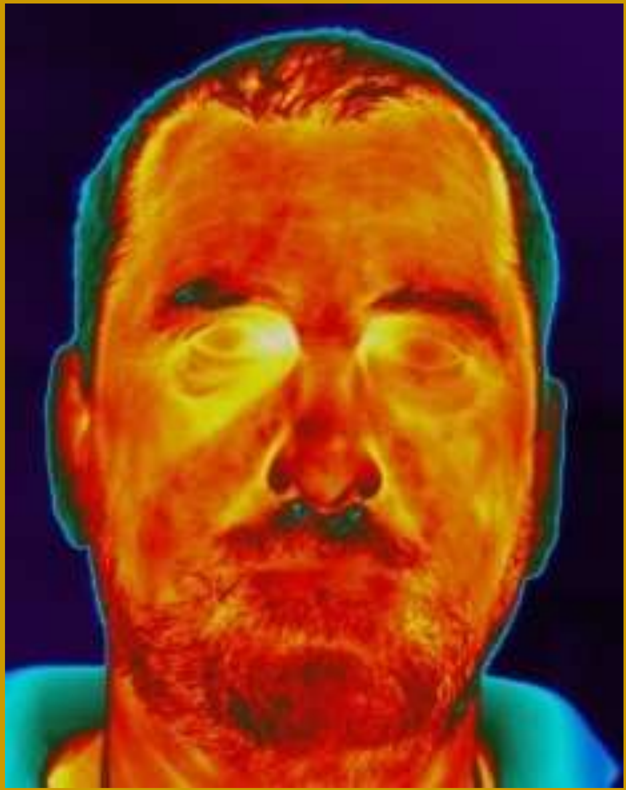
NORTHERN OHIO CHAPTER

The Use of Thermal Imaging Technology

Anchor Elite, LLC

Stockton
Infrared Thermographic Services



Greg Stockton

Abstract

Thermal imaging has become much more popular over the past 10 years because uncooled microbolometer technology has lowered prices significantly on the infrared (IR) equipment. Low-end infrared cameras are priced in the $4-$9k range and very low resolution imagers are now even available as add-ons to cell phones priced in the couple of hundred dollar range.

Knowing the potential uses -and importantly, the limitations of thermal imaging will help you decide whether it might be wise to perform thermal imaging of facilities and/or electro-mechanical equipment for purposes of commissioning, diagnostic and/or condition-based maintenance activities. As shown in the abstract, this presentation gives an overview of IR cameras and uses for IR thermography.

NORTHERN OHIO CHAPTER

Overview

- Basic physics of thermal infrared imaging
- IR imagers available and their limitations
- Building infrared thermography
  - Heat loss
  - Air leakage
  - HVAC systems
  - Structural defects and design flaws
  - Moisture intrusion
  - Roof moisture detection
- Aerial thermal mapping
  - Various infrastructure uses
  - Steam, hot water, and chilled water distribution systems
  - Water mains, storm water and sewer systems
  - Solar panels and solar fields
- Electrical switchgear testing thermal modeling
- Thermal mapping at data centers
- Steam systems and infrared

Basics of Thermal Imaging

NORTHERN OHIO CHAPTER

Gregory R. Stockton, CIT

About the Presenter

Stockton Infrared Thermographic Services, Inc.
United Infrared, Inc.

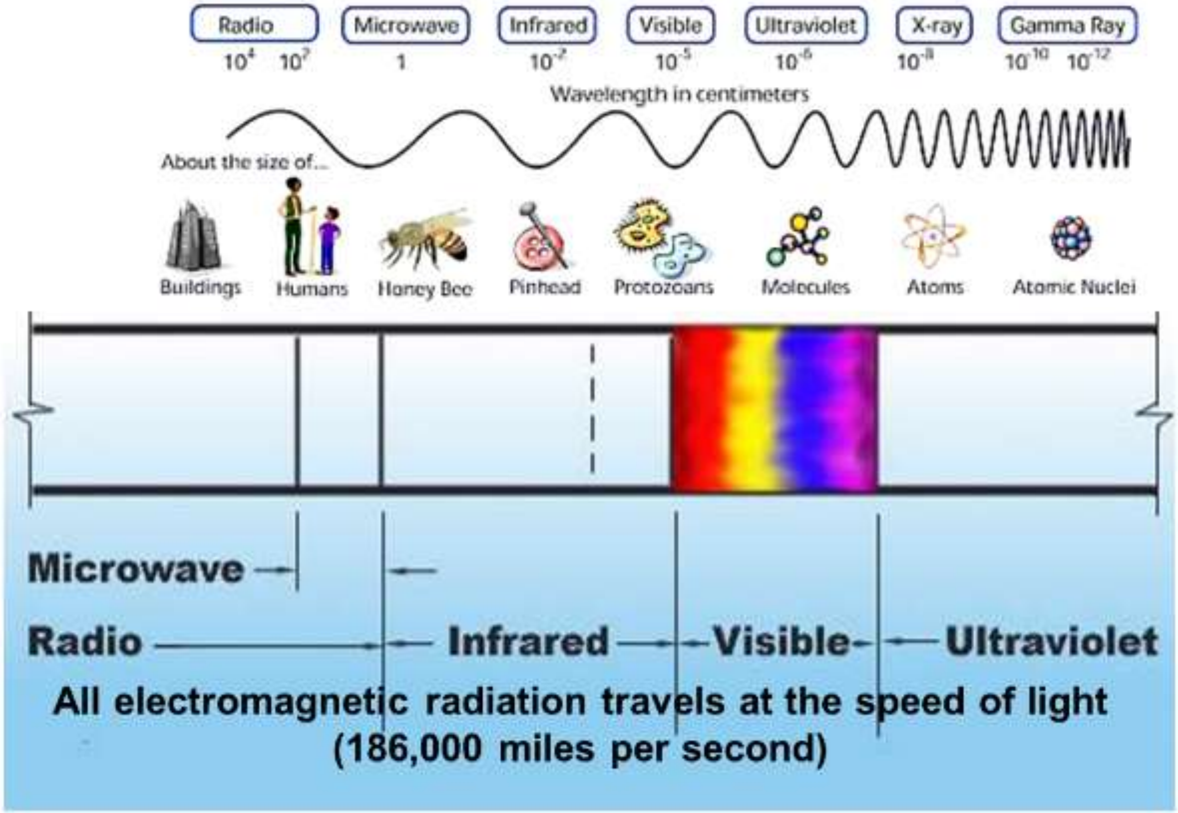
Greg has been a practicing infrared thermographer since 1989. He is a Level III Certified Infrared Thermographer with twenty-seven years experience in the construction industry, specializing in maintenance and energy-related technologies.

Mr. Stockton has published fourteen technical papers on the subject of infrared thermography and written numerous articles about applications for infrared thermography in trade publications. He is a member of the Program Committee of SPIE (Society of Photo-Optical Instrumentation Engineers), 2012-2013 Chairman of Thermosense and Chairman of the Buildings & Infrastructures Session at the Defense and Security Symposium.

Thermal 101

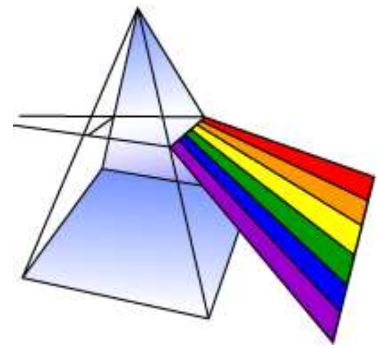
Electromagnetic waves travels at the speed of light(c), and are characterized by frequency (ν) or wavelength (λ) and amplitude. The frequency and wavelength are related by the equation $c = \nu\lambda$. The relationship between energy and frequency is given by Planck's Law, $E = h\nu$, which can be expressed as $E = hc / \lambda$.

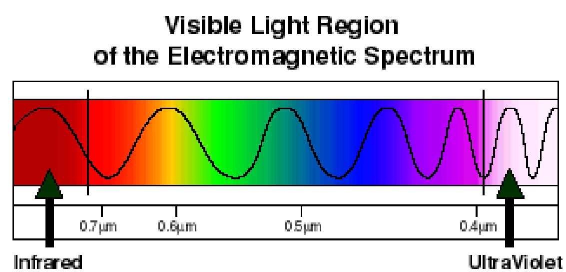
All objects that are not at absolute zero emit infrared radiation. Absolute zero defines the temperature where all molecular motion ceases, and is the coldest possible temperature. It corresponds to about minus 273 degrees Celsius, or minus 460 degrees Fahrenheit. Physicists define this point to be zero degrees Kelvin, with each increment on the Kelvin scale identical to that of the Celsius scale.



Visible Light = 400-700 namometers

violet	380–450 nm
blue	450–495 nm
green	495–570 nm
yellow	570–590 nm
orange	590–620 nm
red	620–750 nm





Energy with wavelengths too short for humans to see is Ultra-Violet light.

"Ultra" means higher than.

Energy with wavelengths too long for humans to see is Infra-Red light.

"Infra" means lower than.

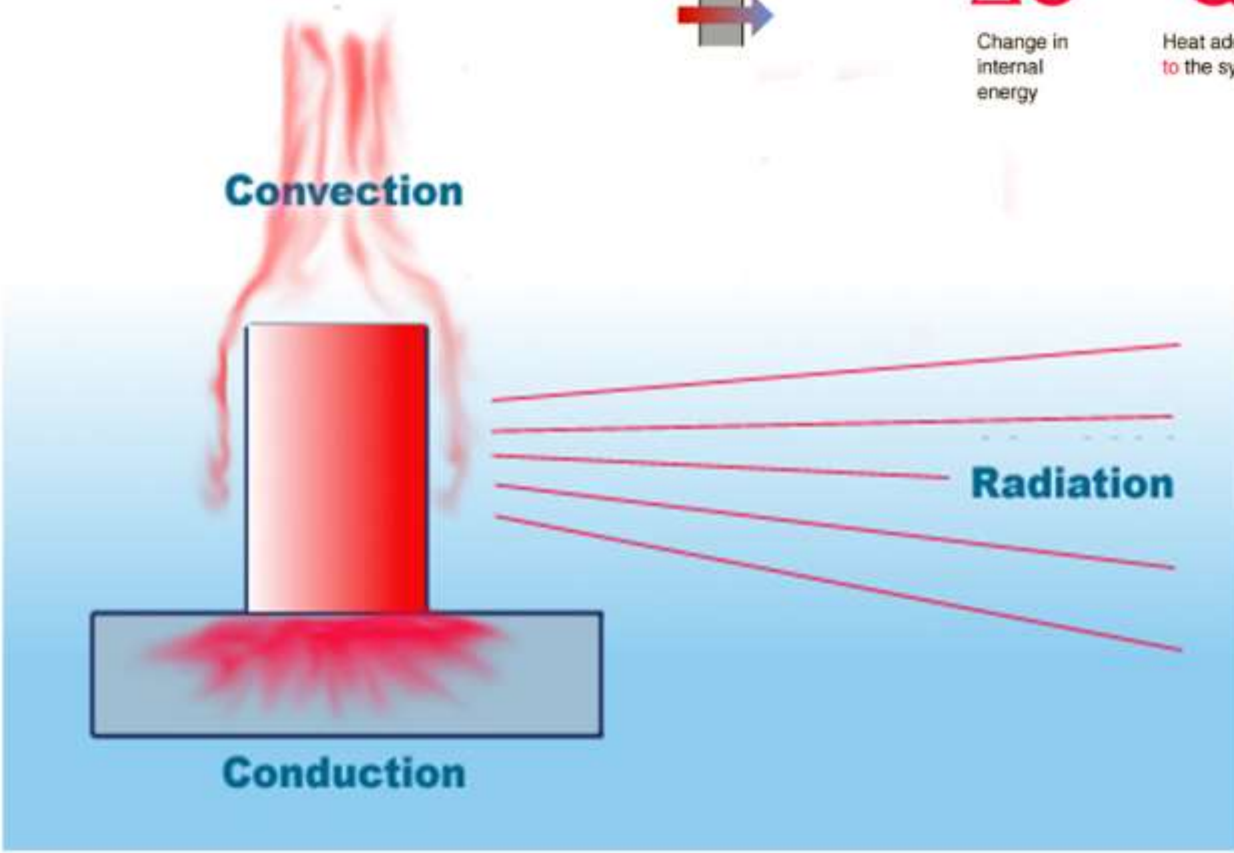
Thermal Infrared

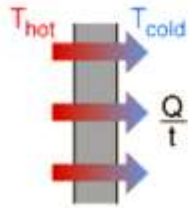
short-wave (1.3-2.5 µm)

mid-wave (3-5 µm)

long-wave (8-14 µm)

Thermal Imaging Basics





First Law of Thermodynamics

The change in internal energy of a system is equal to the heat added to the system minus the work done by the system.

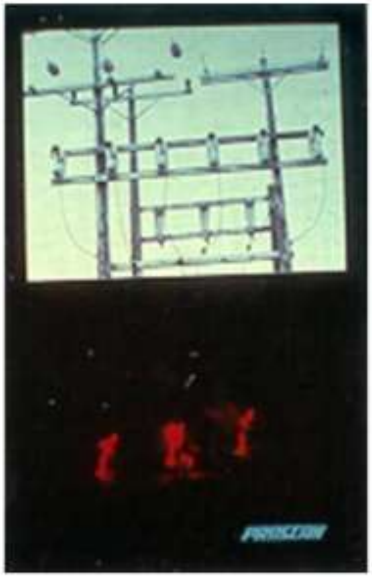
$$\Delta U = Q - W$$

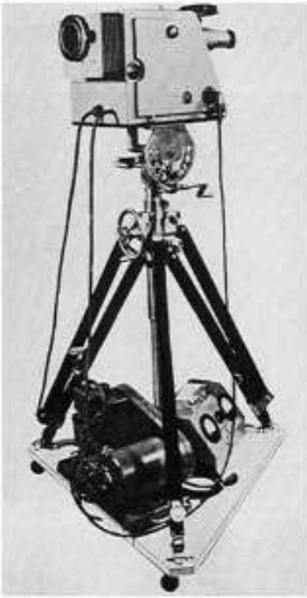
Change in internal energy — Heat added to the system — Work done by the system

Ludwig Boltzmann

- 1940
  - PbS, Tl_2S
- 1950
  - PbSe, PbTe
  - Ge:X, InSb
  - HgCdTe
- 1960
  - PbSnTe
  - Si:X
- 1970
  - Silicide Schottky-barrier detectors Si:X/CCD
  - HgCdTe, PbSnTe/CCD
- 1980
  - HgCdTe SPRITE
  - InGaAs
  - QWIP Multirow (TDI function) second/third (staring) generation MCT hybrid arrays
- 1990
  - FPAs
- 2000
  - Uncooled Microbolometers
  - In the Future ---Thin Films

Next...photodiode and phototransistor





Infrared Imager History and Current Technology

Thermal imaging is one of the most powerful technologies ever developed to enhance human vision.

Normally, our vision is limited to a very small portion of the electromagnetic spectrum. Thermal energy has a much longer wavelength than visible light. So long, in fact, that the human eye can't even see it, just like we can't see radio waves.

With thermal imaging, the portion of the spectrum we perceive is dramatically expanded, helping us "see" heat. Visible light doesn't affect the thermal world, so you can see equally well in highly lit and totally dark environments.

The FLIR ONE™ thermal camera allows us to see things the naked eye could never perceive on its own.

WHAT DO YOU GET?

FLIR ONE is lightweight, easy to connect and easy to use.

LIGHT AND COMPACT

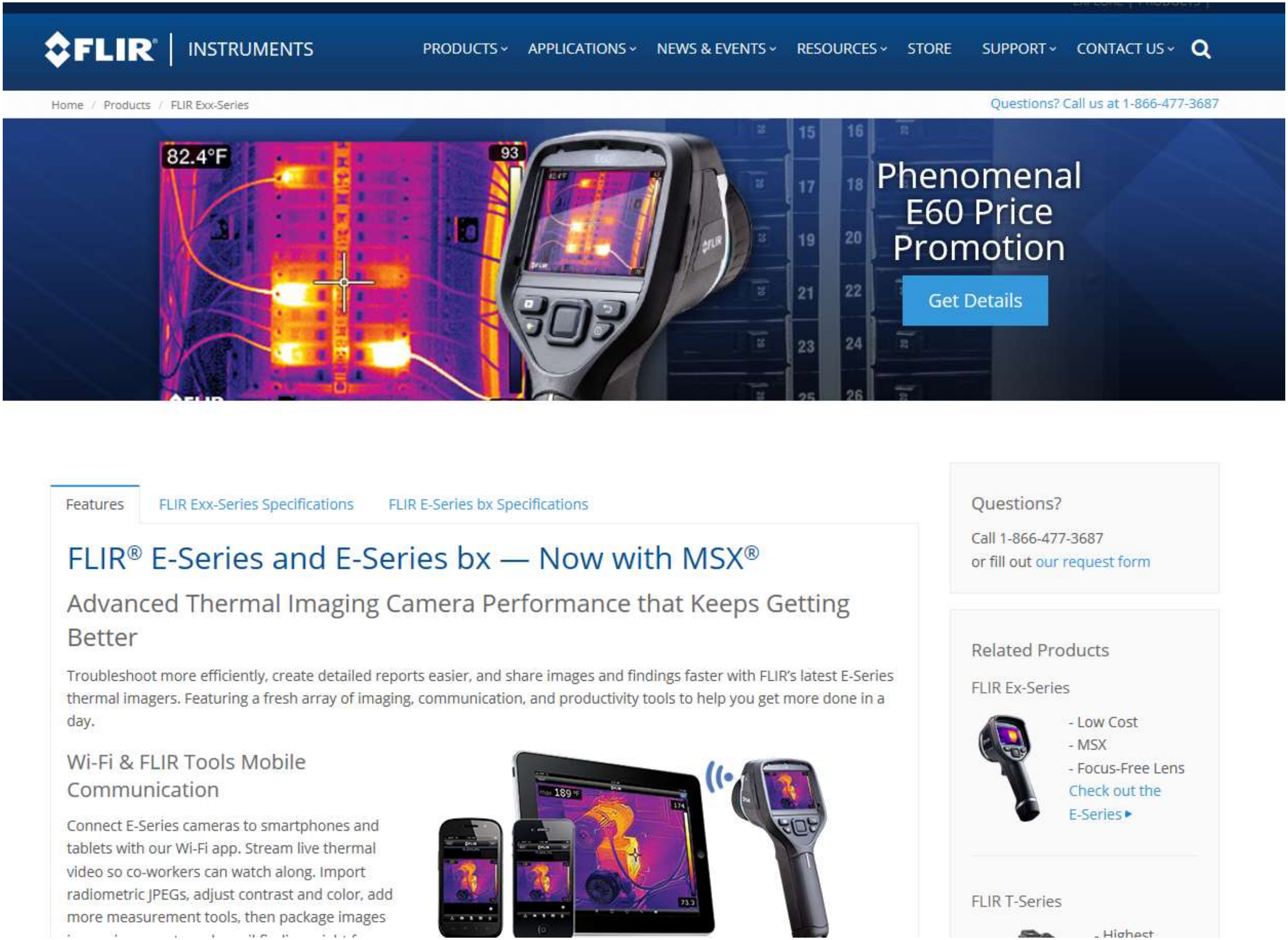
Weighs just 3.9 ounces, and displays directly on your phone's screen.

You'll explore the world around you in ways you never thought possible, with no additional cords, cases, devices or screens necessary. Pop it onto your iPhone5 or 5s, and take it with you wherever you go. A new world of vision in the palm of your hand.

Why does my FLIR ONE have two cameras?

MSX® Technology

Raw thermal images are beautiful, however, they don't provide too much physical detail. So the FLIR ONE blends both images using MSX Technology, providing physical detail to the raw thermal reading.



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Phenomenal E60 Price Promotion

Get Details

Features | FLIR Exx-Series Specifications | FLIR E-Series bx Specifications

FLIR® E-Series and E-Series bx — Now with MSX®

Advanced Thermal Imaging Camera Performance that Keeps Getting Better

Troubleshoot more efficiently, create detailed reports easier, and share images and findings faster with FLIR's latest E-Series thermal imagers. Featuring a fresh array of imaging, communication, and productivity tools to help you get more done in a day.

Wi-Fi & FLIR Tools Mobile Communication

Connect E-Series cameras to smartphones and tablets with our Wi-Fi app. Stream live thermal video so co-workers can watch along. Import radiometric JPEGs, adjust contrast and color, add more measurement tools, then package images

Questions?

Call 1-866-477-3687
or fill out our request form

Related Products

FLIR Ex-Series

- Low Cost
- MSX
- Focus-Free Lens

Check out the E-Series ▸

FLIR T-Series

- Highest

FLIR T-Series Thermal Imaging Cameras

Now featuring UltraMax™ and the New T460 & T660

You need troubleshooting tools that can help you find and report equipment problems fast. That's exactly what T-Series cameras do. They let you see invisible heat caused by electrical resistance and mechanical wear early enough to help you head off expensive downtime and potential danger.

Watch the video to learn why no other line of infrared cameras makes it easier to capture images, share findings, and get more done with time to spare. And be sure to ask for an onsite demonstration to see firsthand why T-Series is the ultimate way to unleash the power of FLIR.

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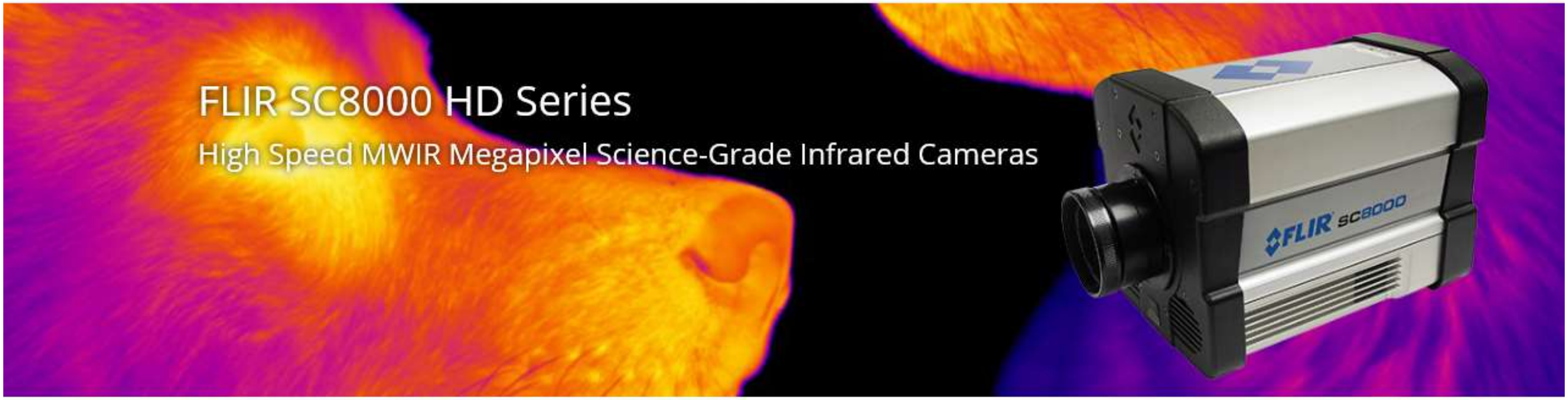


Research & Science

- Research & Development
- Life Sciences
- Environmental
- Animal Sciences
- Science & Theory
- Electronics
- Auto Racing

Entry Level Systems

- FLIR Bench Top Test Kits
- FLIR A325sc
- FLIR T400 Series

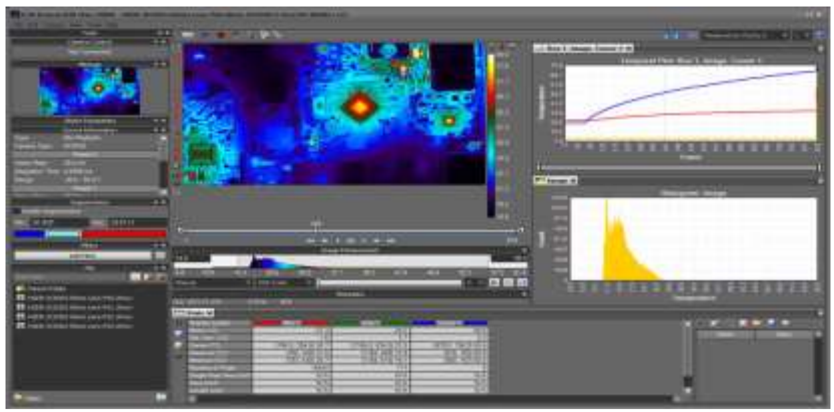
Performance Systems

- FLIR A655sc
- FLIR T600 Series
- FLIR A6250sc
- FLIR A6700sc
- FLIR A8300sc
- FLIR SC7000 Series

FLIR SC8000 HD Series

High Speed MWIR Megapixel Science-Grade Infrared Cameras

With highly sensitive cooled InSb detectors, superb resolution, and all of the cutting edge functionality scientists and researchers have come to expect from FLIR, the SC8000 HD Series brings science and R&D thermography to a whole new level.



Camera Features

Portability	Expandability
Ergonomics	Ruggedness
Electronics	Software Compatibility
Cost	Training/Technical Support

Detector Specs:

Type and Wavelength

Is the detector cooled or un-cooled? What type of detector materials? What wavelength will be required.

Thermal Sensitivity

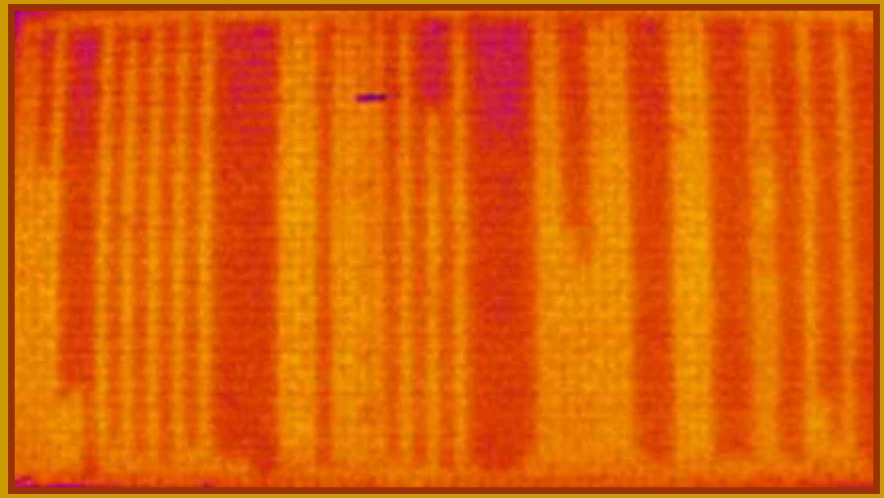
Is the detector sensitive enough to see the slight differences in temperature sometimes needed for given application?

Spatial Resolution

Does the detector have enough pixels to make the picture needed? How much signal degradation will I get from using a wider or longer lens?

Thermal Sensitivity

Is the detector sensitive enough to see the slight differences in temperature sometimes needed for the application?

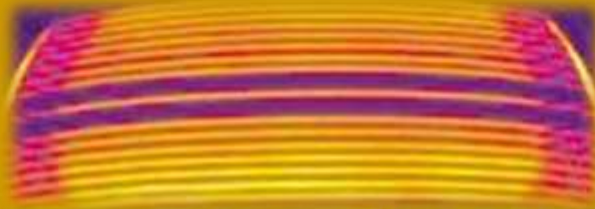


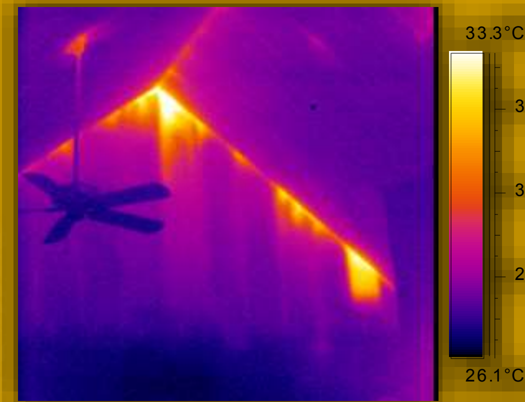
Spatial Resolution

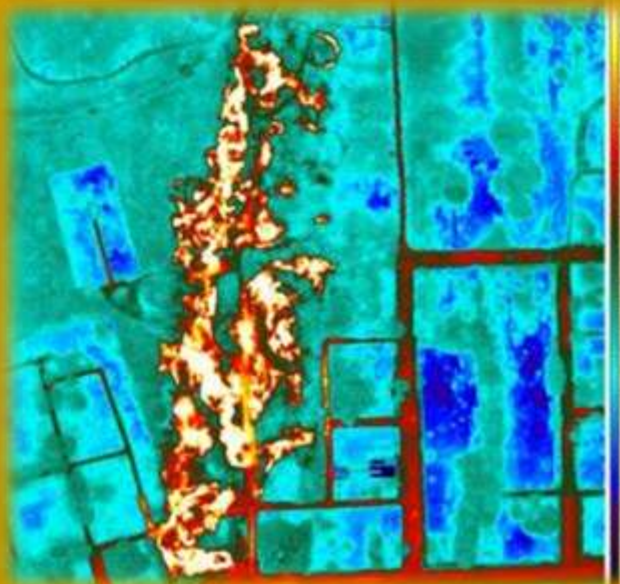
Does the detector have enough pixels to make the picture I need?

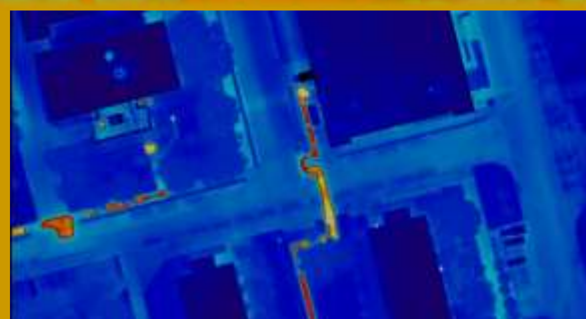
How much signal degradation will I get from using a wider or longer lens?

Infrared Applications Everywhere





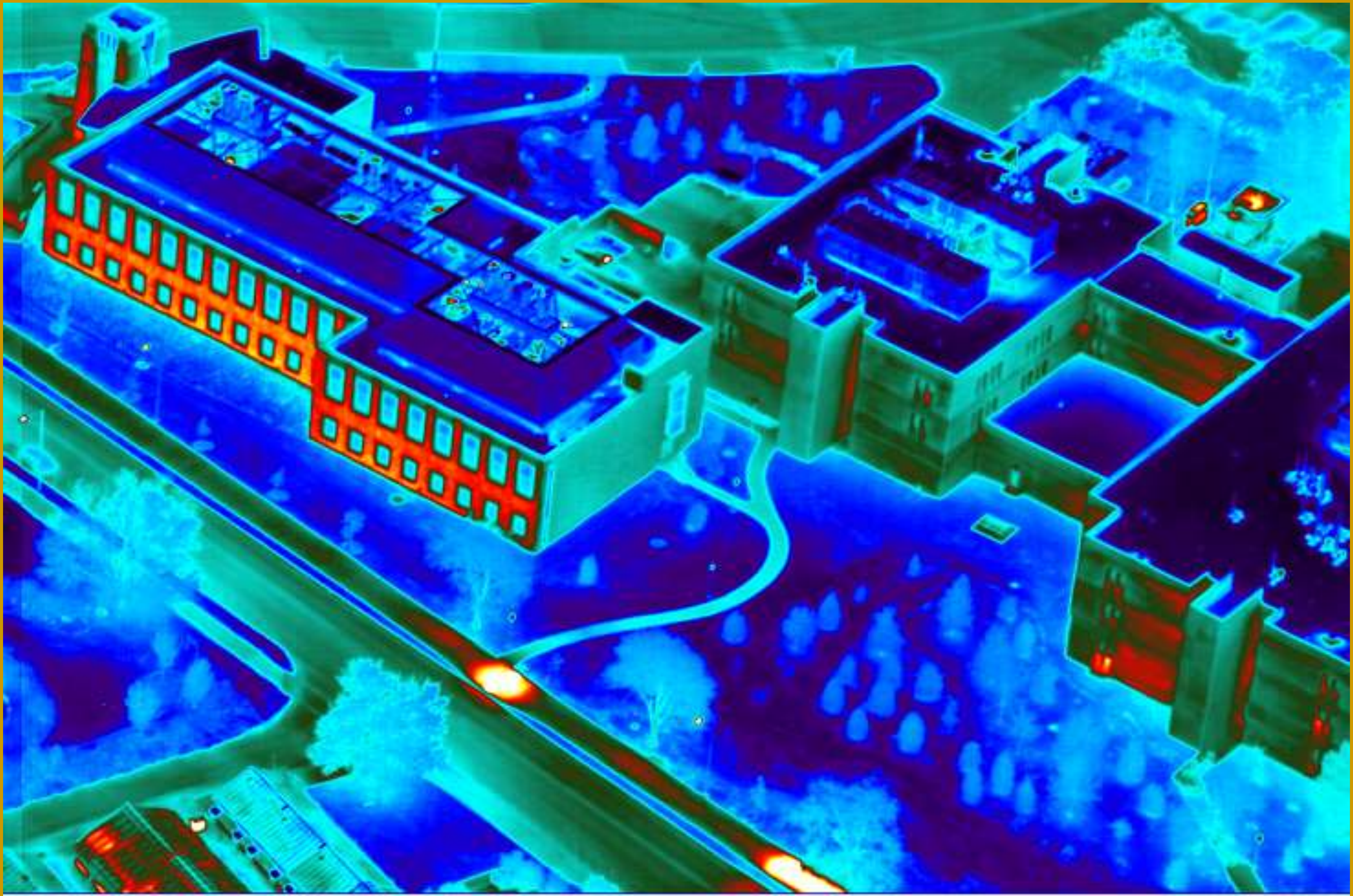




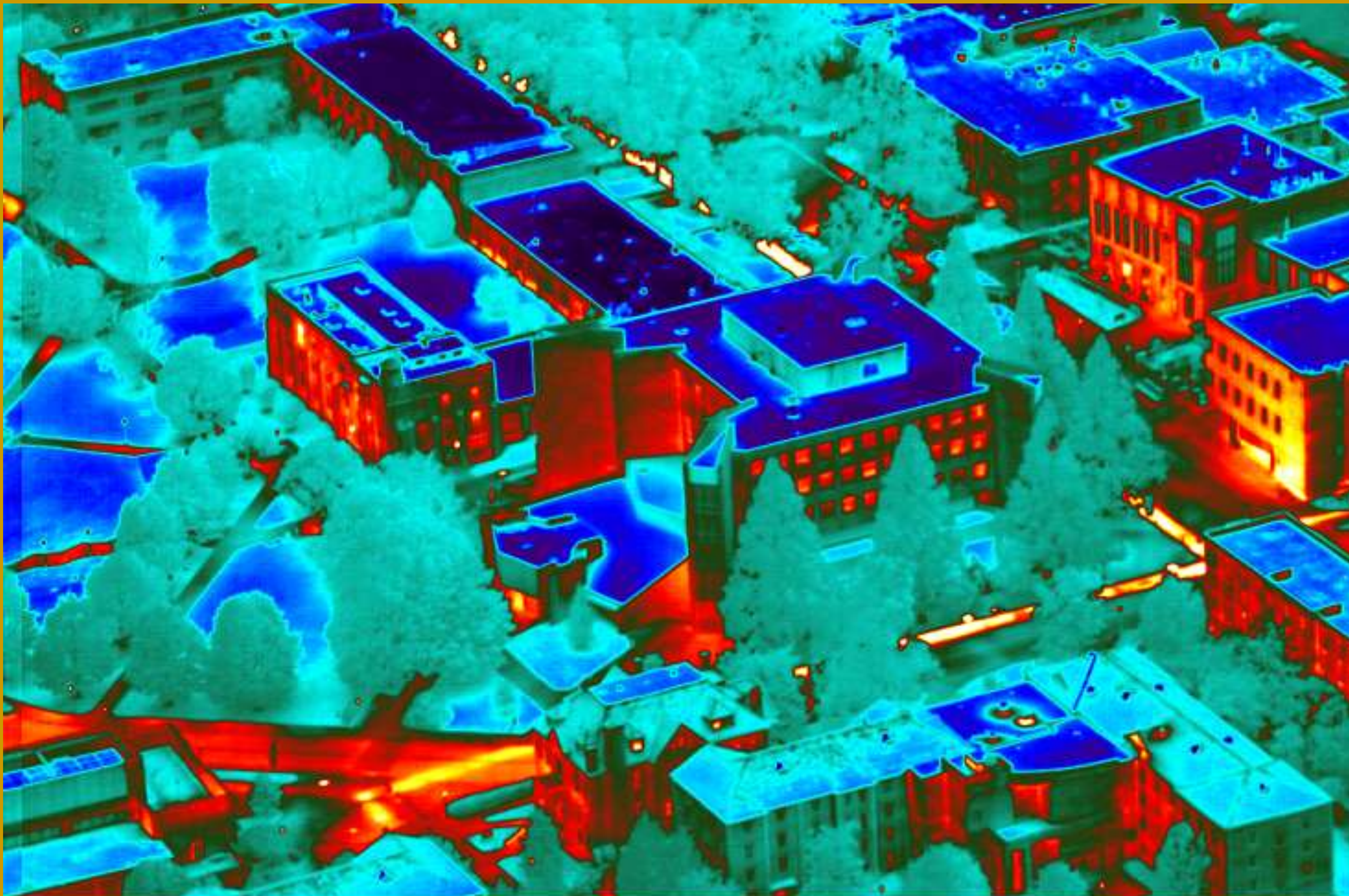
Building Heat & Air

NORTHERN OHIO CHAPTER

Oblique IR Imaging Showing Building Heat Loss



Oblique IR Imaging Showing Varying Amounts of Heat Loss



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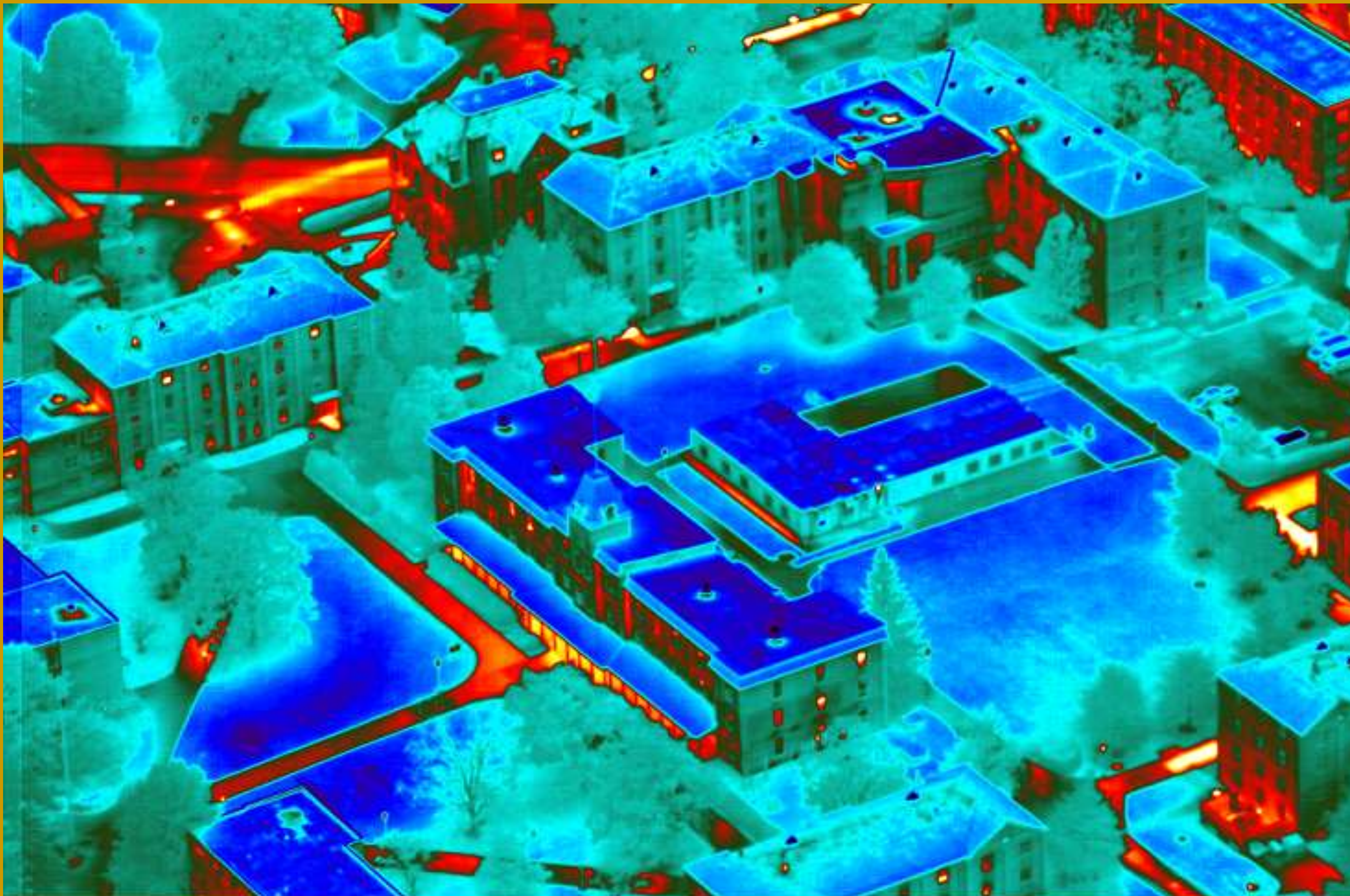

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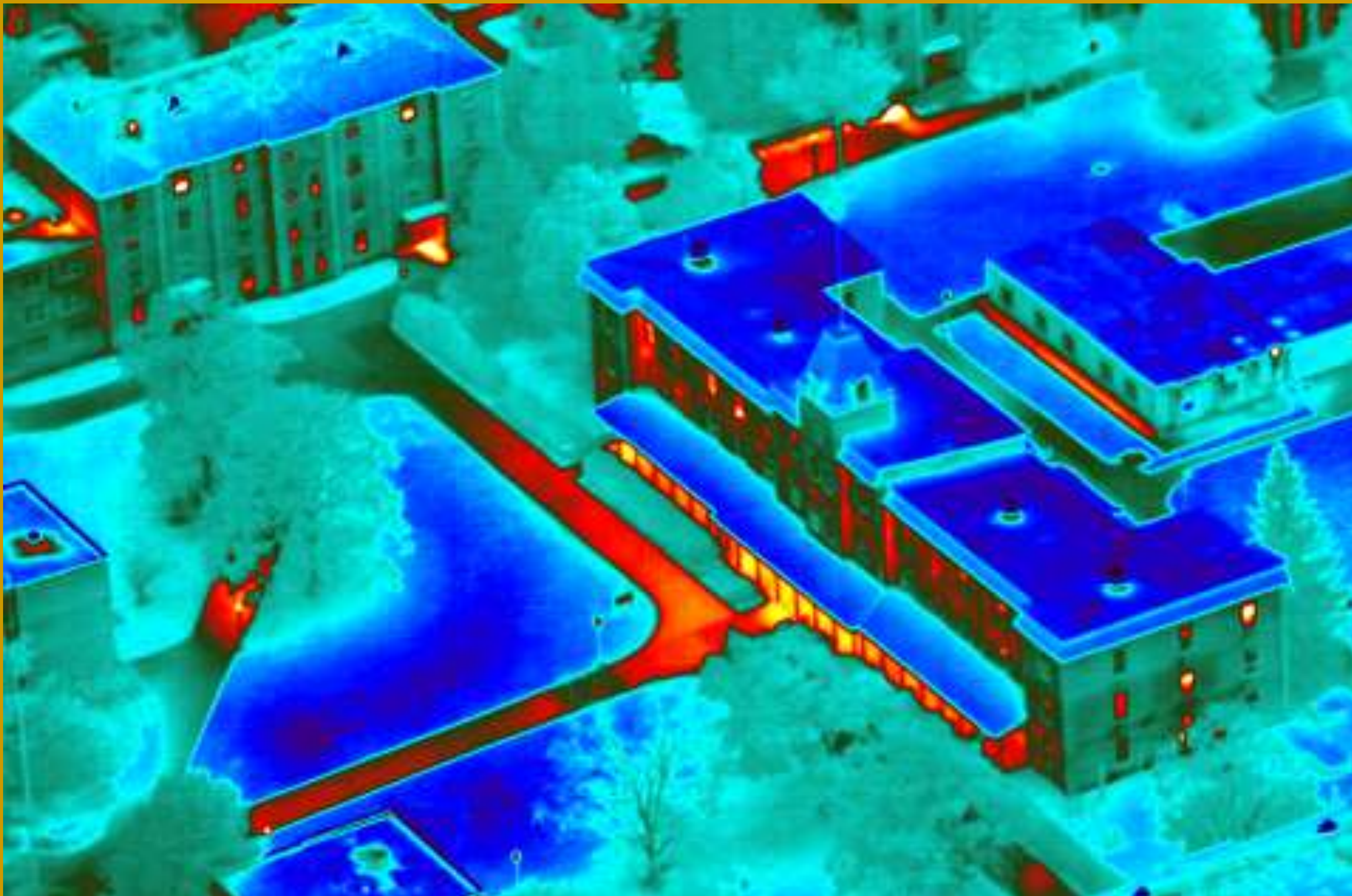

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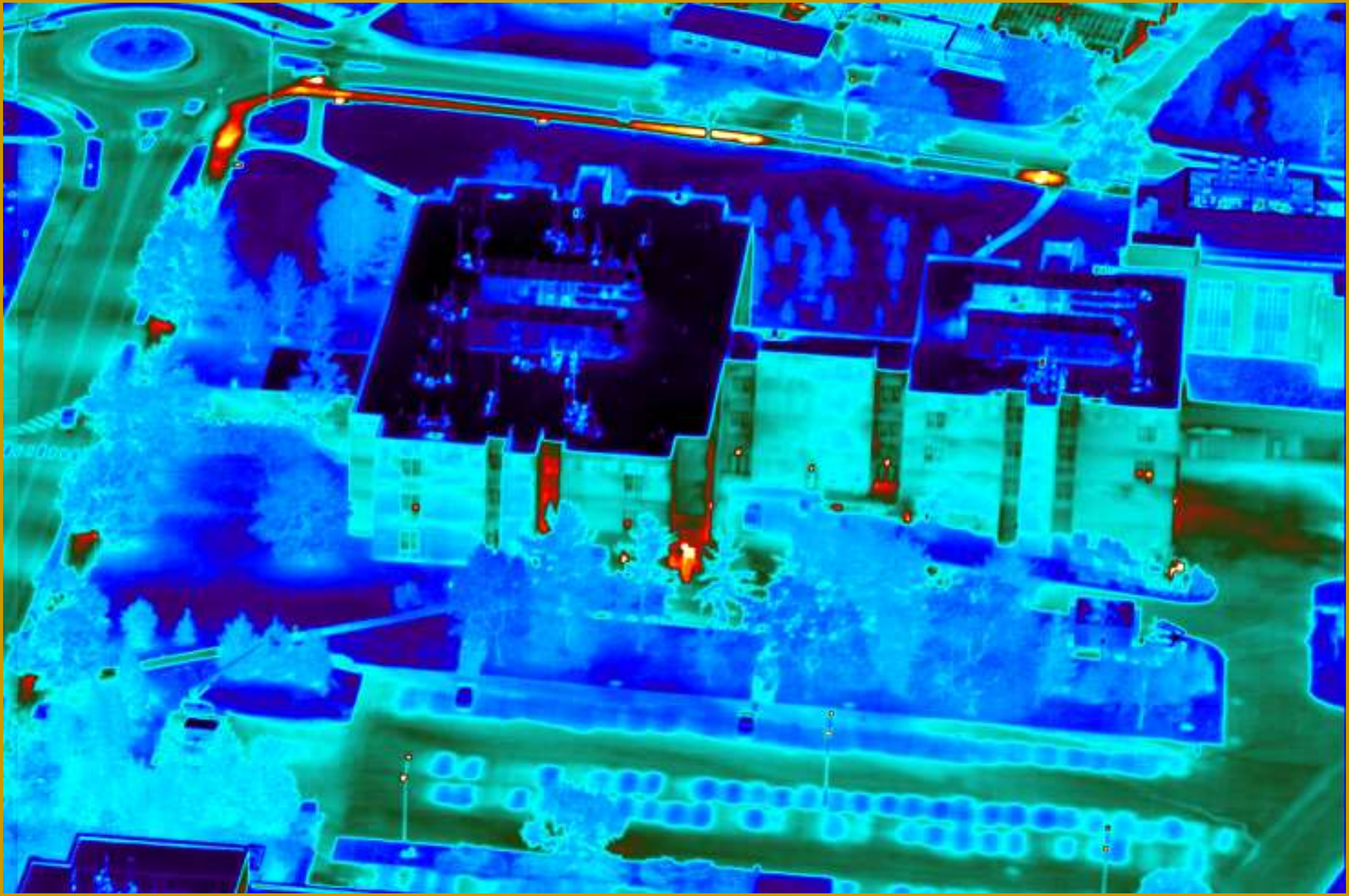

