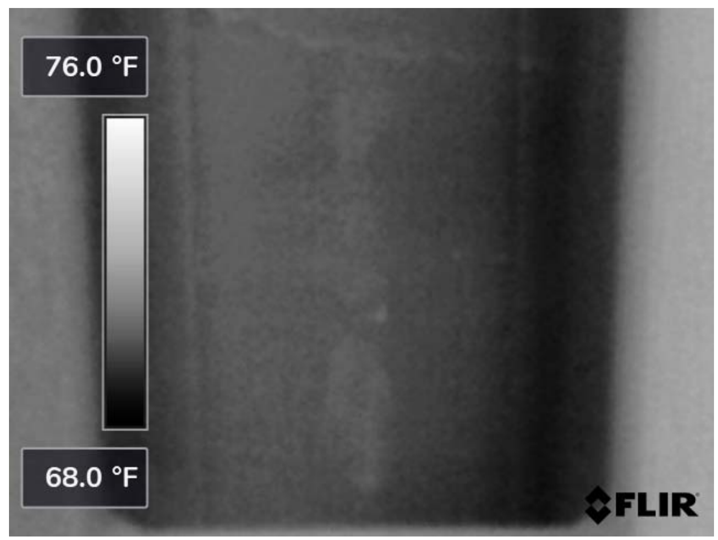
C5_Loc07_07_FLIR0819



E8_Loc07_08_FLIR1018



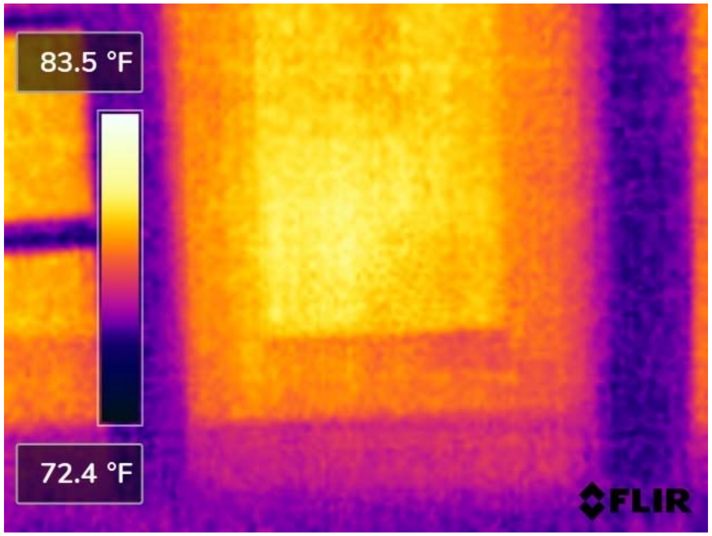
E86_Loc07_09_FLIR0949



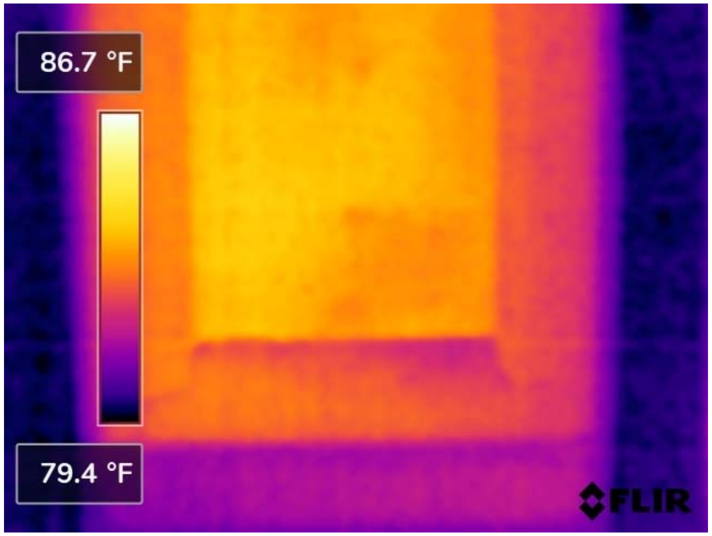
E96_Loc7_11_FLIR1039

4E5, Location 8 – Comparison of Camera Imagery

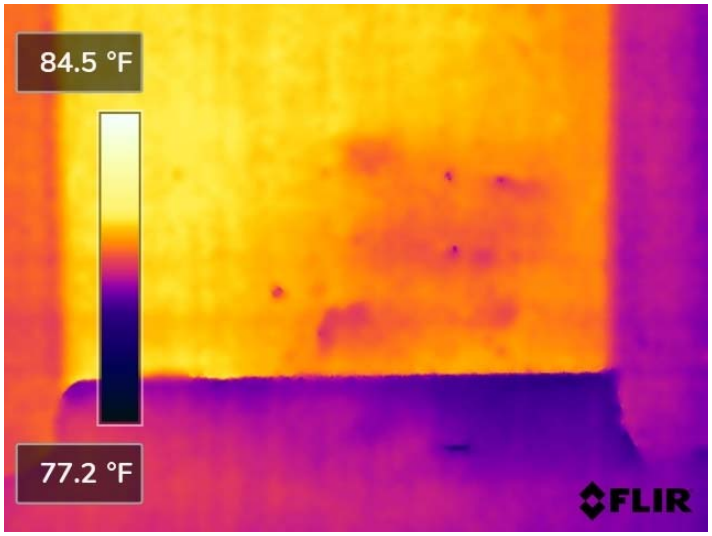
Ironbow Palette, Automatic Settings



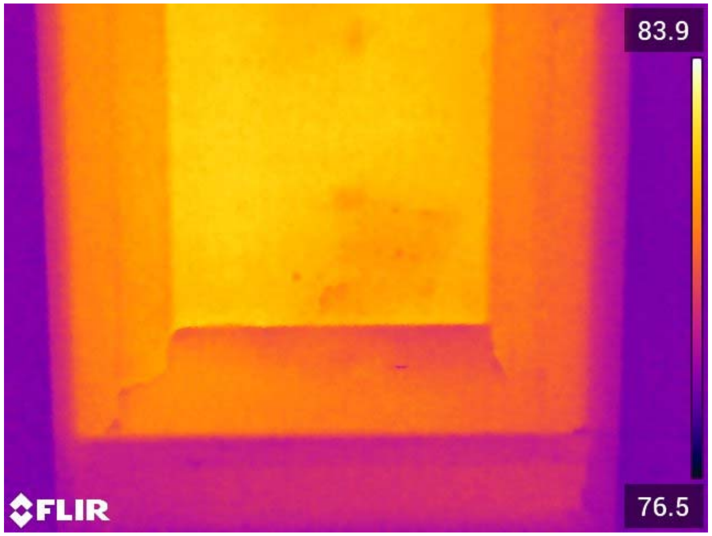
C5_Loc08_11_FLIR1341



E8_Loc08_12_FLIR1644



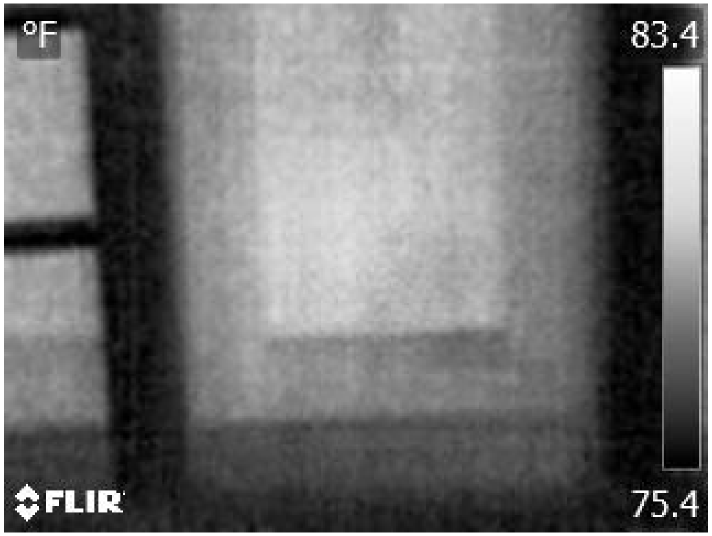
E86_Loc08_13_FLIR1381



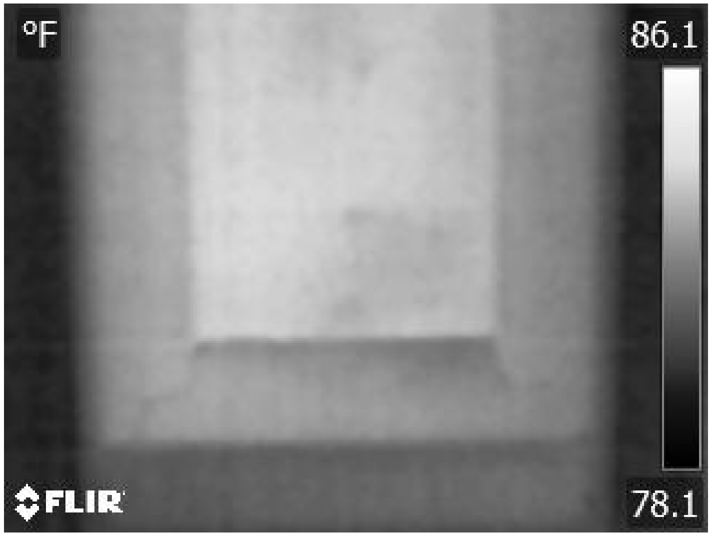
E96_Loc8_16_FLIR1995

4E5, Location 8 – Comparison of Camera Imagery

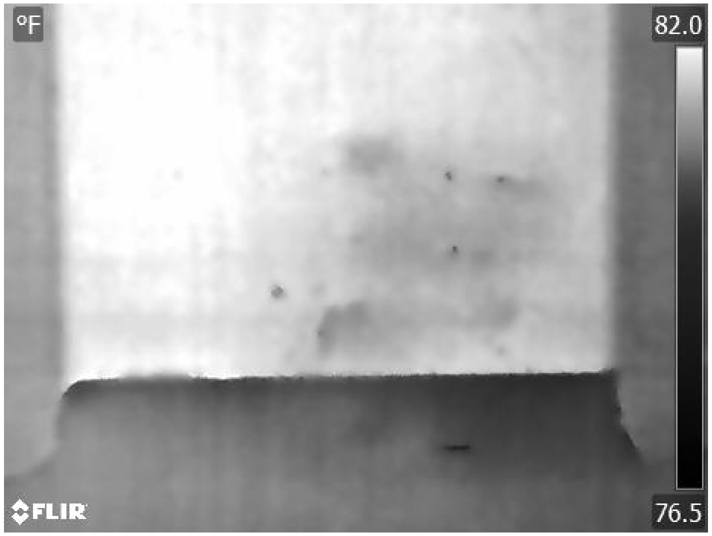
Grayscale Palette, Manual Settings



C5_Loc08_11_FLIR1341



E8_Loc08_12_FLIR1644

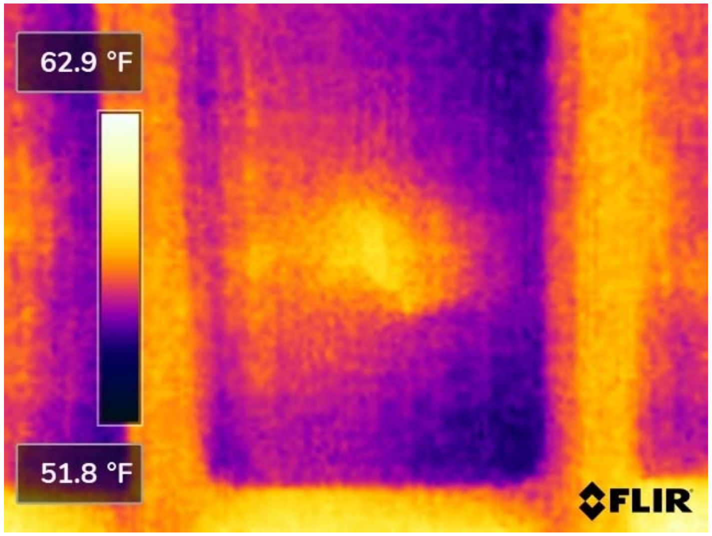


E86_Loc08_13_FLIR1381

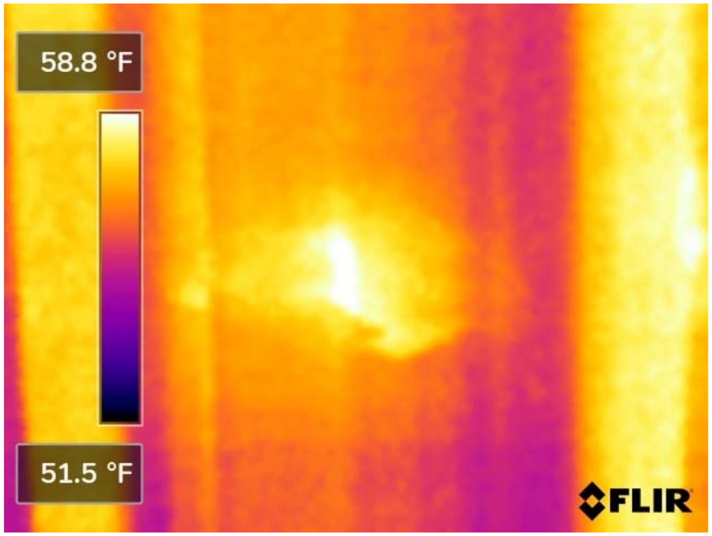
E96_Loc8_16_FLIR1995

4E5, Location 9 – Comparison of Camera Imagery

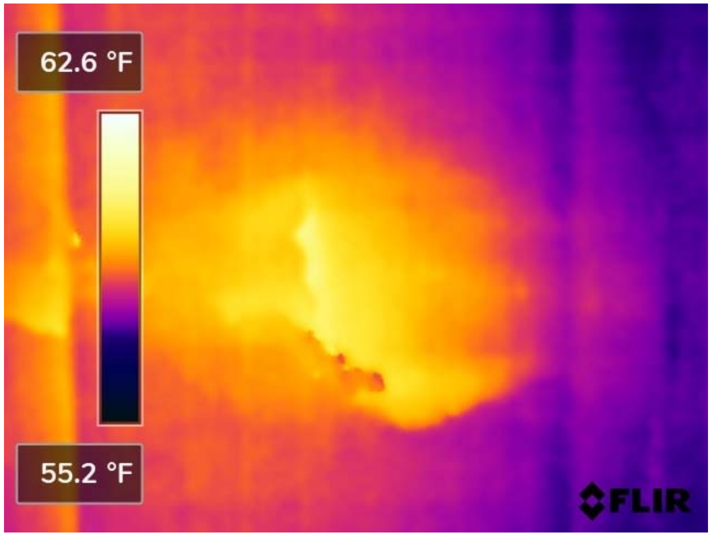
Ironbow Palette, Automatic Settings



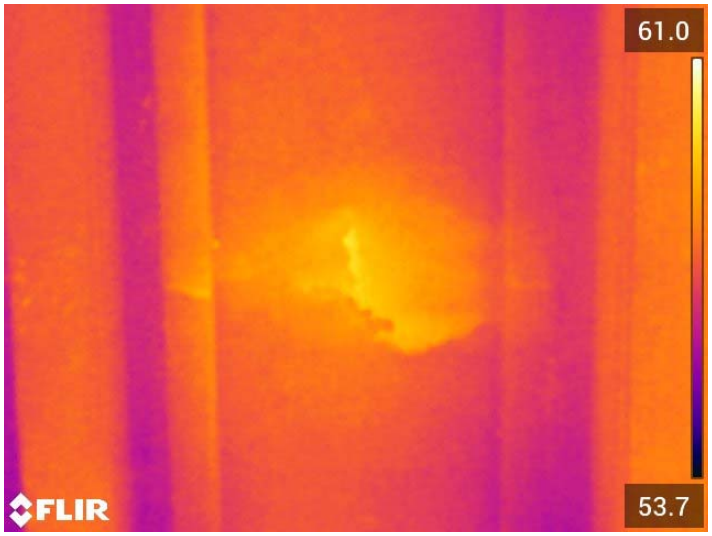
C5_Loc09_19_FLIR2085



E8_Loc09_21_FLIR2364



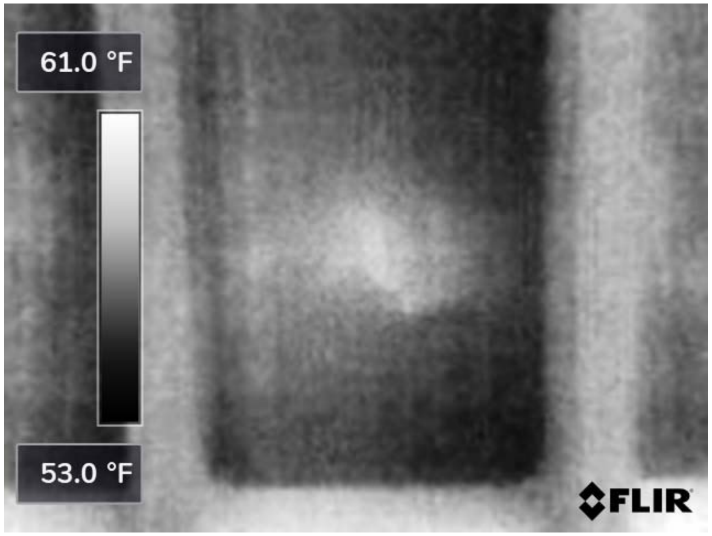
E86_Loc09_22_FLIR2059



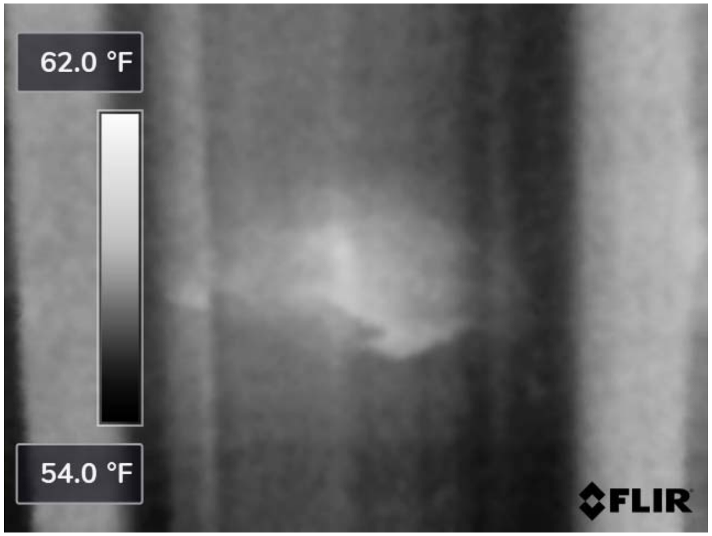
E96_Loc9_29_FLIR3352

4E5, Location 9 – Comparison of Camera Imagery

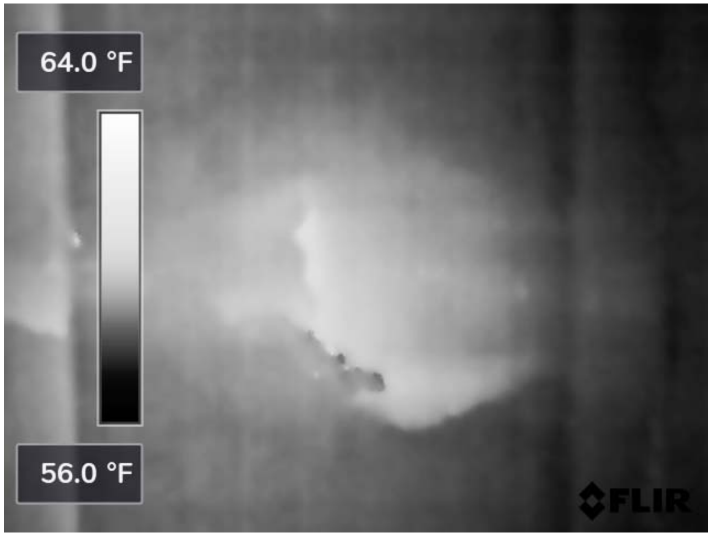
Grayscale Palette, Manual Settings



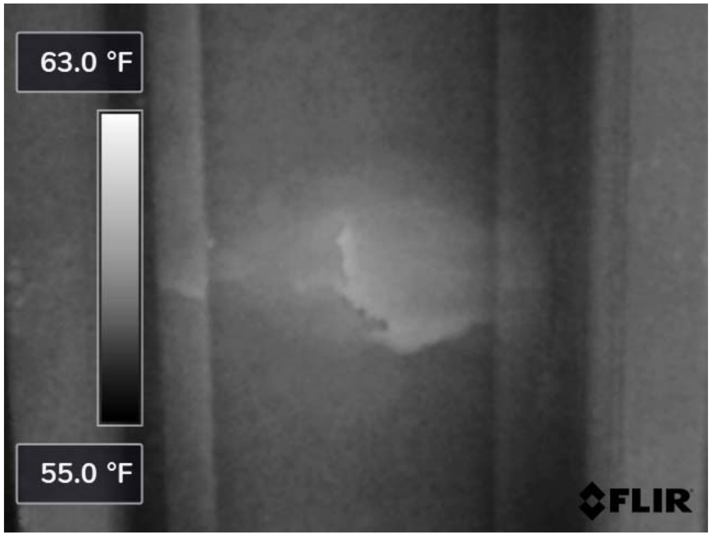
C5_Loc09_19_FLIR2085



E8_Loc09_21_FLIR2364



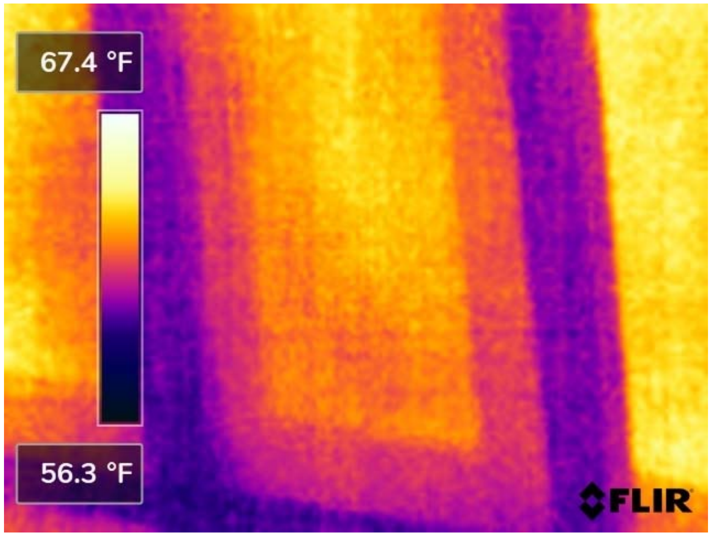
E86_Loc09_22_FLIR2059



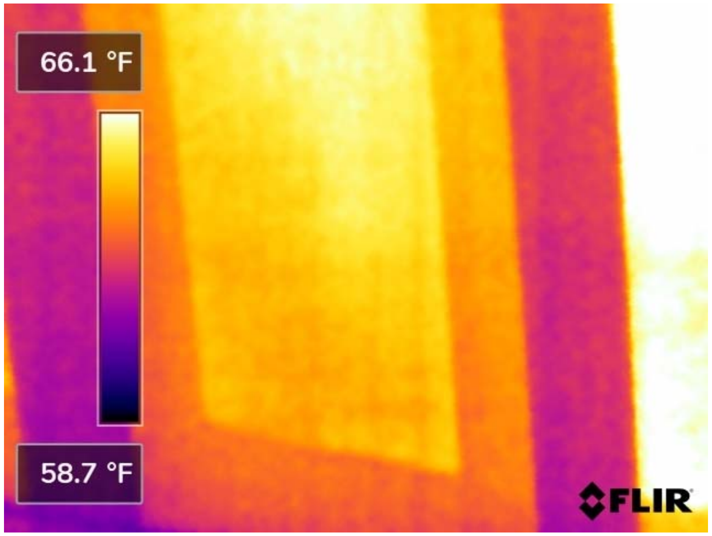
E96_Loc9_29_FLIR3352

4E5, Location 10 – Comparison of Camera Imagery

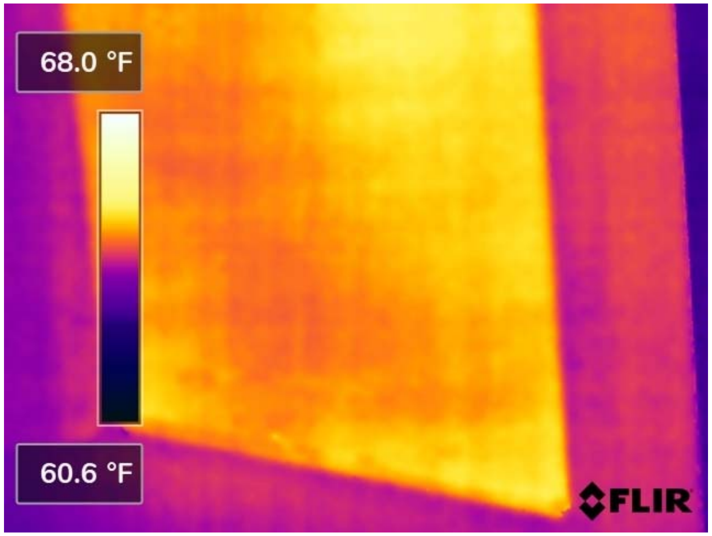
Ironbow Palette, Automatic Settings



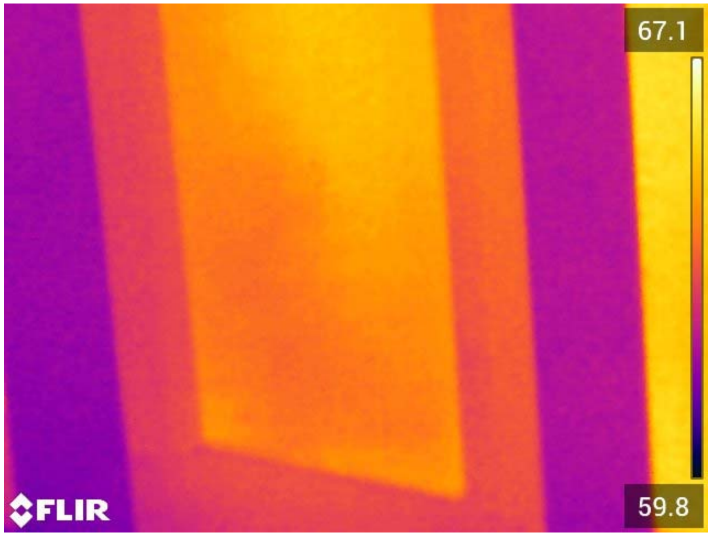
C5_Loc10_18_FLIR1981



E8_Loc10_20_FLIR2242



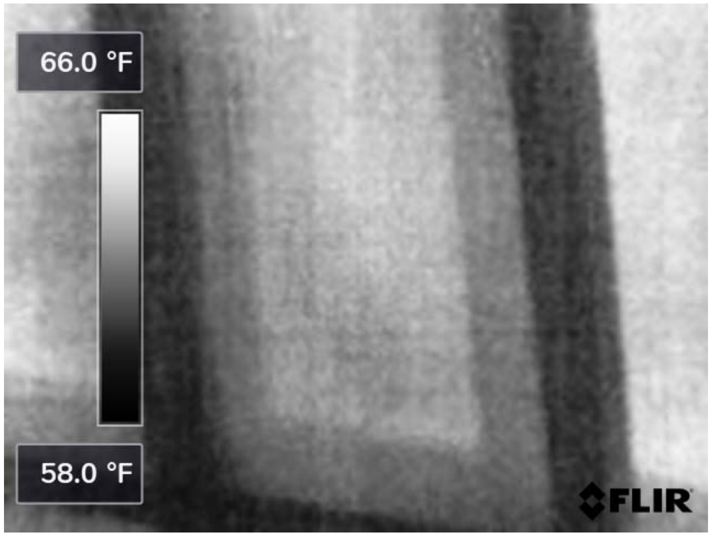
E86_Loc10_21_FLIR1921



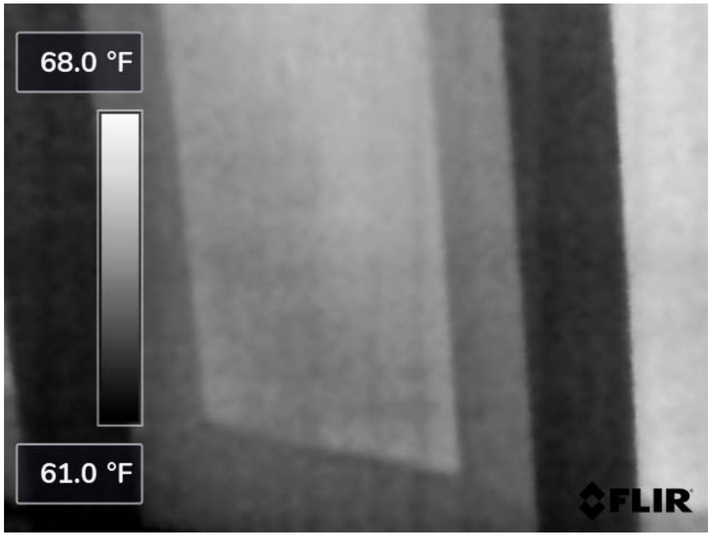
E96_Loc10_27_FLIR3139

4E5, Location 10 – Comparison of Camera Imagery

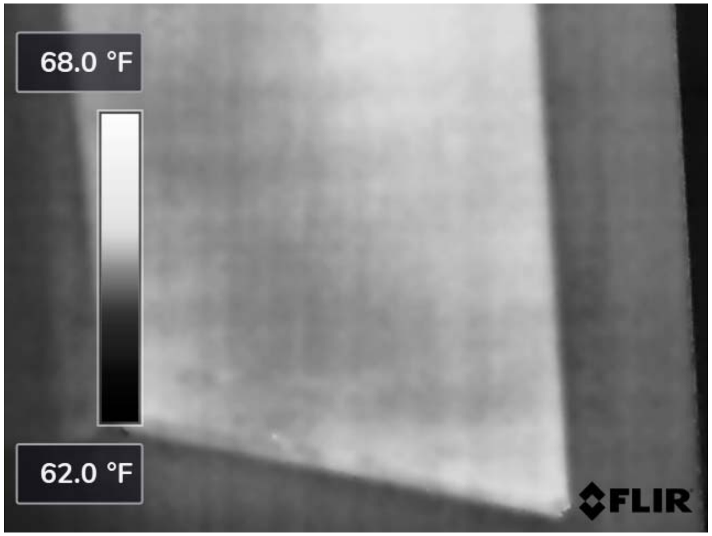
Grayscale Palette, Manual Settings



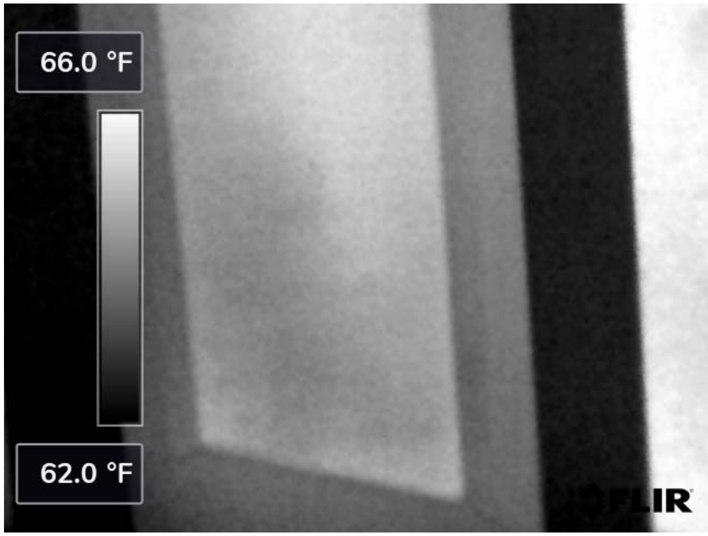
C5_Loc10_18_FLIR1981



E8_Loc10_20_FLIR2242



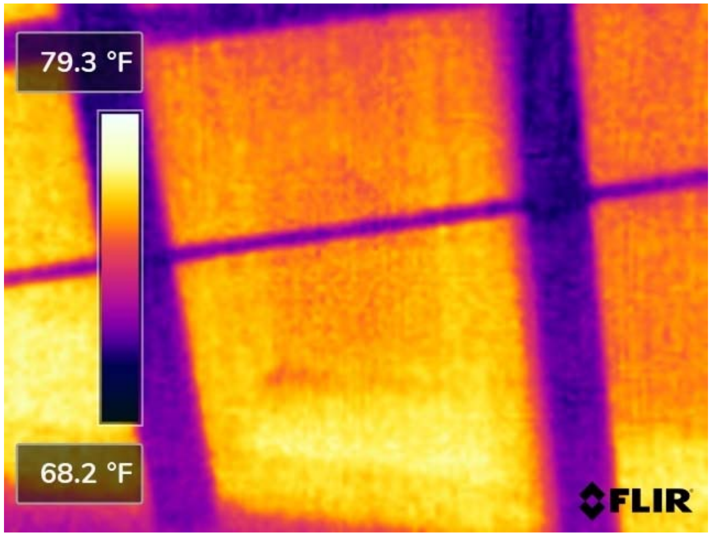
E86_Loc10_21_FLIR1921



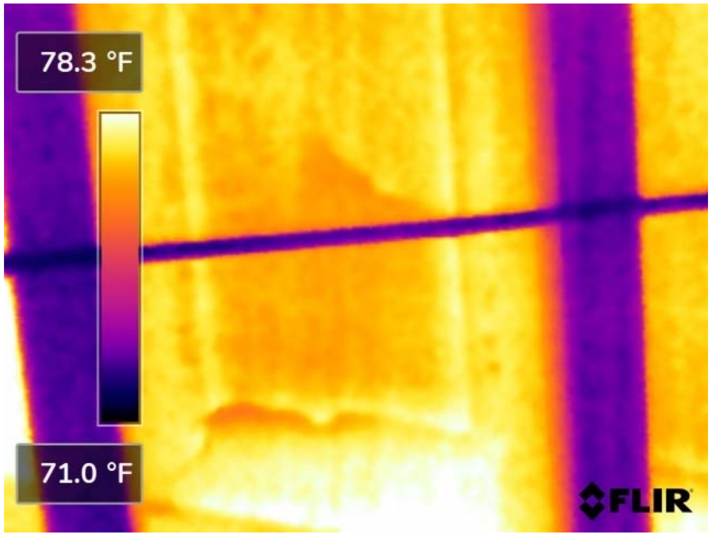
E96_Loc10_27_FLIR3139

4E5, Location 11 – Comparison of Camera Imagery

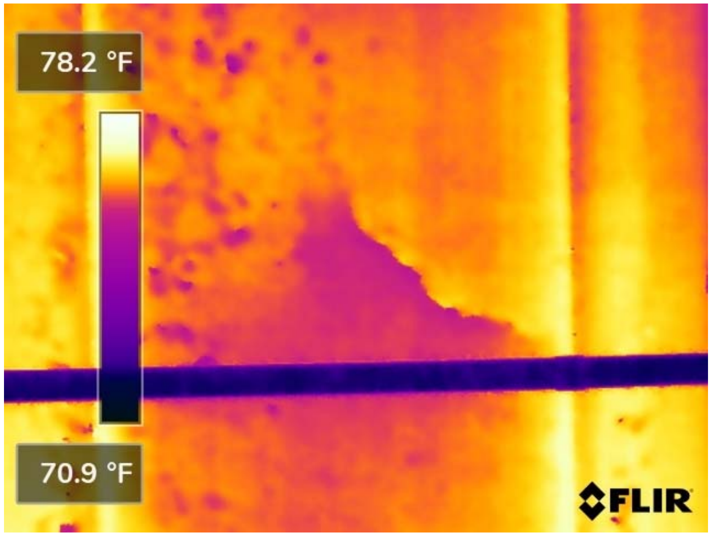
Ironbow Palette, Automatic Settings



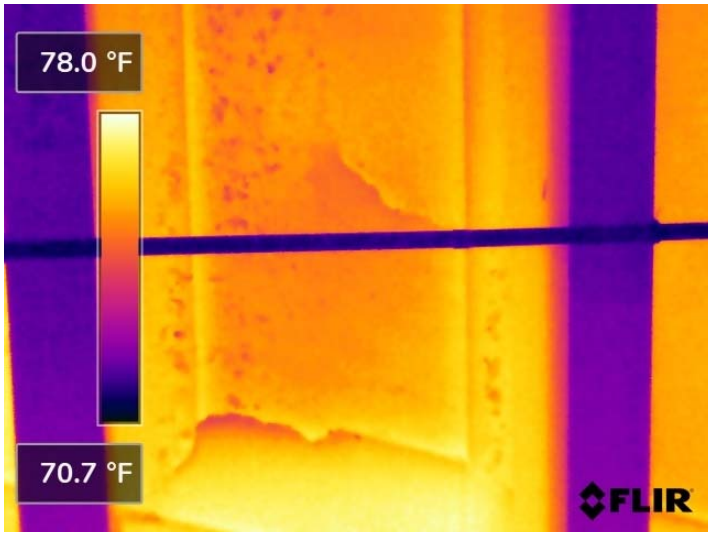
C5_Loc11_05_FLIR0531



E8_Loc11_05_FLIR0570



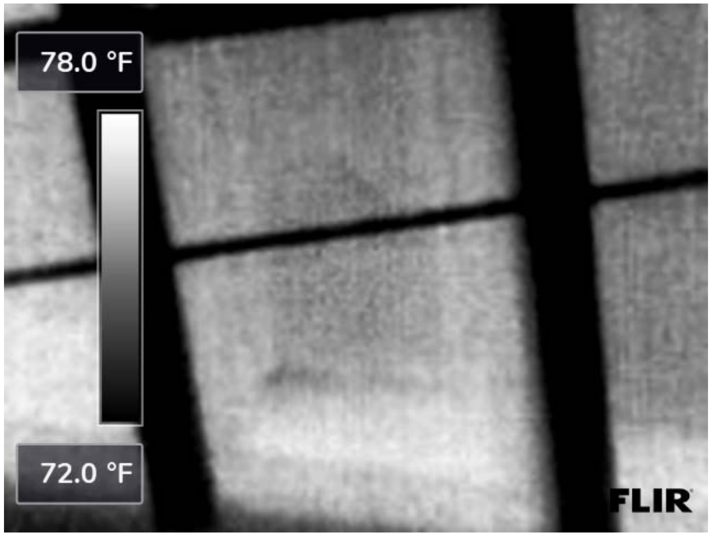
E86_Loc11_06_FLIR0635



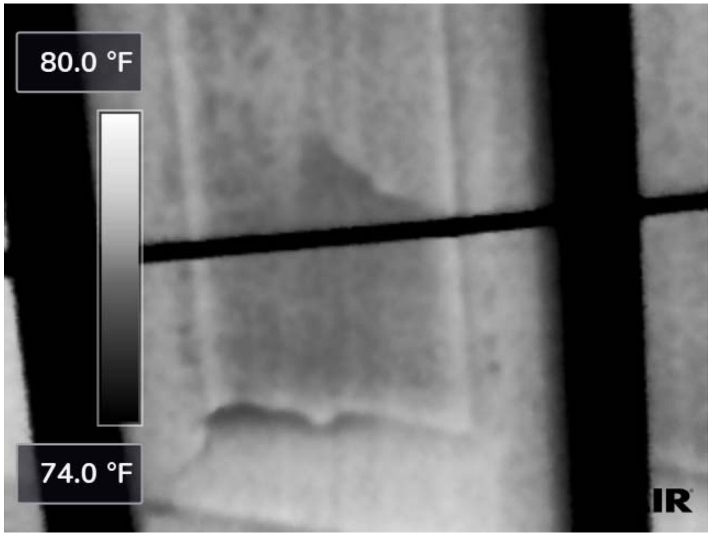
E96_Loc11_08_FLIR0649

4E5, Location 11 – Comparison of Camera Imagery

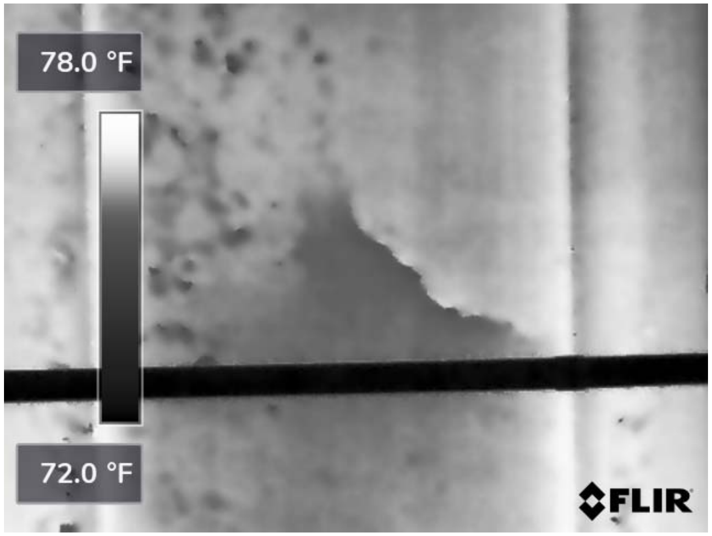
Grayscale Palette, Manual Settings



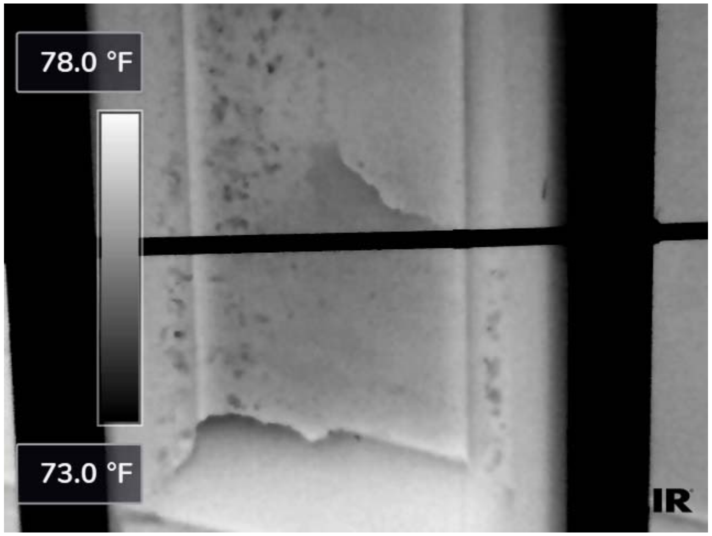
C5_Loc11_05_FLIR0531



E8_Loc11_05_FLIR0570



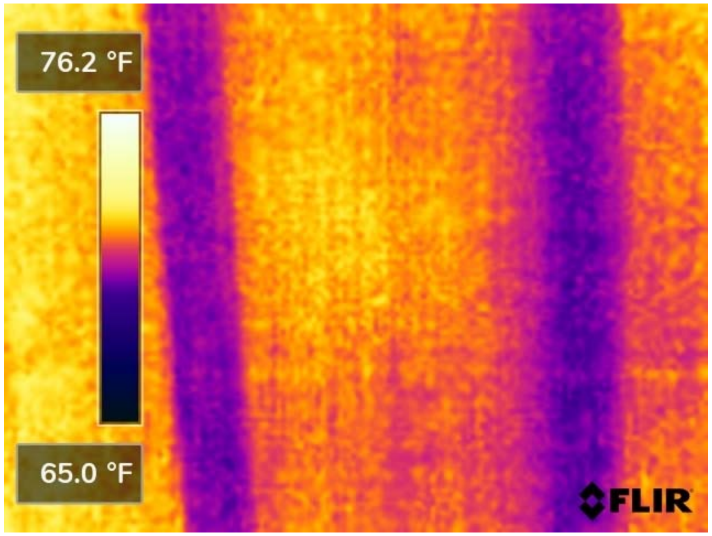
E86_Loc11_06_FLIR0635



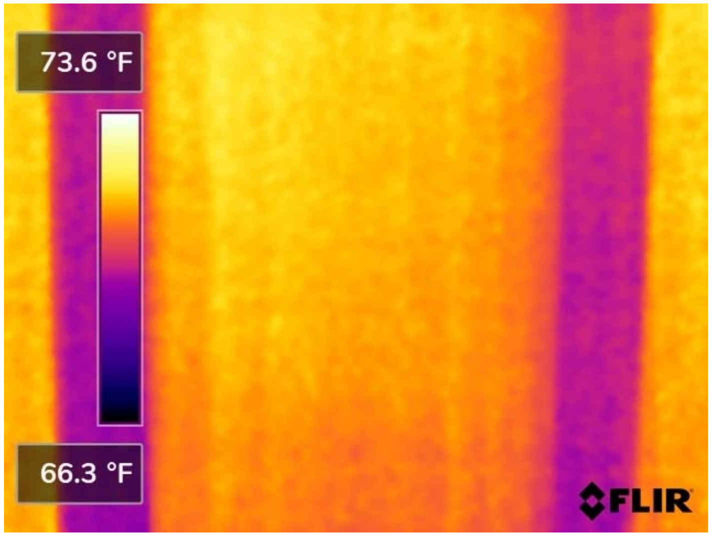
E96_Loc11_08_FLIR0649

4E5, Location 12 – Comparison of Camera Imagery

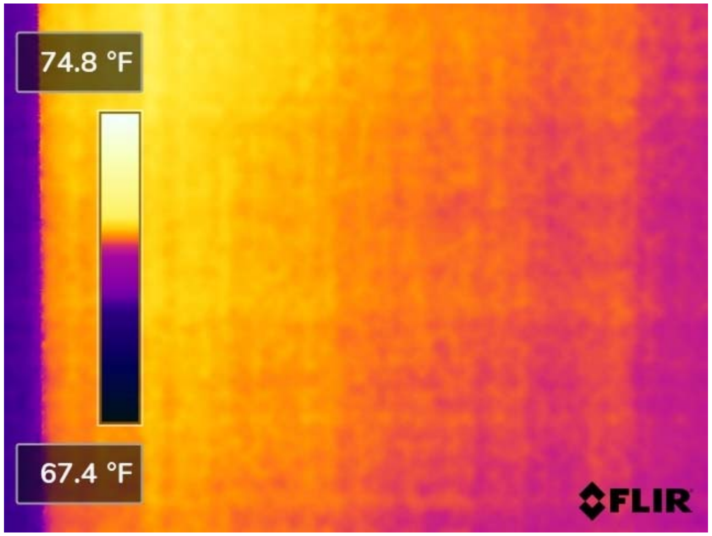
Ironbow Palette, Automatic Settings



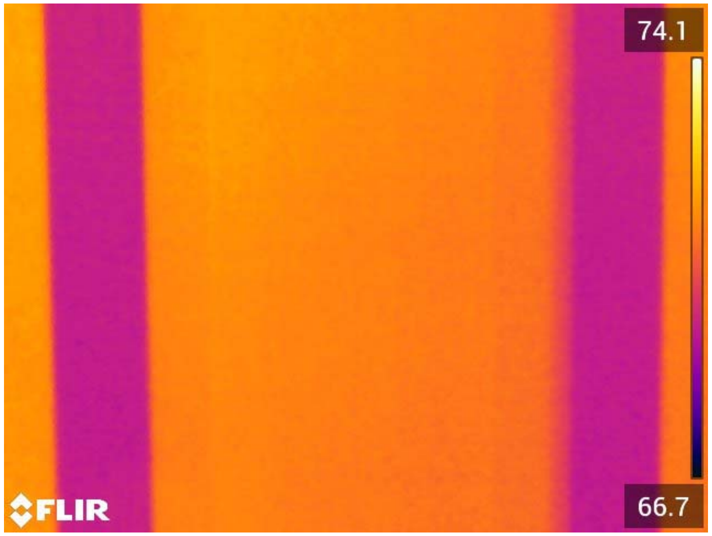
C5_Loc12_13_FLIR1451



E8_Loc12_14_FLIR1750



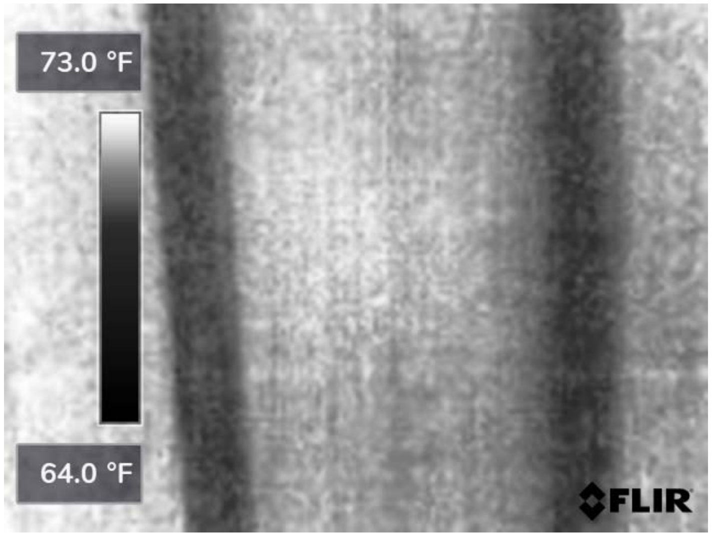
E86_Loc12_15_FLIR1511



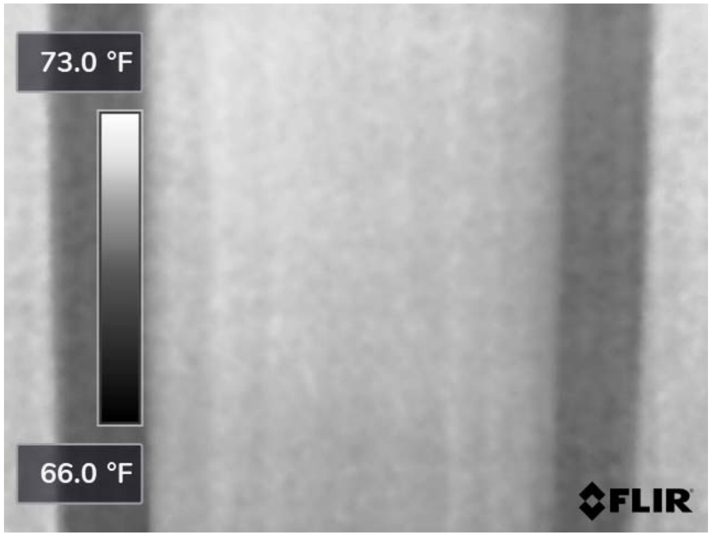
E96_Loc12_19_FLIR2251

4E5, Location 12 – Comparison of Camera Imagery

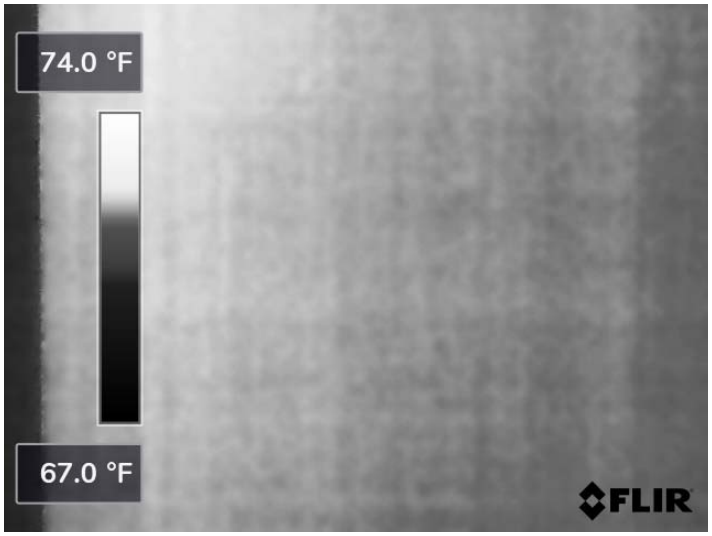
Grayscale Palette, Manual Settings



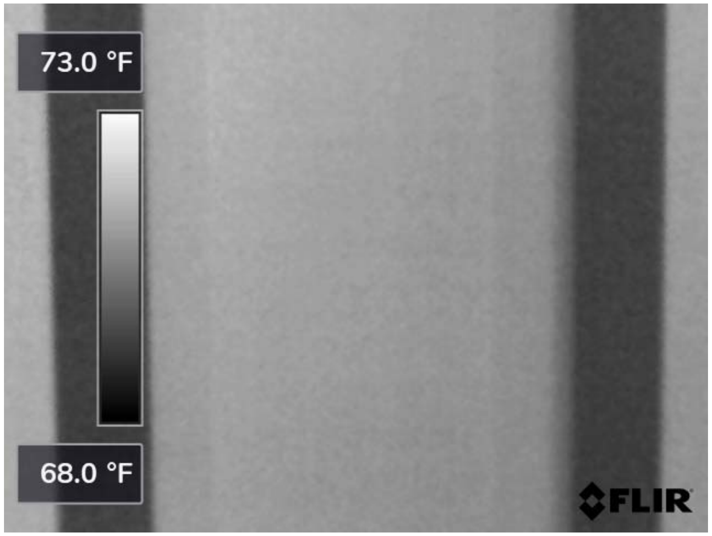
C5_Loc12_13_FLIR1451



E8_Loc12_14_FLIR1750



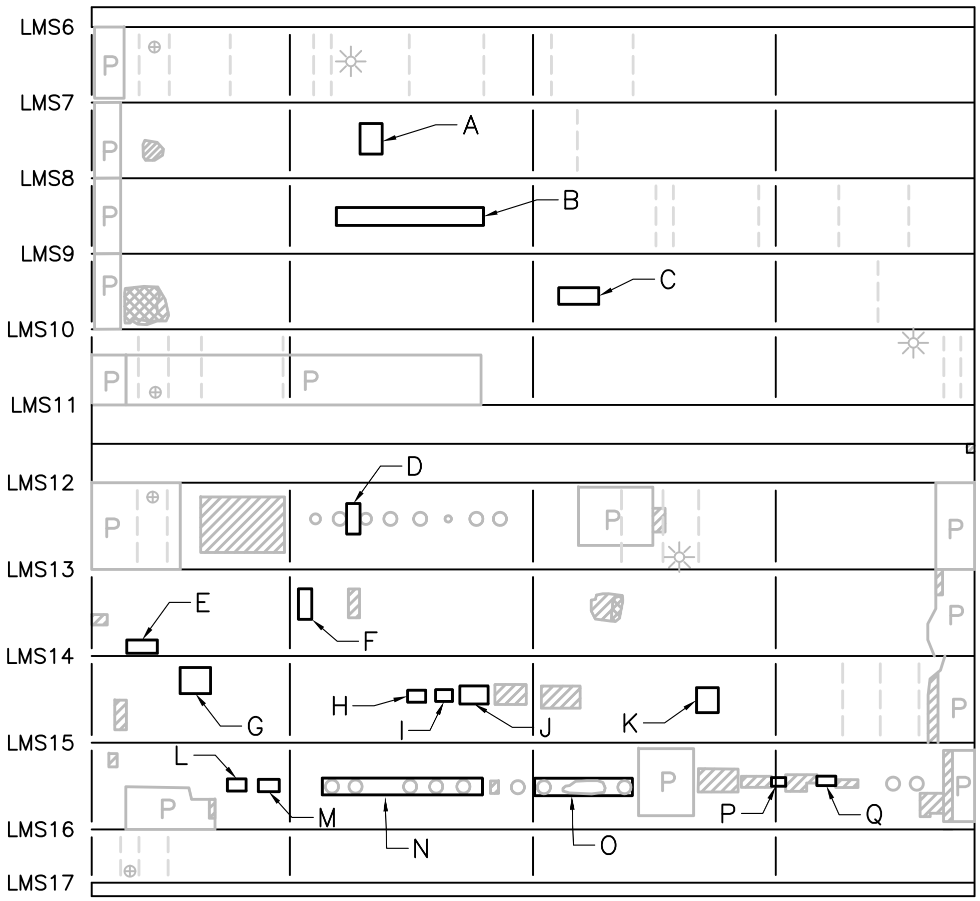
E86_Loc12_15_FLIR1511



E96_Loc12_19_FLIR2251

SOUTHBOUND OFF–RAMP (LMS1–LMS5) NOT INCLUDED WITHIN SCOPE OF INSPECTION

N



FOLLOW UP INSPECTION FINDINGS				
LOCATION	IR IMAGE #	FOLLOW UP INSP. DESCRIPTION	IMAGE #	COMMENTS
A	2725	NO DELAMINATION FOUND	5100	NO APPARENT CAUSE FOR TEMPERATURE DIFFERENTIAL
B	2727	NO DELAMINATION FOUND	5101	NO APPARENT CAUSE FOR TEMPERATURE DIFFERENTIAL
C	2729	NO DELAMINATION FOUND	5102	NO APPARENT CAUSE FOR TEMPERATURE DIFFERENTIAL
D	2731	MINOR DELAMINATION MEASURING 25"W x UP TO 20" L	5122	DELAMINATION VERY HARD TO DISTINGUISH BY SOUNDING
E	2735	DELAMINATION IN DECK MEASURING 25"W x UP TO 26"L. DELAMINATION IN HAUNCH MEASURING 26"L x 5"W	5105	
F	2733	NO DELAMINATION FOUND	5103	NO APPARENT CAUSE FOR TEMPERATURE DIFFERENTIAL
G	2737	NO DELAMINATION FOUND	5107	MINOR DISCOLORATION OF DECK AT LOCATION
H	2739	NO DELAMINATION FOUND	5121	DISCOLORATION AND POOR CONSOLIDATION AT LOCATION
I	2739	NO DELAMINATION FOUND	5121	DISCOLORATION AND POOR CONSOLIDATION AT LOCATION
J	2739	MINOR DELAMINATION MEASURING 38"L x UP TO 15"W	5121	
K	2741	MINOR DELAMINATION MEASURING 19" W x UP TO 10"L	5109	
L	2749	NO DELAMINATION FOUND	5108	PATCHES, DISCOLORATION AND POOR CONSOLIDATION AT LOCATION
M	2749	NO DELAMINATION FOUND	5108	PATCHES, DISCOLORATION AND POOR CONSOLIDATION AT LOCATION
N	2747	MINOR DELAMINATION INCLUDING HOLLOW SOUNDING PATCHES MEASURING 31"L x UP TO 9" w AT SOUTH END; 7"W x UP TO 10"L HOLLOW SOUNDING PATCH AT CENTER; AND 7"W x UP TO 5"L HOLLOW SOUNDING PATCH AT NORTH END	5115	
O	2745	MINOR DELAMINATION BETWEEN HOLLOW SOUNDING PATCHES MEASURING 56"L x UP TO 9"W	5117	POTENTIALLY CAUSED BY POOR QUALITY REPAIR / POOR CONSOLIDATION
P	2743	MINOR DELAMINATION MEASURING 8"W	5112	POTENTIALLY CAUSED BY POOR QUALITY REPAIR / POOR CONSOLIDATION
Q	2743	MINOR DELAMINATION MEASURING UP TO 8" W x 29" L	5111	POTENTIALLY CAUSED BY POOR QUALITY REPAIR / POOR CONSOLIDATION

SPAN L–M

Thermal Survey and Follow up Inspection

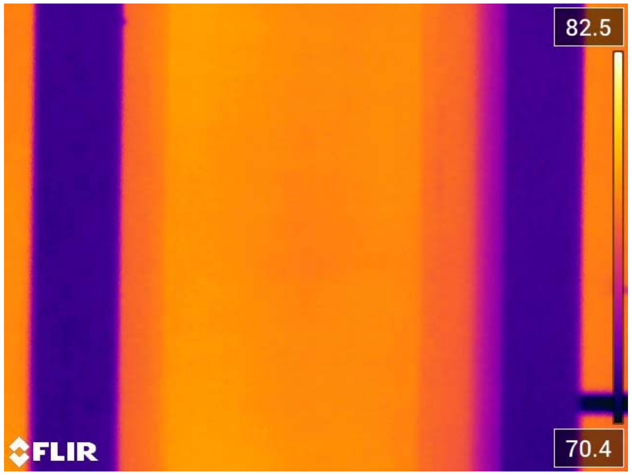
LEGEND:

- Hollow Area
- Spall
- P – Patch
- Diaphragm
- Utility Bracket
- Overhead Light
- Drain

NOTES:

1. This inspection was limited to the mainline portion of Span L–M. The off–ramp portion (LMS1–LSM5) was omitted as the ramp deck separate from the mainline.
2. The sketch shows additional areas of interest based on temperature differentials identified using the Flir E96 handheld thermal camera. An additional follow up inspection was performed to ascertain whether these areas of interest were additional delaminated areas that were not identified during the initial traditional inspection.
3. Refer to the associated appendix for thermal and visual photos of the areas of interest.

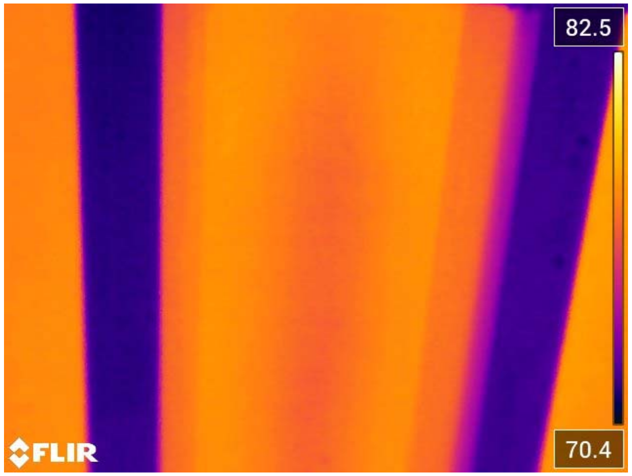
4E5, Thermal Survey Areas of Interest / Follow up Inspection Findings



Location A, IR Image
2725

Location A, IR Camera Visual Image
2726

Location A, Follow Up Insp. Image
5100



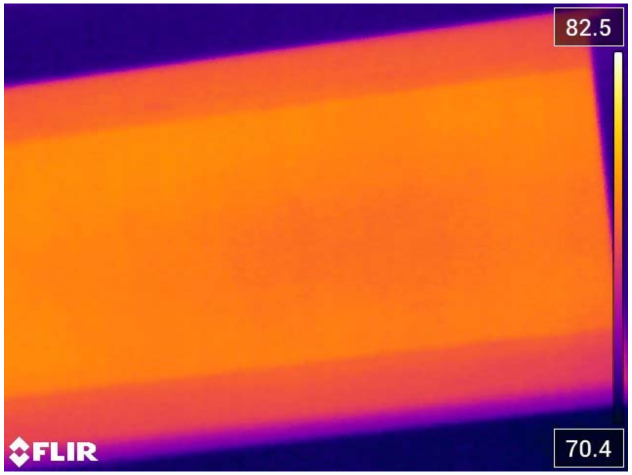
Location B, IR Image
2727

Location B, IR Camera Visual Image
2728

Location B, Follow Up Insp. Image
5101

Notes:
- Refer to Associated AutoCAD Sketches for BIN 4E5, Span L-M for locations and descriptions.
- Thermal imagery was taken with the Flir E96 handheld thermal camera on 9/26/21. The follow up inspection to verify the thermal areas of interest was performed on 10/25/21.
- The follow up inspection used red lumber crayon to outline and hatch delaminated areas. This was to differentiate from the initial inspection, which used yellow lumber crayon.