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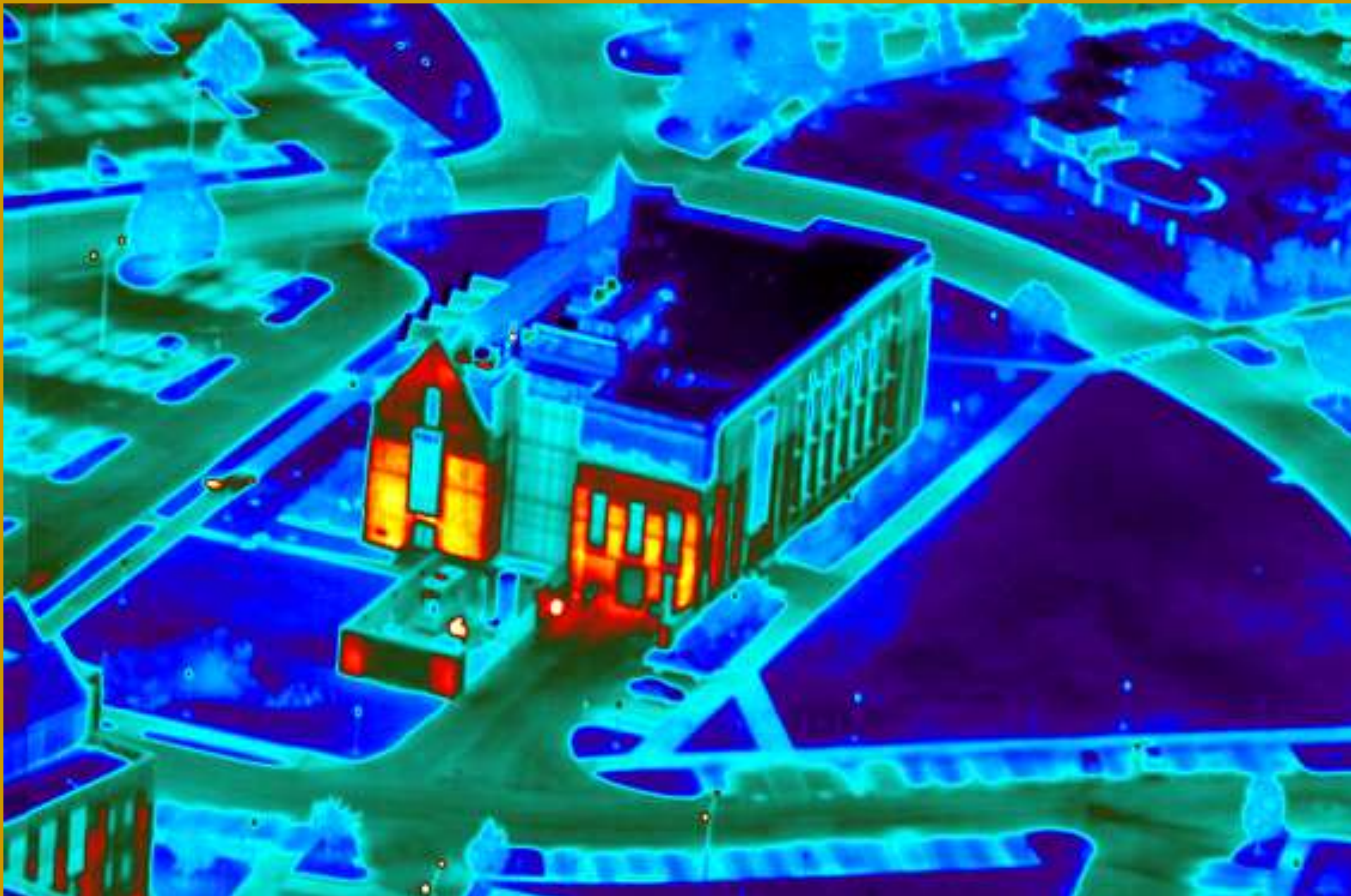
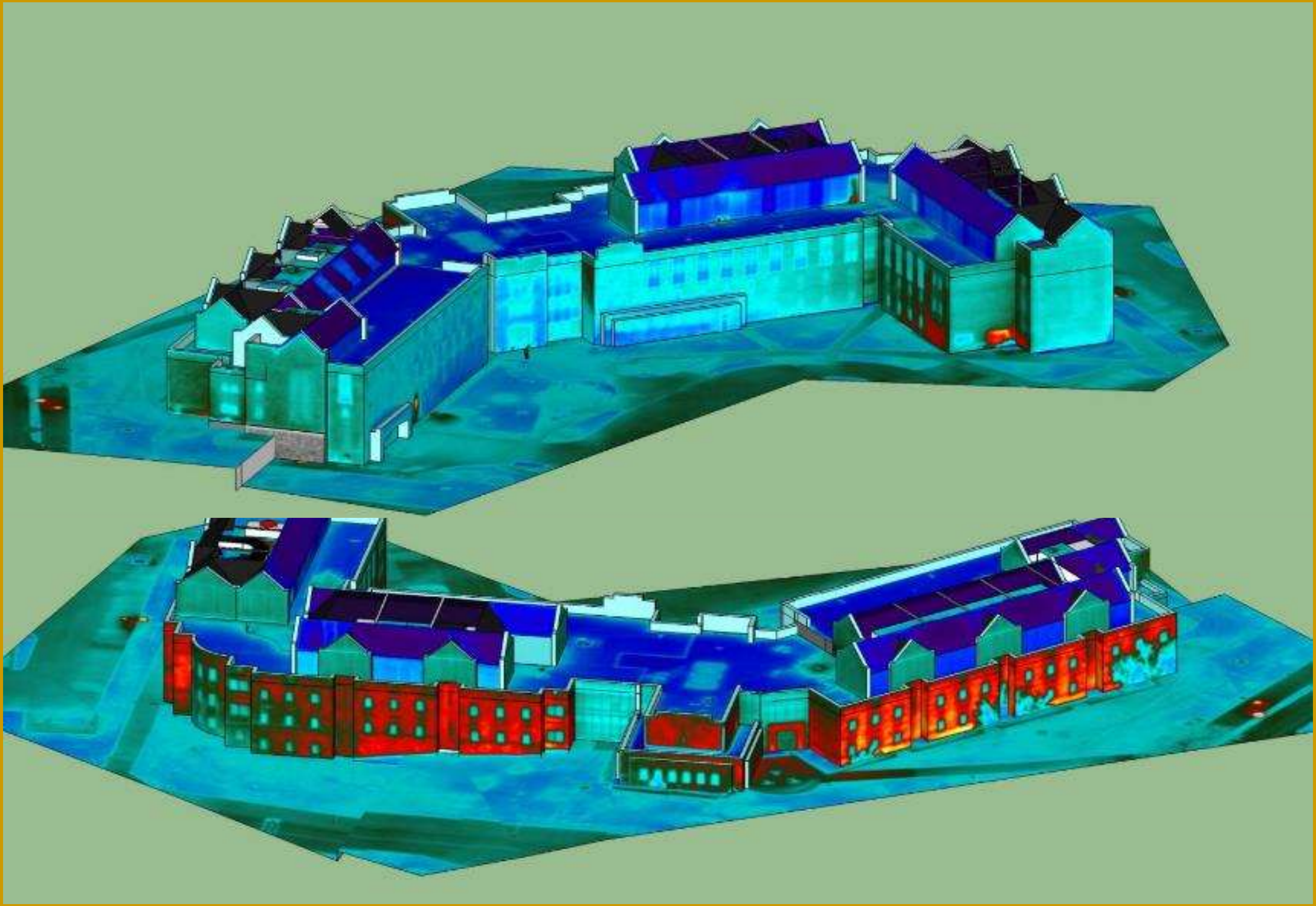
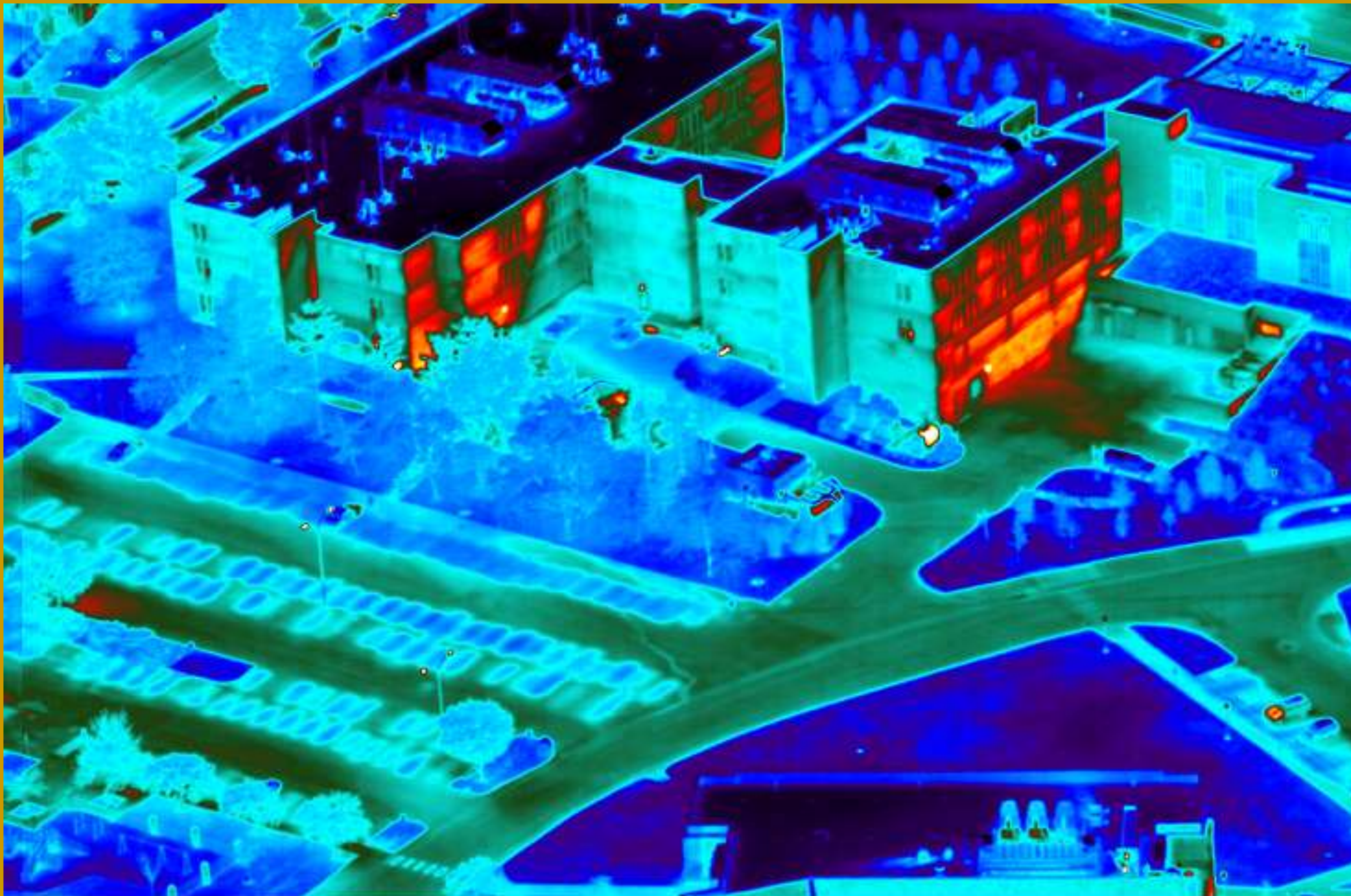


NADIR & Oblique IR Imaging Required for 3D Imaging



Oblique IR Imaging Showing Building Survey Done Too Early



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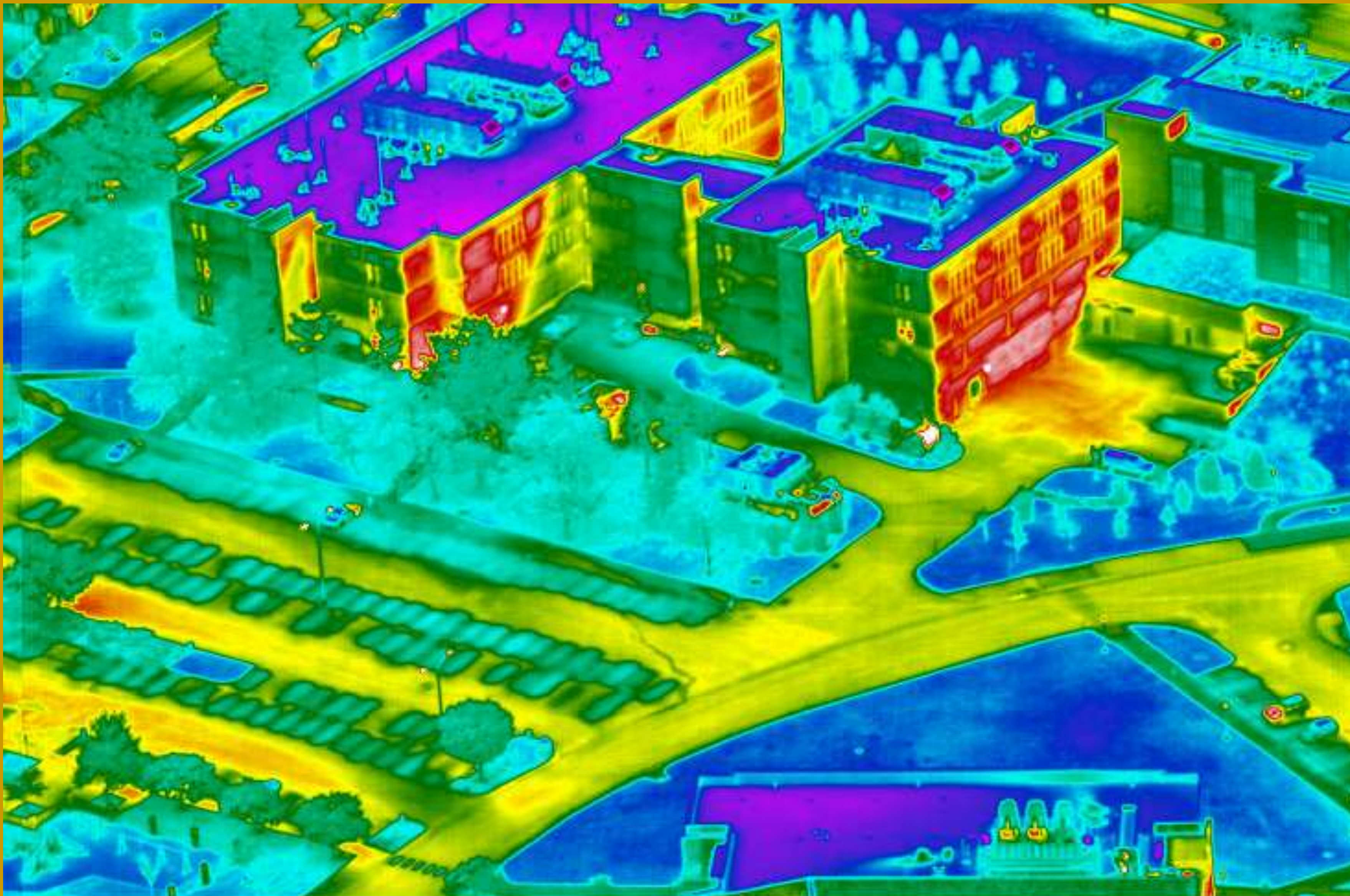
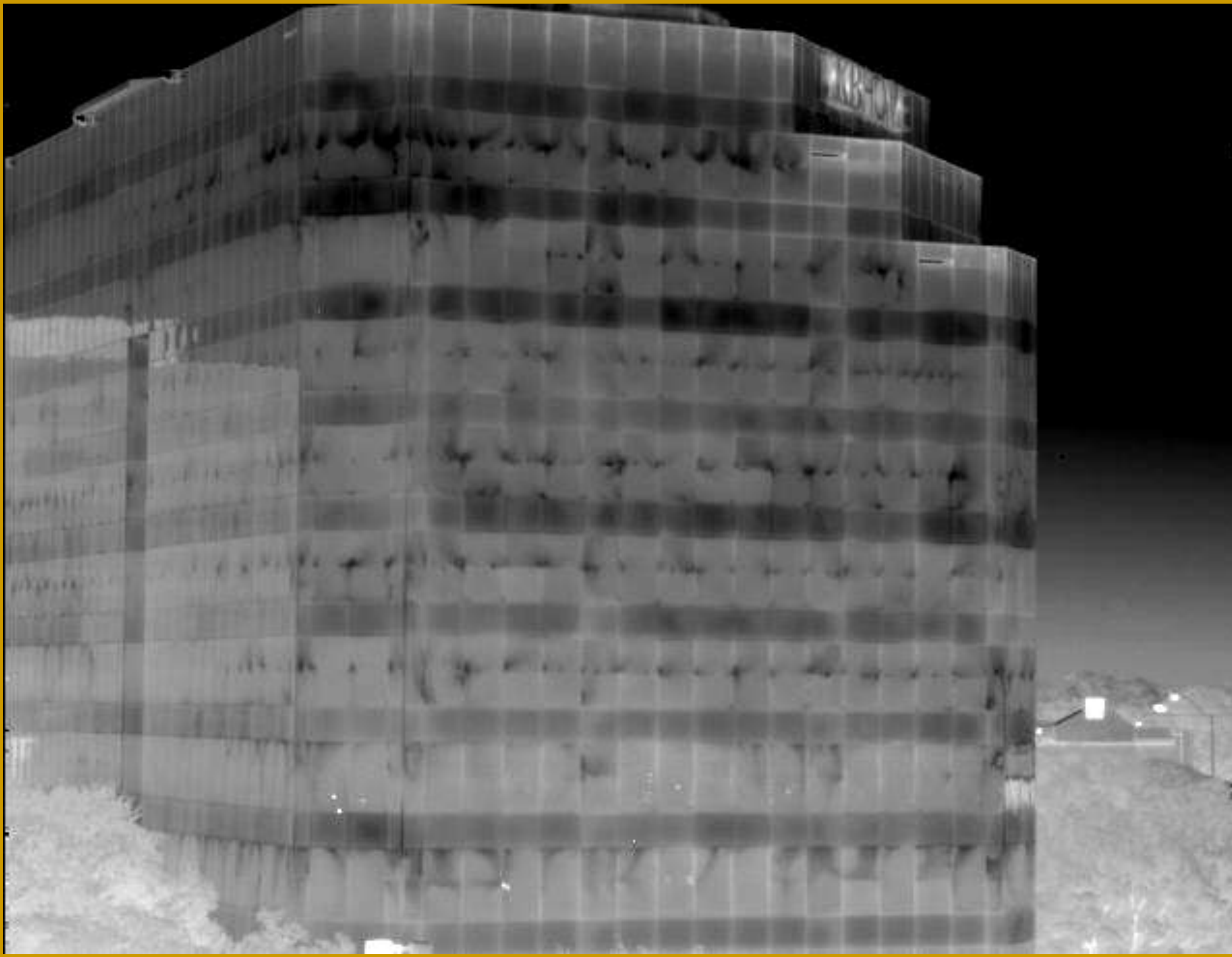



US Army Corps of Engineers®
Engineer Research and Development Center

U.S. Army Corps of Engineers Air Leakage Test Protocol for Measuring Air Leakage in Buildings

Approved for public release; distribution is unlimited.

Typical Large Building Air Leakage Testing



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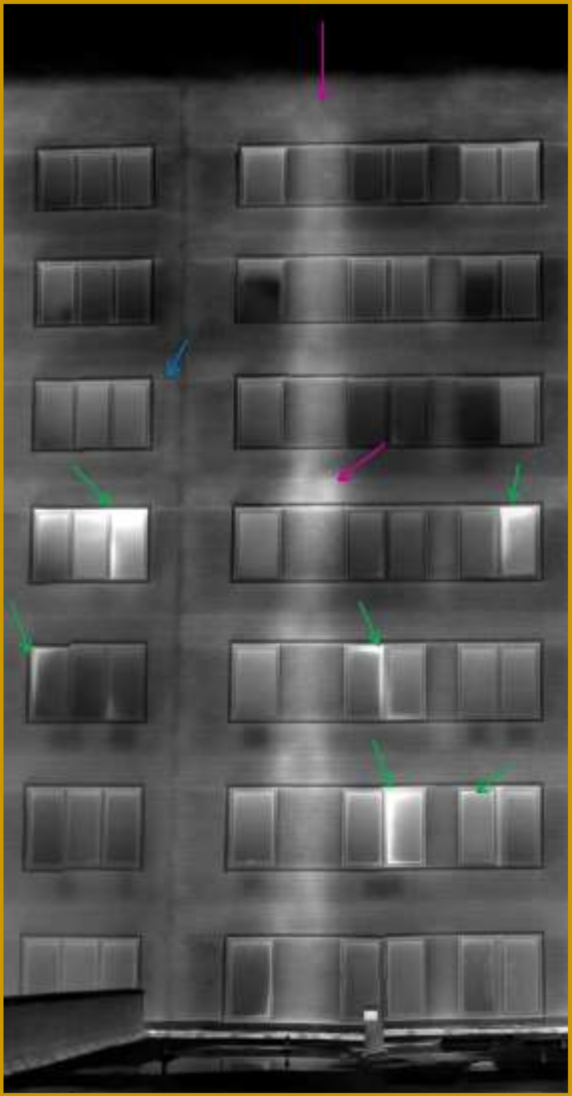

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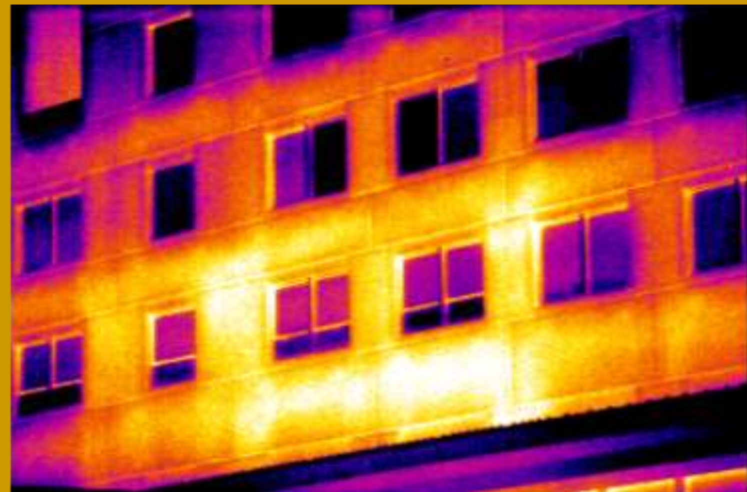
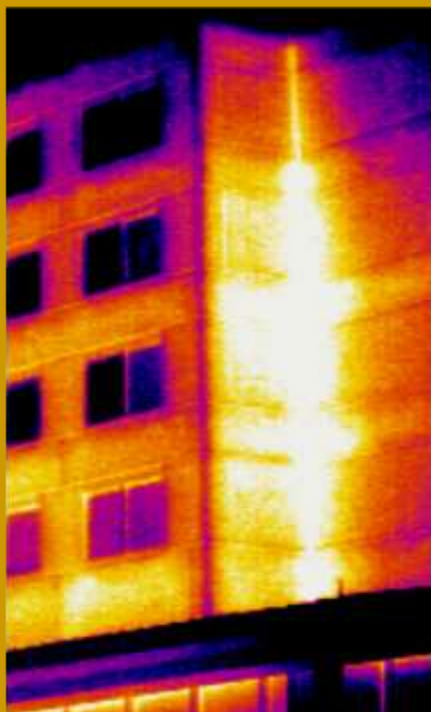
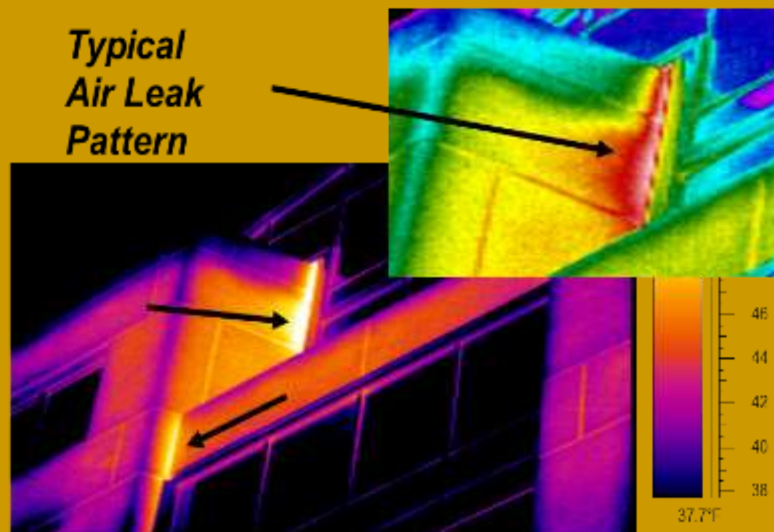
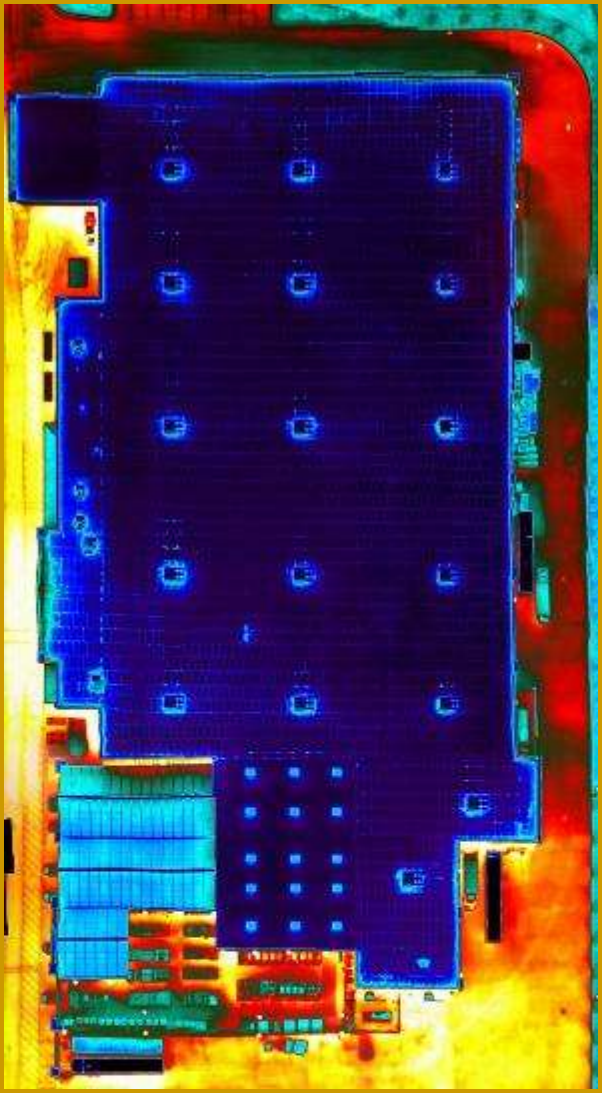




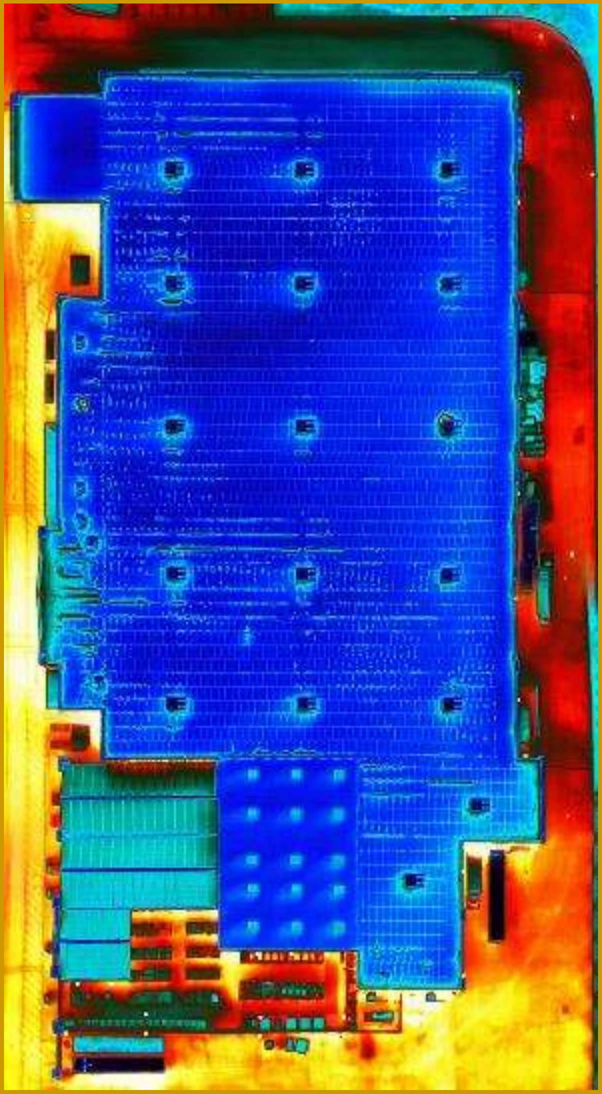
Typical Air Leak Pattern



Typical Large Building Air Leakage Testing

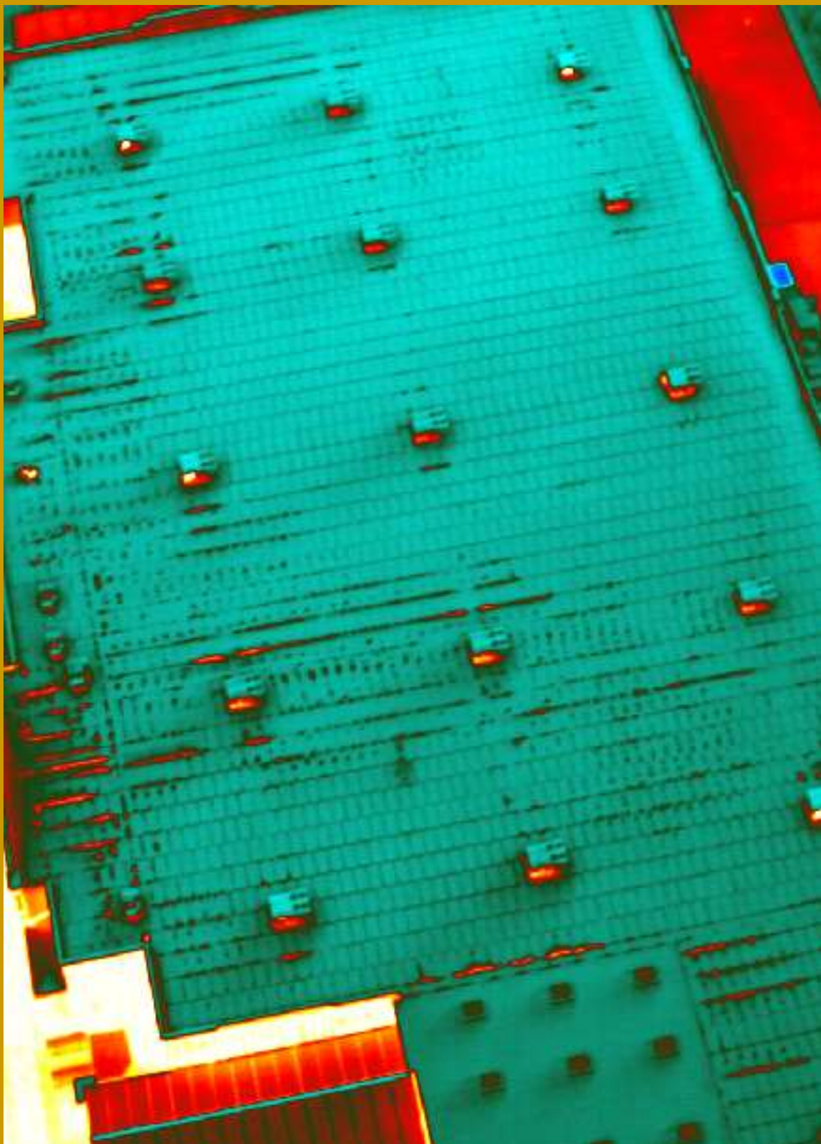


Before Pressurization

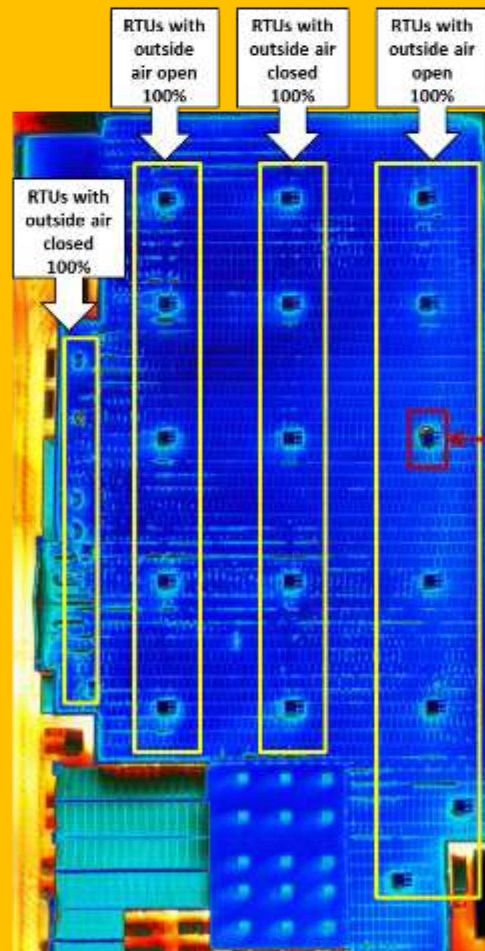


After Pressurization

Typical Large Building Air Leakage Testing



During the pressurization testing, ~50,000 CFM was supplied to the building with the procedure described in Reports 2. This raised the building pressure from normal (slightly negative) to .1 inches or ~25 Pascal).



RTU's Operating in Full Economizer during the <u>survey</u>

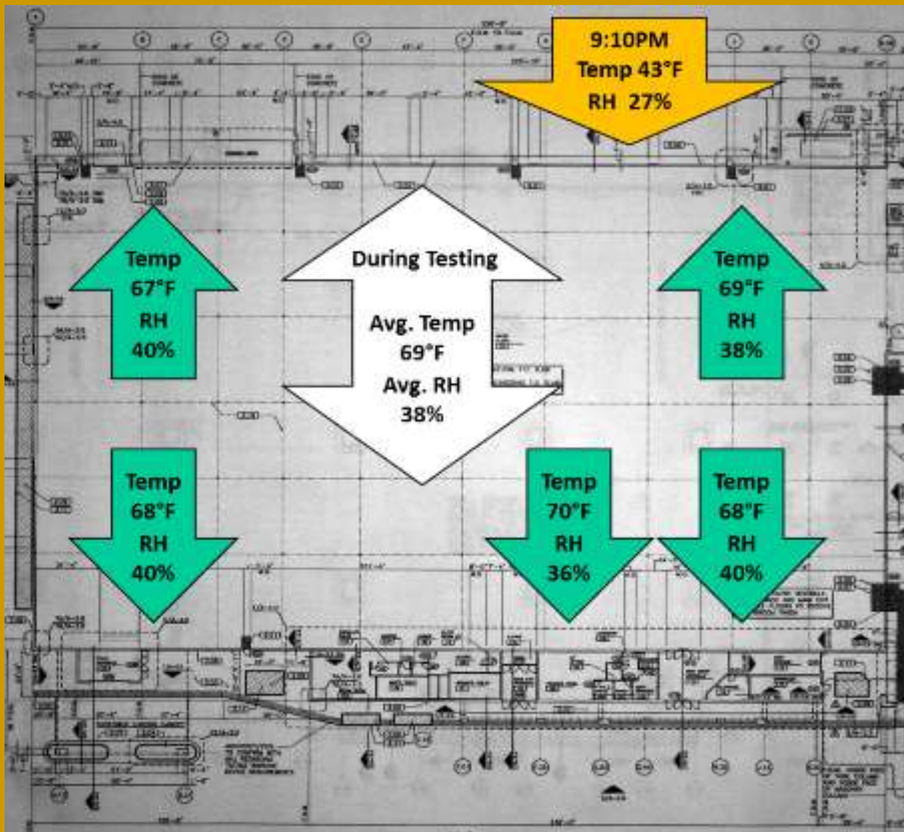
RTU-6
RTU-7
RTU-8
RTU-9
RTU-10
RTU-16
RTU-17
RTU-19
RTU-20
RTU-21
RTU-22

RTU's Operating in Normal during the <u>survey</u>

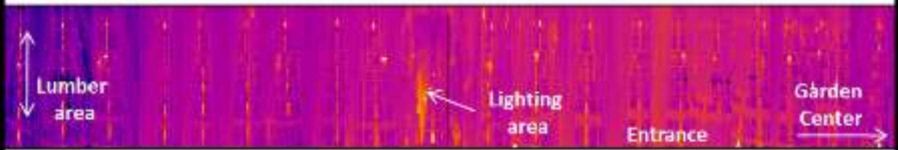
RTU-15
RTU-14
RTU-13
RTU-12
RTU-11
RTU-5
RTU-4
RTU-3
RTU-2
RTU-1

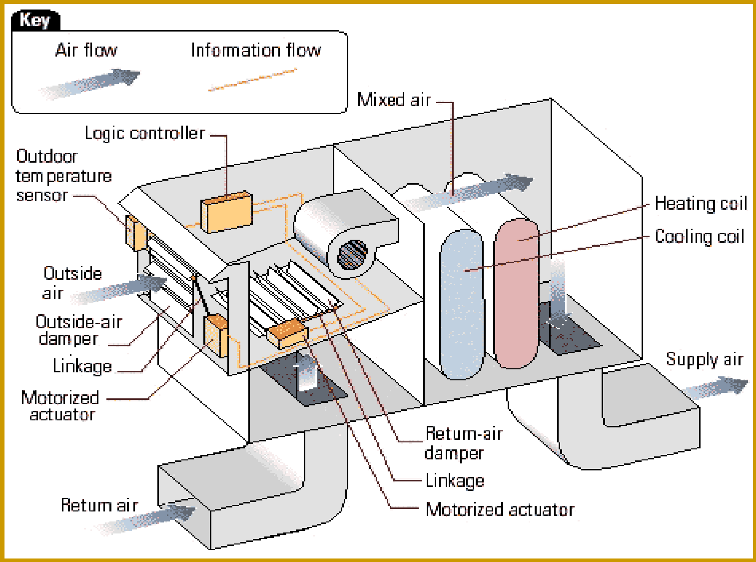
RTU -18
Not Operational

Typical Large Building Air Leakage Testing



Representation of the heat distribution throughout the building





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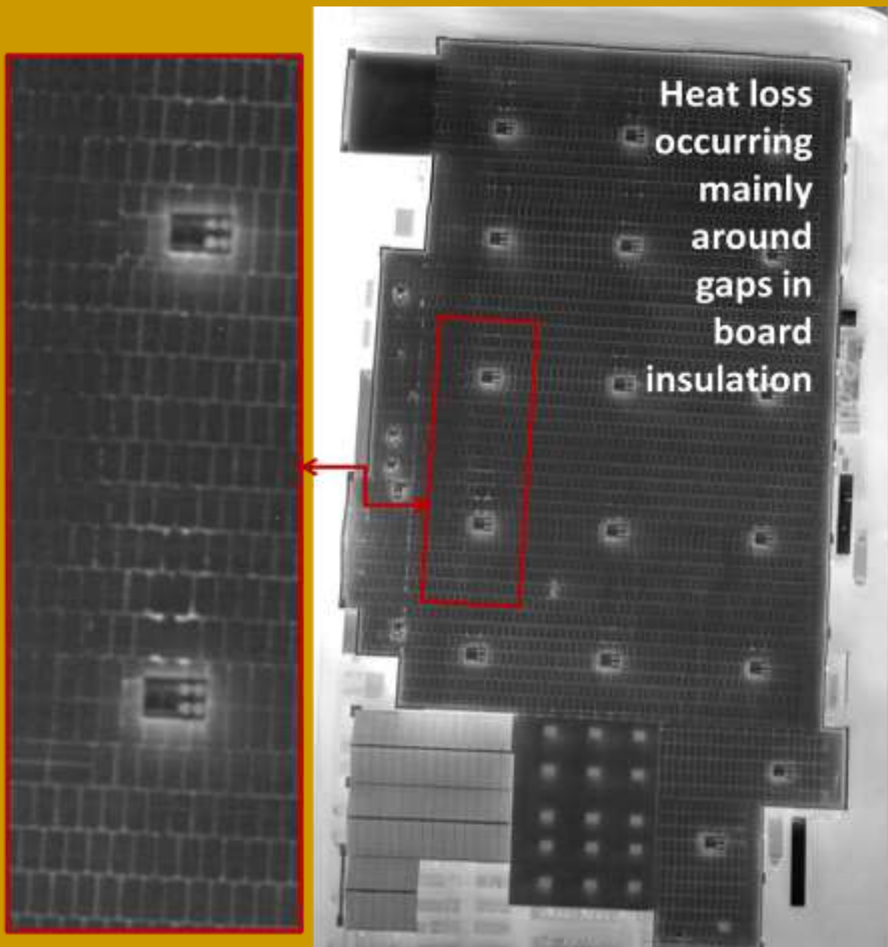
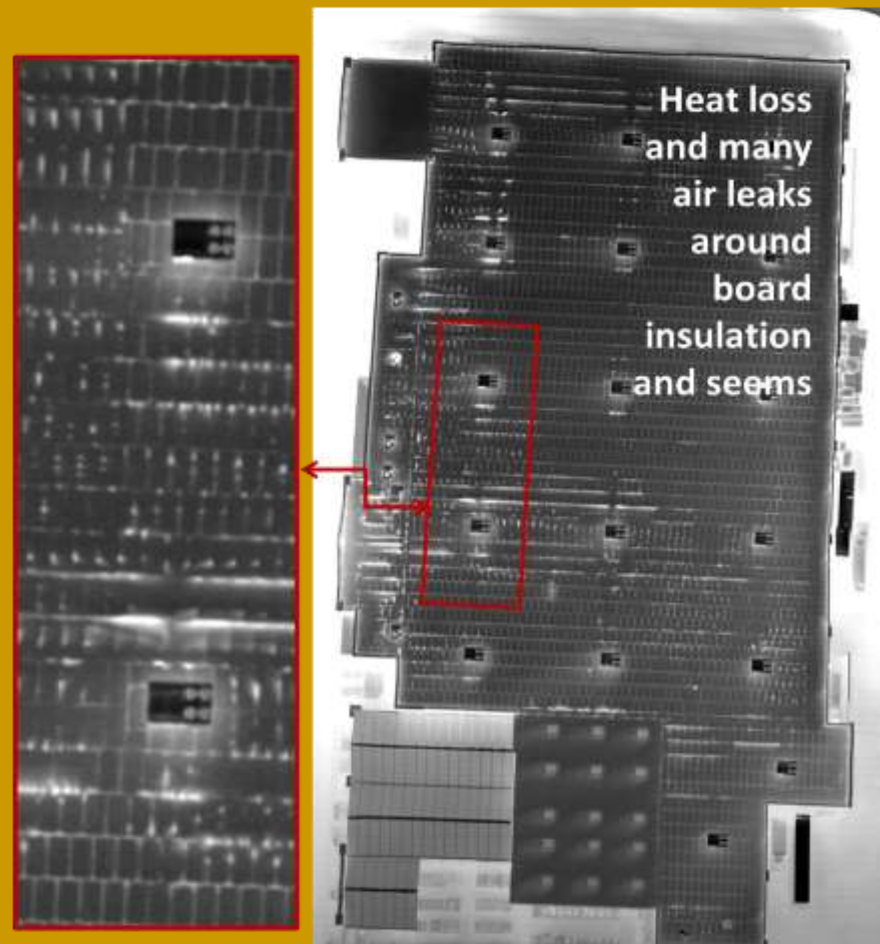
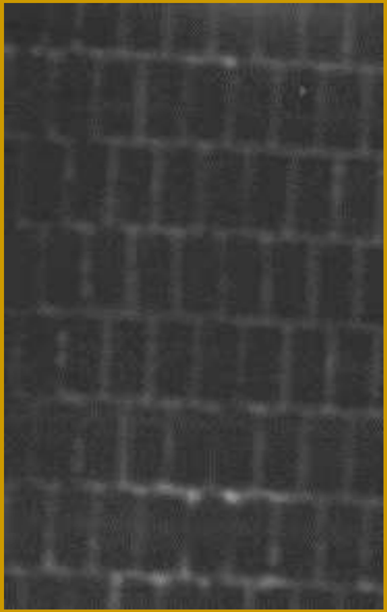


Before Pressurization



After Pressurization

Typical Large Building Air Leakage Testing



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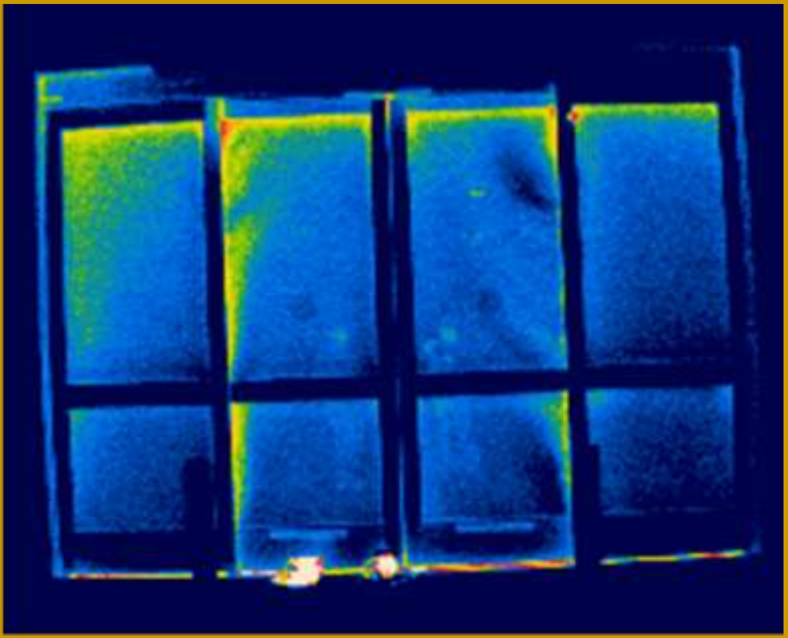
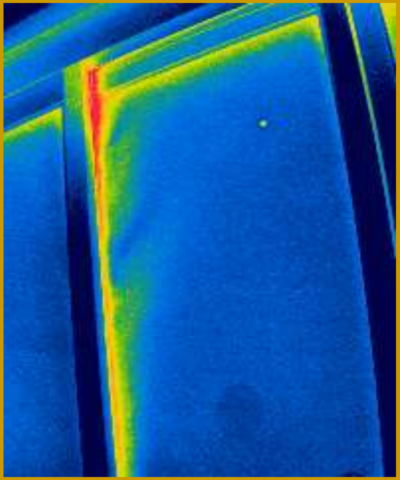
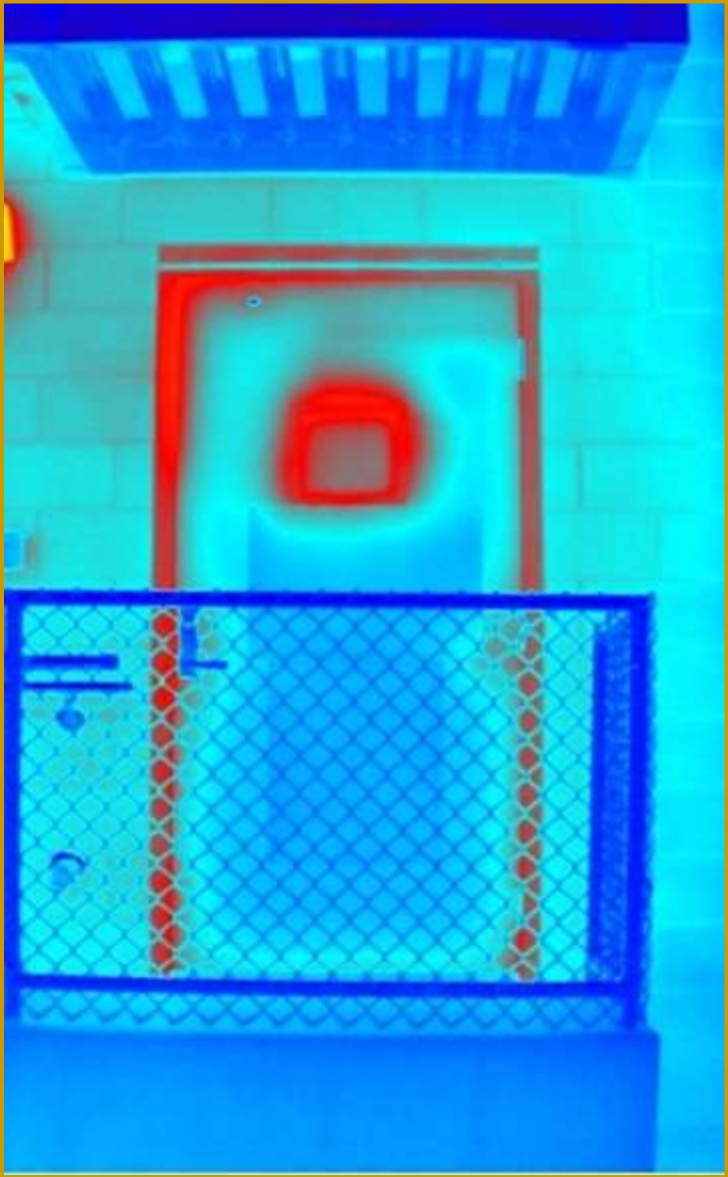
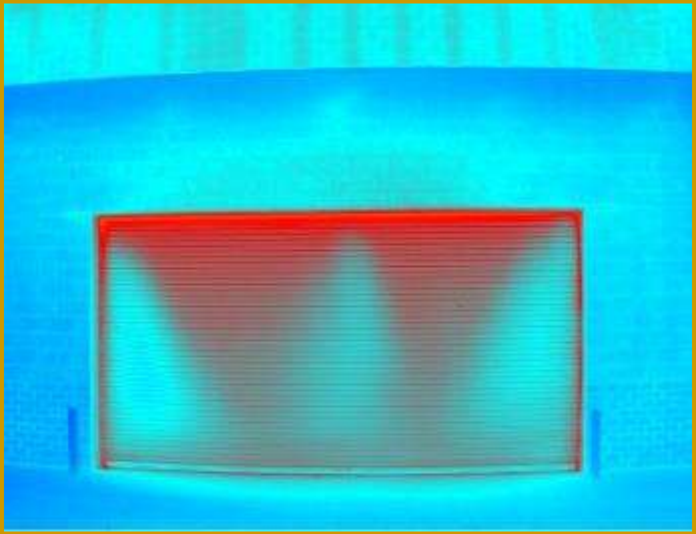


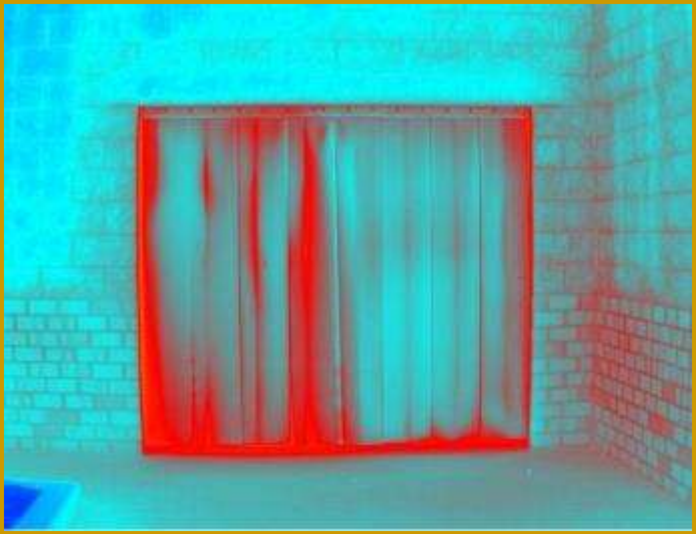


Automatic doors leak at the breakaway hinges more than in the center or around the edges.

Typical Large Building Air Leakage Testing







Typical Large Building Air Leakage Testing

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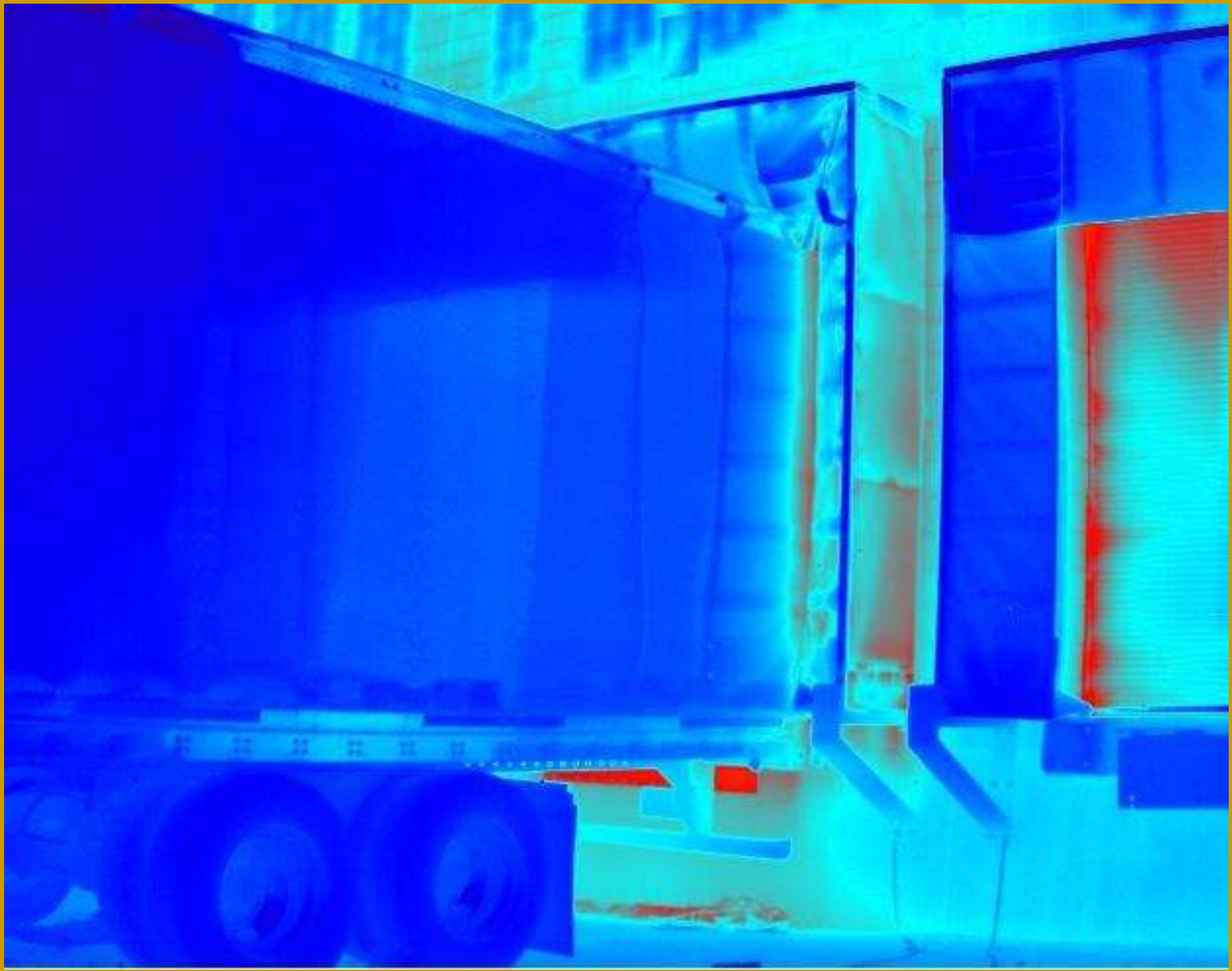
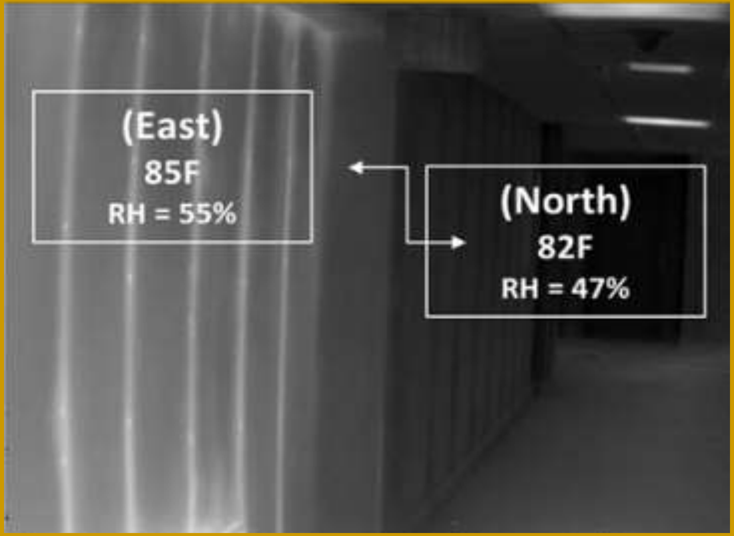


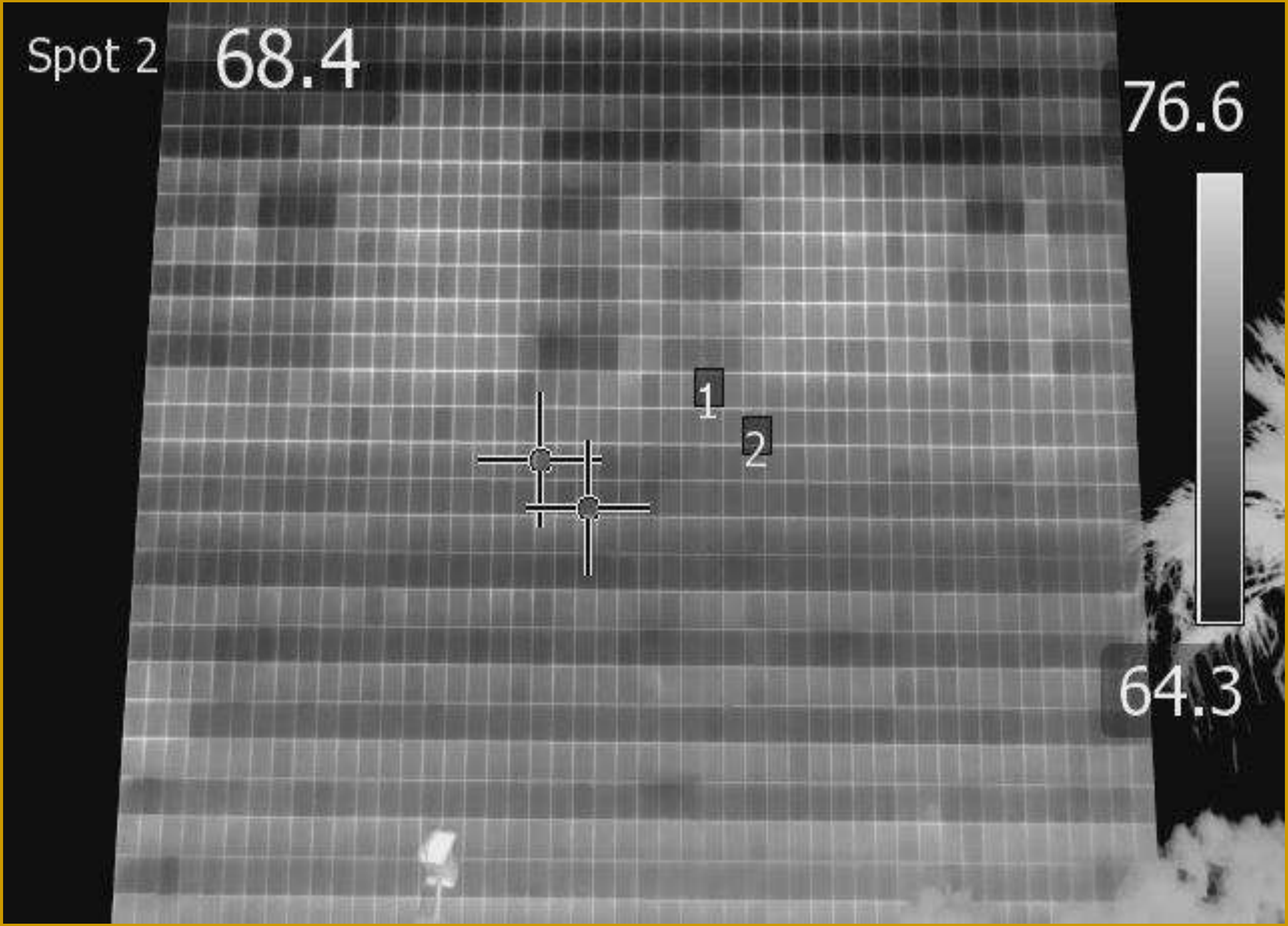
Typical Hotel Air and Heat Loss

Typical Hotel Air and Heat Loss

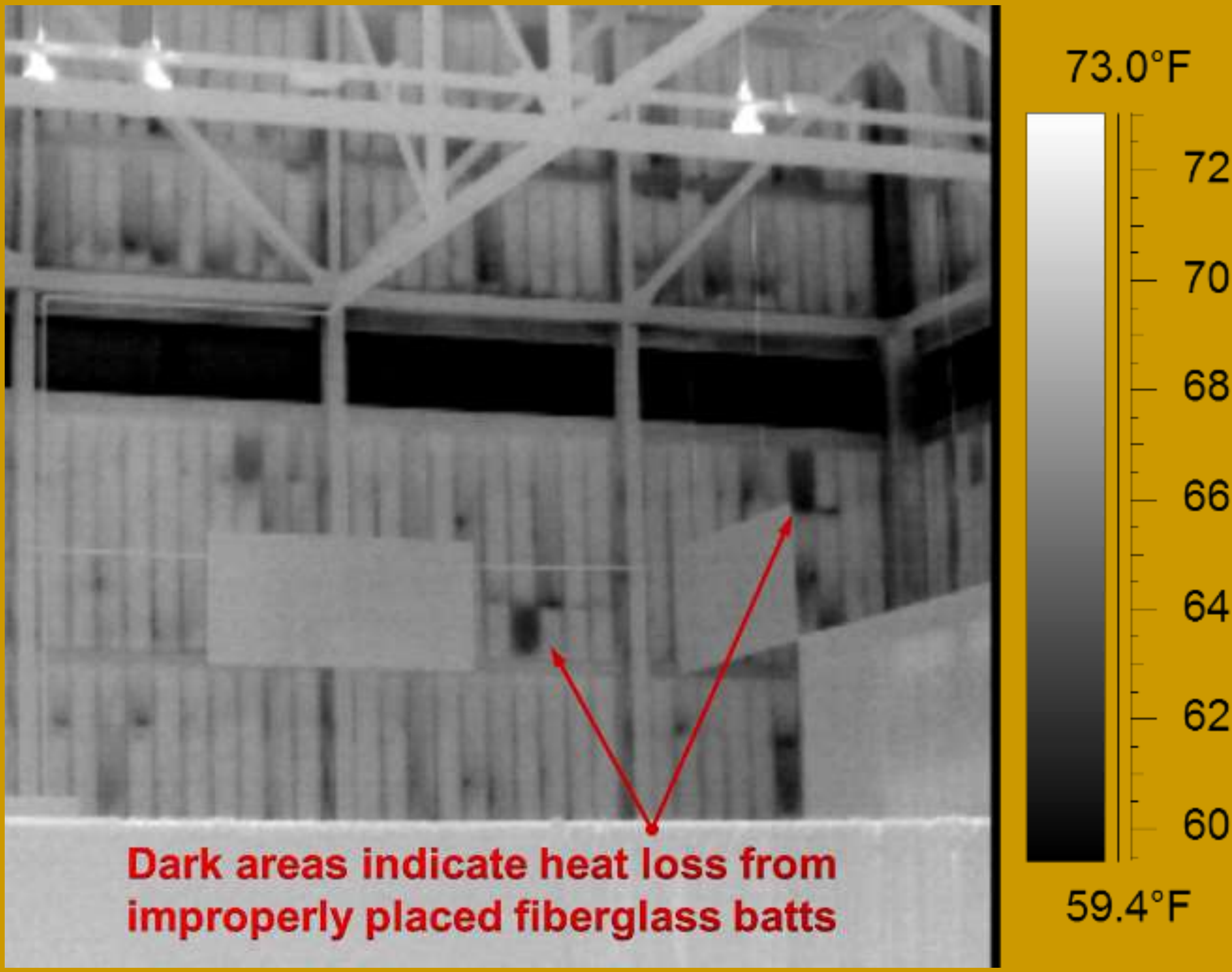


Typical Hotel Air and Heat Loss

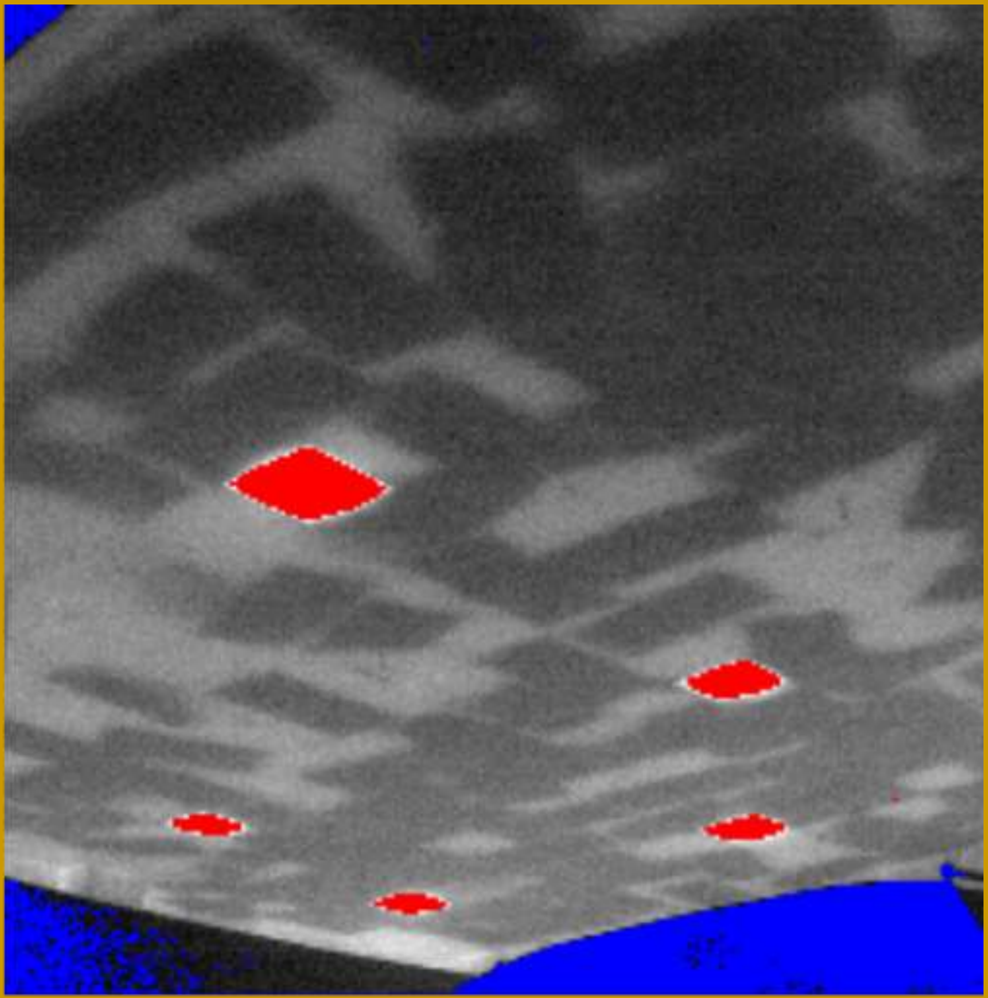
Typical Large Building Heat Loss



Missing Insulation in a Convention Center

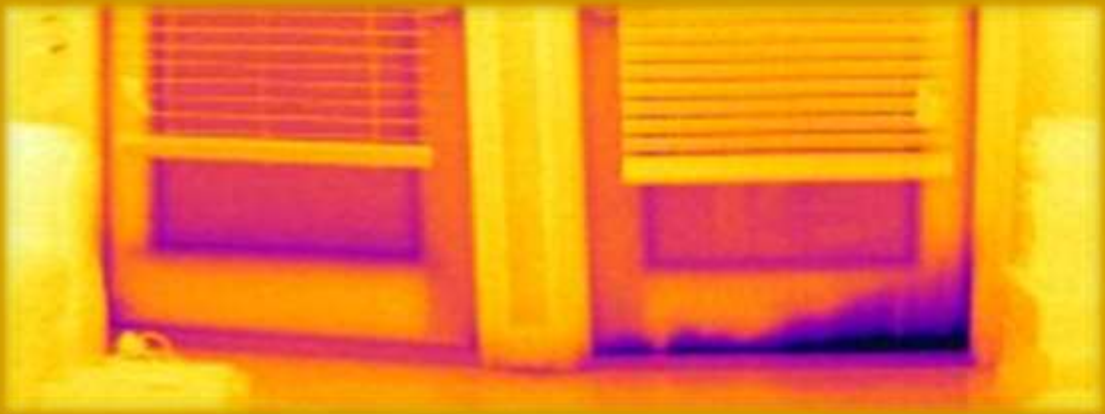


Improperly Installed Batt Insulation in a Commercial Building

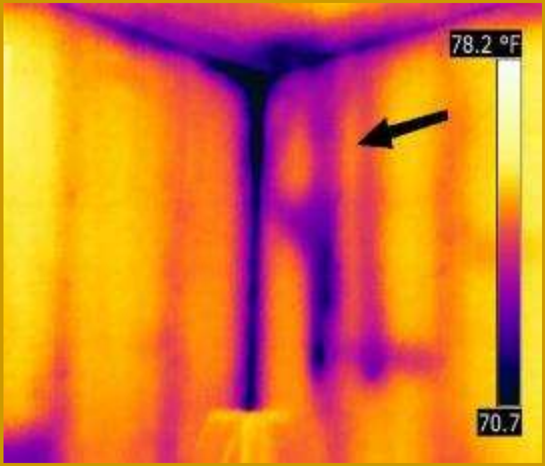


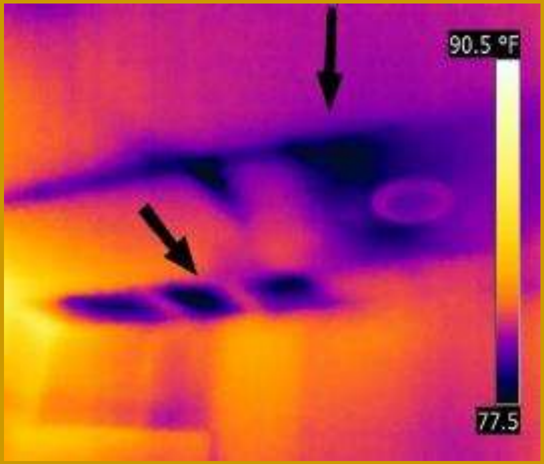
Institutional Building - Air Stratification

Apartment Building Heat Loss Findings



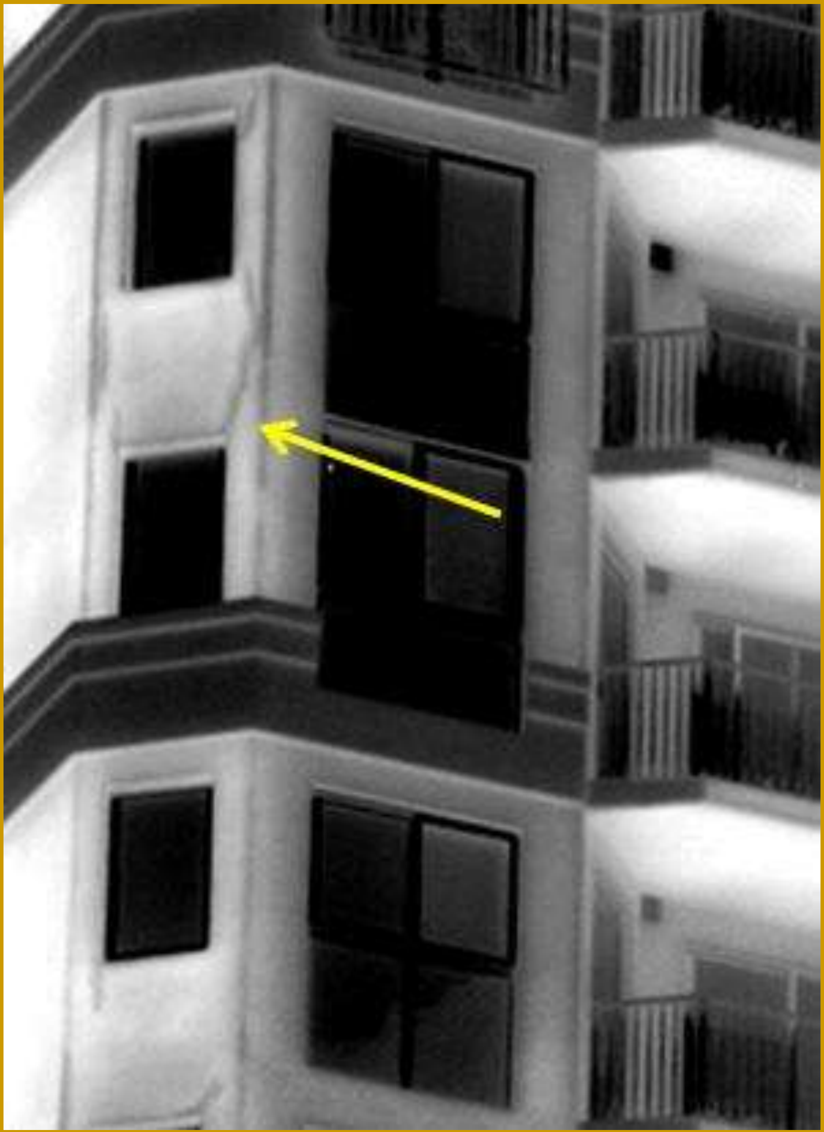
Apartment Building Heat Loss Findings





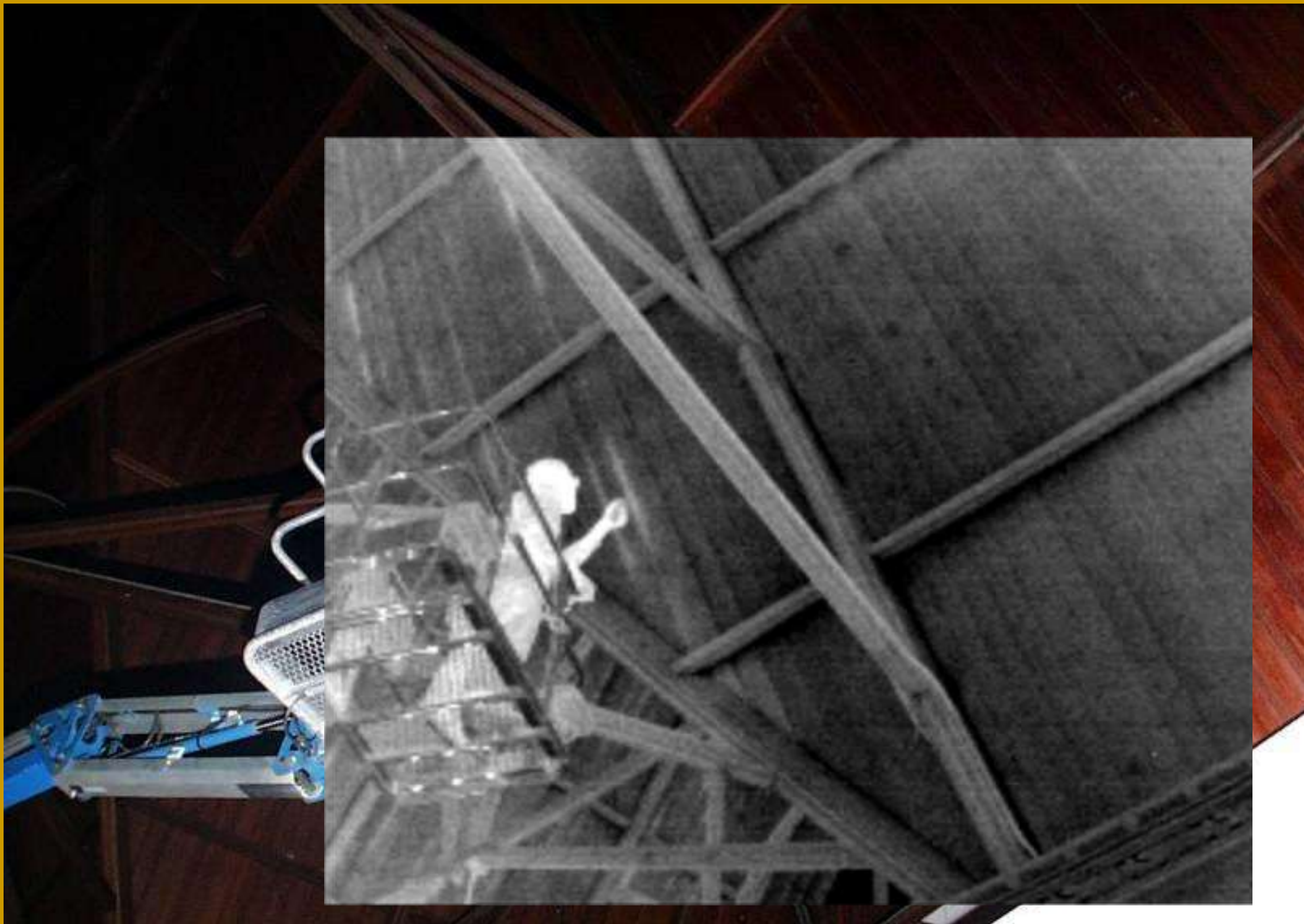
Courtesy of Arizona Infrared

Building IR (Stucco Delamination)



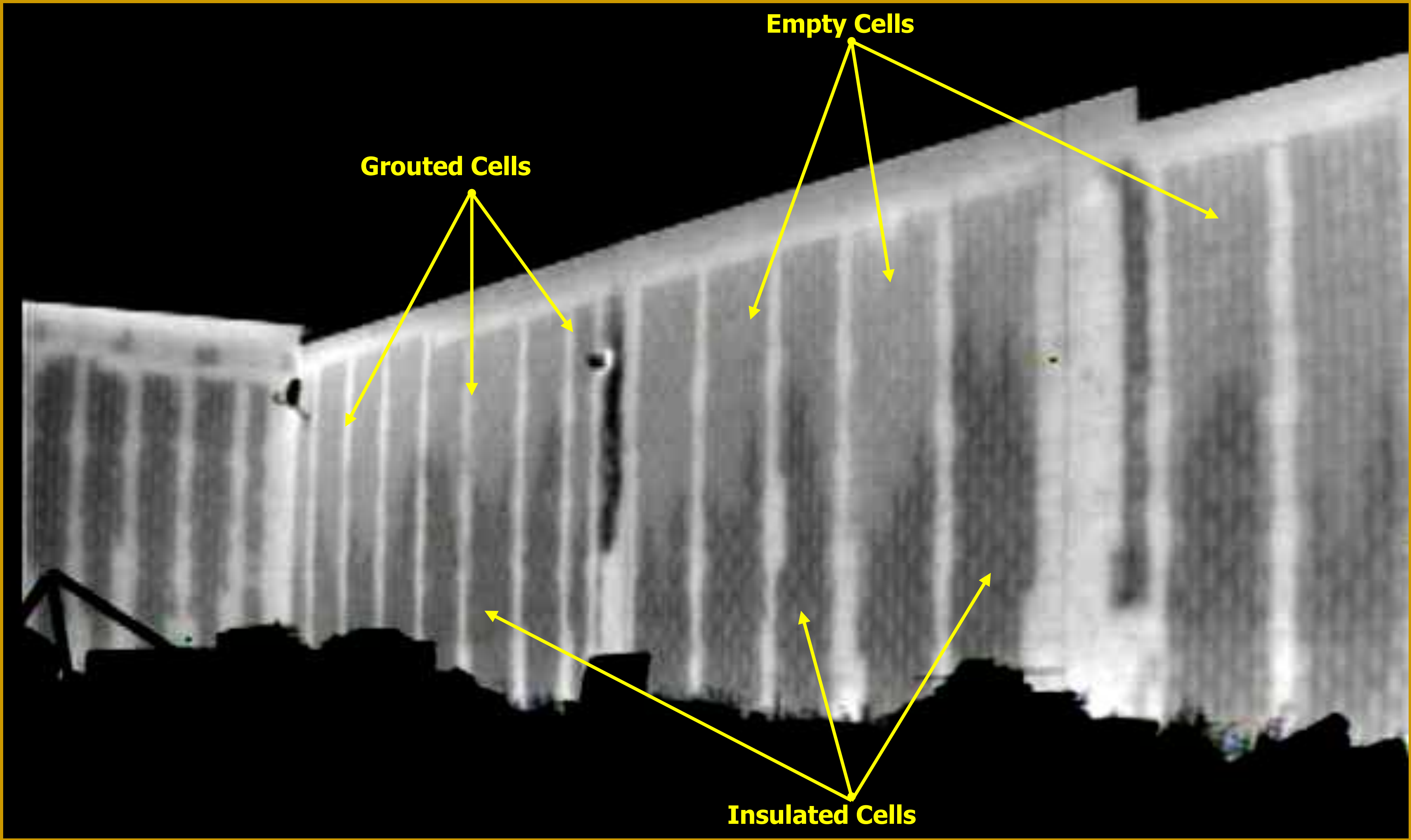
Church Cathedral Ceiling - Looking for Extent of Termite Damage

Church Cathedral Ceiling - Looking for Extent of Termite Damage

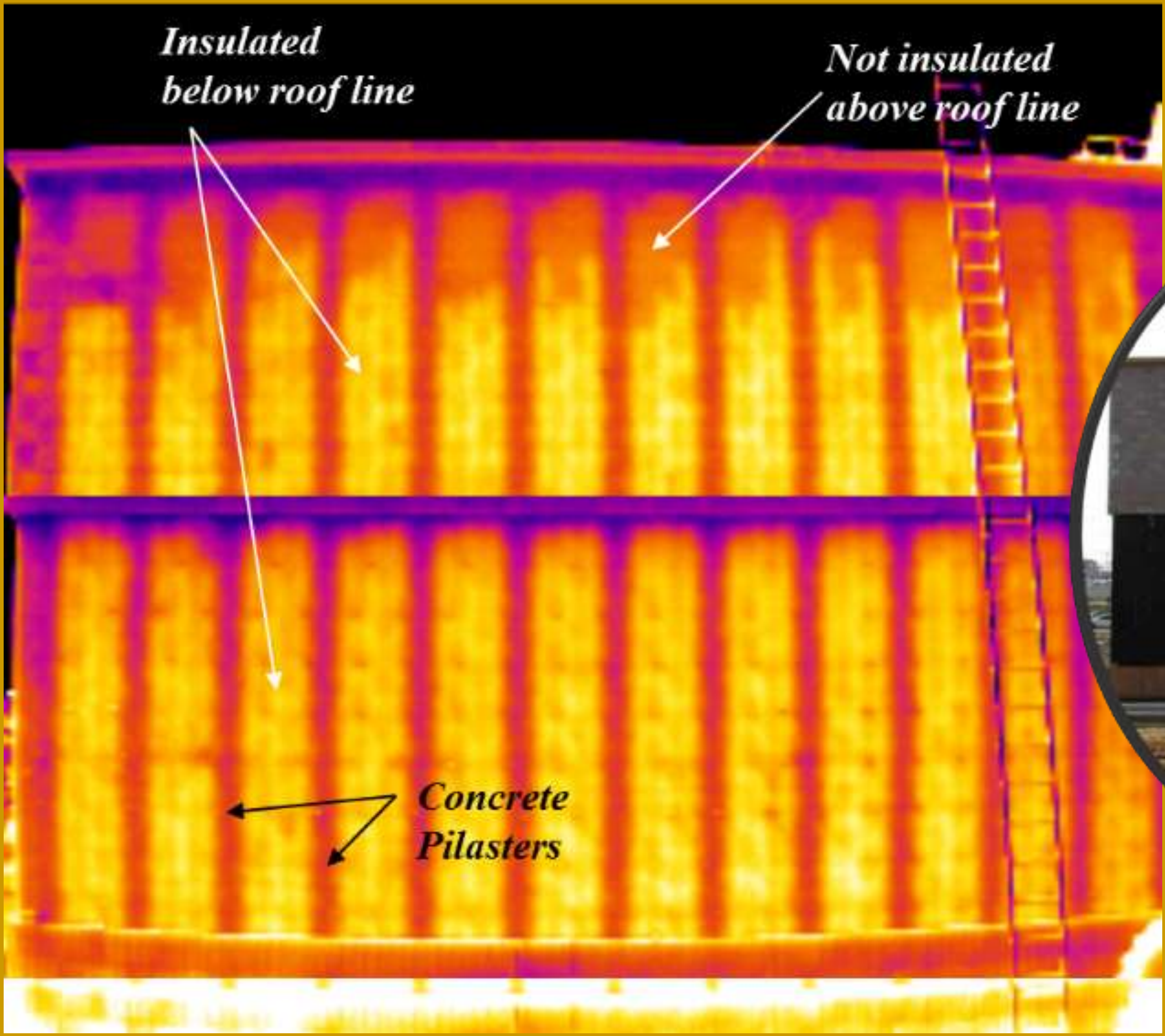


Grouted Cells in Concrete Block Walls

Grouted Cells in Concrete Block Walls



Finding Insulated Cells in Concrete Block Walls



Building Moisture

AEE NORTHERN OHIO CHAPTER

Building IR (Interior Moisture from a Pipe Leak)

93.9°F

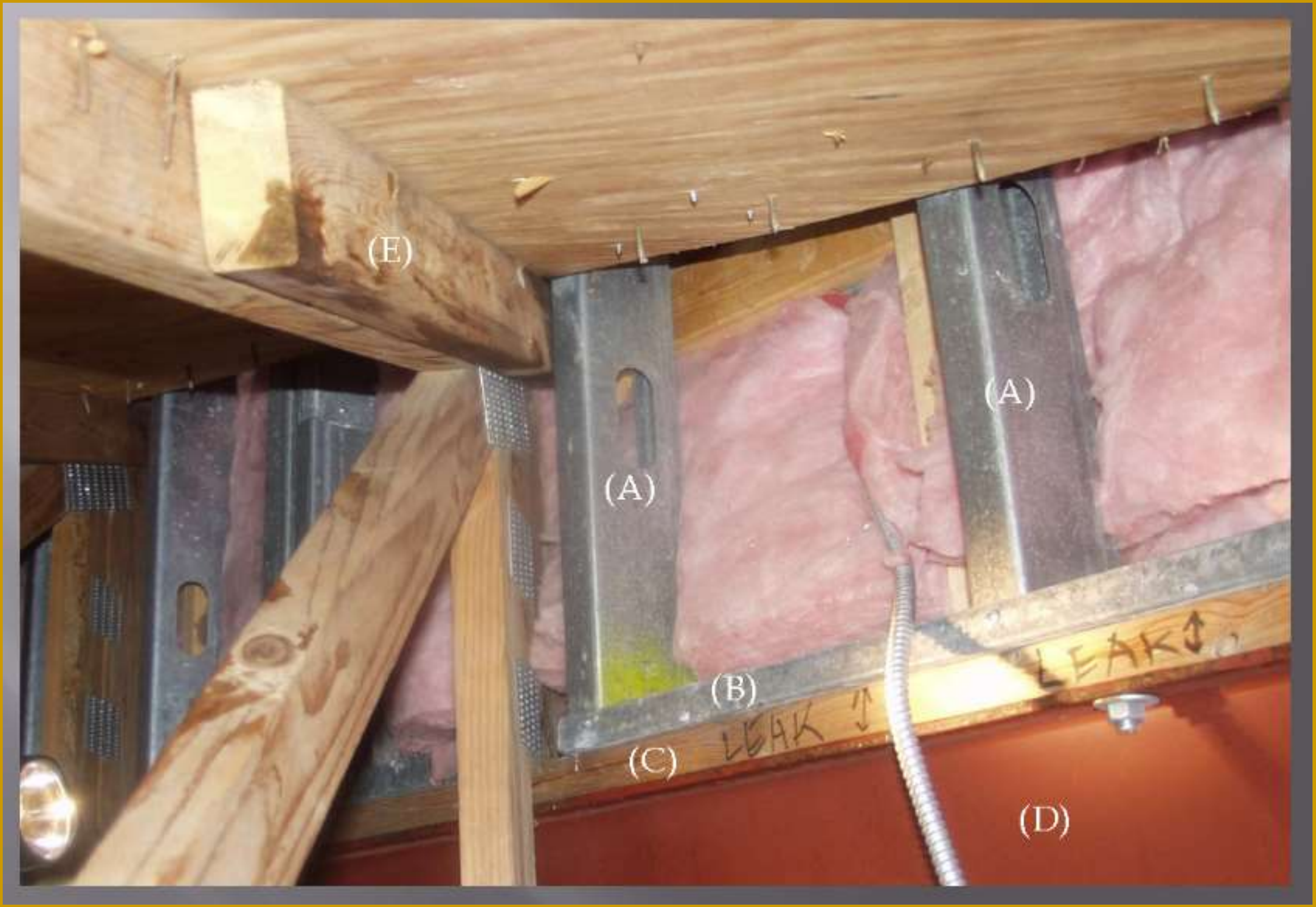
92

86

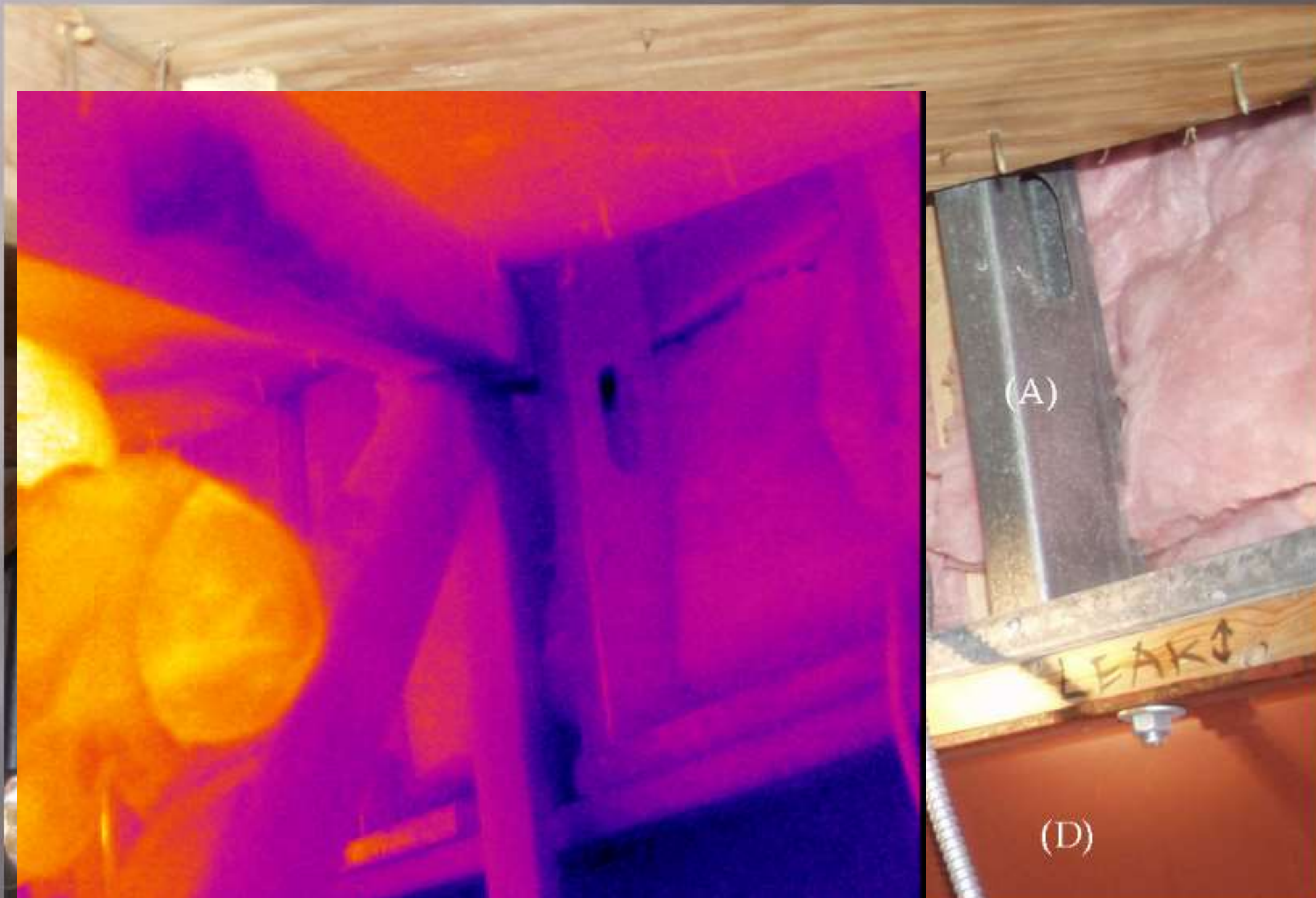
84.1°F

Building IR (Interior Moisture from a Pipe Leak)

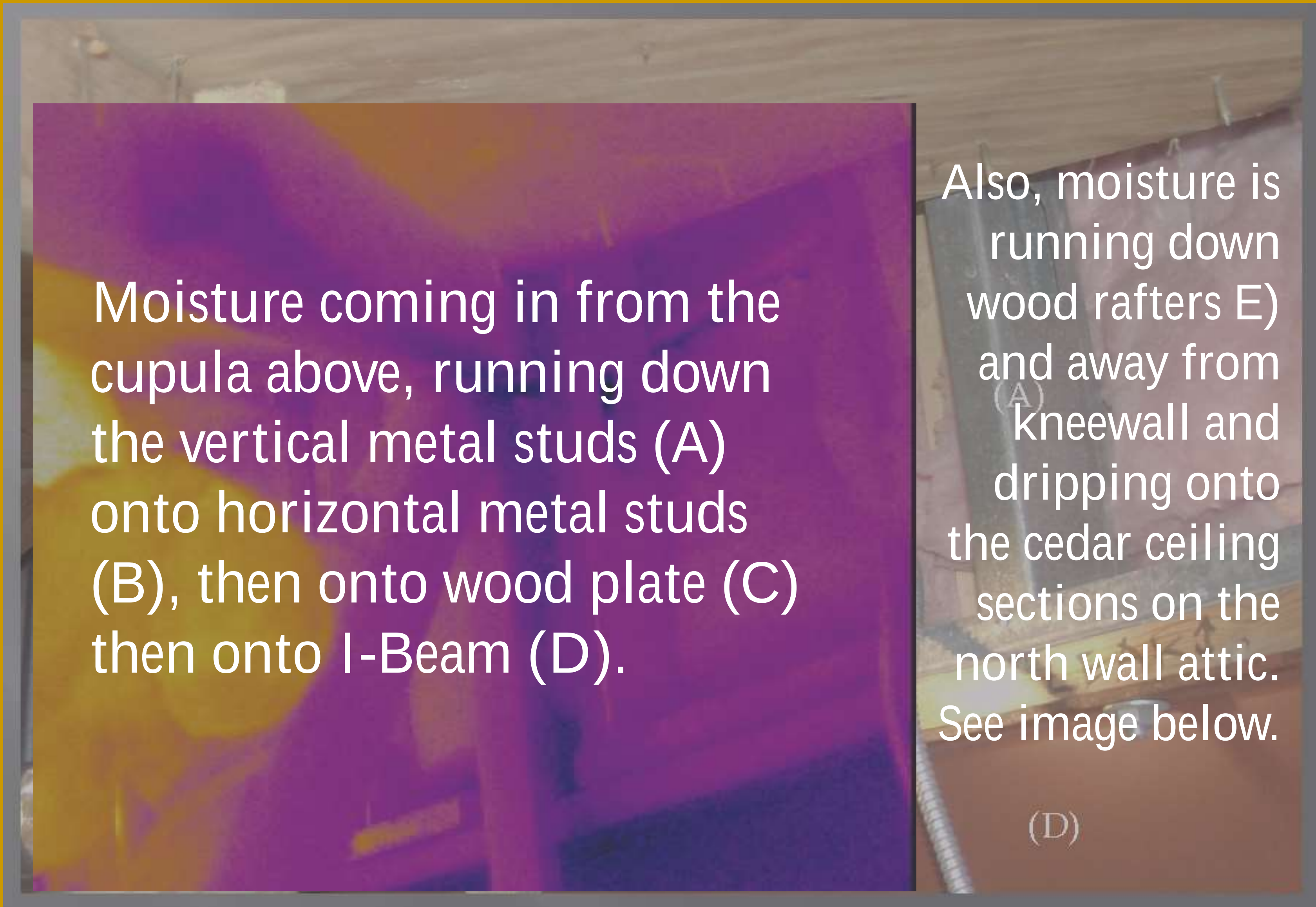
Building IR (Interior Moisture from a Roof Leak)



Building IR (Interior Moisture from a Roof Leak)



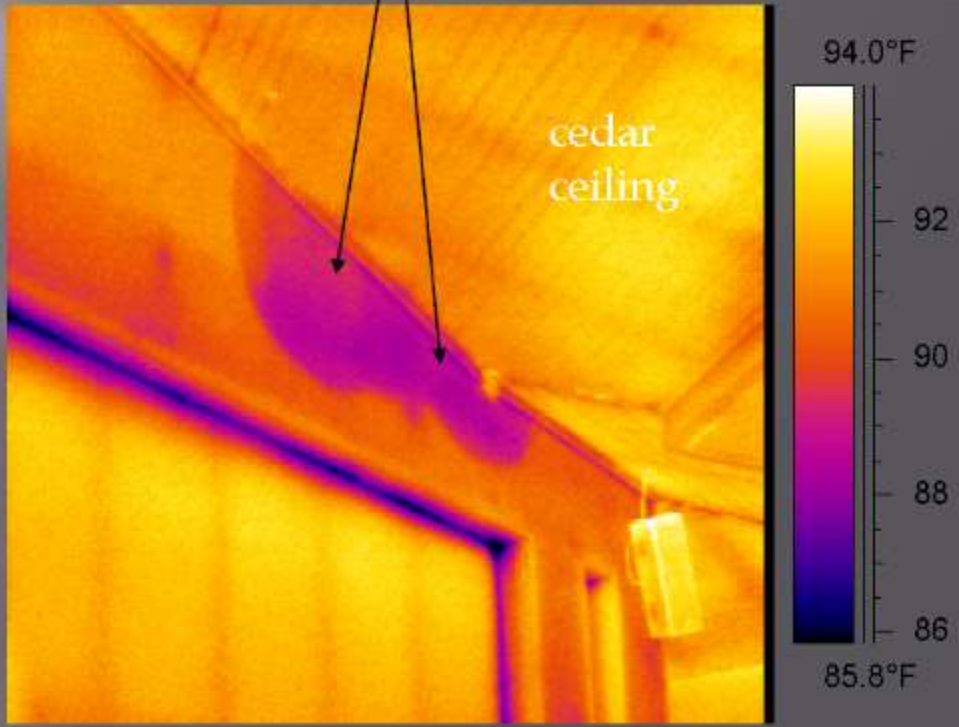
Building IR (Interior Moisture from a Roof Leak)



Moisture coming in from the cupula above, running down the vertical metal studs (A) onto horizontal metal studs (B), then onto wood plate (C) then onto I-Beam (D).