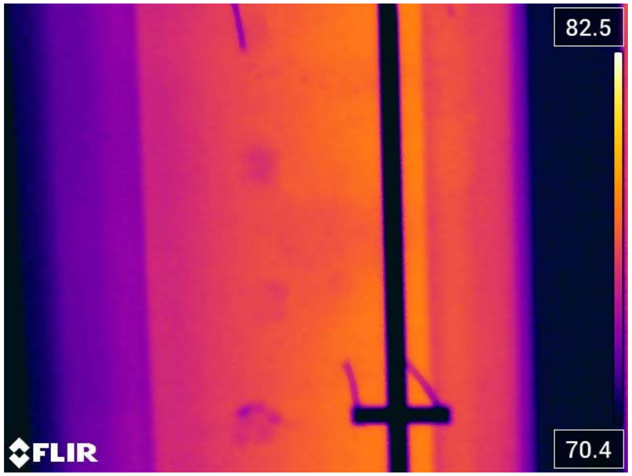
4E5, Thermal Survey Areas of Interest / Follow up Inspection Findings



Location C, IR Image
2729

Location C, IR Camera Visual Image
2730

Location C, Follow Up Insp. Image
5102



Location D, IR Image
2731

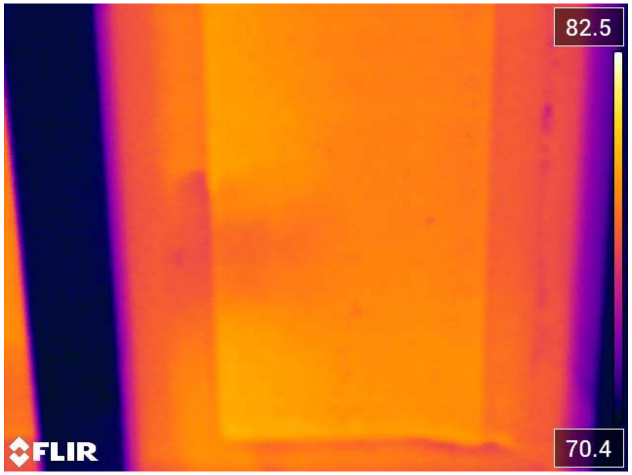
Location D, IR Camera Visual Image
2732

Location D, Follow Up Insp. Image
5122

Notes:

- Refer to Associated AutoCAD Sketches for BIN 4E5, Span L-M for locations and descriptions.
- Thermal imagery was taken with the Flir E96 handheld thermal camera on 9/26/21. The follow up inspection to verify the thermal areas of interest was performed on 10/25/21.
- The follow up inspection used red lumber crayon to outline and hatch delaminated areas. This was to differentiate from the initial inspection, which used yellow lumber crayon.

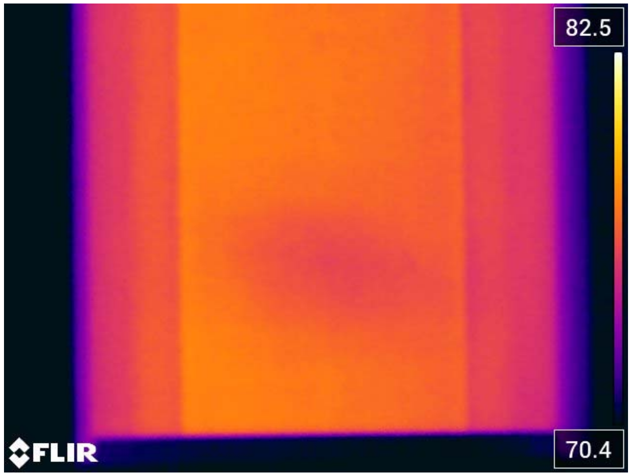
4E5, Thermal Survey Areas of Interest / Follow up Inspection Findings



Location E, IR Image
2735

Location E, IR Camera Visual Image
2736

Location E, Follow Up Insp. Image
5105



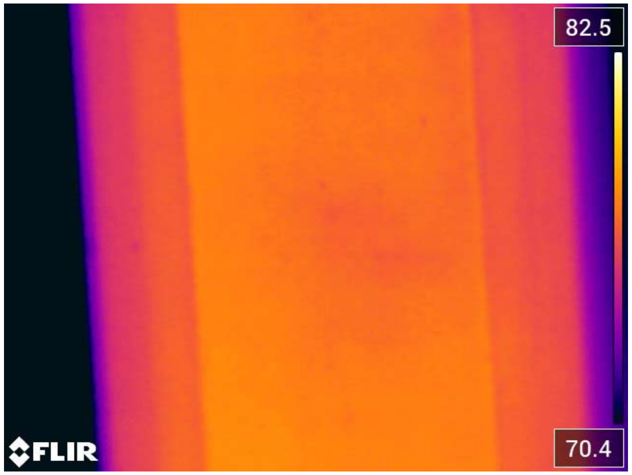
Location F, IR Image
2733

Location F, IR Camera Visual Image
2734

Location F, Follow Up Insp. Image
5103

Notes:
- Refer to Associated AutoCAD Sketches for BIN 4E5, Span L-M for locations and descriptions.
- Thermal imagery was taken with the Flir E96 handheld thermal camera on 9/26/21. The follow up inspection to verify the thermal areas of interest was performed on 10/25/21.
- The follow up inspection used red lumber crayon to outline and hatch delaminated areas. This was to differentiate from the initial inspection, which used yellow lumber crayon.

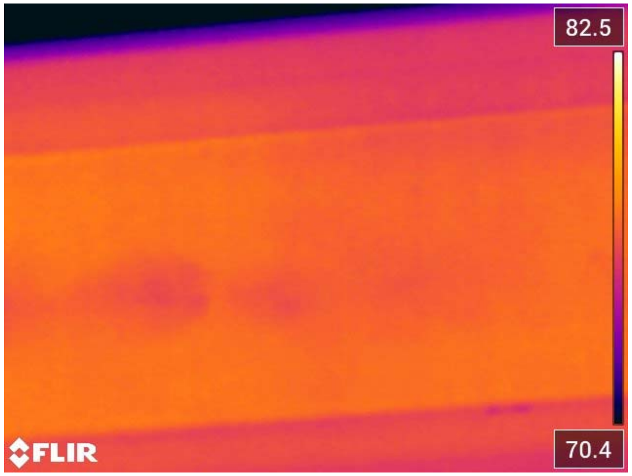
4E5, Thermal Survey Areas of Interest / Follow up Inspection Findings



Location G, IR Image
2737

Location G, IR Camera Visual Image
2738

Location G, Follow Up Insp. Image
5107



Location H,I, J, IR Image
2739

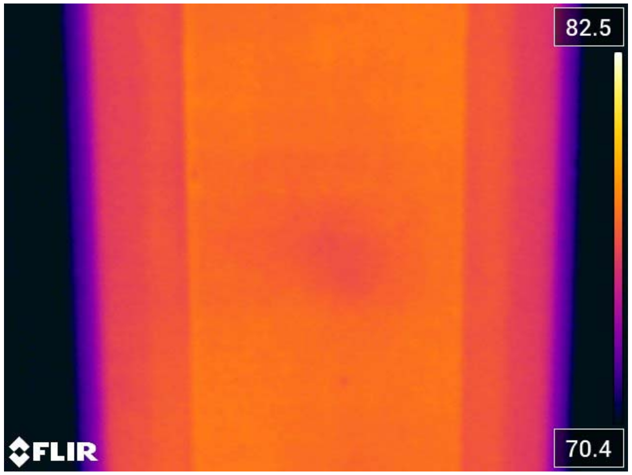
Location H, I, J, IR Camera Visual Image
2740

Location H, I, J, Follow Up Insp. Image
5121

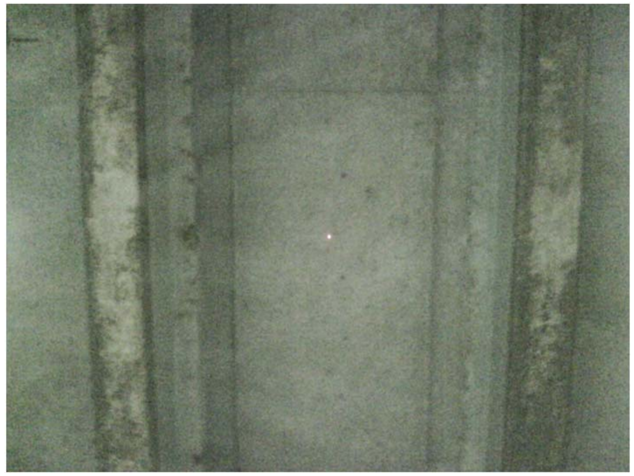
Notes:

- Refer to Associated AutoCAD Sketches for BIN 4E5, Span L-M for locations and descriptions.
- Thermal imagery was taken with the Flir E96 handheld thermal camera on 9/26/21. The follow up inspection to verify the thermal areas of interest was performed on 10/25/21.
- The follow up inspection used red lumber crayon to outline and hatch delaminated areas. This was to differentiate from the initial inspection, which used yellow lumber crayon.

4E5, Thermal Survey Areas of Interest / Follow up Inspection Findings

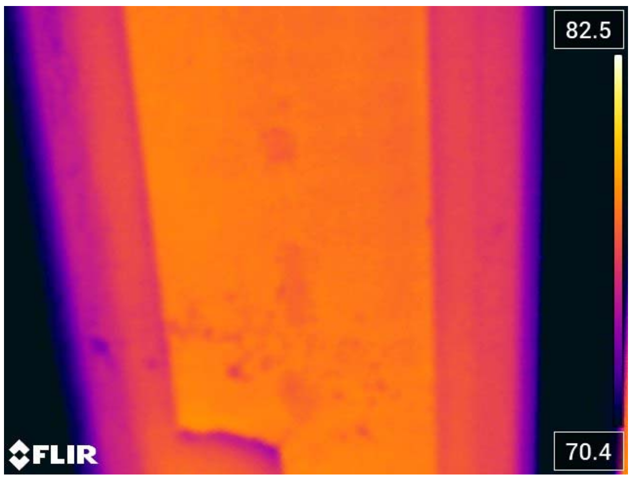


Location K, IR Image
2741



Location K, IR Camera Visual Image
2742

Location K, Follow Up Insp. Image
5109



Location L, M, IR Image
2749

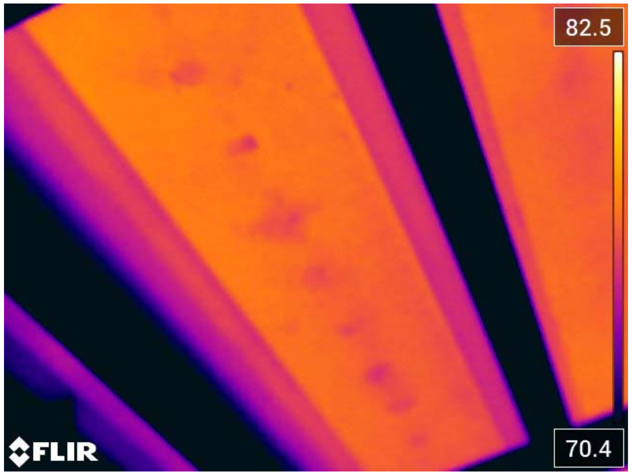
Location L, M, IR Camera Visual Image
2750

Location L, M, Follow Up Insp. Image
5108

Notes:

- Refer to Associated AutoCAD Sketches for BIN 4E5, Span L-M for locations and descriptions.
- Thermal imagery was taken with the Flir E96 handheld thermal camera on 9/26/21. The follow up inspection to verify the thermal areas of interest was performed on 10/25/21.
- The follow up inspection used red lumber crayon to outline and hatch delaminated areas. This was to differentiate from the initial inspection, which used yellow lumber crayon.

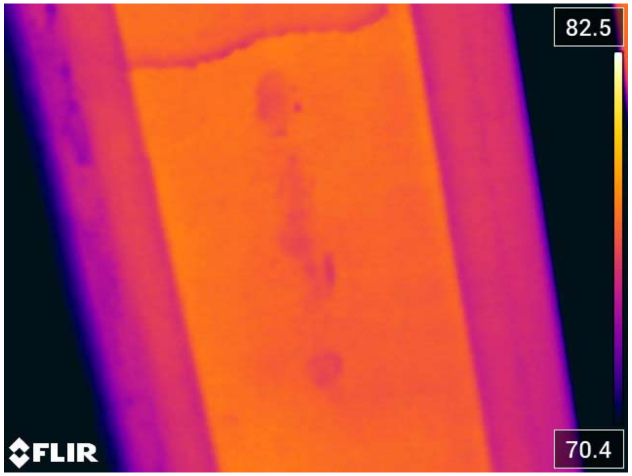
4E5, Thermal Survey Areas of Interest / Follow up Inspection Findings



Location N, IR Image
2747

Location N, IR Camera Visual Image
2748

Location N, Follow Up Insp. Image
5115



Location O, IR Image
2745

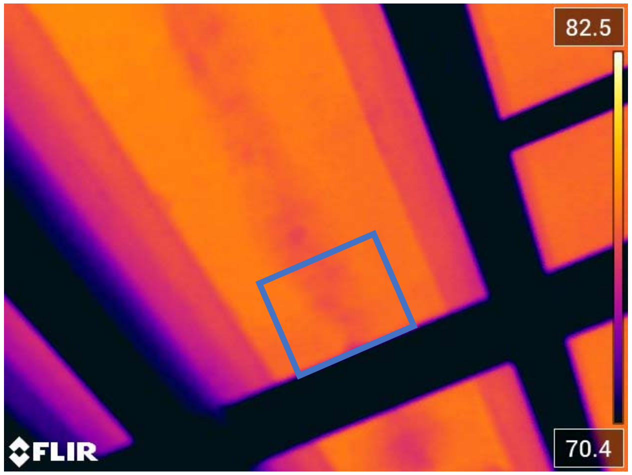
Location O, IR Camera Visual Image
2746

Location O, Follow Up Insp. Image
5117

Notes:

- Refer to Associated AutoCAD Sketches for BIN 4E5, Span L-M for locations and descriptions.
- Thermal imagery was taken with the Flir E96 handheld thermal camera on 9/26/21. The follow up inspection to verify the thermal areas of interest was performed on 10/25/21.
- The follow up inspection used red lumber crayon to outline and hatch delaminated areas. This was to differentiate from the initial inspection, which used yellow lumber crayon.

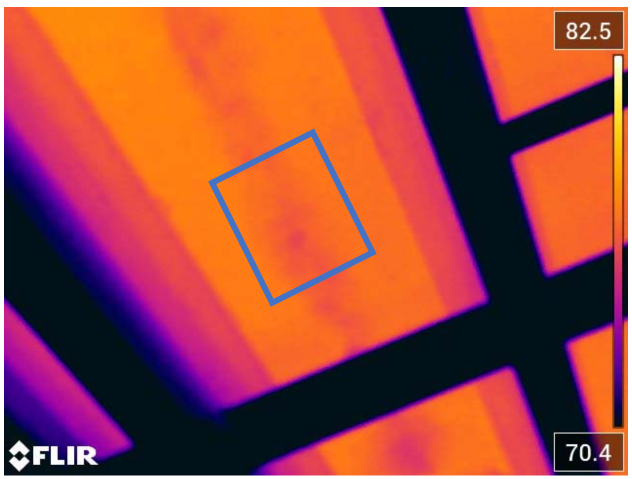
4E5, Thermal Survey Areas of Interest / Follow up Inspection Findings



Location P, IR Image
2743

Location P, IR Camera Visual Image
2744

Location P, Follow Up Insp. Image
5112



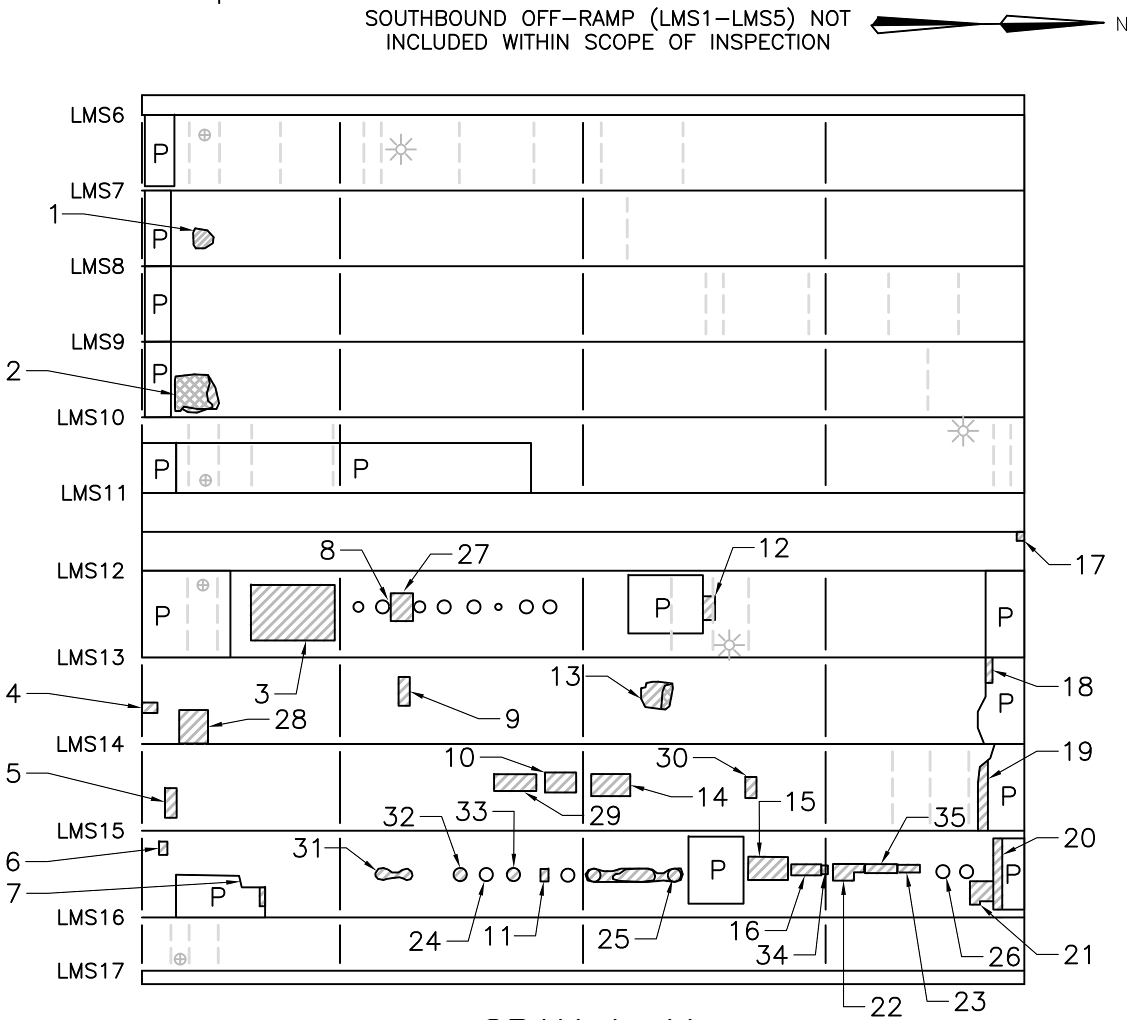
Location Q, IR Image
2743

Location Q, IR Camera Visual Image
2744

Location Q, Follow Up Insp. Image
5111

Notes:

- Refer to Associated AutoCAD Sketches for BIN 4E5, Span L-M for locations and descriptions.
- Thermal imagery was taken with the Flir E96 handheld thermal camera on 9/26/21. The follow up inspection to verify the thermal areas of interest was performed on 10/25/21.
- The follow up inspection used red lumber crayon to outline and hatch delaminated areas. This was to differentiate from the initial inspection, which used yellow lumber crayon.



SPAN L–M
Compiled Inspection Findings

LEGEND:
- Hollow Area
- Spall
- Patch
- Diaphragm
- Utility Bracket
- Overhead Light
- Drain

NOTES:
1. This inspection was limited to the mainline portion of Span L–M. The off–ramp portion (LMS1–LSM5) was omitted as the ramp deck separate from the mainline.
2. The sketch shows the traditional field inspection findings and follow up inspection findings. Deficiencies that were added or modified based on the areas of interest have the alphabetical designation at the start of the deficiency description.

DEFICIENCIES:
1. 16" long x up to 19" wide hollow area (18" wide at south end, 8" wide at north end).
2. 2'–1" long (avg.) x 2'–9" wide spall exposed rebar and adjacent up to 10" long (6" avg) x 18" wide hollow area and 14" long x 4" wide hollow area.
3. Hollow sounding area with moderate efflorescence, honey combing, cracking, and discoloration.
4. Two hollow areas in sloped portion; 7" long x 3" wide and 14" long x up to 5" wide (3" wide avg).
5. 10½" long x 2'–2½" wide minor hollow area.
6. 7½" long x 12" wide hollow area.
7. Patched area with 5" long x 17" wide hollow area due to void.
8. Eight up to 12"ø patches within bay.
9. Up to 10" long x 2'–2" wide hollow area.
10. 2'–4" long x up to 18" wide hollow area.
11. 6" long x 9" wide hollow sounding patch.
12. 2" long x 6" wide hollow area.
13. 10" long x 23" wide spall with exposed rebar and adjacent 20" long x 18" wide hollow area.
14. 2'–11" long x 20" wide hollow area.
15. 3'–0" long x 21" wide hollow area.
16. 2'–3" long x 10" wide hollow area.
17. 4" long x 6" wide hollow area in haunch.
18. 5" long x 23" wide hollow area/void in patch due to void with adjacent 8" long x 7" wide hollow area in the haunch.
19. 8" long x 3'–3" wide hollow area/void in patch. The west edge of the patch has a spall/void extending behind the patch.
20. 8" long x 4'–2" wide hollow area/void in patch.
21. 21" long x 18" wide hollow area (up to 21" wide for 9" length).
22. 2'–4" long x 15" wide minor hollow area.
23. 20" long x 7" wide hollow area.
24. Seven up to 12"ø patches within bay. Sound unless otherwise noted.
25. (o) 56" long x up to 9" wide minor hollow area containing three hollow sounding patches.
26. Seven patches up to 12"ø within bay. Sound unless otherwise noted.
27. (d) 25" wide x up to 20" long minor hollow area.
28. (e) 25" wide x up to 26" long hollow area in deck with adjacent 5" wide x 26" long hollow area in haunch.
29. (j) 38" long x up to 15" wide minor hollow area.
30. (k) 19" wice x up to 10" long minor hollow area.
31. (n) 31" long x up to 9" wide minor hollow area with hollow sounding patches
32. (n) 7" wide x up to 10" hollow sounding patch
33. (n) 7" wide x up to 5" long hollow sounding patch
34. (p) 6" long x 8" wide minor hollow area.
35. (q) 29" long x up to 8" wide minor hollow area.

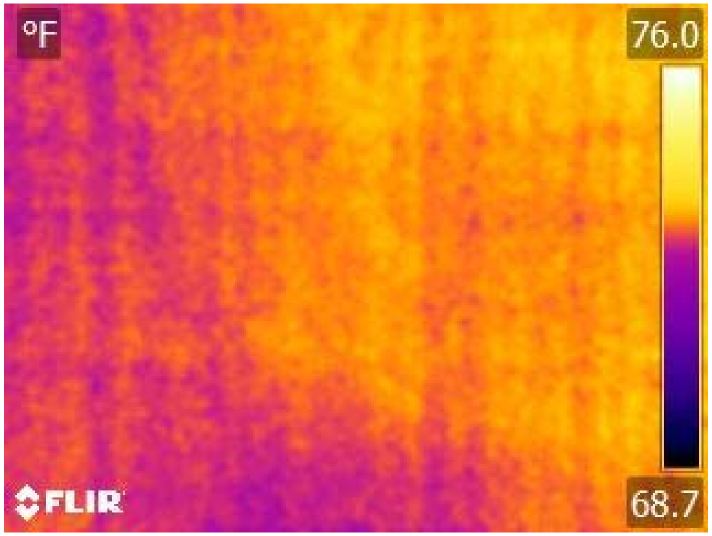
Appendix B

Bridge B-16-033 (BIN 4EU)