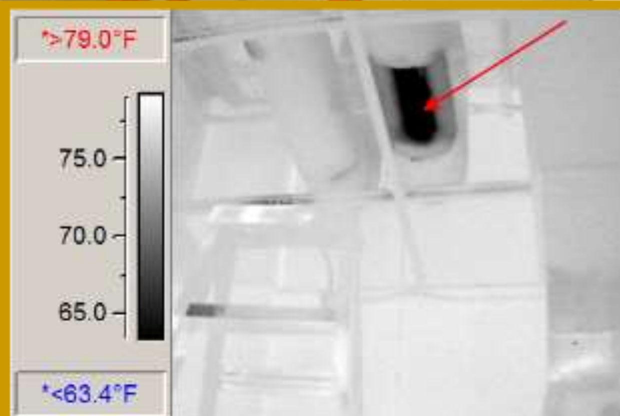
Also, moisture is running down wood rafters E) and away from kneewall and dripping onto the cedar ceiling sections on the north wall attic. See image below.

Building IR (Interior Moisture from a Roof Leak)

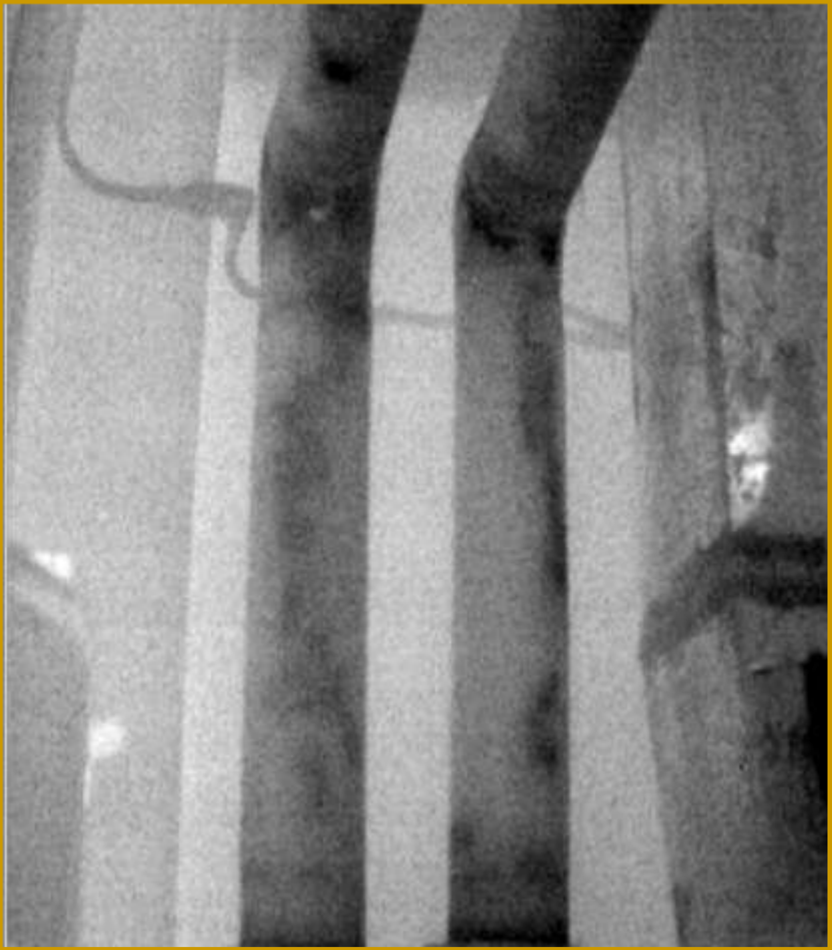


See note above

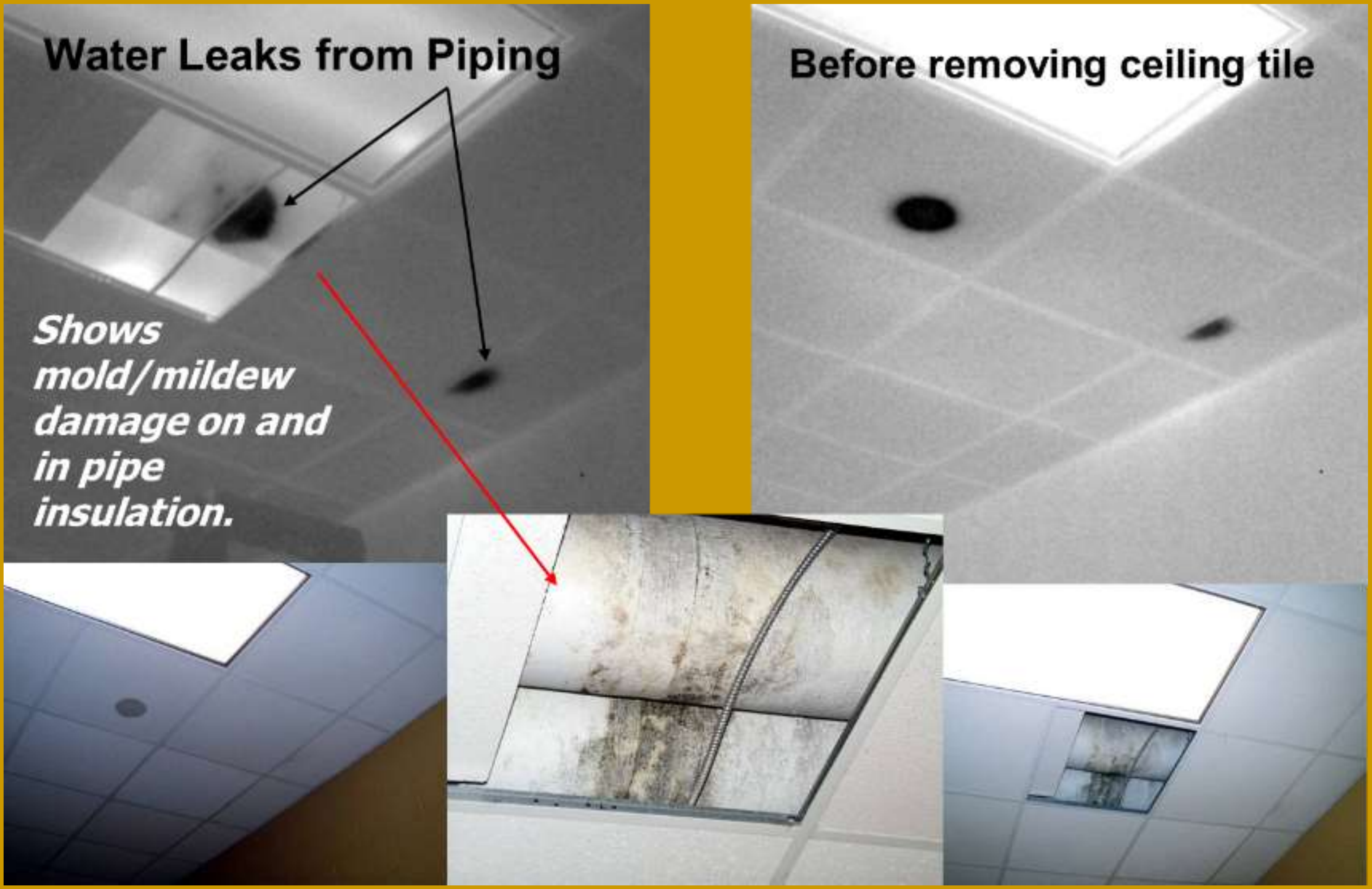
Pipe Condensation in Mechanical Room with Mold Present



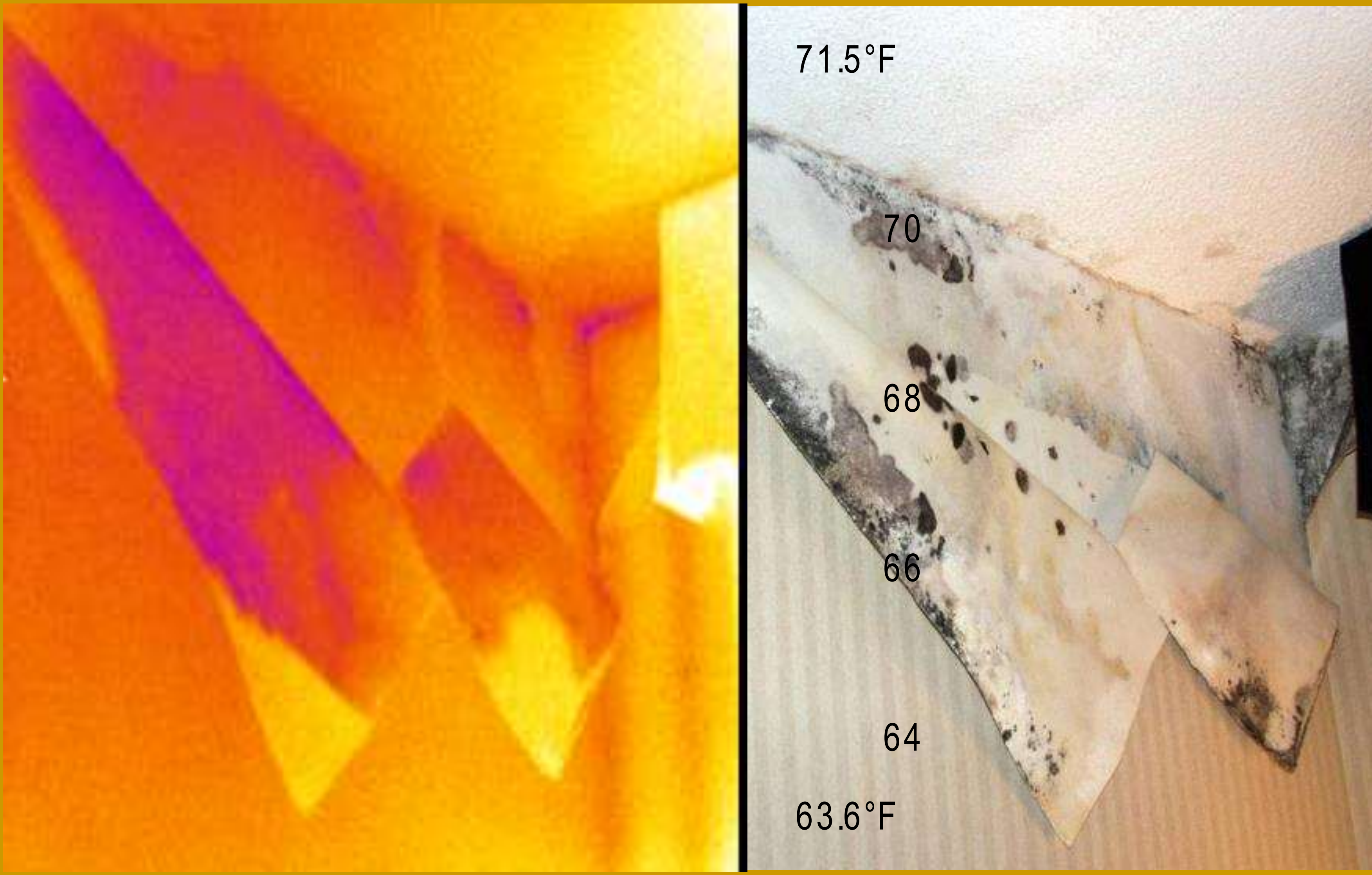
Pipe Condensation in Mechanical Room with Mold Present



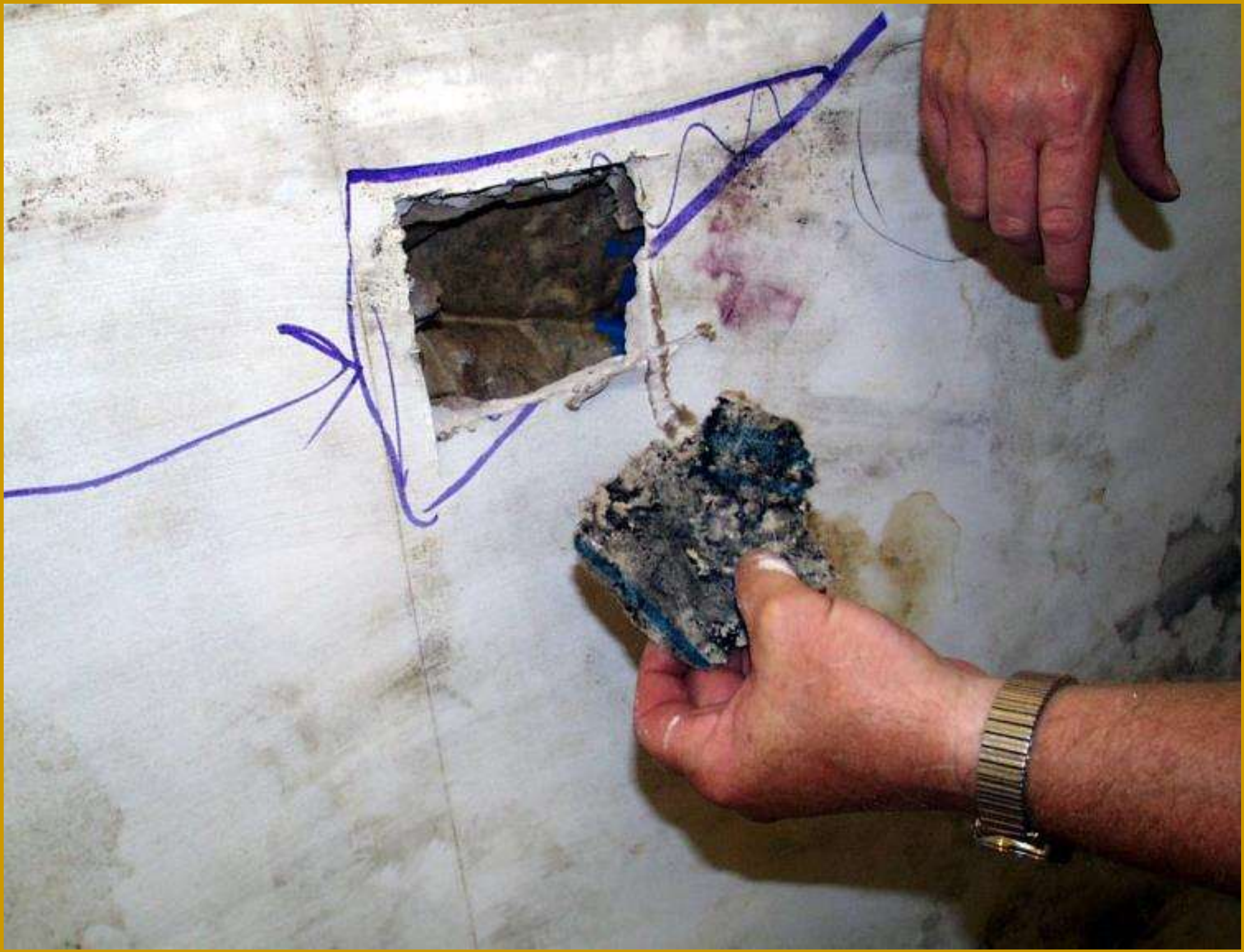
Pipe Condensation in a High School with Mold Present



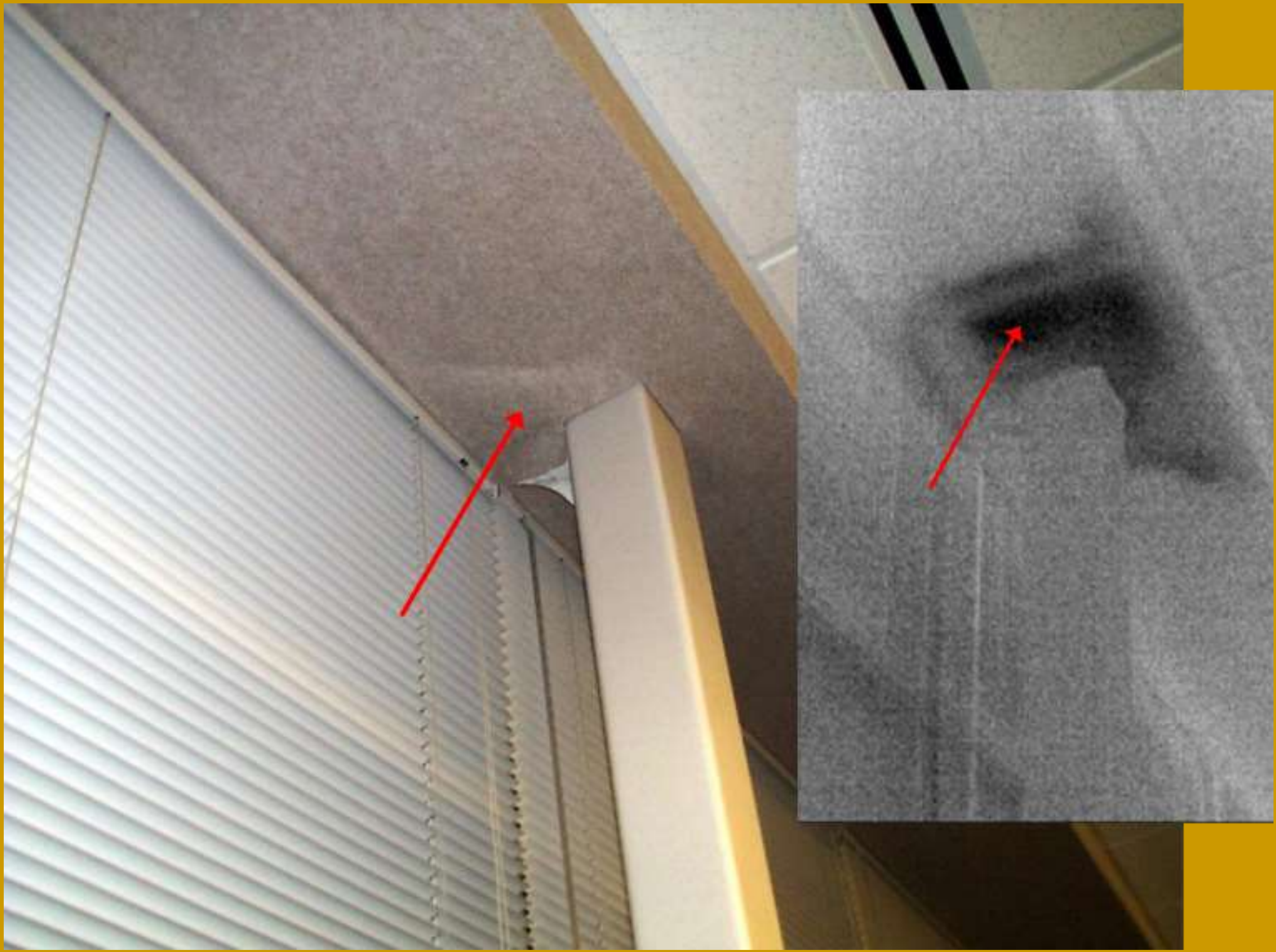
Shows Mold/Mildew Damage on Wallpaper Wall



Mold/Mildew Damage to Inner Wall and Insulation



Moisture Damage at Column Near Ceiling



Water leaks occur from condensation when columns extend into the warm, moist interstitial space

Water leaks also occur from condensation when ductwork does not fit tight to diffusers allowing cold air to leak into interstitial spaces

Water leaks occur from condensation when ductwork in the warm, moist interstitial space meets the cooled air from the inside of the building

Building Roof Moisture

NORTHERN OHIO CHAPTER

Roof Moisture Surveying

Purpose

What makes roof moisture surveying so valuable to the owner of a roof? Of course, cost-savings:

95+% of all roofing materials that are removed are dry

- Best practice condition monitoring (PM) for roof maintenance
- Salvage the thermal value of the existing undamaged insulation
- Avoid costly tear-off expense in labor to R&R wet insulation
- Avoid cost to bury perfectly good insulation in a landfill
- Save time: recover is faster vs. tear-off and replacement
- Minimize risk of leaks and consequential damage
- It is “Green” not to throw away perfectly good materials

Roof Moisture Surveying

Waterproofing problems manifest themselves in two ways:

- **Leakage**
- **Entrained moisture contamination**

NDT is not leak detection!

Leakage is pretty simple, although the leak inside the building rarely directly relates to the exact spot on the roof, since the water flows down the slope of the roof to a spot that is not sealed and into the building at that point. Most leaks [on the roof] occur where the waterproofing is not sealed or where a penetration through the roof that is not sealed. Since most types of roof systems absorb some amount of water, it is harder to find the exact spot of water contamination in the insulation because it may not leak into the building until it has absorbed all the water it can hold.

Roof Moisture Surveying

Two Methods of testing roofs for moisture:

1. Destructive Testing
   - Pin type meters
   - Core Sampling

2. Non-Destructive Testing
   - Nuclear Density Gauges
   - Dielectric Capacitance Meters
   - Thermal Infrared Cameras

Roof Moisture Surveying

Destructive Testing

Pin type

Roof Moisture Surveying

Destructive Testing

Core Sampling

Absolute Verification
of that single point

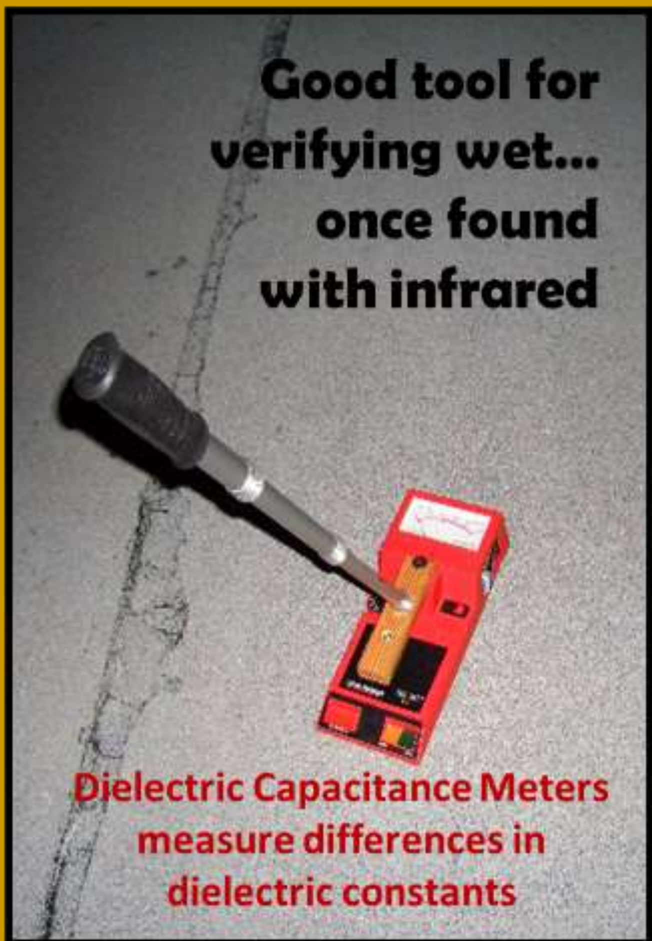
Roof Moisture Surveying

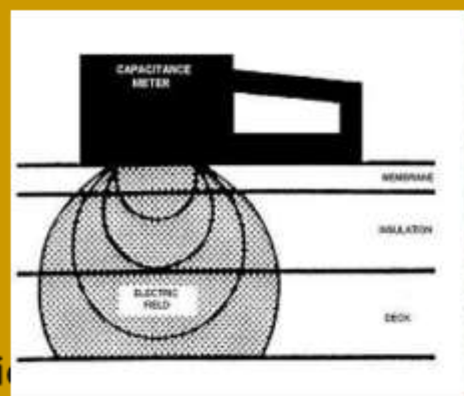
Non-Destructive Testing – Three Devices

- Nuclear Density Gauges
  – which count slowed neutrons
- Dielectric Capacitance Meters
  – which measures differences in dielectric constants
- Thermal Infrared Cameras
  – which measure heat differences

Roof Moisture Surveying

Non-Destructive Testing – Capacitance





Roof Moisture Surveying

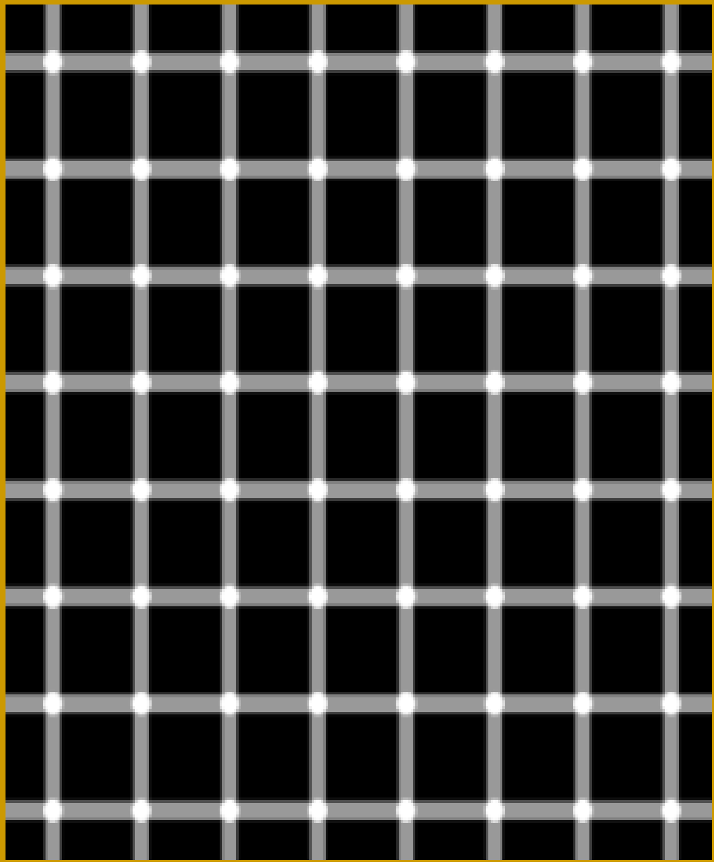
Non-Destructive Testing – Nuclear

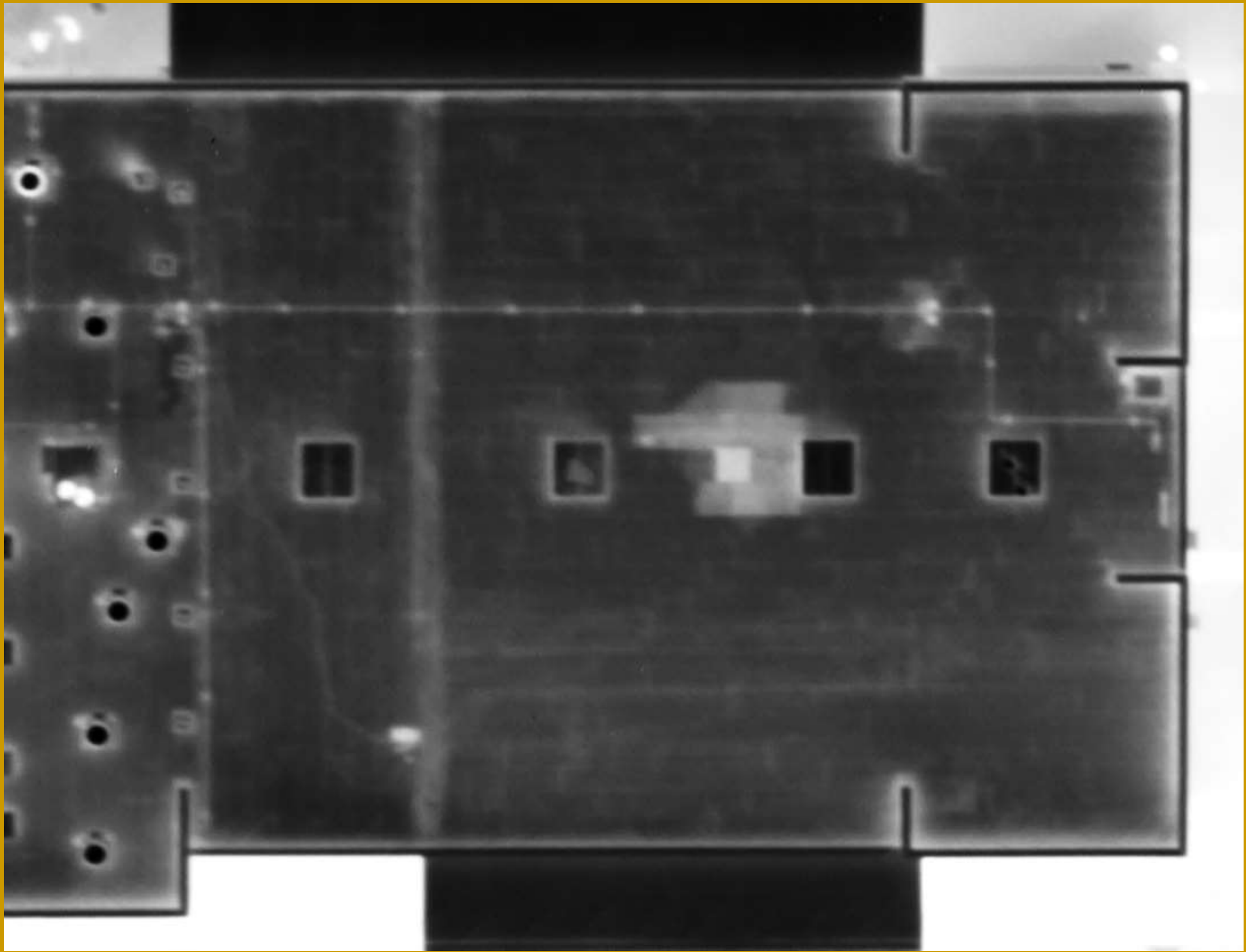
Nuclear Density Gauges count slowed neutrons

Meter surveying takes a long time and presents small sample results

The roof to be surveyed is marked. A reading is obtained. The reading is recorded. Readings are extrapolated to determine where the roof is wet.

Readings can be very misleading and require considerable analysis.





5,000 SF Roof Area

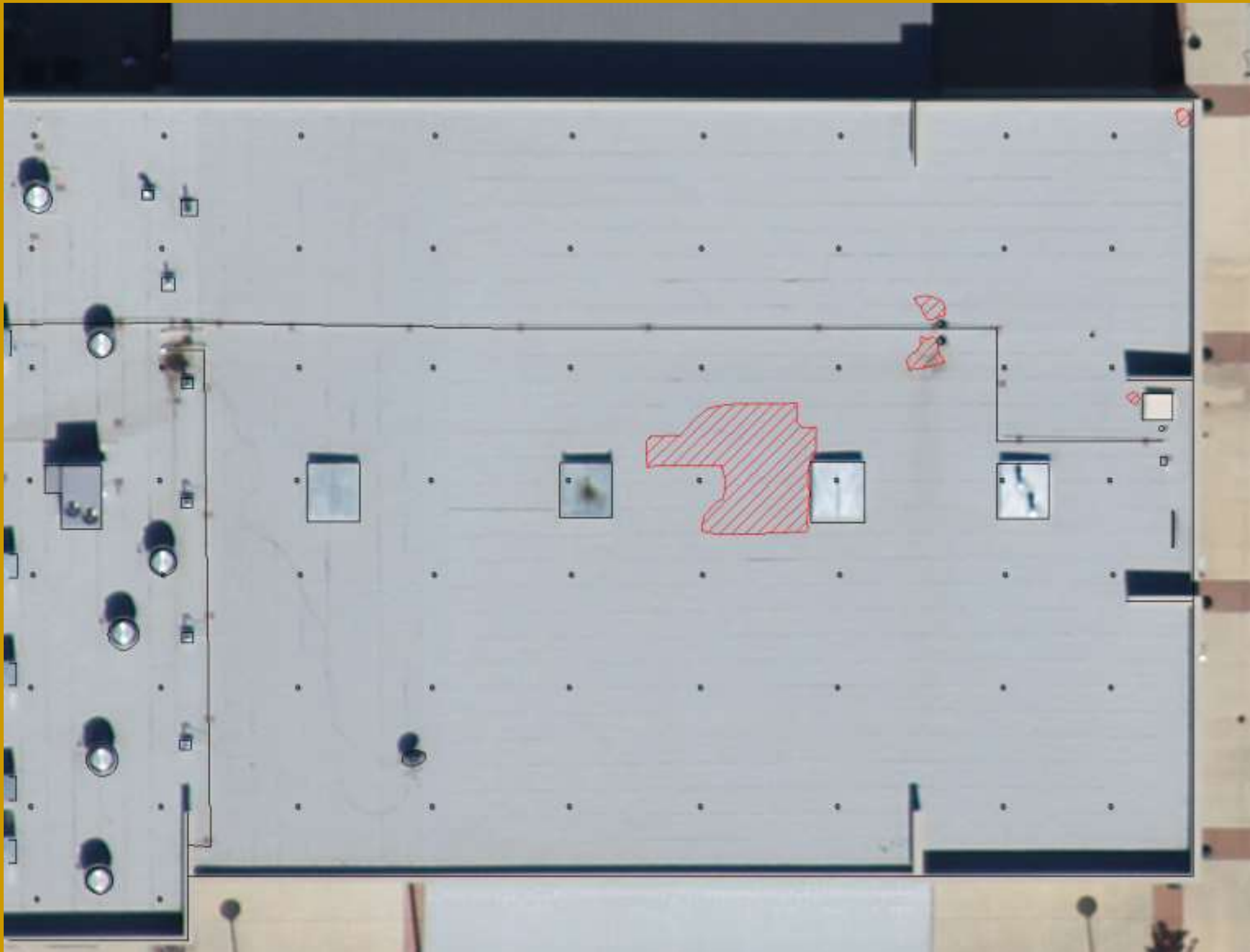
80 SF wet
5 spots
5 found

On-Roof Infrared takes less than an hour to find & mark wet areas

5,000 SF Roof Area

80 SF wet
5 spots
0 found
21 reads
10' x 10' Grid

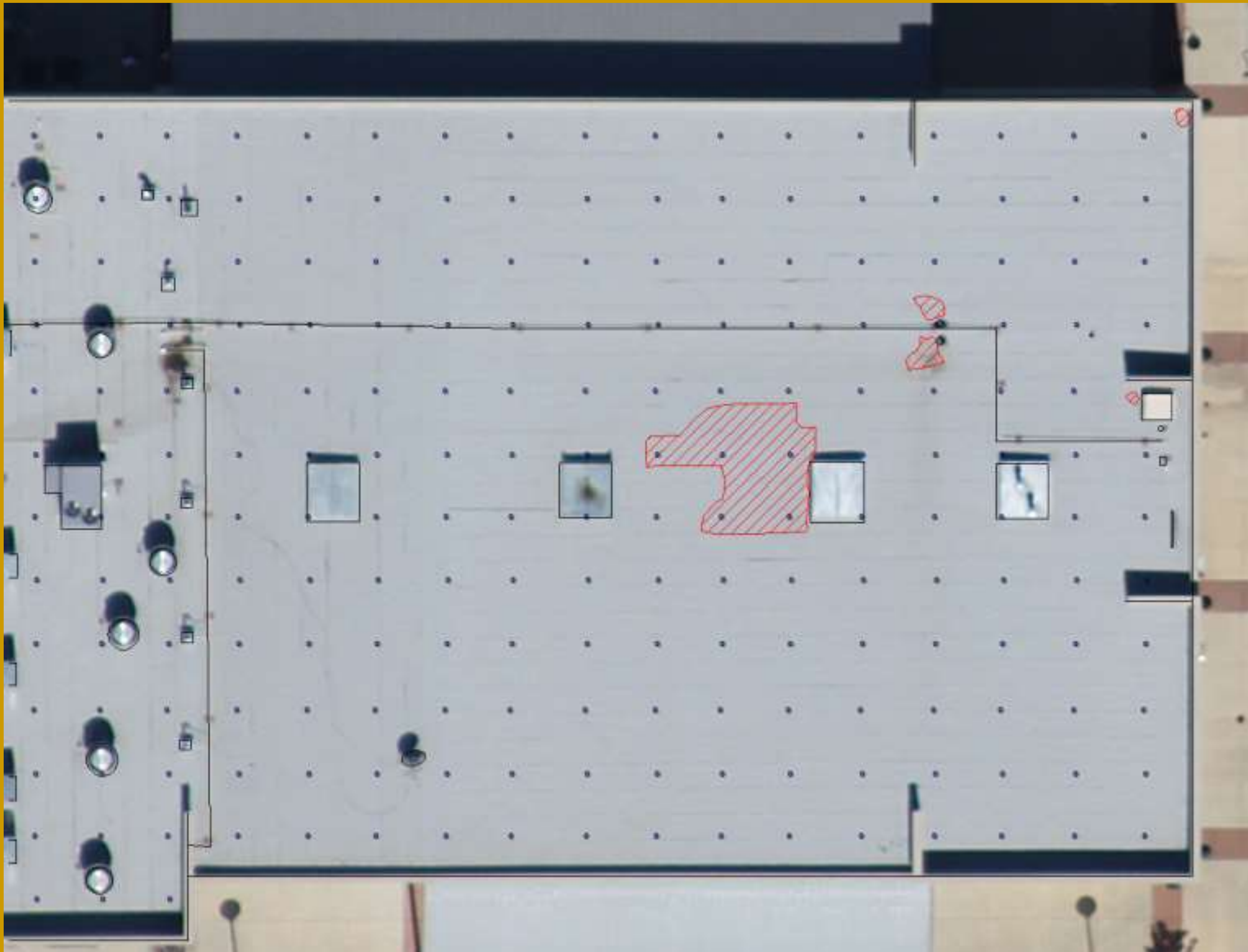
Metering takes 1-2 hours to find & mark wet areas



5,000 SF Roof Area

80 SF wet
5 spots
0 found
65 reads
10' x 10' Grid

Metering takes 2-3 hours to find & mark wet areas



5,000 SF
Roof Area

80 SF wet
5 spots
1 found
207 reads
5' x 5' Grid

Metering takes 4-5 hours to find & mark wet areas

Roof Moisture Surveying

Non-Destructive Testing – Meter Surveys

- Both nuclear gauges and capacitance meters are used to take spot readings on either a 20’x20’ or 10’x10’ or 5’x5’ grid on the roof.
- These measurements are used to extrapolate where the water is from the readings obtained from the gauge.
- Notwithstanding false or inaccurate readings, the sample of the roof is tiny, given the amount of readings and associated labor.

Roof Moisture Surveying

Meter surveys only work to prove that a roof is so widespread wet that they are beyond repair. They are not used to find and delineate areas that need repair.

Meter surveys are primarily used on roof types that do not gain or lose solar energy well or for whatever reason do not lend themselves to infrared.

When you can use it infrared, it is always best, because 100% of the roof surface is surveyed…

Roof Moisture Surveying

Methods to accomplish IR Roof Moisture Surveys...

- Under-Roof Infrared Roof Moisture Surveys
- On-Roof Infrared Roof Moisture Surveys
- Elevated Vantage Point Infrared Roof Moisture Surveys
- Aerial Infrared Roof Moisture Surveys

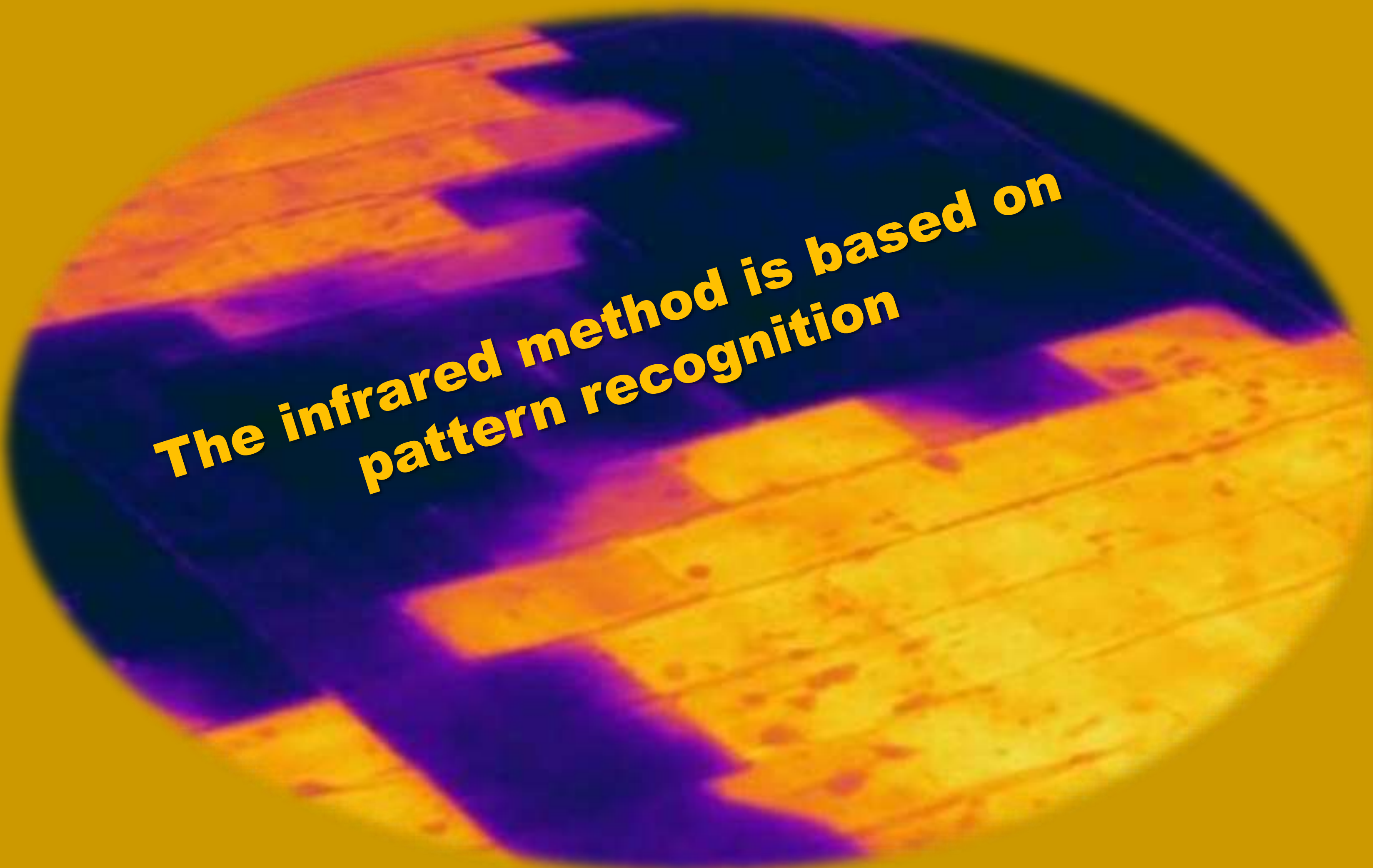
The same thermodynamics and laws of physics apply to all.

A dry roof, low winds and no rain are needed on the night of the survey. The more clear the sky, the better.

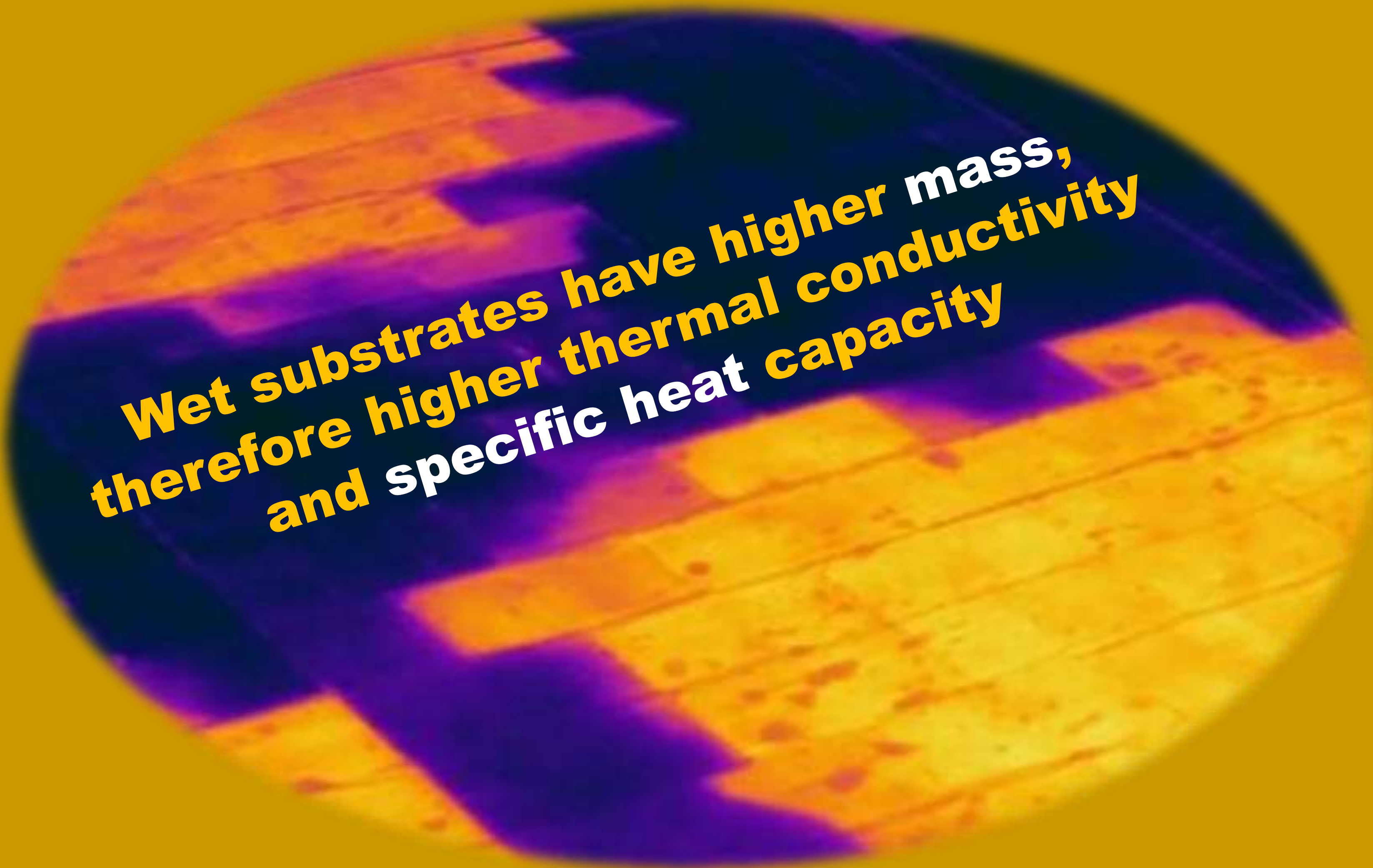
Solar Insolation is the main factor as far as thermal conditions.

All three methods have advantages and disadvantages...

Roof Moisture Surveying



Roof Moisture Surveying

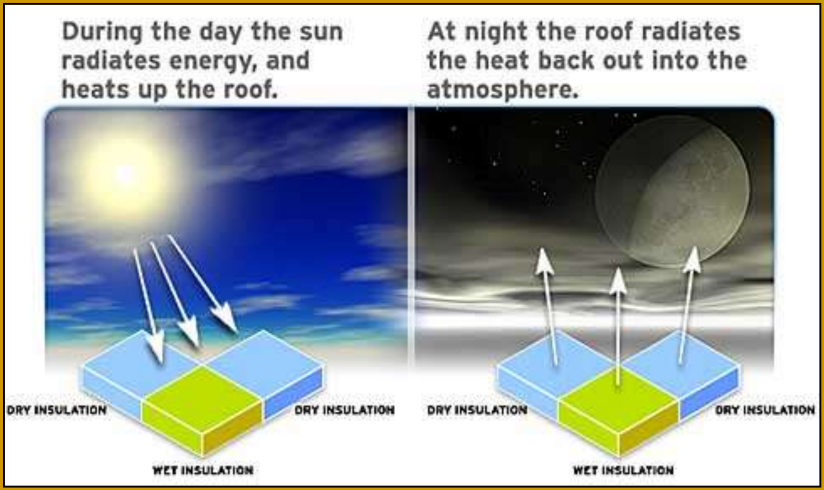


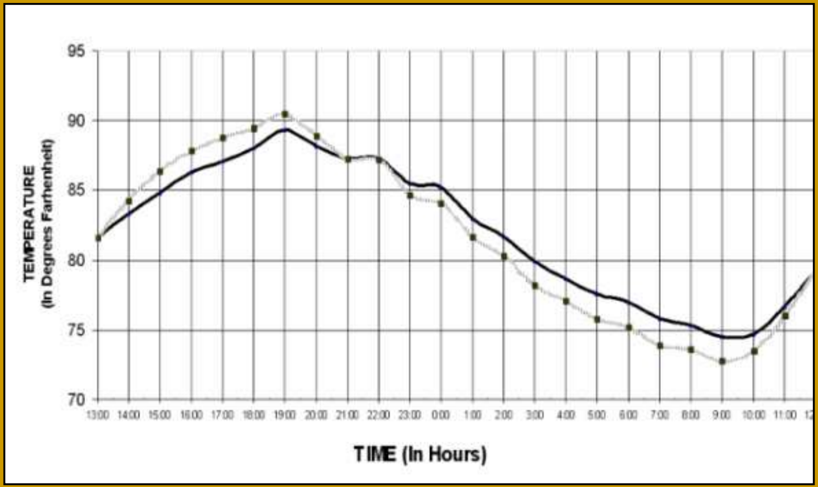
Roof Moisture Surveying

Understanding Infrared Roof Imagery

Infrared imagery is often a grayscale picture whose scales (or shades of gray) represent the differences in temperature and emissivity of objects in the image. As a general rule, objects in the image that are lighter in color are warmer and darker objects are cooler. No object in the images is detected via visible light wavelengths (400-700 nanometers) rather, only from infrared wavelengths in the 3000-5000 nanometers or the 8000-14000 nanometers range. Lights and other relatively hot objects are very evident, but as a result of their heat, and not light emissions.

When an image is taken by an infrared camera, it is often recorded on videotape and/or digitally saved to a storage device later converted to a digital image file with the help of a computer. The image may then be modified in a number of ways to enhance its value to the end user. The printed pictures are used as a convenient reference when making the building drawings or accompanying a roof report.



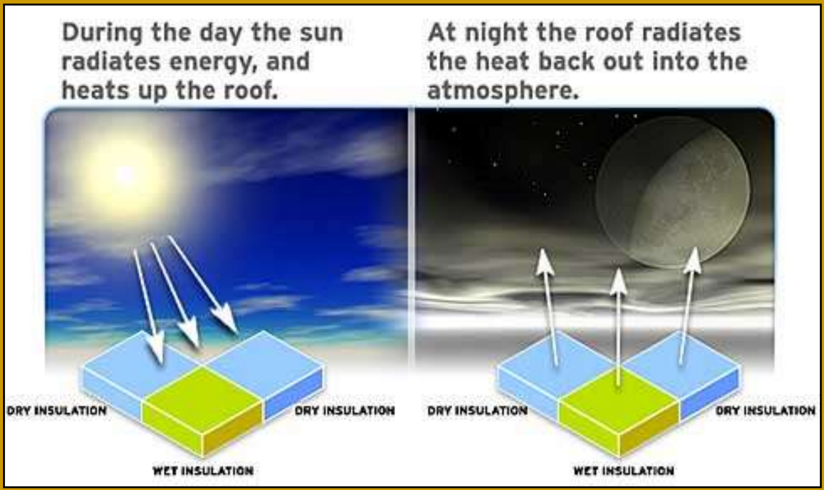


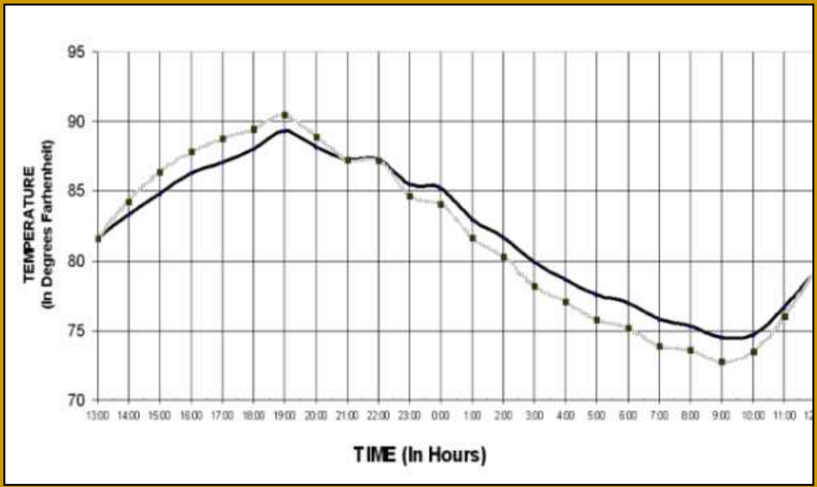
Roof Moisture Surveying

Understanding Infrared Roof Imagery

Areas of roof moisture contamination often manifest themselves as warmer (lighter colored) areas that may be nebulous in shape and sometimes mottled in appearance, although they are commonly found in linear or puddle-like shapes. The linear shapes many times follow low areas, drainage routes, roof edges and seams. Puddle-like round or oblong shapes often form around roof penetrations such as mechanical equipment, standpipes, vents and drains.

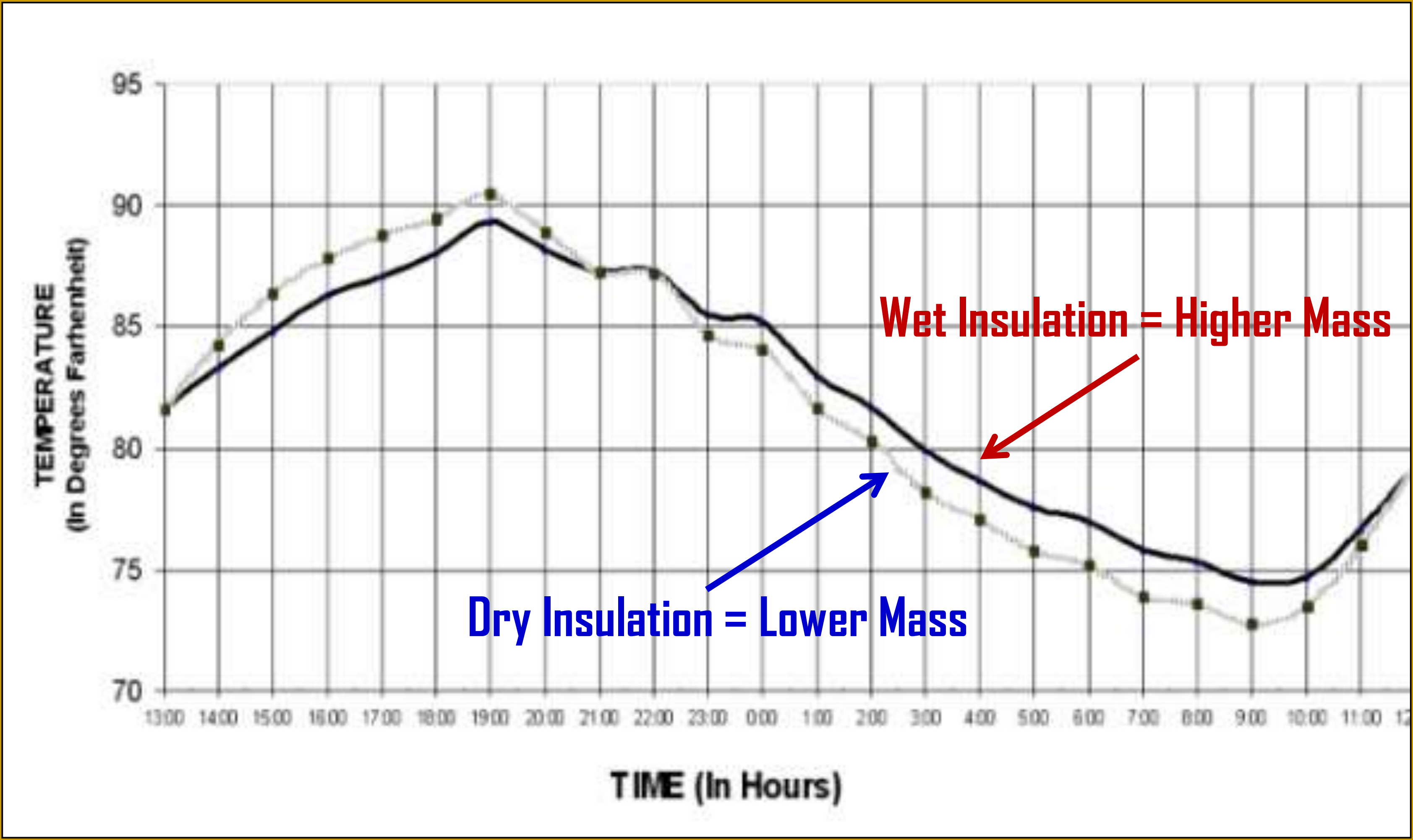
The wet areas are lighter in color because the latent heat (from daylight sunshine) in the trapped water mass is greater than in the dry, functioning insulation or roof substrate. After sunset when the roof structure cools down, wet areas of roof insulation and other materials continue to radiate heat, allowing our sensitive infrared cameras to detect the sources of heat and record them for later analysis.





Roof Moisture Surveying

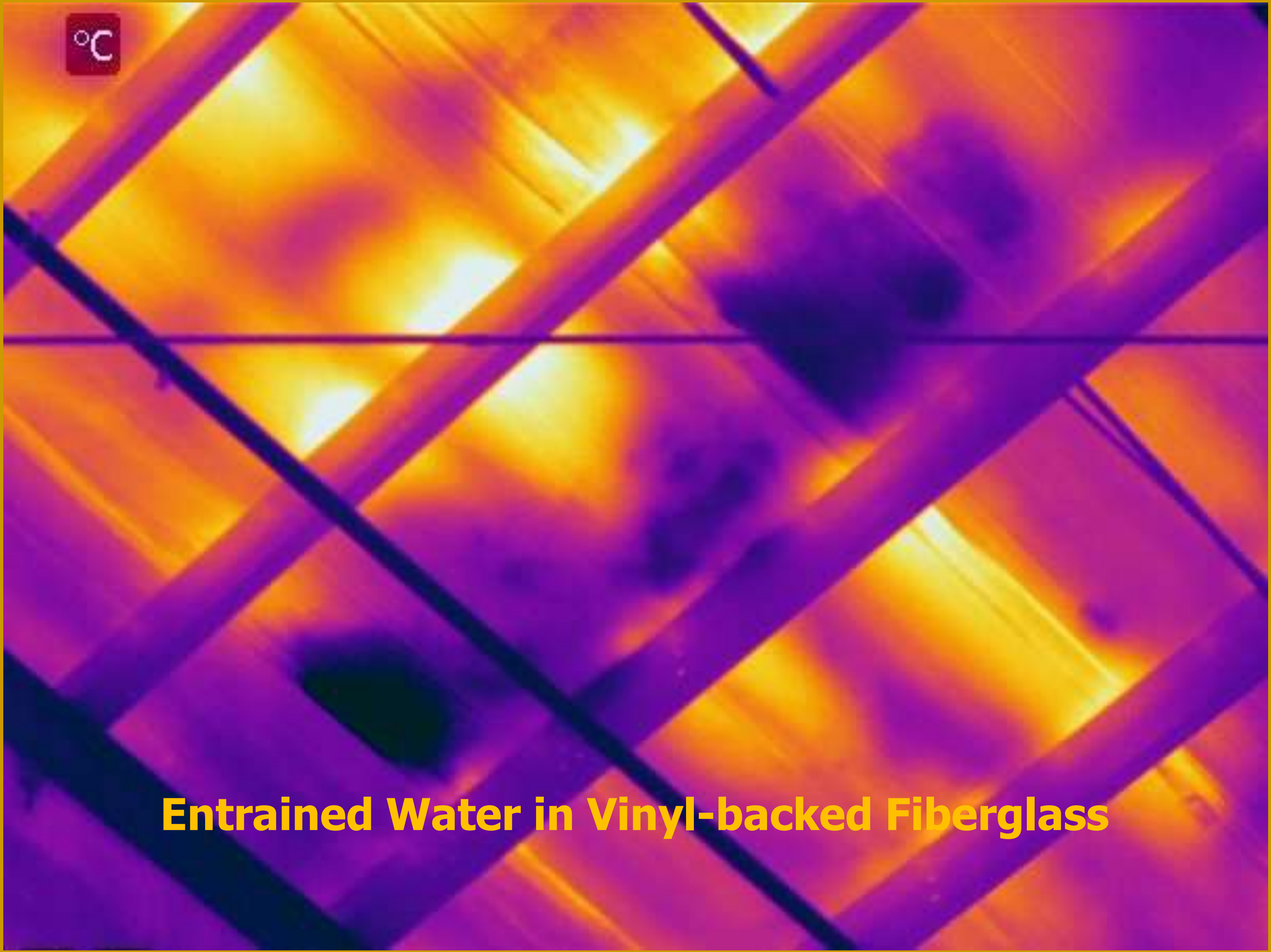
Understanding Infrared Roof Imagery



Under-Roof Moisture Surveying

Under-Roof Moisture Surveying

Under-Roof Moisture Surveying

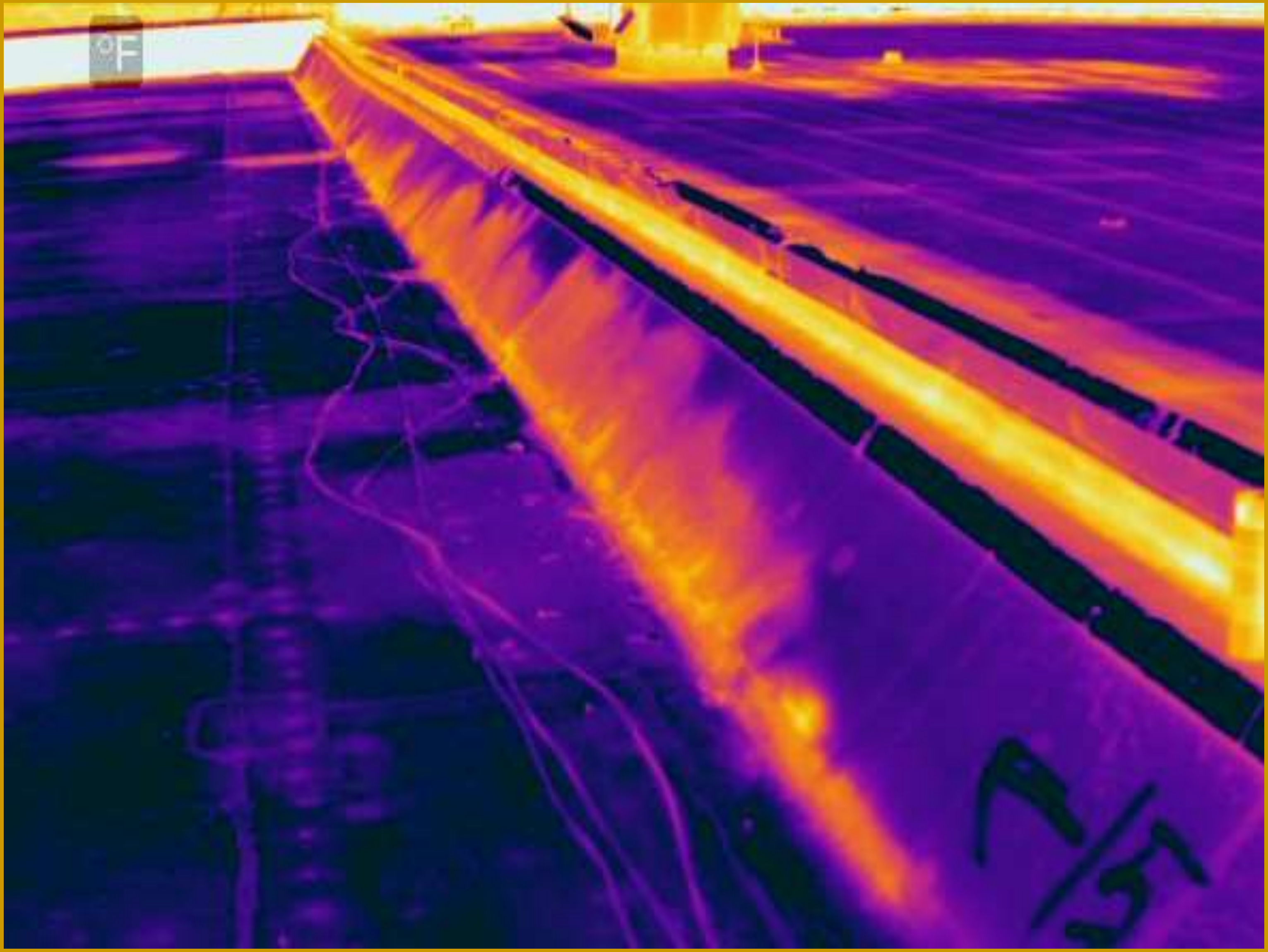


Entrained Water in Vinyl-backed Fiberglass

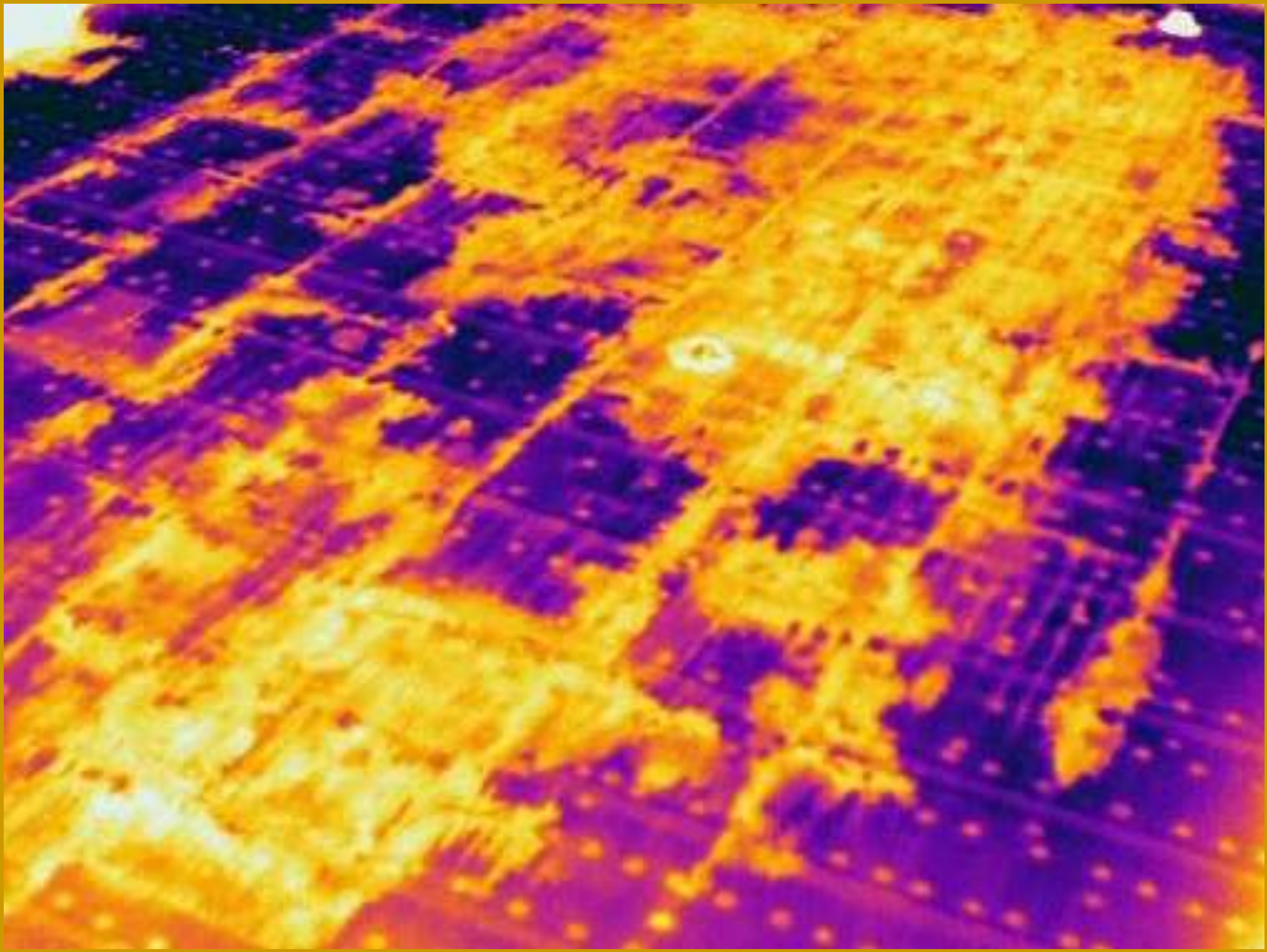
On-Roof Moisture Surveying

On-Roof Moisture Surveying

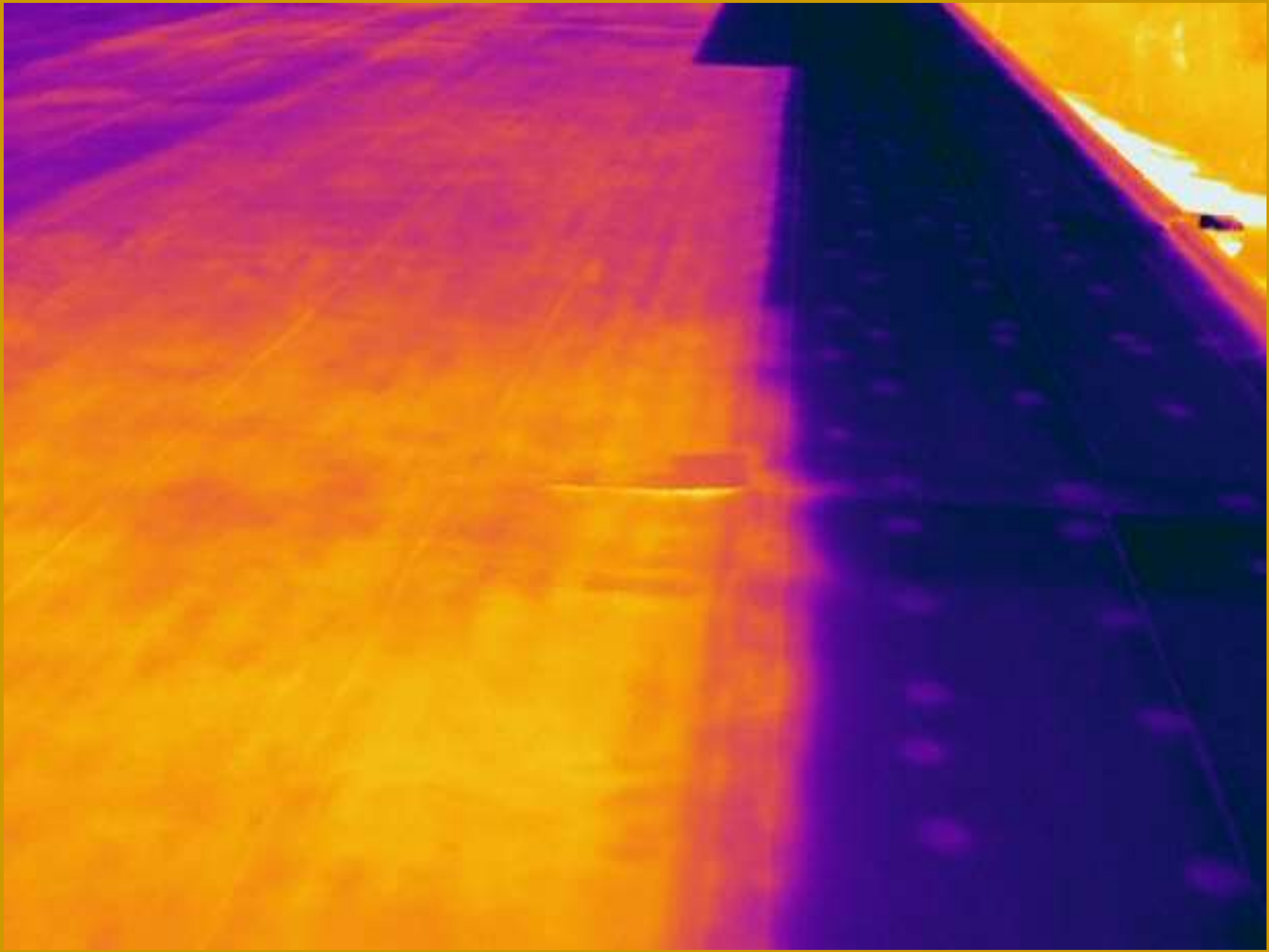
On-Roof Moisture Surveying



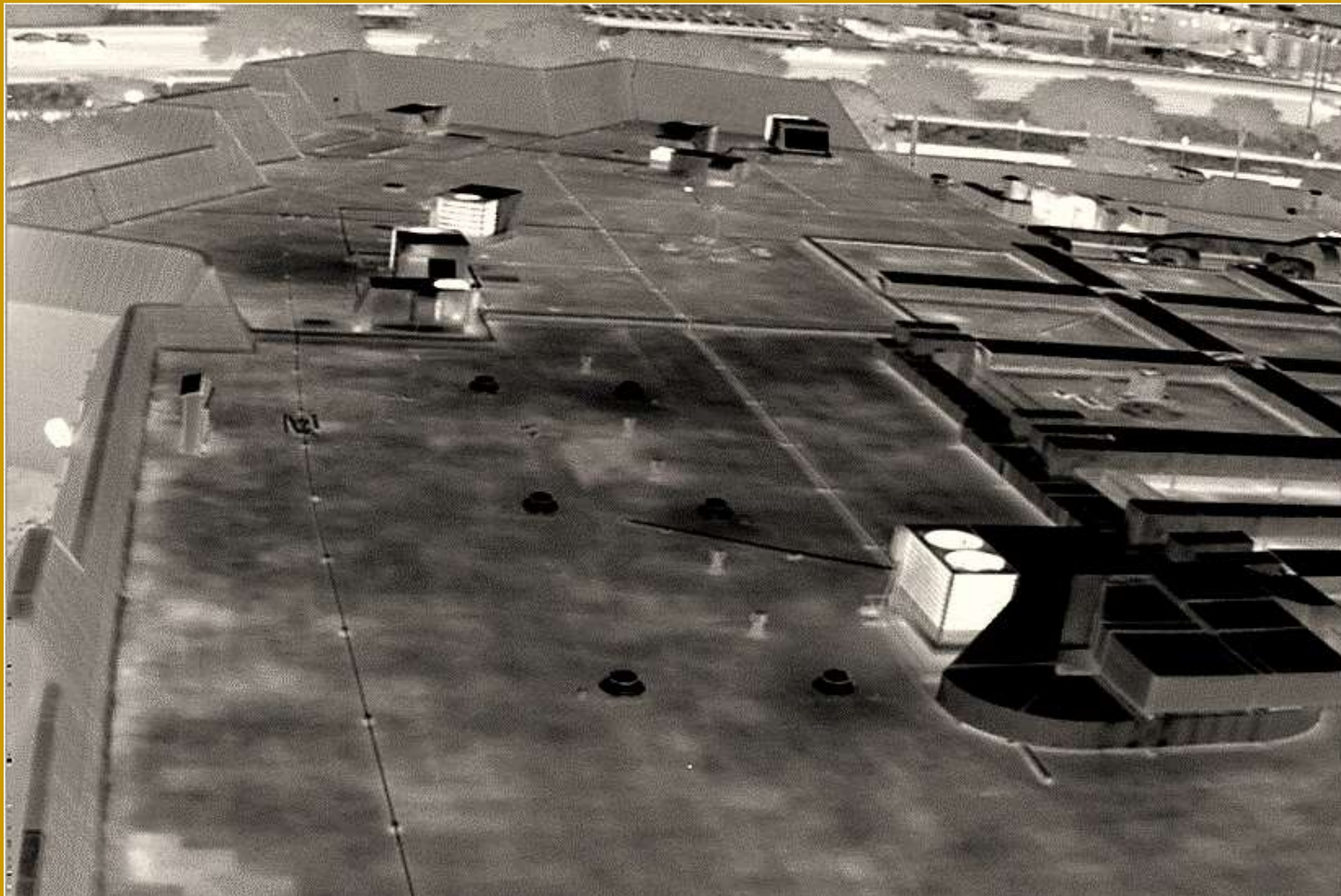
On-Roof Moisture Surveying



On-Roof Moisture Surveying

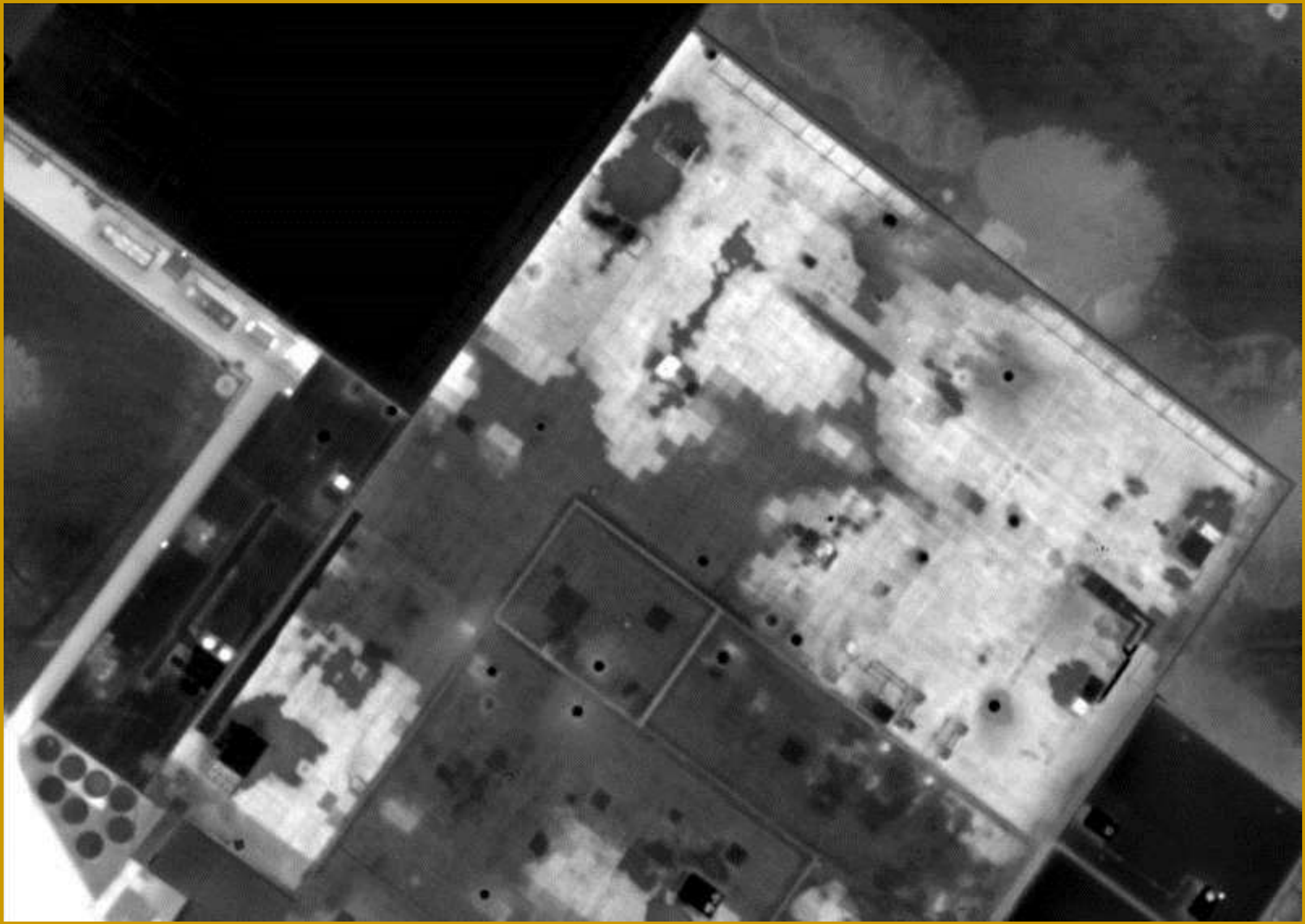


Elevated Roof Moisture Surveying

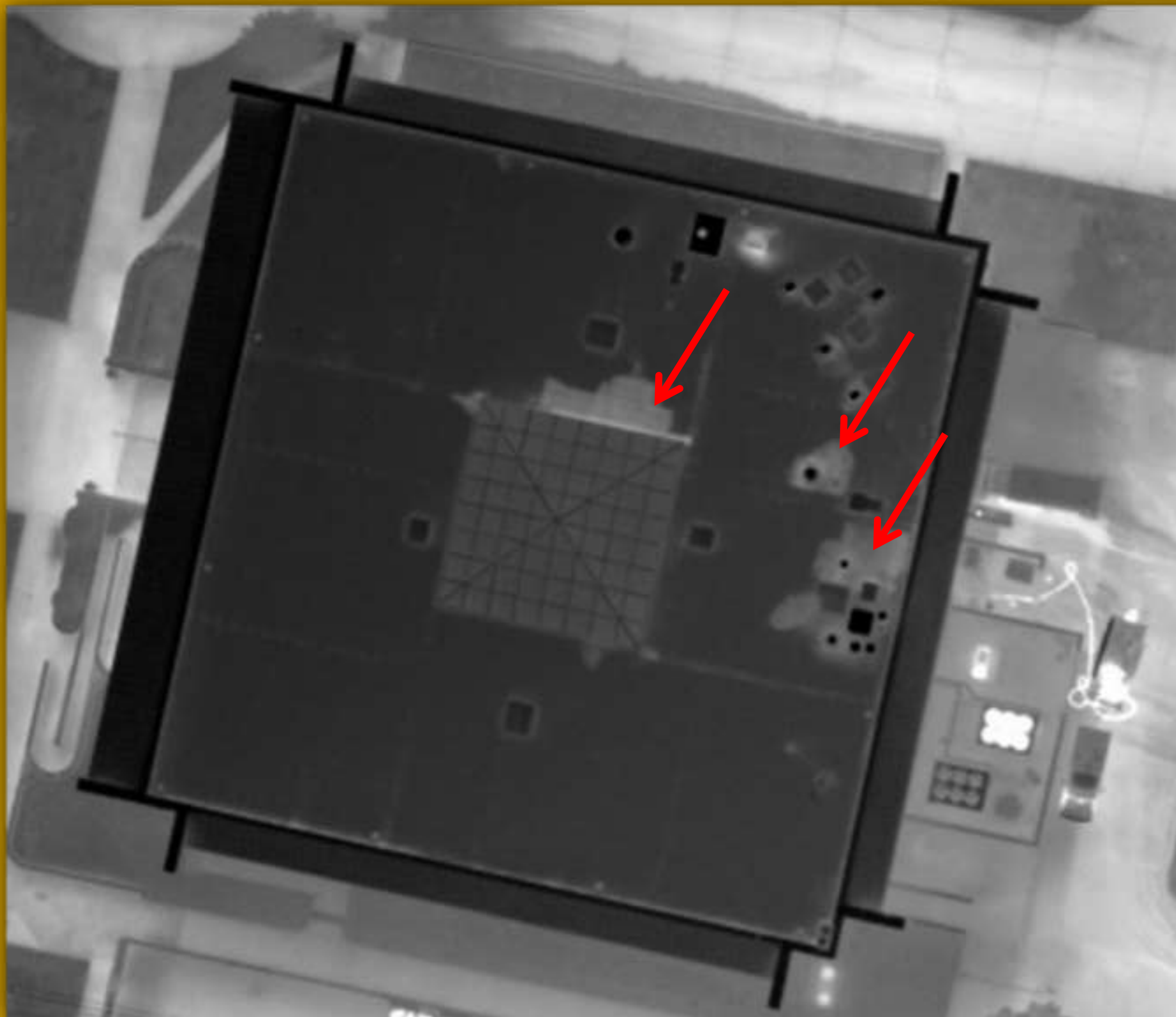


Elevated Roof Moisture Surveying

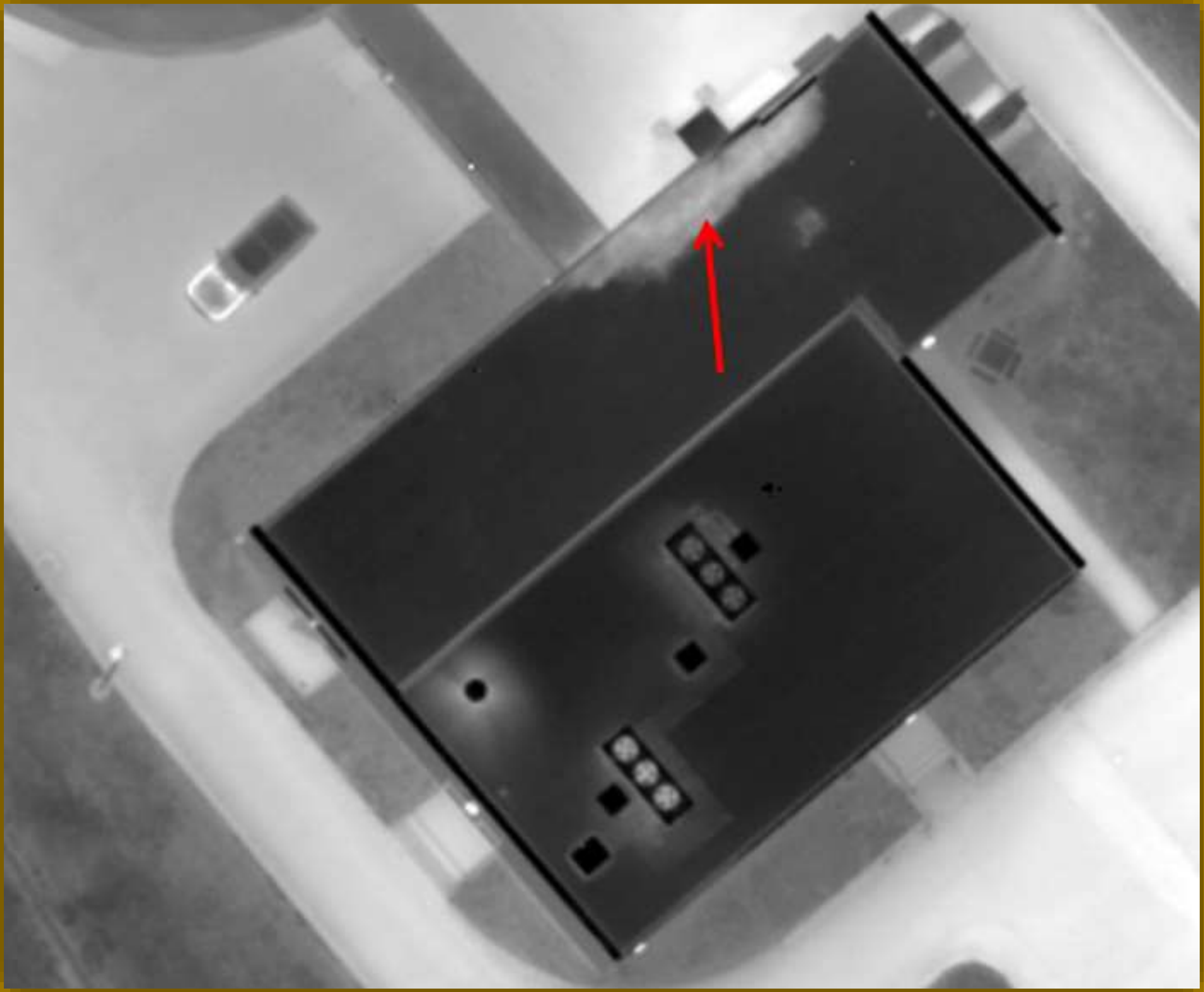
Aerial Roof Moisture Surveying



Aerial Roof Moisture Surveying

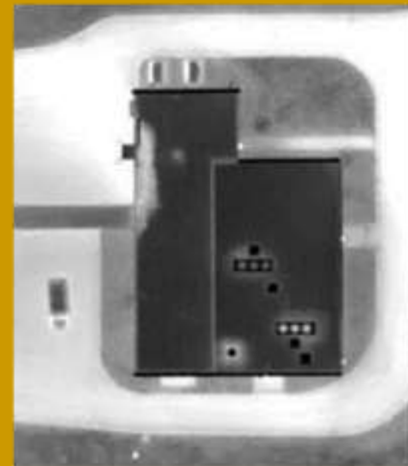


Aerial Roof Moisture Surveying

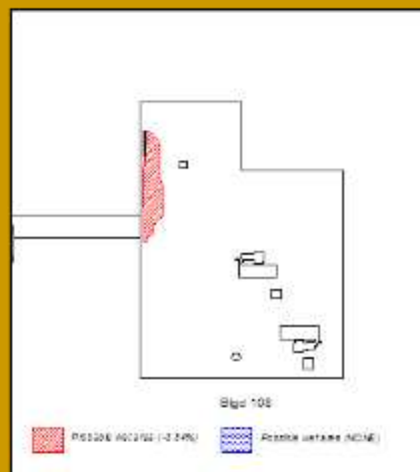


Aerial Roof Moisture Surveying

PHOTOGRAPH



THERMOGRAPH

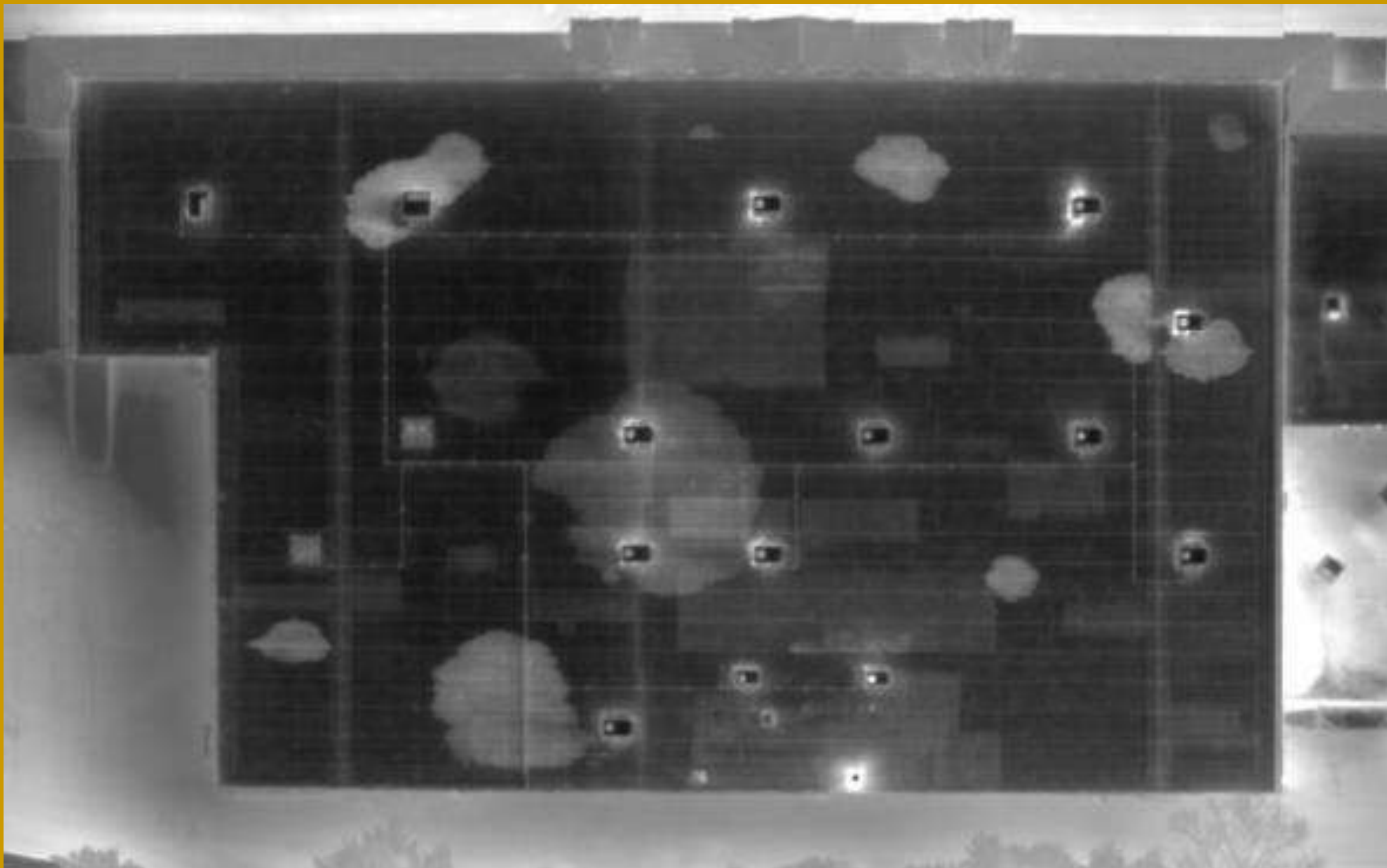


CAD DRAWING

CAD OVERLAY

Aerial Roof Moisture Surveying

Aerial Roof Moisture Surveying

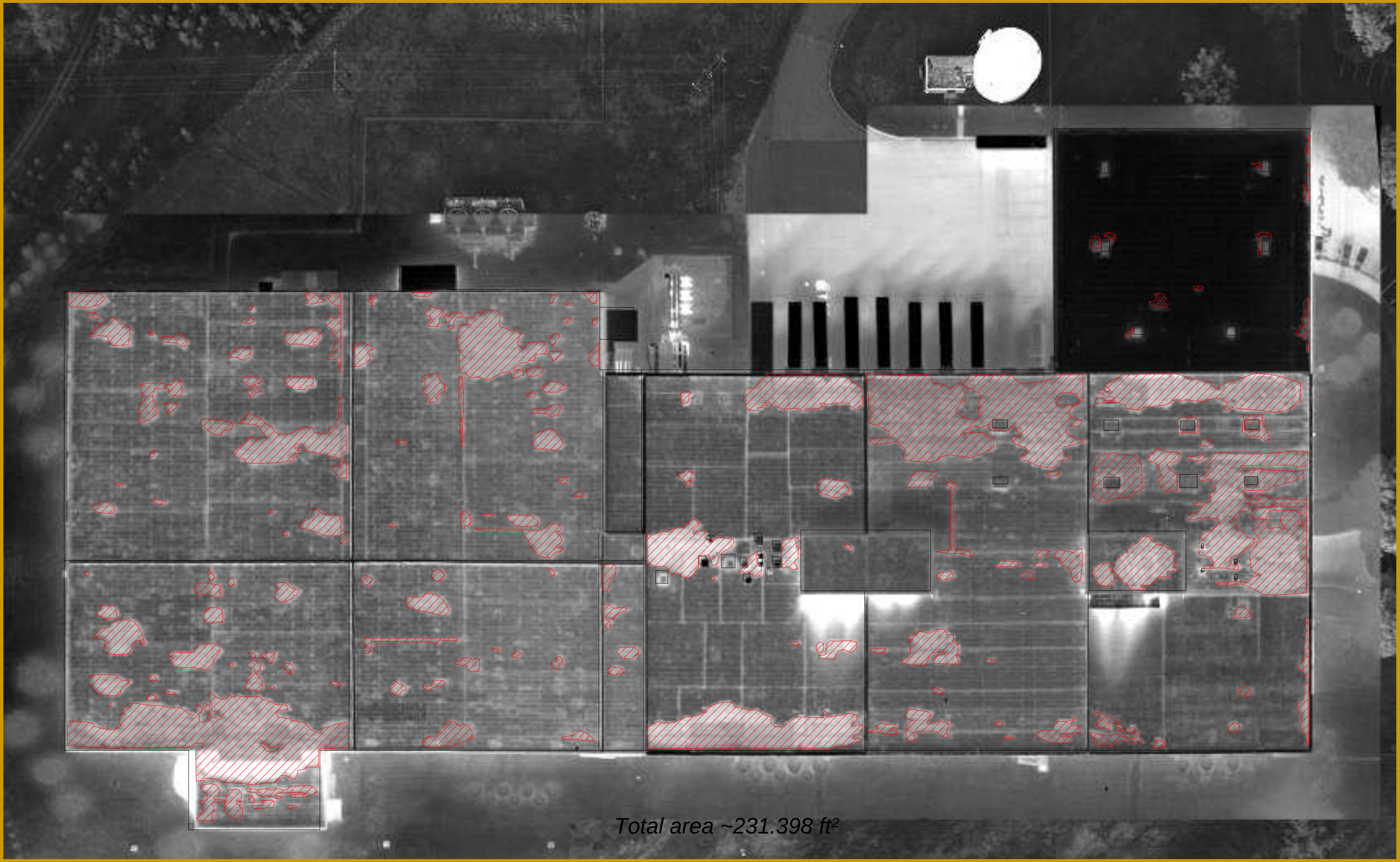


Aerial Roof Moisture Surveying

Probable wet area (~39,609 ft², 17.11%) *Possible wet area (NONE)*

Photograph W/Cad Overlay

Aerial Roof Moisture Surveying



Probable wet area (~39,609 ft², 17.11%) Thermograph W/Cad Overlay *Possible wet area (NONE)*