4EU, Flir E8, All Thermal Data

Deficiency 1

First Data Set

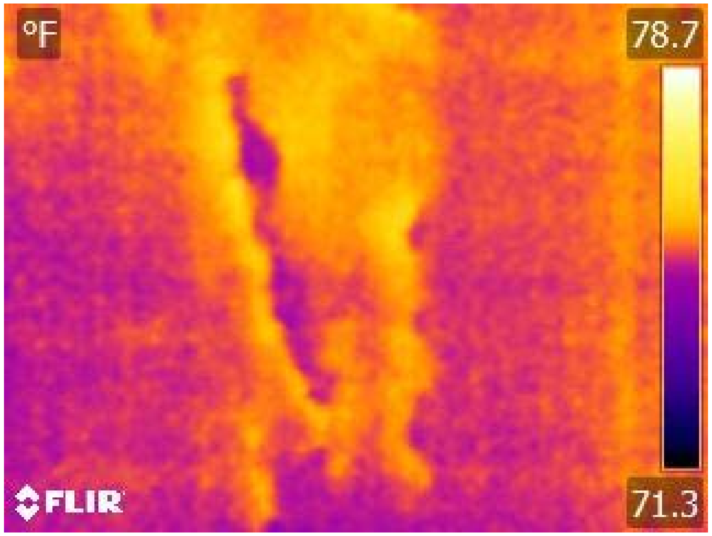


E8_01_01_IR_FLIR1404

Visual of Delamination

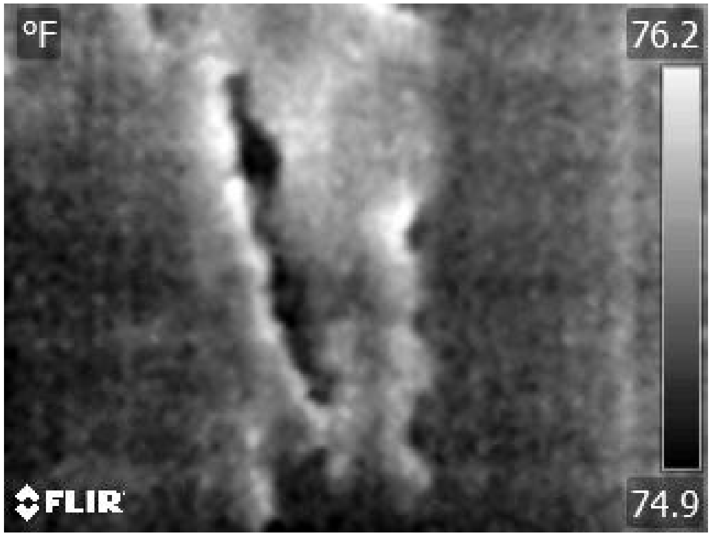
E8_01_01_RGB_FLIR1405

Second Data Set



E8_02_01_IR_FLIR1482

Second Data Set – Post Processed

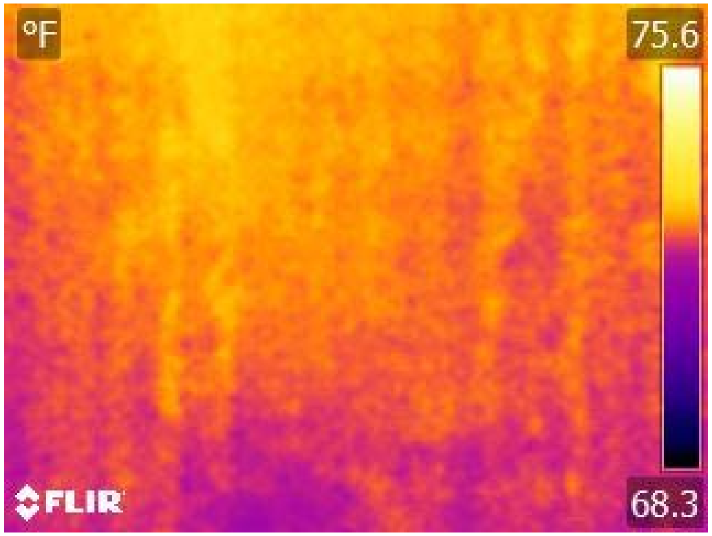


E8_02p_01_IR_FLIR1482

4EU, Flir E8, All Thermal Data

Deficiency 2

First Data Set

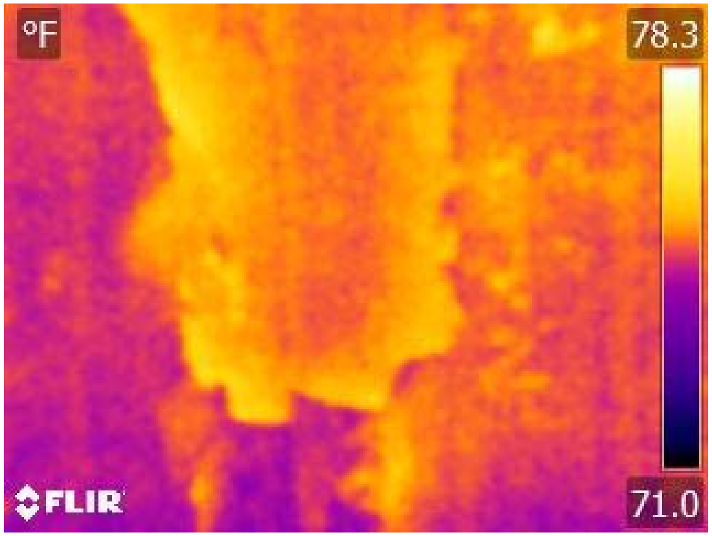


E8_01_02_IR_FLIR1410

Visual of Delamination

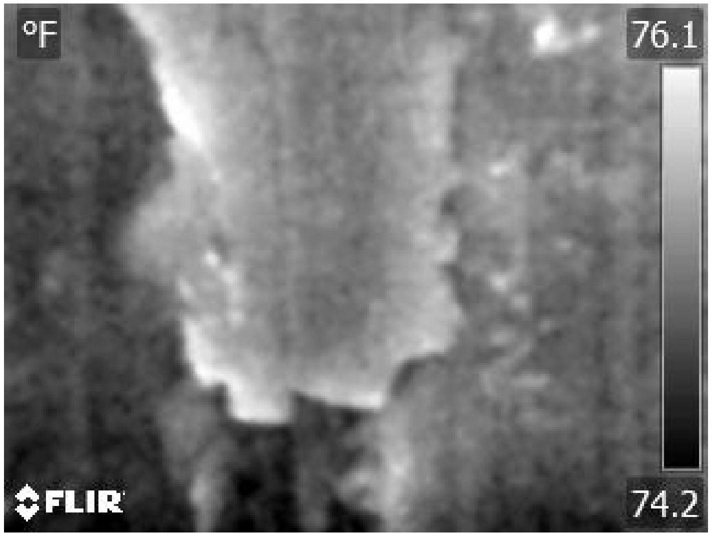
E8_01_02_RGB_FLIR1411

Second Data Set



E8_02_02_IR_FLIR1492

Second Data Set – Post Processed

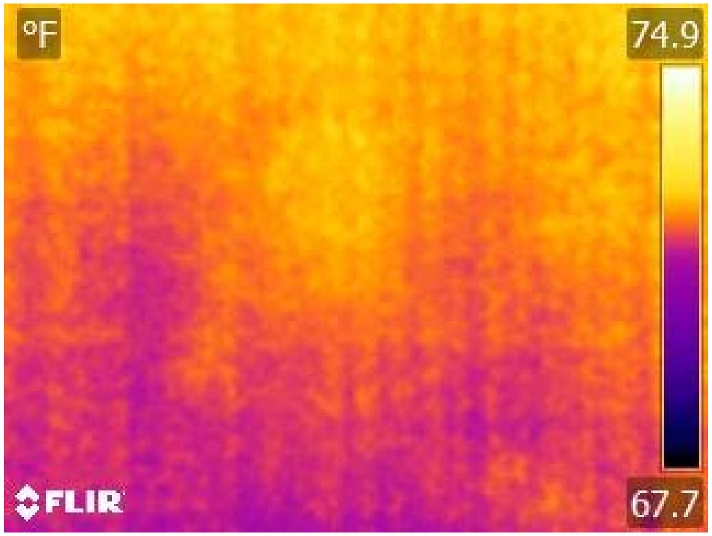


E8_02p_02_IR_FLIR1492

4EU, Flir E8, All Thermal Data

Deficiency 3

First Data Set

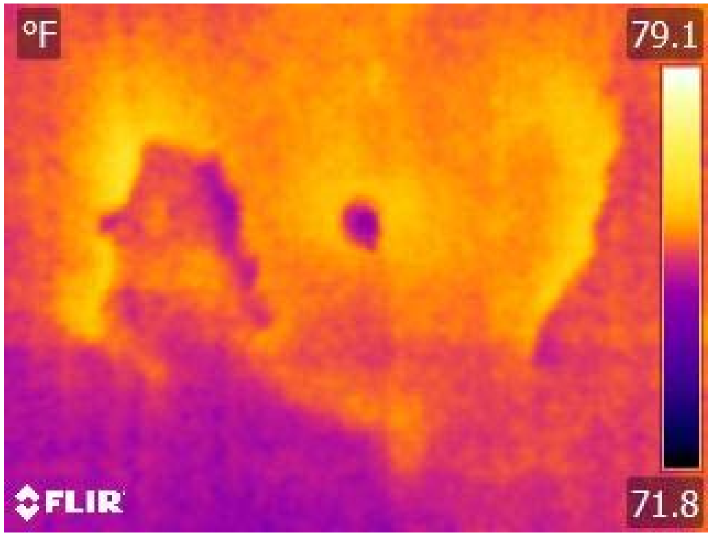


E8_01_03_IR_FLIR1416

Visual of Delamination

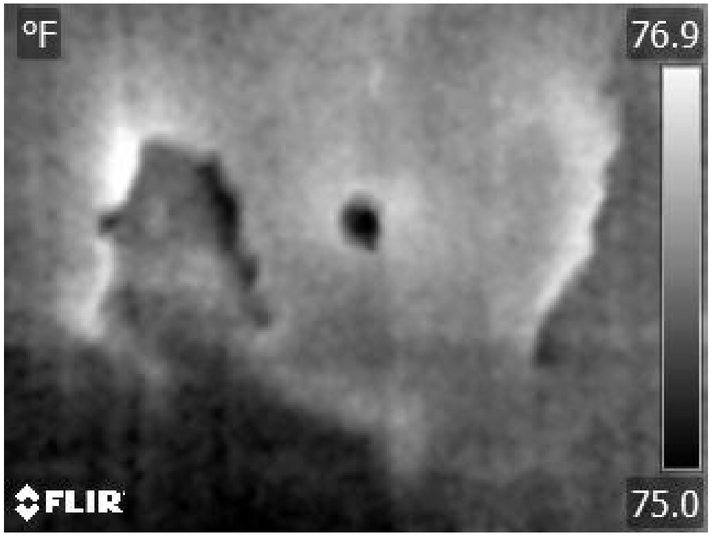
E8_01_03_RGB_FLIR1417

Second Data Set



E8_02_03_IR_FLIR1486

Second Data Set – Post Processed

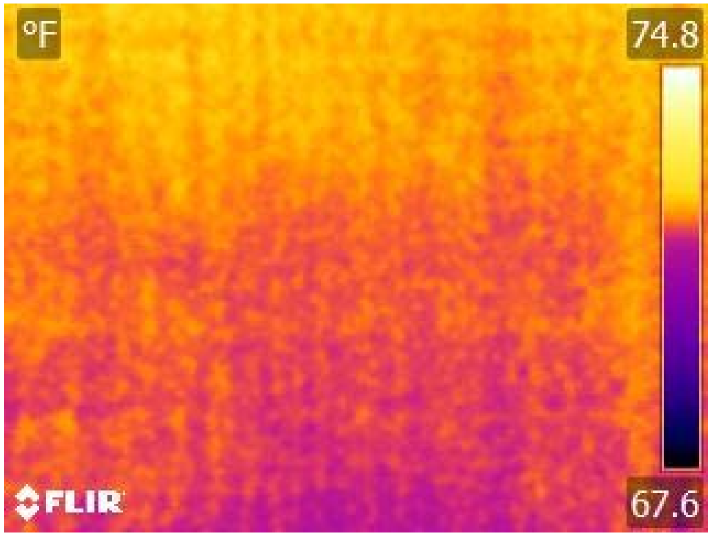


E8_02p_03_IR_FLIR1486

4EU, Flir E8, All Thermal Data

Deficiency 4

First Data Set

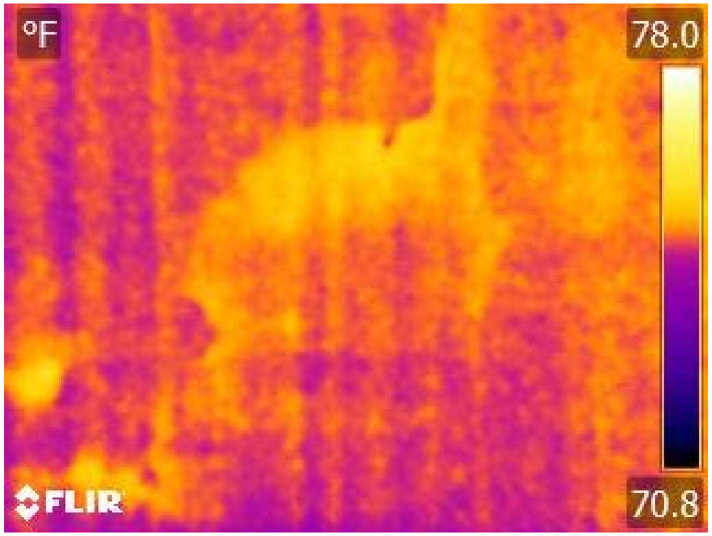


E8_01_04_IR_FLIR1422

Visual of Delamination

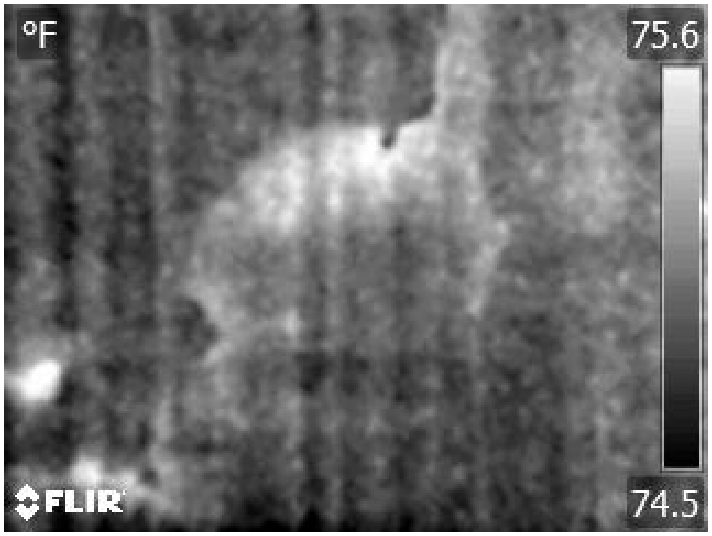
E8_01_04_RGB_FLIR1423

Second Data Set



E8_02_04_IR_FLIR1504

Second Data Set – Post Processed

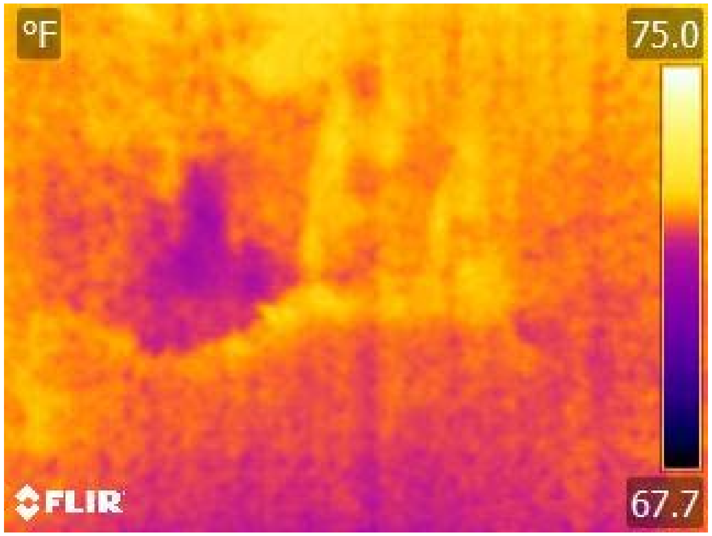


E8_02p_04_IR_FLIR1504

4EU, Flir E8, All Thermal Data

Deficiency 5

First Data Set

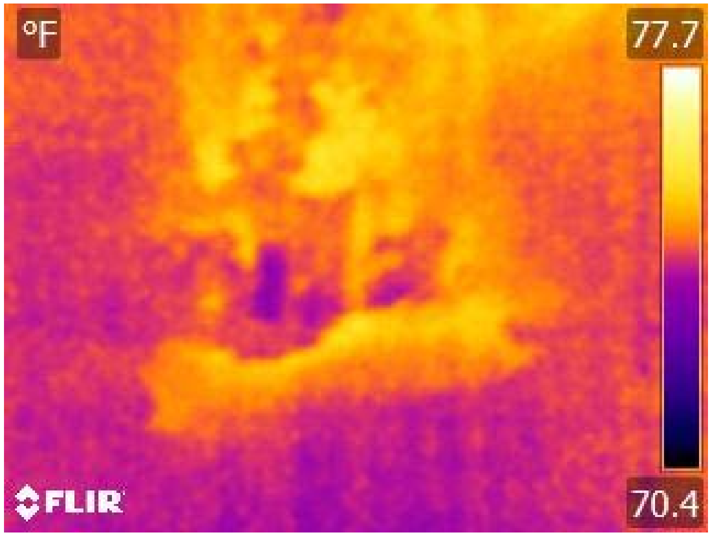


E8_01_05_IR_FLIR1430

Visual of Delamination

E8_01_05_RGB_FLIR1431

Second Data Set



E8_02_05_IR_FLIR1494

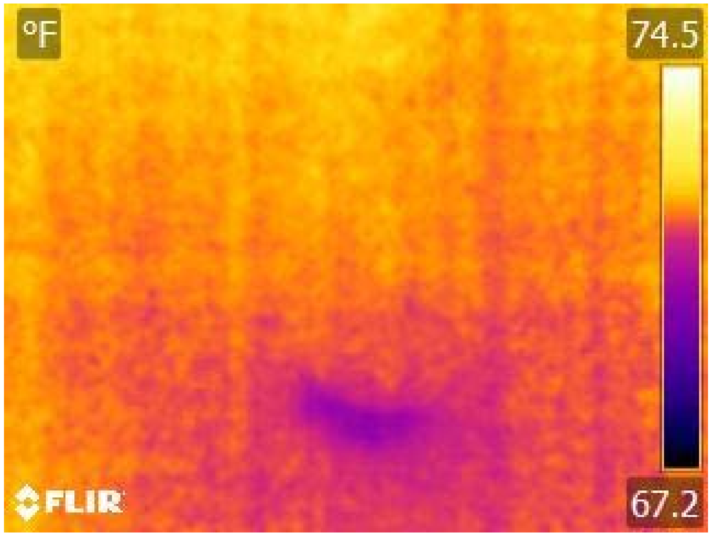
Second Data Set – Post Processed

E8_02p_05_IR_FLIR1494

4EU, Flir E8, All Thermal Data

Deficiency 6

First Data Set

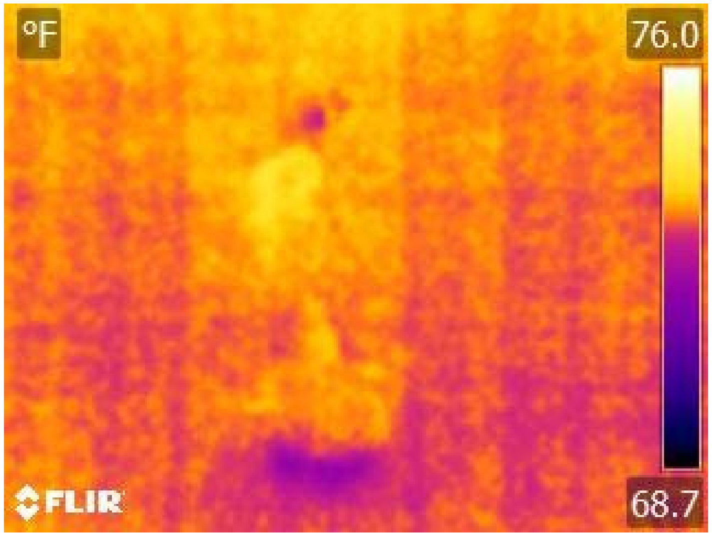


E8_01_06_IR_FLIR1432

Visual of Delamination

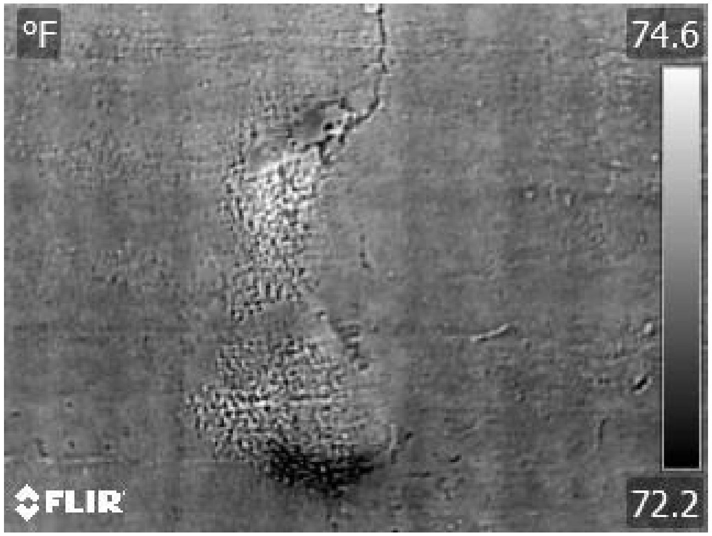
E8_01_06-RGB_FLIR1433

Second Data Set



E8_02_06_IR_FLIR1496

Second Data Set – Post Processed

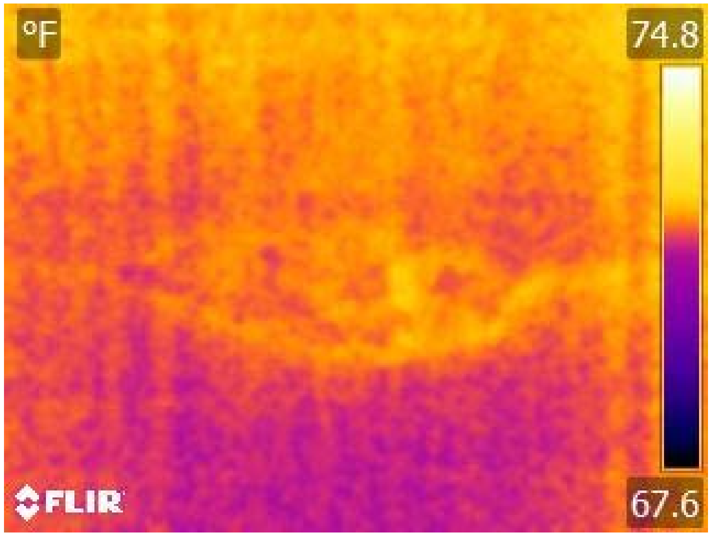


E8_02p_06_IR_FLIR1496

4EU, Flir E8, All Thermal Data

Deficiency 7

First Data Set

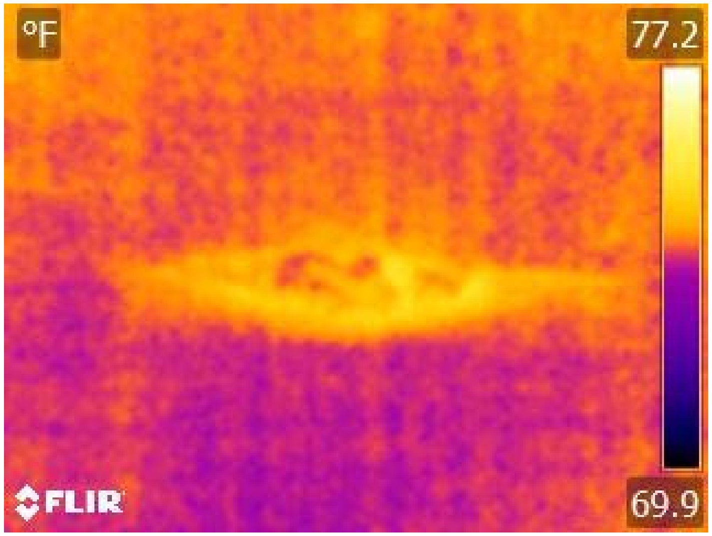


E8_01_07_FLIR1434

Visual of Delamination

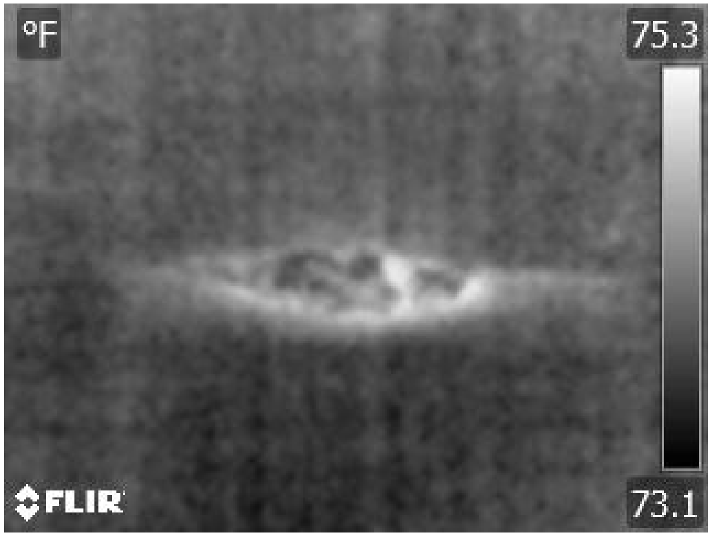
E8_01_07_RGB_FLIR1435

Second Data Set



E8_02_07_IR_FLIR1498

Second Data Set – Post Processed

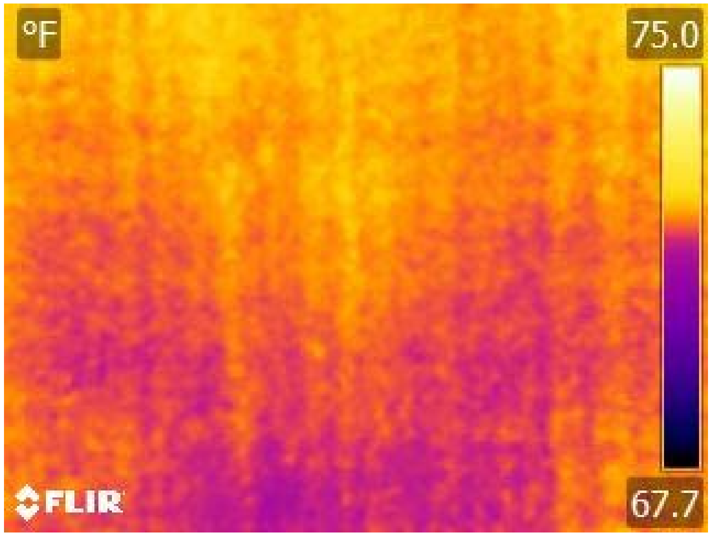


E8_02p_07_IR_FLIR1498

4EU, Flir E8, All Thermal Data

Deficiency 8

First Data Set

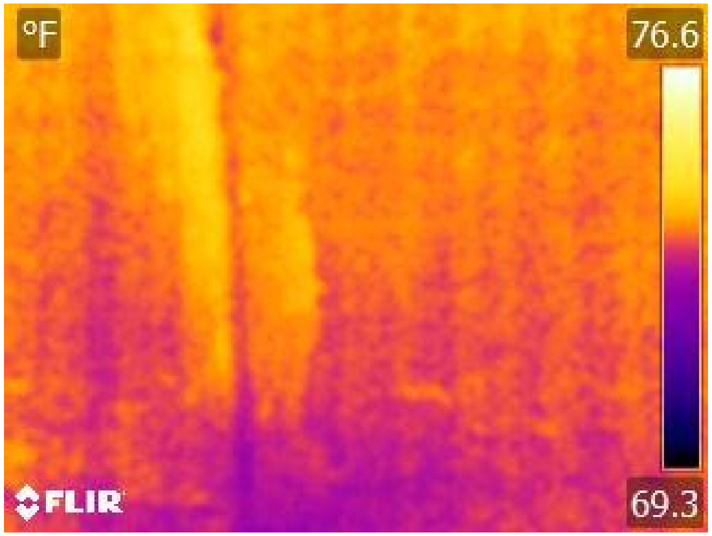


E8_01_08_IR_FLIR1444

Visual of Delamination

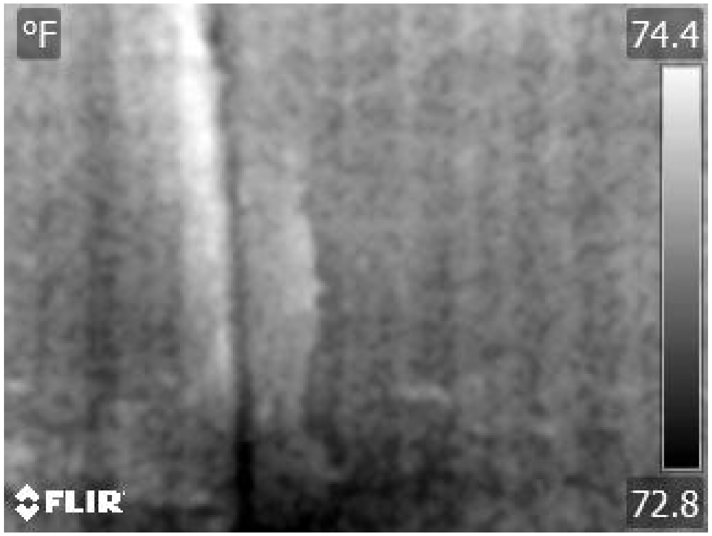
E8_01_08_RGB_FLIR1445

Second Data Set



E8_02_08_IR_FLIR1508

Second Data Set – Post Processed

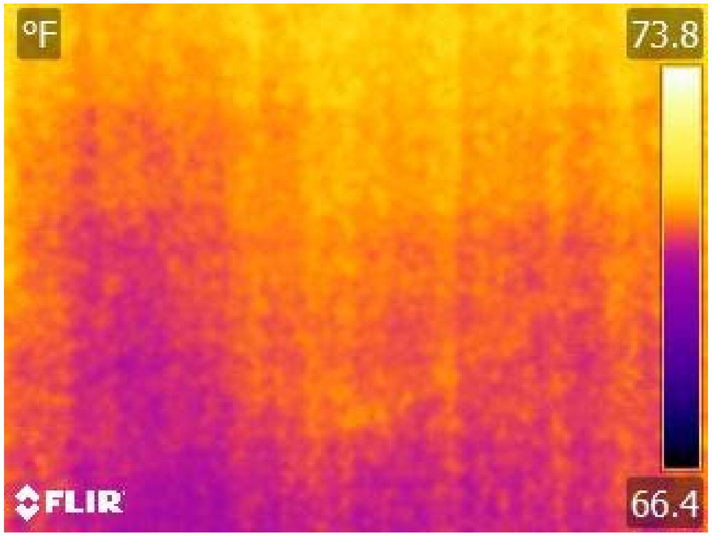


E8_02p_08_IR_FLIR1508

4EU, Flir E8, All Thermal Data

Deficiency 9

First Data Set

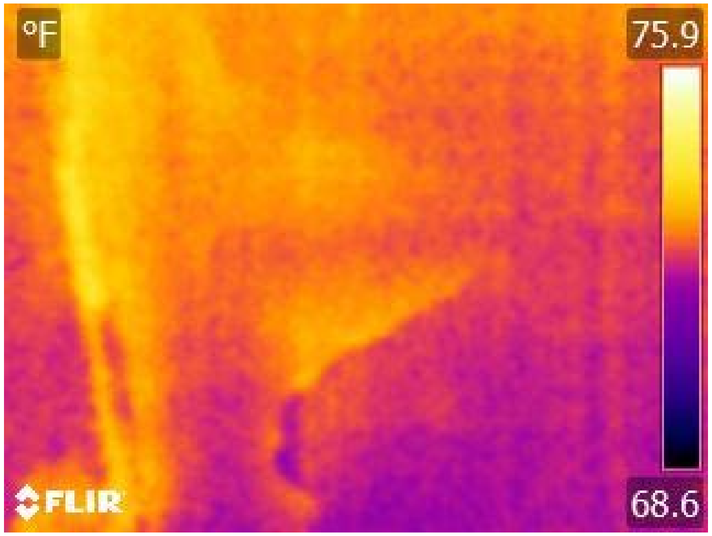


E8_01_09_IR_FLIR1446

Visual of Delamination

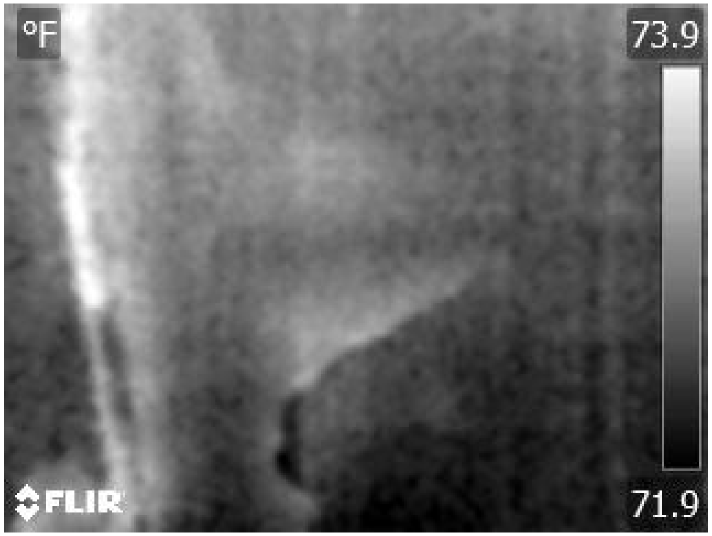
E8_01_09_RGB_FLIR1447

Second Data Set



E8_02_09_IR_FLIR1520

Second Data Set – Post Processed

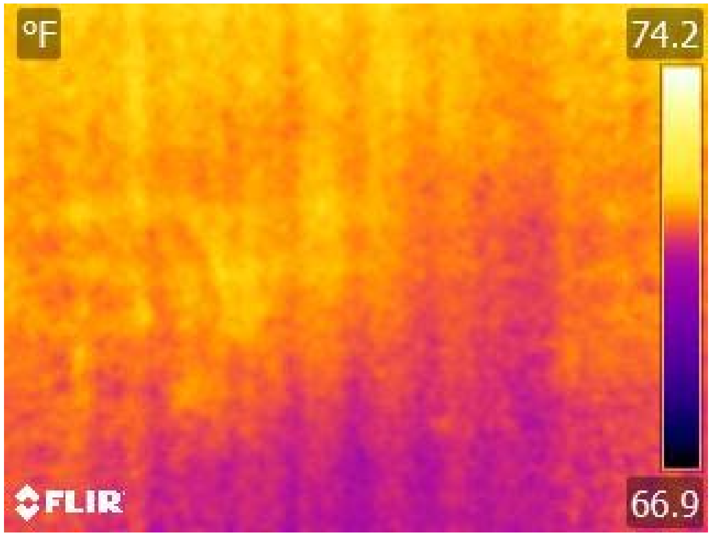


E8_02p_09_IR_FLIR1520

4EU, Flir E8, All Thermal Data

Deficiency 10

First Data Set

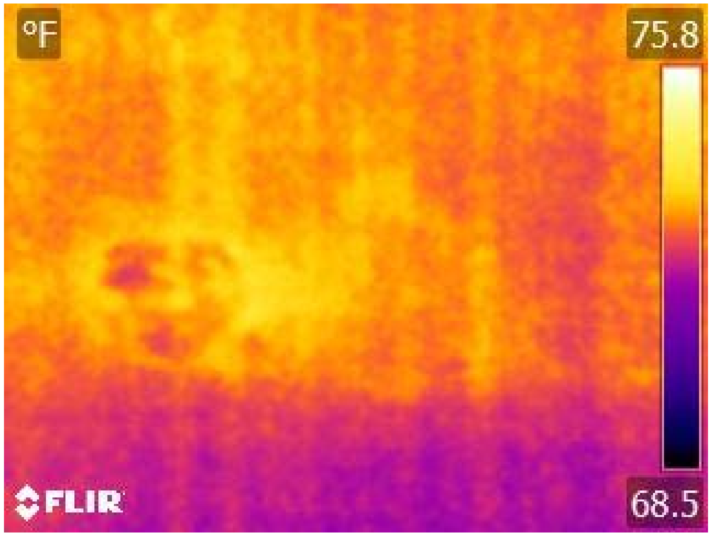


E8_01_10_IR_FLIR1452

Visual of Delamination

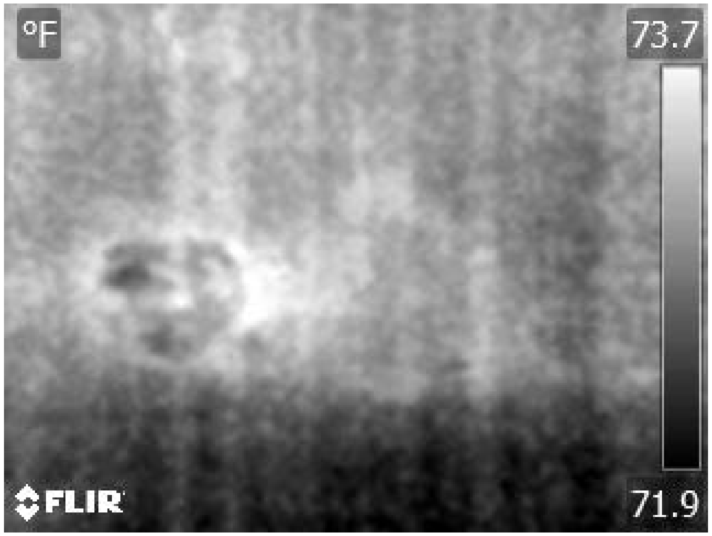
E8_01_10_RGB_FLIR1453

Second Data Set



E8_02_10_IR_FLIR1514

Second Data Set – Post Processed

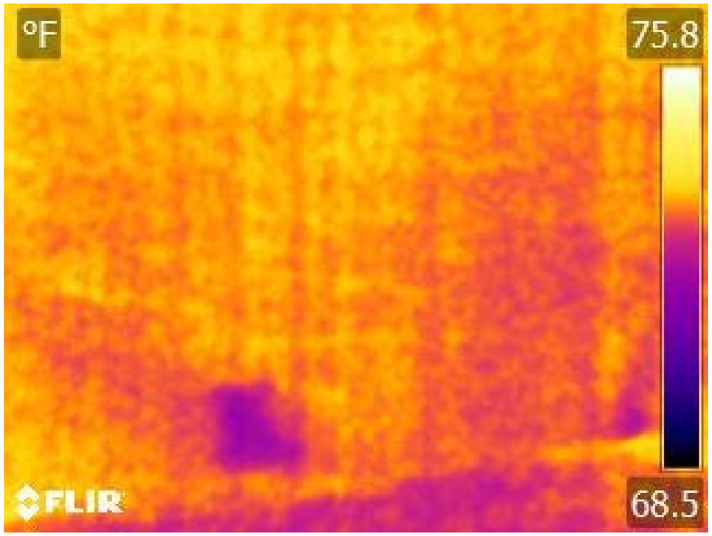


E8_02p_10_IR_FLIR1514

4EU, Flir E8, All Thermal Data

Deficiency 11

First Data Set

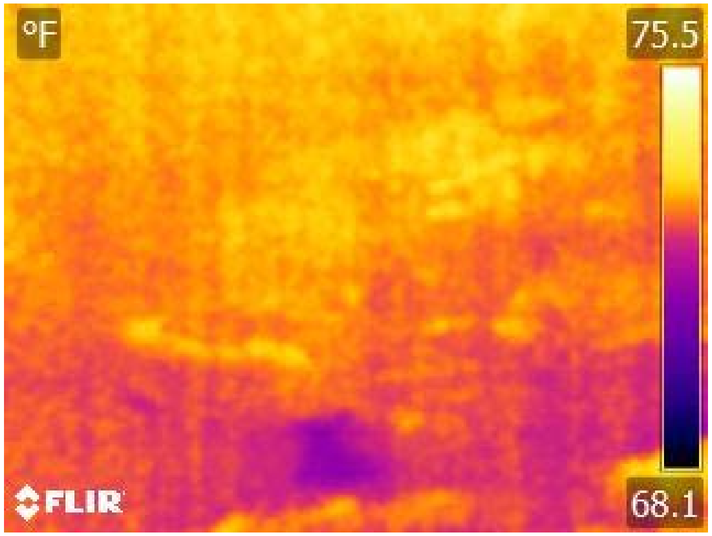


E8_01_11_IR_FLIR1470

Visual of Delamination

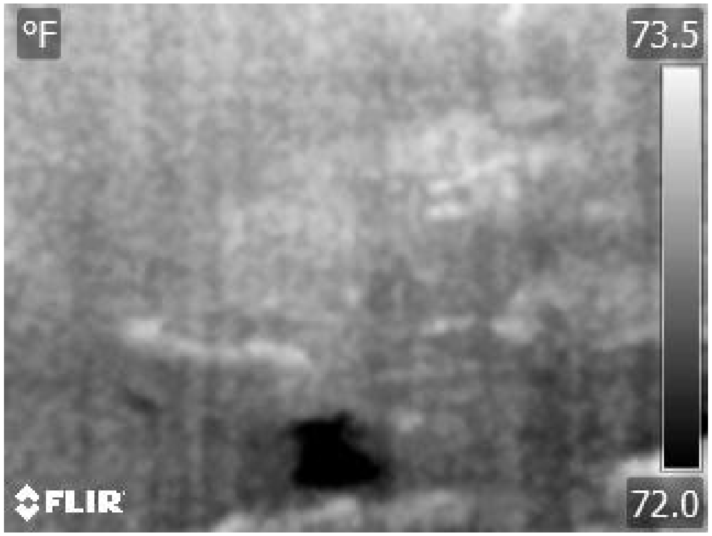
E8_01_11_RGB_FLIR1471

Second Data Set



E8_02_11_IR_FLIR1522

Second Data Set – Post Processed

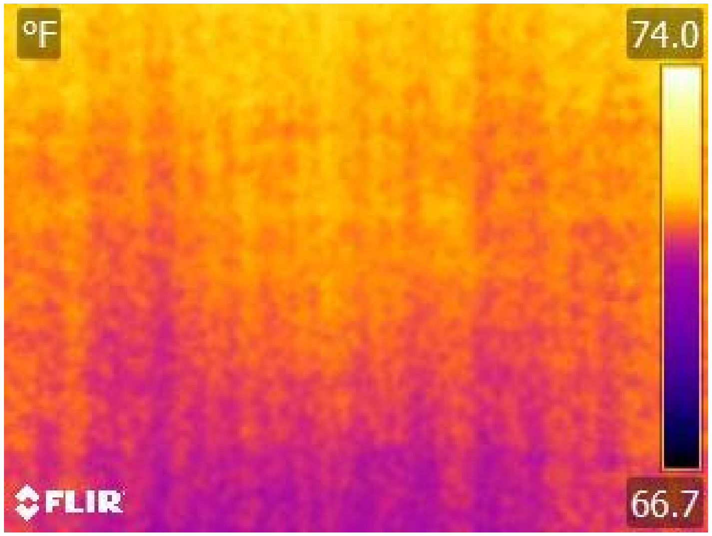


E8_02p_11_IR_FLIR1522

4EU, Flir E8, All Thermal Data

Deficiency 12

First Data Set

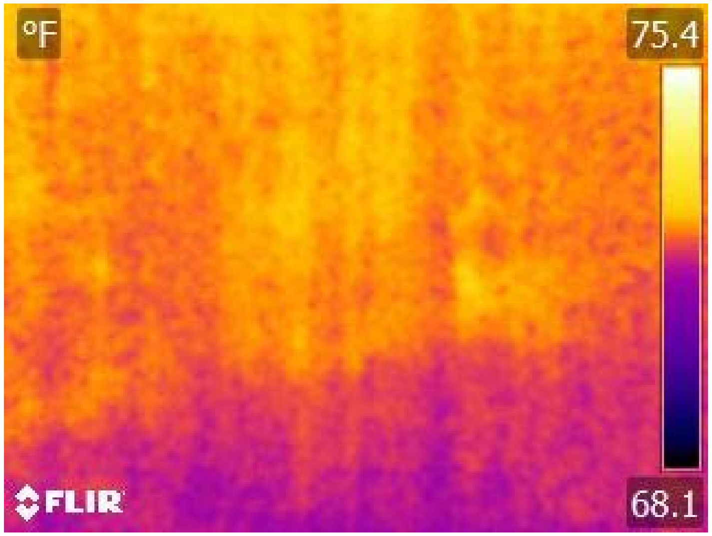


E8_01_12_IR_FLIR1454

Visual of Delamination

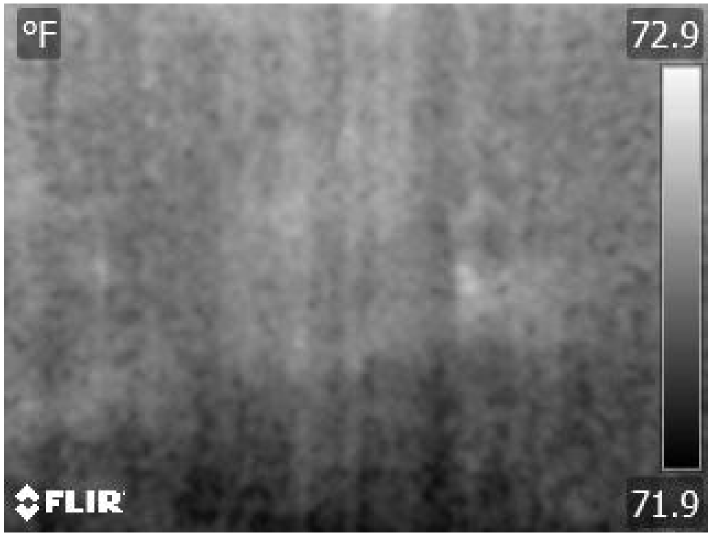
E8_01_12_RGB_FLIR1455

Second Data Set



E8_02_12_IR_FLIR1516

Second Data Set – Post Processed

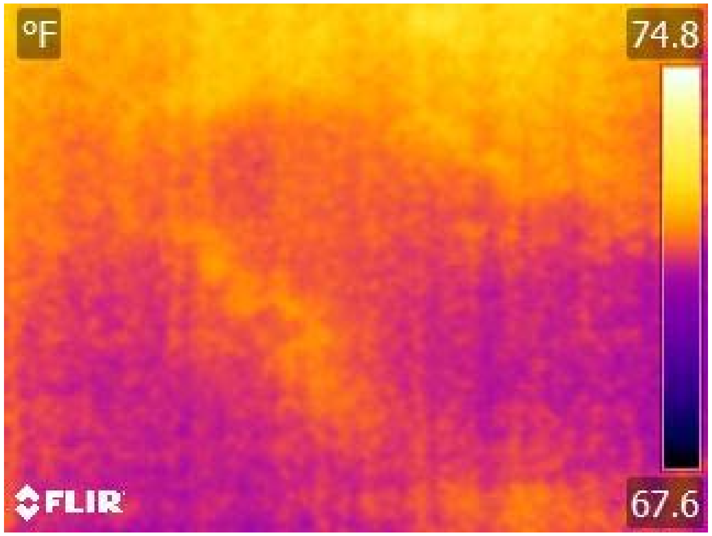


E8_02p_12_IR_FLIR1516

4EU, Flir E8, All Thermal Data

Deficiency 13

First Data Set

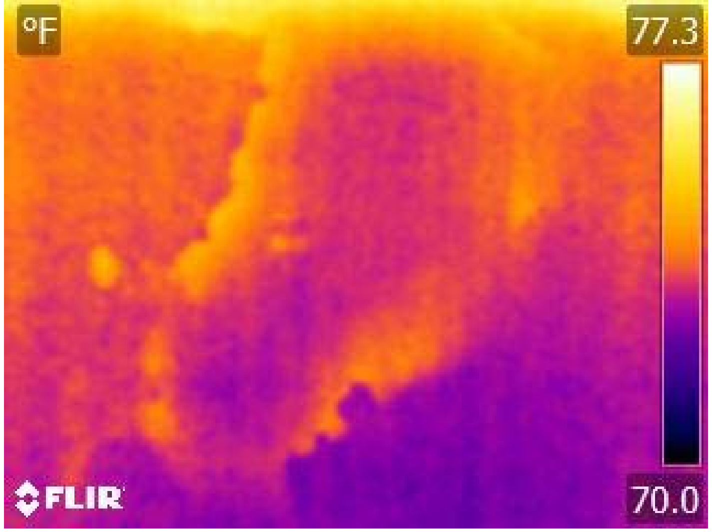


E8_01_13_IR_FLIR1462

Visual of Delamination

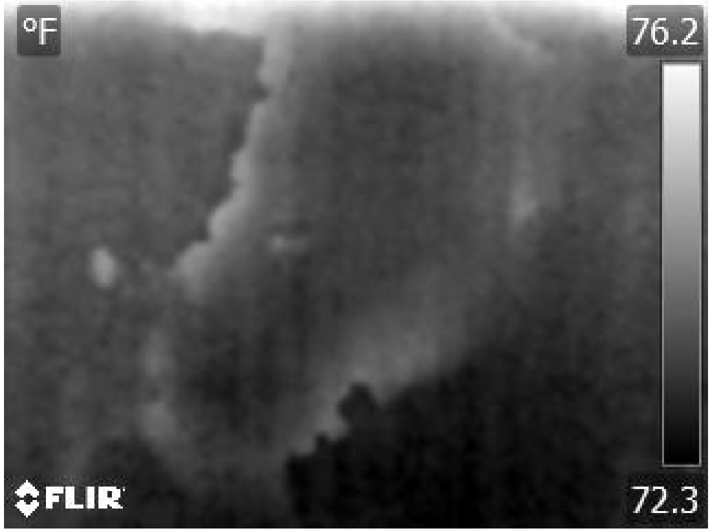
E8_01_13_RGB_FLIR1463

Second Data Set



E8_02_13_IR_FLIR1538

Second Data Set – Post Processed

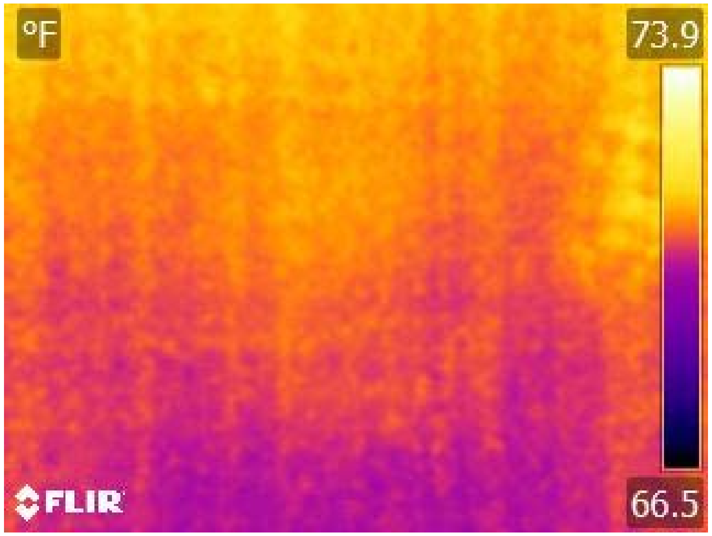


E8_02p_13_IR_FLIR1538

4EU, Flir E8, All Thermal Data

Deficiency 14

First Data Set

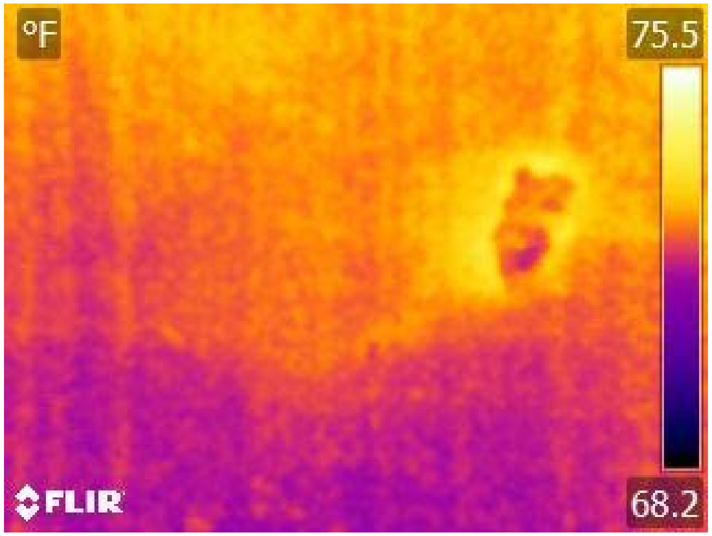


E8_01_14_IR_FLIR1456

Visual of Delamination

E8_01_14_RGB_FLIR1457

Second Data Set



E8_02_14_IR_FLIR1532

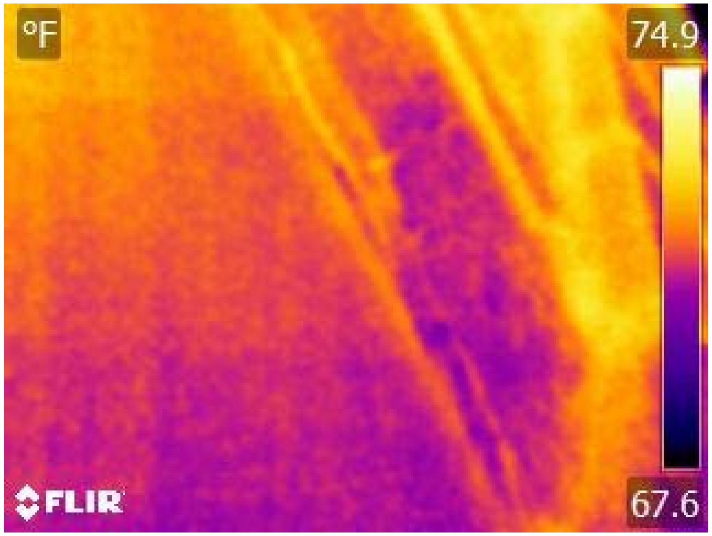
Second Data Set – Post Processed

E8_02p_14_IR_FLIR1532

4EU, Flir E8, All Thermal Data

Deficiency 15

First Data Set

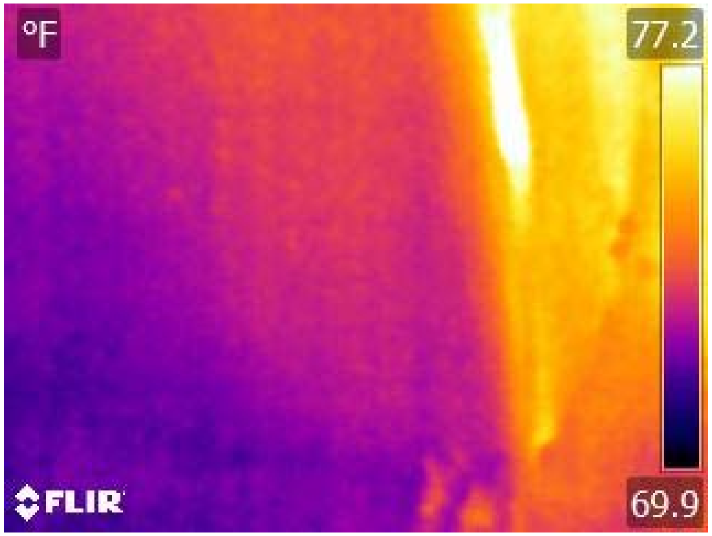


E8_01_15_IR_FLIR1458

Visual of Delamination

E8_01_15_RGB_FLIR1459

Second Data Set



E8_02_15_IR_FLIR1536

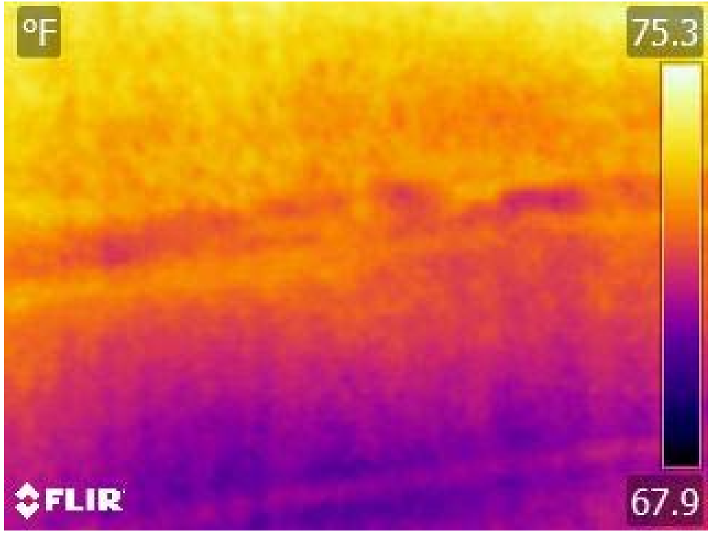
Second Data Set – Post Processed

E8_02p_15_IR_FLIR1536

4EU, Flir E8, All Thermal Data

Deficiency 16

First Data Set

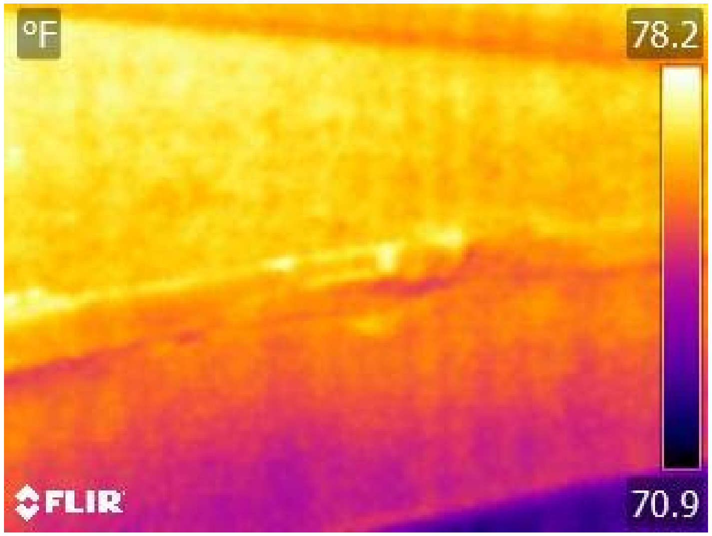


E8_01_16_IR_FLIR1474

Visual of Delamination

E8_01_16_RGB_FLIR1475

Second Data Set



E8_02_16_IR_FLIR1540

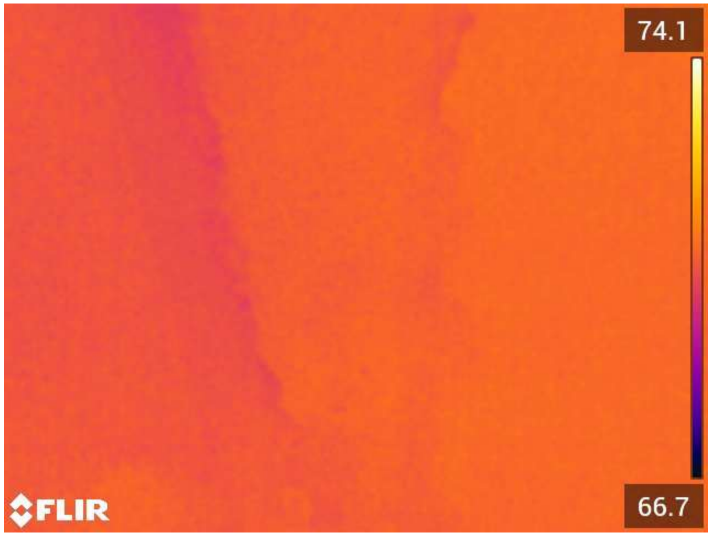
Second Data Set – Post Processed

E8_02p_16_IR_FLIR1540

4EU, Flir E96, All Thermal Data

Deficiency 1

First Data Set

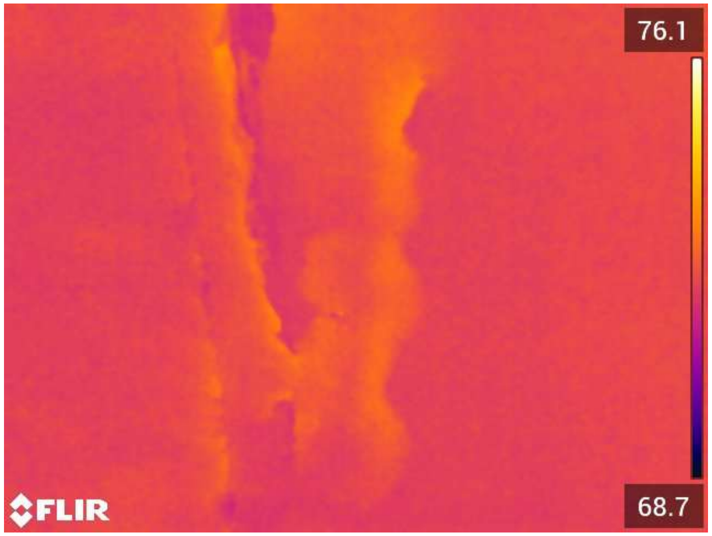


E96_01_01_IR_FLIR1685

Visual of Delamination

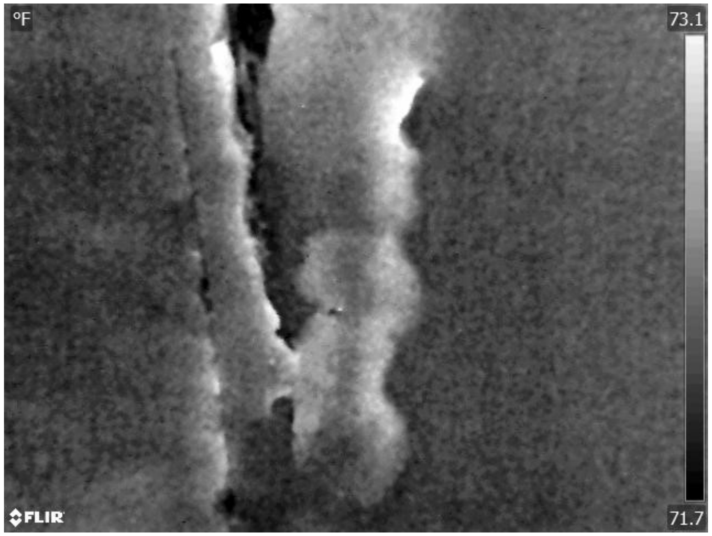
E96_01_01_RGB_FLIR1686

Second Data Set



E96_02_01_IR_FLIR1749

Second Data Set – Post Processed

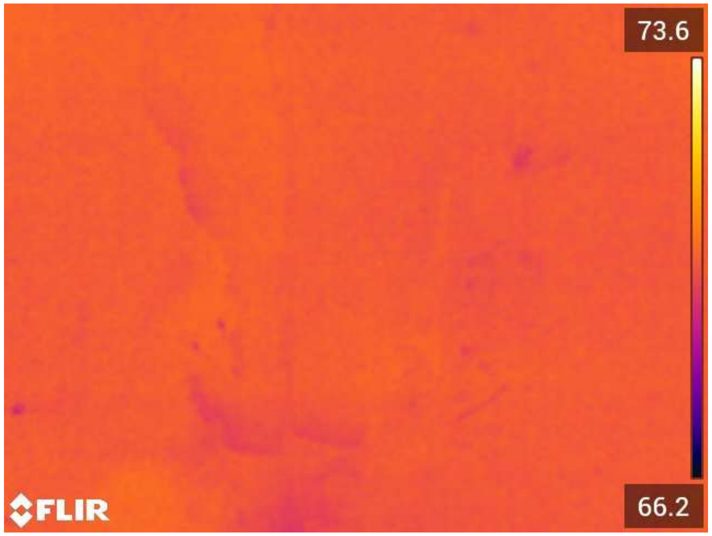


E96_02p_01_IR_FLIR1749

4EU, Flir E96, All Thermal Data

Deficiency 2

First Data Set

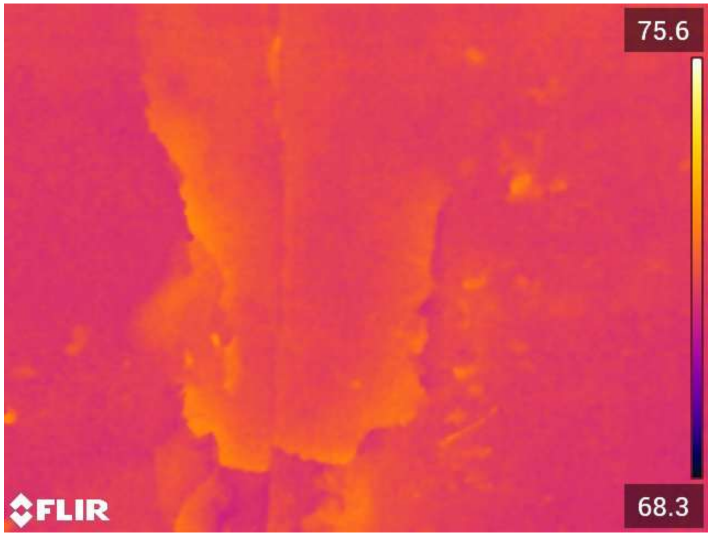


E96_01_02_IR_FLIR1695

Visual of Delamination

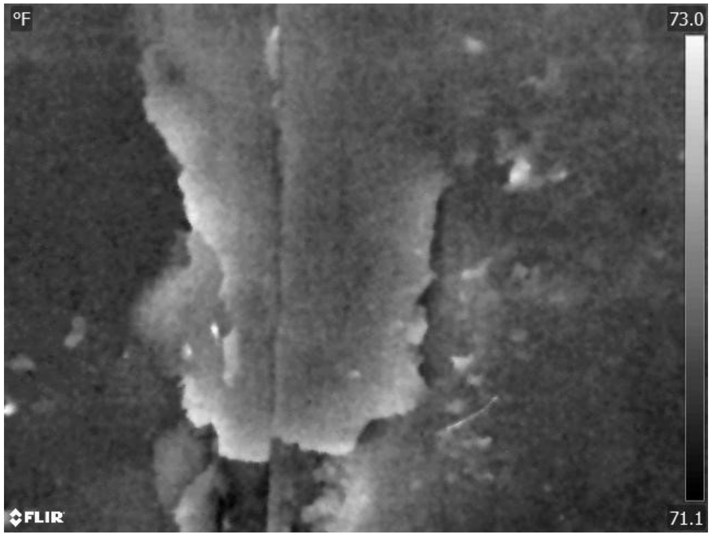
E96_01_02_RGB_FLIR1696

Second Data Set



E96_02_02_IR_FLIR1753

Second Data Set – Post Processed

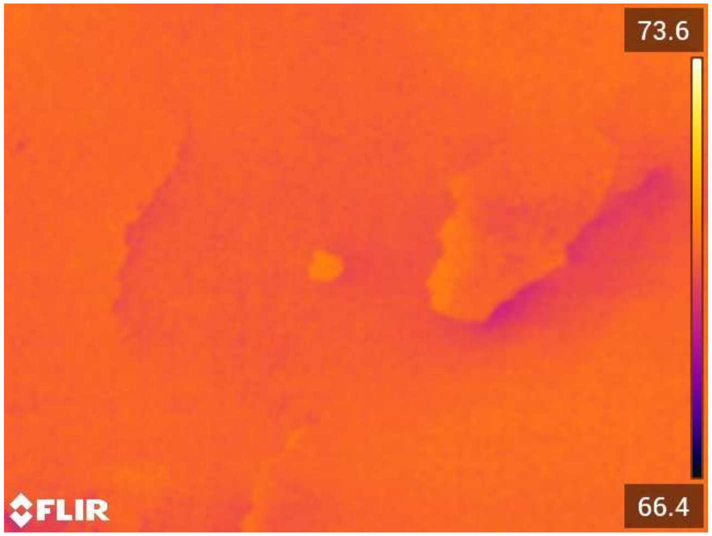


E96_02p_02_IR_FLIR1753

4EU, Flir E96, All Thermal Data

Deficiency 3

First Data Set

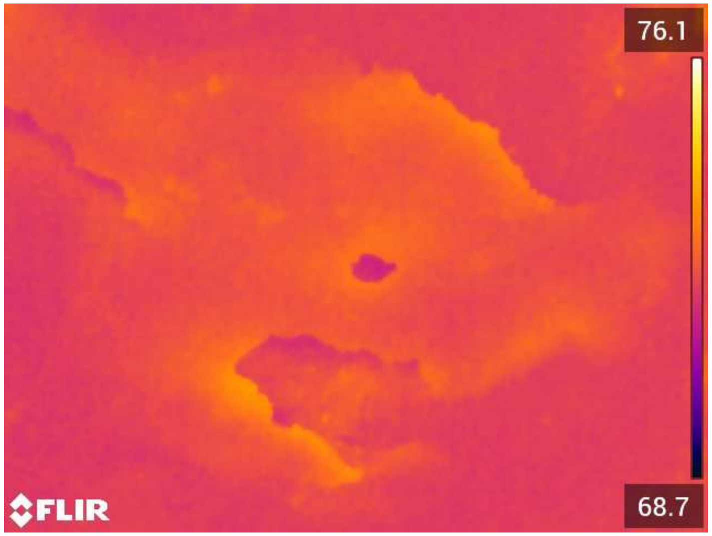


E96_01_03_IR_FLIR1691

Visual of Delamination

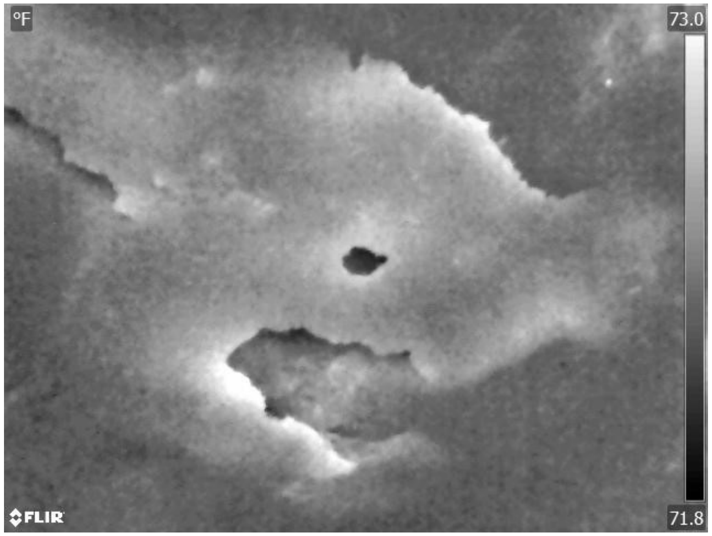
E96_01_03_RGB_FLIR1692

Second Data Set



E96_02_03_IR_FLIR1767

Second Data Set – Post Processed

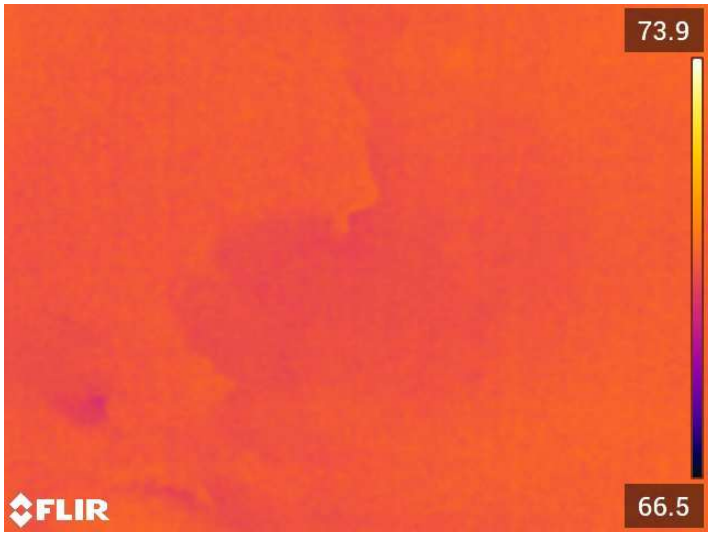


E96_02p_03_IR_FLIR1767

4EU, Flir E96, All Thermal Data

Deficiency 4

First Data Set

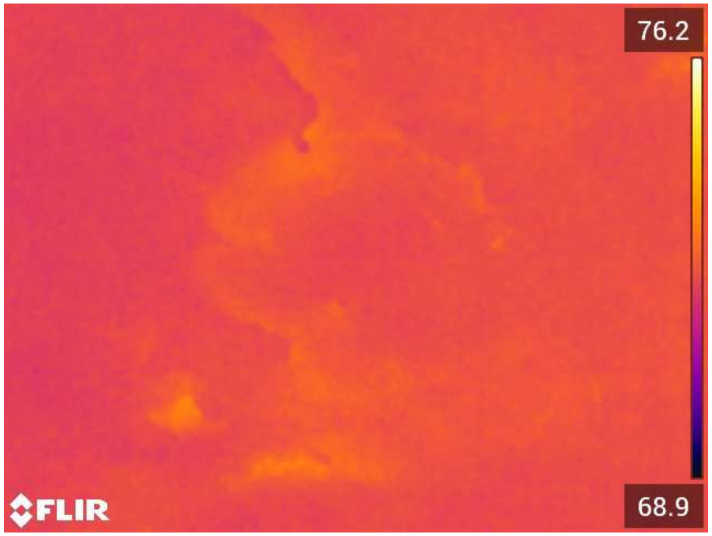


E96_01_04_IR_FLIR1713

Visual of Delamination

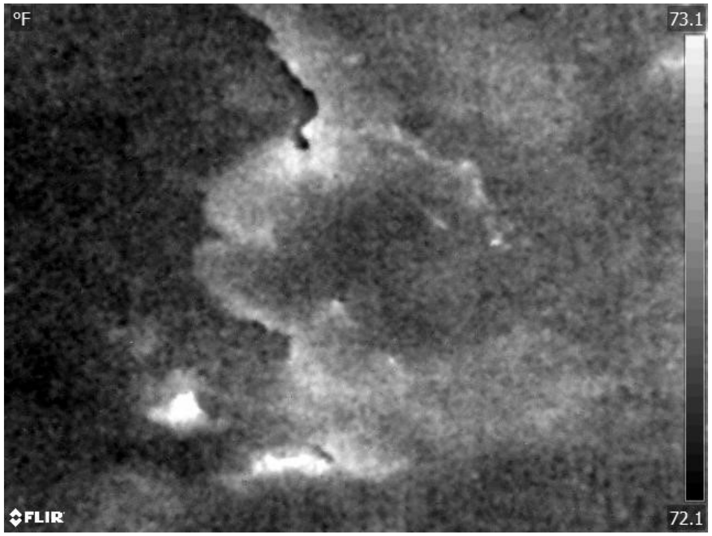
E96_01_04_RGB_FLIR1714

Second Data Set



E96_02_04_IR_FLIR1773

Second Data Set – Post Processed

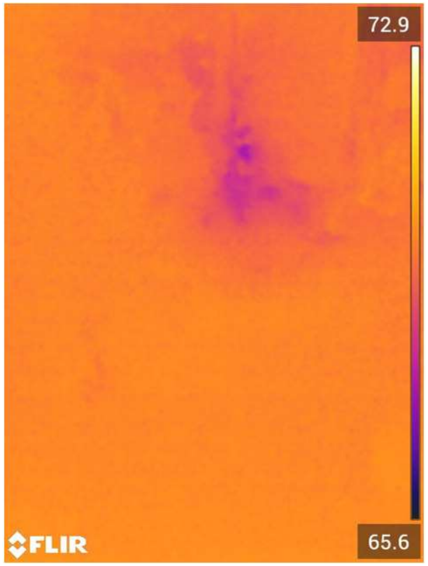


E96_02p_04_IR_FLIR1773

4EU, Flir E96, All Thermal Data

Deficiency 5

First Data Set

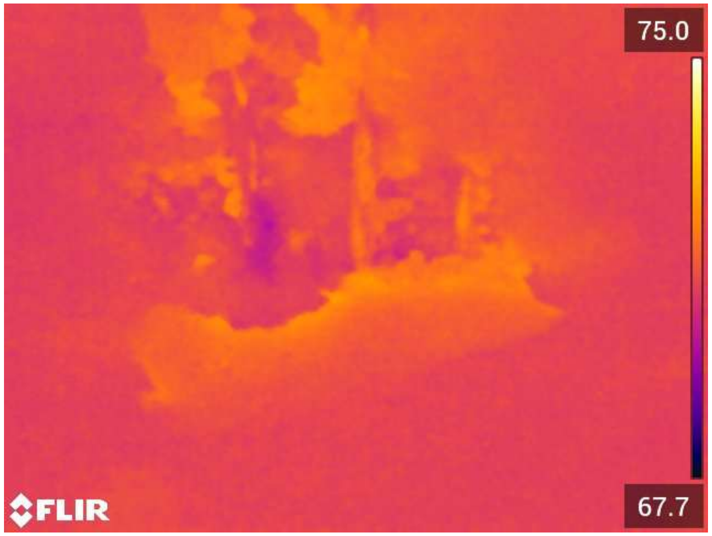


E96_01_05_IR_FLIR1697

Visual of Delamination

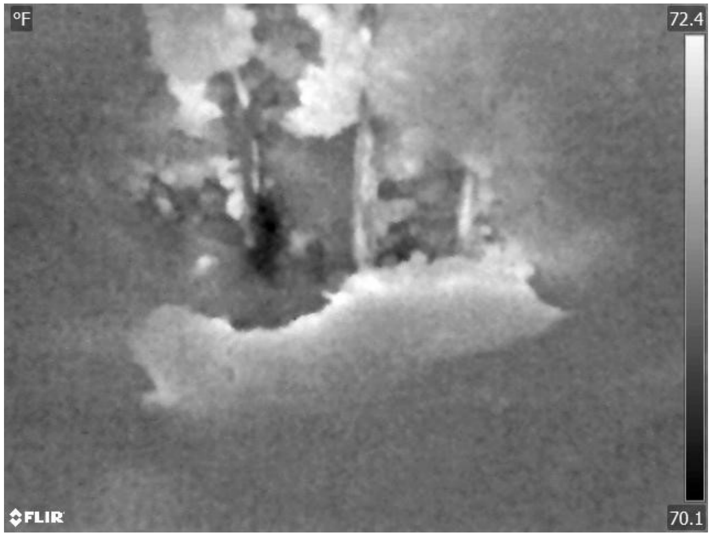
E96_02_05_RGB_FLIR1756

Second Data Set



E96_02_05_IR_FLIR1755

Second Data Set – Post Processed

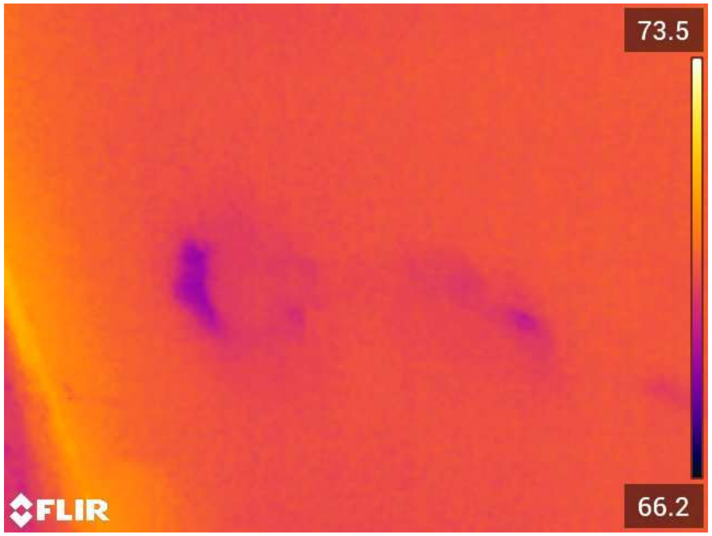


E96_02p_05_IR_FLIR1755

4EU, Flir E96, All Thermal Data

Deficiency 6

First Data Set

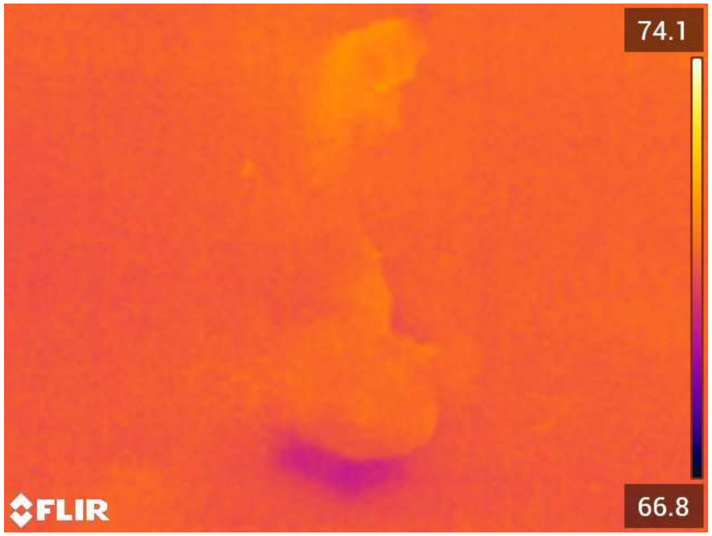


E96_01_06_IR_FLIR1699

Visual of Delamination

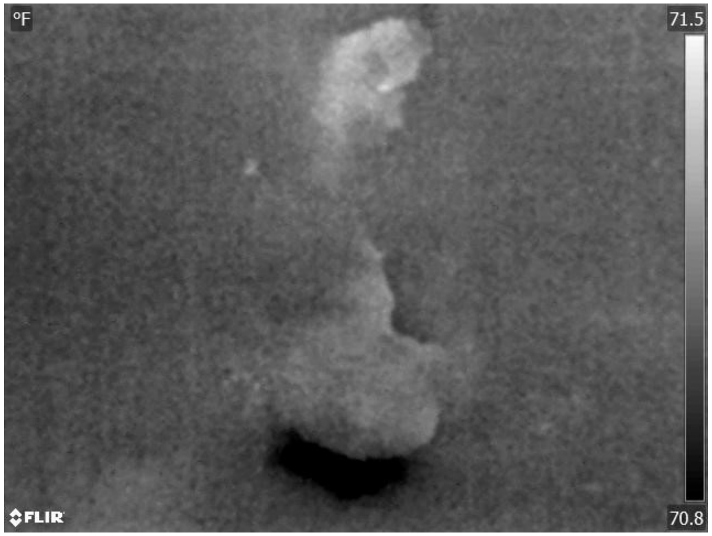
E96_01_06_RGB_FLIR1700

Second Data Set



E96_02_06_IR_FLIR1759

Second Data Set – Post Processed

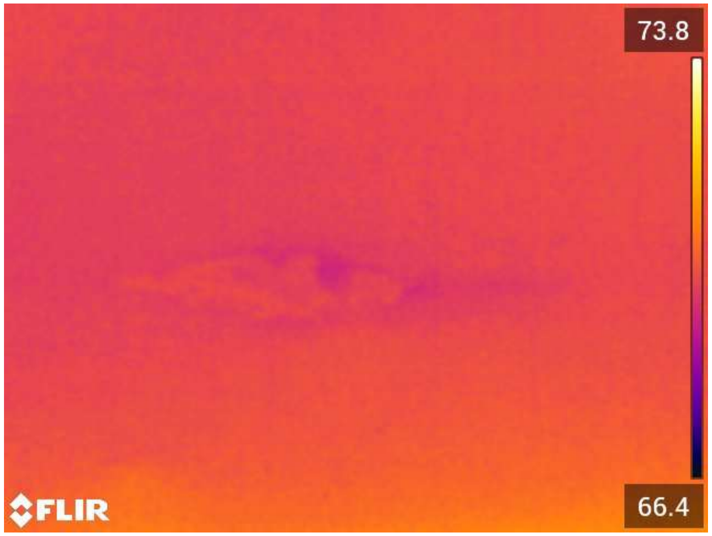


E96_02p_06_IR_FLIR1759

4EU, Flir E96, All Thermal Data

Deficiency 7

First Data Set

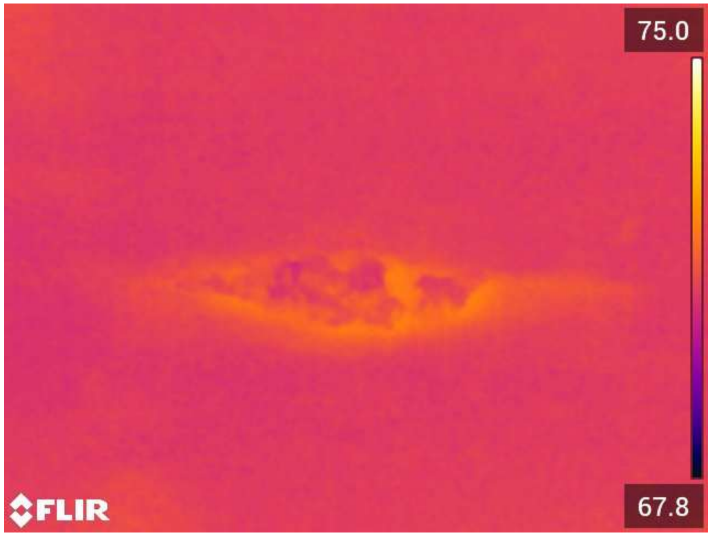


E96_01_07_IR_FLIR1701

Visual of Delamination

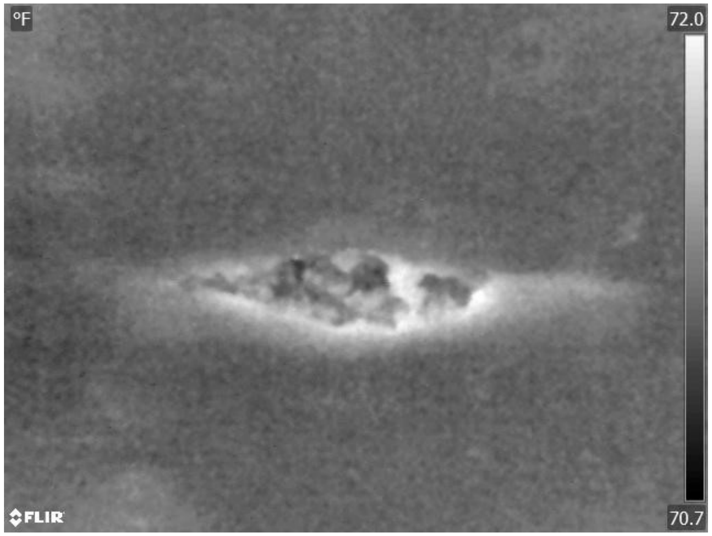
E96_01_07_RGB_FLIR1702

Second Data Set



E96_02_07_IR_FLIR1783

Second Data Set – Post Processed

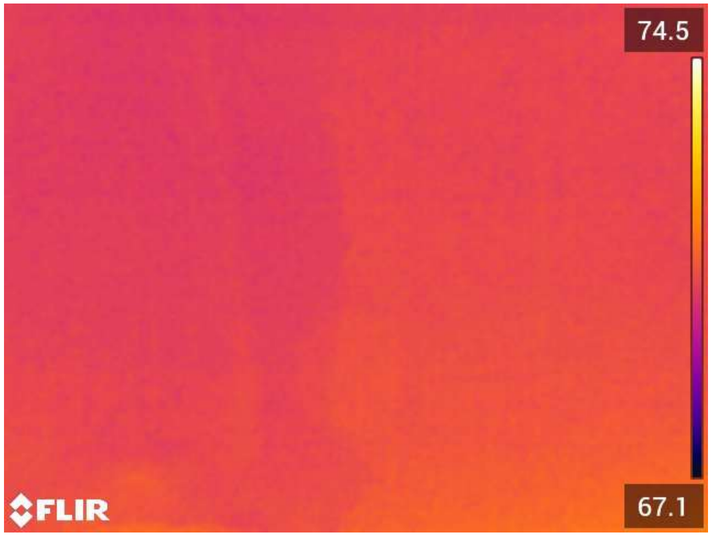


E96_02p_07_IR_FLIR1783

4EU, Flir E96, All Thermal Data

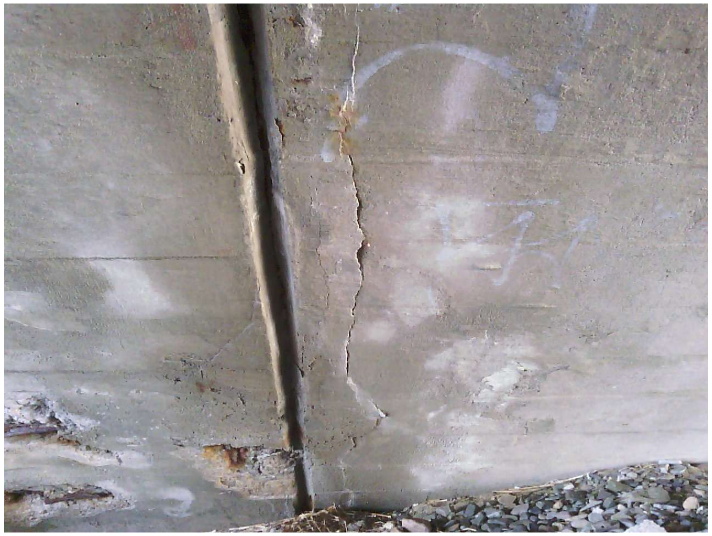
Deficiency 8

First Data Set



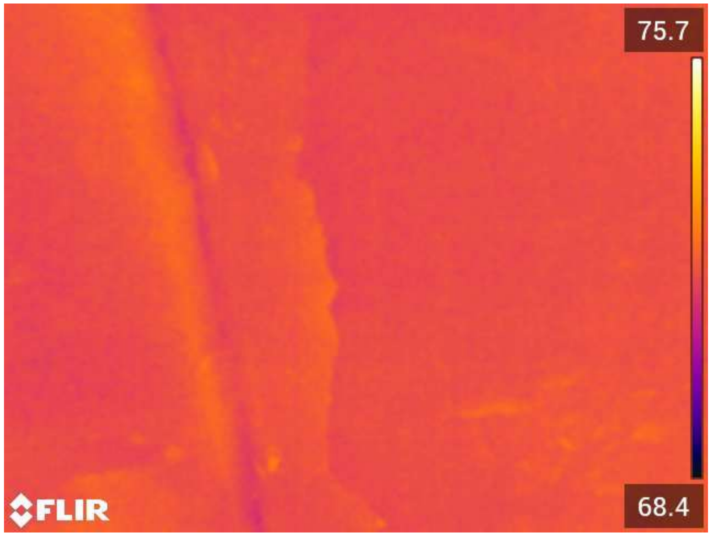
E96_01_08_IR_FLIR1717

Visual of Delamination



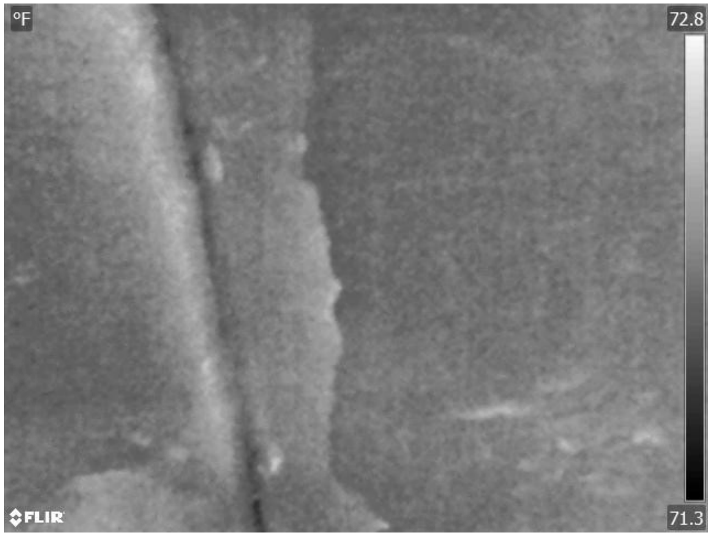
E96_01_08_RGB_FLIR1718

Second Data Set



E96_02_08_IR_FLIR1789

Second Data Set – Post Processed

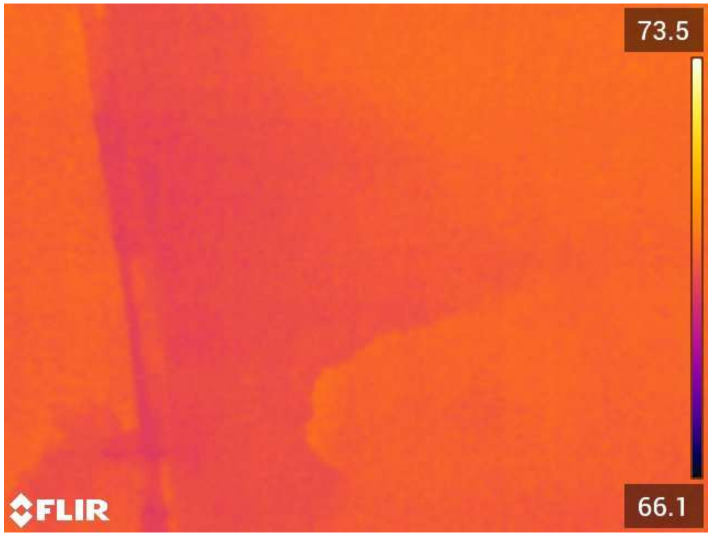


E96_02p_08_IR_FLIR1789

4EU, Flir E96, All Thermal Data

Deficiency 9

First Data Set

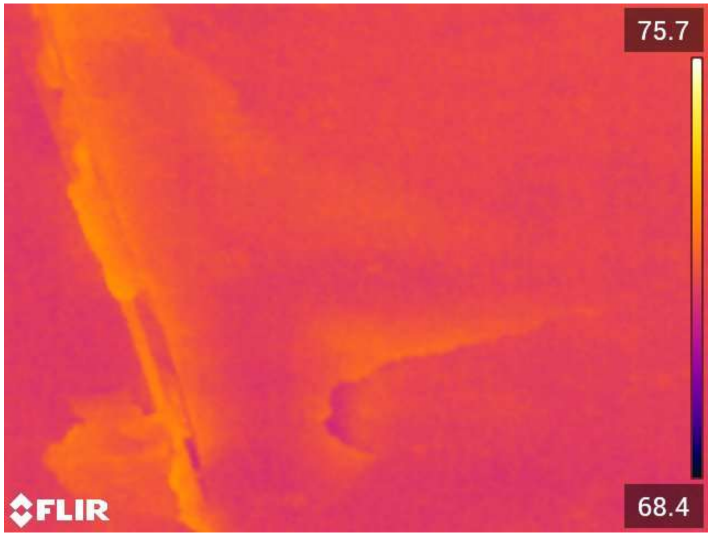


E96_01_09_IR_FLIR1721

Visual of Delamination

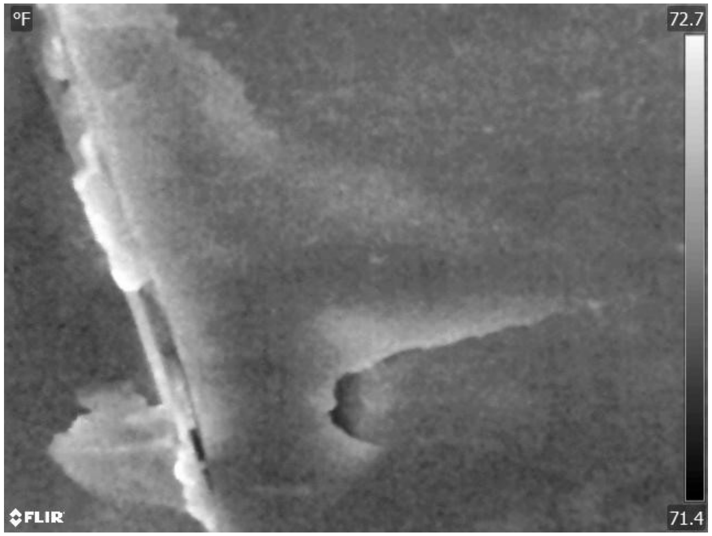
E96_01_09_RGB_FLIR1722

Second Data Set



E96_02_09_IR_FLIR1799

Second Data Set – Post Processed

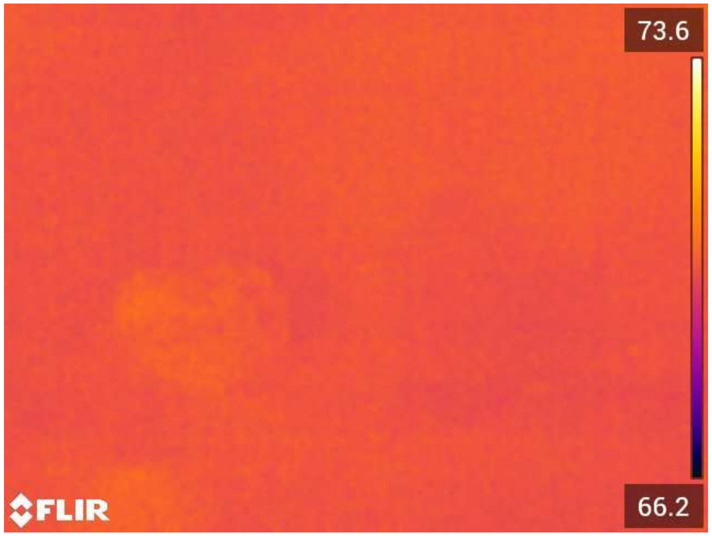


E96_02p_09_IR_FLIR1799

4EU, Flir E96, All Thermal Data

Deficiency 10

First Data Set

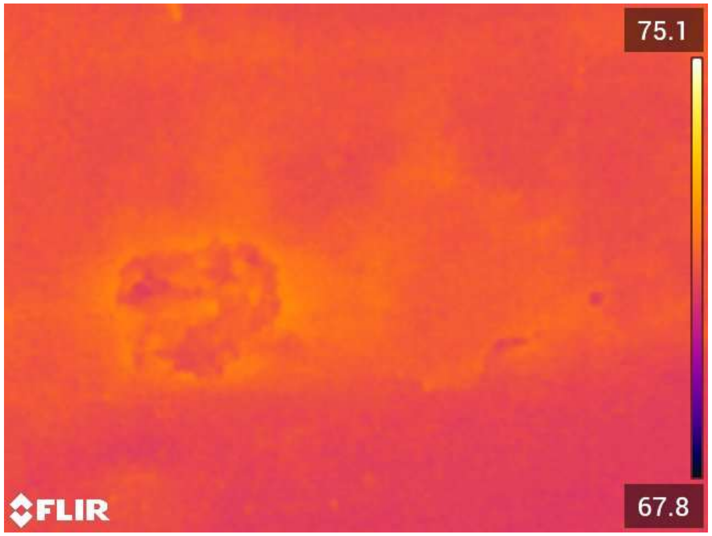


E96_01_10_IR_FLIR1725

Visual of Delamination

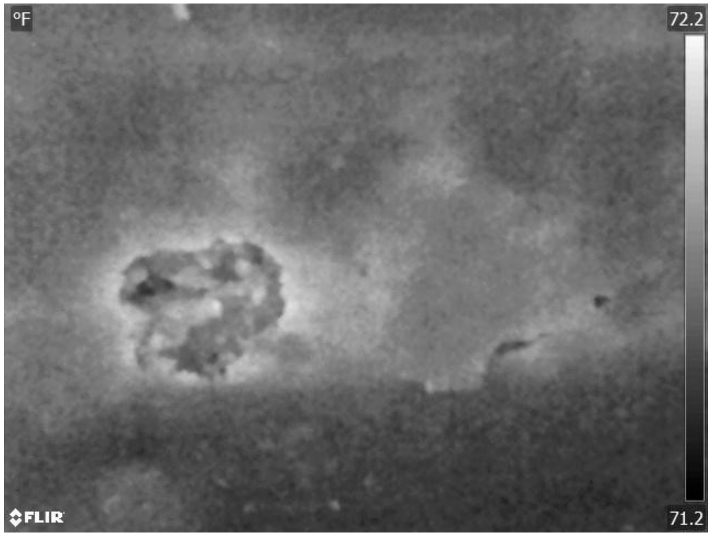
E96_01_10_RGB_FLIR1726

Second Data Set



E96_02_10_IR_FLIR1803

Second Data Set – Post Processed



E96_02p_10_IR_FLIR1803

4EU, Flir E96, All Thermal Data

Deficiency 11

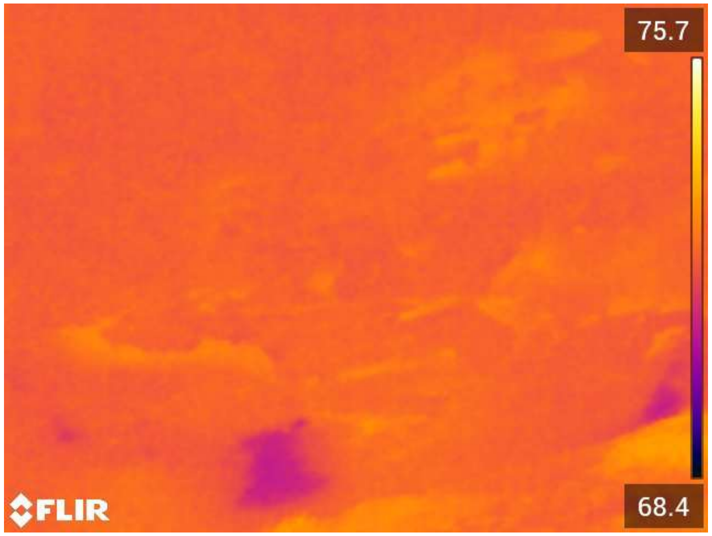
First Data Set

E96_01_11_IR_FLIR1743

Visual of Delamination

E96_02_11_RGB_FLIR1792

Second Data Set



E96_02_11_IR_FLIR1791

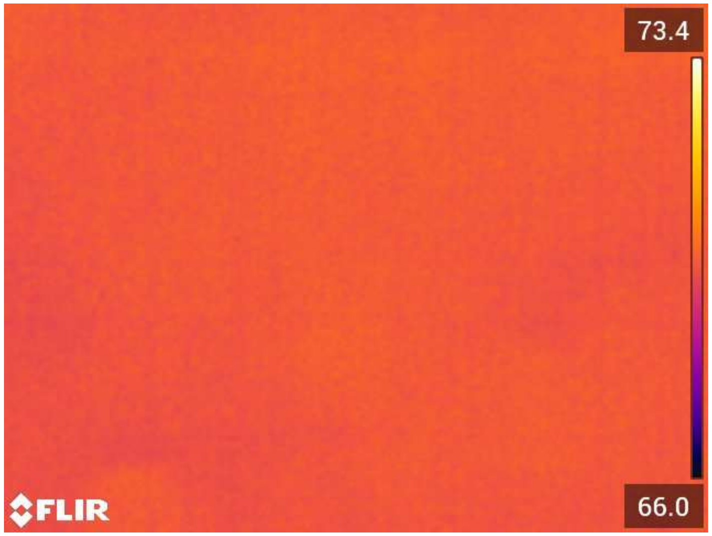
Second Data Set – Post Processed

E96_02p_11_IR_FLIR1791

4EU, Flir E96, All Thermal Data

Deficiency 12

First Data Set

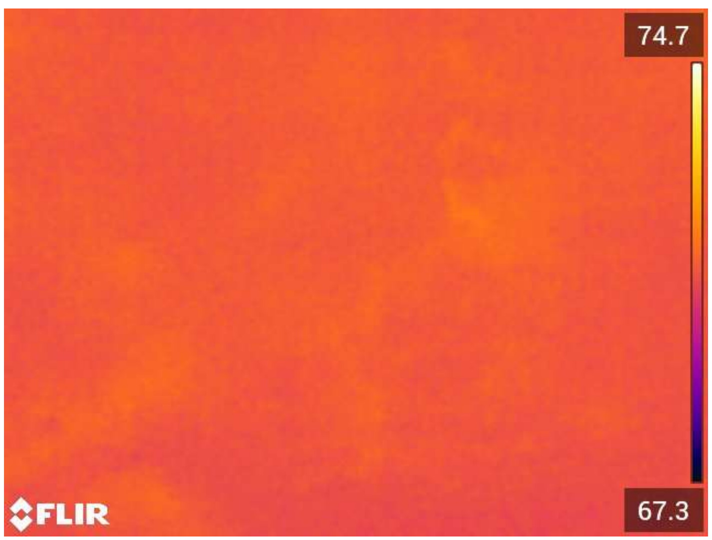


E96_01_12_IR_FLIR1727

Visual of Delamination

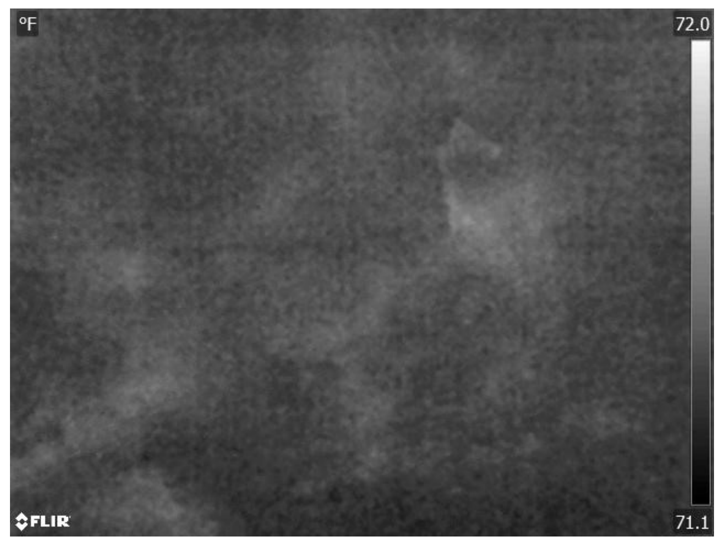
E96_01_12_RGB_FLIR1728

Second Data Set



E96_02_12_IR_FLIR1805

Second Data Set – Post Processed



E96_02p_12_IR_FLIR1805

4EU, Flir E96, All Thermal Data

Deficiency 13

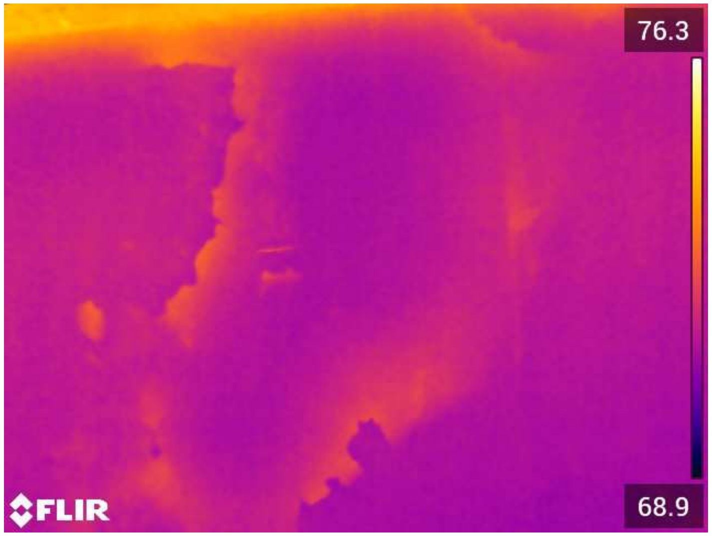
First Data Set

E96_01_13_IR_FLIR1737

Visual of Delamination

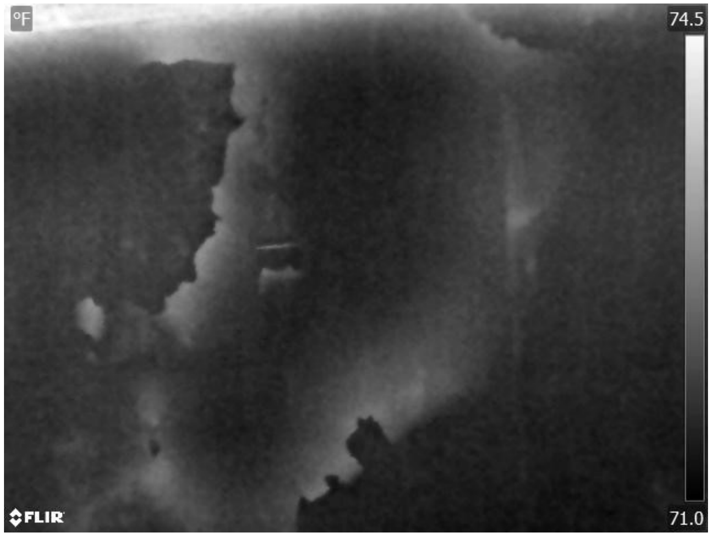
E96_01_13_RGB_FLIR1738

Second Data Set



E96_02_13_IR_FLIR1811

Second Data Set – Post Processed

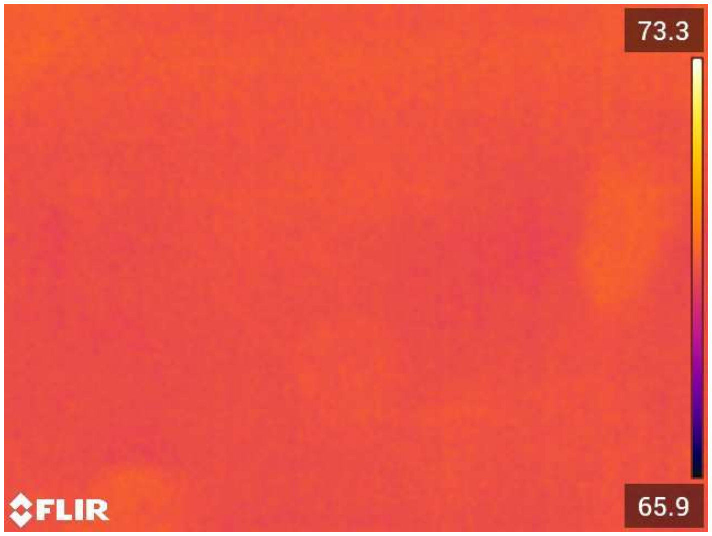


E96_02p_13_IR_FLIR1811

4EU, Flir E96, All Thermal Data

Deficiency 14

First Data Set

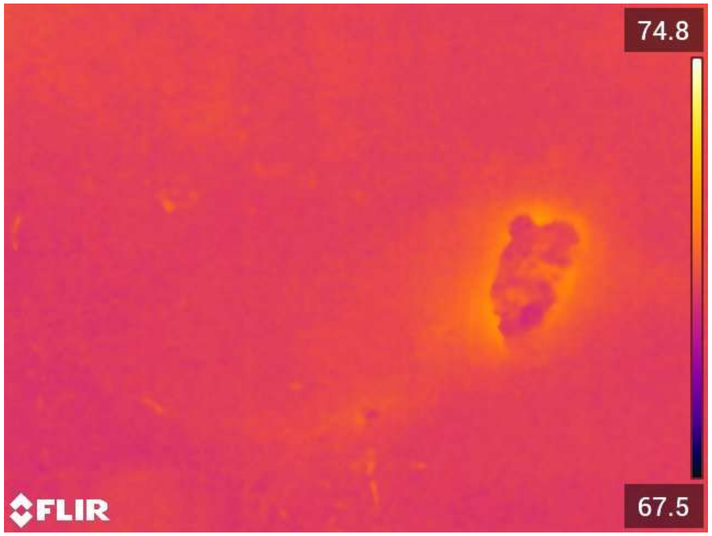


E96_01_14_IR_FLIR1731

Visual of Delamination

E96_01_14_RGB_FLIR1732

Second Data Set



E96_02_14_IR_FLIR1807

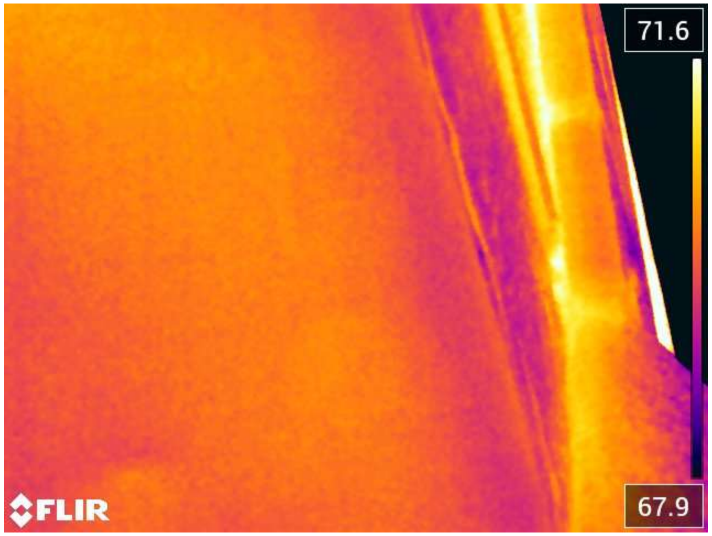
Second Data Set – Post Processed

E96_02p_14_IR_FLIR1807

4EU, Flir E96, All Thermal Data

Deficiency 15

First Data Set

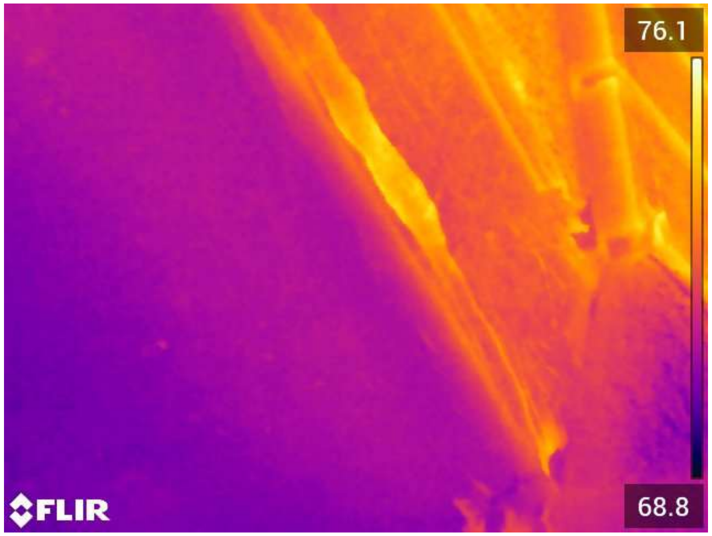


E96_01_15_IR_FLIR1733

Visual of Delamination

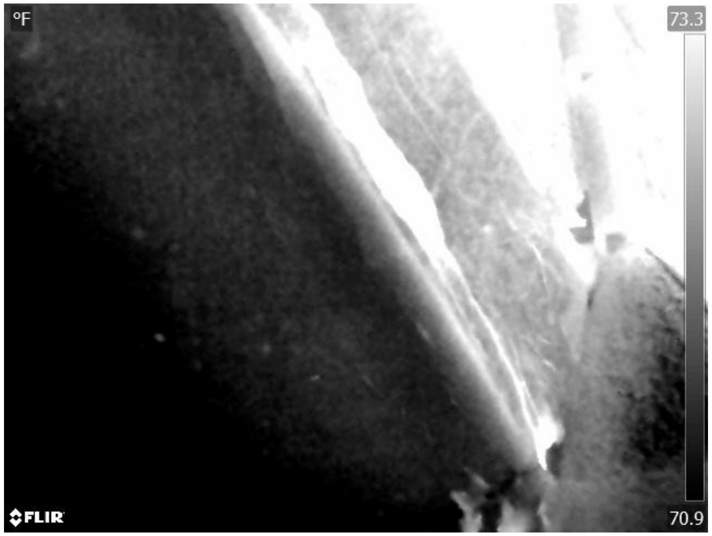
E96_01_15_RGB_FLIR1734

Second Data Set



E96_02_15_IR_FLIR1809

Second Data Set – Post Processed

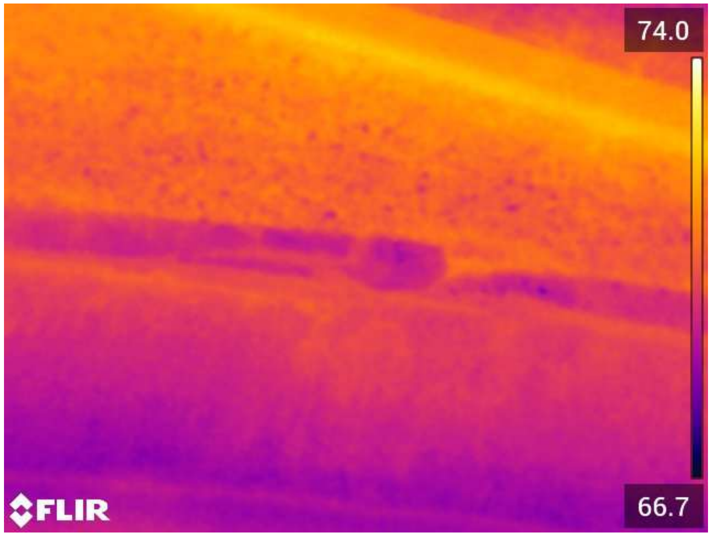


E96_02p_15_IR_FLIR1809

4EU, Flir E96, All Thermal Data

Deficiency 16

First Data Set

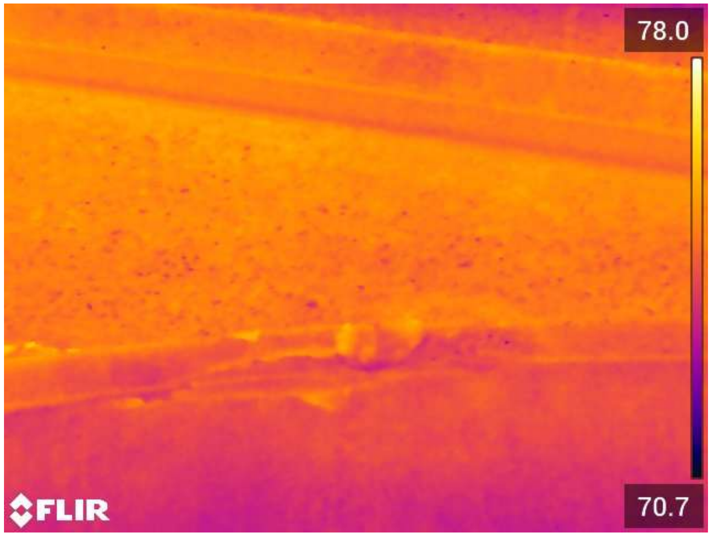


E96_01_16_IR_FLIR1745

Visual of Delamination

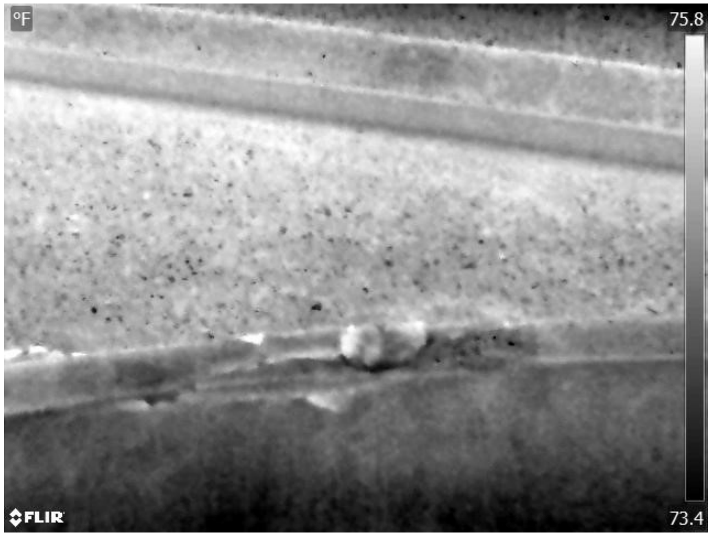
E96_01_16_RGB_FLIR1746

Second Data Set



E96_02_16_IR_FLIR1815

Second Data Set – Post Processed



E96_02p_16_IR_FLIR1815

Appendix C

Bridge 07001

Washington Bridge (07001), Span 2, Traditional Inspection Findings						
Bay / Corbel / Beam	**Element (Deck, Beam, Corbel, or Cant.)**	**Location**	**Deficiencies**	**Comment(s)**	**Use for Thermal Testing (Yes / No)**	**Deficiency # for Thermal Chart**
North Overhang	Deck	Over West Corbel	Active deck joint leakage	Leakage, not included as part of thermal testing	N	-
A	Deck	West of West Corbel	1'-8"W x 8"L hollow area adjacent to repair		Y	1
A	Corbel A	West Corbel, East Face	Upper section, north side - 1'W x 2'H hollow area	Not visible from ground due to bridge geometry	N	-
A	Corbel A	West Corbel, East Face	Lower section, north side - 1'W x 1'-4"H hollow area		Y	2
A	Beam A	West Corbel, North Face	Web at beam end - Up to 2'L x 1'-11"H hollow area with 8"L x 1'-2"H x 3"D spall with exposed rebar	Not visible from ground due to bridge geometry	N	-
A	Deck	East of West Corbel	1'W x up to 8"L (5"L avg) minor hollow area with minor rust/leakage staining		Y	3
A	Deck	West of Midspan	1'-2"W x 4"L avg hollow area with adjacent 10"W x up to 5"L x 1/2"D spall with rust staining		Y	4
A	Deck	West of Midspan	Adjacent to beam B - 1'-2"W x 4"L hollow area		Y	5
A	Deck	East of Midspan	4"L x 1'W hollow area with adjacent 1"L x 1'W spall	Red hatching for limits of delamination, yellow is incorrect	Y	6
A	Beam A	North Face at East Corbel	Web at beam dapped end - 17"H x 16"W x 1"D spall with exposed rebar	Not visible from ground due to bridge geometry	N	-
A	Beam A	North Face at East Corbel	Hidden by steel repair plate - Previously noted as web over bearing - full height x 7"L hollow area and a 1'L x 1'-2"H 'L-shaped' hollow area	Hidden	N	-
A	Corbel A	East Corbel, West Face	Hidden by steel repair plate - Previously noted as lower section, north side - 27"H x 1'W x 2"D spall with exposed rebar	Hidden	N	-
A	Corbel A	East Corbel, West Face	Hidden by steel repair plate - Previously noted as lower section, south side - Patched - 1'-2"H x 1'-2"W x 1-1/2"D spall with exposed anchor plate	HIdden	N	-
A	Corbel A	East Corbel, Underside	North end - 8"L x 5"W hollow area with 10"L x 3"W spall		Y	7
A	Corbel A	East Corbel, Underside	South end - 2'-8"L x 1'-2"W hollow area extending up to 1'-2"H onto south face		Y	8
B	Corbel B	West Corbel, East Face	Lower section, north side - 1'-1"W x 10"H minor hollow area		Y	9
C	Corbel C	West Corbel, East Face	Hidden by steel repair plate - Previously noted as 1'-8"W x 1'H x 1"D spall with exposed anchor plate	Hidden	N	-
C	Beam C	North Face at East Corbel	Web at beam end - 8"W x 6"H x 1"D spall with exposed rebar	Spall, not included as part of thermal testing	N	-
C	Corbel C	East Corbel, West Face	North side - 1'-2"W x 1'H spall	Spall, not included as part of thermal testing	N	-
C	Corbel C	East Corbel, West Face	Lower section, south side - 1'-2"L x 1'-3"W spall on west with 1'H x 5"W hollow area on south		Y	10
C	Corbel C	East Corbel, South Face	South side - 16"L hairline vertical crack	Crack, not included as part of thermal testing	N	-
C	Corbel C	East Corbel, Underside	South edge - 18"L x 1'-2"W hollow area and 5"L x 10"W hollow area		Y	11
D	Deck	West of West Corbel	2-8"W x up to 8"L hollow area adjacent to previous repair		Y	12

Washington Bridge (07001), Span 2, Traditional Inspection Findings						
Bay / Corbel / Beam	**Element (Deck, Beam, Corbel, or Cant.)**	**Location**	**Deficiencies**	**Comment(s)**	**Use for Thermal Testing (Yes / No)**	**Deficiency # for Thermal Chart**
D	Corbel D	West Corbel, East Face	Behind drop-in beam, north side - 1'W x 8"H x 5"D spall that extends up to the bearing pad edge	Not visible from ground due to bridge geometry	N	-
D	Deck	West of East Corbel	1'-10"W x 7"L hollow patch		Y	13
D	Corbel D	East Corbel, West Face	North side - 32"W x up to 1'H spall that extends 2" onto the north face	Spall, not included as part of thermal testing	N	-
D	Corbel D	East Corbel, West Face	Upper section, north side - 2'W x 2'H spall/hollow area with 1/8"W boundary cracks, efflorescence, and rust staining	Not visible from ground due to bridge geometry	N	-
E	Corbel E	West Corbel, East Face	Top of lower section, south side - 1'-3"W x 8"H x 1"D spall in front of bearing with an adjacent 2'-6"H x 1'W hollow area on south lower face	Partially hidden by beam	Y	14
E	Corbel E	West Corbel, Underside	Upper section, south side - 1'-8"W x 24"H hollow area.	Not visible due to geometry	N	-
E	Beam E	West Quarter Point	6"L x 3"H x 1/2"D spall	Spall, not included as part of thermal testing	N	-
E	Deck	East Quarter Point	Patch with 1" diameter hollow area		Y	15
E	Deck	East of Midspan	1'-8"L x 1'-1"W hollow area		Y	16
E	Corbel E	East Corbel, West Face	North side, behind diaphragm - 1'W x 8"H hollow area	Not visible from ground due to bridge geometry	N	-
E	Corbel E	East Corbel, West Face	South side, behind diaphragm - 1'W x 8"H hollow area	Not visible from ground due to bridge geometry	N	-
E	Corbel E	East Corbel, West Face	North end - 1'W x 1'H hollow area		Y	17
E	Corbel E	East Corbel, West Face	South end - 1'W x 1'H spall	Spall, not included as part of thermal testing	N	-
E	Deck	East of East Corbel	1'L x 1'-7"W hollow area with rust staining along cantilever F		Y	18
E	Deck	East of East Corbel	3'-11"W x up to 1'-8"L hollow area with rust staining		Y	19
F	Corbel F	West Corbel, East Face	Upper section, south side - 1'-4"W x 1'H x 1"D spall with exposed anchor plate at the south end	Spall, not included as part of thermal testing	N	-
F	Corbel F	West Corbel, East Face	Lower section, south side - 4"W x 1'H hollow area		Y	20
F	Corbel F	West Corbel, South Face	3'-4"L x 1/16"W diagonal crack with efflorescence	Crack, not included as part of thermal testing	N	-
F	Corbel F	West Corbel, Underside	1-1"L x 1'-2"W hollow area with adjacent spalling 1'L x 10"W x up to 2"D		Y	21
F	Beam F	South Face at West Corbel	Web at beam end - 3"W x 10"H hollow area with 1/2"D spalling that extends full width across the back face	Not visible from ground due to bridge geometry	N	-
F	Beam F	South Face at West Corbel	Web at dapped end, behind bearing - 3"W x 5"H x 1/2"D spall at top	Spall, not included as part of thermal testing	N	-
F	Beam F	South Face at East Corbel	Web over bearing - 2'L x 1'-2"H hollow area at top; 27"L x up to 2'H x 2"D spall with three (3) exposed stirrups and the bearing area reduced by 1"W x 1'L at bottom. 9"L x full height x 5"D spall with one (1) exposed stirrup at beam end beyond bearing.	Spall, not included as part of thermal testing	N	-
F	Corbel F	East Corbel, West Face	Lower section, north side & south side - 1'-2"W x 13"H x 1.5"D spall with exposed anchor plate.	Spall, not included as part of thermal testing	N	-
F	Cantilever F	East Cantilever Underside, near Pier	Patched with up to 1'-2"W x 1'-6"L hollow area extending 1 1/2" onto north face with separation crack		Y	22

07001, Flir E96, All Thermal Data

Deficiency 1

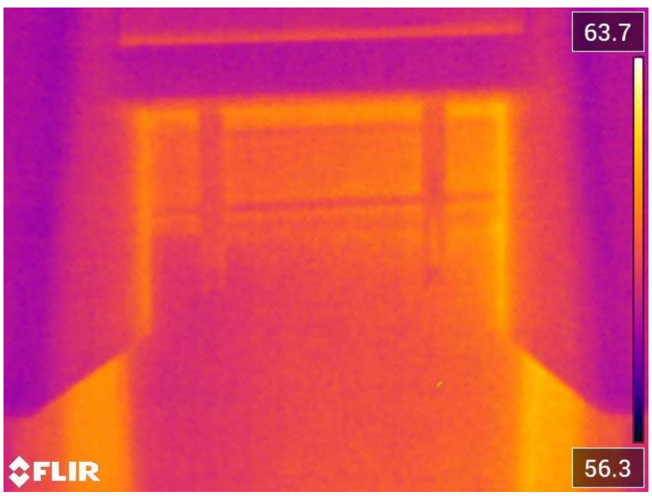
Visual of Delamination

07001_E96_01_01_RGB_FLIR0203

Visual Close-up

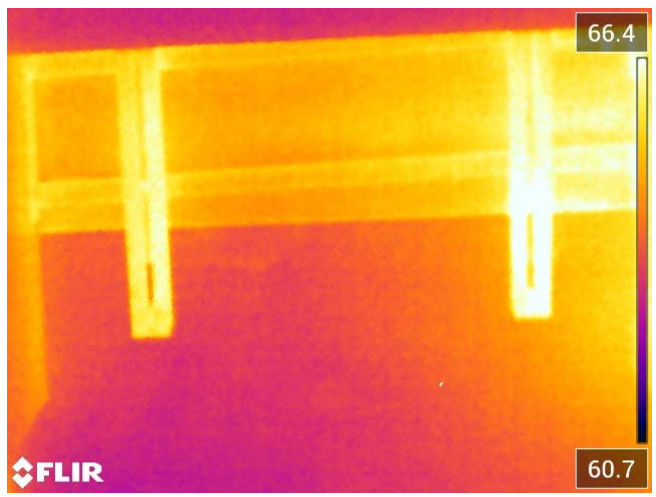
07001_Def_01_DSCF0597

First Data Set



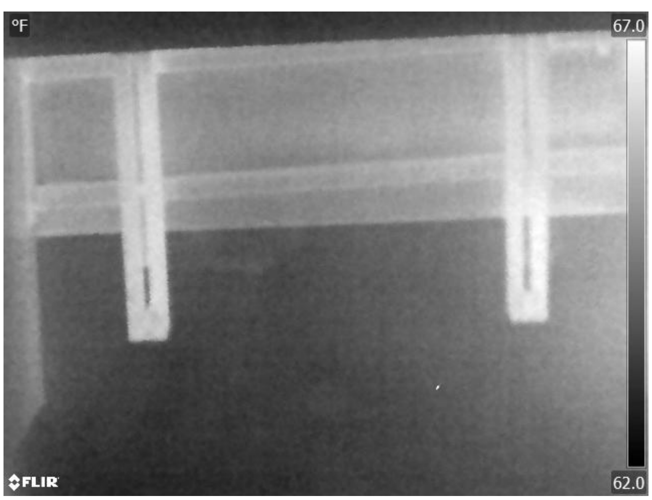
07001_E96_01_01_IR_FLIR0202

Second Data Set



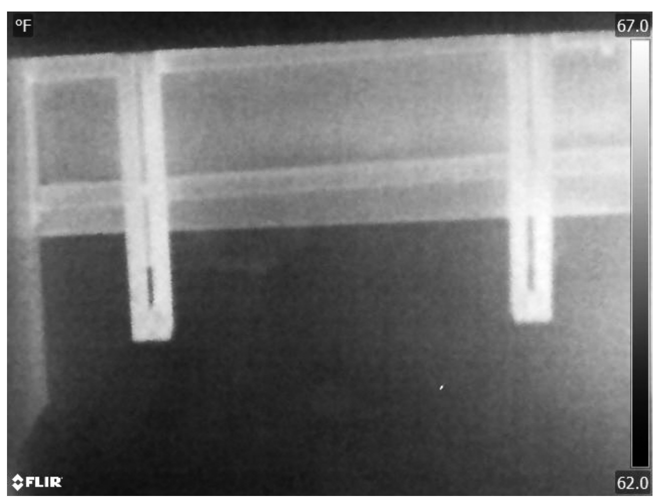
07001_E96_02_01_IR_FLIR0256

Second Data Set – Post Processed 1



07001_E96_02_01_IRp1_FLIR0256

Second Data Set – Post Processed 2



07001_E96_02_01_IRp2_FLIR0256

07001, Flir E96, All Thermal Data

Deficiency 2

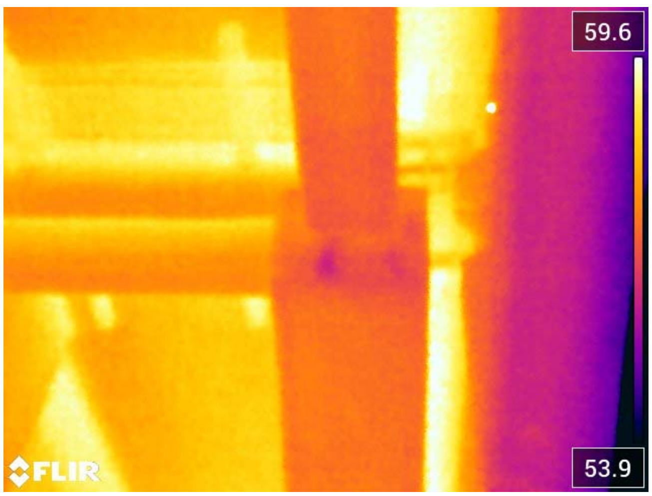
Visual of Delamination

07001_E96_01_02_RGB_FLIR0227

Visual Close-up

07001_Def_02_DSCF0603

First Data Set



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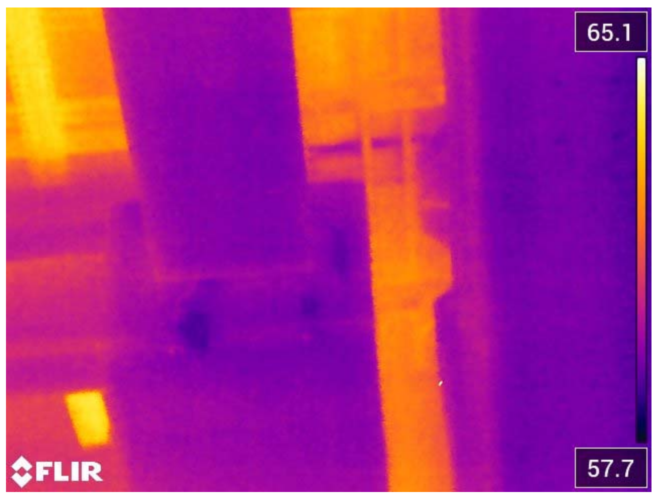
Second Data Set



07001_E96_02_02_IR_FLIR0280

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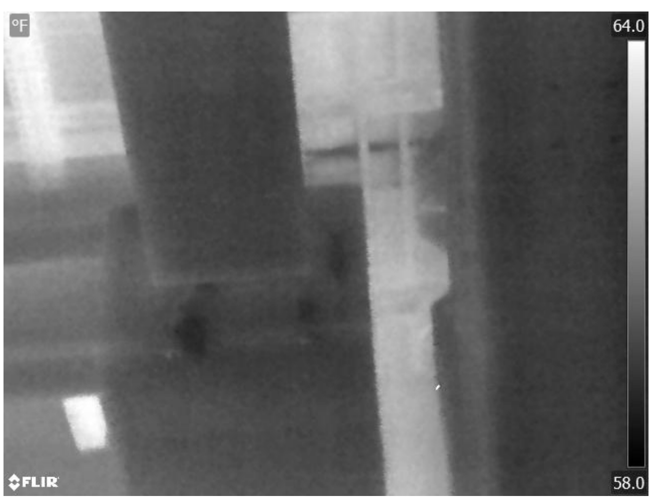
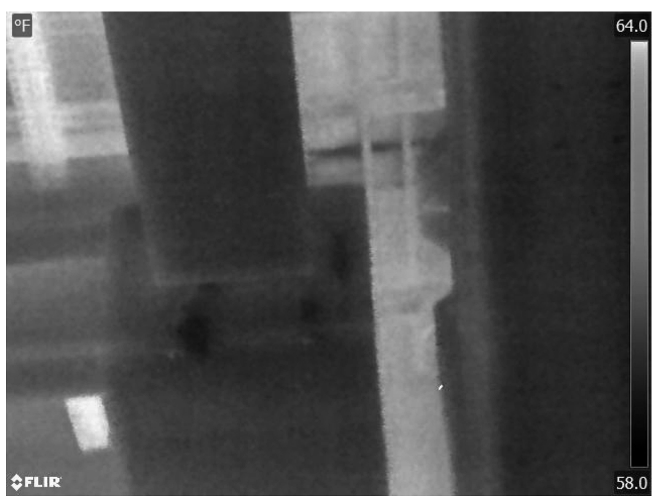


07001_E96_02_02_IRp1_FLIR0280

Second Data Set – Post Processed 2



07001_E96_02_02_IRp2_FLIR0280

07001, Flir E96, All Thermal Data

Deficiency 3

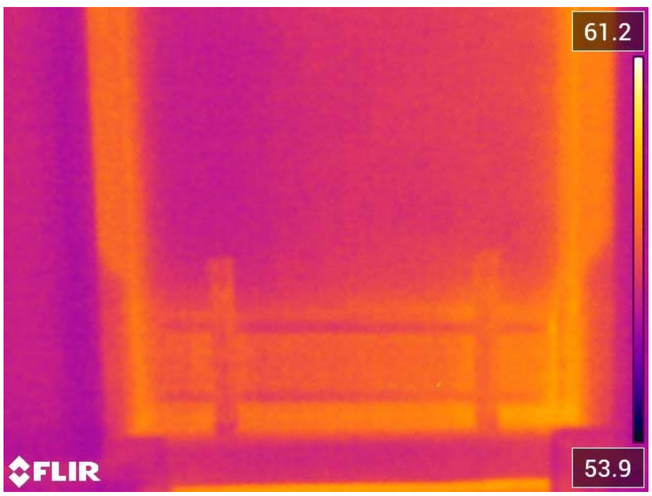
Visual of Delamination

07001_E96_01_03_RGB_FLIR0205

Visual Close-up

07001_Def_03_DSCF0599

First Data Set



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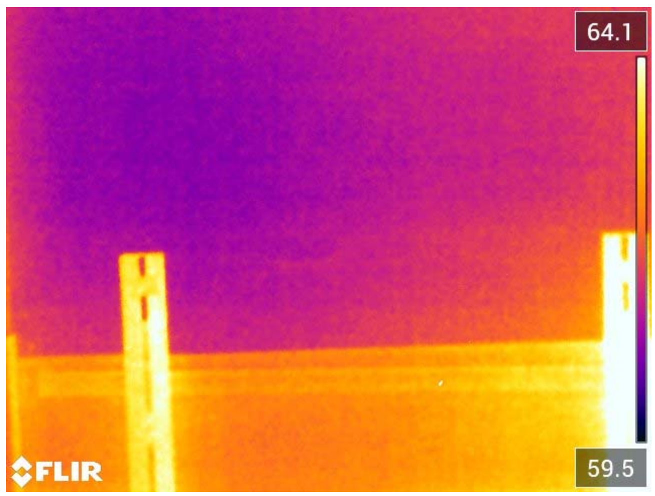
Second Data Set



07001_E96_02_03_IR_FLIR0258

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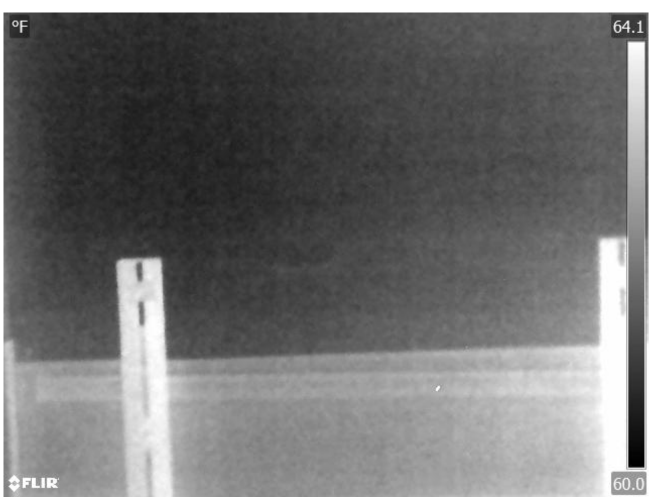

07001_E96_02_03_IRp1_FLIR0258

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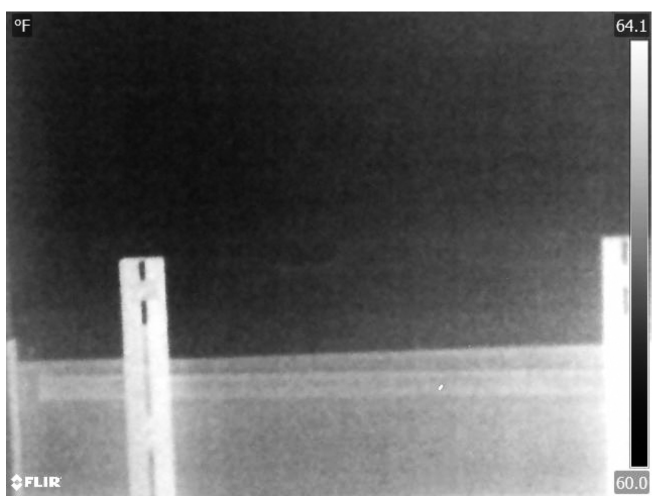


07001_E96_02_03_IRp2_FLIR0258

07001, Flir E96, All Thermal Data

Deficiency 4

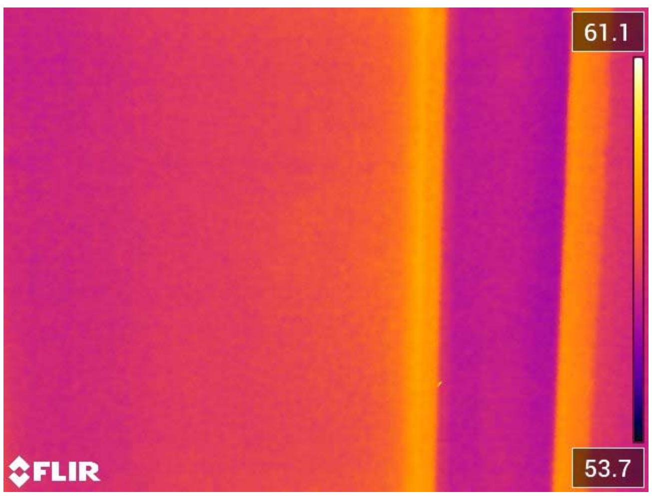
Visual of Delamination

07001_E96_01_04_RGB_FLIR0207

Visual Close-up

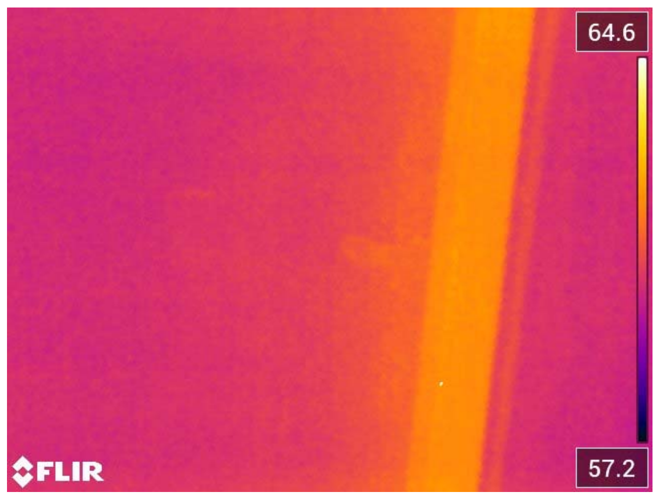
07001_Def_04_DSCF0600

First Data Set



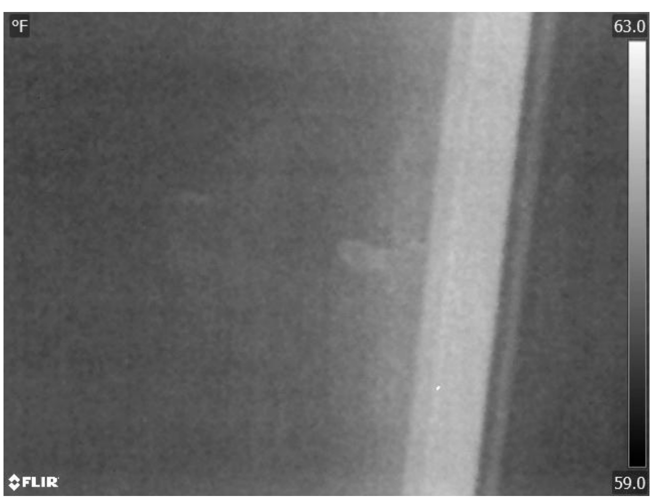
07001_E96_01_04_IR_FLIR0206

Second Data Set



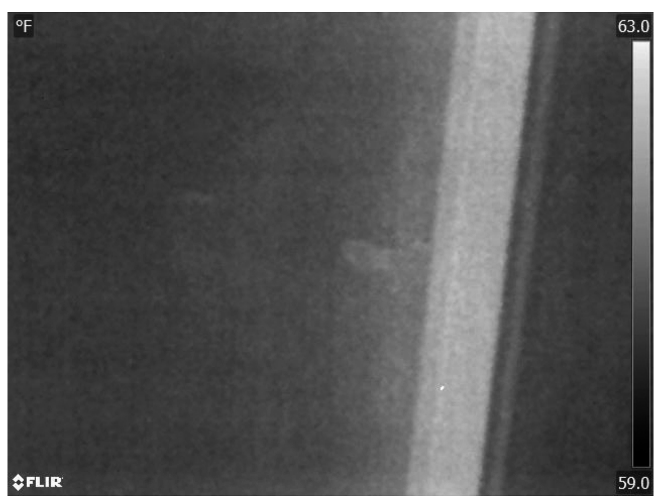
07001_E96_02_04_IR_FLIR0260

Second Data Set – Post Processed 1



07001_E96_02_04_IRp1_FLIR0260

Second Data Set – Post Processed 2



07001_E96_02_04_IRp2_FLIR0260

07001, Flir E96, All Thermal Data

Deficiency 5

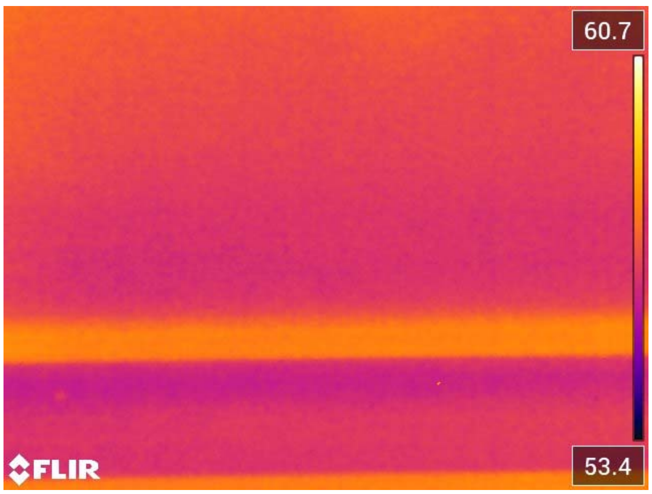
Visual of Delamination

07001_E96_01_05_RGB_FLIR0209

Visual Close-up

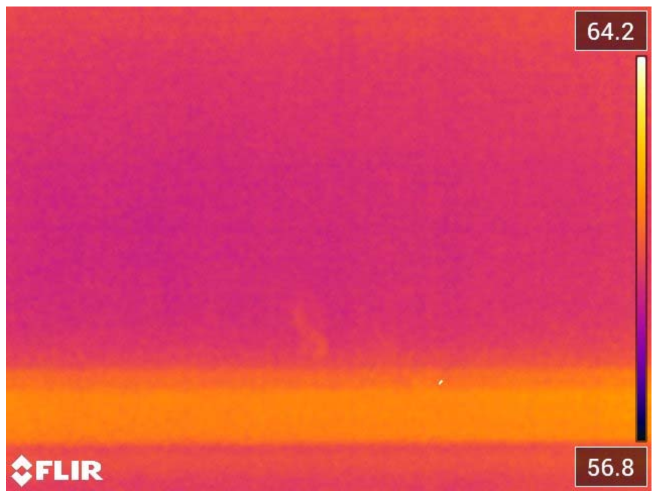
07001_Def_05_DSCF0601

First Data Set



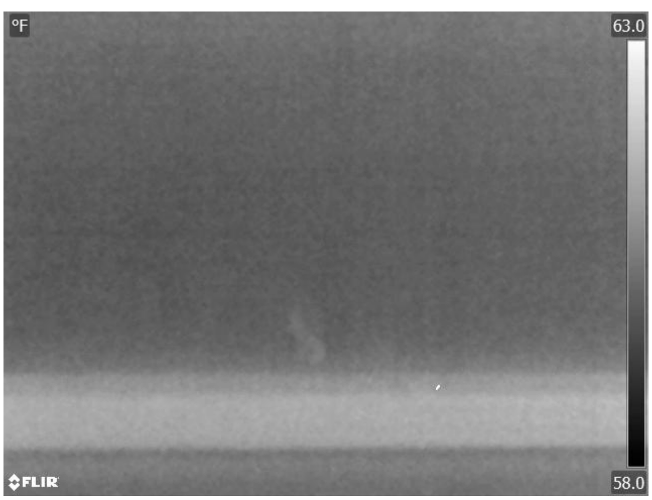
07001_E96_01_05_IR_FLIR0208

Second Data Set



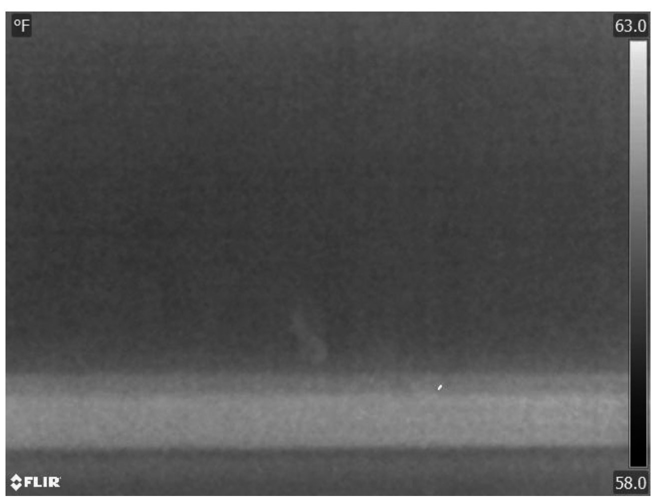
07001_E96_02_05_IR_FLIR0262

Second Data Set – Post Processed 1



07001_E96_02_05_IRp1_FLIR0262

Second Data Set – Post Processed 2

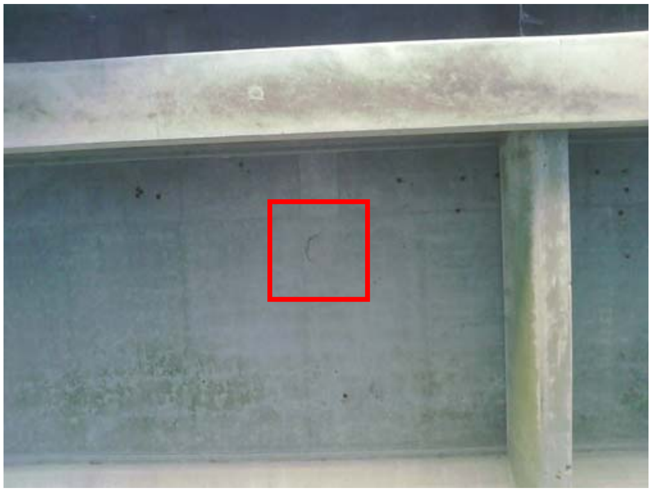


07001_E96_02_05_IRp2_FLIR0262

07001, Flir E96, All Thermal Data

Deficiency 6

Visual of Delamination

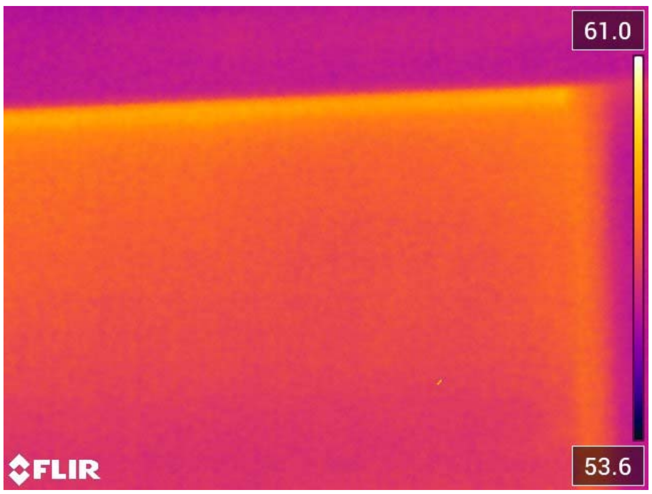


07001_E96_01_06_RGB_FLIR0211

Visual Close-up

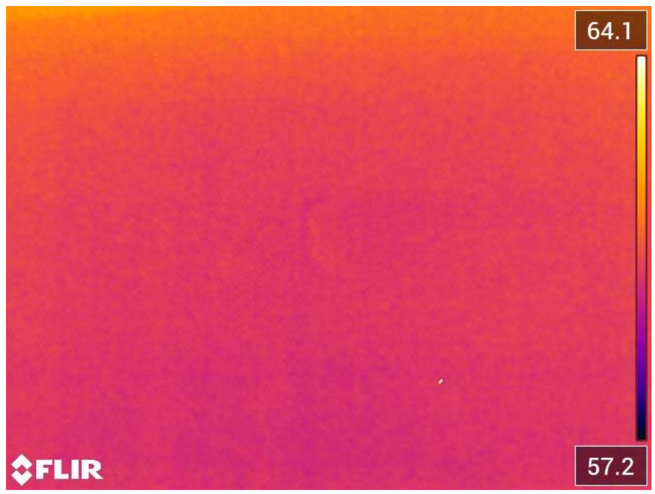
07001_Def_06_DSCF0652

First Data Set



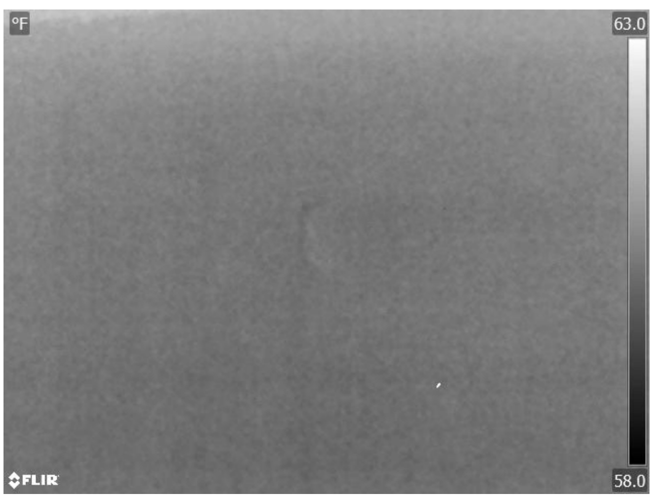
07001_E96_01_06_IR_FLIR0210

Second Data Set



07001_E96_02_06_IR_FLIR0264

Second Data Set – Post Processed 1



07001_E96_02_06_IRp1_FLIR0264

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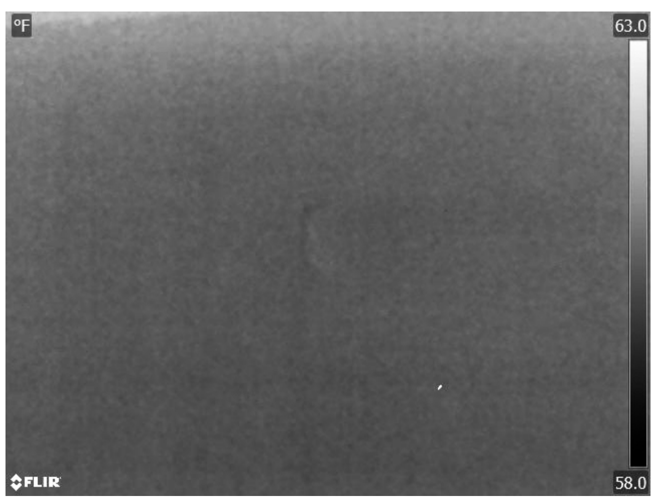