Aerial Roof Moisture Surveying

KEY to Drawings

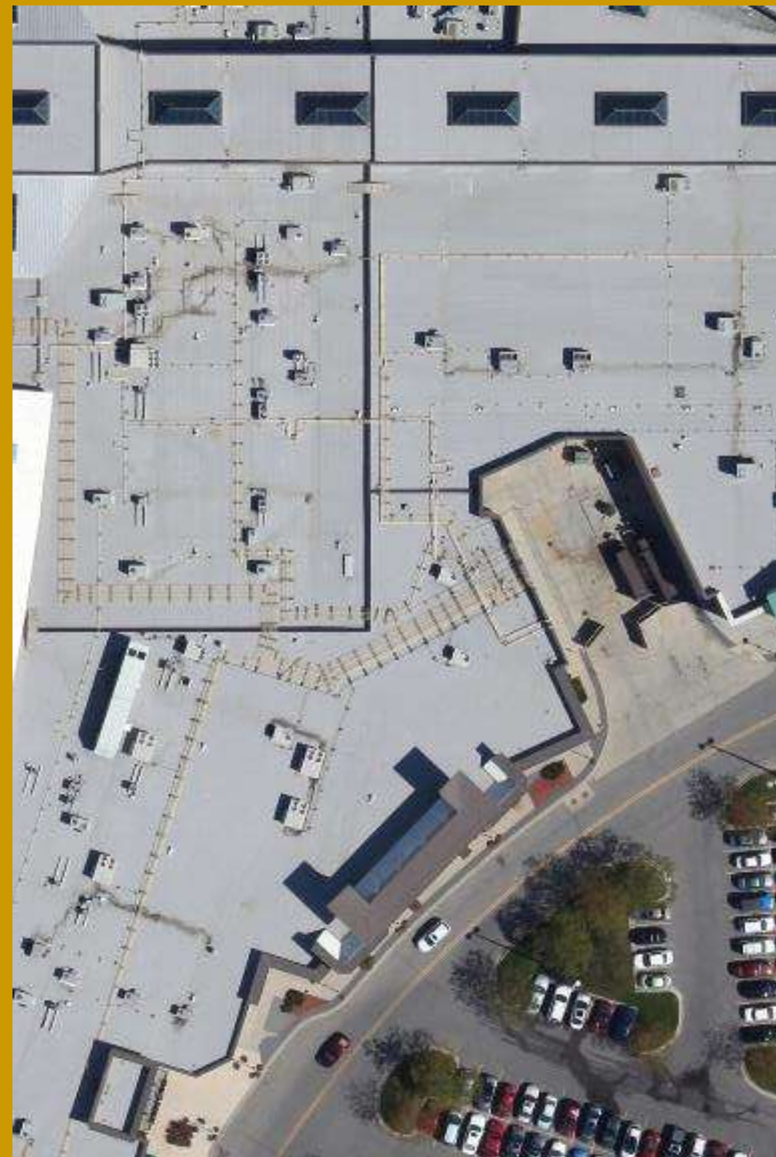
CAD Drawing

Thermograph

Photograph

Thermograph with CAD Overlay

Photograph with CAD Overlay



Aerial Roof Moisture Surveying

KEY to Drawings

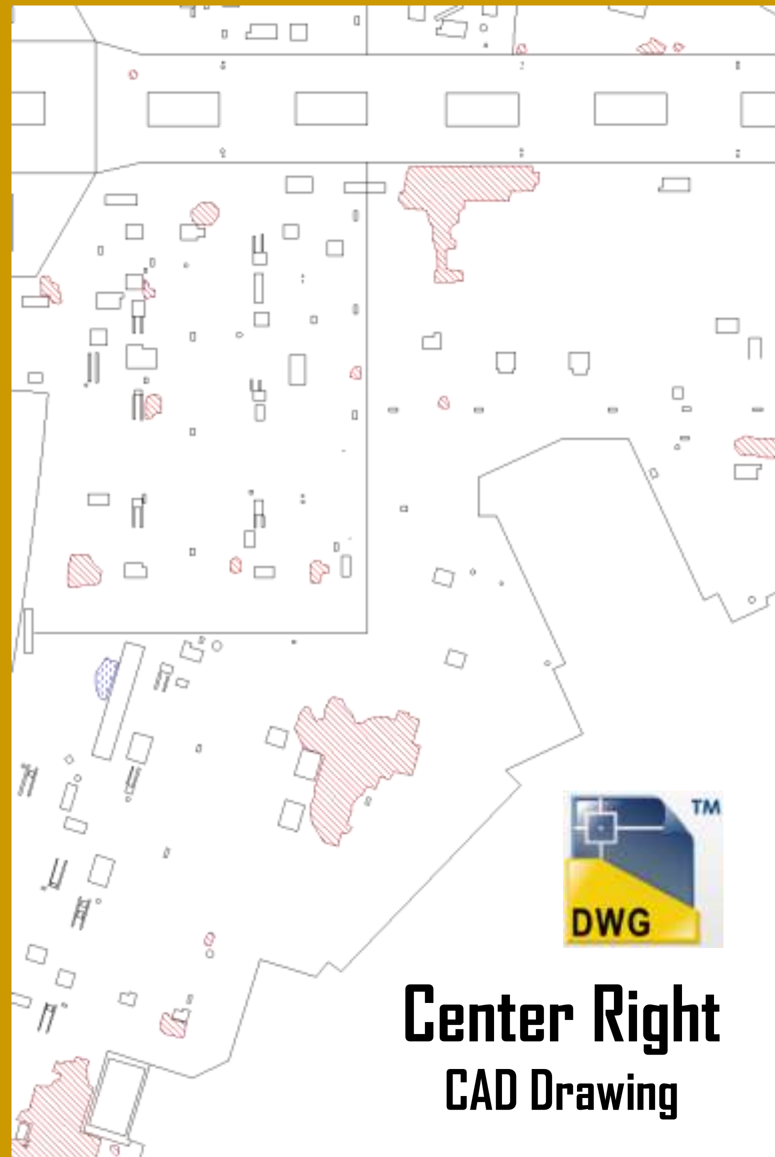
CAD Drawing

Thermograph

Photograph

Thermograph with CAD Overlay

Photograph with CAD Overlay



Center Right
CAD Drawing

Aerial Roof Moisture Surveying

KEY to Drawings


CAD Drawing


Thermograph


Photograph


Thermograph with CAD Overlay


Photograph with CAD Overlay

Aerial Roof Moisture Surveying

KEY to Drawings

CAD Drawing

Thermograph

Photograph

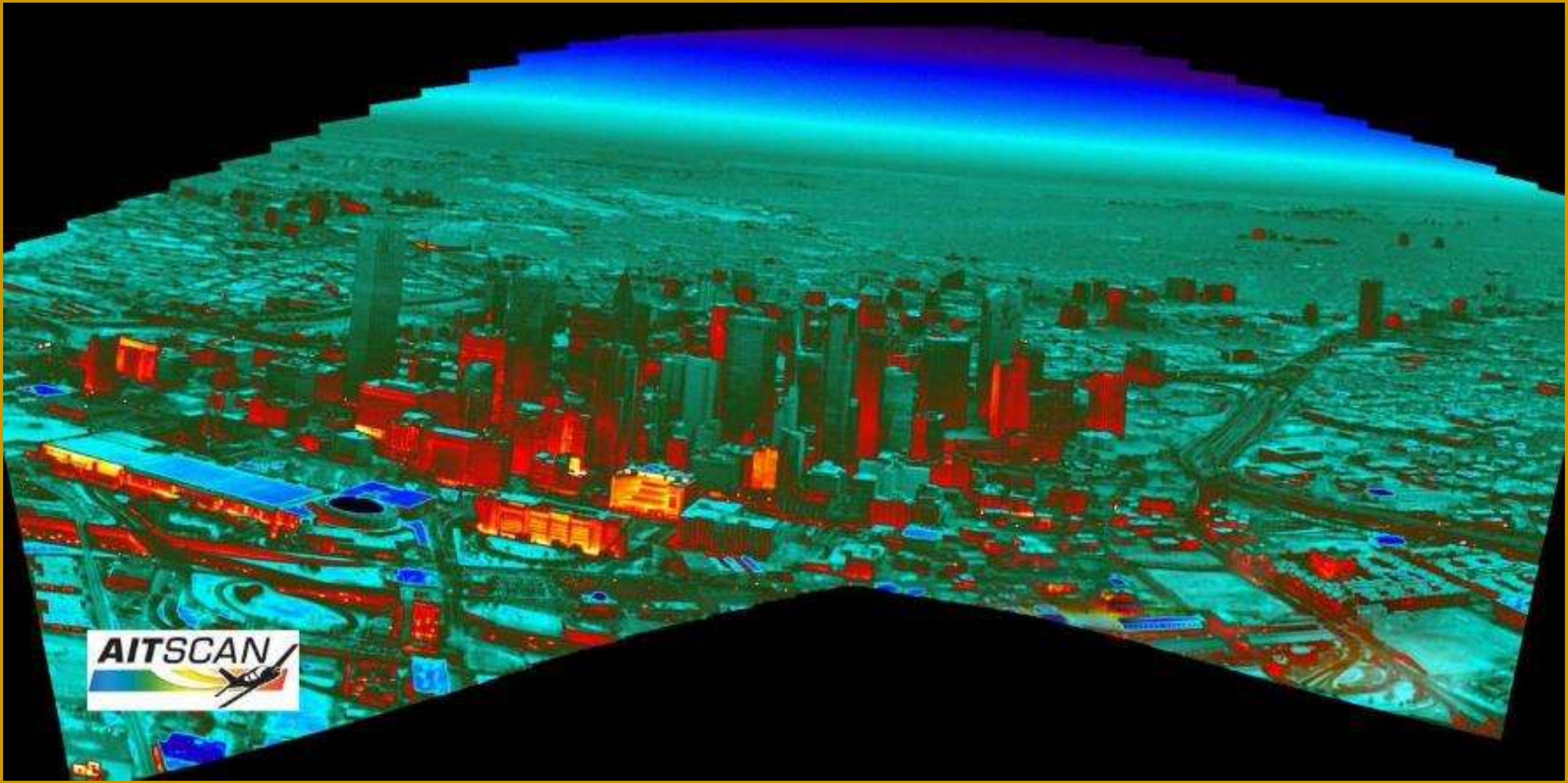
Thermograph with CAD Overlay

Photograph with CAD Overlay

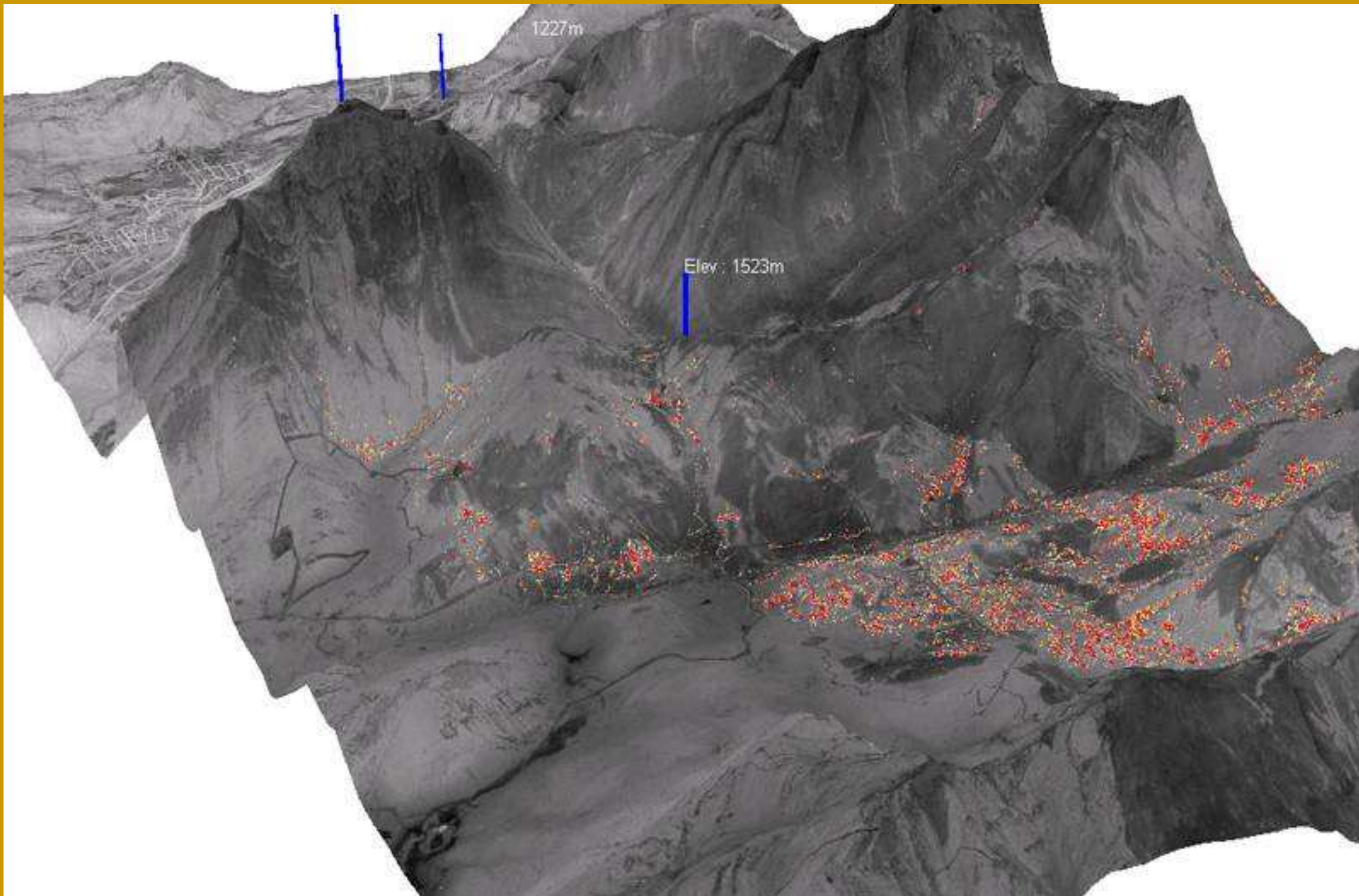
Aerial Thermal Mapping

NORTHERN OHIO CHAPTER

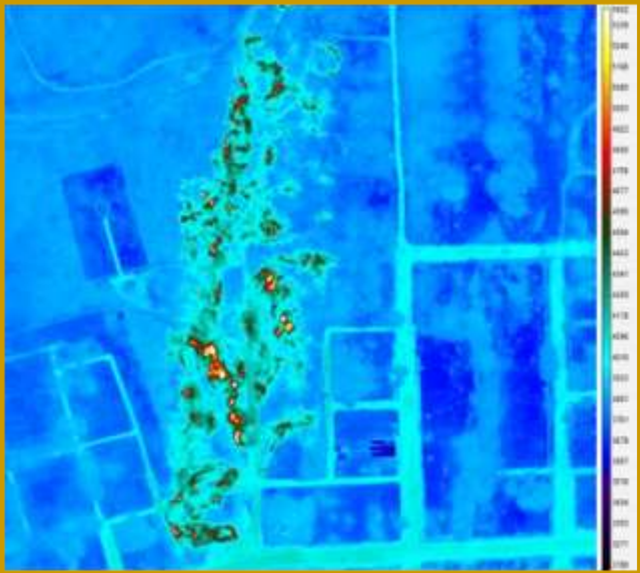
Wide Area Thermal Mapping of Cities, Universities, Prisons, Military Bases

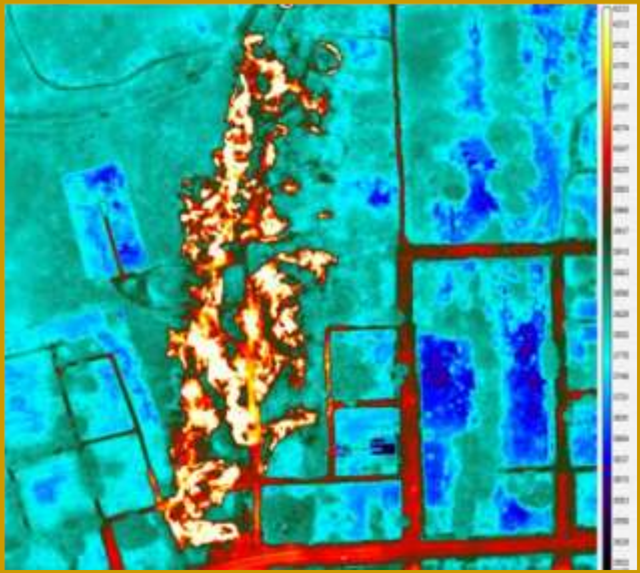


1000-image IR Mosaic of Forest Fires, Draped on a 3D Terrain Model

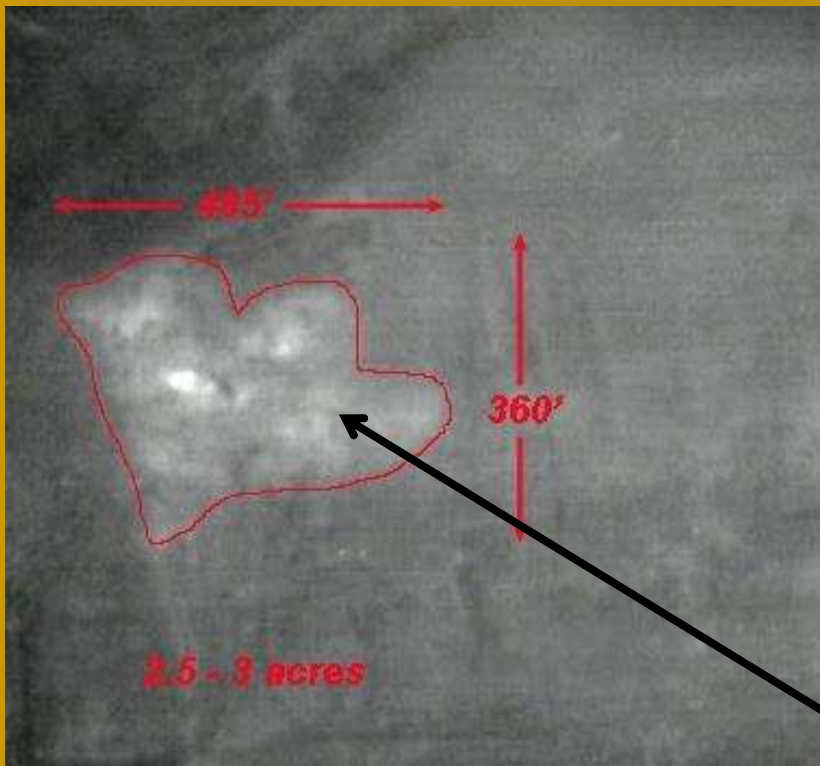


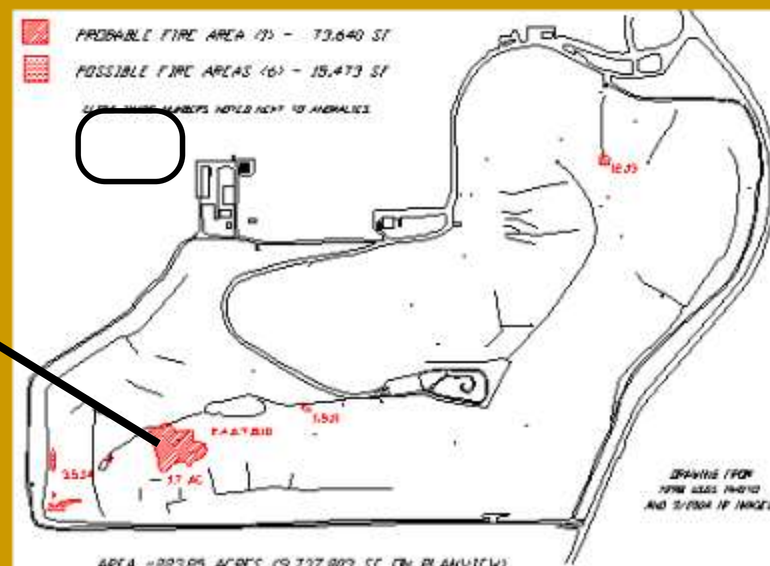
Thermal Map of a Coal Fire (Centralia, PA)



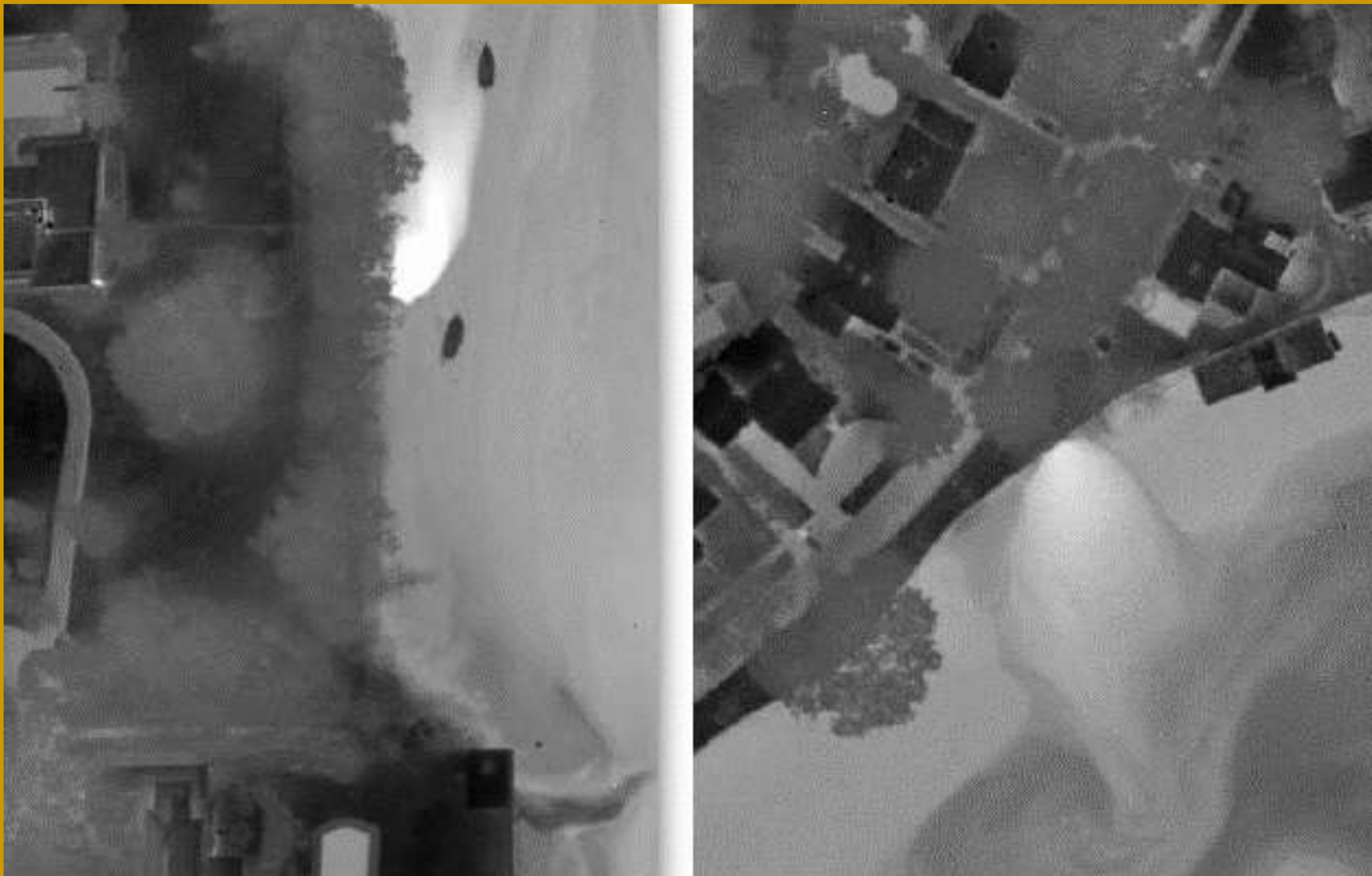


Thermal Map of a Landfill Fire





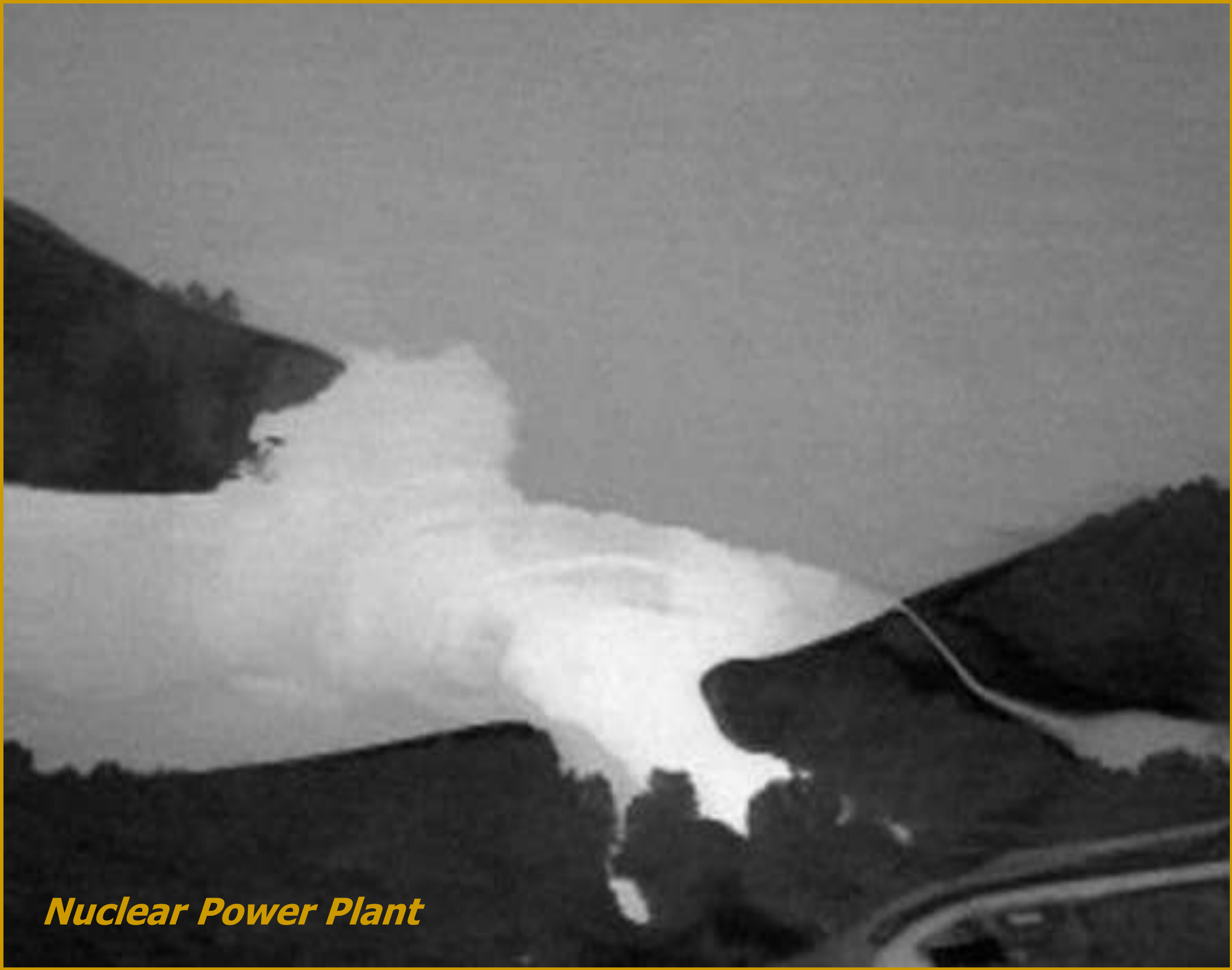
IR Imagery of Leaking Storm Drains



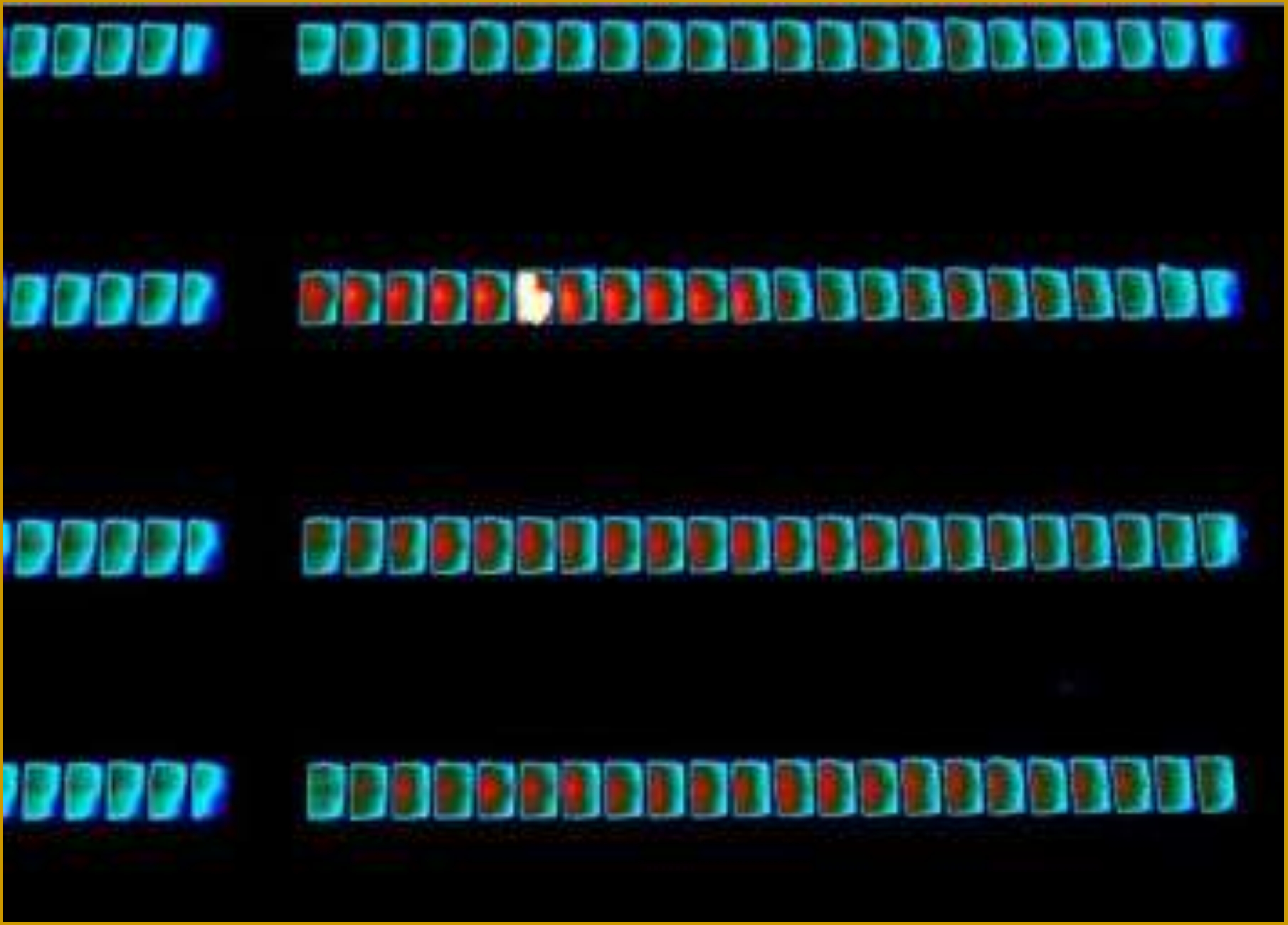
IR Image of a Storm Drain With Non-permitted Discharge

IR Image of a Storm Drain With Non-permitted Discharge

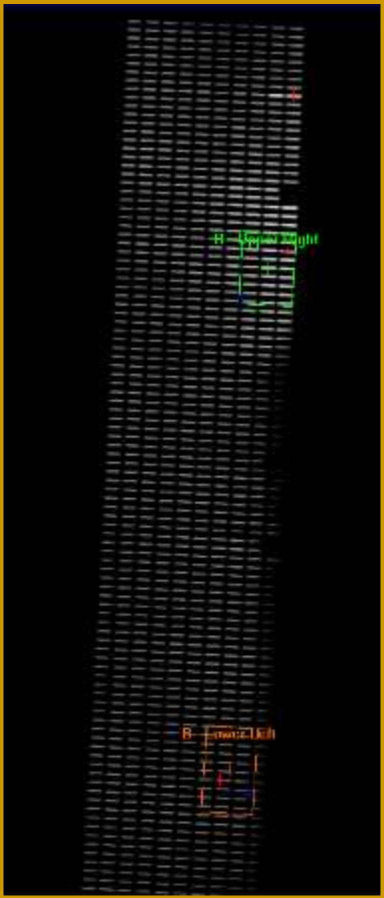
Power Plant Cooling Tower Discharge

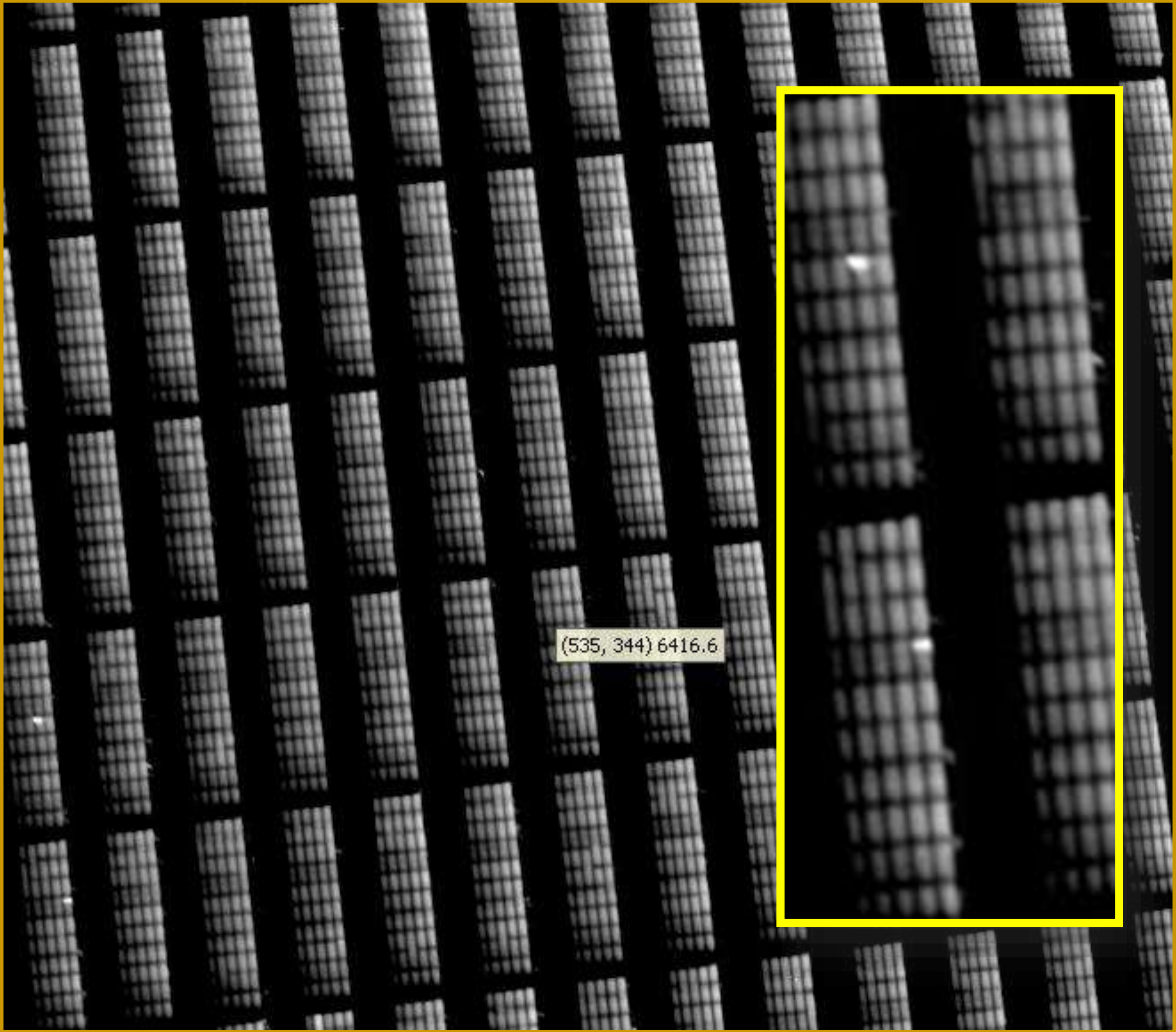


Thermal Mapping of Photovoltaic Solar Fields

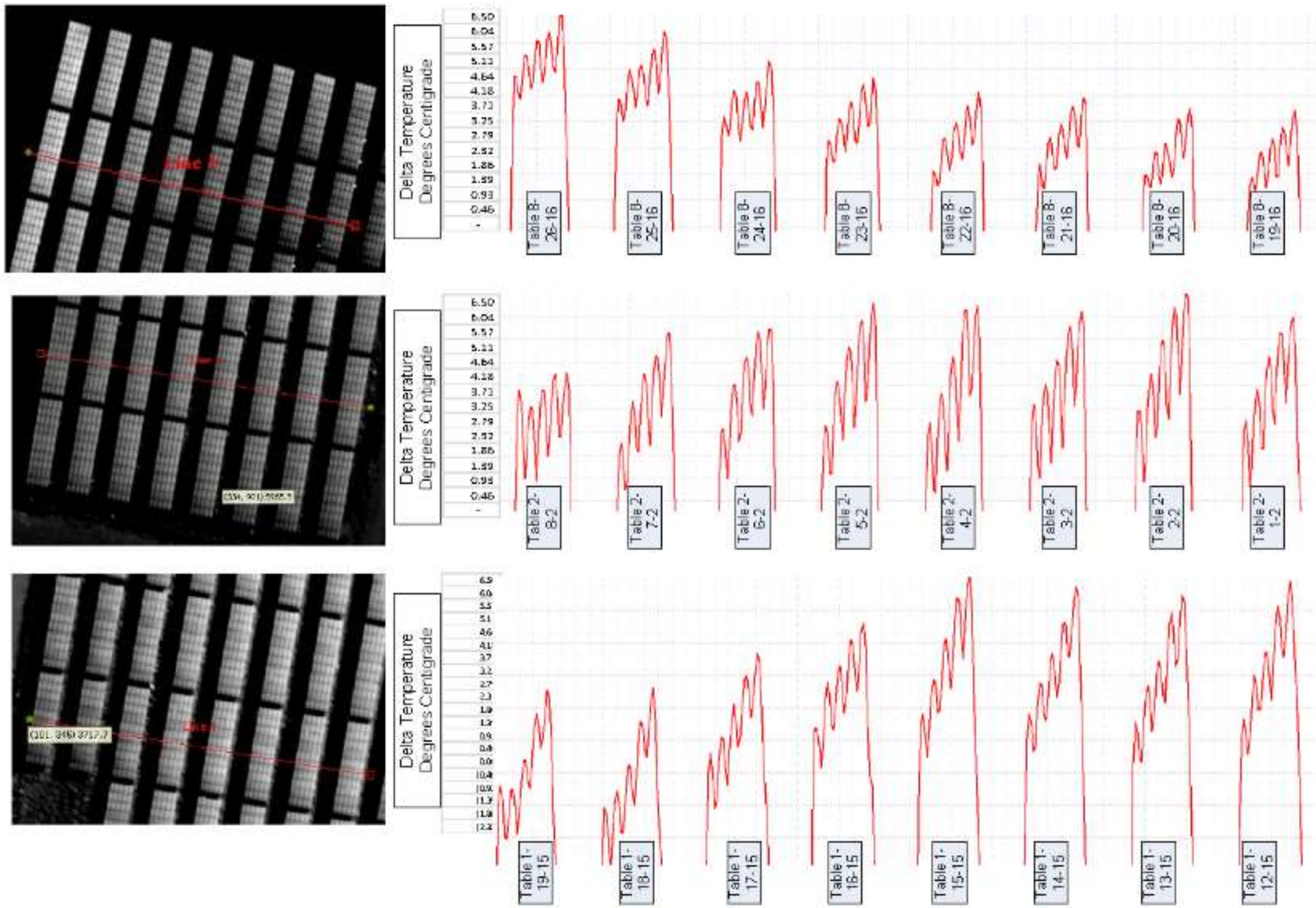


Thermal Mapping of Photovoltaic Solar Fields



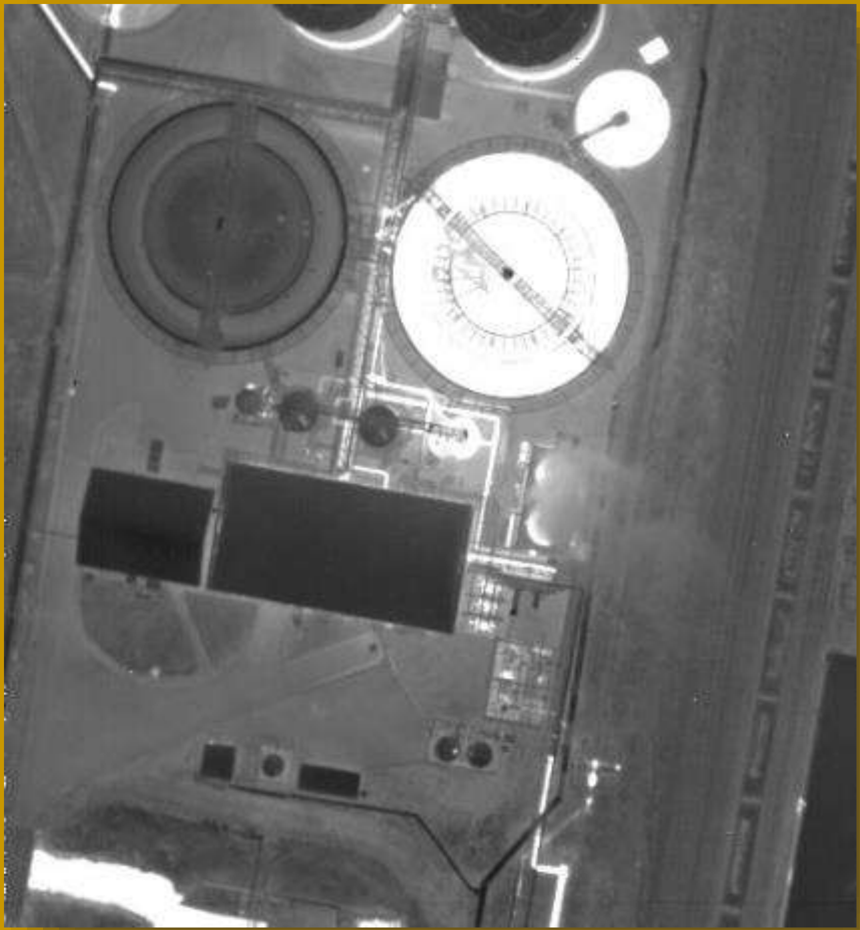


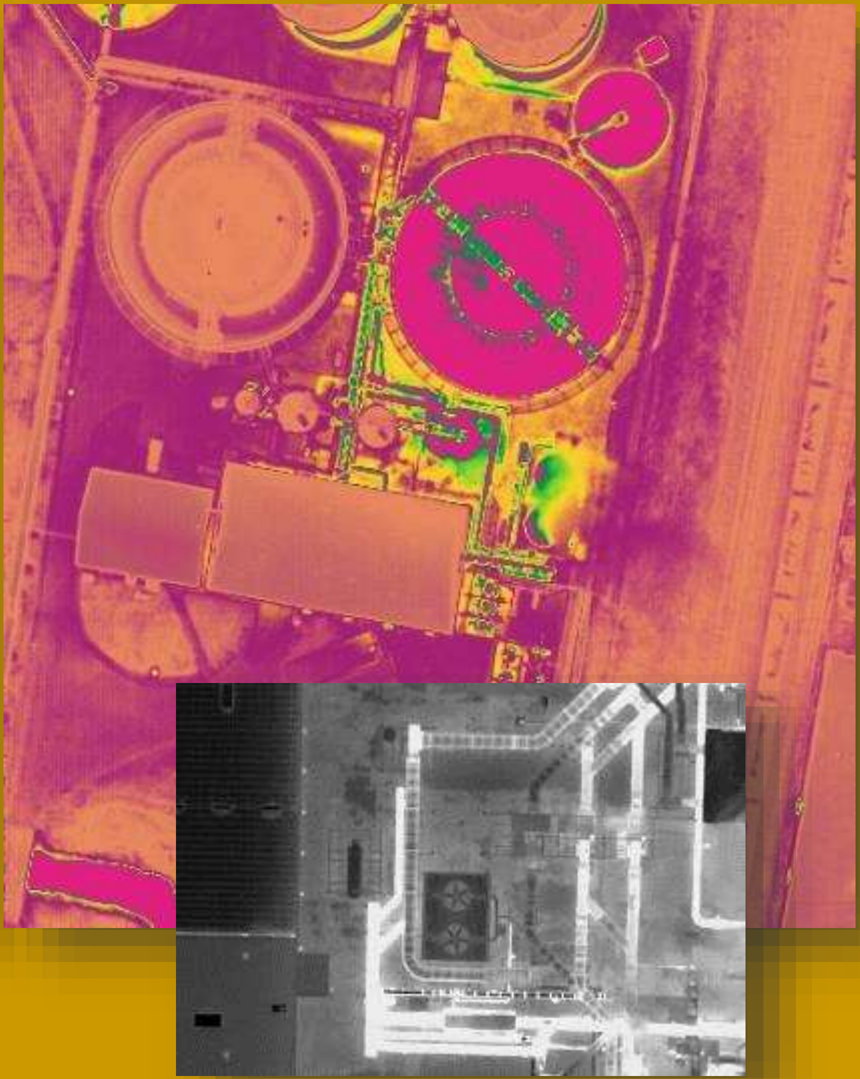
Thermal Mapping of Photovoltaic Solar Fields



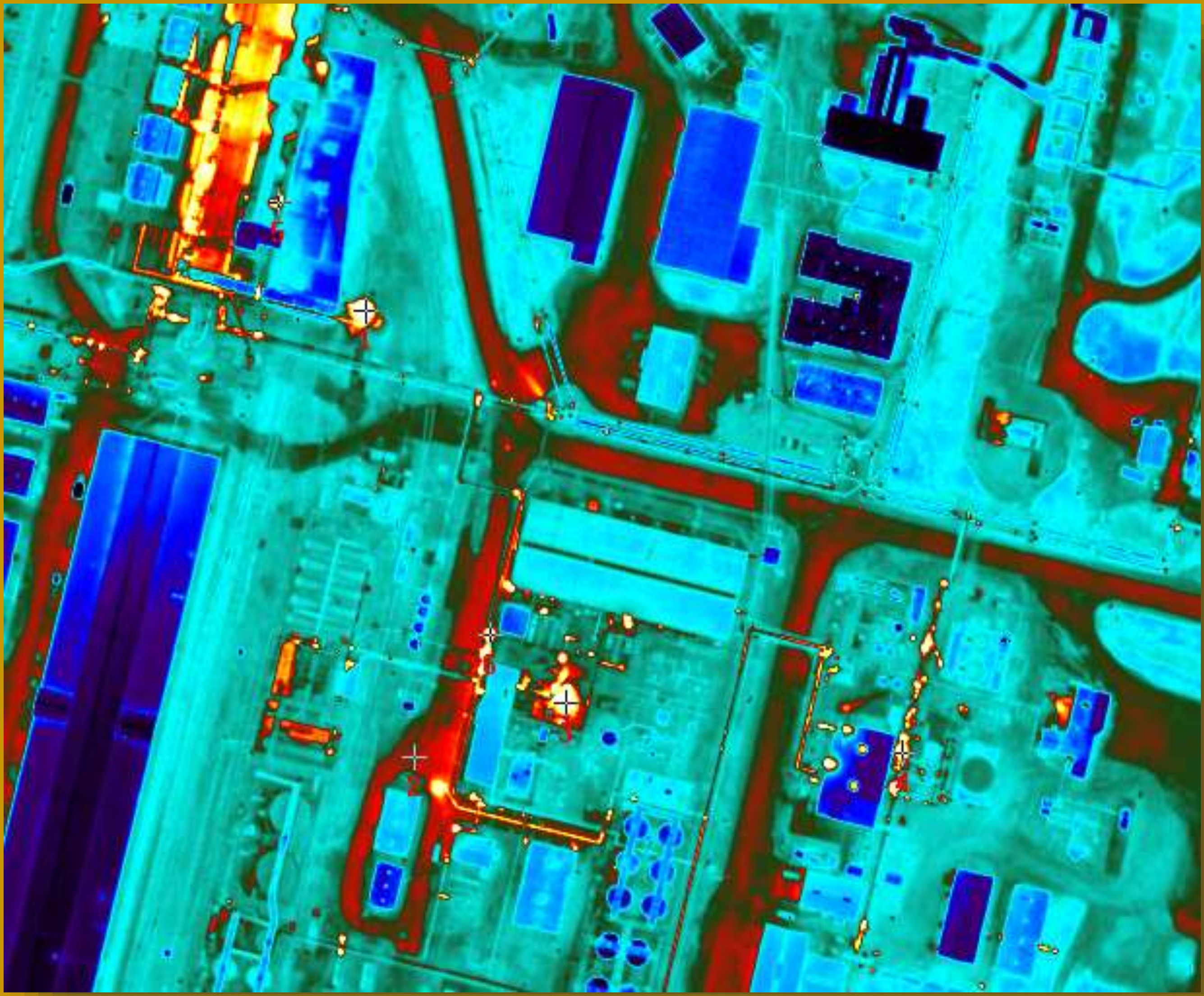
Aerial Infrared Imagery of Industrial Complexes

Aerial Infrared Imagery of Industrial Complexes

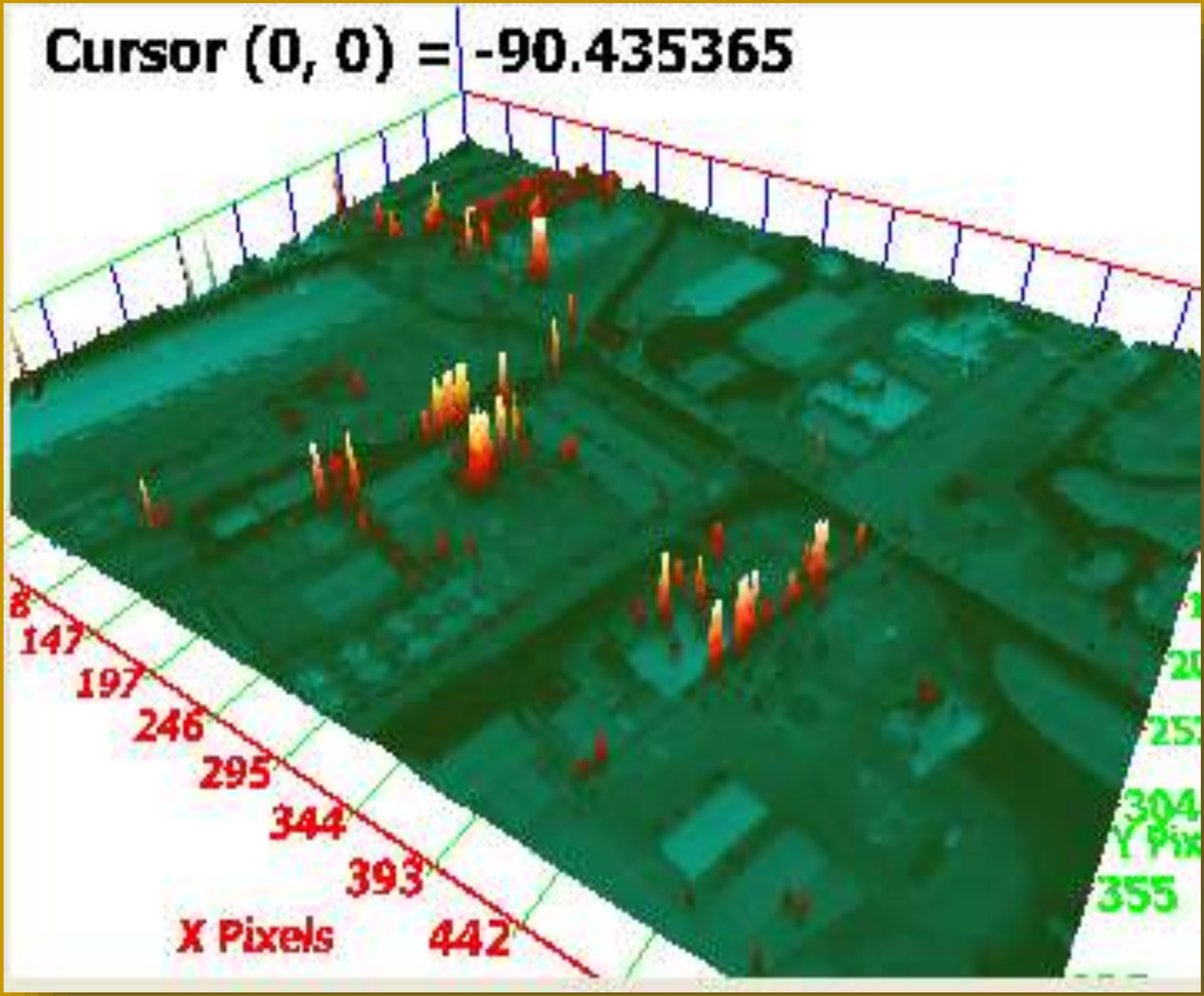




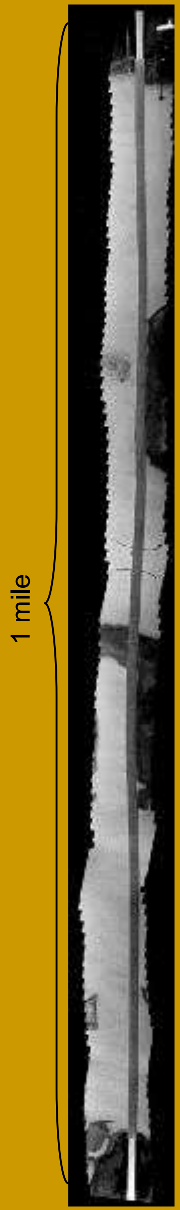
Aerial Infrared Imagery of Industrial Complexes

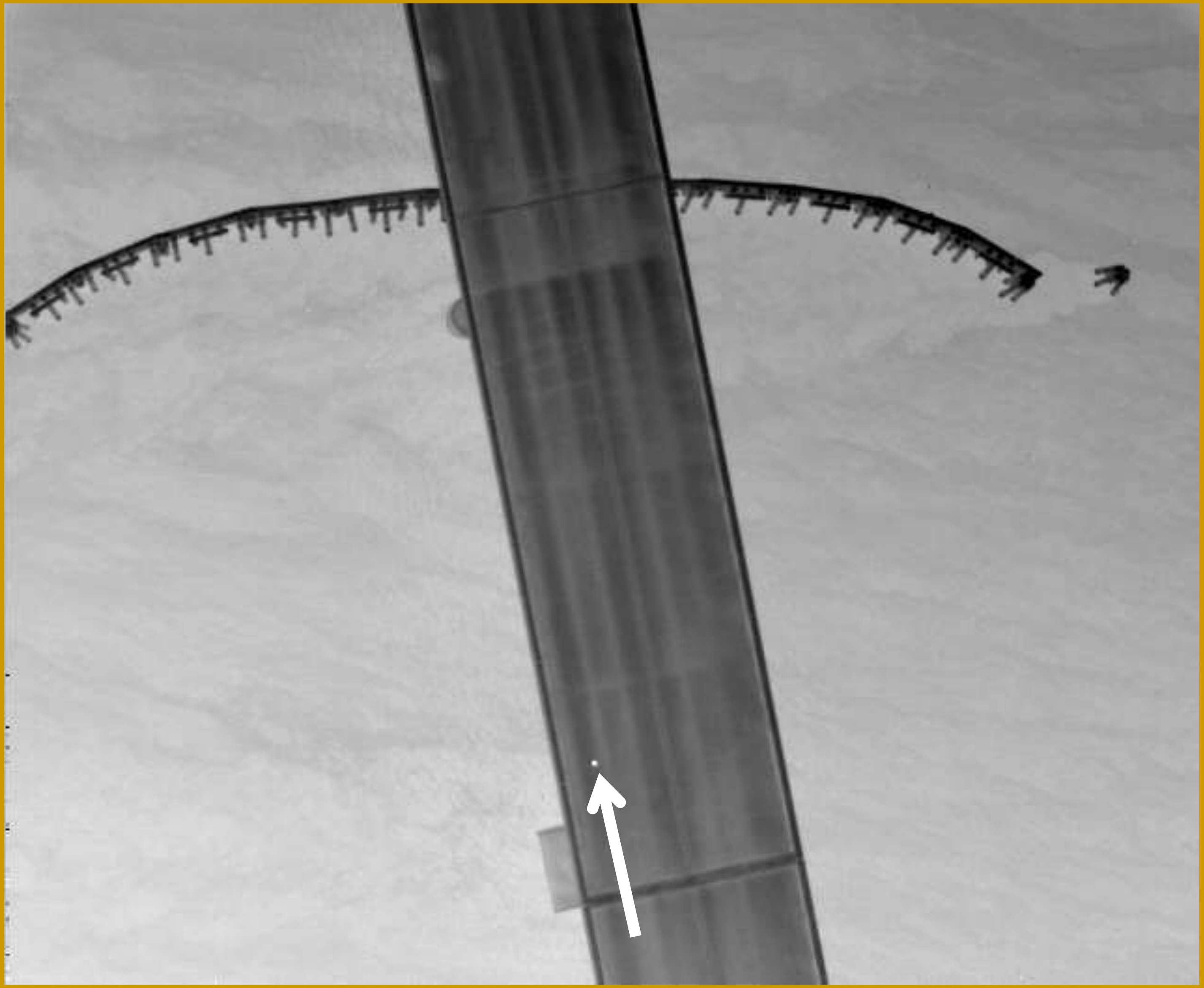


Aerial Infrared Imagery of Industrial Complexes

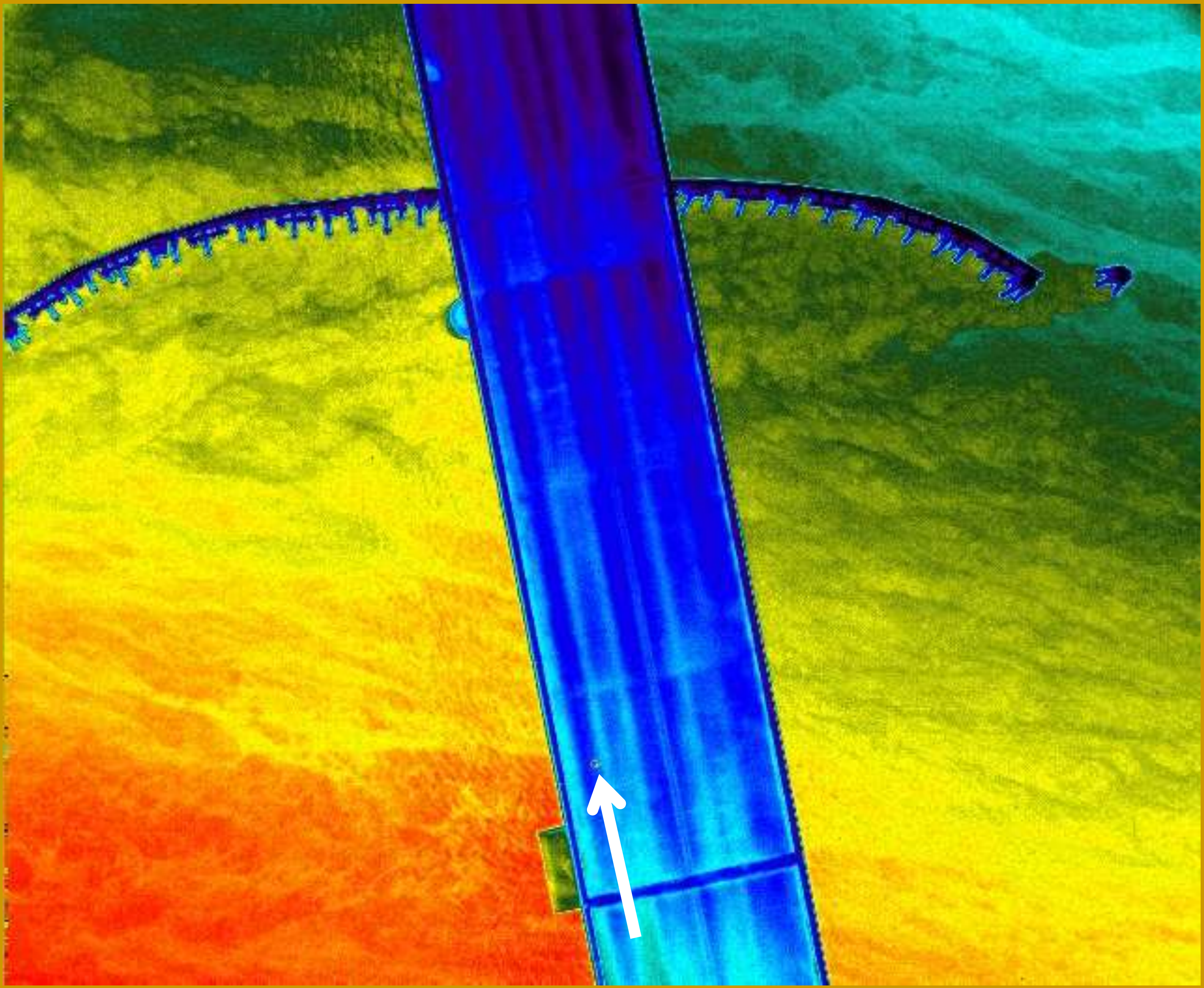


Aerial Infrared Imagery of Bridge Decks

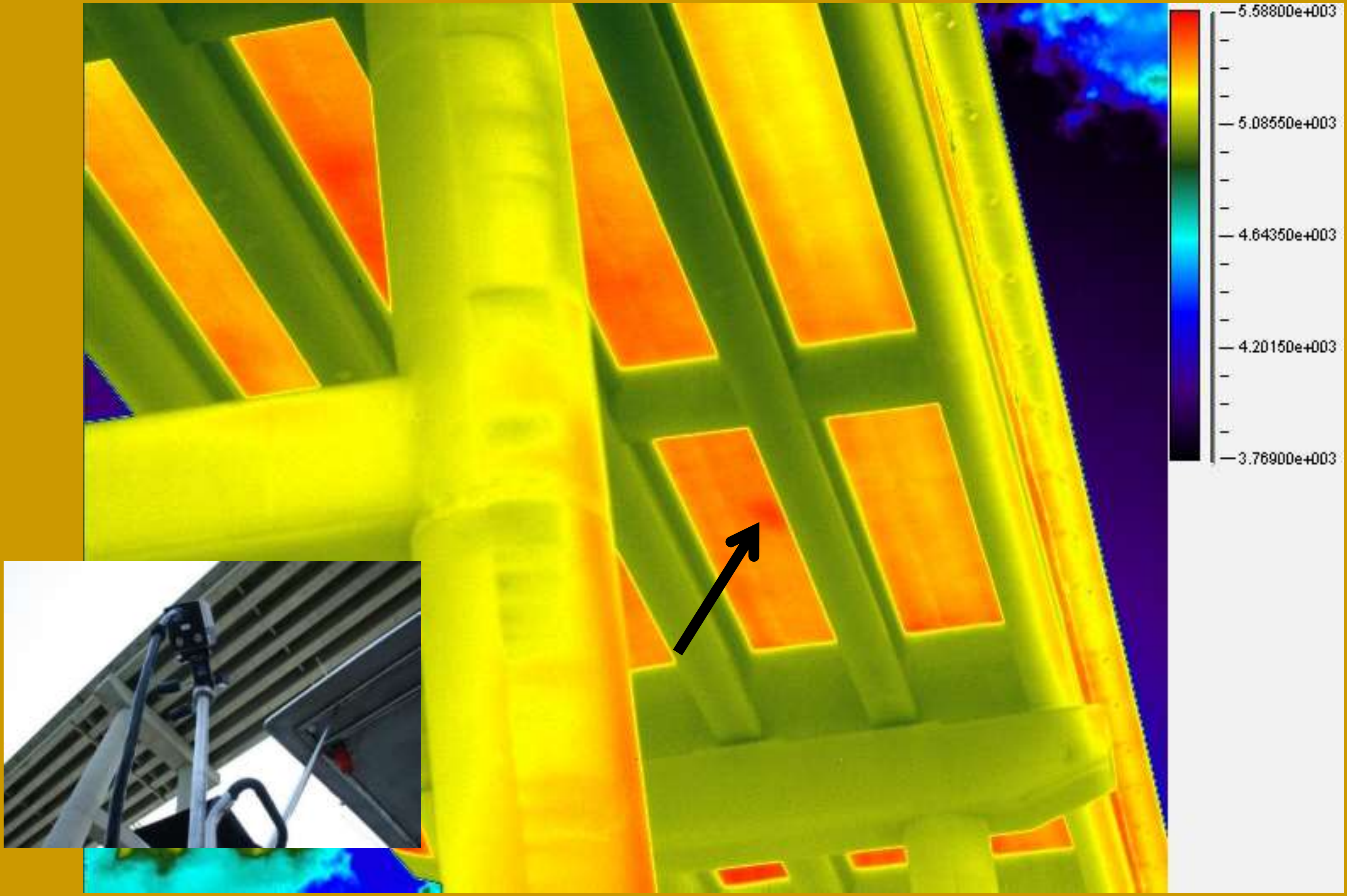




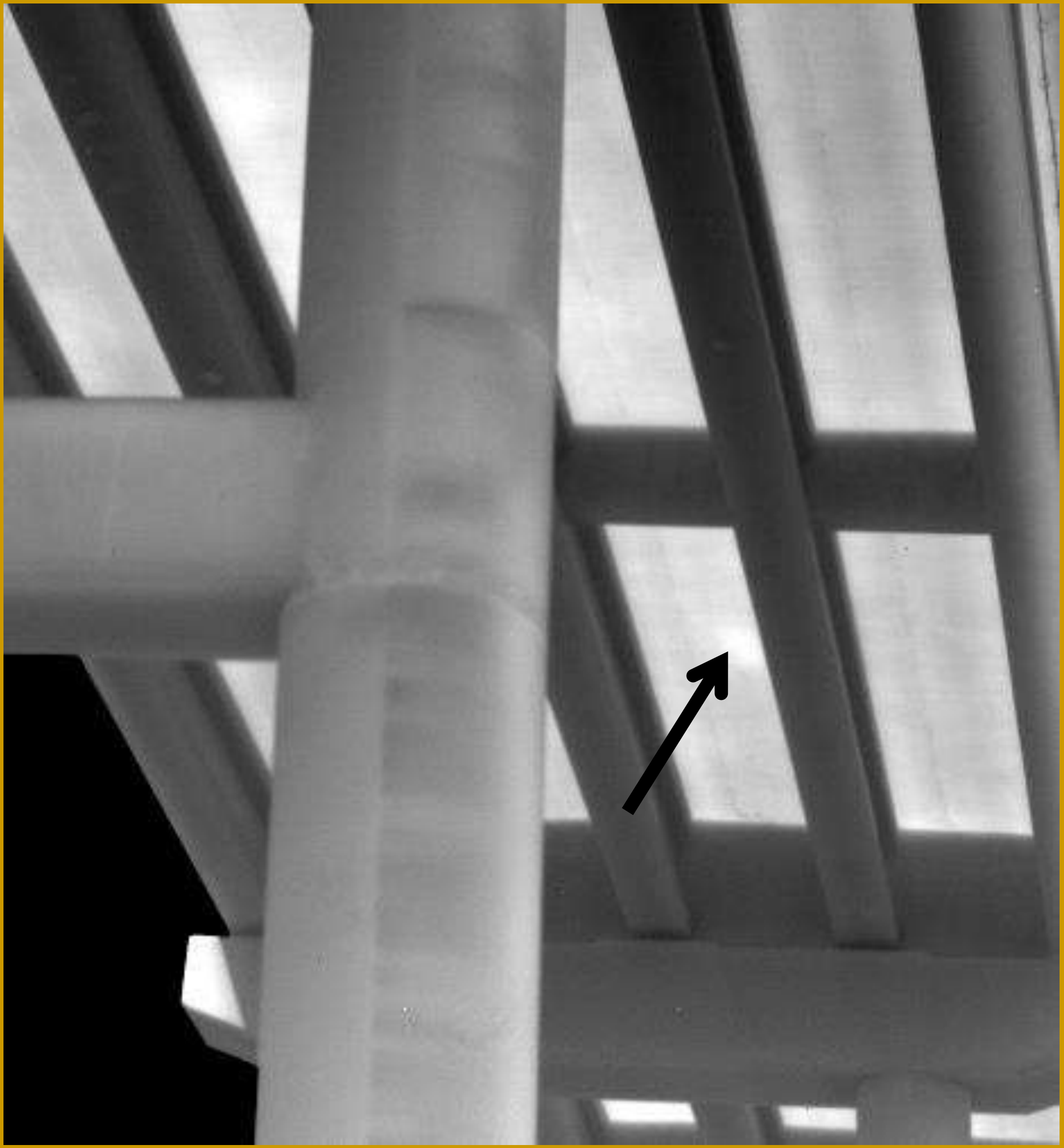
Aerial Infrared Imagery of Bridge Decks

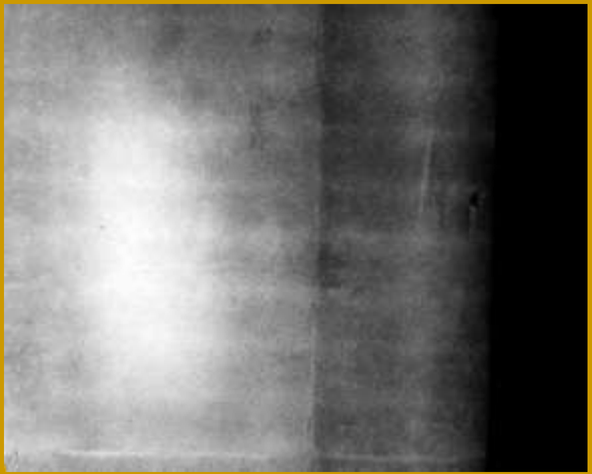


Aerial Infrared Imagery of Bridge Decks



Aerial Infrared Imagery of Bridge Decks

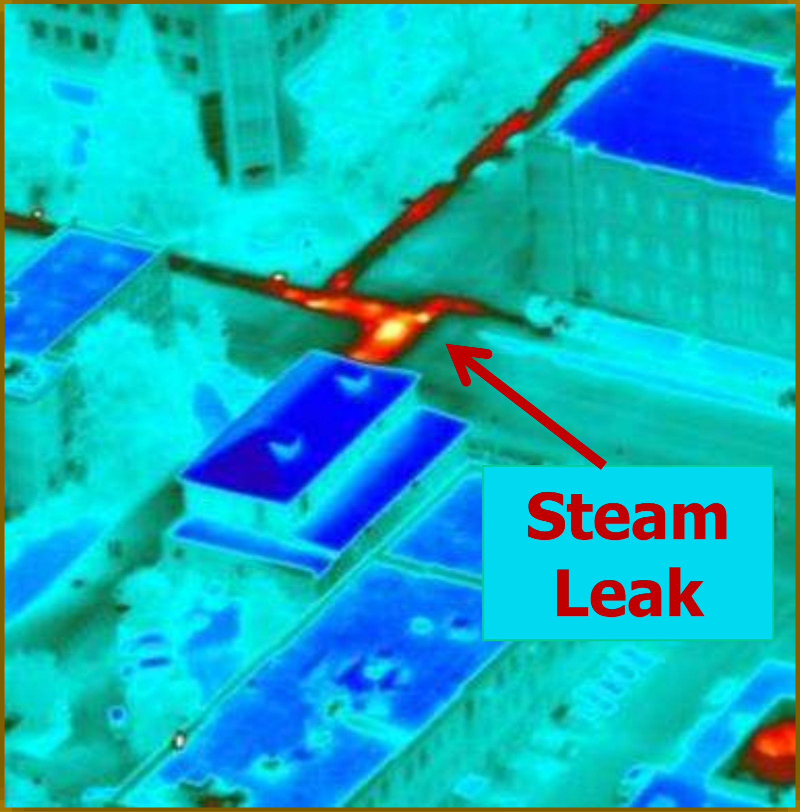




Aerial Mapping of Steam Distribution Systems

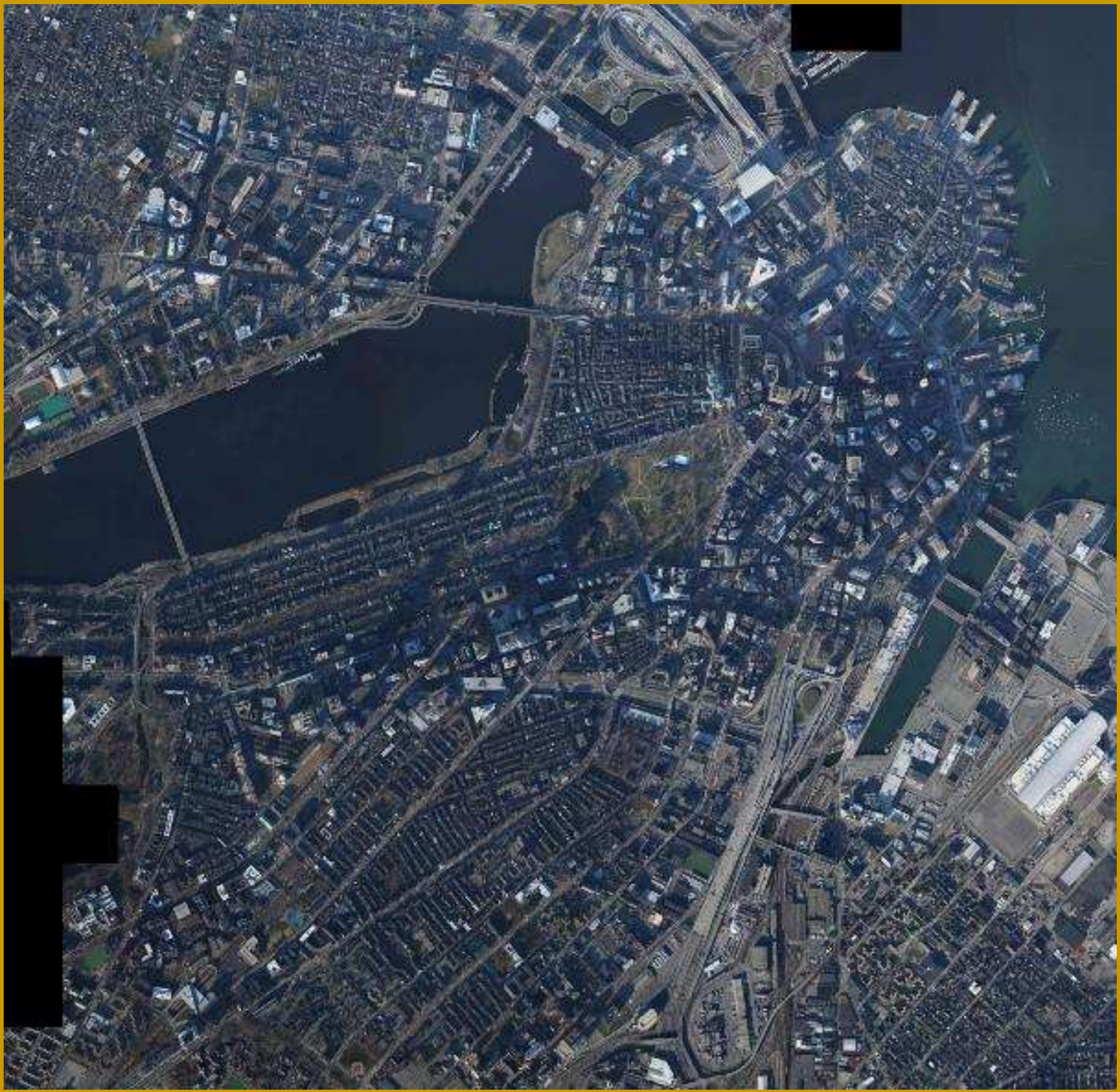
NORTHERN OHIO CHAPTER

Oblique IR Imaging Showing Steam Plant and Steam Leaks



Aerial Infrared Surveying of Steam, Hot Water & Chilled Water Systems

Thermal Map of a City



Aerial Infrared Surveying of Steam, Hot Water & Chilled Water Systems

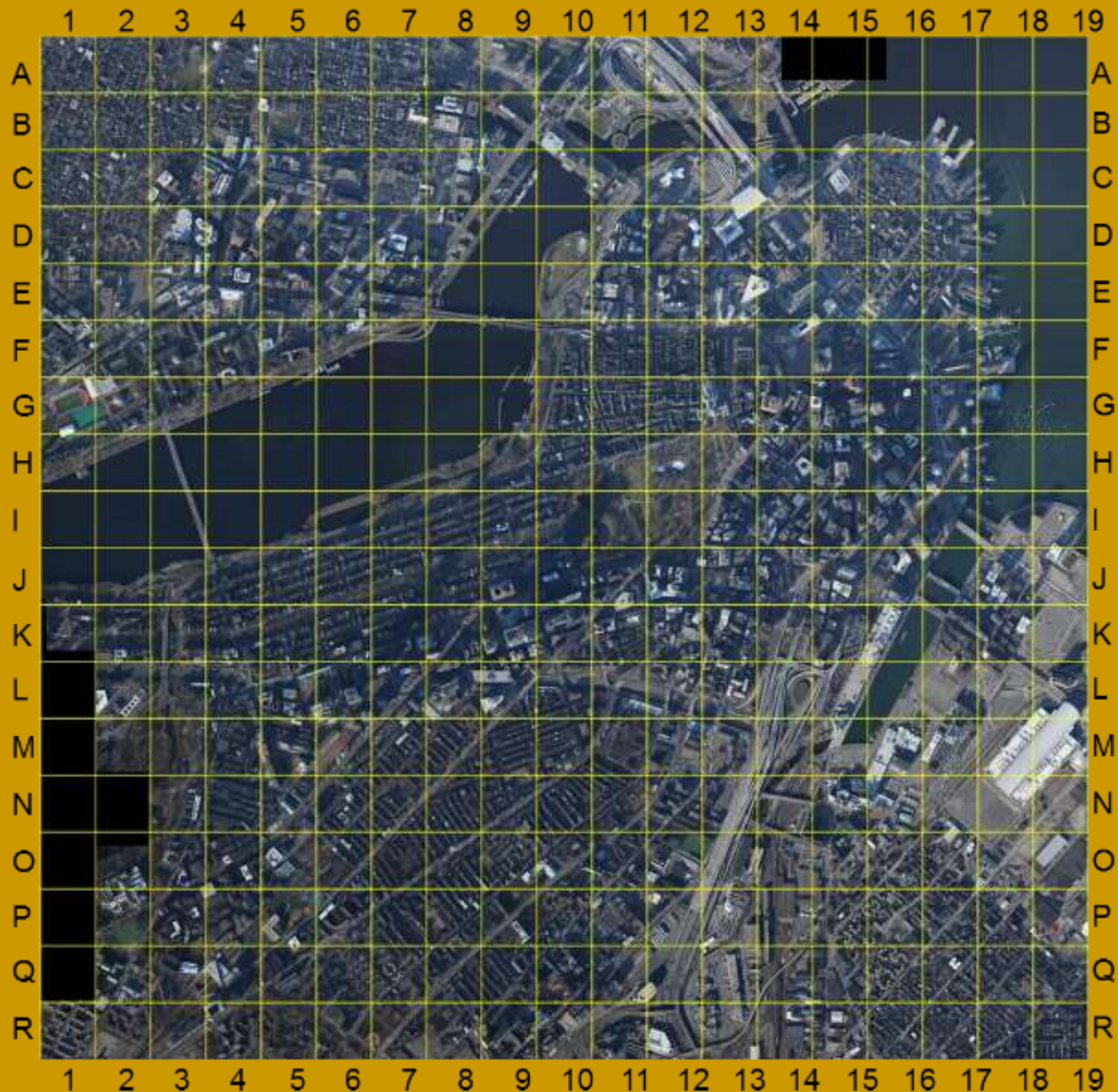
Thermal Map of a City

Aerial Infrared Surveying of Steam, Hot Water & Chilled Water Systems

Thermal Map of a City

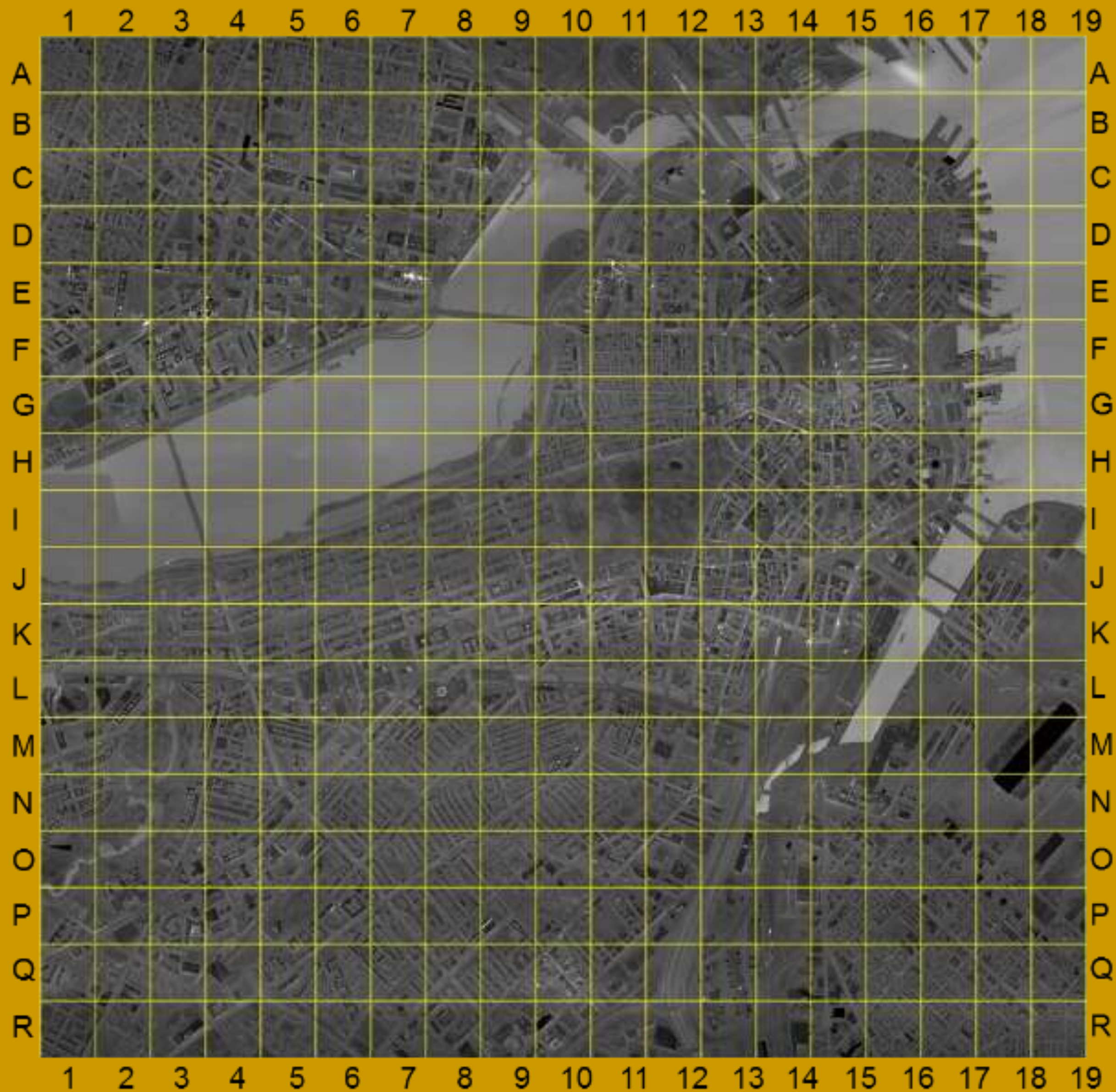
Aerial Infrared Surveying of Steam, Hot Water & Chilled Water Systems

Thermal Map of a City



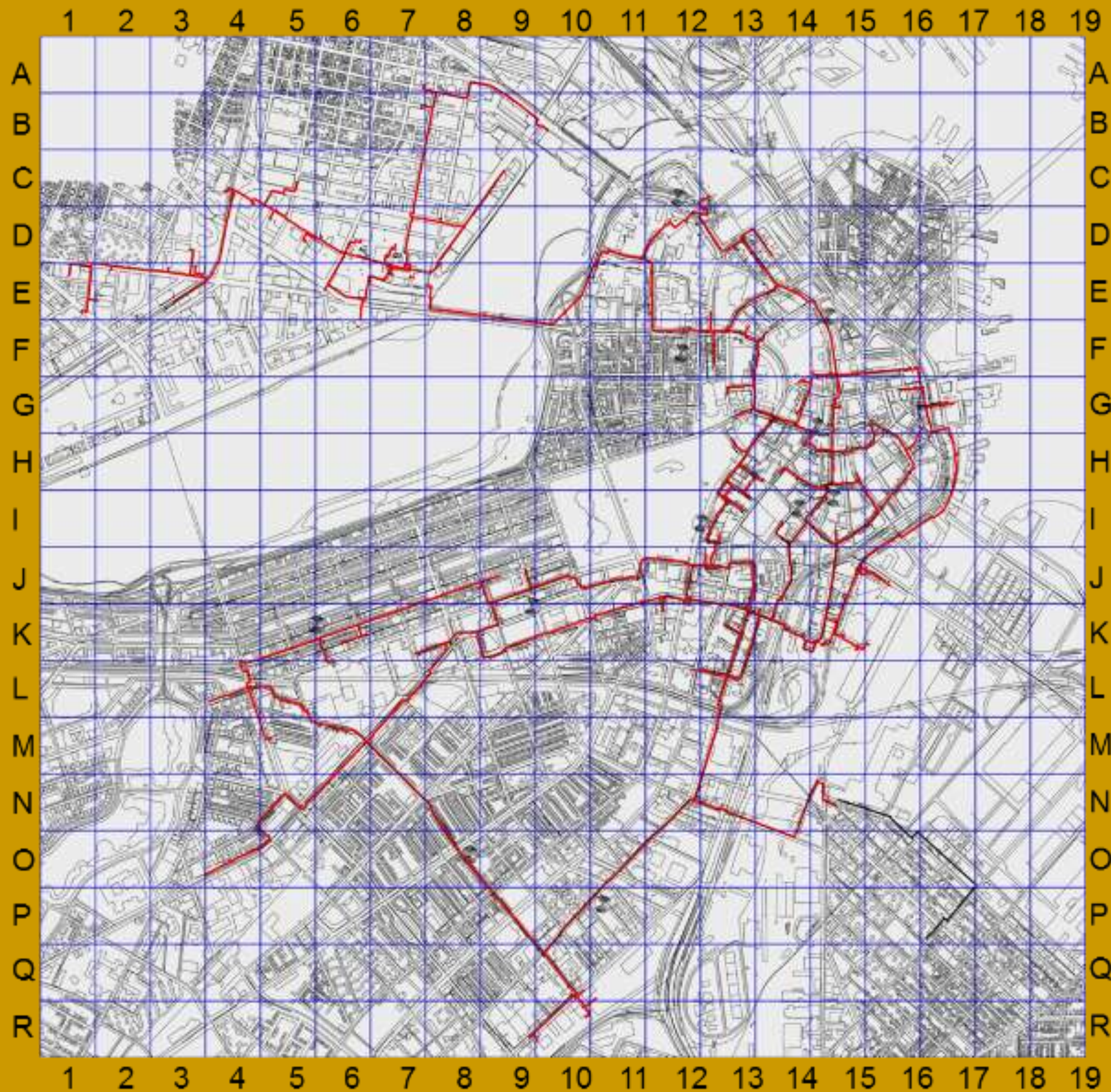
Aerial Infrared Surveying of Steam, Hot Water & Chilled Water Systems

Thermal Map of a City



Aerial Infrared Surveying of Steam, Hot Water & Chilled Water Systems

Thermal Map of a City



Aerial Infrared Surveying of Steam, Hot Water & Chilled Water Systems

Ground Resolution Element (GRE) = 30”

Aerial Infrared Surveying of Steam, Hot Water & Chilled Water Systems

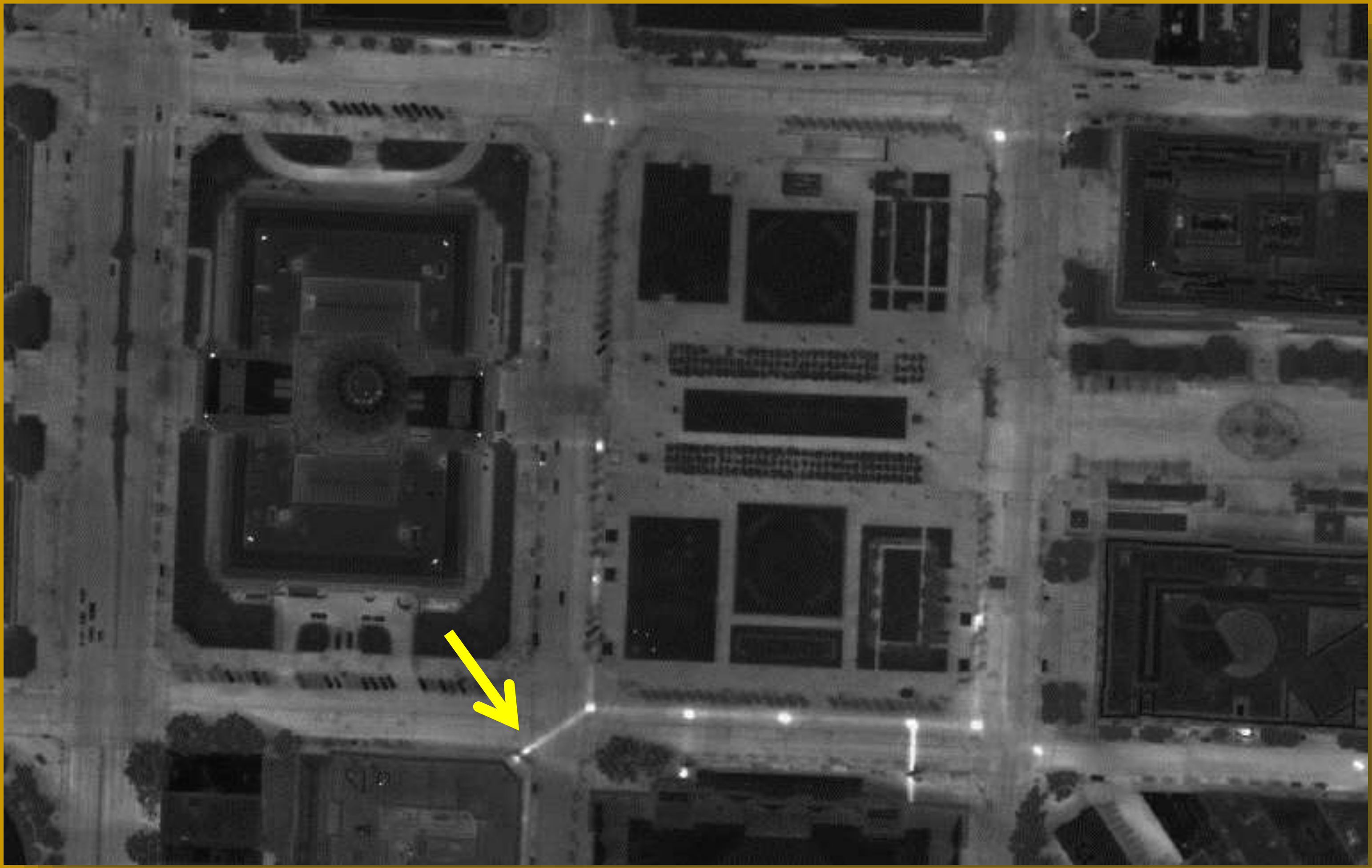
Ground Resolution Element (GRE) = 24"

Aerial Infrared Surveying of Steam, Hot Water & Chilled Water Systems

Ground Resolution Element (GRE) = 18”

Aerial Infrared Surveying of Steam, Hot Water & Chilled Water Systems

Ground Resolution Element (GRE) = 12”