07001_E96_02_06_IRp2_FLIR0264

07001, Flir E96, All Thermal Data

Deficiencies 7, 8

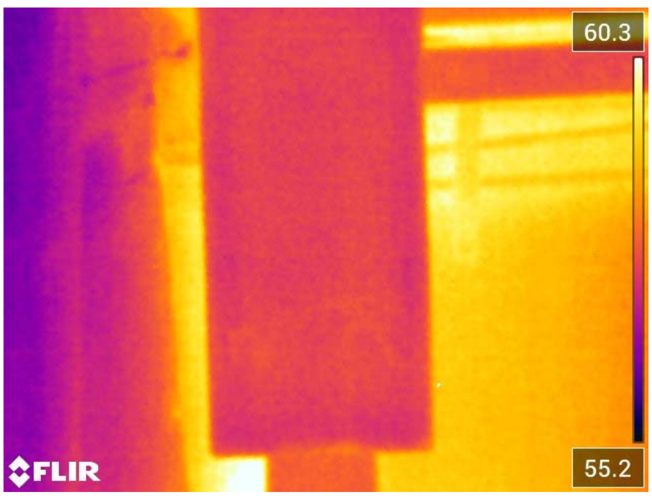
Visual of Delamination

07001_E96_01_07,08_RGB_FLIR0239

Visual Close-up

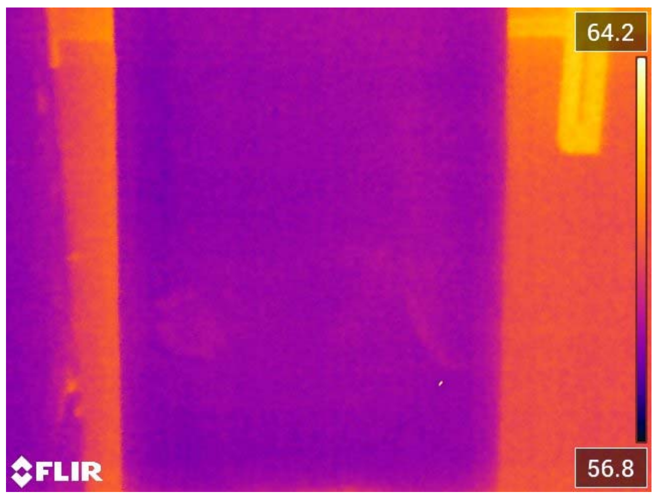
07001_Def_07,08_FLIR0291

First Data Set



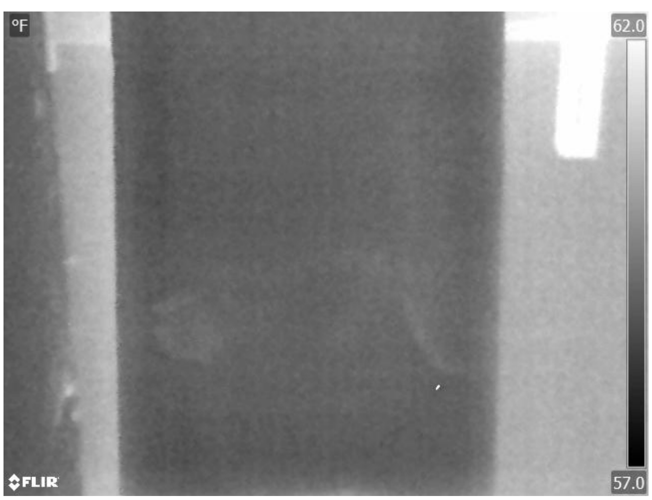
07001_E96_01_07,08_IR_FLIR0238

Second Data Set



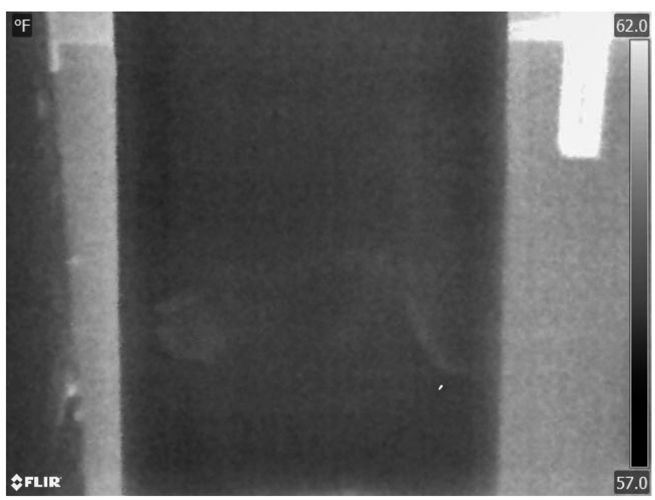
07001_E96_02_07,08_IR_FLIR0290

Second Data Set – Post Processed 1



07001_E96_02_07,08_IRp1_FLIR0290

Second Data Set – Post Processed 2



07001_E96_02_07,08_IRp2_FLIR0290

07001, Flir E96, All Thermal Data

Deficiency 9

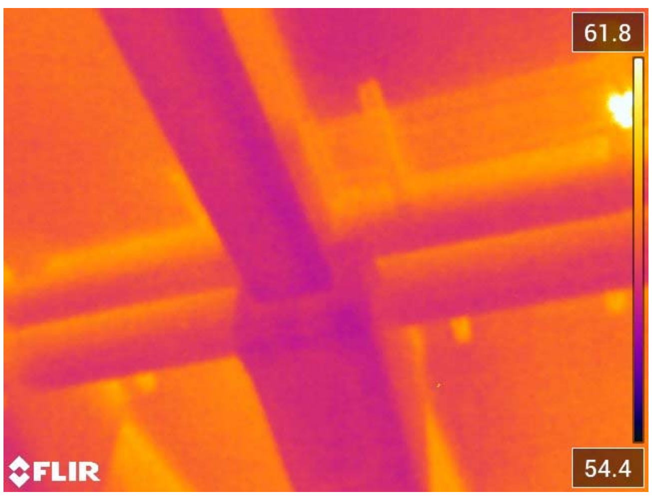
Visual of Delamination

07001_E96_01_09_RGB_FLIR0229

Visual Close-up

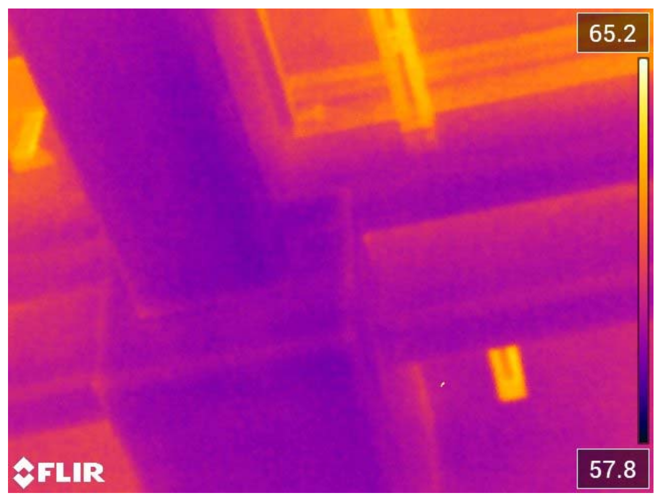
07001_Def_09_DSCF0602

First Data Set



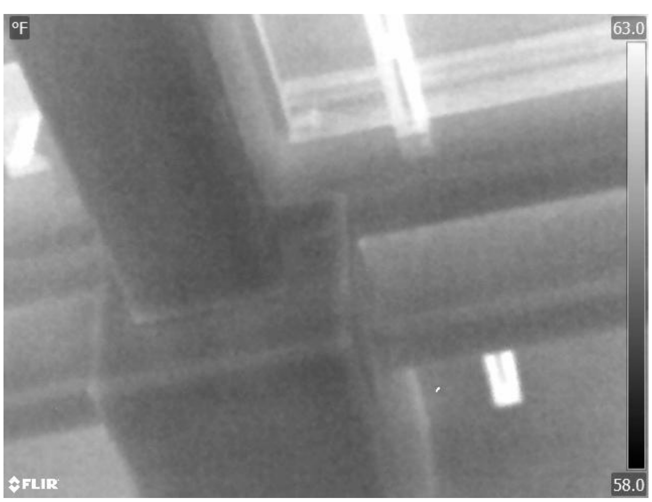
07001_E96_01_09_IR_FLIR0228

Second Data Set



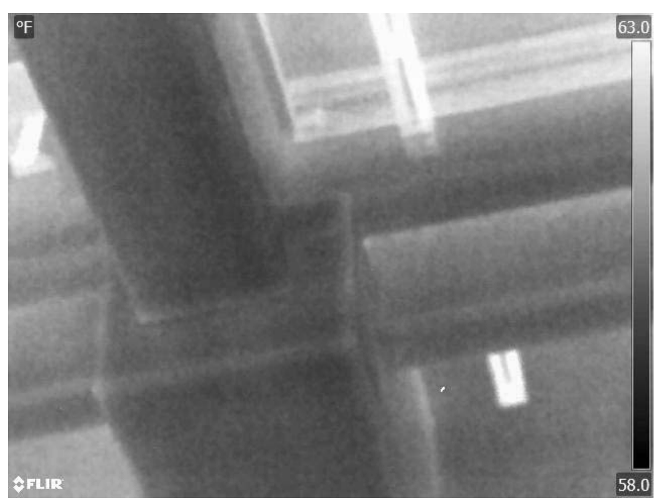
07001_E96_02_09_IR_FLIR0282

Second Data Set – Post Processed 1



07001_E96_02_09_IRp1_FLIR0282

Second Data Set – Post Processed 2



07001_E96_02_09_IRp2_FLIR0282

07001, Flir E96, All Thermal Data

Deficiency 10

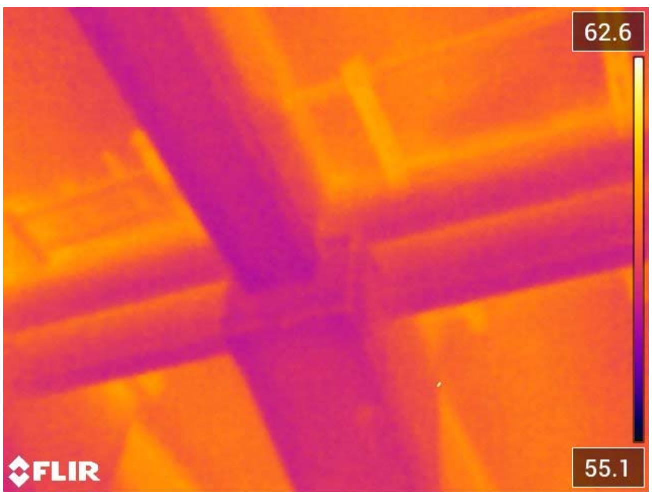
Visual of Delamination

07001_E96_01_10_RGB_FLIR0245

Visual Close-up

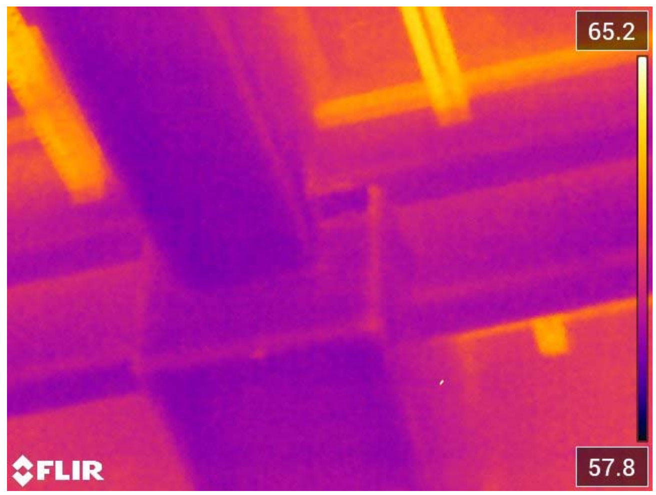
07001_Def_10_DSCF0641

First Data Set



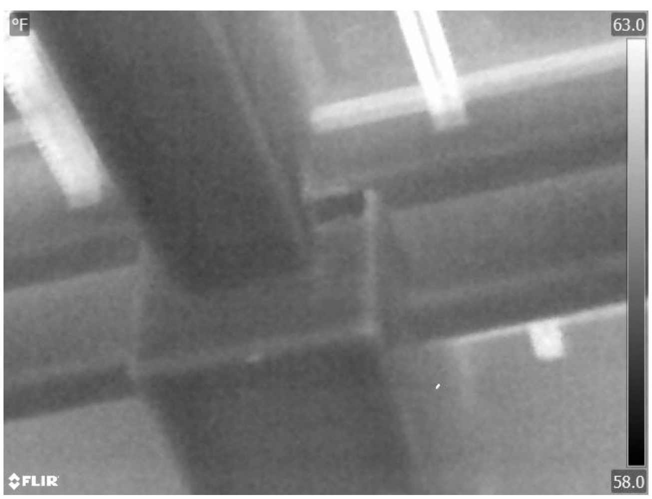
07001_E96_01_10_IR_FLIR0244

Second Data Set



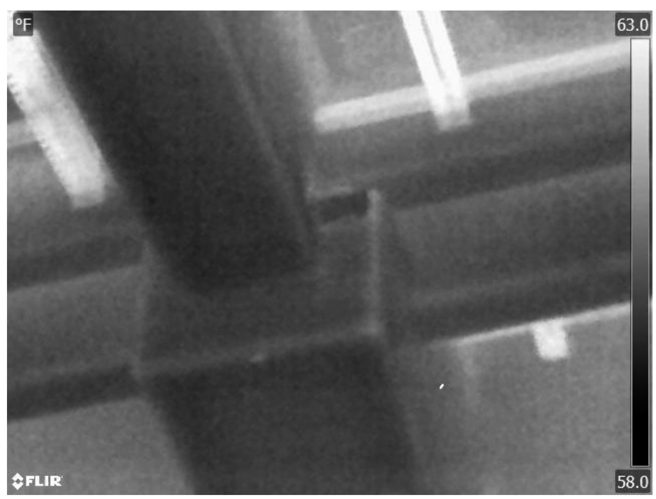
07001_E96_02_10_IR_FLIR0294

Second Data Set – Post Processed 1



07001_E96_02_10_IRp1_FLIR0294

Second Data Set – Post Processed 2

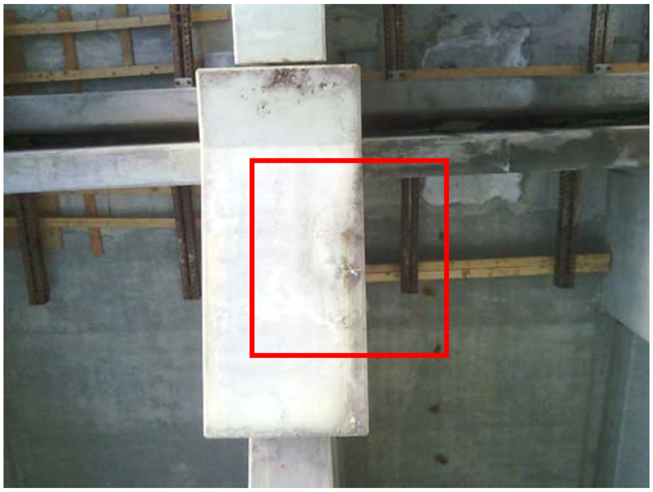


07001_E96_02_10_IRp2_FLIR0294

07001, Flir E96, All Thermal Data

Deficiency 11

Visual of Delamination

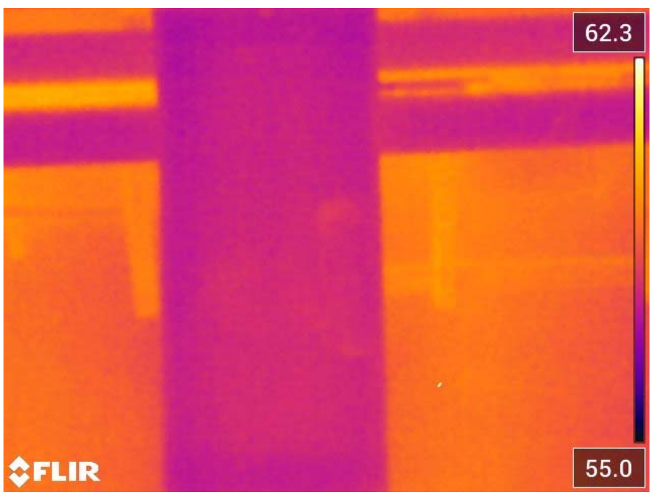


07001_E96_01_11_RGB_FLIR0243

Visual Close-up

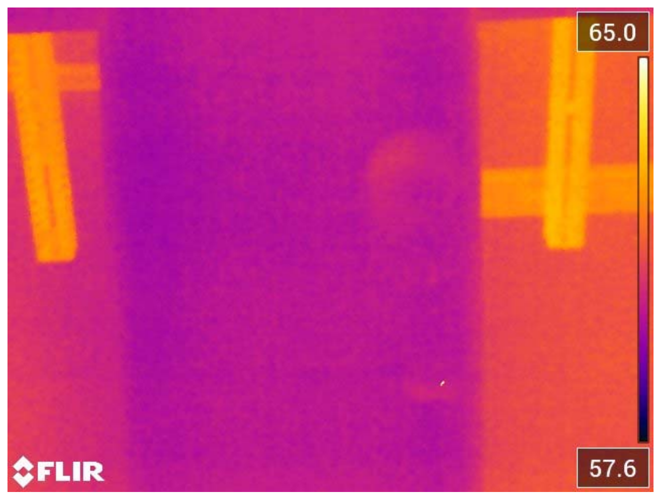
07001_Def_11_DSCF0643

First Data Set



07001_E96_01_11_IR_FLIR0242

Second Data Set



07001_E96_02_11_IR_FLIR0292

Second Data Set – Post Processed 1

07001_E96_02_11_IRp1_FLIR0292

Second Data Set – Post Processed 2

07001_E96_02_11_IRp2_FLIR0292

07001, Flir E96, All Thermal Data

Deficiency 12

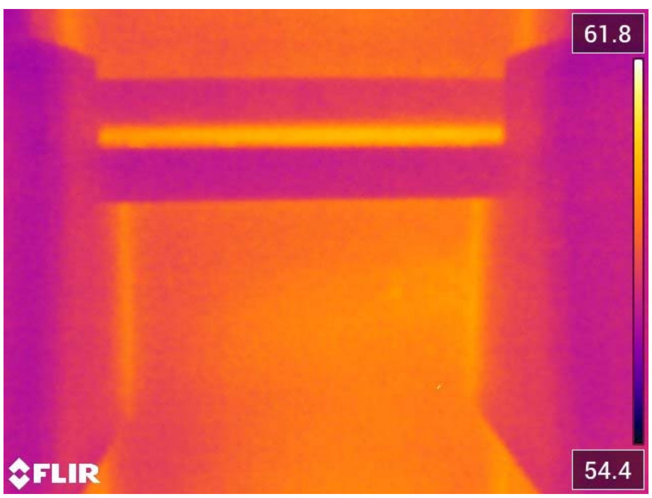
Visual of Delamination

07001_E96_01_12_RGB_FLIR0215

Visual Close-up

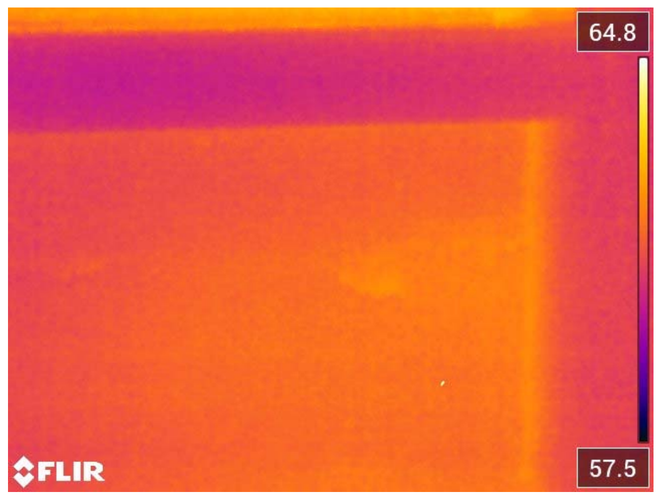
07001_Def_12_DSCF0608

First Data Set



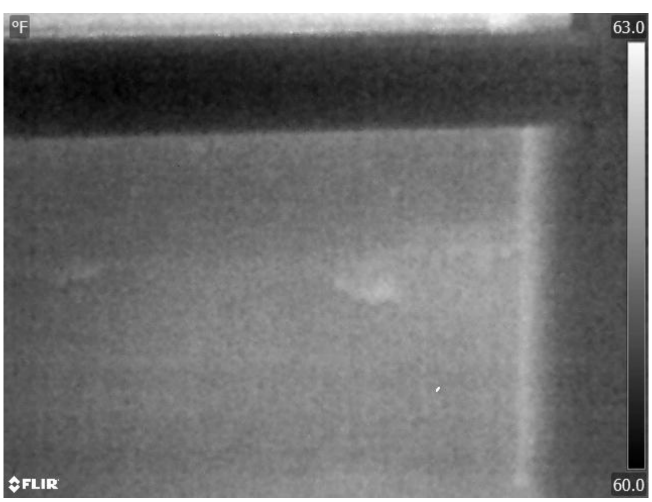
07001_E96_01_12_IR_FLIR0214

Second Data Set



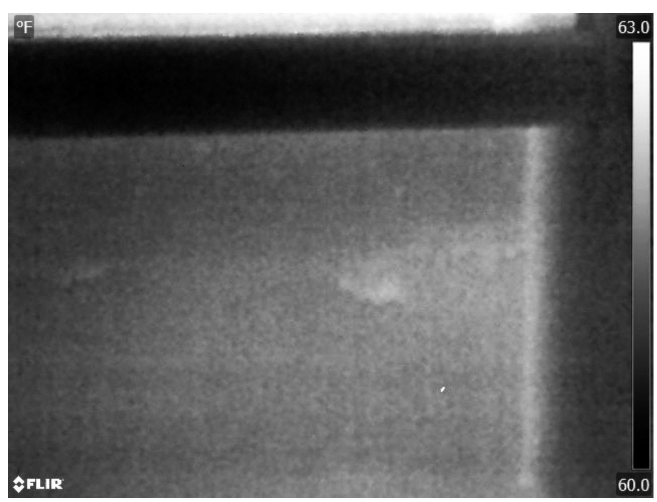
07001_E96_02_12_IR_FLIR0268

Second Data Set – Post Processed 1



07001_E96_02_12_IRp1_FLIR0268

Second Data Set – Post Processed 2



07001_E96_02_12_IRp2_FLIR0268

07001, Flir E96, All Thermal Data

Deficiency 13

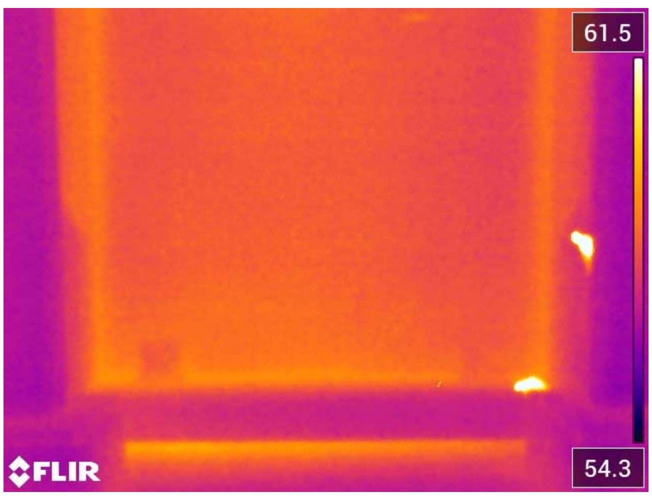
Visual of Delamination

07001_E96_01_13_RGB_FLIR0213

Visual Close-up

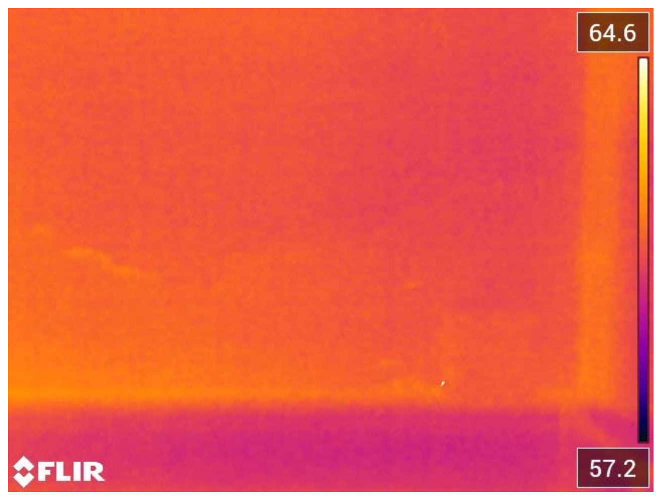
07001_Def_13_DSCF0626

First Data Set



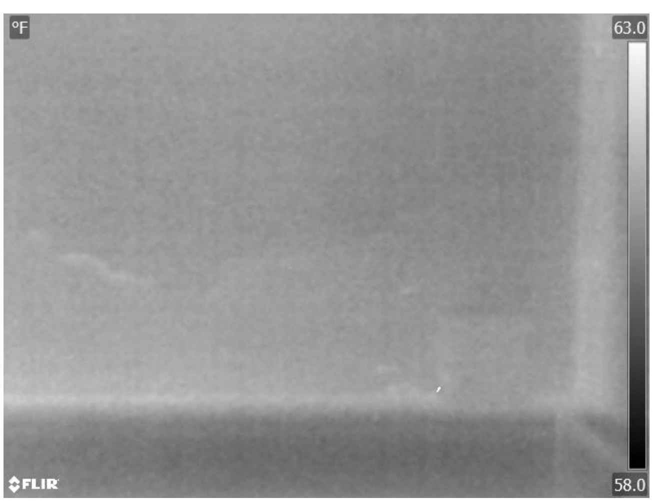
07001_E96_01_13_IR_FLIR0212

Second Data Set



07001_E96_02_13_IR_FLIR0266

Second Data Set – Post Processed 1



07001_E96_02_13_IRp1_FLIR0266

Second Data Set – Post Processed 2

07001_E96_02_13_IRp2_FLIR0266

07001, Flir E96, All Thermal Data

Deficiency 14

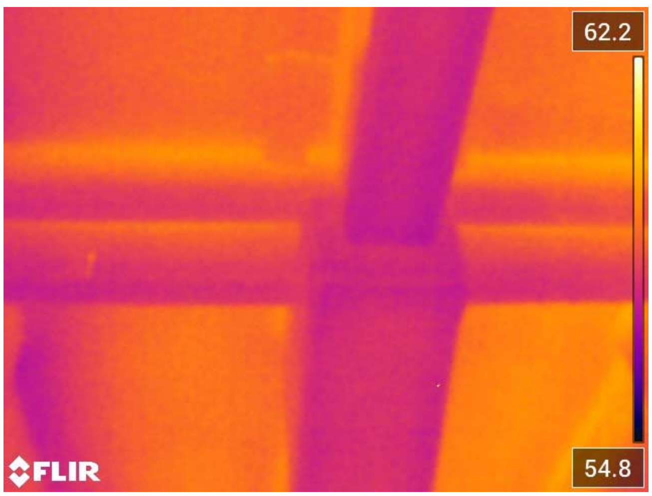
Visual of Delamination

07001_E96_01_14_RGB_FLIR0235

Visual Close-up

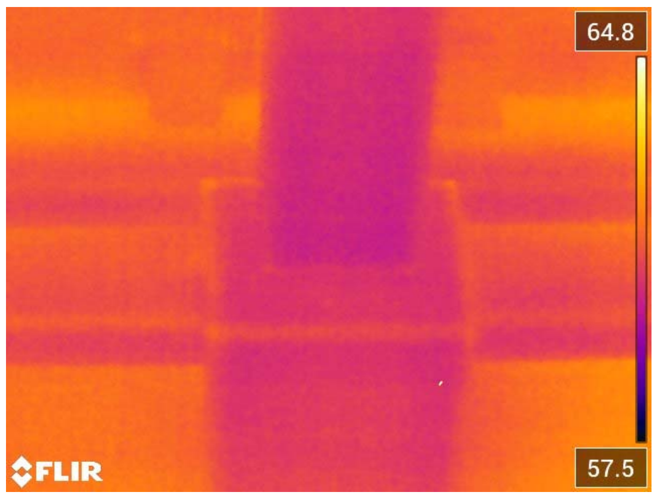
07001_Def_14_DSCF0611

First Data Set



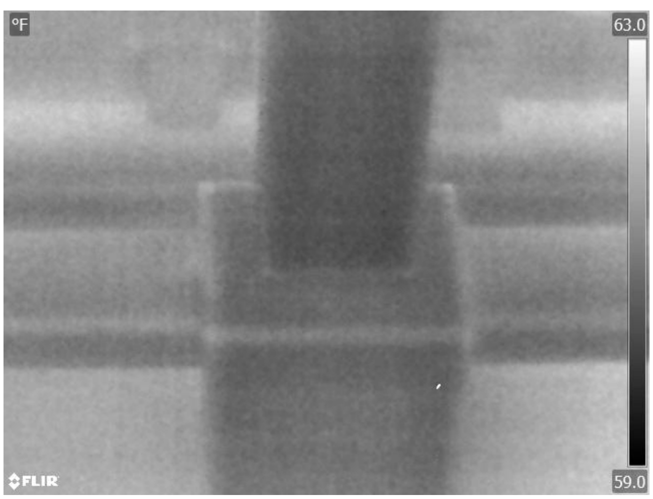
07001_E96_01_14_IR_FLIR0234

Second Data Set



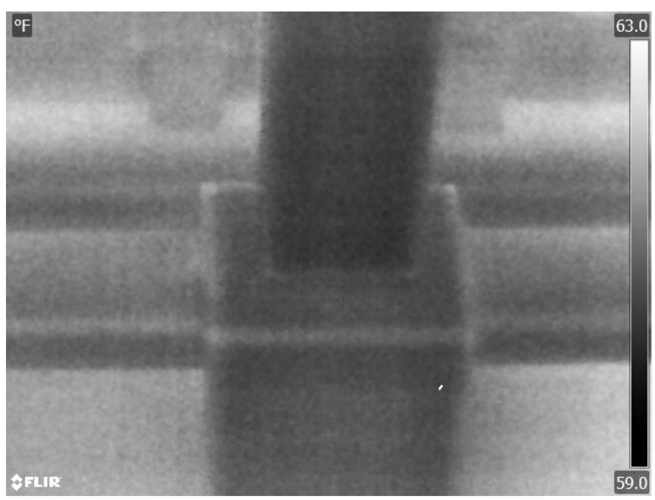
07001_E96_02_14_IR_FLIR0284

Second Data Set – Post Processed 1



07001_E96_02_14_IRp1_FLIR0284

Second Data Set – Post Processed 2

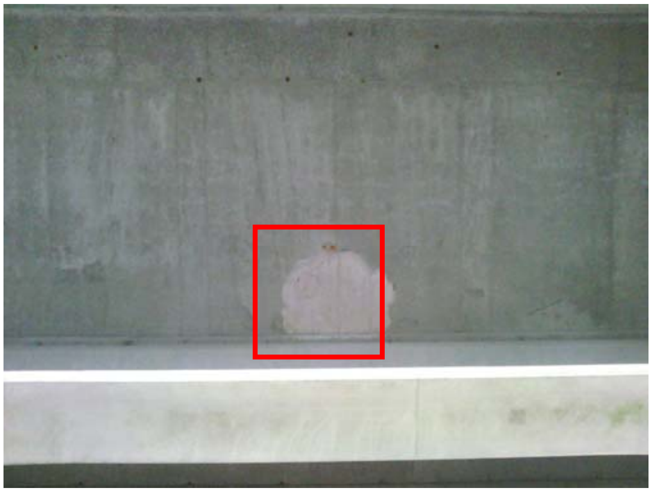


07001_E96_02_14_IRp2_FLIR0284

07001, Flir E96, All Thermal Data

Deficiency 15

Visual of Delamination

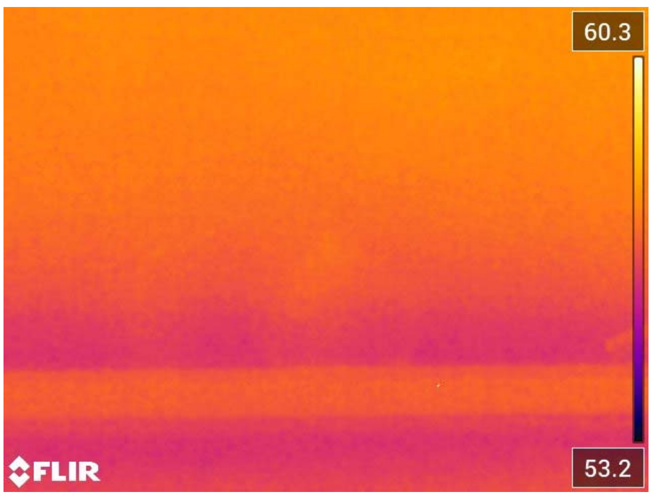


07001_E96_01_15_RGB_FLIR0221

Visual Close-up

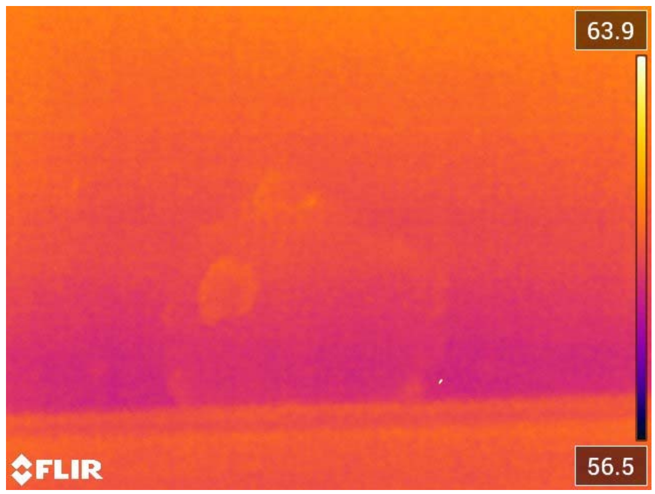
07001_Def_15_DSCF0651

First Data Set



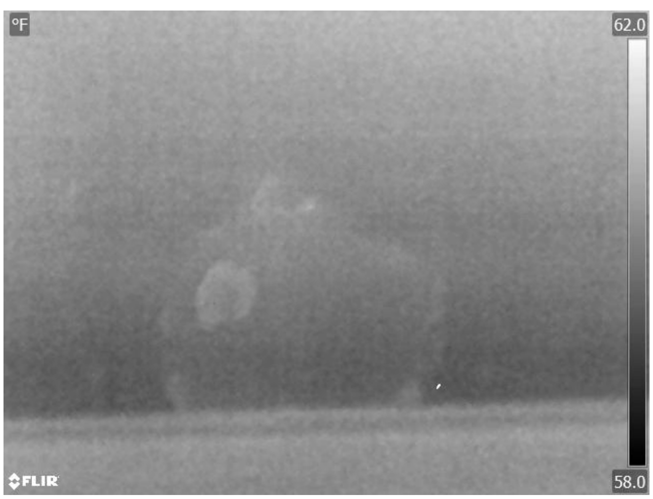
07001_E96_01_15_IR_FLIR0220

Second Data Set



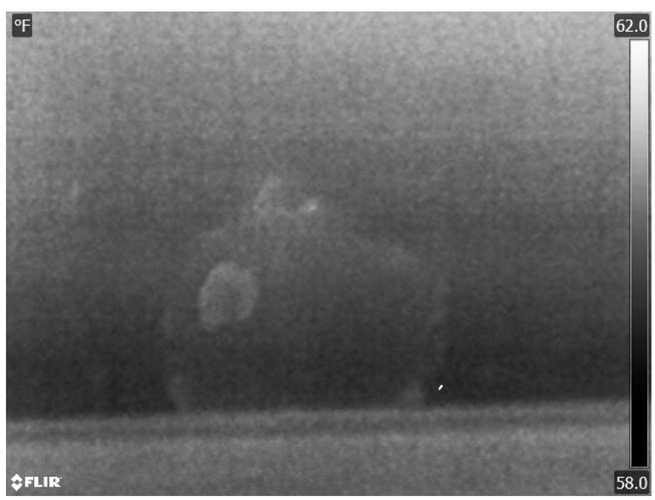
07001_E96_02_15_IR_FLIR0274

Second Data Set – Post Processed 1



07001_E96_02_15_IRp1_FLIR0274

Second Data Set – Post Processed 2

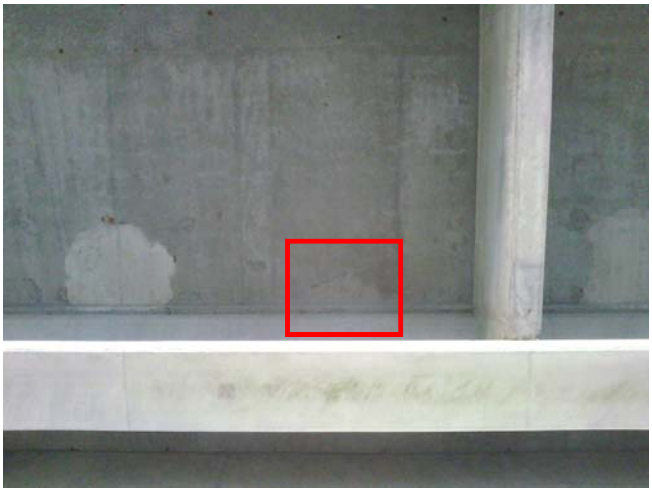


07001_E96_02_15_IRp2_FLIR0274

07001, Flir E96, All Thermal Data

Deficiency 16

Visual of Delamination

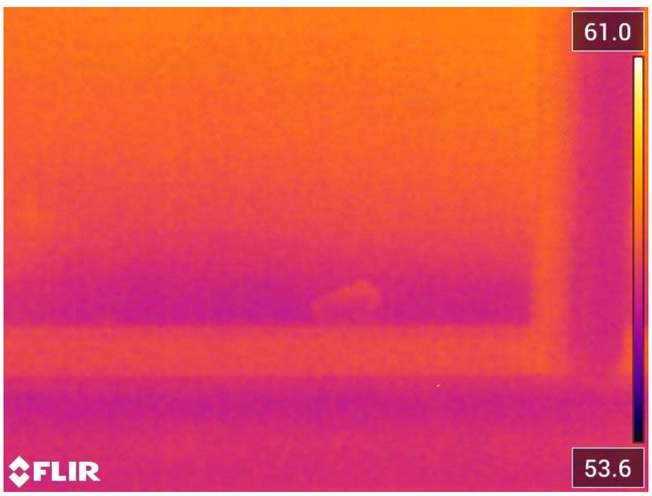


07001_E96_01_16_RGB_FLIR0219

Visual Close-up

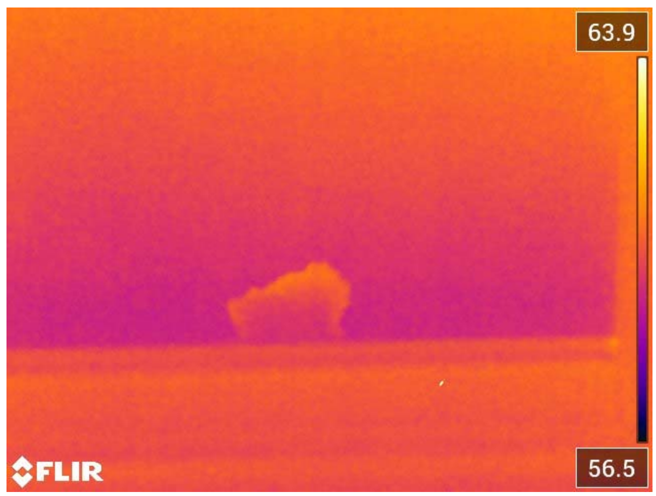
07001_Def_16_DSCF0649

First Data Set



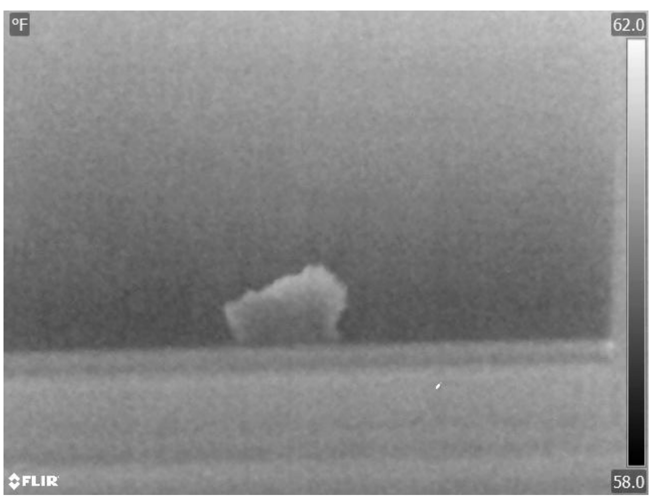
07001_E96_01_16_IR_FLIR0218

Second Data Set



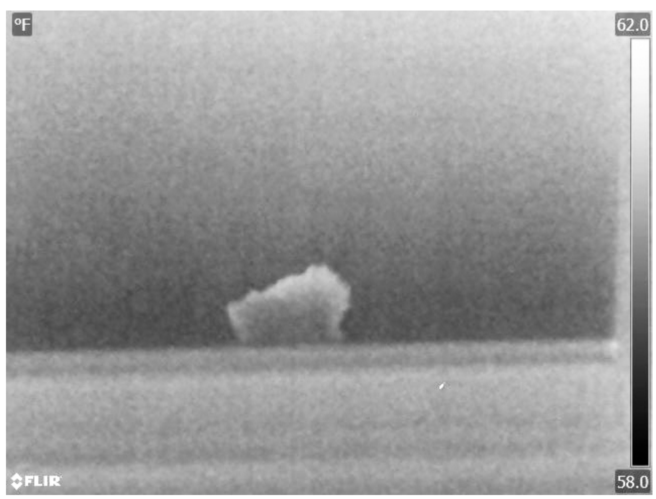
07001_E96_02_16_IR_FLIR0272

Second Data Set – Post Processed 1



07001_E96_02_16_IRp1_FLIR0272

Second Data Set – Post Processed 2



07001_E96_02_16_IRp2_FLIR0272

07001, Flir E96, All Thermal Data

Deficiency 17

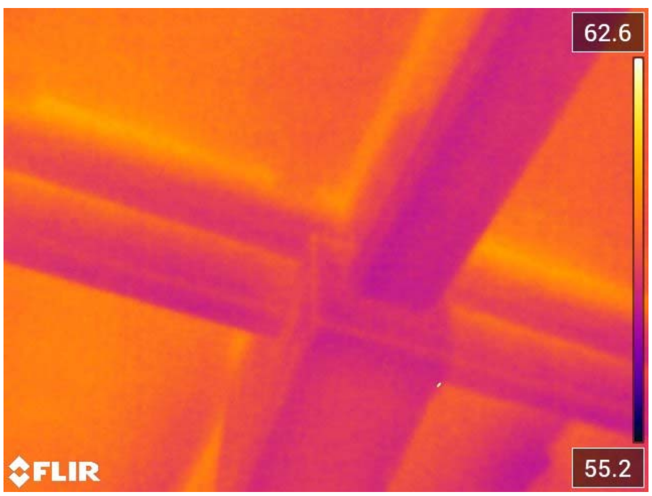
Visual of Delamination

07001_E96_01_17_RGB_FLIR0247

Visual Close-up

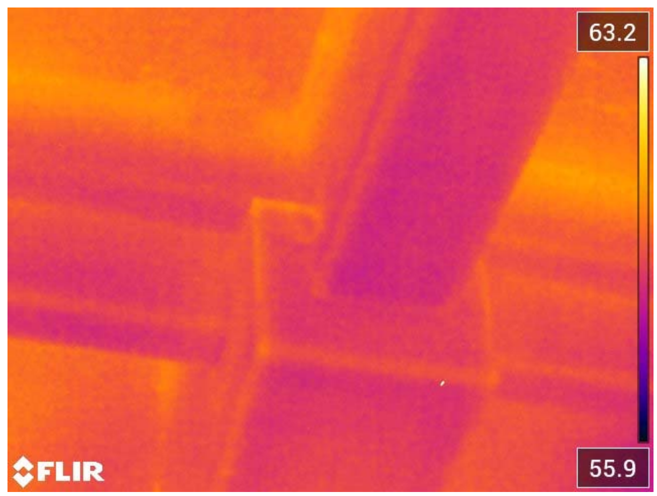
07001_Def_17_DSCF0636

First Data Set



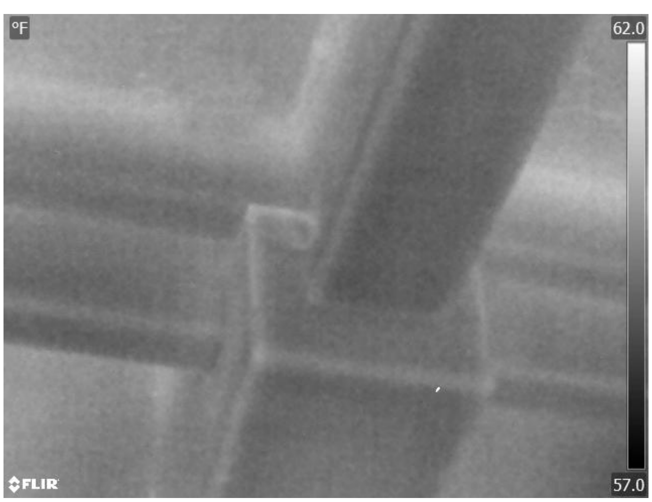
07001_E96_01_17_IR_FLIR0246

Second Data Set



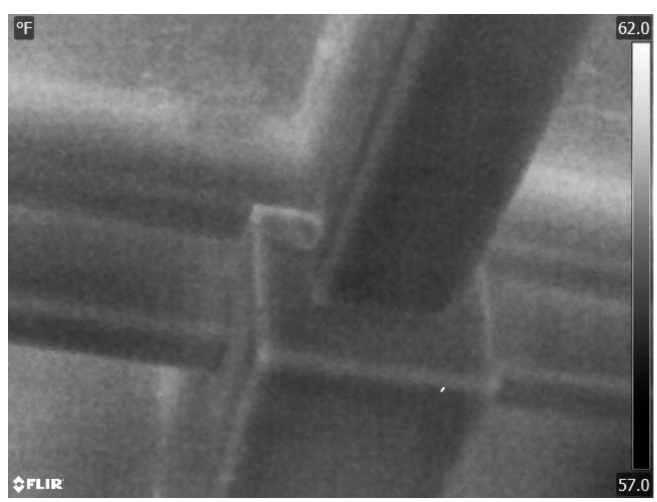
07001_E96_02_17_IR_FLIR0296

Second Data Set – Post Processed 1



07001_E96_02_17_IRp1_FLIR0296

Second Data Set – Post Processed 2



07001_E96_02_17_IRp2_FLIR0296

07001, Flir E96, All Thermal Data

Deficiency 18

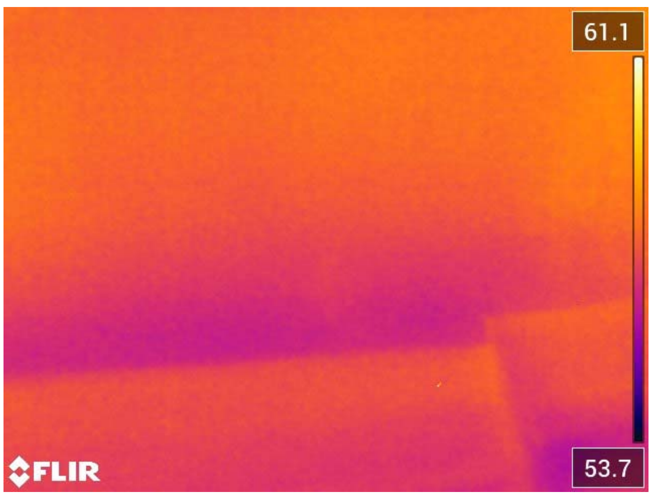
Visual of Delamination

07001_E96_01_18_RGB_FLIR0225

Visual Close-up

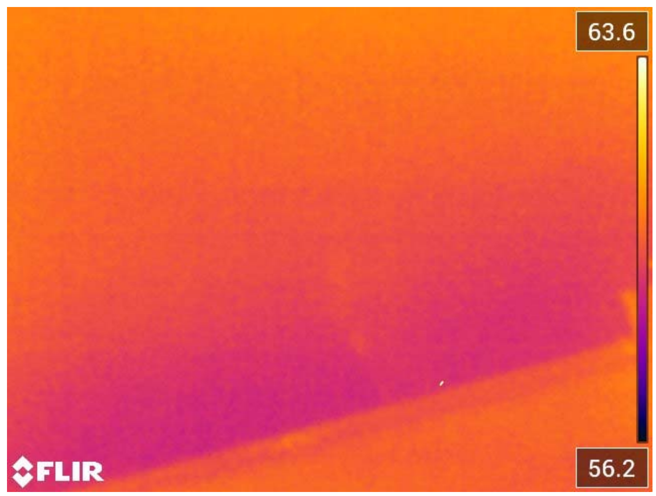
07001_Def_18_DSCF0632

First Data Set



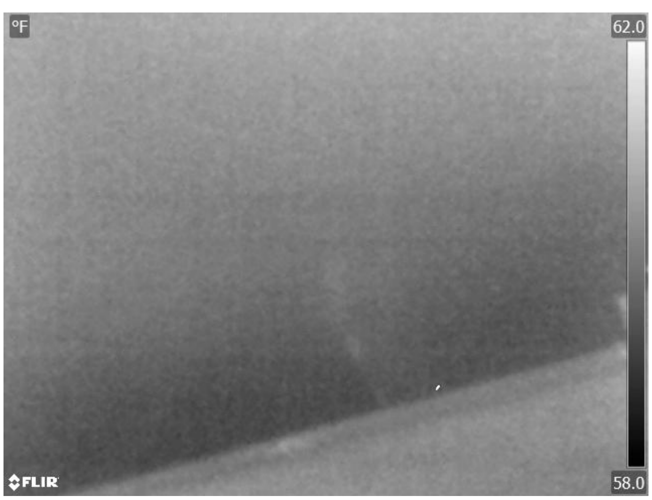
07001_E96_01_18_IR_FLIR0224

Second Data Set



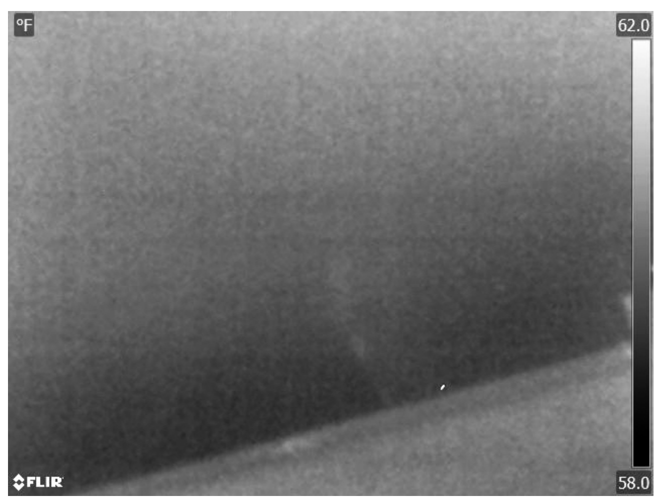
07001_E96_02_18_IR_FLIR0278

Second Data Set – Post Processed 1



07001_E96_02_18_IRp1_FLIR0278

Second Data Set – Post Processed 2



07001_E96_02_18_IRp2_FLIR0278

07001, Flir E96, All Thermal Data

Deficiency 19

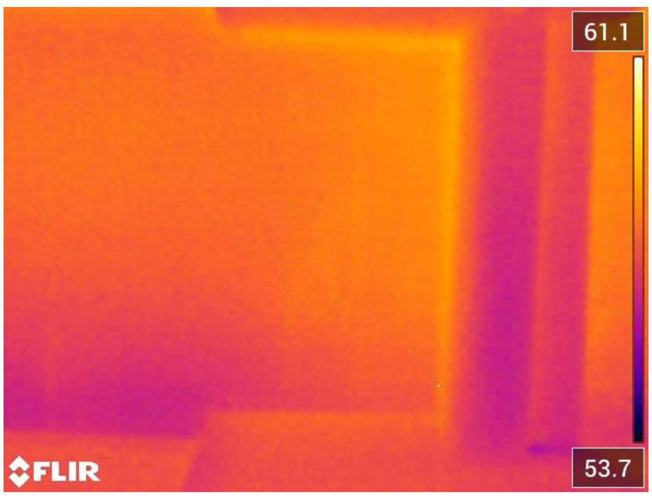
Visual of Delamination

07001_E96_01_19_RGB_FLIR0223

Visual Close-up

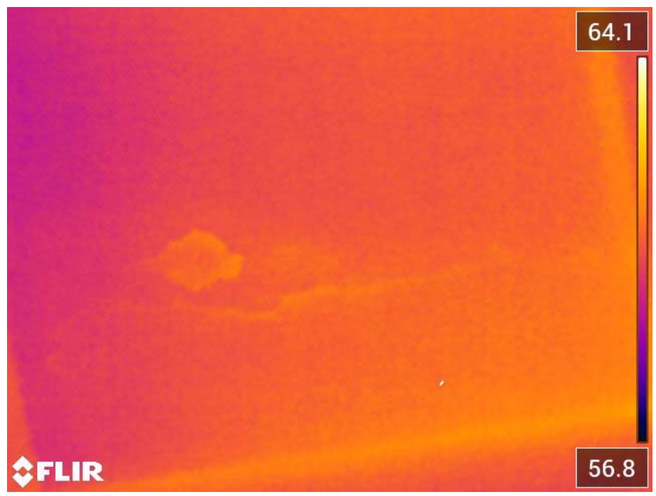
07001_Def_19_DSCF0633

First Data Set



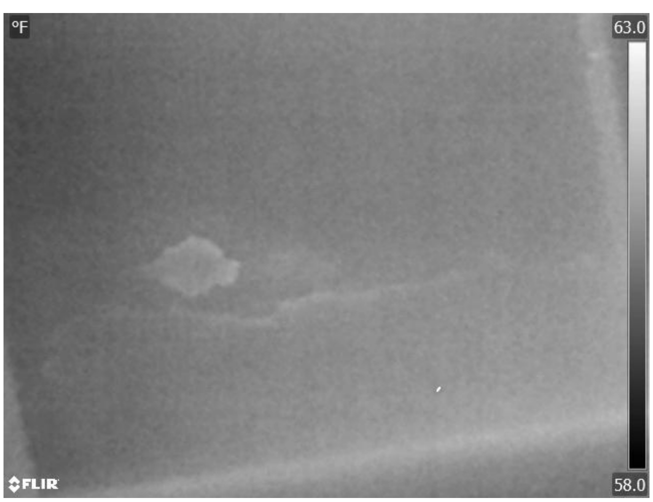
07001_E96_01_19_IR_FLIR0222

Second Data Set



07001_E96_02_19_IR_FLIR0276

Second Data Set – Post Processed 1



07001_E96_02_19_IRp1_FLIR0276

Second Data Set – Post Processed 2

07001_E96_02_19_IRp2_FLIR0276

07001, Flir E96, All Thermal Data

Deficiency 20

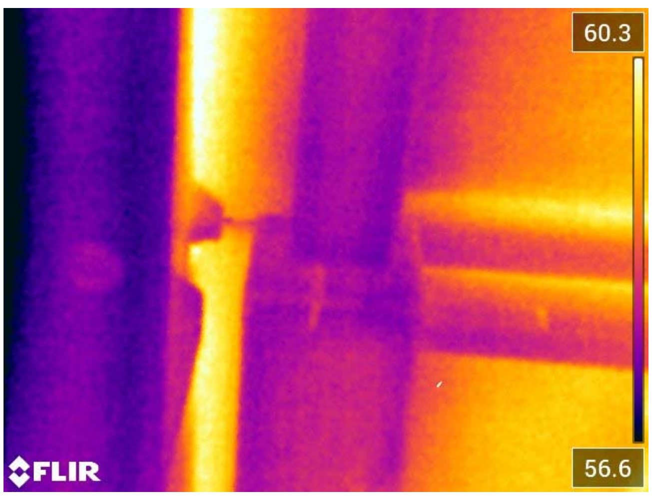
Visual of Delamination

07001_E96_01_20_RGB_FLIR0233

Visual Close-up

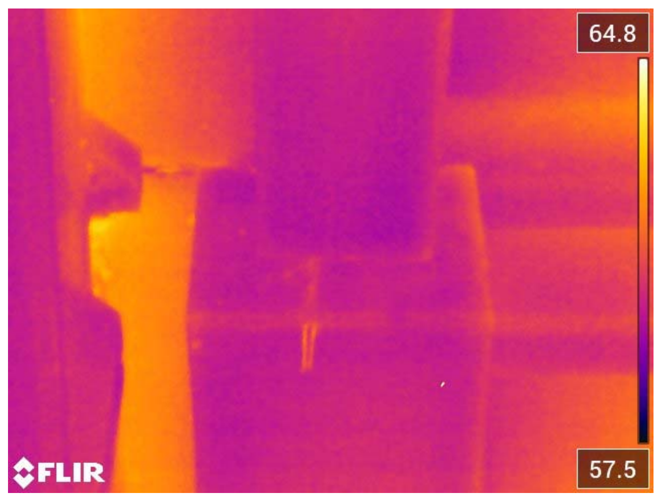
07001_Def_20_DSCF0618

First Data Set



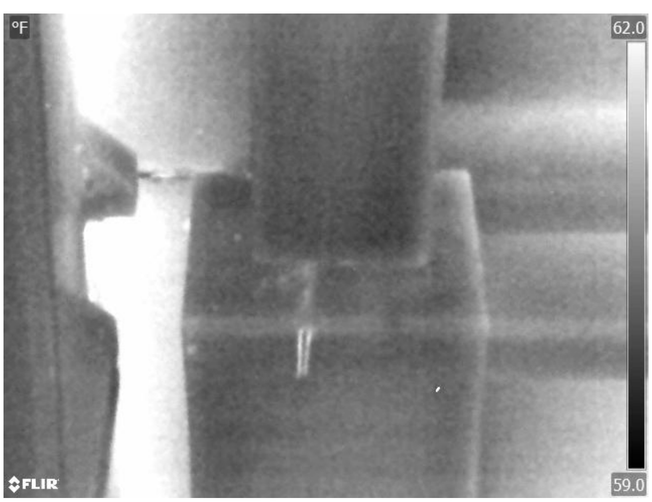
07001_E96_01_20_IR_FLIR0232

Second Data Set



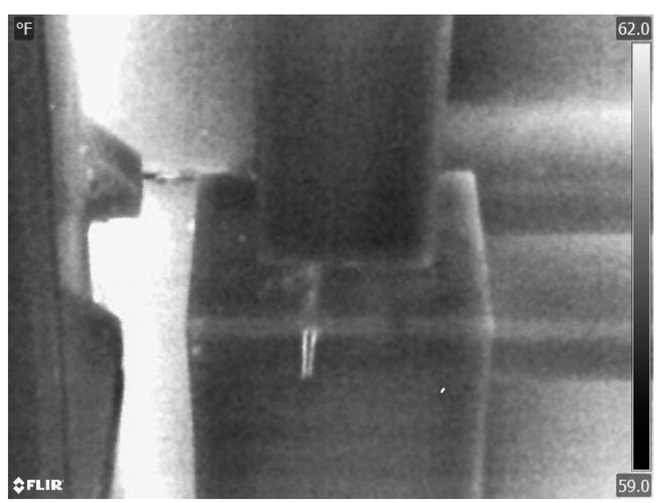
07001_E96_02_20_IR_FLIR0288

Second Data Set – Post Processed 1



07001_E96_02_20_IRp1_FLIR0288

Second Data Set – Post Processed 2

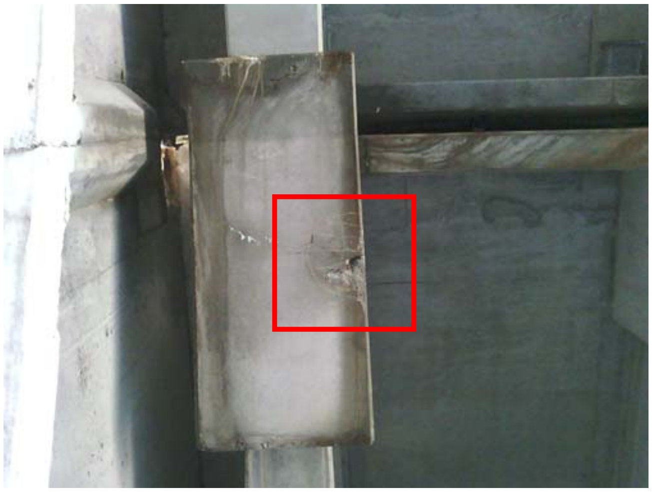


07001_E96_02_20_IRp2_FLIR0288

07001, Flir E96, All Thermal Data

Deficiency 21

Visual of Delamination

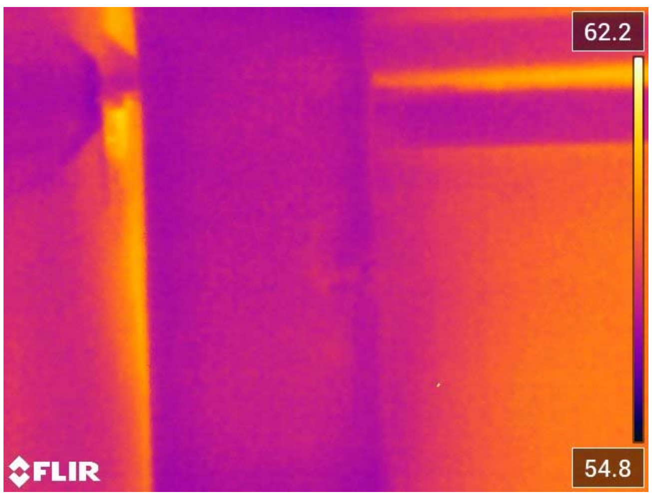


07001_E96_01_21_RGB_FLIR0237

Visual Close-up

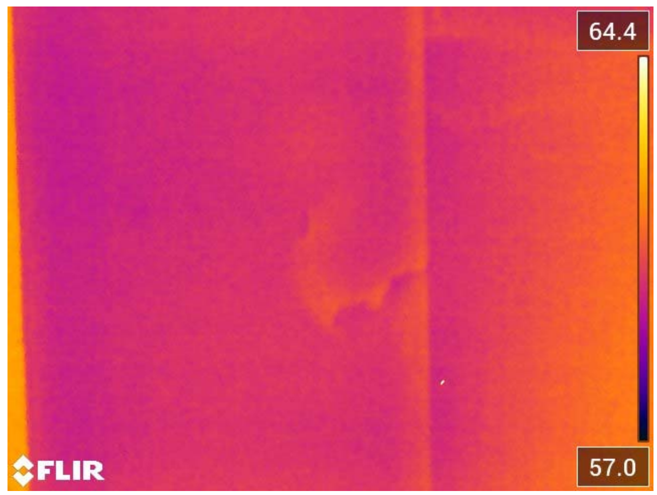
07001_Def_21_DSCF0615

First Data Set



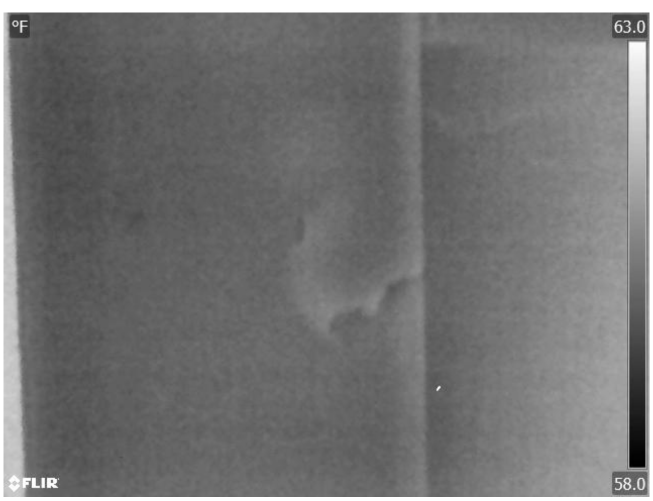
07001_E96_01_21_IR_FLIR0236

Second Data Set



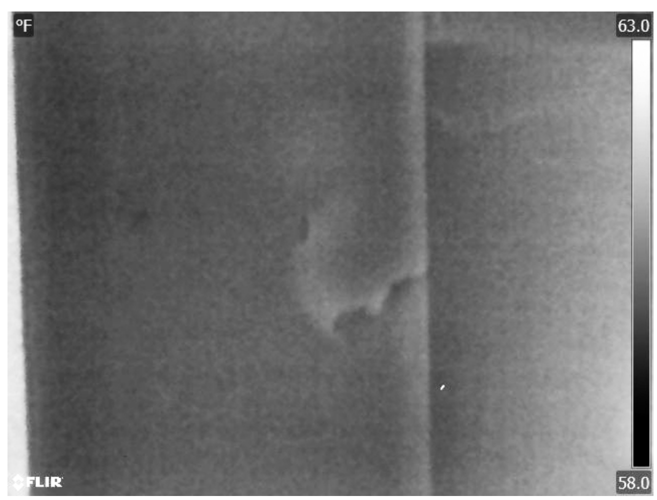
07001_E96_02_21_IR_FLIR0286

Second Data Set – Post Processed 1



07001_E96_02_21_IRp1_FLIR0286

Second Data Set – Post Processed 2



07001_E96_02_21_IRp2_FLIR0286

07001, Flir E96, All Thermal Data

Deficiency 22

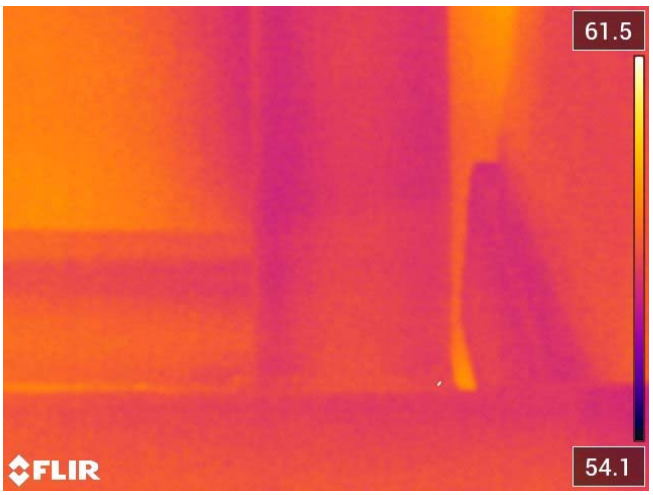
Visual of Delamination

07001_E96_01_22_RGB_FLIR0251

Visual Close-up

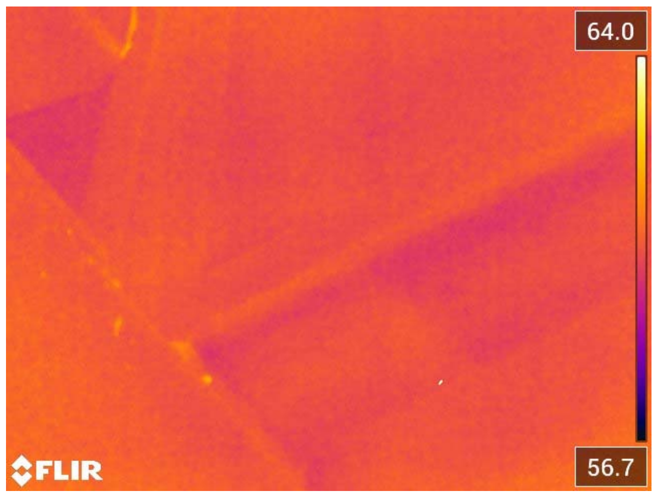
07001_Def_22_DSCF0630

First Data Set



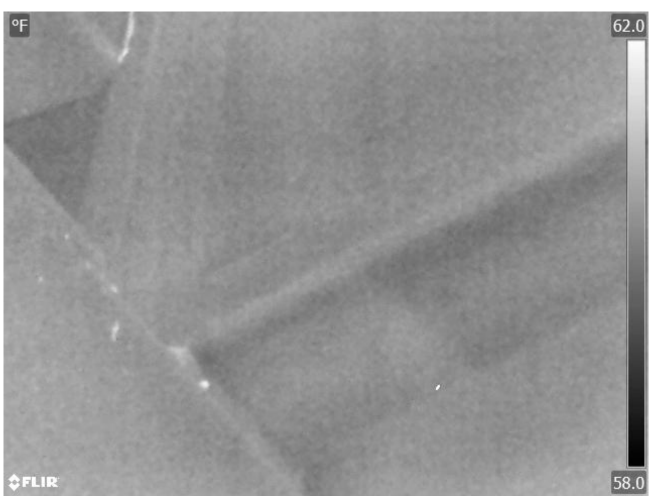
07001_E96_01_22_IR_FLIR0250

Second Data Set



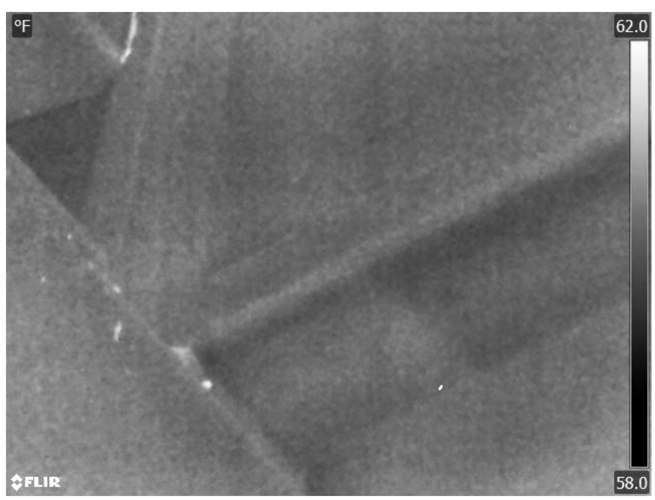
07001_E96_02_22_IR_FLIR0300

Second Data Set – Post Processed 1



07001_E96_02_22_IRp1_FLIR0300

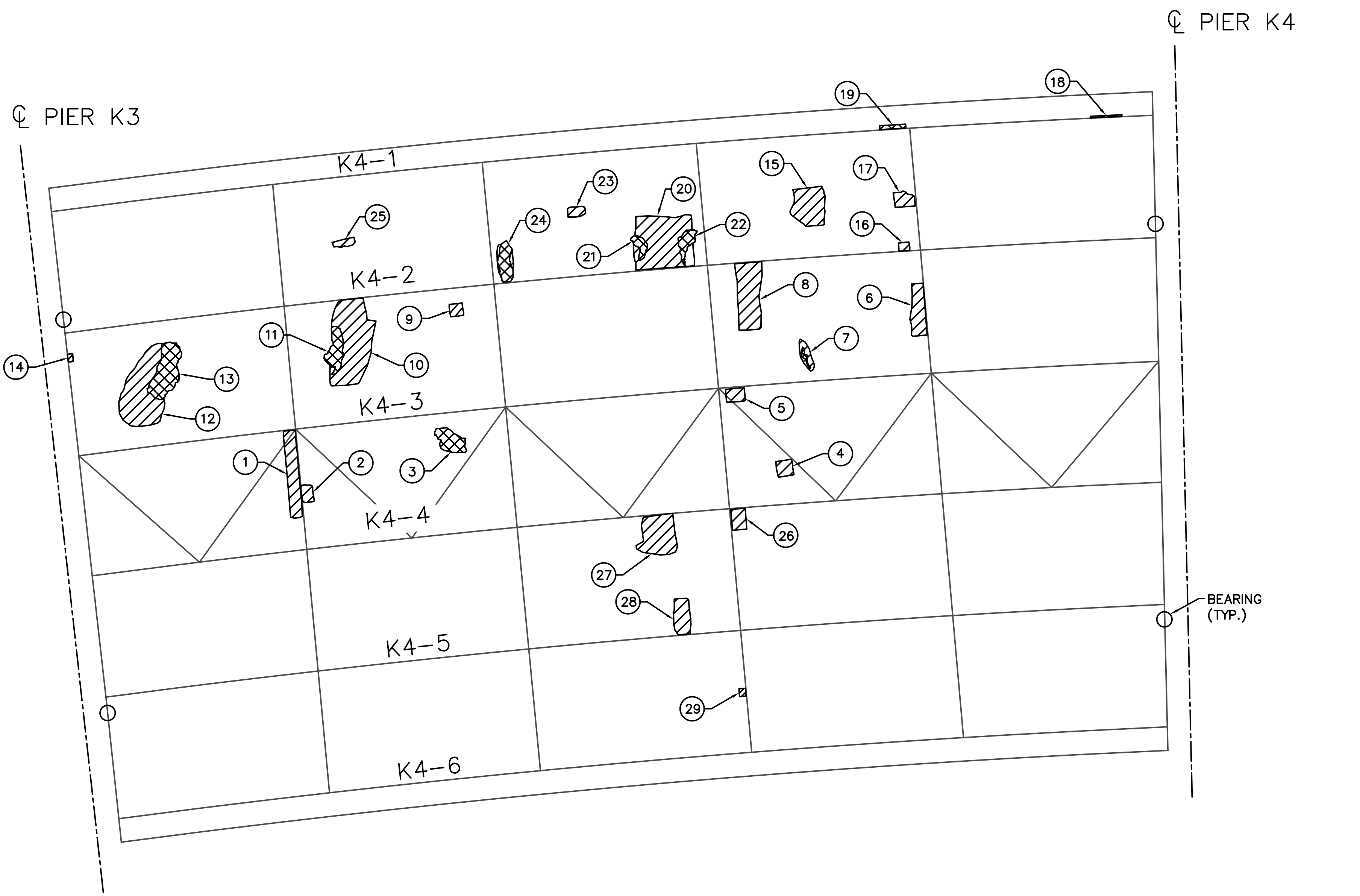
Second Data Set – Post Processed 2



07001_E96_02_22_IRp2_FLIR0300

Appendix D

Bridge S-24-083 (BIN 114)



SPAN K4

TRADITIONAL INSPECTION FINDINGS
PROJECTED VIEW

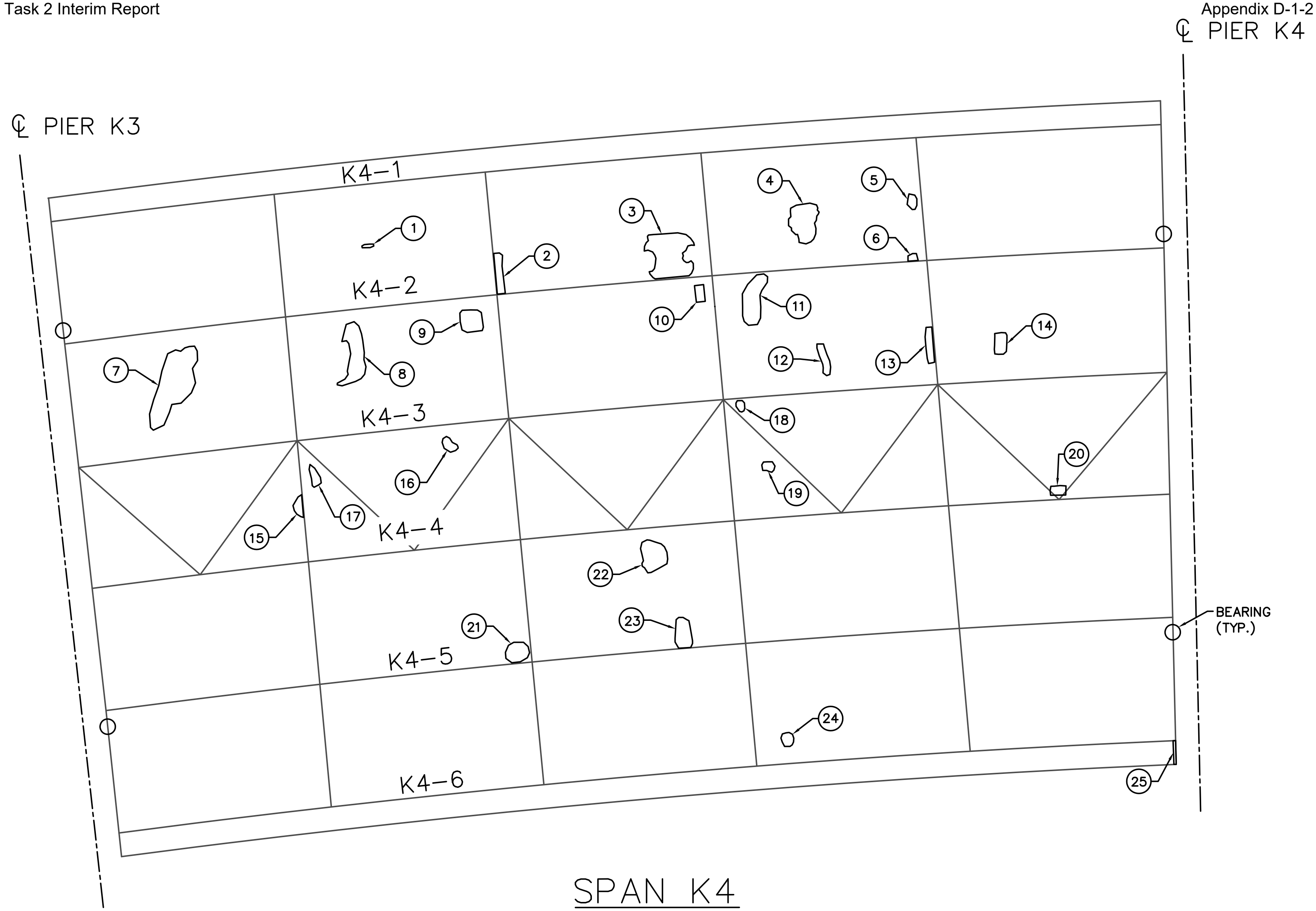
NOTE:
1. Detailed deficiency descriptions and measurements are included on the following sketch.

SPAN K4

TRADITIONAL INSPECTION FINDINGS

DEFICIENCIES

1. 66” wide x 9” long hollow sounding area (HSA)
2. 9” wide x 13” long HSA
3. 26” wide x 30” long spall
4. 12” wide x 12” long HSA
5. 14” wide x 10” long HSA
6. 45” wide x 9” long HSA
7. 24” wide x 4” long HSA with adjacent $2\frac{1}{2}$” wide x 16” long spall
8. 50” wide x 21” long (18” long average) minor HSA
9. $9\frac{1}{2}$” wide x 10” long minor HSA
10. 61” wide x up to 23” long spall
11. 33” wide x 14” long HSA
12. 60” wide x up to 34” long HSA
13. 41” wide x 22” long spall
14. 6” wide x 4” high HSA in haunch
15. 30” wide x up to 27” long HSA
16. 6” wide x 10” long minor HSA
17. 13” wide x 14” long HSA
18. $1\frac{1}{2}$” wide x 14” long spall
19. Up to 3” wide x 20” long spall
20. 38” wide x 46” long HSA
21. 21” wide x 12” long spall
22. 18” wide x 9” long spall
23. 7” wide x 14” long HSA
24. 30” wide x 10” long spall with two adjacent HSA measuring 14” wide x 3” long and 20” wide x up to 5” long
25. 6” wide x 17” long HSA
26. 16” wide x 11” long HSA
27. 28” wide x up to 31” long HSA
28. 25” wide x 13” long HSA
29. 5” wide x 6” long HSA



SPAN K4

MATRICE 210 WITH XT2 SENSOR

PROJECTED VIEW

NOTES

1. AREAS INDICATED ON THIS SKETCH ARE TEMPERATURE DIFFERENTIALS BELIEVED TO BE DELAMINATIONS ALONG THE UNDERSIDE OF BRIDGE DECK. LOCATIONS, SIZES, AND SHAPES ARE APPROXIMATED BASED ON THE THERMAL IMAGERY.
2. TEMPERATURE DIFFERENTIALS WERE CROSS CHECKED WITH VISUAL IMAGERY TO REMOVE FALSE–POSITIVES DURING DATA COLLECTION.

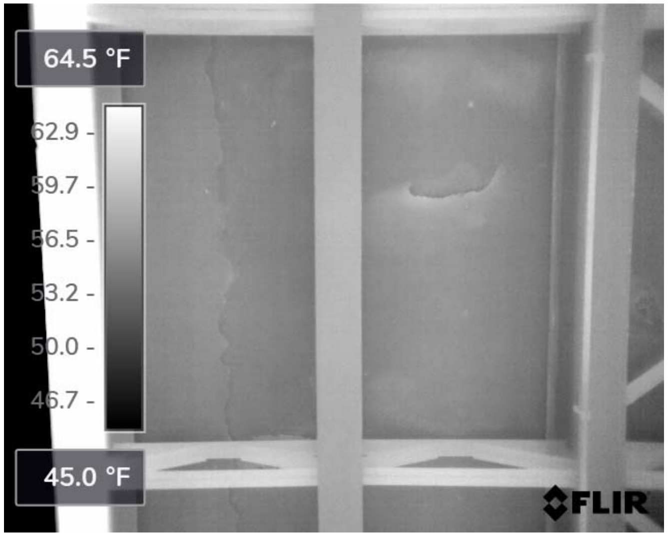
114, Span K4, Thermal Data

Thermal Deficiency 1

Thermal

114_Sp4_Def01_IR_DJI_0682_R

Thermal – Post Processed



114_Sp4_Def01_IR_pDJI_0682_R

Visual Image

114_Sp4_Def01_RGB_DJI_0683

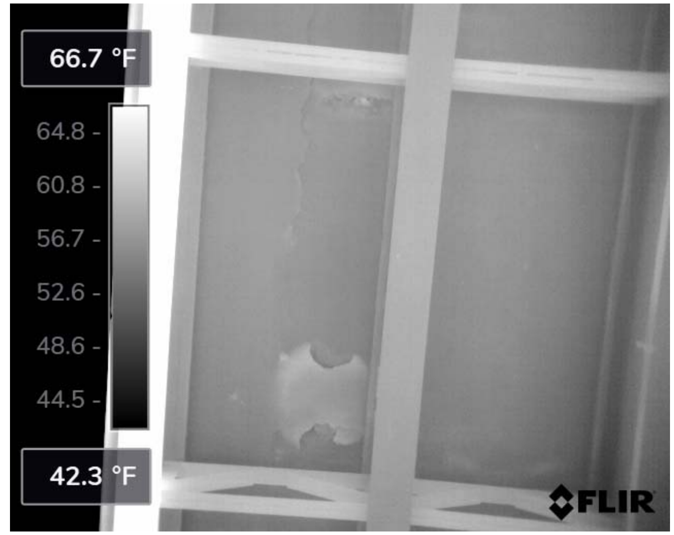
114, Span K4, Thermal Data

Thermal Deficiencies 2,3

Thermal

114_Sp4_Def02,03_IR_DJI_0684_R

Thermal – Post Processed



114_Sp4_Def02,03_IRp_DJI_0684_R

Visual Image

114_Sp4_Def02,03_RGB_DJI_0685

114, Span K4, Thermal Data

Thermal Deficiencies 4, 5, 6

Thermal

114_Sp4_Def04,05,06_IR_DJI_0696_R

Thermal – Post Processed

114_Sp4_Def04,05,06_IRp_DJI_0696_R

Visual Image

114_Sp4_Def04,05,06_RGB_DJI_0697

114, Span K4, Thermal Data

Thermal Deficiency 7

Thermal

114_Sp4_Def07_IRDJI_0674_R

Thermal – Post Processed

114_Sp4_Def07_IRp_DJI_0674_R

Visual Image

114_Sp4_Def07_RGB_DJI_0675

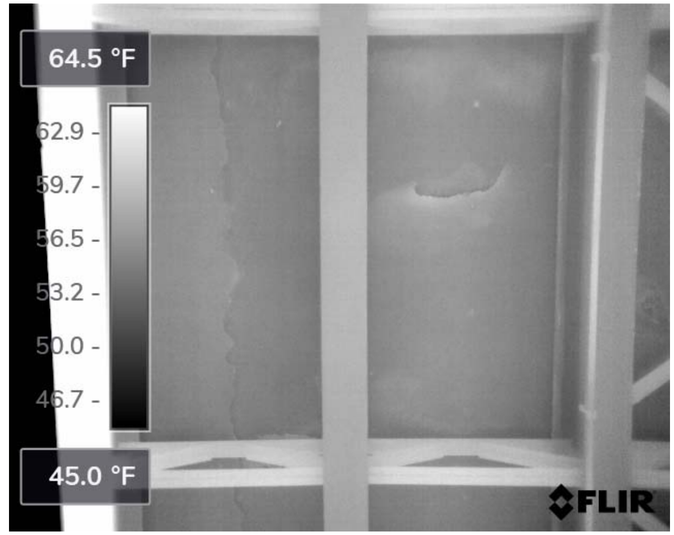
114, Span K4, Thermal Data

Thermal Deficiencies 8, 9

Thermal

114_Sp4_Def08,09_IR_DJI_0682_R

Thermal – Post Processed



114_Sp4_Def08,09_IRp_DJI_0682_R

Visual Image

114_Sp4_Def08,09_RGB_DJI_0683

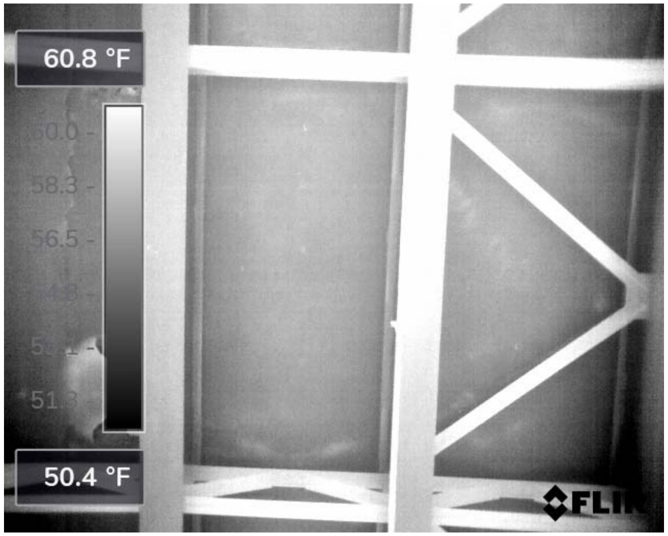
114, Span K4, Thermal Data

Thermal Deficiency 10

Thermal

114_Sp4_Def10_IR_DJI_0686_R

Thermal – Post Processed



114_Sp4_Def10_IRpDJI_0686_R

Visual Image

114_Sp4_Def10_RGB_DJI_0687

114, Span K4, Thermal Data

Thermal Deficiencies 11, 12, 13

Thermal

114_Sp4_Def11,12,13_IR_DJI_0696_R

Thermal – Post Processed

114_Sp4_Def11,12,13_IRp_DJI_0696_R

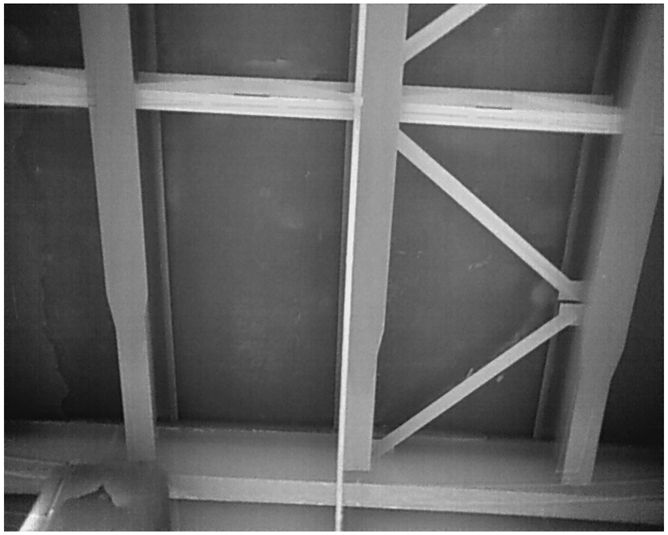
Visual Image

114_Sp4_Def11,12,13_RGB_DJI_0697

114, Span K4, Thermal Data

Thermal Deficiency 14

Thermal



114_Sp4_Def14_IR_DJI_0700_R

Thermal – Post Processed

114_Sp4_Def14_IRp_DJI_0700_R

Visual Image

114_Sp4_Def14_RGB_DJI_0701

114, Span K4, Thermal Data

Thermal Deficiency 15

Thermal

114_Sp4_Def15_IR_DJI_0676_R

Thermal – Post Processed

114_Sp4_Def15_IRp_DJI_0676_R

Visual Image

114_Sp4_Def15_RGB_DJI_0677

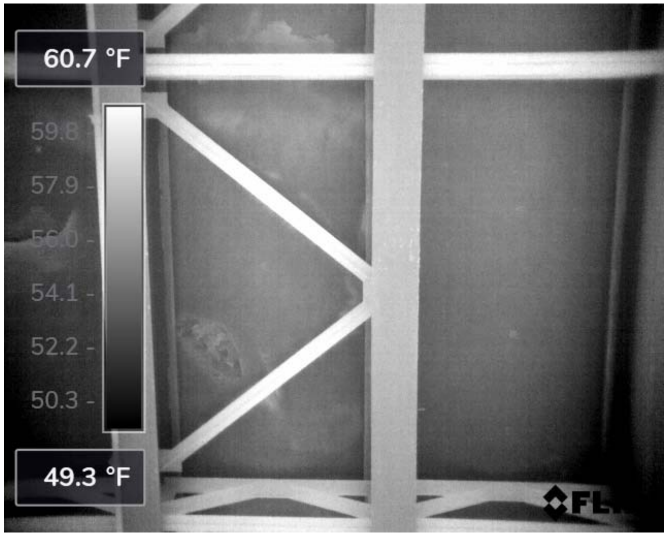
114, Span K4, Thermal Data

Thermal Deficiencies 16, 17

Thermal

114_Sp4_Def16,17_IR_DJI_0680_R

Thermal – Post Processed



114_Sp4_Def16,17_IRp_DJI_0680_R

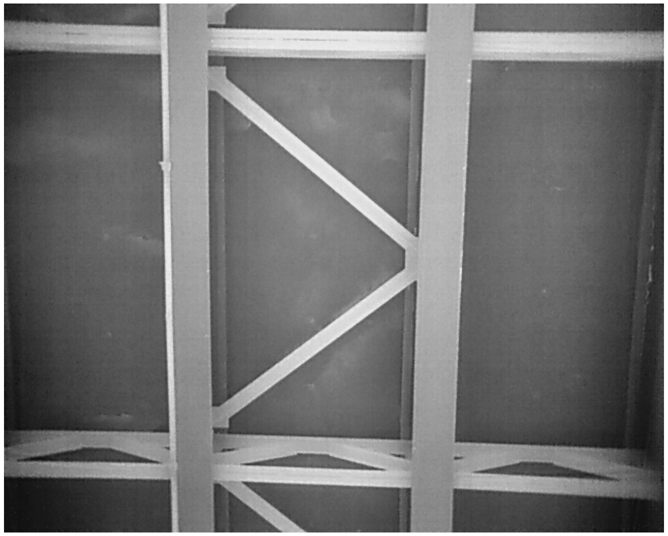
Visual Image

114_Sp4_Def16,17_RGB_DJI_0681

114, Span K4, Thermal Data

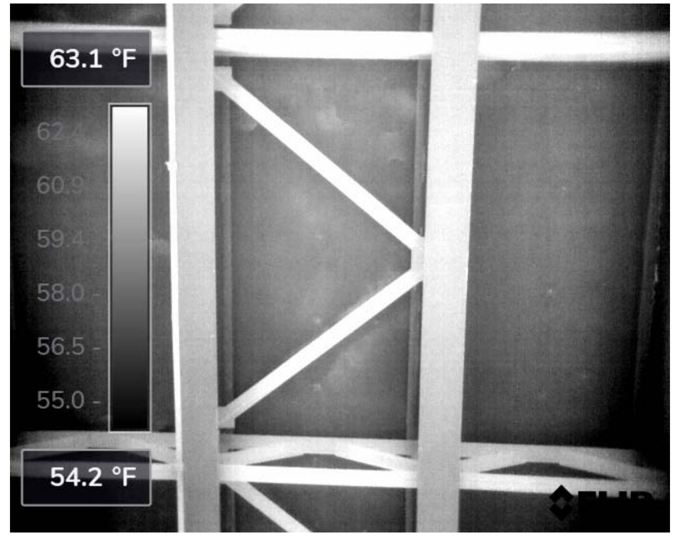
Thermal Deficiencies 18, 19

Thermal



114_Sp4_Def18,19_IR_DJI_0694_R

Thermal – Post Processed



114_Sp4_Def18,19_IRp_DJI_0694_R

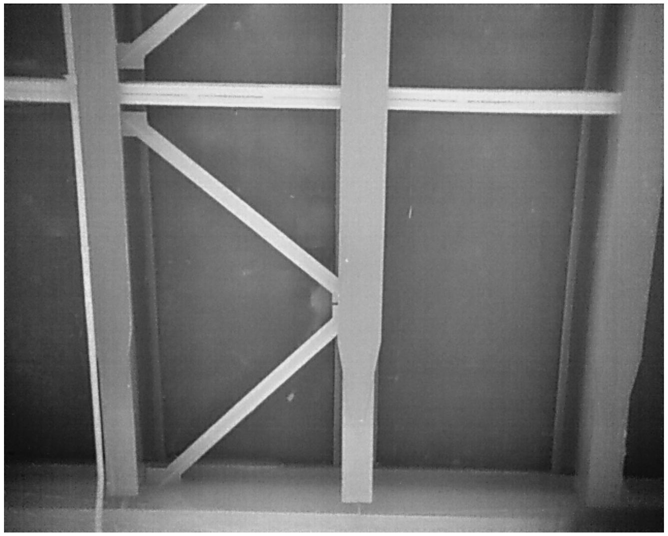
Visual Image

114_Sp4_Def18,19_RGB_DJI_0695

114, Span K4, Thermal Data

Thermal Deficiency 20

Thermal



114_Sp4_Def20_IR_DJI_0702_R

Thermal – Post Processed

114_Sp4_Def20_IRp_DJI_0702_R

Visual Image

114_Sp4_Def20_RGB_DJI_0703

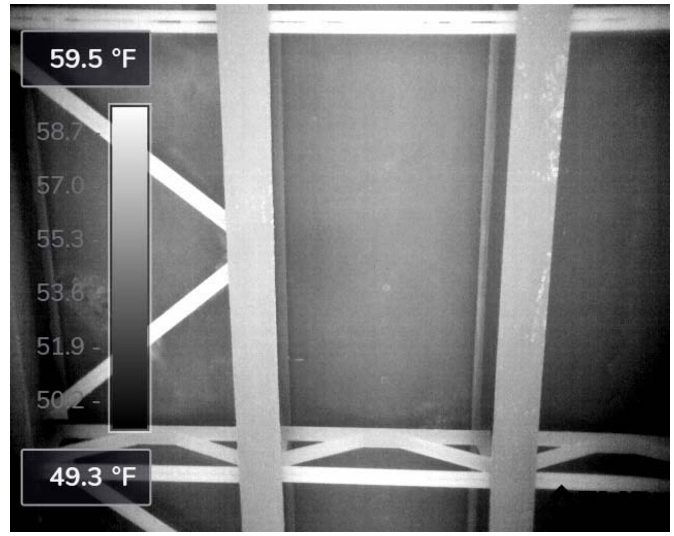
114, Span K4, Thermal Data

Thermal Deficiency 21

Thermal

114_Sp4_Def21_IR_DJI_0678_R

Thermal – Post Processed



114_Sp4_Def21_IRp_DJI_0678_R

Visual Image

114_Sp4_Def21_RGB_DJI_0679

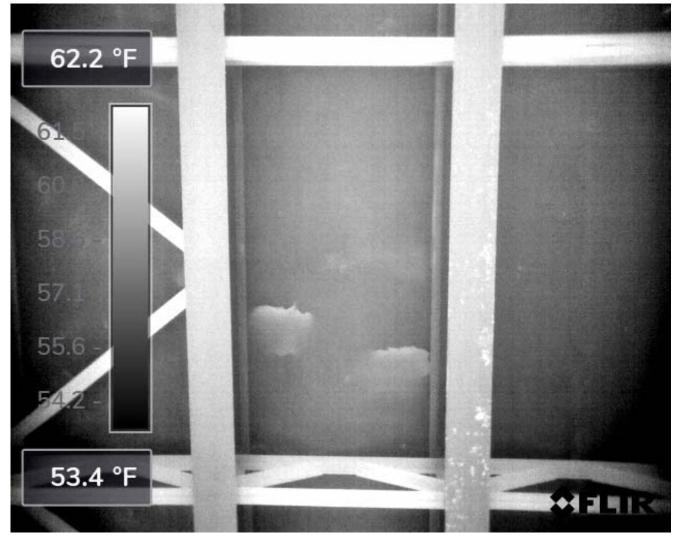
114, Span K4, Thermal Data

Thermal Deficiencies 22, 23

Thermal

114_Sp4_Def22,23_IR_DJI_0688_R

Thermal – Post Processed



114_Sp4_Def22,23_IRp_DJI_0688_R

Visual Image

114_Sp4_Def22,23_RGB_DJI_0689

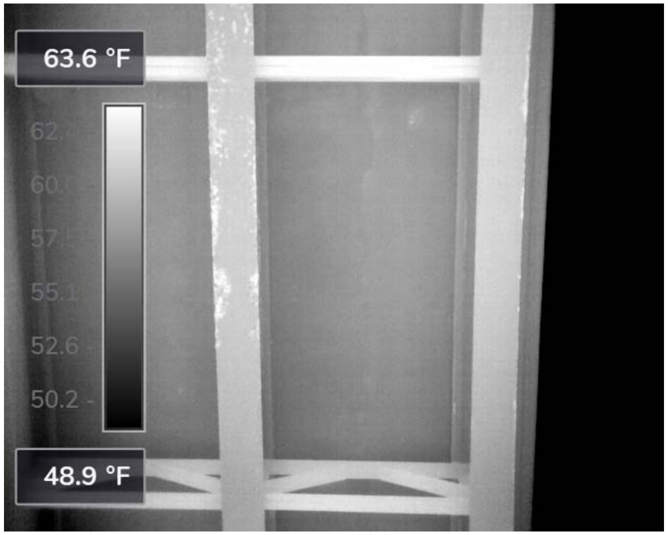
114, Span K4, Thermal Data

Thermal Deficiency 24

Thermal

114_Sp4_Def24_IR_DJI_0692_R

Thermal – Post Processed



114_Sp4_Def24_IRp_DJI_0692_R

Visual Image

114_Sp4_Def24_RGB_DJI_0693

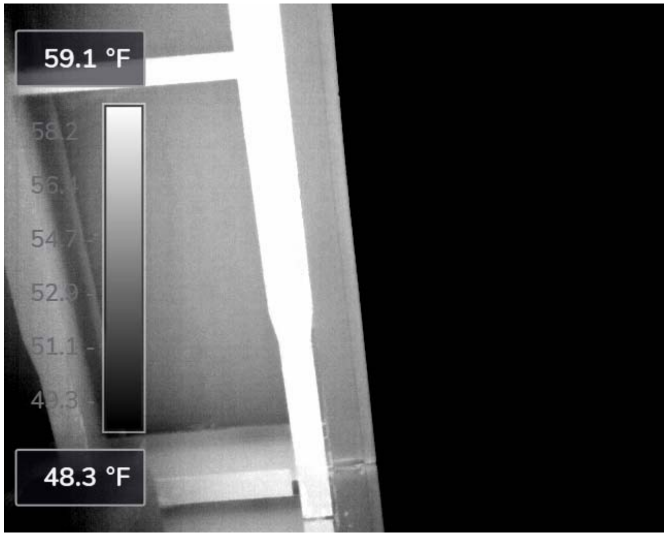
114, Span K4, Thermal Data

Thermal Deficiency 25

Thermal

114_Sp4_Def25_IR_DJI_0704_R

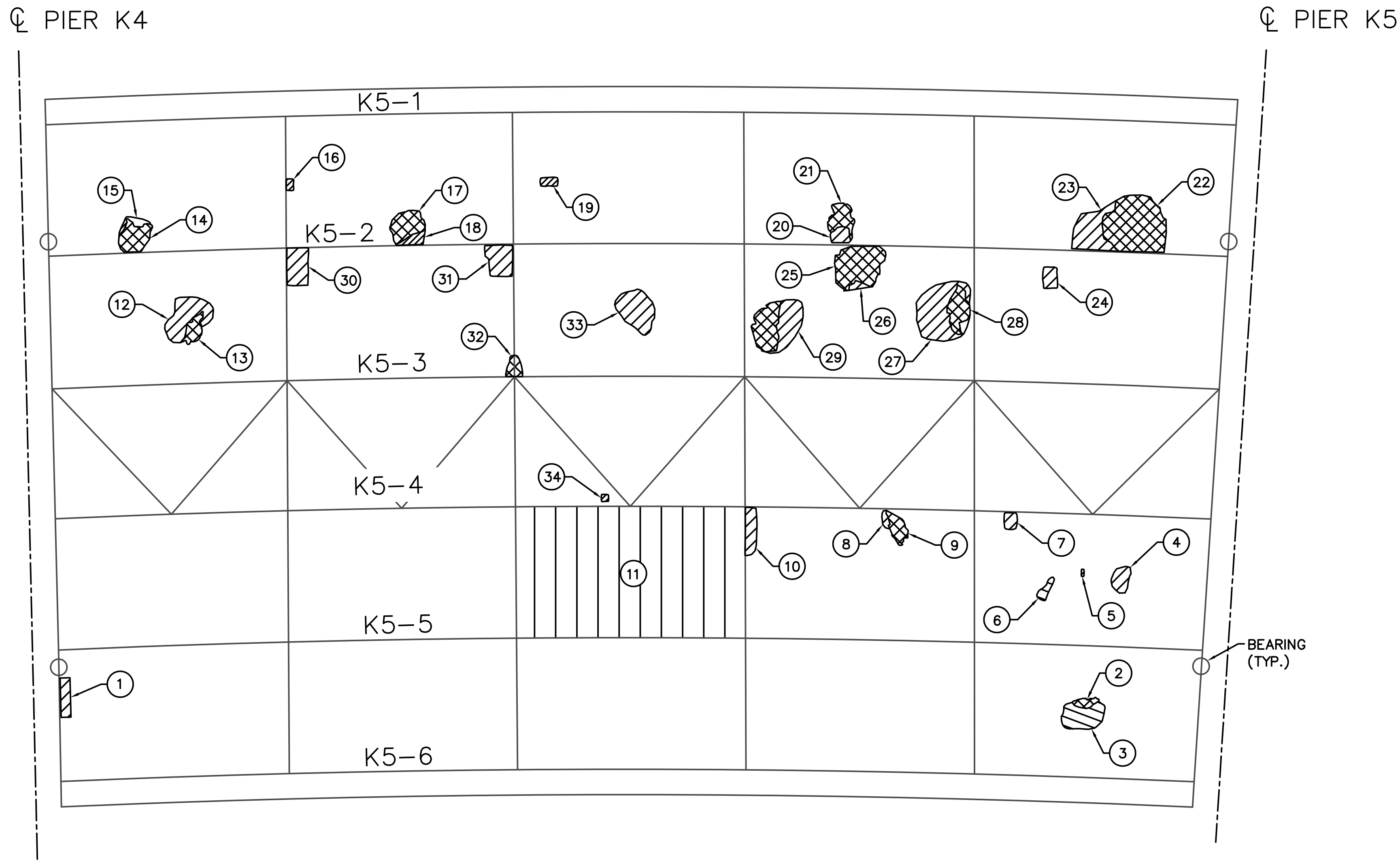
Thermal – Post Processed



114_Sp4_Def25_IRp_DJI_0704_R

Visual Image

114_Sp4_Def25_RGB_DJI_0705



SPAN K5

TRADITIONAL INSPECTION FINDINGS
PROJECTED VIEW

LEGEND

Hollow Area

Spall

Patch

NOTE:

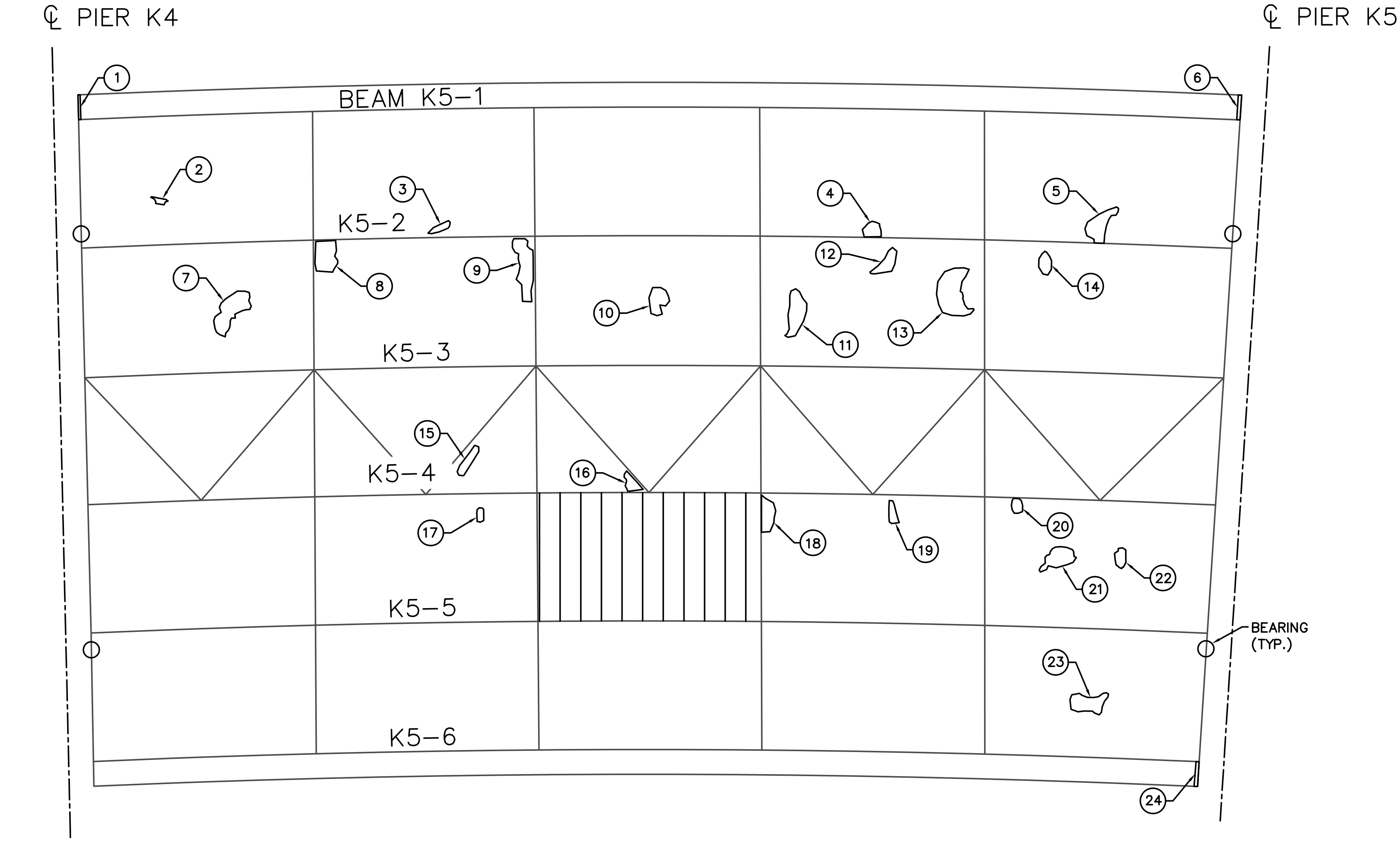
1. Detailed deficiency descriptions and measurements are included on the following sketch.

SPAN K5

TRADITIONAL INSPECTION FINDINGS
PROJECTED VIEW

DEFICIENCIES

1. 28” wide x up to 7” long hollow sounding area (HSA)
2. 7” wide x 26” long spall
3. 20” wide x 30” long HSA
4. 20” wide x 12” long HSA
5. 5” wide x 2” long HSA
6. 8” wide x 18” long HSA
7. 12” wide x 9” long HSA
8. 26” wide x 12” long spall
9. 14” wide x 4” long HSA
10. 34” wide x 8” long HSA extending into shielded area
11. Shielded area (area not inspected)
12. 32” wide x up to 28” long HSA
13. 20” wide x 11” long spall
14. 22” wide x 22” long spall
15. 6” wide x 15” long HSA
16. 8” wide x 5” long HSA
17. Up to 22” wide x 24” long spall
18. Up to 9” wide x 19” long HSA
19. 6” wide x 12” long HSA (overpour)
20. 12” wide x 14” long HSA
21. 26” wide x 18” long spall
22. 38” wide x 42” long spall
23. 25” wide x up to 30” long HSA
24. 15” wide x 10” long HSA
25. 32” wide x 32” long spall
26. 6” wide x 8” long HSA
27. 40” wide x 23” long HSA
28. 34” wide x 14” long spall
29. 38” wide x 18” long spall with adjacent 17” long x 36” wide HSA
30. 26” wide x 15” long HSA
31. 22” wide x up to 20” long HSA
32. 15” wide x 12” long spall
33. 27” wide x up to 26” long HSA
34. 5” wide x 5” long HSA



SPAN K5

MATRICE 210 WITH XT2 SENSOR
PROJECTED VIEW

NOTES
1. AREAS INDICATED ON THIS SKETCH ARE TEMPERATURE DIFFERENTIALS BELIEVED TO BE DELAMINATIONS ALONG THE UNDERSIDE OF BRIDGE DECK. LOCATIONS, SIZES, AND SHAPES ARE APPROXIMATED BASED ON THE THERMAL IMAGERY.
2. TEMPERATURE DIFFERENTIALS WERE CROSS CHECKED WITH VISUAL IMAGERY TO REMOVE FALSE–POSITIVES DURING DATA COLLECTION.

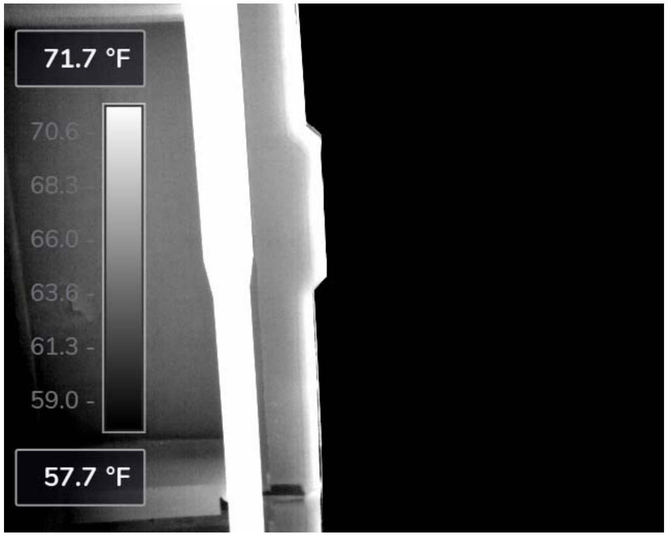
114, Span K5, Thermal Data

Thermal Deficiency 1

Thermal

114_Sp5_Def01_IR_DJI_0185_R

Thermal – Post Processed



114_Sp5_Def01_IRp_DJI_0185_R

Visual Image

114_Sp5_Def01_RGB_DJI_0186

114, Span K5, Thermal Data

Thermal Deficiency 2

Thermal

114_Sp5_Def02_IR_DJI_0187_R

Thermal – Post Processed

114_Sp5_Def02_IRp_DJI_0187_R

Visual Image

114_Sp5_Def02_RGB_DJI_0188

114, Span K5, Thermal Data

Thermal Deficiency 3

Thermal

114_Sp5_Def03_IR_DJI_0183_R

Thermal – Post Processed

114_Sp5_Def03_IRp_DJI_0183_R

Visual Image

114_Sp5_Def03_RGB_DJI_0184

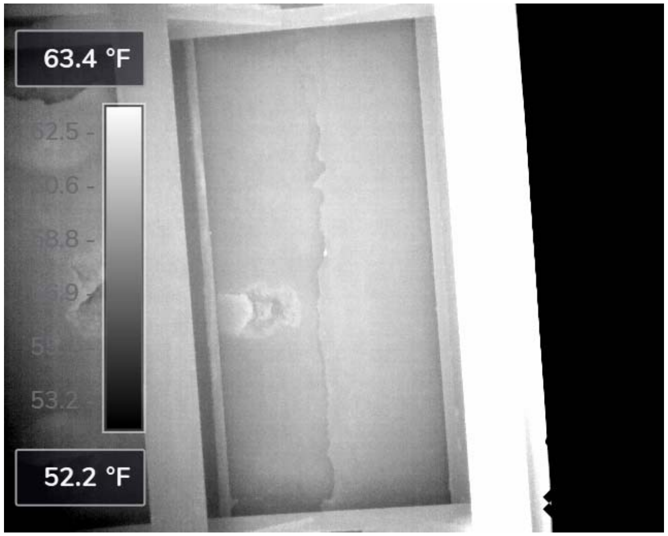
114, Span K5, Thermal Data

Thermal Deficiency 4

Thermal

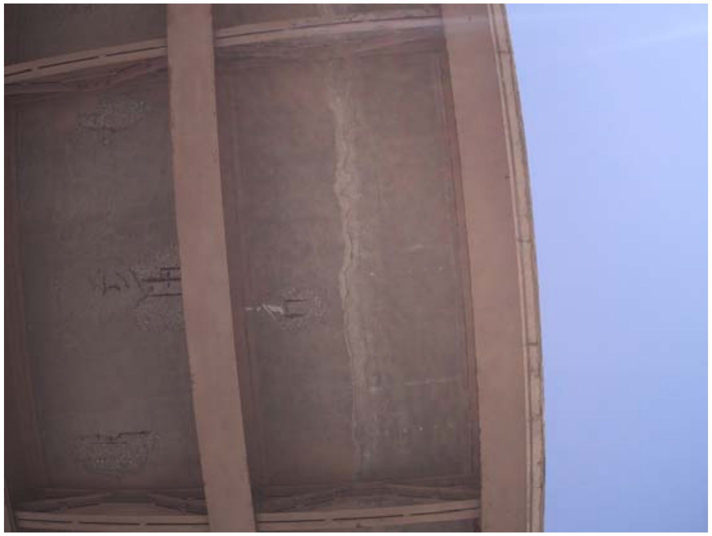
114_Sp5_Def04_IR_DJI_0171_R

Thermal – Post Processed



114_Sp5_Def04_IRp_DJI_0171_R

Visual Image



114_Sp5_Def04_RGB_DJI_0172

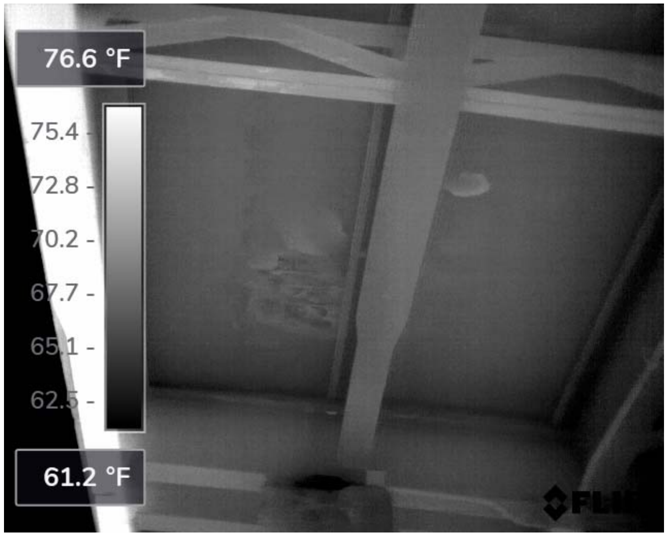
114, Span K5, Thermal Data

Thermal Deficiency 5

Thermal

114_Sp5_Def05_IR_DJI_0157_R

Thermal – Post Processed



114_Sp5_Def05_IRp_DJI_0157_R

Visual Image

114_Sp5_Def05_RGB_DJI_0158

114, Span K5, Thermal Data

Thermal Deficiency 6

Thermal

114_Sp5_Def06_IR_DJI_0155_R

Thermal – Post Processed

114_Sp5_Def06_IRp_DJI_0155_R

Visual Image

114_Sp5_Def06_RGB_DJI_0156

114, Span K5, Thermal Data

Thermal Deficiency 7

Thermal

114_Sp5_Def07_IR_DJI_0189_R

Thermal – Post Processed

114_Sp5_Def07_IRp_DJI_0189_R

Visual Image

114_Sp5_Def07_RGB_DJI_0190

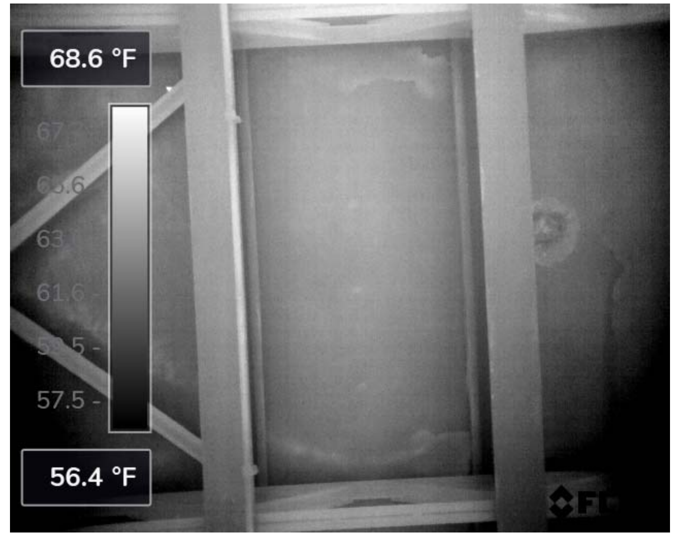
114, Span K5, Thermal Data

Thermal Deficiencies 8, 9

Thermal

114_Sp5_Def08,09_IR_DJI_0181_R

Thermal – Post Processed



114_Sp5_Def08,09_IRp_DJI_0181_R

Visual Image

114_Sp5_Def08,09_RGB_DJI_0182

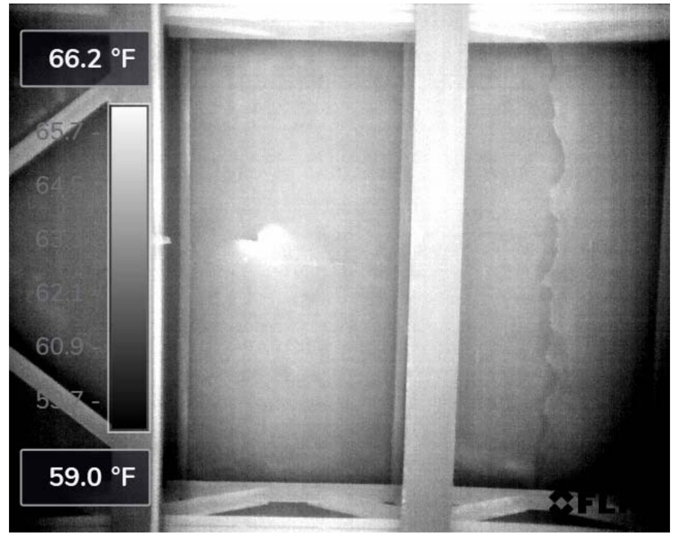
114, Span K5, Thermal Data

Thermal Deficiency 10

Thermal

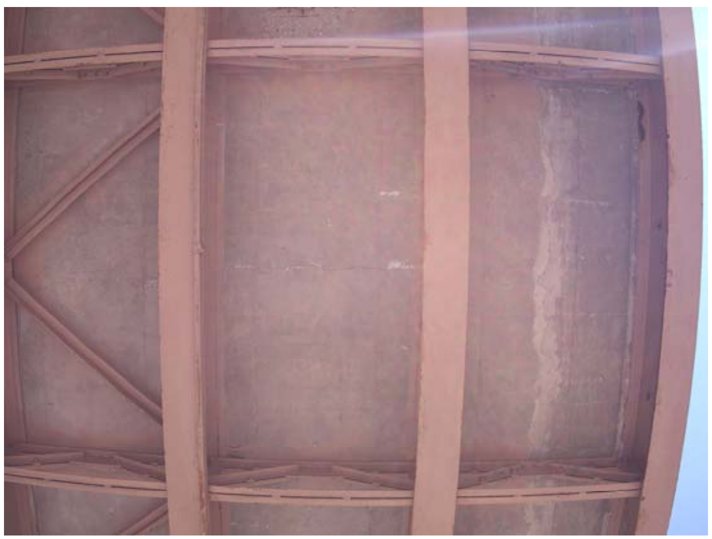
114_Sp5_Def10_IR_DJI_0173_R

Thermal – Post Processed



114_Sp5_Def10_IRp_DJI_0173_R

Visual Image



114_Sp5_Def10_RGB_DJI_0174

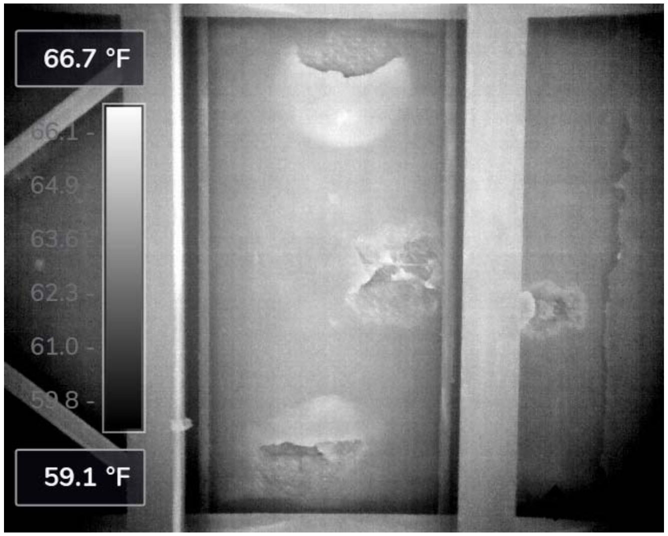
114, Span K5, Thermal Data

Thermal Deficiencies 11, 12, 13

Thermal

114_Sp5_Def11,12,13_IR_DJI_0169_R

Thermal – Post Processed



114_Sp5_Def11,12,13_IRp_DJI_0169_R

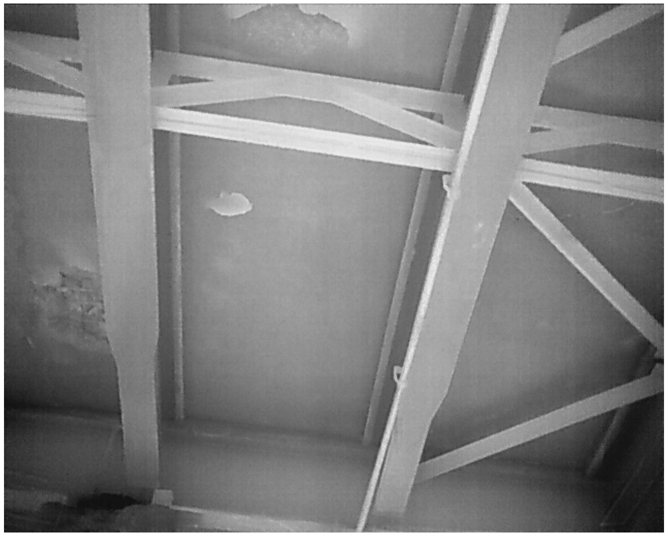
Visual Image

114_Sp5_Def11,12,13_RGB_DJI_0170

114, Span K5, Thermal Data

Thermal Deficiency 14

Thermal



114_Sp5_Def14_IR_DJI_0159_R

Thermal – Post Processed

114_Sp5_Def14_IRp_DJI_0159_R

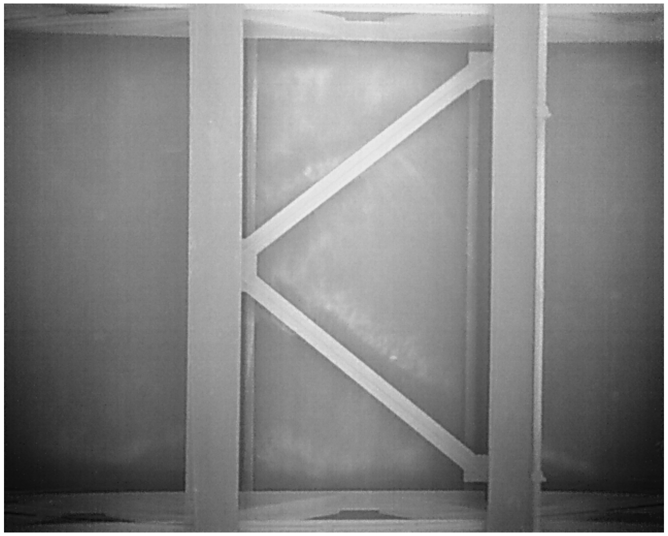
Visual Image

114_Sp5_Def14_RGB_DJI_0160

114, Span K5, Thermal Data

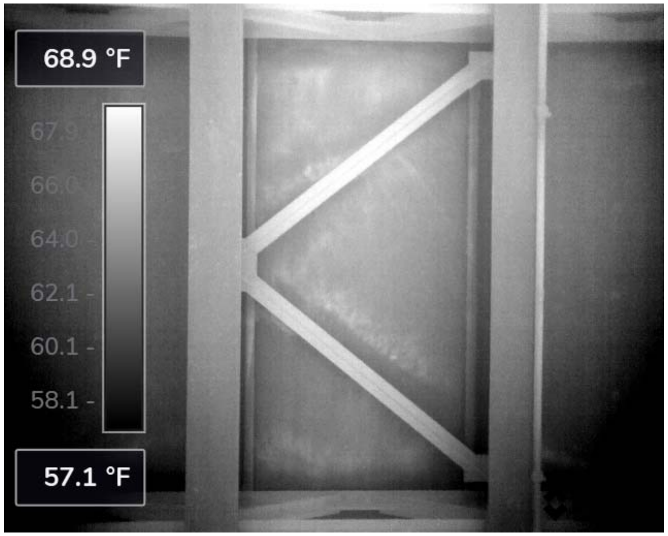
Thermal Deficiency 15

Thermal



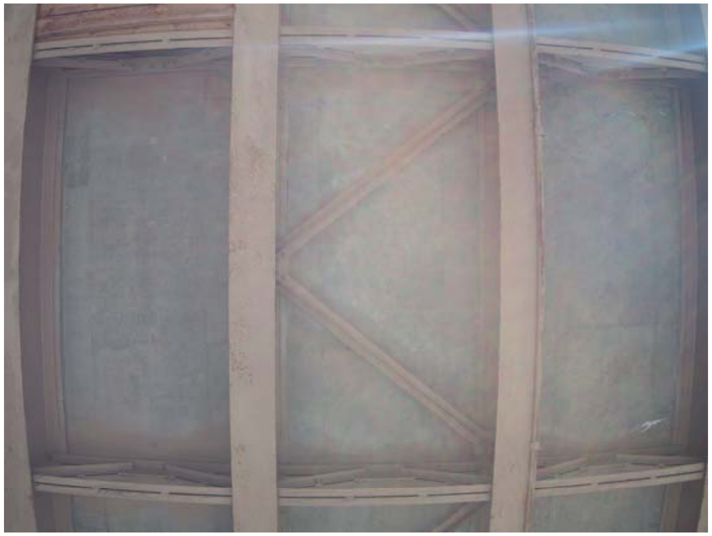
114_Sp5_Def15_IR_DJI_0179_R

Thermal – Post Processed



114_Sp5_Def15_IRp_DJI_0179_R

Visual Image

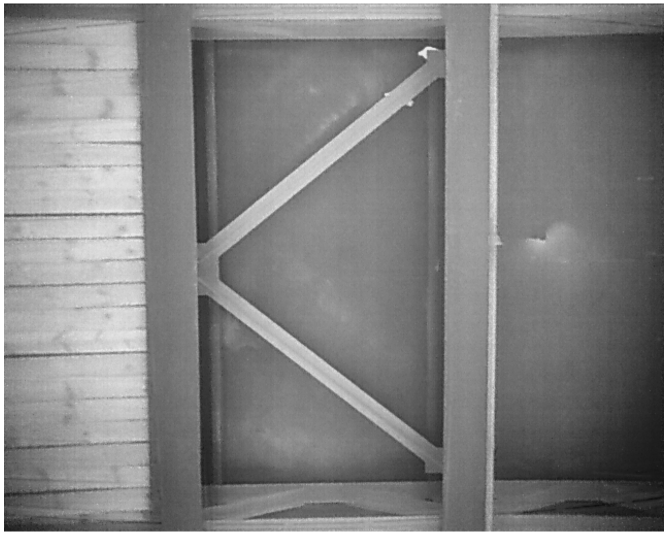


114_Sp5_Def15_RGB_DJI_0180

114, Span K5, Thermal Data

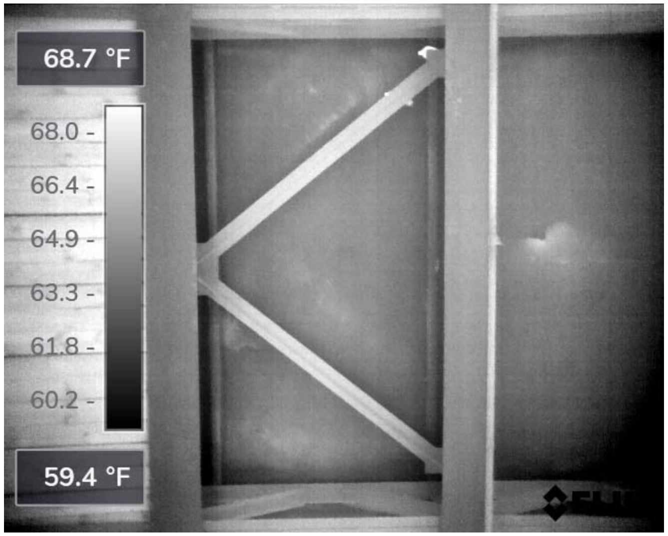
Thermal Deficiency 16

Thermal



114_Sp5_Def16_IR_DJI_0175_R

Thermal – Post Processed



114_Sp5_Def16_IRp_DJI_0175_R

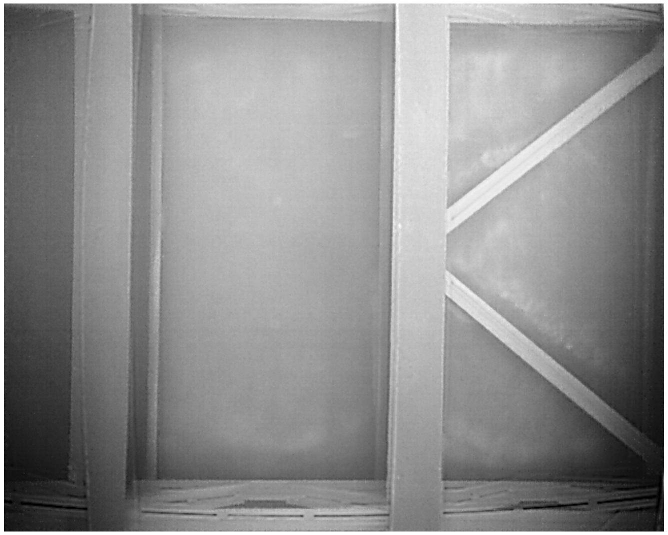
Visual Image

114_Sp5_Def16_RGB_DJI_0176

114, Span K5, Thermal Data

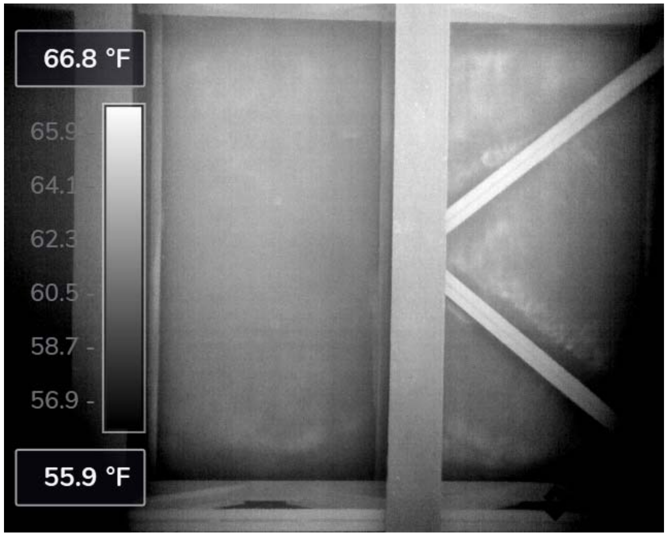
Thermal Deficiency 17

Thermal



114_Sp5_Def17_IR_DJI_0177_R

Thermal – Post Processed



114_Sp5_Def17_IRp_DJI_0177_R

Visual Image

114_Sp5_Def17_RGB_DJI_0178

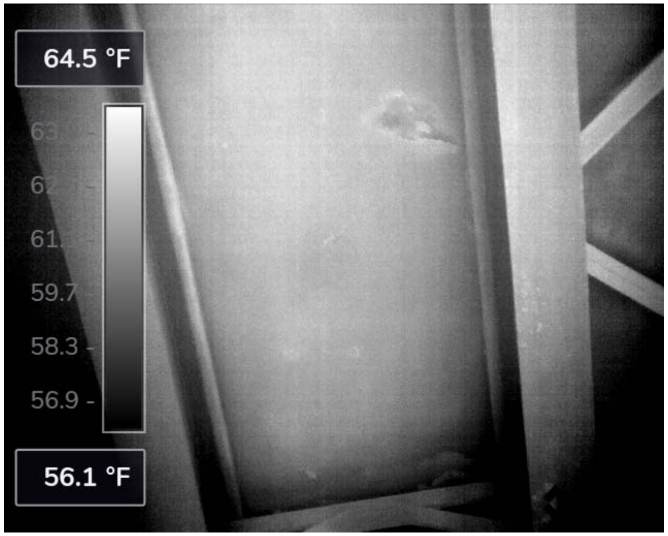
114, Span K5, Thermal Data

Thermal Deficiencies 18, 19

Thermal

114_Sp5_Def18,19_IR_DJI_0167_R

Thermal – Post Processed



114_Sp5_Def18,19_IRp_DJI_0167_R

Visual Image

114_Sp5_Def18,19_RGB_DJI_0168

114, Span K5, Thermal Data

Thermal Deficiencies 20, 21, 22

Thermal

114_Sp5_Def20,21,22_IR_DJI_0161_R

Thermal – Post Processed

114_Sp5_Def20,21,22_IRp_DJI_0161_R

Visual Image

114_Sp5_Def20,21,22_RGB_DJI_0162

114, Span K5, Thermal Data

Thermal Deficiency 23

Thermal

114_Sp5_Def23_IR_DJI_0163_R

Thermal – Post Processed

114_Sp5_Def23_IRp_DJI_0163_R

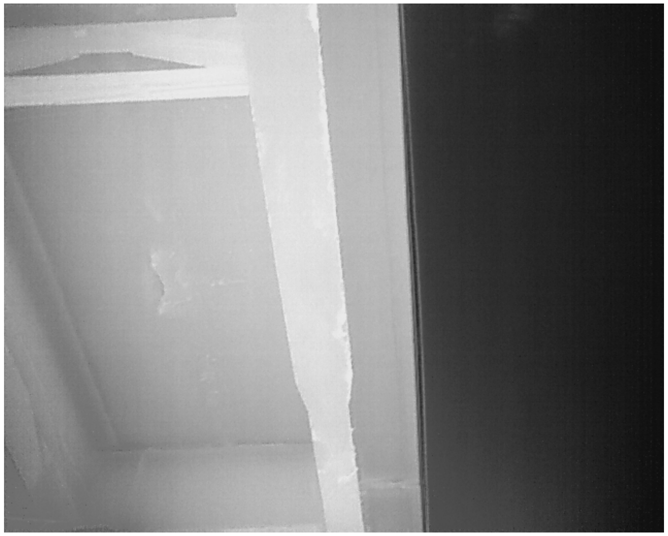
Visual Image

114_Sp5_Def23_RGB_DJI_0164

114, Span K5, Thermal Data

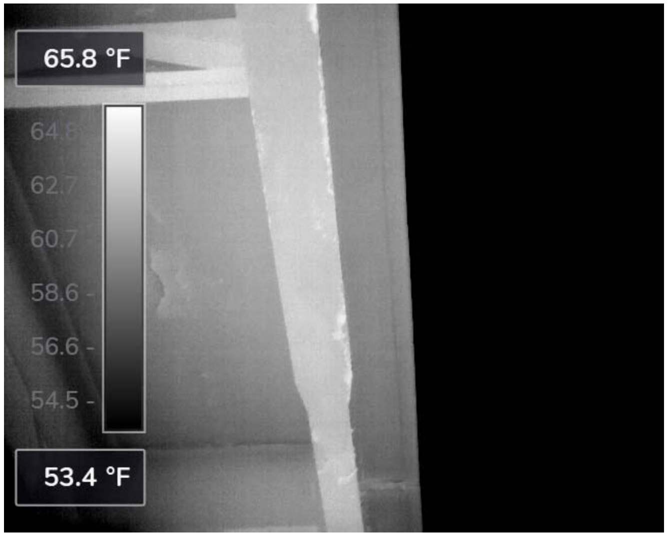
Thermal Deficiency 16

Thermal



114_Sp5_Def24_IR_DJI_0165_R

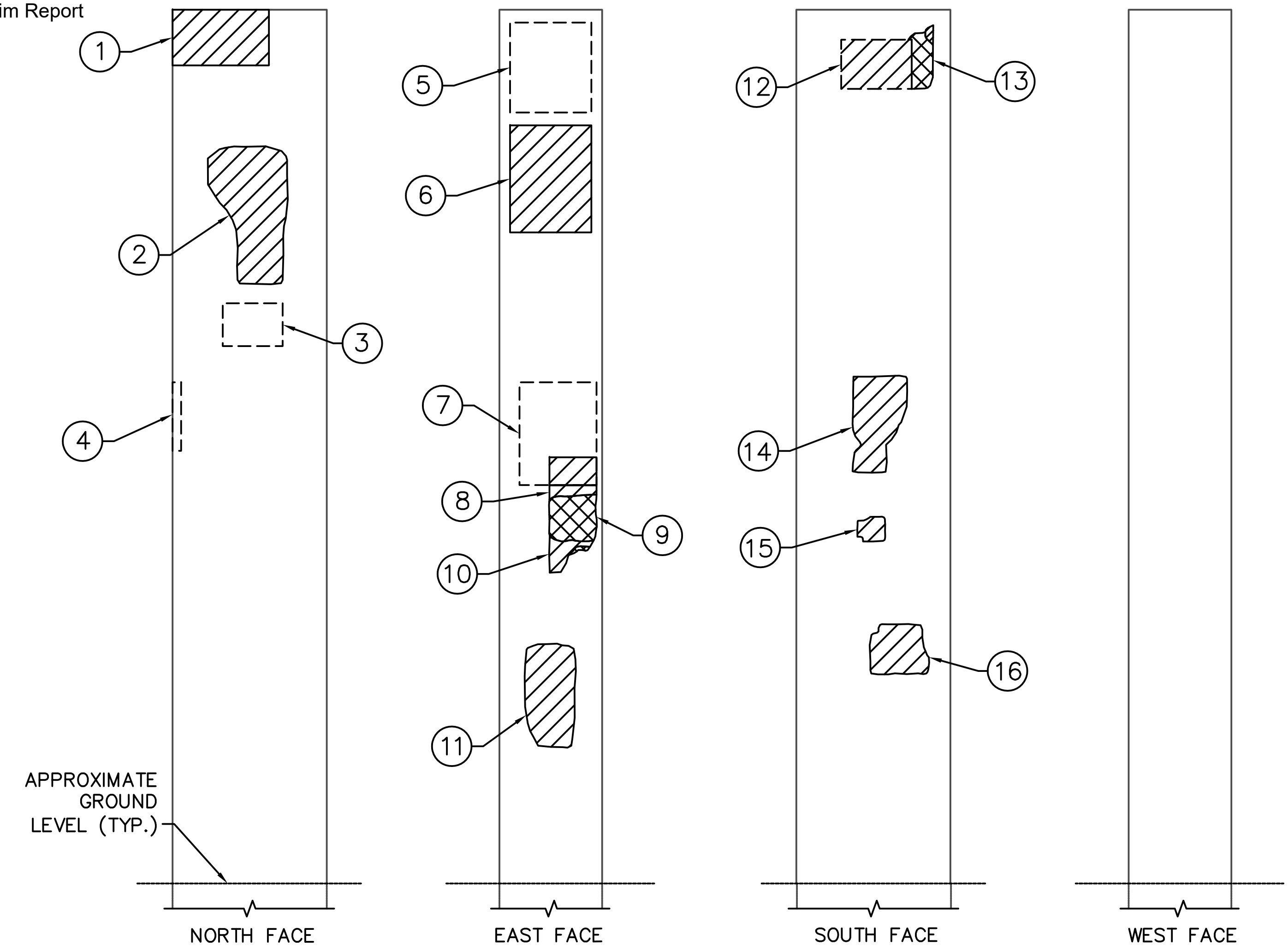
Thermal – Post Processed



114_Sp5_Def24_IRp_DJI_0165_R

Visual Image

114_Sp5_Def24_RGB_DJI_0166



PIER K3 SOUTH COLUMN

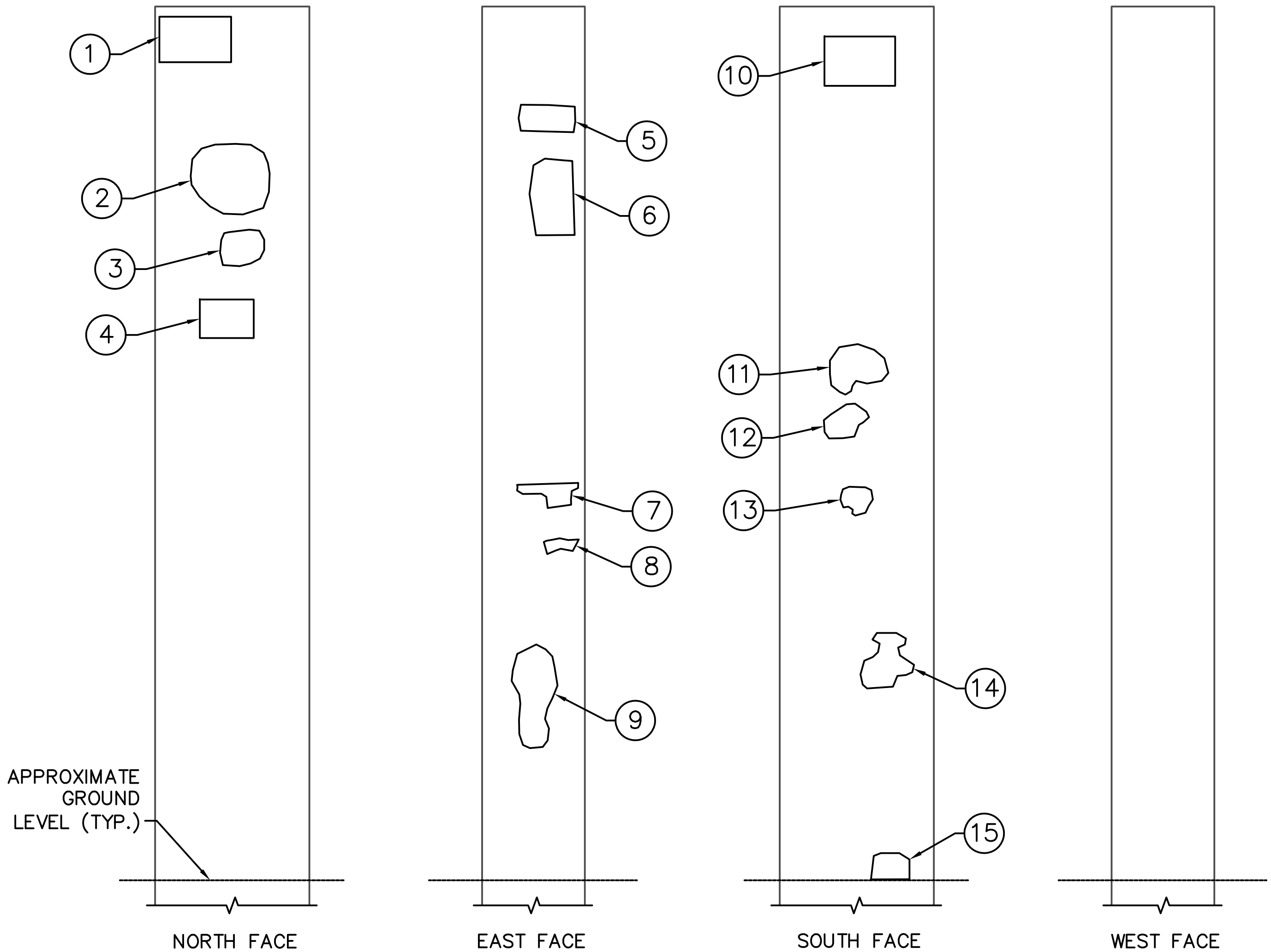
TRADITIONAL INSPECTION FINDINGS

DEFICIENCIES

1. 45” wide x 26” high hollow sounding patch
2. 37” wide x 65” high hollow sounding area
3. 28” wide x 20” high patch (sound)
4. 4” wide x 32” high patch (sound)
5. 38” wide x 42” high patch (sound)
6. 38” wide x 50” high hollow sounding patch
7. 36” wide x 48” high patch (mostly sound) containing 22” wide x 13” high hollow sounding area at bottom corner
8. 22” wide x up to 5” high hollow sounding area
9. 23” wide x 22” high spall
10. 22” wide x up to 15” high hollow sounding area with 10” wide x 3” high edge spalling
11. 23” wide x 48” high hollow sounding area
12. 33” wide x 23” high hollow sounding patch
13. 10” wide x 26” high spall with adjacent 4” wide x 9” high hollow sounding area
14. Up to 23” wide x 45” high hollow sounding area
15. 13” wide x up to 11½” high hollow sounding area
16. Up to 27” wide x 23” high hollow sounding area

LEGEND

Hollow Sounding Area   Spall   Patch



PIER K3 SOUTH COLUMN

TRADITIONAL INSPECTION FINDINGS

NOTES
1. AREAS INDICATED ON THIS SKETCH ARE TEMPERATURE DIFFERENTIALS BELIEVED TO BE DELAMINATIONS ALONG THE UNDERSIDE OF BRIDGE DECK. LOCATIONS, SIZES, AND SHAPES ARE APPROXIMATED BASED ON THE THERMAL IMAGERY.
2. TEMPERATURE DIFFERENTIALS WERE CROSS CHECKED WITH VISUAL IMAGERY TO REMOVE FALSE–POSITIVES DURING DATA COLLECTION.

114, Pier K3 South Column, Thermal Data

Thermal Deficiencies 1, 2, 3, 4

Thermal

114_K3S_Def01,02,03,04_IR_DJI_0736_R

Thermal – Post Processed

114_K3S_Def01,02,03,04_IRp_DJI_0736_R

Visual Image

114_K3S_Def01,02,03,04_RGB_DJI_0737

114, Pier K3 South Column, Thermal Data

Thermal Deficiencies 5, 6

Thermal

114_K3S_Def05,06_IR_DJI_0730_R

Thermal – Post Processed

114_K3S_Def05,06_IRp_DJI_0730_R

Visual Image

114_K3S_Def05,06_RGB_DJI_0731

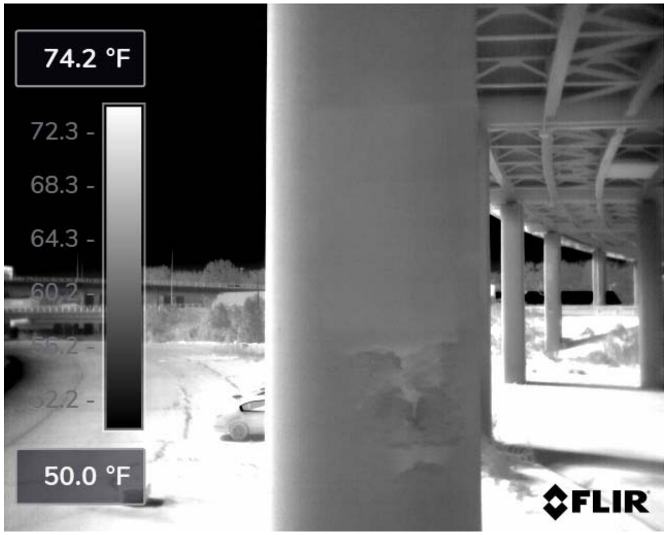
114, Pier K3 South Column, Thermal Data

Thermal Deficiencies 7, 8

Thermal

114_K3S_Def07,08_IR_DJI_0732_R

Thermal – Post Processed



114_K3S_Def07,08_IRp_DJI_0732_R

Visual Image

114_K3S_Def07,08_RGB_DJI_0733

114, Pier K3 South Column, Thermal Data

Thermal Deficiency 9

Thermal

114_K3S_Def09_IR_DJI_0734_R

Thermal – Post Processed

114_K3S_Def09_IRp_DJI_0734_R

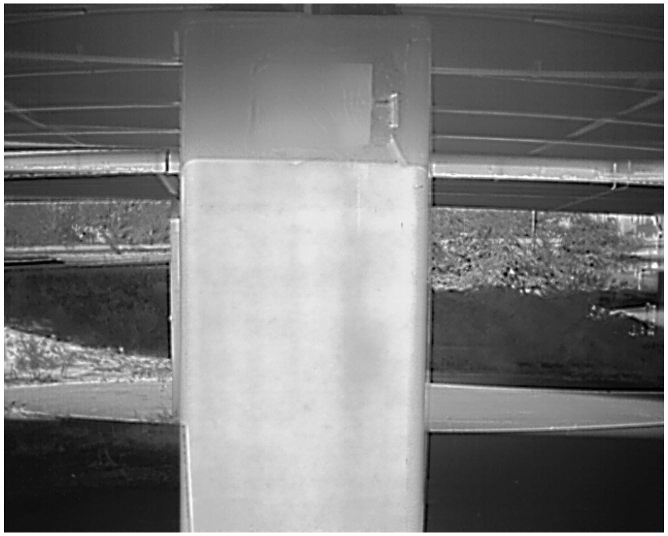
Visual Image

114_K3S_Def09_RGB_DJI_0735

114, Pier K3 South Column, Thermal Data

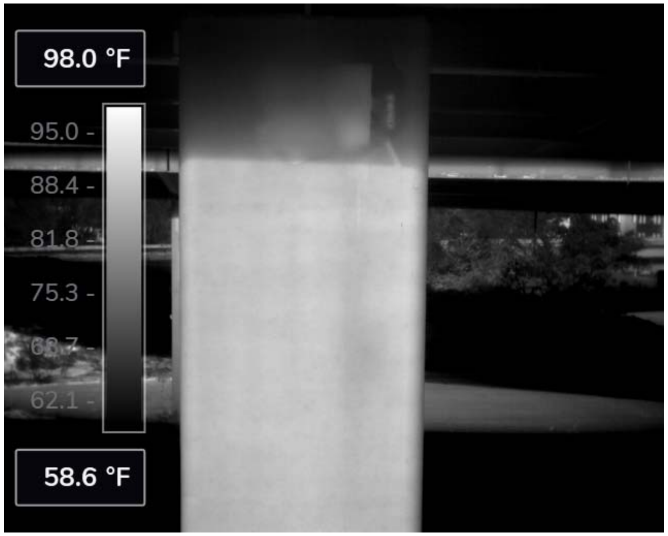
Thermal Deficiency 10

Thermal



114_K3S_Def10_IR_DJI_0722_R

Thermal – Post Processed



114_K3S_Def10_IRp_DJI_0722_R

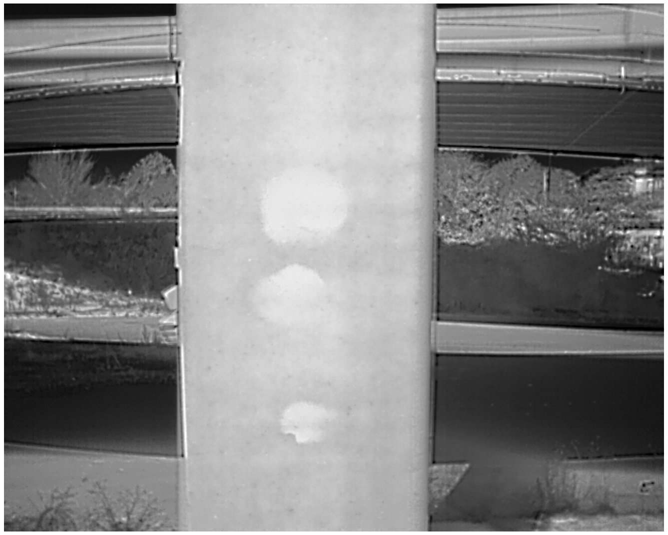
Visual Image

114_K3S_Def10_RGB_DJI_0723

114, Pier K3 South Column, Thermal Data

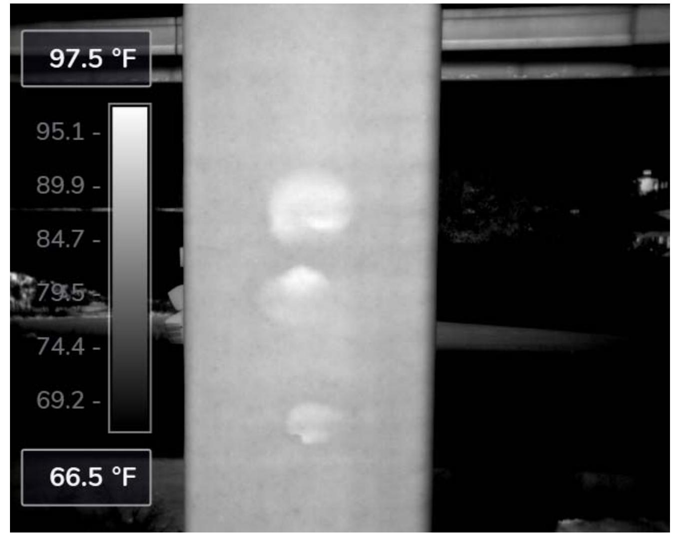
Thermal Deficiencies 11, 12, 13

Thermal



114_K3S_Def11,12,13_IR_DJI_0724_R

Thermal – Post Processed



114_K3S_Def11,12,13_IRp_DJI_0724_R

Visual Image

114_K3S_Def11,12,13_RGB_DJI_0725

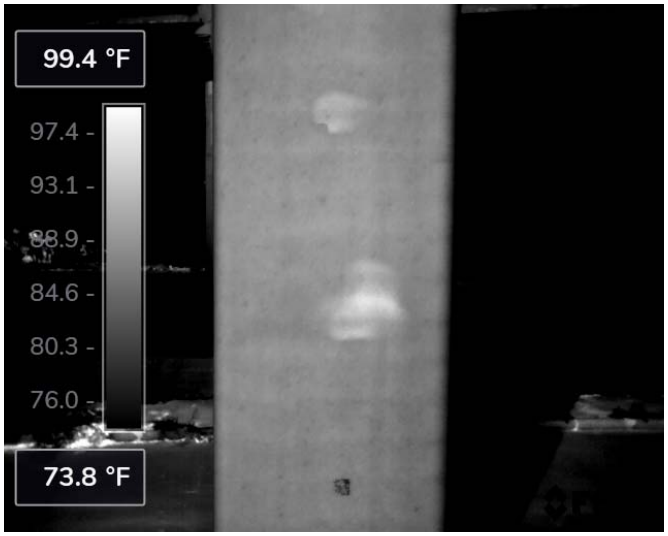
114, Pier K3 South Column, Thermal Data

Thermal Deficiency 14

Thermal

114_K3S_Def14_IR_DJI_0726_R

Thermal – Post Processed



114_K3S_Def14_IRp_DJI_0726_R

Visual Image

114_K3S_Def14_RGB_DJI_0727

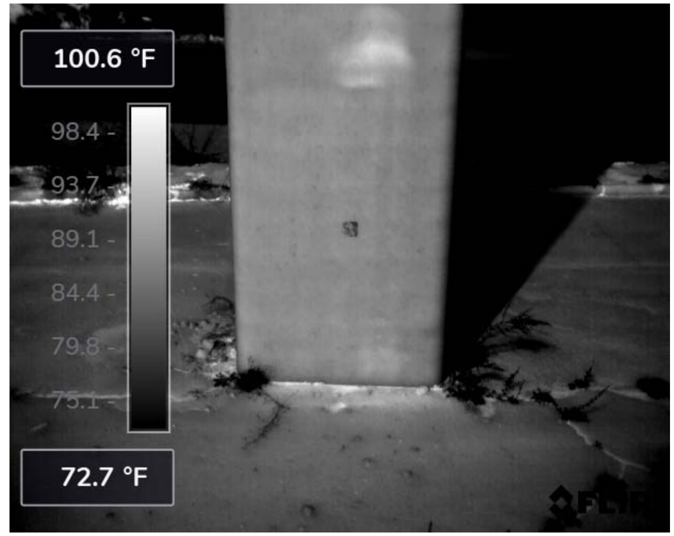
114, Pier K3 South Column, Thermal Data

Thermal Deficiency 15

Thermal

114_K3S_Def15_IR_DJI_0728_R

Thermal – Post Processed



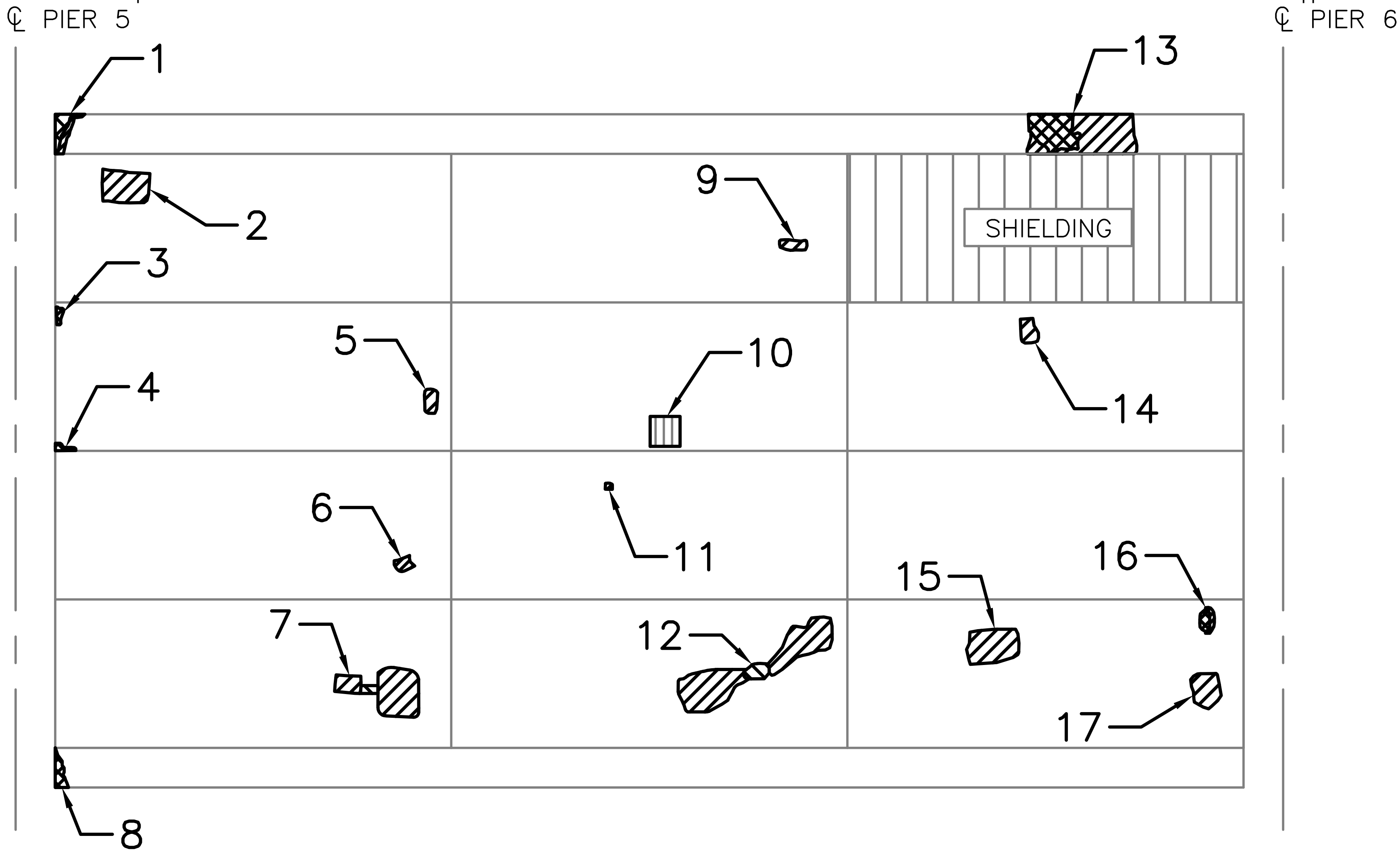
114_K3S_Def15_IRp_DJI_0728_R

Visual Image

114_K3S_Def15_RGB_DJI_0729

Appendix E

B-16-369 (BIN 4RT)



BIN 4RT, SPAN 6
TRADITIONAL INSPECTION FINDINGS
PROJECTED VIEW

NOTE:
1. Detailed deficiency descriptions and measurements are included on the following sketch.

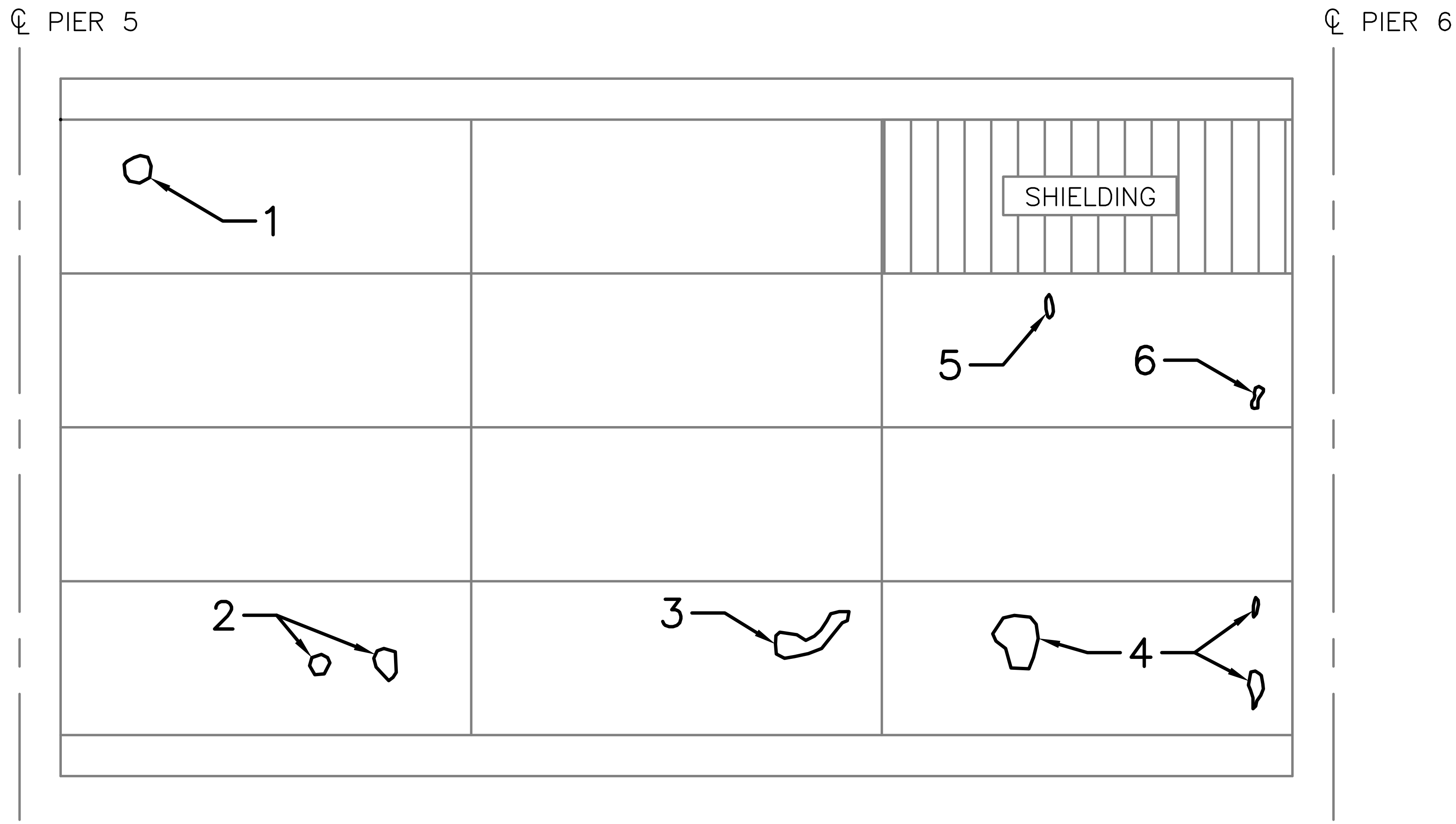
LEGEND:
- Hollow Area
- Spall
- Timber

BIN 4RT, SPAN 6

TRADITIONAL INSPECTION FINDINGS

DEFICIENCIES

1. 13" long x full width x 3" deep spall with rebar and full width x 4" long hollow sounding area (HSA).
2. 29" long x 19" wide HSA
3. 1" wide x 4" long x 1" deep spall.
4. 13" long x 4" wide x 2" deep spall.
5. 15" long x 7" wide HSA.
6. 10" long x 8" wide HSA.
7. 17" long x 11" wide HSA, 12" long x 5" wide HSA, 29" long x 25" wide HSA.
8. 8" long x full depth x full width spall.
9. 19" long x 7" wide HSA.
10. Formwork left in place.
11. 4" x 4" HSA.
12. Up to 36" long x 19" wide HSA, 10" long x 7" wide HSA, 38" long x up to 20" wide HSA.
13. 24" long x full width x 1" deep spall with two HSA's measuring 9" long x full width and 38" long x full width
14. 16" long x 16" wide HSA.
15. 30" long x 20" wide HSA.
16. 16" wide x 5" long HSA with a 16" wide x 5" long spall.
17. 17" long x 20" wide HSA.



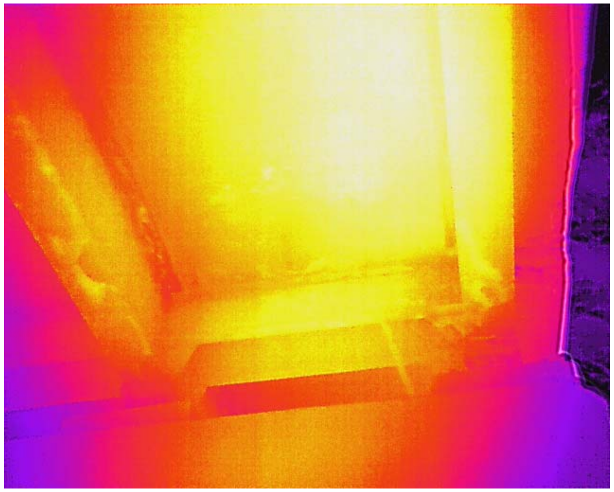
BIN 4RT, SPAN 6, FIRST DATA SET

MATRICE 210 WITH ZENMUSE XT2 (10/19/21)
LOCATING DEFICIENCIES WITH NO PREVIOUS INFORMATION
PROJECTED VIEW

NOTES:
1. AREAS INDICATED ON THIS SKETCH ARE TEMPERATURE DIFFERENTIALS BELIEVED TO BE DELAMINATIONS ALONG THE UNDERSIDE OF THE BRIDGE DECK. LOCATIONS, SIZES, AND SHAPES ARE APPROXIMATED BASED ON THE THERMAL IMAGERY.
2. TEMPERATURE DIFFERENTIALS WERE CROSS CHECKED WITH VISUAL IMAGERY TO REMOVE FALSE POSITIVES DURING DATA COLLECTION.

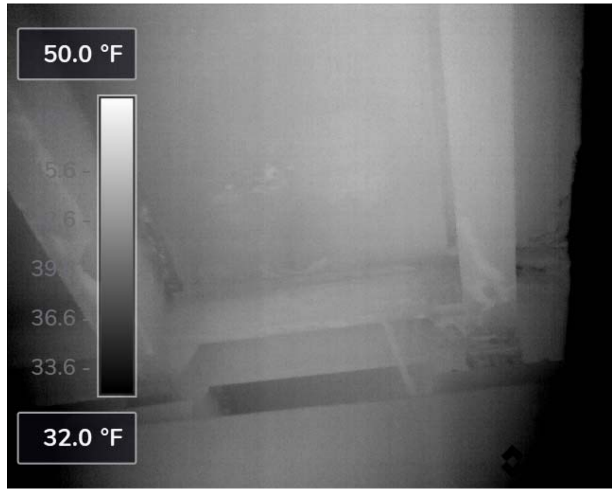
4RT, UAV-IR Survey, First Data Set (10/19/21) Thermal Deficiencies 1, 2

Automatic Settings



4RT_XT2_Sp6_01_01_IR_DJI_0222_R

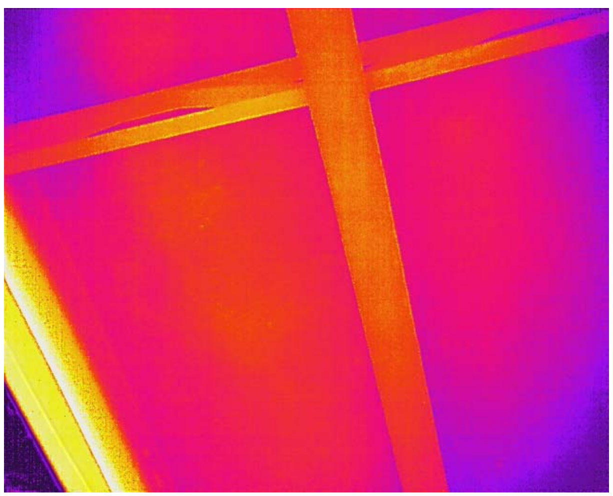
Post Processed



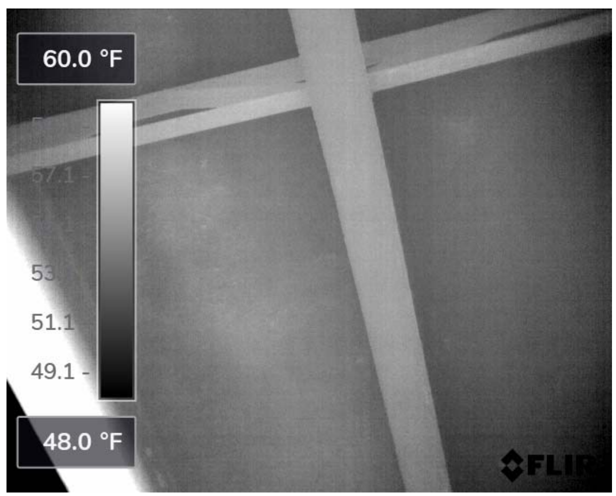
4RT_XT2_Sp6_01_01_IRp_DJI_0222_R

Visual Image

4RT_XT2_Sp6_01_01_RGB_DJI_0223



4RT_XT2_Sp6_01_02_IR_DJI_0220_R



4RT_XT2_Sp6_01_02_IRp_DJI_0220_R

4RT_XT2_Sp6_01_02_RGB_DJI_0221

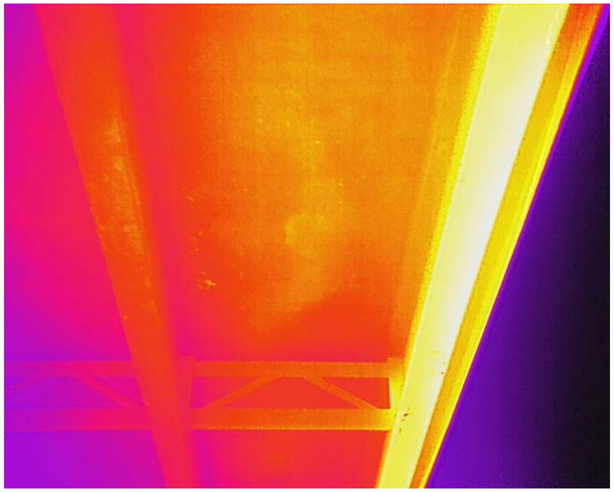
4RT, UAV-IR Survey, First Data Set (10/19/21)

Thermal Deficiencies 3, 4

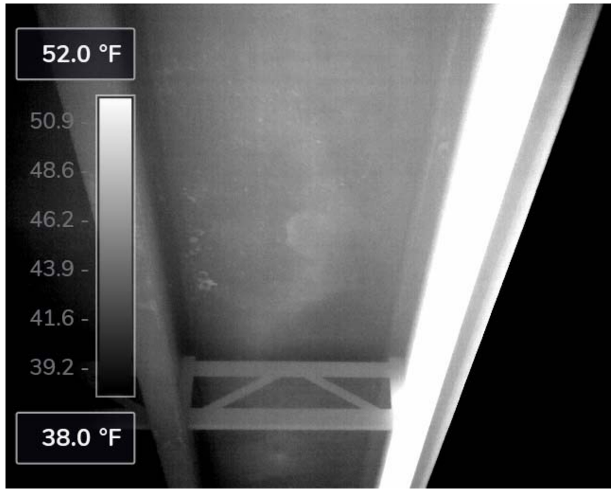
Automatic Settings

Post Processed

Visual Image

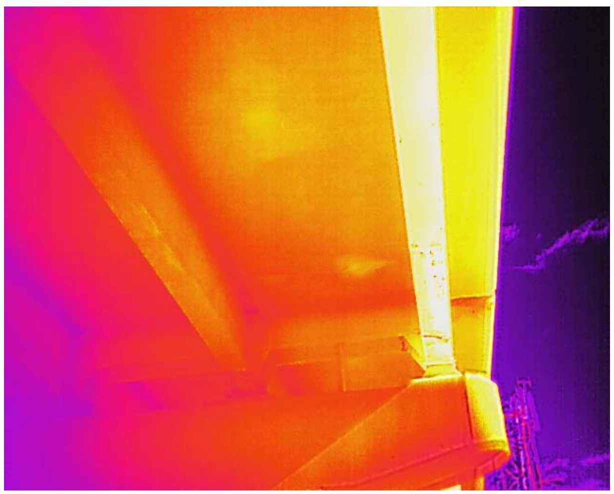


4RT_XT2_Sp6_01_03_IR_DJI_0224_R

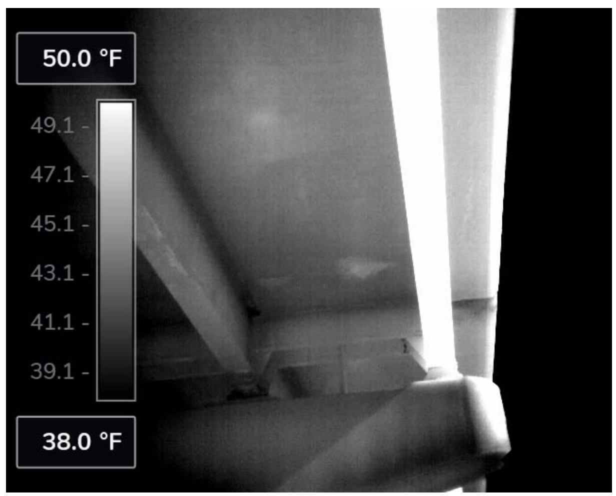


4RT_XT2_Sp6_01_03_IRp_DJI_0224_R

4RT_XT2_Sp6_01_03_RGB_DJI_0225



4RT_XT2_Sp6_01_04_IR_DJI_0226_R



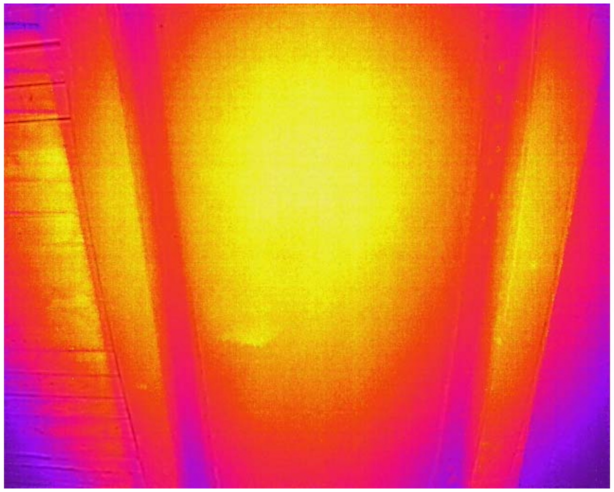
4RT_XT2_Sp6_01_04_IRp_DJI_0226_R

4RT_XT2_Sp6_01_04_RGB_DJI_0227

4RT, UAV-IR Survey, First Data Set (10/19/21)

Thermal Deficiencies 5, 6

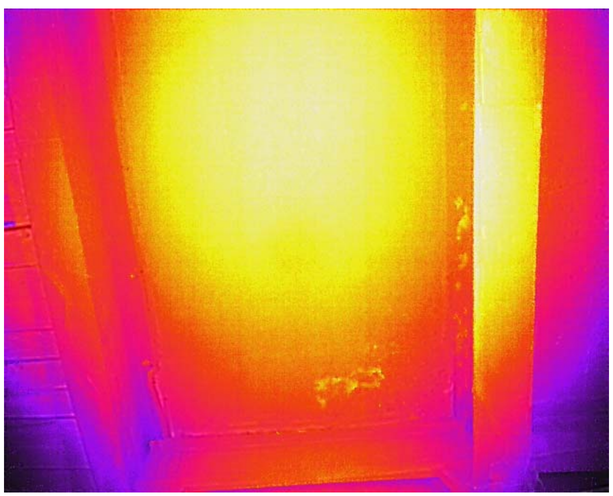
Automatic Settings | Post Processed | Visual Image



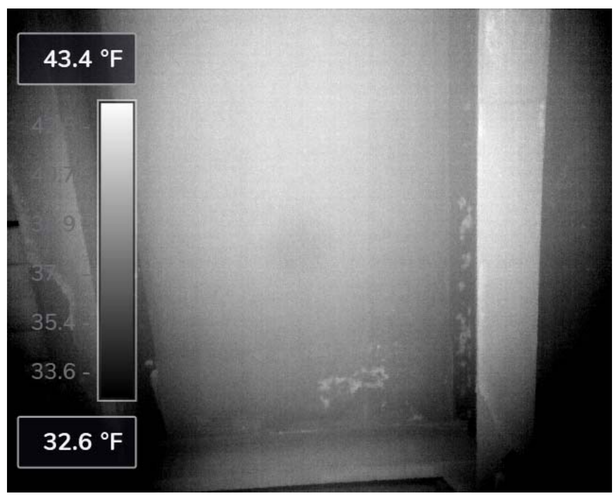
4RT_XT2_Sp6_01_05_IR_DJI_0228_R

4RT_XT2_Sp6_01_05_IRp_DJI_0228_R

4RT_XT2_Sp6_01_05_RGB_DJI_0229

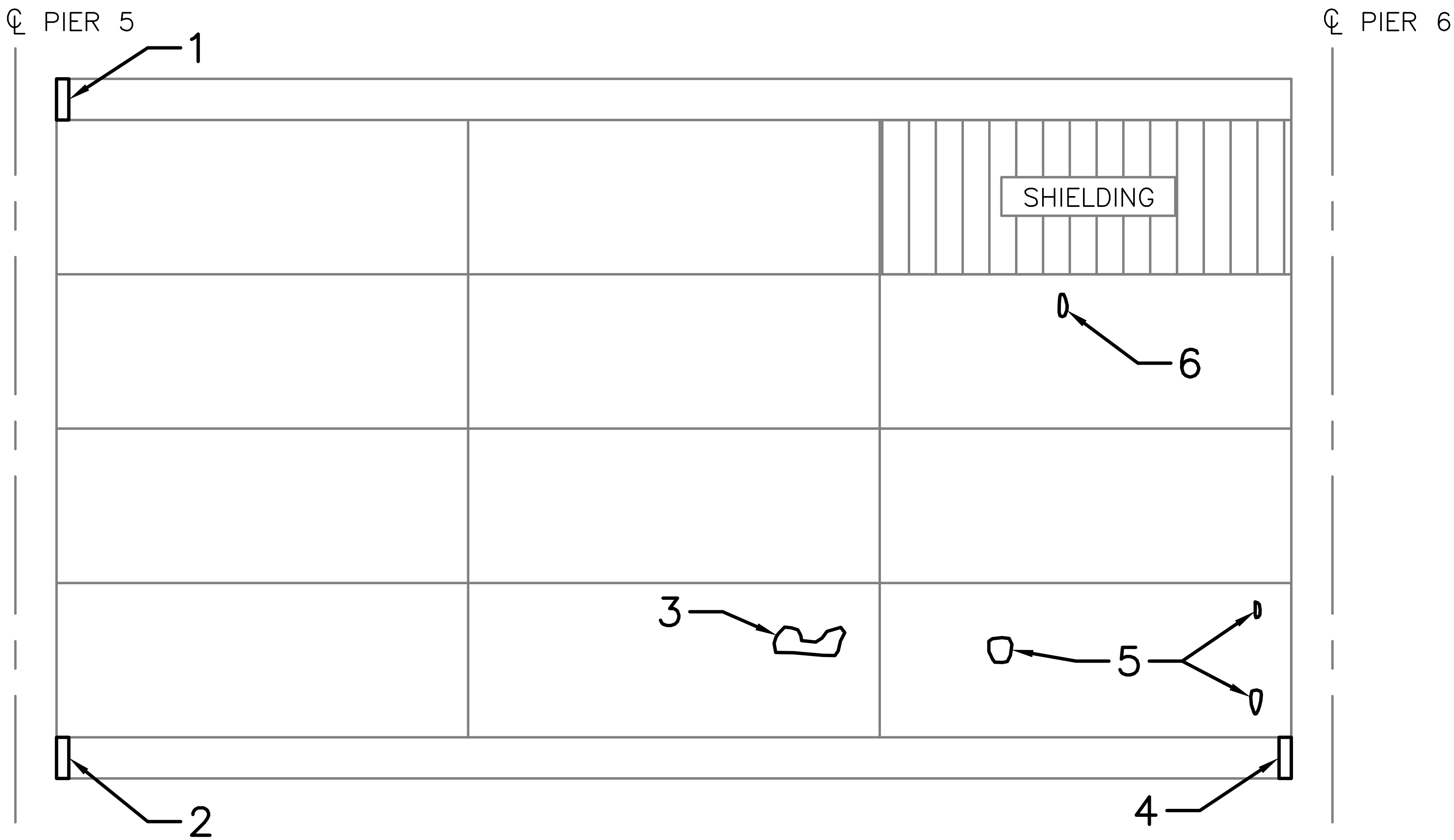


4RT_XT2_Sp6_01_06_IR_DJI_0230_R



4RT_XT2_Sp6_01_06_IRp_DJI_0230_R

4RT_XT2_Sp6_01_06_RGB_DJI_0231



BIN 4RT, SPAN 6, SECOND DATA SET

MATRICE 210 WITH ZENMUSE XT2 (10/22/21)
LOCATING DEFICIENCIES WITH NO PREVIOUS INFORMATION
PROJECTED VIEW

NOTES:
1. AREAS INDICATED ON THIS SKETCH ARE TEMPERATURE DIFFERENTIALS BELIEVED TO BE DELAMINATIONS ALONG THE UNDERSIDE OF THE BRIDGE DECK. LOCATIONS, SIZES, AND SHAPES ARE APPROXIMATED BASED ON THE THERMAL IMAGERY.
2. TEMPERATURE DIFFERENTIALS WERE CROSS CHECKED WITH VISUAL IMAGERY TO REMOVE FALSE POSITIVES DURING DATA COLLECTION.

4RT, UAV-IR Survey, Second Data Set (10/22/21)

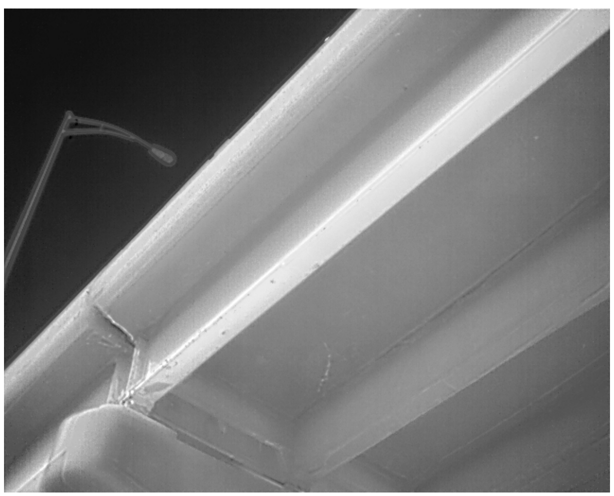
Thermal Deficiencies 1, 2

Automatic Settings	Post Processed	Visual Image

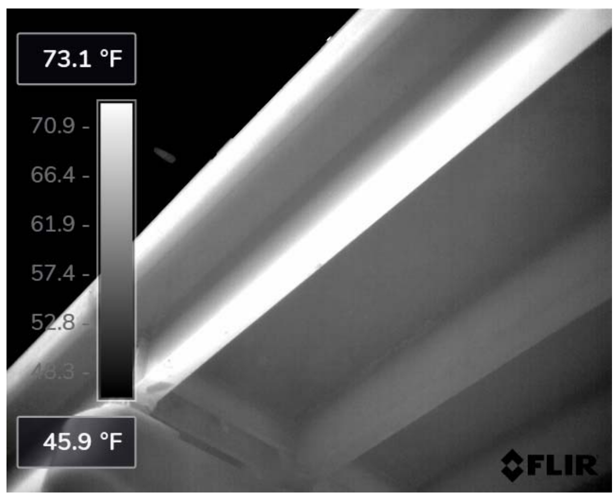
4RT_XT2_Sp6_02_01_IR_DJI_0615_R

4RT_XT2_Sp6_02_01_IRp_DJI_0615_R

4RT_XT2_Sp6_02_01_RGB_DJI_0616



4RT_XT2_Sp6_02_02_IR_DJI_0613_R



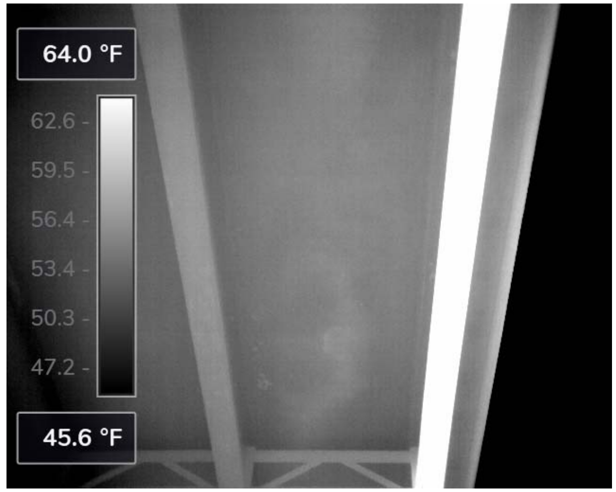
4RT_XT2_Sp6_02_02_IRp_DJI_0613_R

4RT_XT2_Sp6_02_02_RGB_DJI_0614

4RT, UAV-IR Survey, Second Data Set (10/22/21) Thermal Deficiencies 3, 4

Automatic Settings | Post Processed | Visual Image

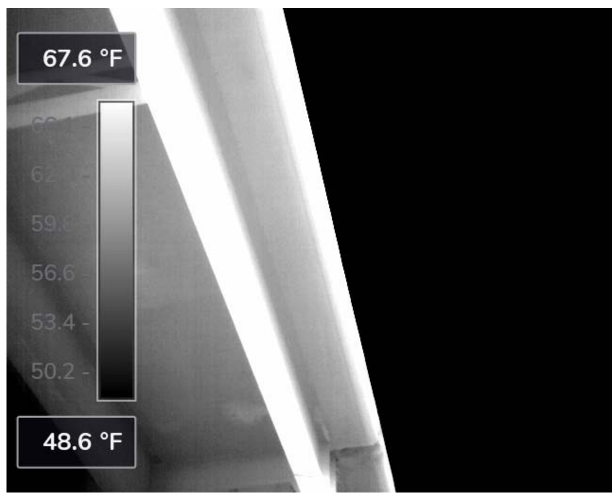
4RT_XT2_Sp6_02_03_IR_DJI_0611_R



4RT_XT2_Sp6_02_03_IRp_DJI_0611_R

4RT_XT2_Sp6_02_03_RGB_DJI_0612

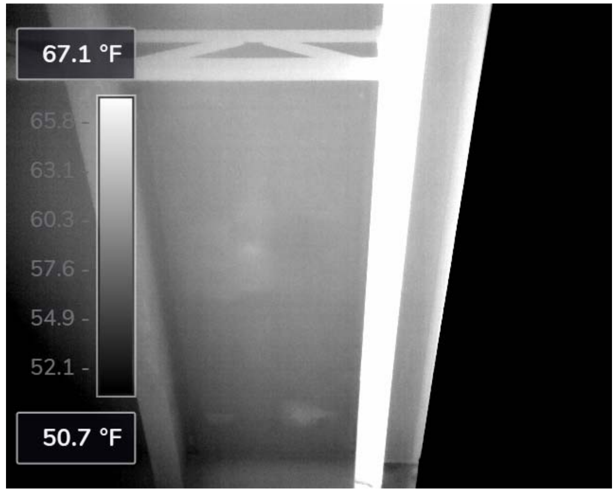
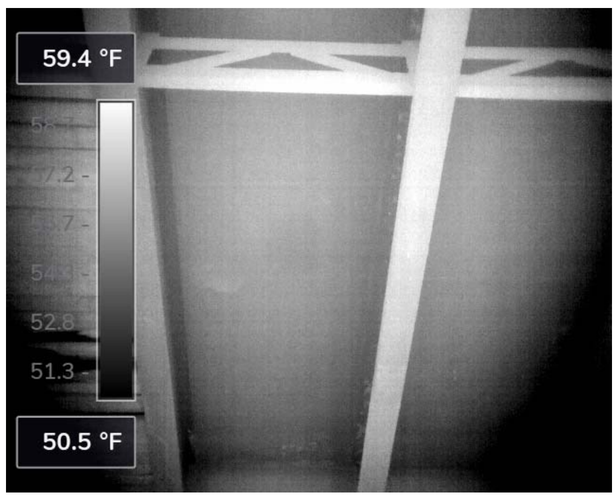
4RT_XT2_Sp6_02_04_IR_DJI_0603_R

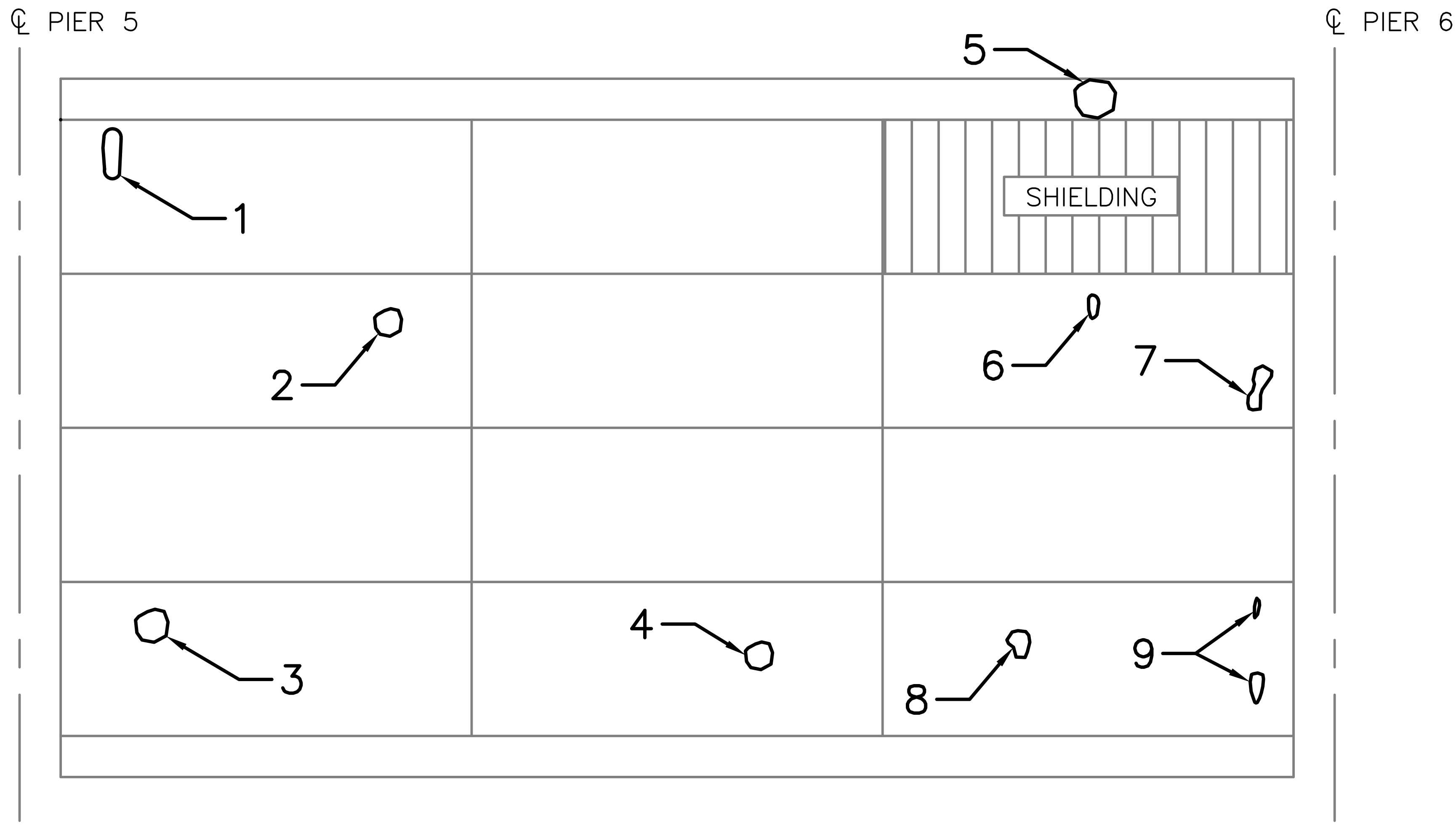


4RT_XT2_Sp6_02_04_IRp_DJI_0603_R

4RT_XT2_Sp6_02_04_RGB_DJI_0604

4RT, UAV-IR Survey, Second Data Set (10/22/21) Thermal Deficiencies 5, 6

Automatic Settings	Post Processed	Visual Image
		
4RT_XT2_Sp6_02_05_IR_DJI_0605_R	4RT_XT2_Sp6_02_05_IRp_DJI_0605_R	4RT_XT2_Sp6_02_05_RGB_DJI_0606
		
4RT_XT2_Sp6_02_06_IR_DJI_0607_R	4RT_XT2_Sp6_02_06_IRp_DJI_0607_R	4RT_XT2_Sp6_02_06_RGB_DJI_0608



BIN 4RT, SPAN 6, THIRD DATA SET

MATRICE 300 WITH ZENMUSE XT2 (1/19/22)
LOCATING DEFICIENCIES WITH NO PREVIOUS INFORMATION
PROJECTED VIEW

NOTES:
1. AREAS INDICATED ON THIS SKETCH ARE TEMPERATURE DIFFERENTIALS BELIEVED TO BE DELAMINATIONS ALONG THE UNDERSIDE OF THE BRIDGE DECK. LOCATIONS, SIZES, AND SHAPES ARE APPROXIMATED BASED ON THE THERMAL IMAGERY.
2. TEMPERATURE DIFFERENTIALS WERE CROSS CHECKED WITH VISUAL IMAGERY TO REMOVE FALSE POSITIVES DURING DATA COLLECTION.

4RT, UAV-IR Survey, Third Data Set (1/19/22)

Thermal Deficiencies 1, 2

Automatic Settings

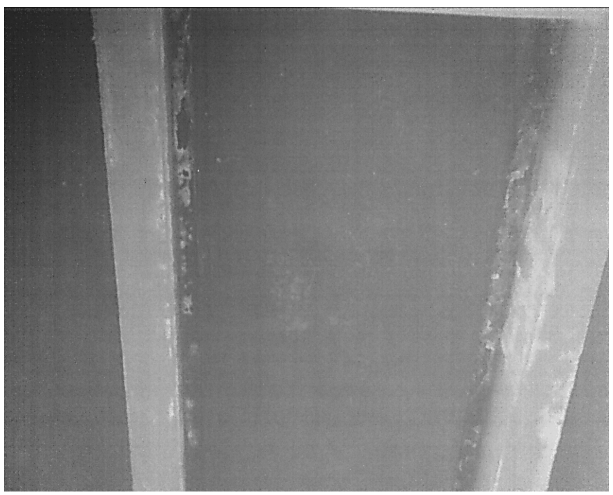
Post Processed

Visual Image

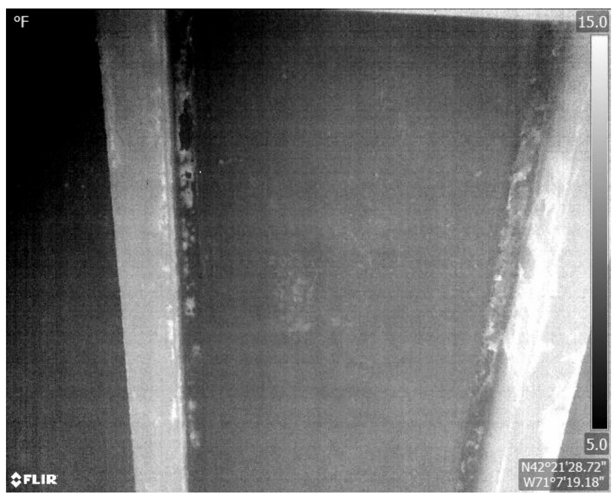
4RT_XT2_Sp6_03_01_IR_DJI_0885_R

4RT_XT2_Sp6_03_01_IRp_DJI_0885_R

4RT_XT2_Sp6_03_01_RGB_DJI_0886



4RT_XT2_Sp6_03_02_IR_DJI_0883_R



4RT_XT2_Sp6_03_02_IRp_DJI_0883_R

4RT_XT2_Sp6_03_02_RGB_DJI_0884

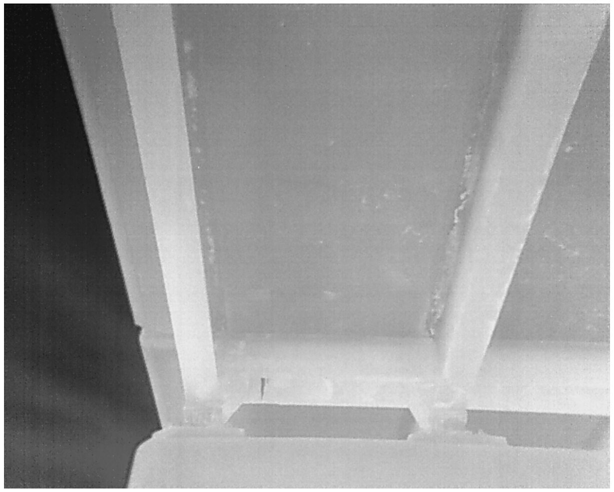
4RT, UAV-IR Survey, Third Data Set (1/19/22)

Thermal Deficiencies 3, 4

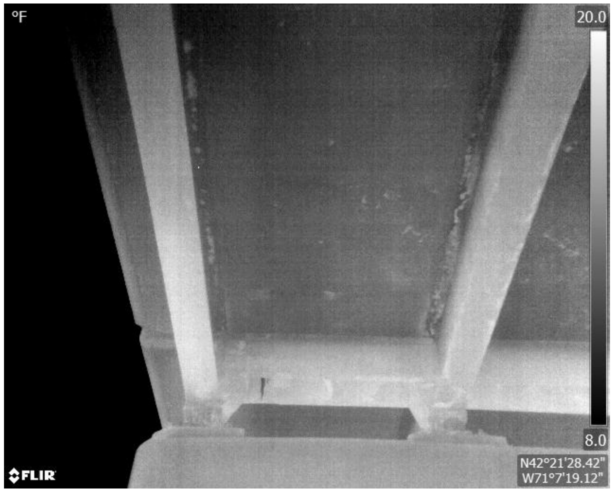
Automatic Settings

Post Processed

Visual Image

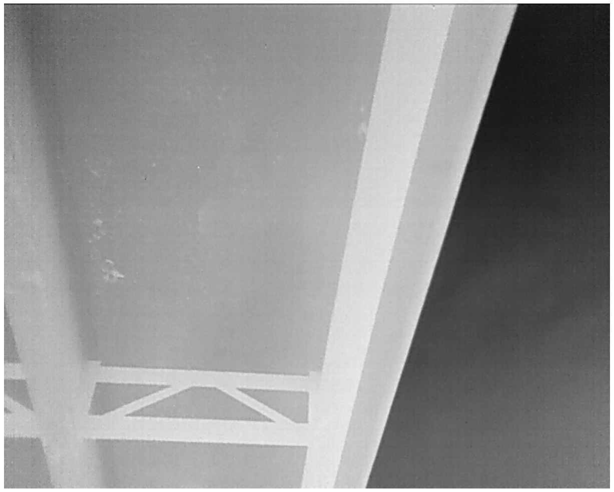


4RT_XT2_Sp6_03_03_IR_DJI_0881_R

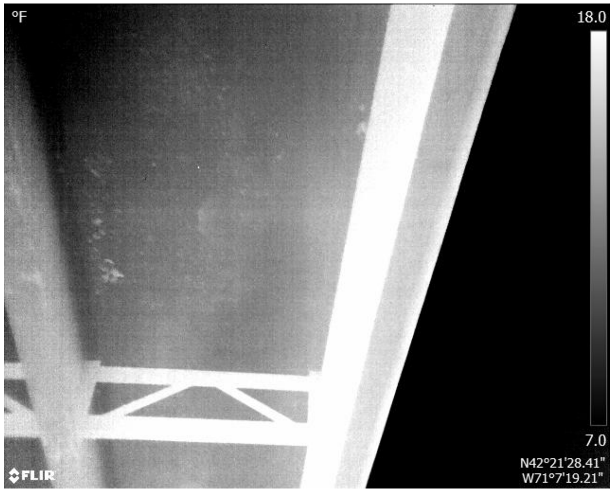


4RT_XT2_Sp6_03_03_IRp_DJI_0881_R

4RT_XT2_Sp6_03_03_RGB_DJI_0882



4RT_XT2_Sp6_03_04_IR_DJI_0879_R

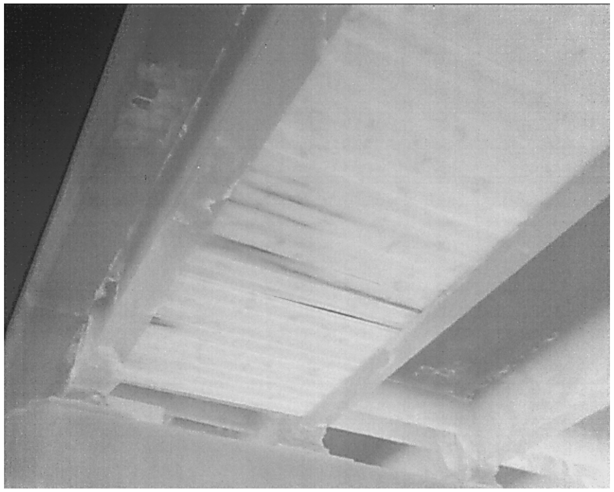


4RT_XT2_Sp6_03_04_IRp_DJI_0879_R

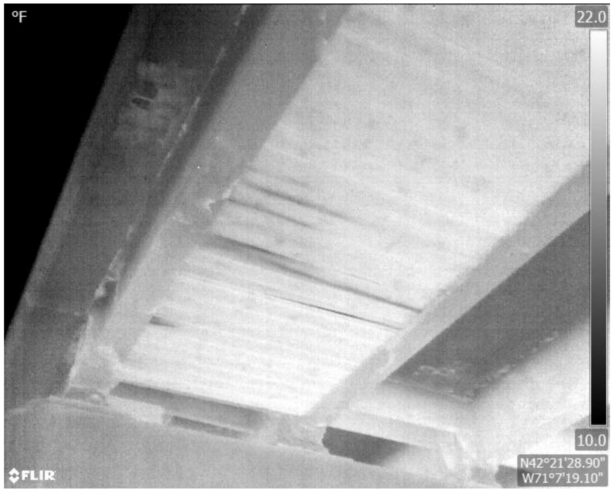
4RT_XT2_Sp6_03_04_RGB_DJI_0880

4RT, UAV-IR Survey, Third Data Set (1/19/22) Thermal Deficiencies 5, 6

Automatic Settings	Post Processed	Visual Image

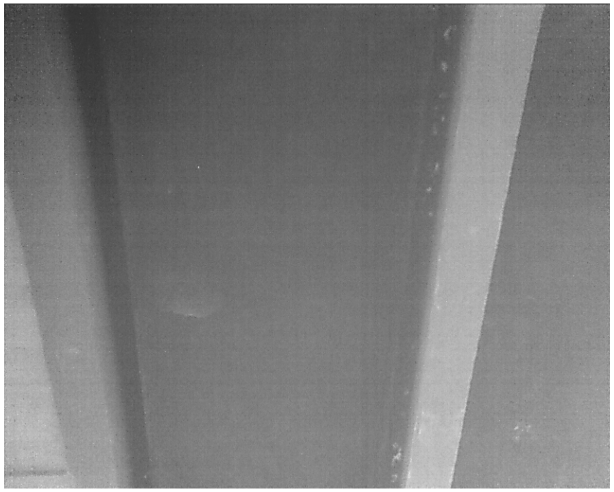


4RT_XT2_Sp6_03_05_IR_DJI_0877_R

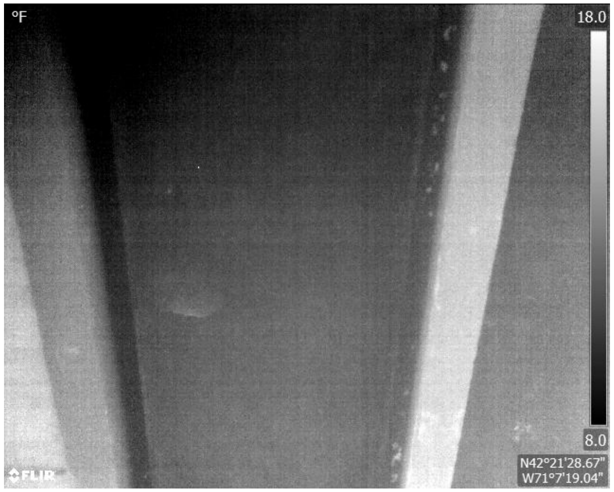


4RT_XT2_Sp6_03_05_IRp_DJI_0877_R

4RT_XT2_Sp6_03_05_RGB_DJI_0878



4RT_XT2_Sp6_03_06_IR_DJI_0871_R

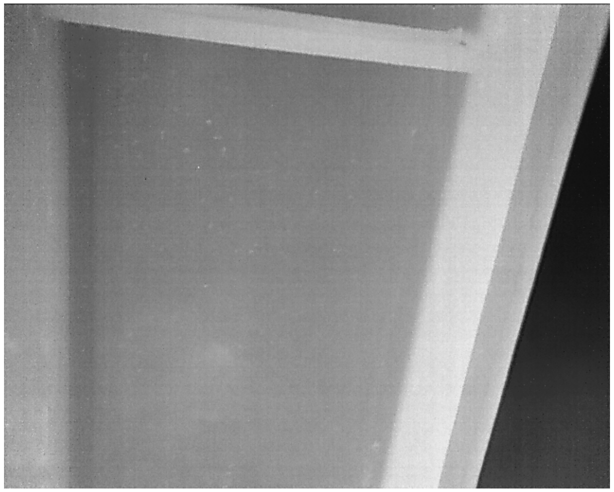
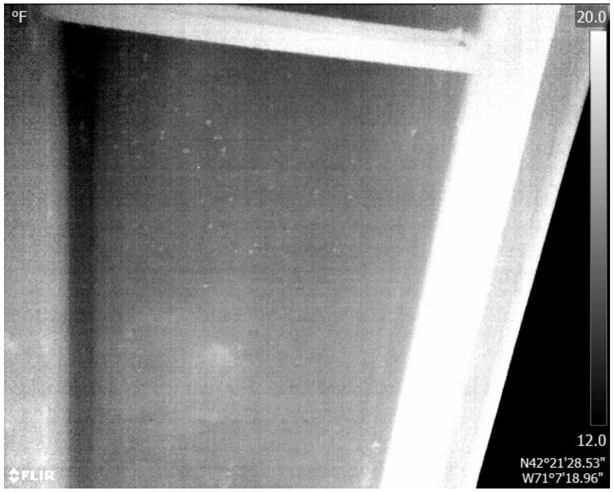


4RT_XT2_Sp6_03_06_IRp_DJI_0871_R

4RT_XT2_Sp6_03_06_RGB_DJI_0872

4RT, UAV-IR Survey, Third Data Set (1/19/22)

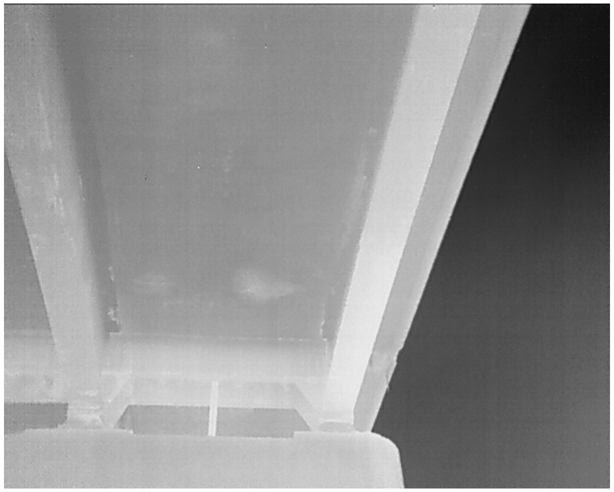
Thermal Deficiencies 7, 8

Automatic Settings	Post Processed	Visual Image
		
4RT_XT2_Sp6_03_07_IR_DJI_0873_R	4RT_XT2_Sp6_03_07_IRp_DJI_0873_R	4RT_XT2_Sp6_03_07_RGB_DJI_0874
		
4RT_XT2_Sp6_03_08_IR_DJI_0869_R	4RT_XT2_Sp6_03_08_IRp_DJI_0869_R	4RT_XT2_Sp6_03_08_RGB_DJI_0870

4RT, UAV-IR Survey, Third Data Set (1/19/22)

Thermal Deficiency 9

Automatic Settings



4RT_XT2_Sp6_03_09_IR_DJI_0867_R

Post Processed

4RT_XT2_Sp6_03_09_IRp_DJI_0867_R

Visual Image

4RT_XT2_Sp6_03_09_RGB_DJI_0868

4RT, IR of Delaminations, First Data Set (10/19/21) Deficiencies 1, 2

Automatic Settings	Post Processed	Visual Image


4RT_XT2_Sp6_VEN_01_01_IR_DJI_0242_R

4RT_XT2_Sp6_VEN_01_01_IRp_DJI_0242_R


4RT_XT2_Sp6_VEN_01_01_RGB_DJI_0243

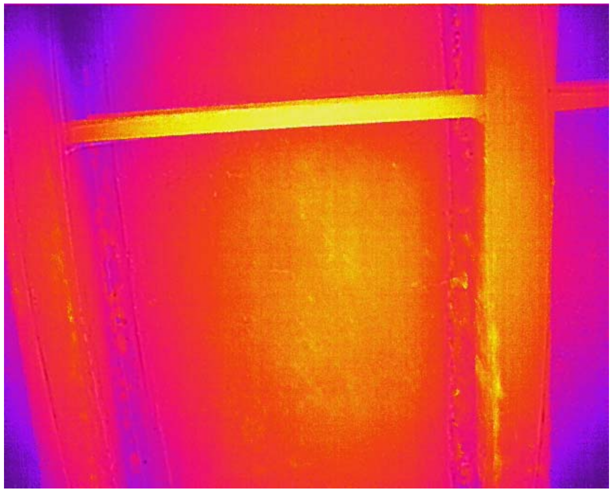
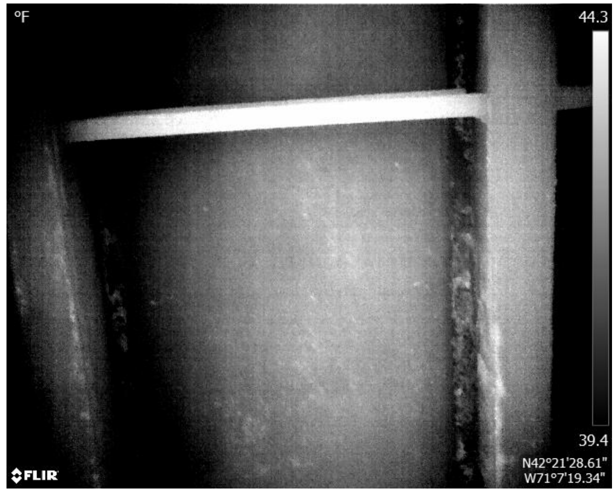
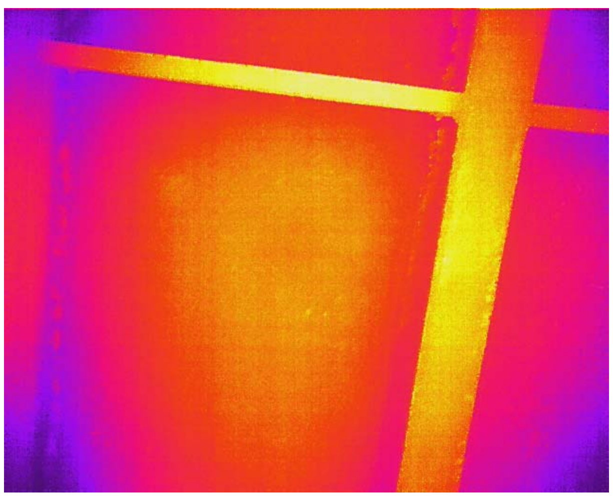
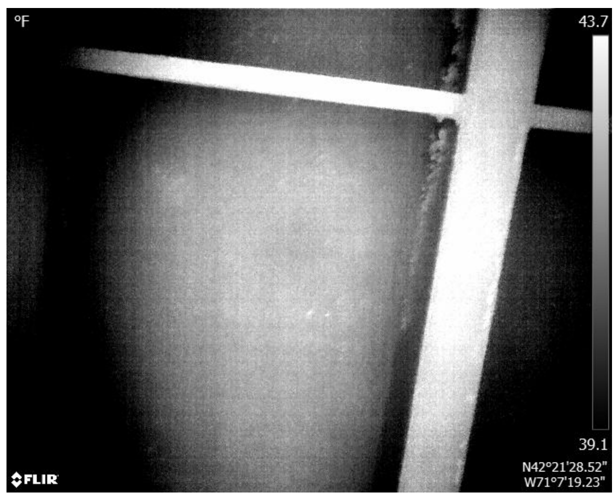

4RT_XT2_Sp6_VEN_01_02_IR_DJI_0240_R

4RT_XT2_Sp6_VEN_01_02_IRp_DJI_0240_R


4RT_XT2_Sp6_VEN_01_02_RGB_DJI_0241

Note: Deficiency numbers correspond to the traditional inspection findings sketch. Only delaminations are included as part of this sketch.

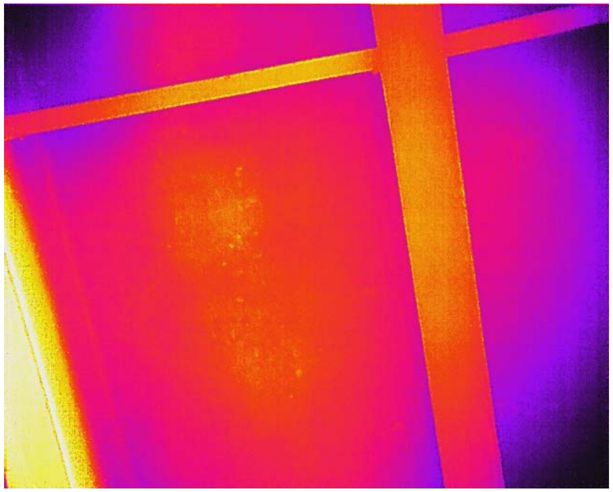
4RT, IR of Delaminations, First Data Set (10/19/21) Deficiencies 5, 6

Automatic Settings	Post Processed	Visual Image
		
4RT_XT2_Sp6_VEN_01_05_IR_DJI_0238_R	4RT_XT2_Sp6_VEN_01_05_IRp_DJI_0238_R	4RT_XT2_Sp6_VEN_01_05_RGB_DJI_0239
		
4RT_XT2_Sp6_VEN_01_06_IR_DJI_0236_R	4RT_XT2_Sp6_VEN_01_06_IRp_DJI_0236_R	4RT_XT2_Sp6_VEN_01_06_RGB_DJI_0237

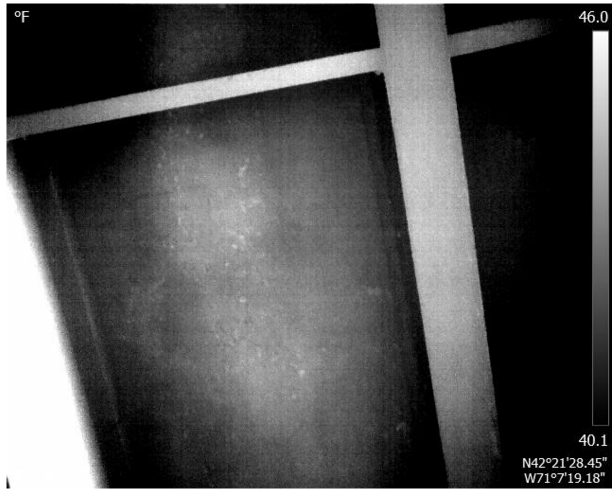
Note: Deficiency numbers correspond to the traditional inspection findings sketch. Only delaminations are included as part of this sketch.

4RT, IR of Delaminations, First Data Set (10/19/21) Deficiencies 7, 9

Automatic Settings | Post Processed | Visual Image



4RT_XT2_Sp6_VEN_01_07_IR_DJI_0234_R



4RT_XT2_Sp6_VEN_01_07_IRp_DJI_0234_R

4RT_XT2_Sp6_VEN_01_07_RGB_DJI_0235

4RT_XT2_Sp6_VEN_01_09_IR_DJI_0244_R

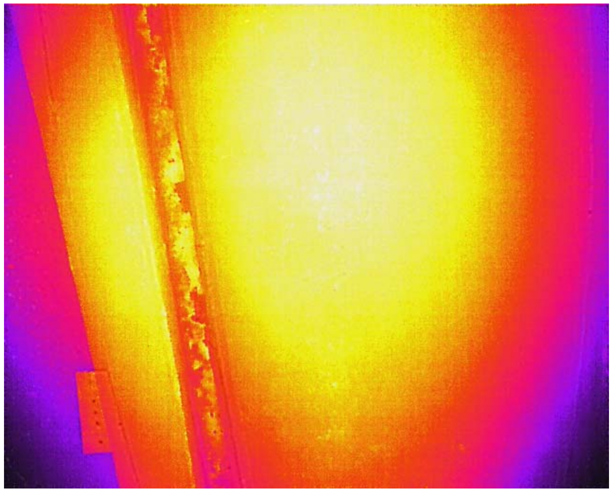
4RT_XT2_Sp6_VEN_01_09_IRp_DJI_0244_R

4RT_XT2_Sp6_VEN_01_09_RGB_DJI_0245

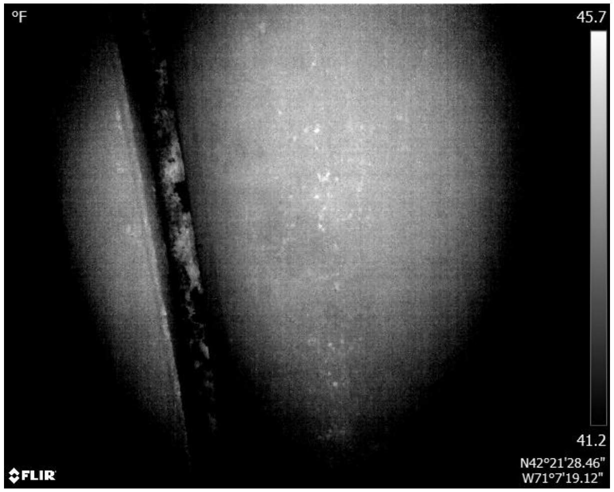
Note: Deficiency numbers correspond to the traditional inspection findings sketch. Only delaminations are included as part of this sketch.

4RT, IR of Delaminations, First Data Set (10/19/21) Deficiencies 11, 12

Automatic Settings | Post Processed | Visual Image

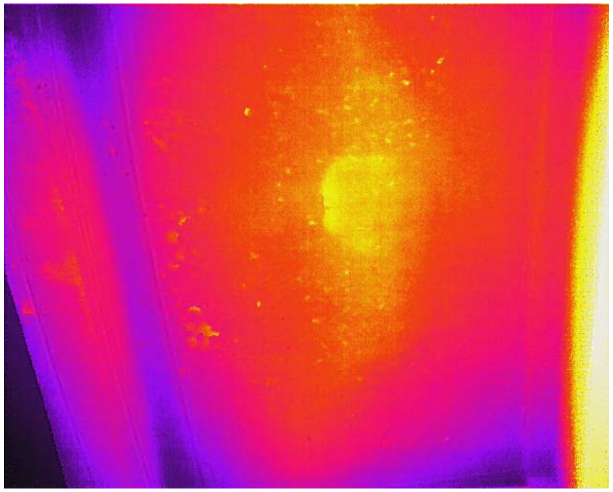


4RT_XT2_Sp6_VEN_01_11_IR_DJI_0246_R



4RT_XT2_Sp6_VEN_01_11_IRp_DJI_0246_R

4RT_XT2_Sp6_VEN_01_11_RGB_DJI_0247



4RT_XT2_Sp6_VEN_01_12_IR_DJI_0248_R

4RT_XT2_Sp6_VEN_01_12_IRp_DJI_0248_R

4RT_XT2_Sp6_VEN_01_12_RGB_DJI_0249

Note: Deficiency numbers correspond to the traditional inspection findings sketch. Only delaminations are included as part of this sketch.

4RT, IR of Delaminations, First Data Set (10/19/21)

Deficiencies 13, 14

Automatic Settings

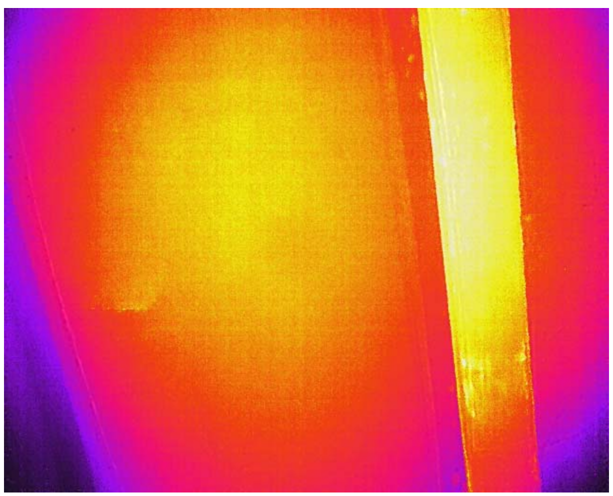
4RT_XT2_Sp6_VEN_01_13_IR_DJI_0258_R

Post Processed

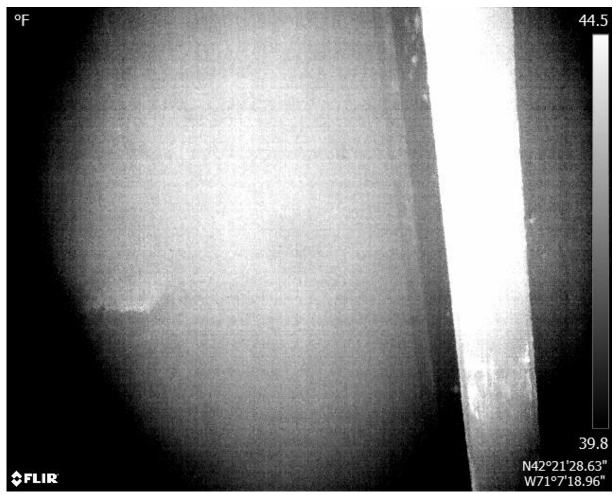
4RT_XT2_Sp6_VEN_01_13_IRp_DJI_0258_R

Visual Image

4RT_XT2_Sp6_VEN_01_13_RGB_DJI_0259



4RT_XT2_Sp6_VEN_01_14_IR_DJI_0256_R

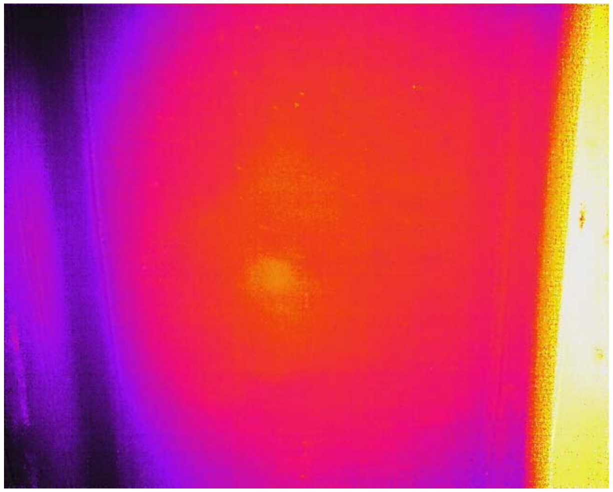
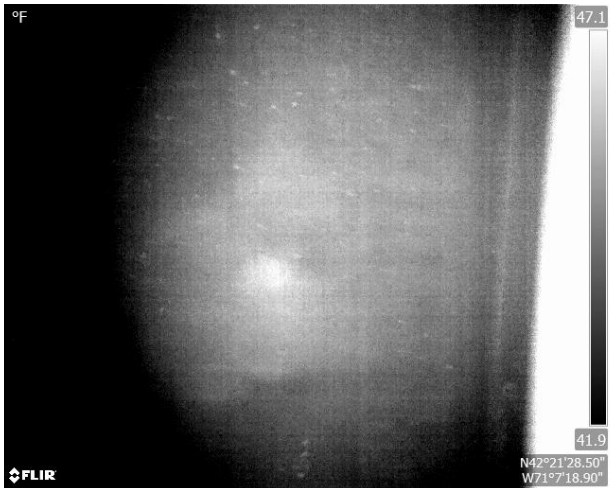
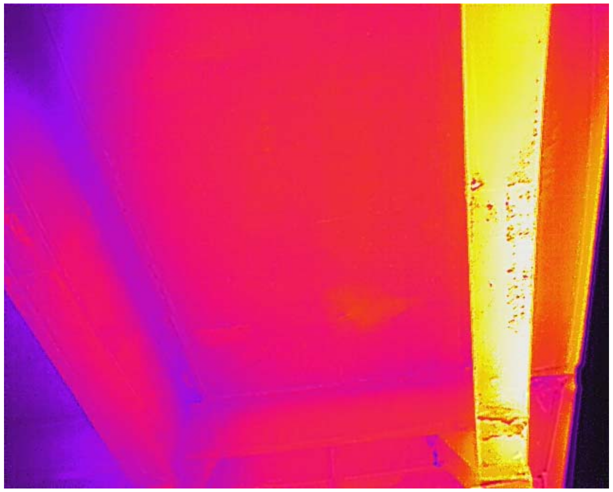


4RT_XT2_Sp6_VEN_01_14_IRp_DJI_0256_R

4RT_XT2_Sp6_VEN_01_14_RGB_DJI_0257

Note: Deficiency numbers correspond to the traditional inspection findings sketch. Only delaminations are included as part of this sketch.

4RT, IR of Delaminations, First Data Set (10/19/21) Deficiencies 15, 16, 17

Automatic Settings	Post Processed	Visual Image
		
4RT_XT2_Sp6_VEN_01_15_IR_DJI_0250_R	4RT_XT2_Sp6_VEN_01_15_IRp_DJI_0250_R	4RT_XT2_Sp6_VEN_01_15_RGB_DJI_0251
		
4RT_XT2_Sp6_VEN_01_16,17_IR_DJI_0252_R	4RT_XT2_Sp6_VEN_01_16,17_IRp_DJI_0252_R	4RT_XT2_Sp6_VEN_01_16,17_RGB_DJI_0253

Note: Deficiency numbers correspond to the traditional inspection findings sketch. Only delaminations are included as part of this sketch.

4RT, IR of Delaminations, Second Data Set (10/22/21) Deficiencies 1, 2

Automatic Settings	Post Processed	Visual Image

4RT_XT2_Sp6_VEN_02_01_IR_DJI_0645_R

4RT_XT2_Sp6_VEN_02_01_IRp_DJI_0645_R

4RT_XT2_Sp6_VEN_02_01_RGB_DJI_0646

4RT_XT2_Sp6_VEN_02_02_IR_DJI_0643_R

4RT_XT2_Sp6_VEN_02_02_IRp_DJI_0643_R

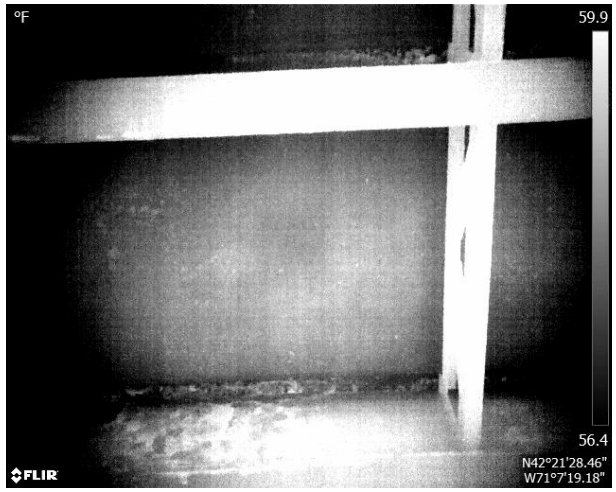
4RT_XT2_Sp6_VEN_02_02_RGB_DJI_0644

Note: Deficiency numbers correspond to the traditional inspection findings sketch. Only delaminations are included as part of this sketch.

4RT, IR of Delaminations, Second Data Set (10/22/21) Deficiencies 5, 6

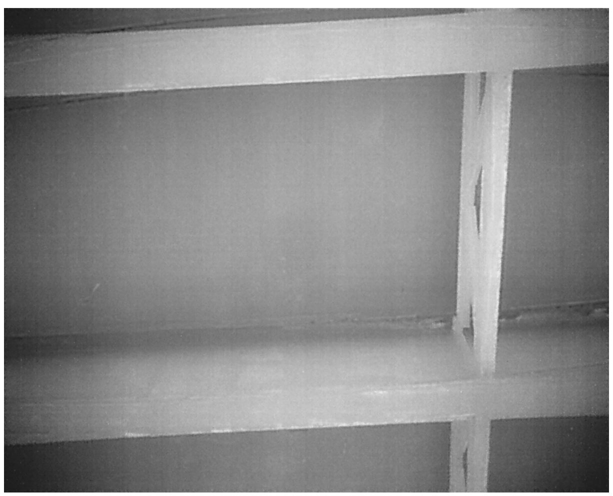
Automatic Settings	Post Processed	Visual Image

4RT_XT2_Sp6_VEN_02_05_IR_DJI_0639_R

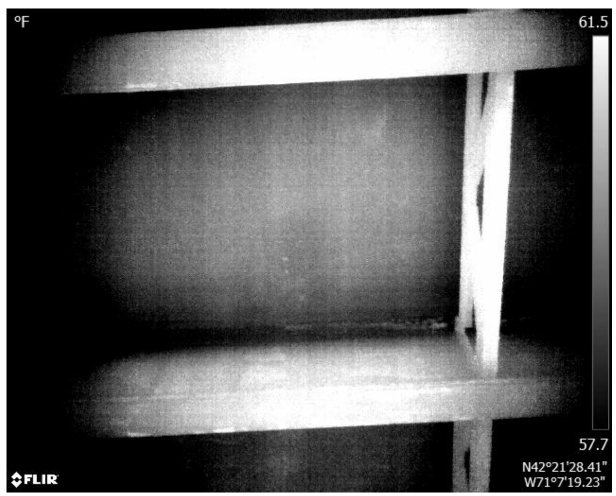


4RT_XT2_Sp6_VEN_02_05_IRp_DJI_0639_R

4RT_XT2_Sp6_VEN_02_05_RGB_DJI_0640



4RT_XT2_Sp6_VEN_02_06_IR_DJI_0637_R



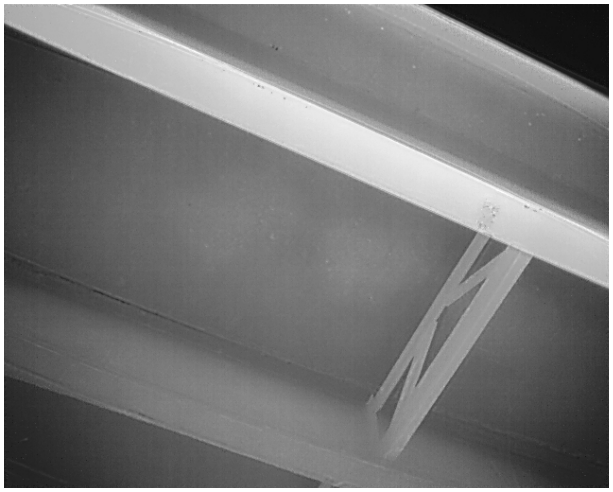
4RT_XT2_Sp6_VEN_02_06_IRp_DJI_0637_R

4RT_XT2_Sp6_VEN_02_06_RGB_DJI_0638

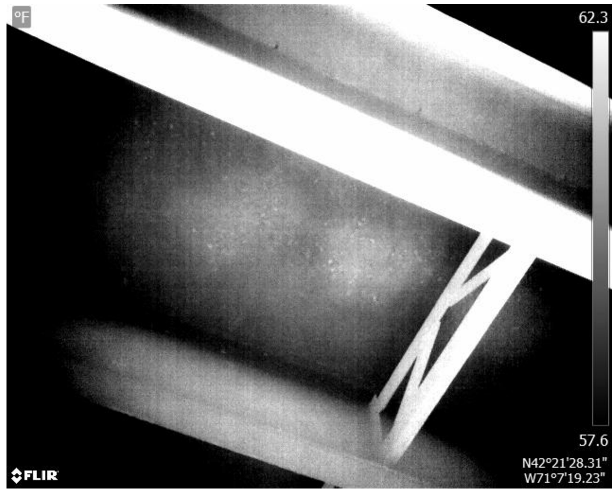
Note: Deficiency numbers correspond to the traditional inspection findings sketch. Only delaminations are included as part of this sketch.

4RT, IR of Delaminations, Second Data Set (10/22/21) Deficiencies 7, 9

Automatic Settings | Post Processed | Visual Image

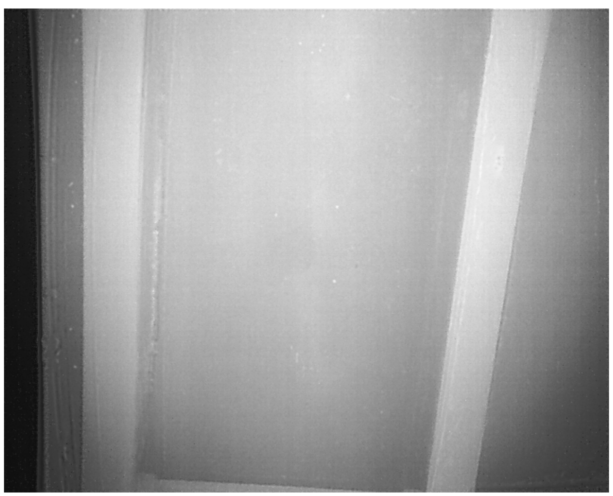


4RT_XT2_Sp6_VEN_02_07_IR_DJI_0635_R

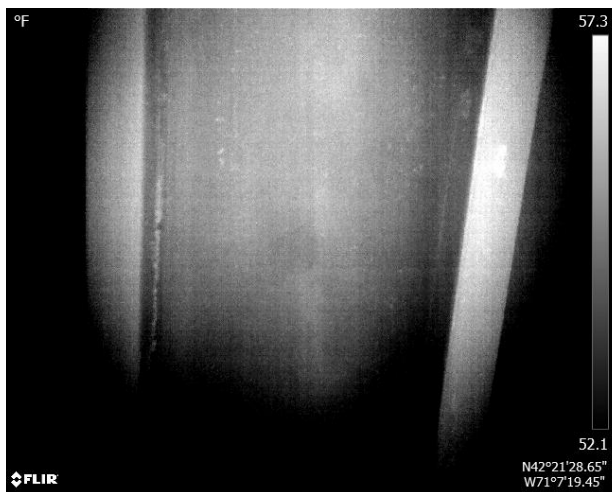


4RT_XT2_Sp6_VEN_02_07_IRp_DJI_0635_R

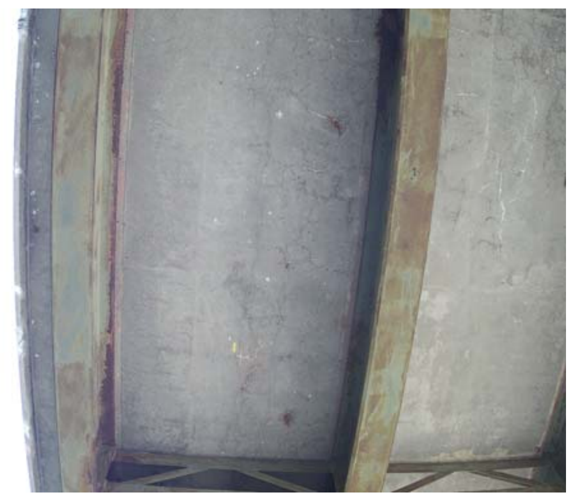
4RT_XT2_Sp6_VEN_02_07_RGB_DJI_0636



4RT_XT2_Sp6_VEN_02_09_IR_DJI_0627_R



4RT_XT2_Sp6_VEN_02_09_IRp_DJI_0627_R



4RT_XT2_Sp6_VEN_02_09_RGB_DJI_0628

Note: Deficiency numbers correspond to the traditional inspection findings sketch. Only delaminations are included as part of this sketch.

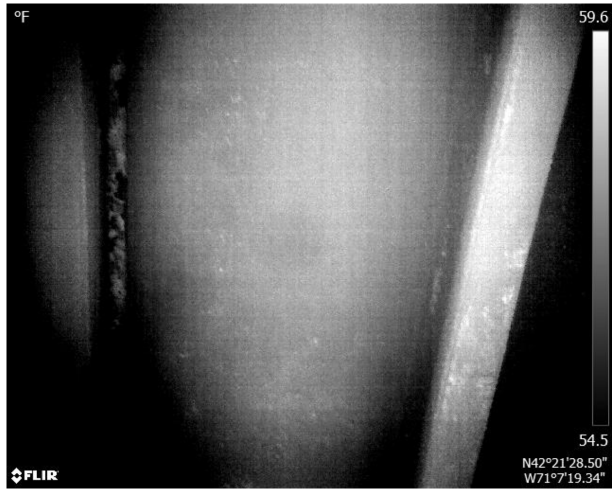
4RT, IR of Delaminations, Second Data Set (10/22/21) Deficiencies 11, 12

Automatic Settings

Post Processed

Visual Image

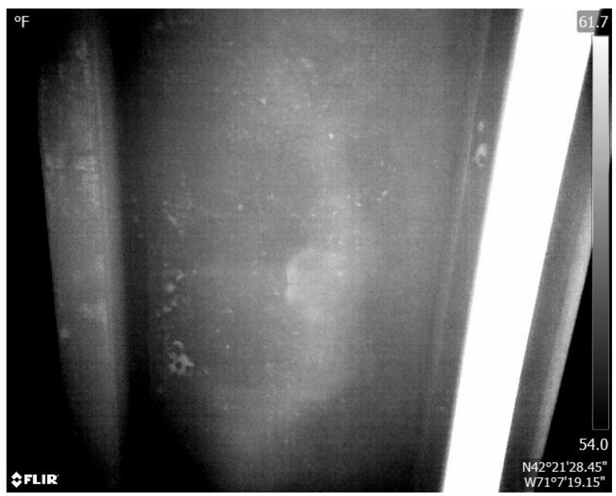
4RT_XT2_Sp6_VEN_02_11_IR_DJI_0629_R



4RT_XT2_Sp6_VEN_02_11_IRp_DJI_0629_R

4RT_XT2_Sp6_VEN_02_11_RGB_DJI_0630

4RT_XT2_Sp6_VEN_02_12_IR_DJI_0631_R



4RT_XT2_Sp6_VEN_02_12_IRp_DJI_0631_R

4RT_XT2_Sp6_VEN_02_12_RGB_DJI_0632

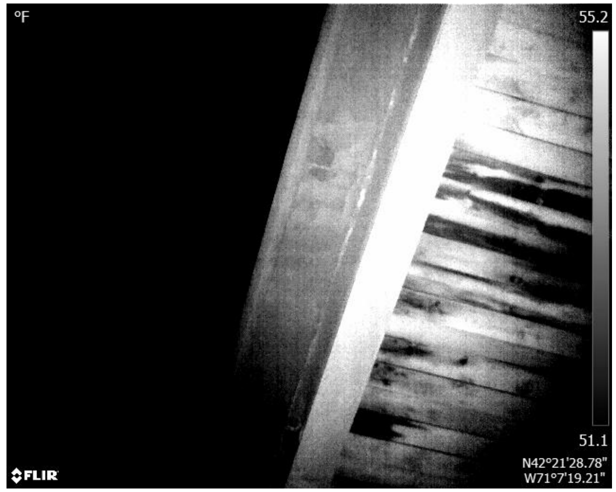
Note: Deficiency numbers correspond to the traditional inspection findings sketch. Only delaminations are included as part of this sketch.

4RT, IR of Delaminations, Second Data Set (10/22/21)

Deficiencies 13, 14

Automatic Settings	Post Processed	Visual Image

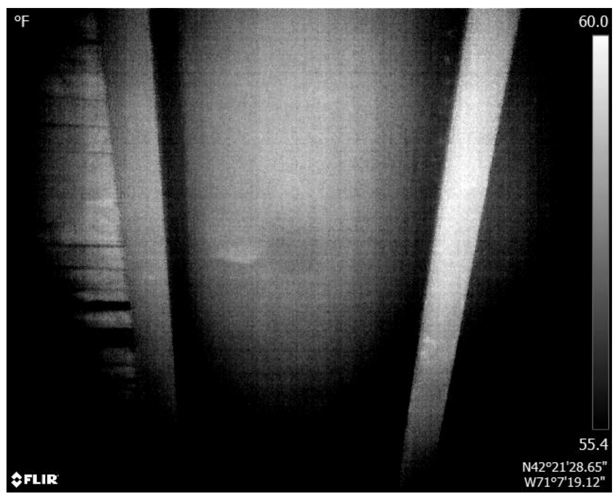
4RT_XT2_Sp6_VEN_02_13_IR_DJI_0625_R



4RT_XT2_Sp6_VEN_02_13_IRp_DJI_0625_R

4RT_XT2_Sp6_VEN_02_13_RGB_DJI_0626

4RT_XT2_Sp6_VEN_02_14_IR_DJI_0623_R



4RT_XT2_Sp6_VEN_02_14_IRp_DJI_0623_R

4RT_XT2_Sp6_VEN_02_14_RGB_DJI_0624

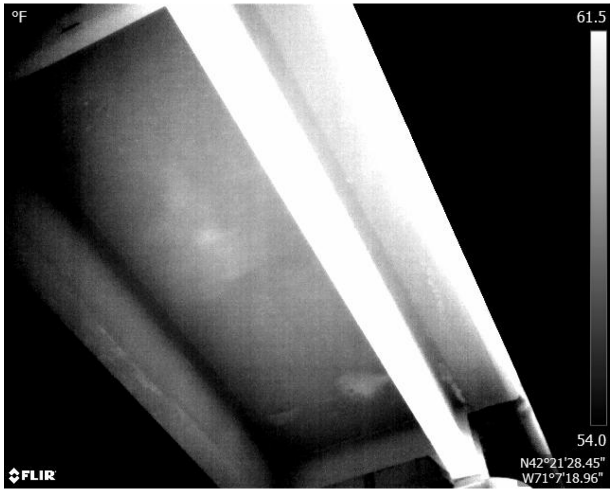
Note: Deficiency numbers correspond to the traditional inspection findings sketch. Only delaminations are included as part of this sketch.

4RT, IR of Delaminations, Second Data Set (10/22/21) Deficiencies 15, 16, 17

Automatic Settings

4RT_XT2_Sp6_VEN_02_15,16,17_IR_DJI_0621_R

Post Processed



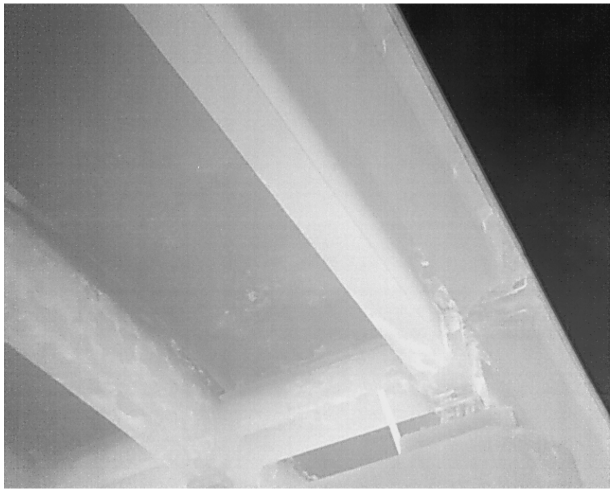
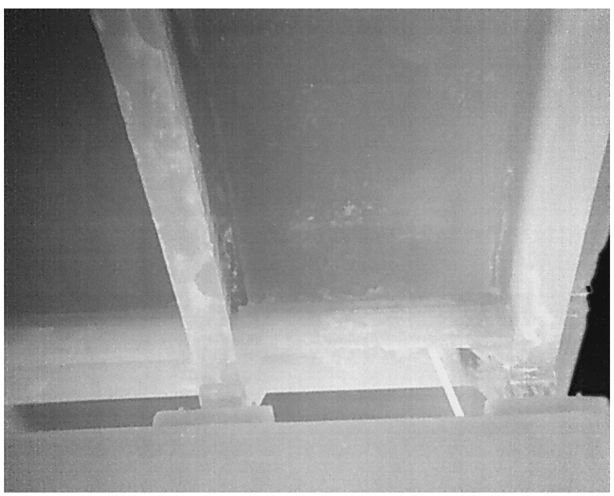
4RT_XT2_Sp6_VEN_02_15,16,17_IRp_DJI_0621_R

Visual Image

4RT_XT2_Sp6_VEN_02_15,16,17_RGB_DJI_0622

Note: Deficiency numbers correspond to the traditional inspection findings sketch. Only delaminations are included as part of this sketch.

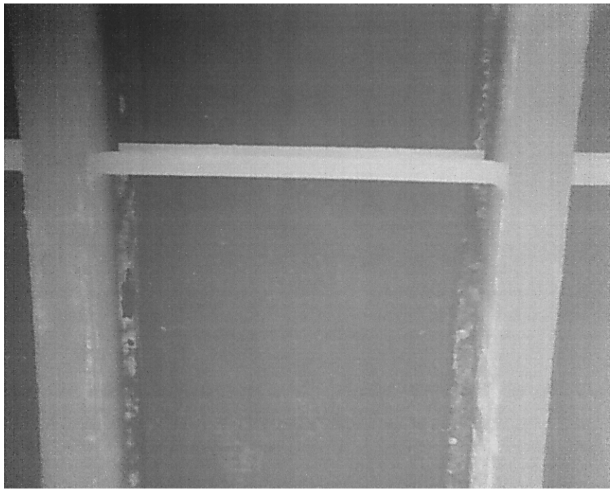
4RT, IR of Delaminations, Third Data Set (1/19/22) Deficiencies 1, 2

Automatic Settings	Post Processed	Visual Image
		
4RT_XT2_Sp6_VEN_03_01_IR_DJI_0917_R	4RT_XT2_Sp6_VEN_03_01_IRp_DJI_0917_R	4RT_XT2_Sp6_VEN_03_01_RGB_DJI_0918
		
4RT_XT2_Sp6_VEN_03_02_IR_DJI_0915_R	4RT_XT2_Sp6_VEN_03_02_IRp_DJI_0915_R	4RT_XT2_Sp6_VEN_03_02_RGB_DJI_0916

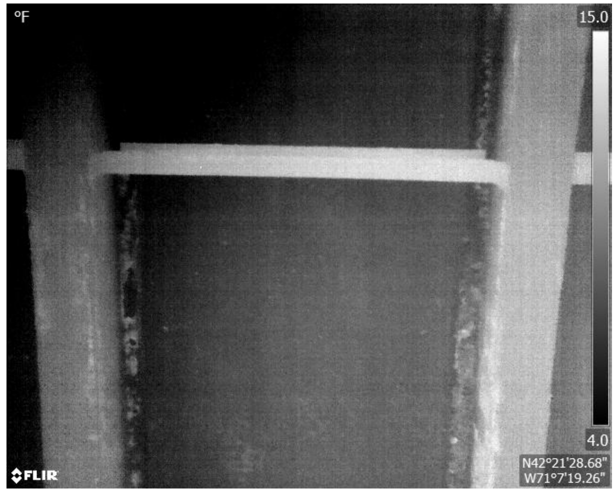
Note: Deficiency numbers correspond to the traditional inspection findings sketch. Only delaminations are included as part of this sketch.

4RT, IR of Delaminations, Third Data Set (1/19/22) Deficiencies 5, 6

Automatic Settings	Post Processed	Visual Image

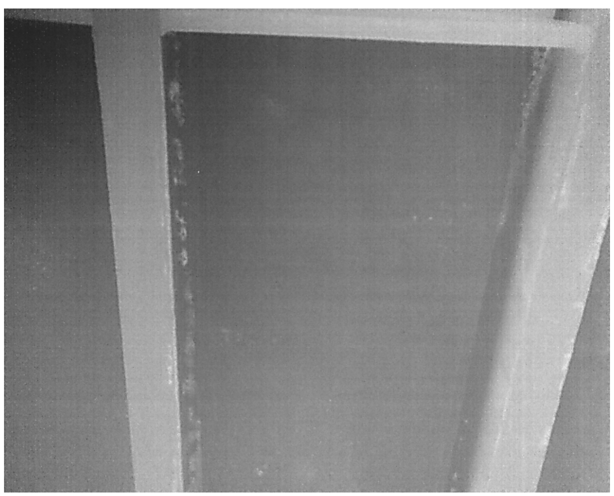


4RT_XT2_Sp6_VEN_03_05_IR_DJI_0911_R

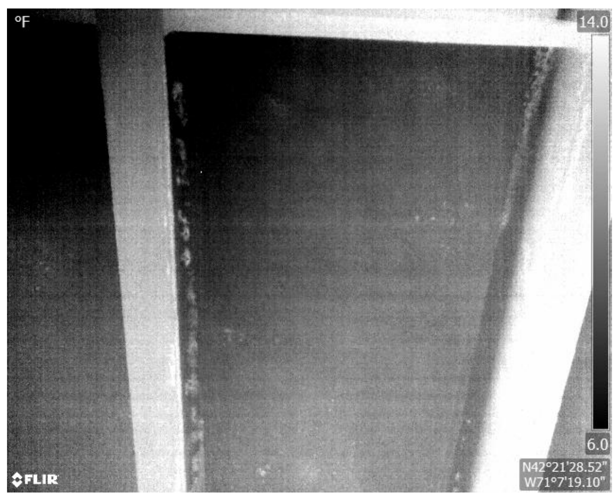


4RT_XT2_Sp6_VEN_03_05_IRp_DJI_0911_R

4RT_XT2_Sp6_VEN_03_05_RGB_DJI_0912



4RT_XT2_Sp6_VEN_03_06_IR_DJI_0907_R



4RT_XT2_Sp6_VEN_03_06_IRp_DJI_0907_R

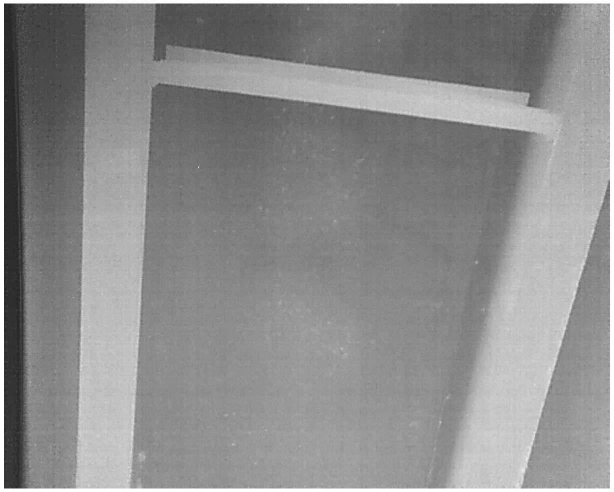
4RT_XT2_Sp6_VEN_03_06_RGB_DJI_0908

Note: Deficiency numbers correspond to the traditional inspection findings sketch. Only delaminations are included as part of this sketch.

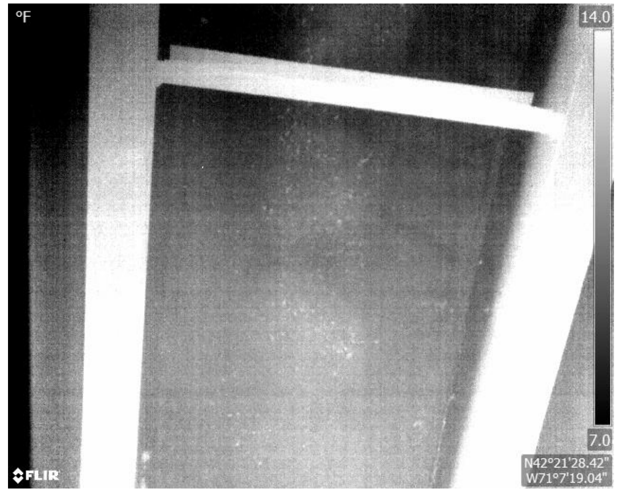
4RT, IR of Delaminations, Third Data Set (1/19/22)

Deficiencies 7, 9

Automatic Settings	Post Processed	Visual Image

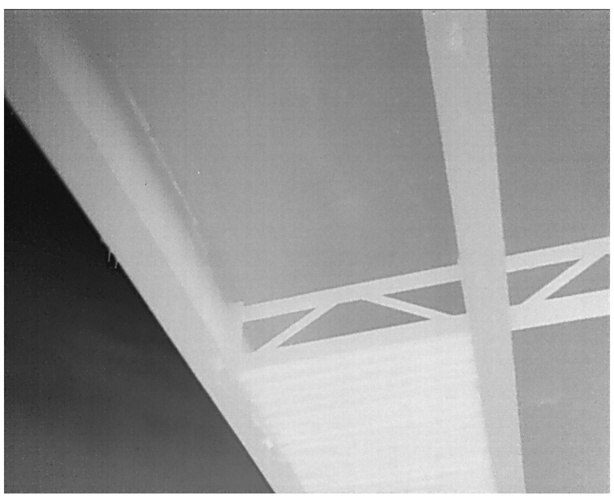


4RT_XT2_Sp6_VEN_03_07_IR_DJI_0905_R



4RT_XT2_Sp6_VEN_03_07_IRp_DJI_0905_R

4RT_XT2_Sp6_VEN_03_07_RGB_DJI_0906



4RT_XT2_Sp6_VEN_03_09_IR_DJI_0897_R

4RT_XT2_Sp6_VEN_03_09_IRp_DJI_0897_R

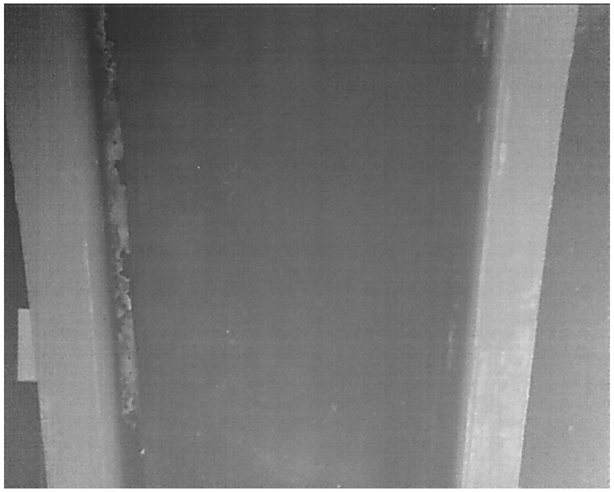
4RT_XT2_Sp6_VEN_03_09_RGB_DJI_0898

Note: Deficiency numbers correspond to the traditional inspection findings sketch. Only delaminations are included as part of this sketch.

4RT, IR of Delaminations, Third Data Set (1/19/22)

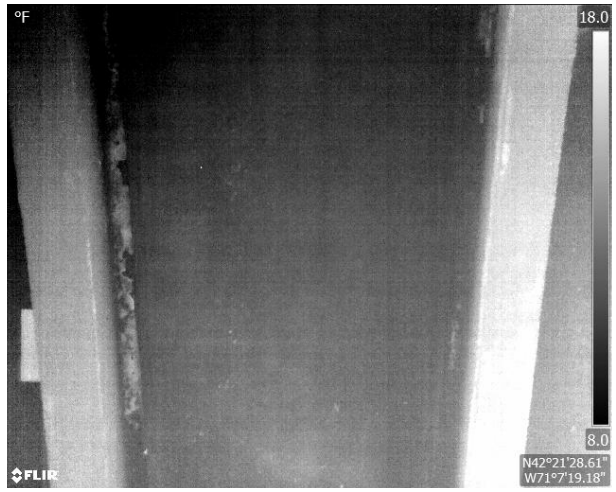
Deficiencies 11, 12

Automatic Settings



4RT_XT2_Sp6_VEN_03_11_IR_DJI_0901_R

Post Processed



4RT_XT2_Sp6_VEN_03_11_IRp_DJI_0901_R

Visual Image

4RT_XT2_Sp6_VEN_03_11_RGB_DJI_0902

4RT_XT2_Sp6_VEN_03_12_IR_DJI_0903_R

4RT_XT2_Sp6_VEN_03_12_IRp_DJI_0903_R

4RT_XT2_Sp6_VEN_03_12_RGB_DJI_0904

Note: Deficiency numbers correspond to the traditional inspection findings sketch. Only delaminations are included as part of this sketch.

4RT, IR of Delaminations, Third Data Set (1/19/22)

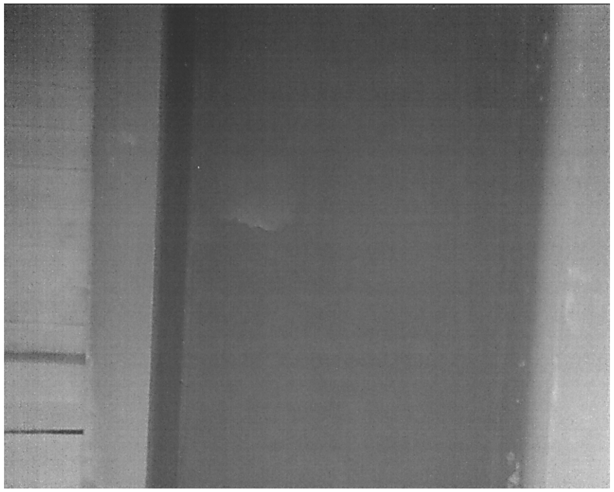
Deficiencies 13, 14

Automatic Settings | Post Processed | Visual Image

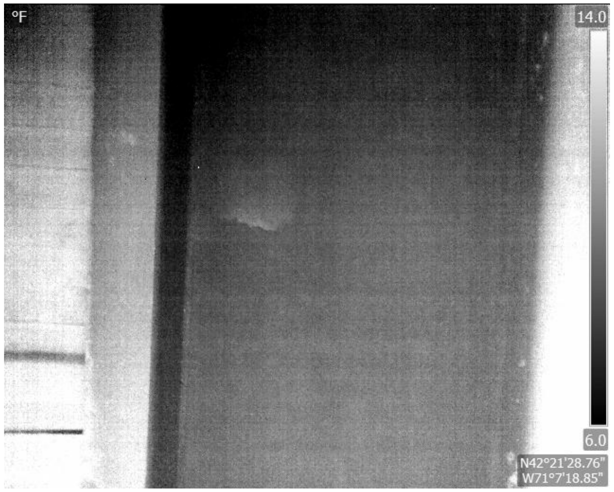
4RT_XT2_Sp6_VEN_03_13_IR_DJI_0895_R

4RT_XT2_Sp6_VEN_03_13_IRp_DJI_0895_R

4RT_XT2_Sp6_VEN_03_13_RGB_DJI_0896



4RT_XT2_Sp6_VEN_03_14_IR_DJI_0893_R



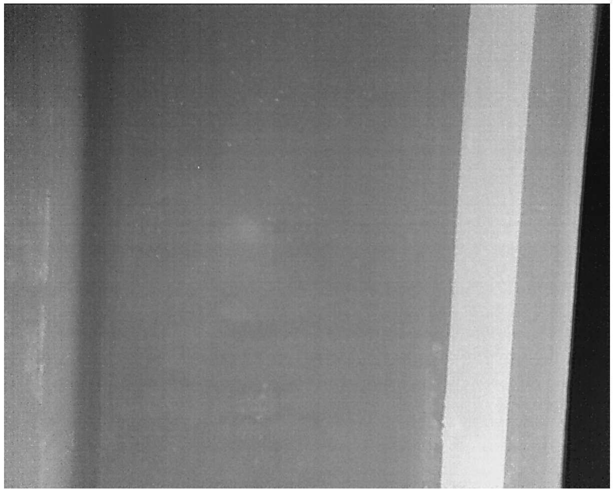
4RT_XT2_Sp6_VEN_03_14_IRp_DJI_0893_R

4RT_XT2_Sp6_VEN_03_14_RGB_DJI_0894

Note: Deficiency numbers correspond to the traditional inspection findings sketch. Only delaminations are included as part of this sketch.

4RT, IR of Delaminations, Third Data Set (1/19/22) Deficiencies 15, 16 ,17

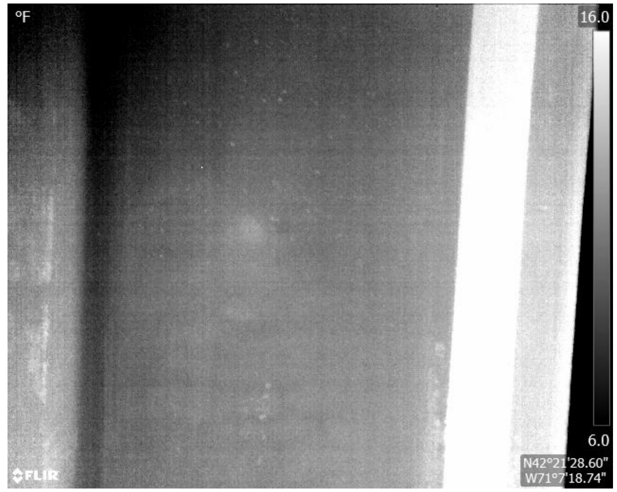
Automatic Settings



4RT_XT2_Sp6_VEN_03_15_IR_DJI_0891_R

4RT_XT2_Sp6_VEN_03_16,17_IR_DJI_0889_R

Post Processed



4RT_XT2_Sp6_VEN_03_15_IRp_DJI_0891_R

4RT_XT2_Sp6_VEN_03_16,17_IRp_DJI_0889_R

Visual Image

4RT_XT2_Sp6_VEN_03_15_RGB_DJI_0892

4RT_XT2_Sp6_VEN_03_16,17_RGB_DJI_0890

Note: Deficiency numbers correspond to the traditional inspection findings sketch. Only delaminations are included as part of this sketch.