Aerial Infrared Surveying of Steam, Hot Water & Chilled Water Systems

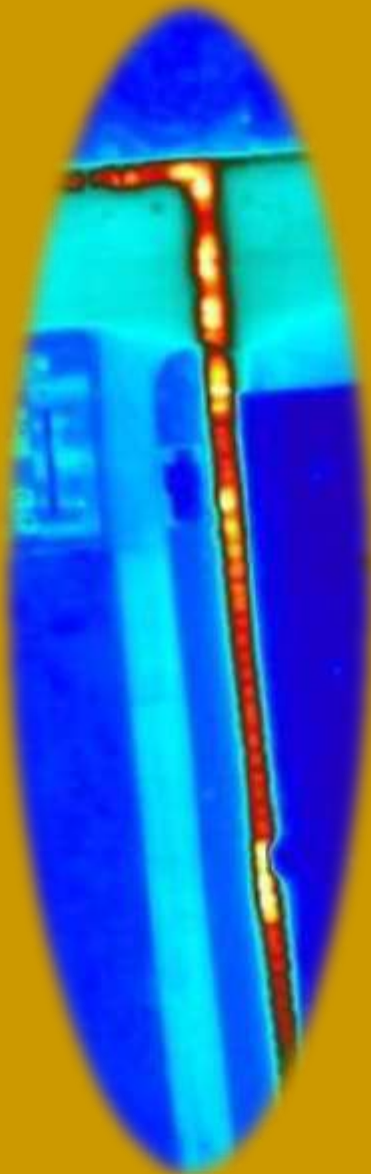
Ground Resolution Element (GRE) = 6”

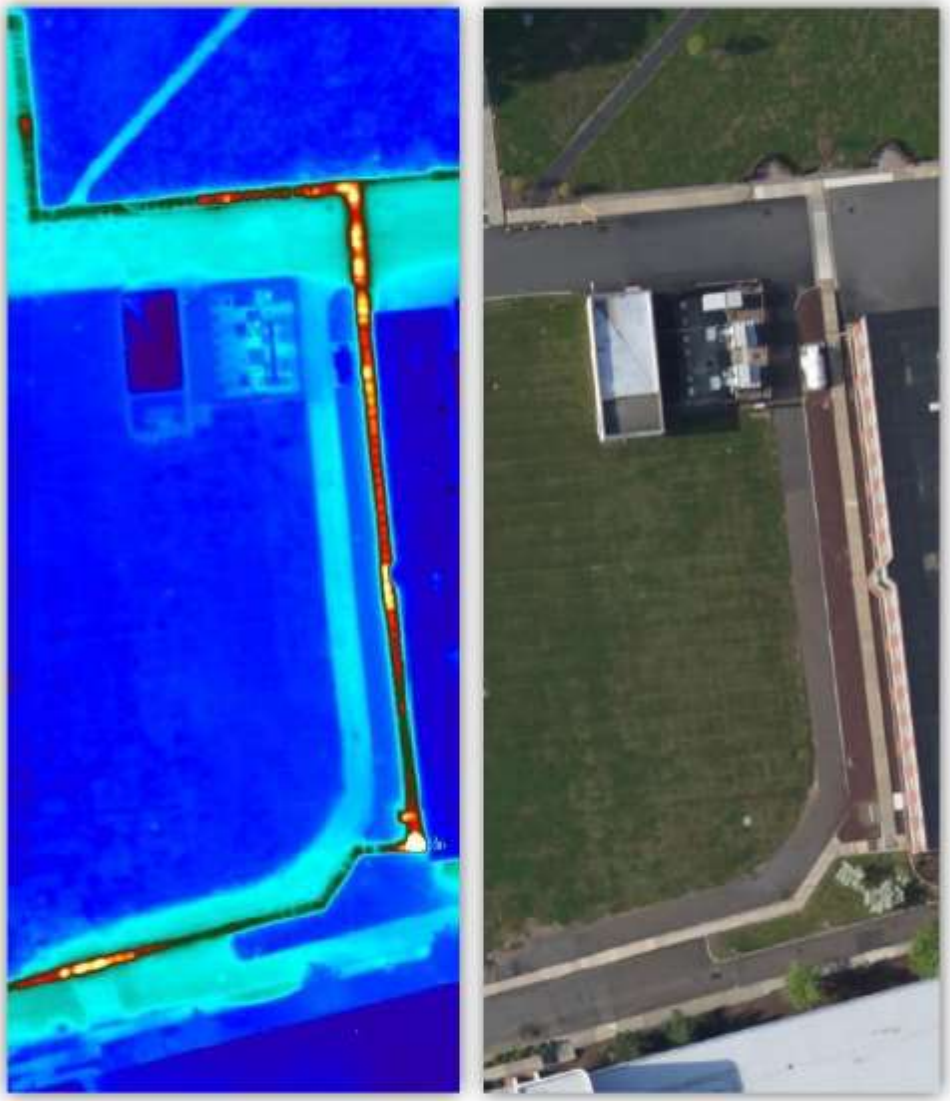
Aerial Infrared Surveying of Steam, Hot Water & Chilled Water Systems

Ground Resolution Element (GRE) = 3”

Steam and Condensate Return Lines Heat the Ground Above The Line

Steam and Condensate Return Lines Heat the Ground Above The Line

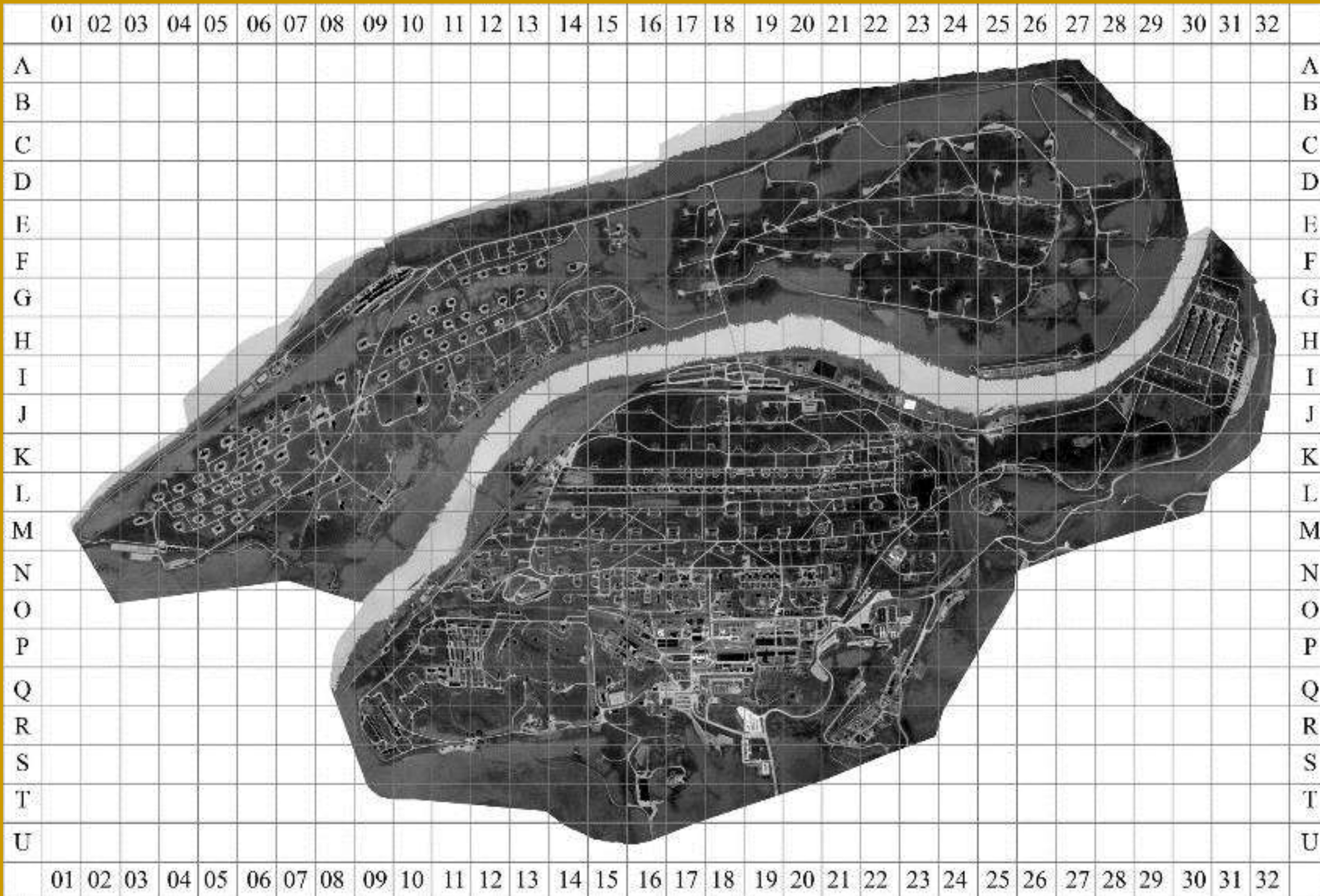




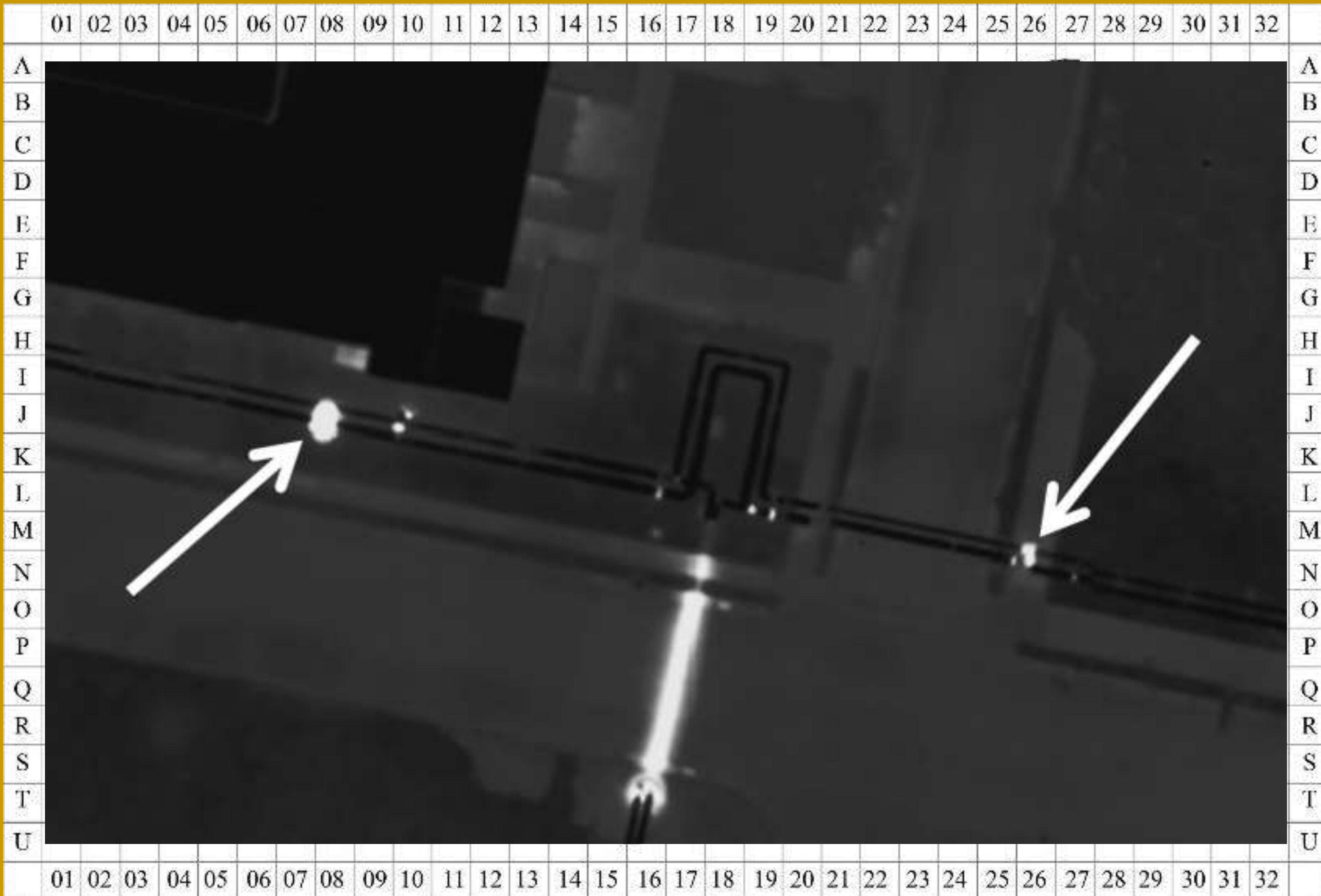
IR Image (Color) Photo Image

Steam and Condensate Return Lines Heat the Ground Above The Line

Overhead Steam and Condensate Return Lines Heat the Piping and Leak

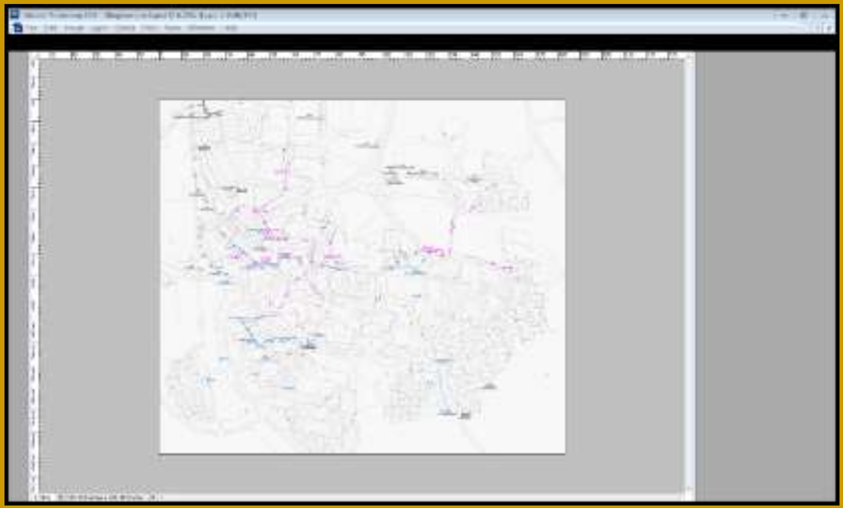


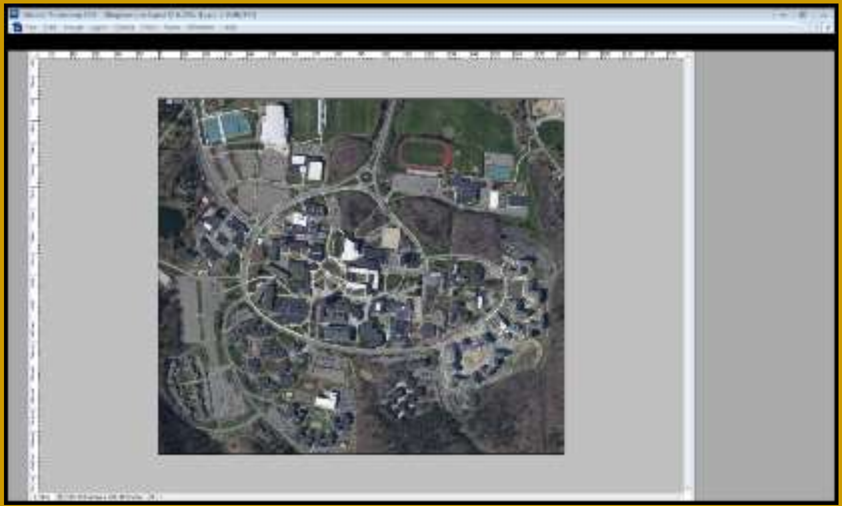
Overhead Steam and Condensate Return Lines Heat the Piping and Leak

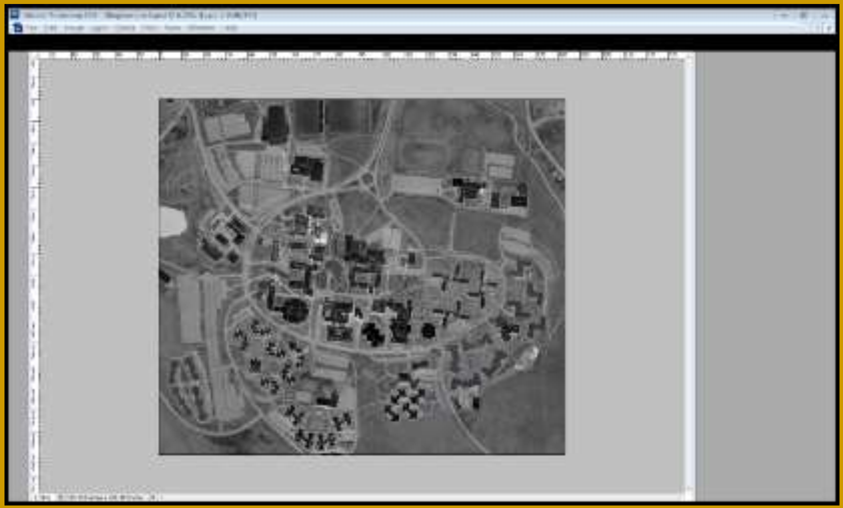


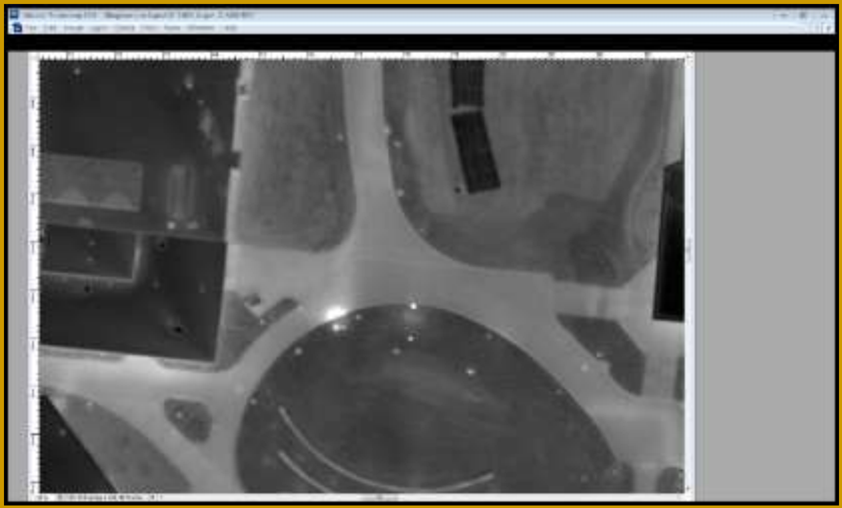
Buried Chilled Water Lines Cool the Surface Above the Line

Thermal mapping GIS layers









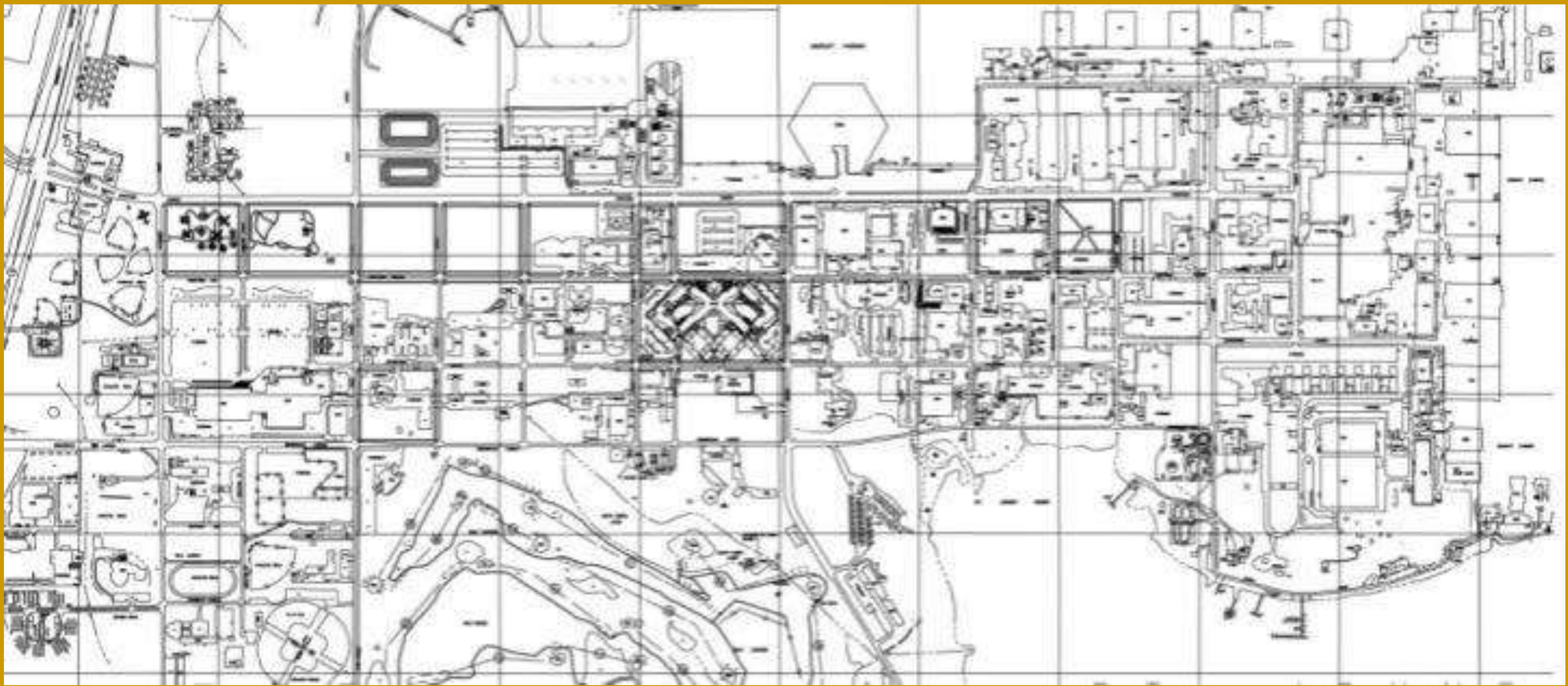
Aerial Infrared Surveying of Steam, Hot Water & Chilled Water Systems

Visible Map of NAX-JAX

Aerial Infrared Surveying of Steam, Hot Water & Chilled Water Systems

Thermal Map of NAX-JAX

Aerial Infrared Surveying of Steam, Hot Water & Chilled Water Systems

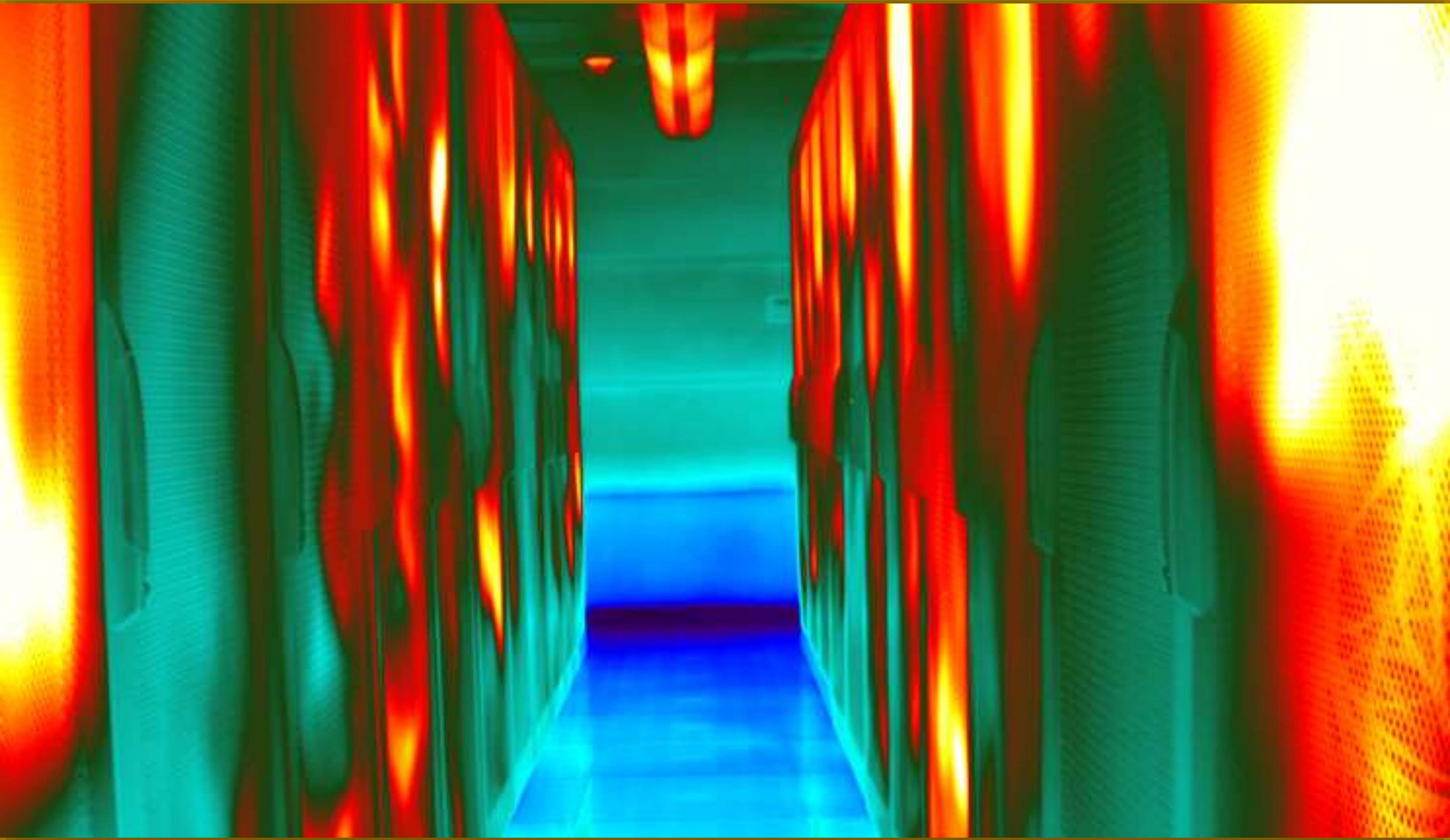


DRAWING Map of NAX-JAX

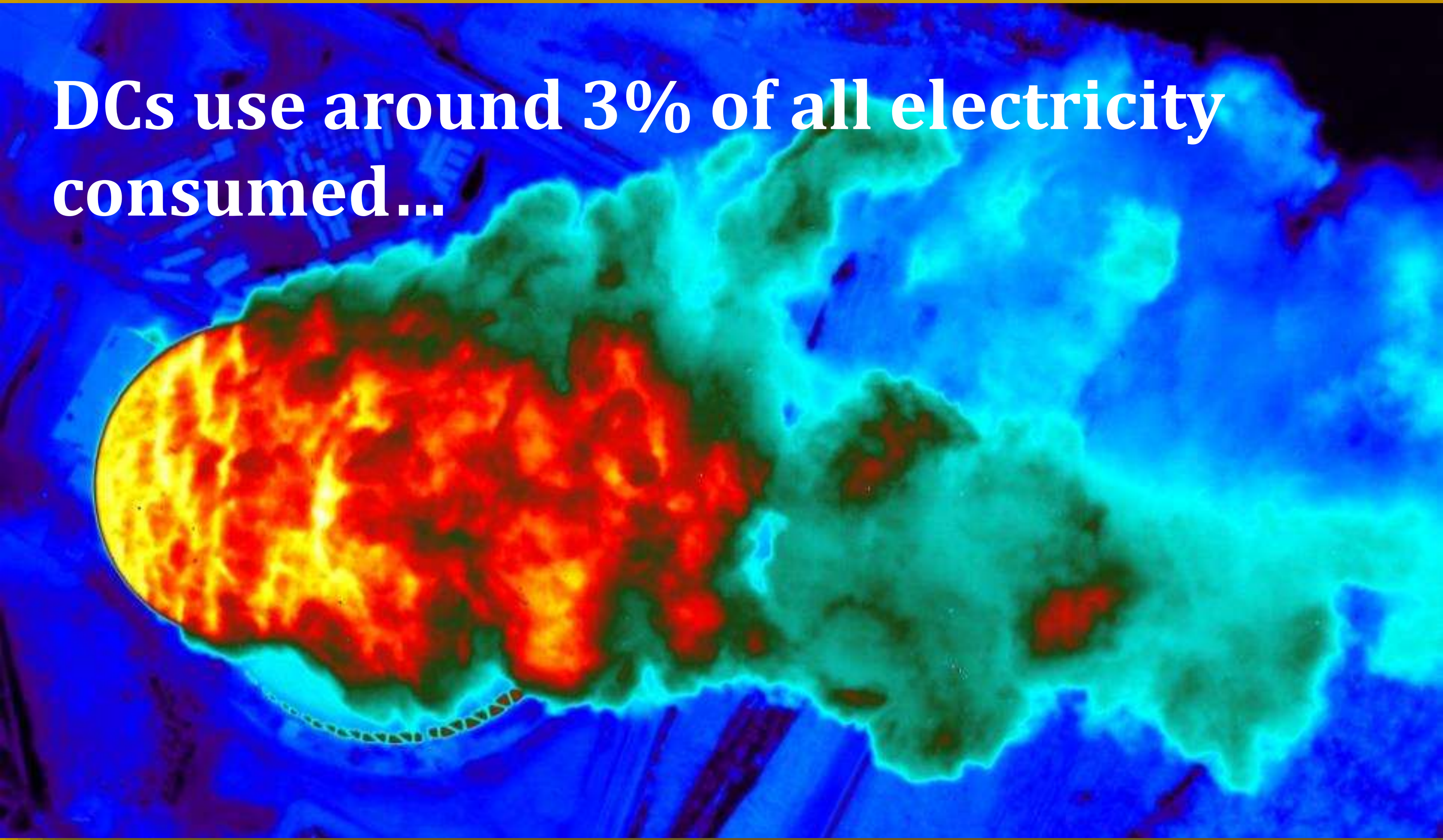
Thermal Mapping at Data Centers

NORTHERN OHIO CHAPTER

Thermal Mapping of Data Centers



Power Use at Data Centers



Power Use at Data Centers

The US E.P.A. (August of 2007) estimated national energy consumption by computer servers and data centers would double from 2005 - 2010 (100 billion kwhs) but the recession makes those estimates a little high.

DCs are inherently inefficient with electricity…

Around 90% of their total energy usage is from failsafe, redundant systems and only 10% is actually used for server or network communications.

Power Use at Data Centers

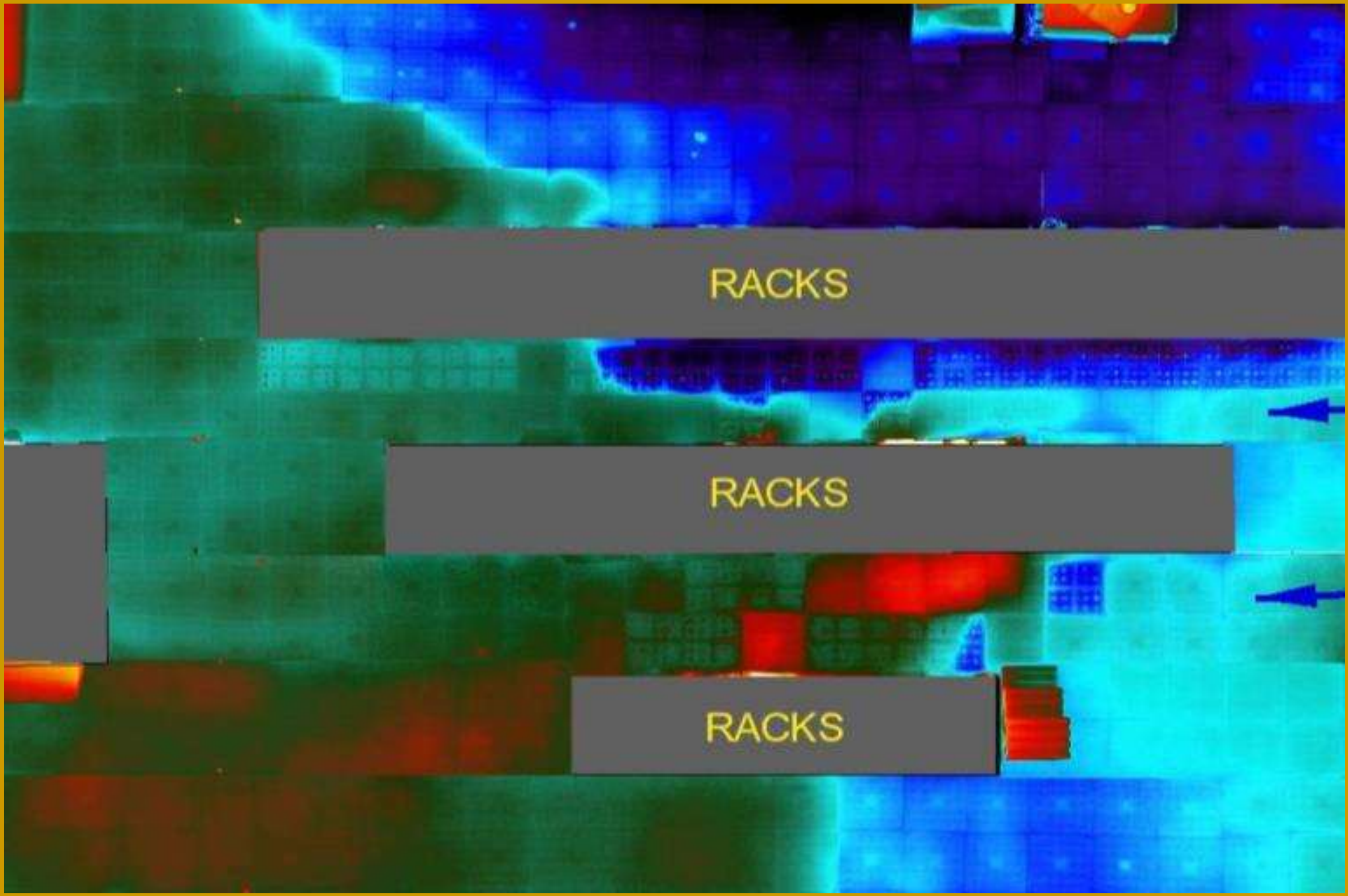
Given: **Raising the temperature in the DC reduces electricity use and therefore money. Why don't facilities manager raise the temperatures?**

***Top 7 Reasons Why Data Centers Don't Raise Their Thermostats:**
7 - Some HVAC Equipment Can't Handle Higher Return Air Temperatures
6 - Colocation Data Centers Have To Be All Things To All People
5 - Fear, Uncertainty, Doubt (FUD)/Ignorance
4 - Intolerable Work Environment
3 - Cultural Norms and Inertia
2 - Concern Over Higher Failure Rates and Performance Issues
1 - Thermal Ride-Through Time

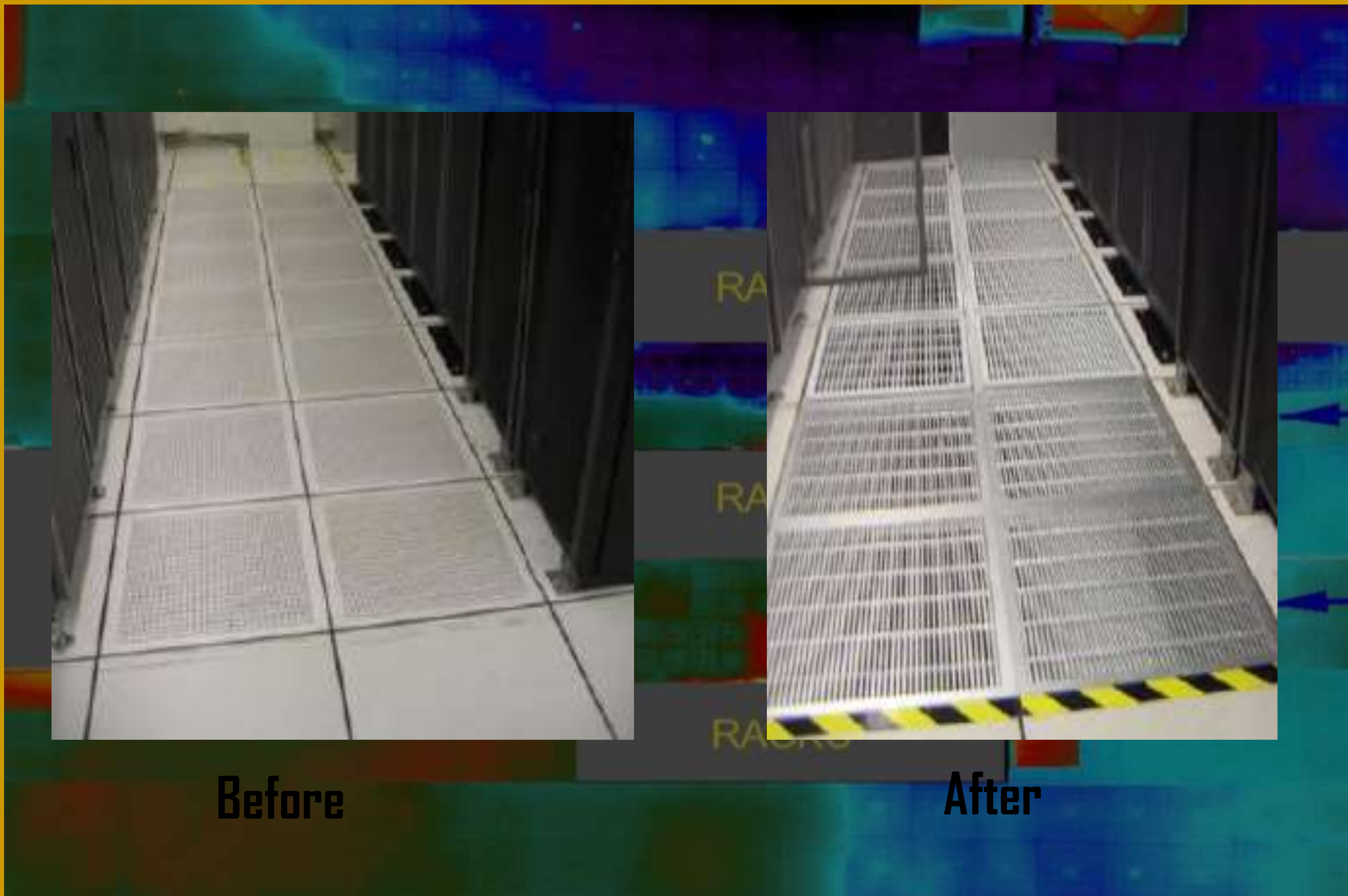
The reason is that pressure is not put on them to do it!

**From a recent article by Ron Vokoun – JE Dunn Construction*

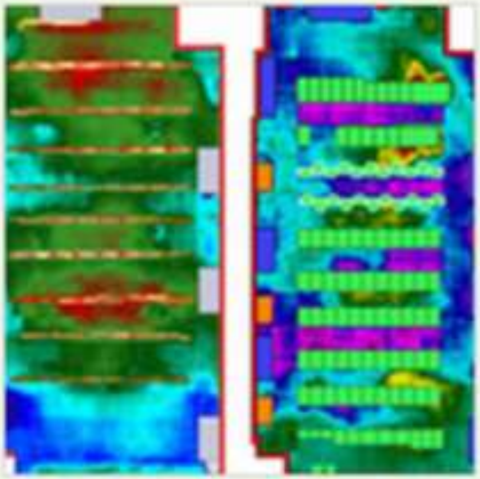
Typical Thermal Image of a Raised Floor DC in USA



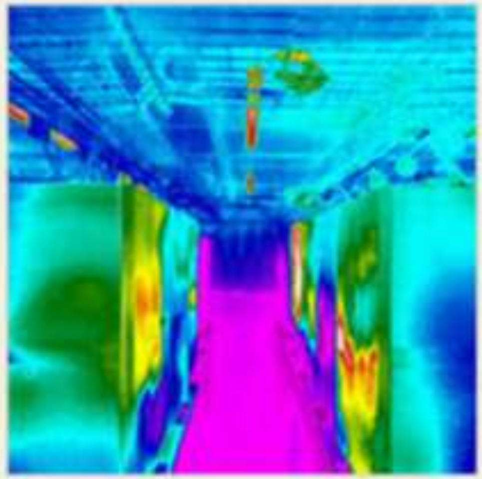
Typical Thermal Image of a Raised Floor DC in USA



Three different types of Thermal Imaging Possible



Images provide a heat view look at the overall thermal performance of your facility.



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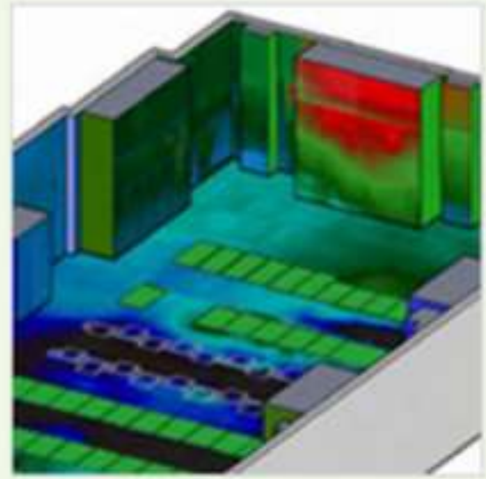
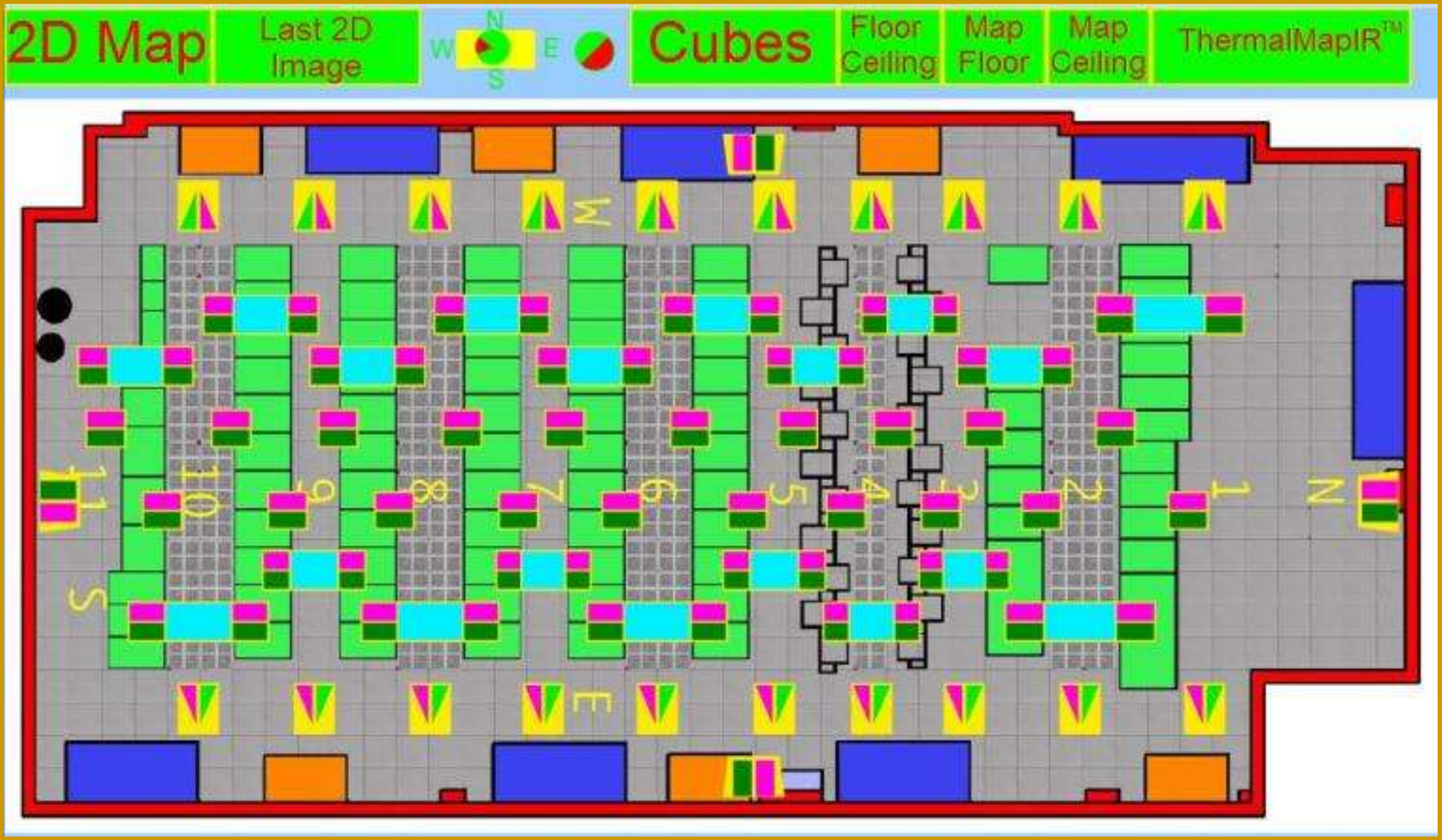
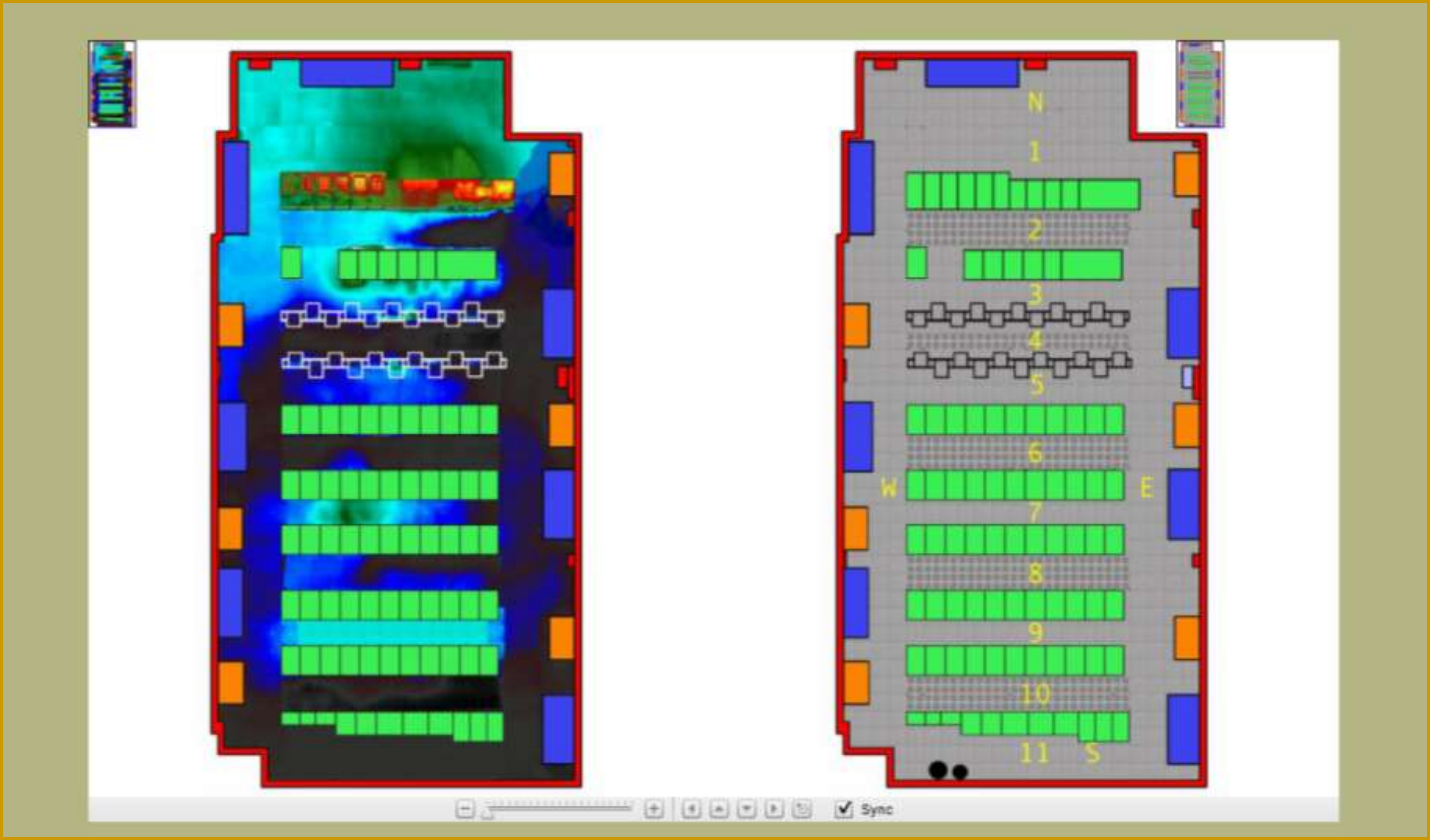


Thermal mapping of your facility to validate the performance of the cooling system system.

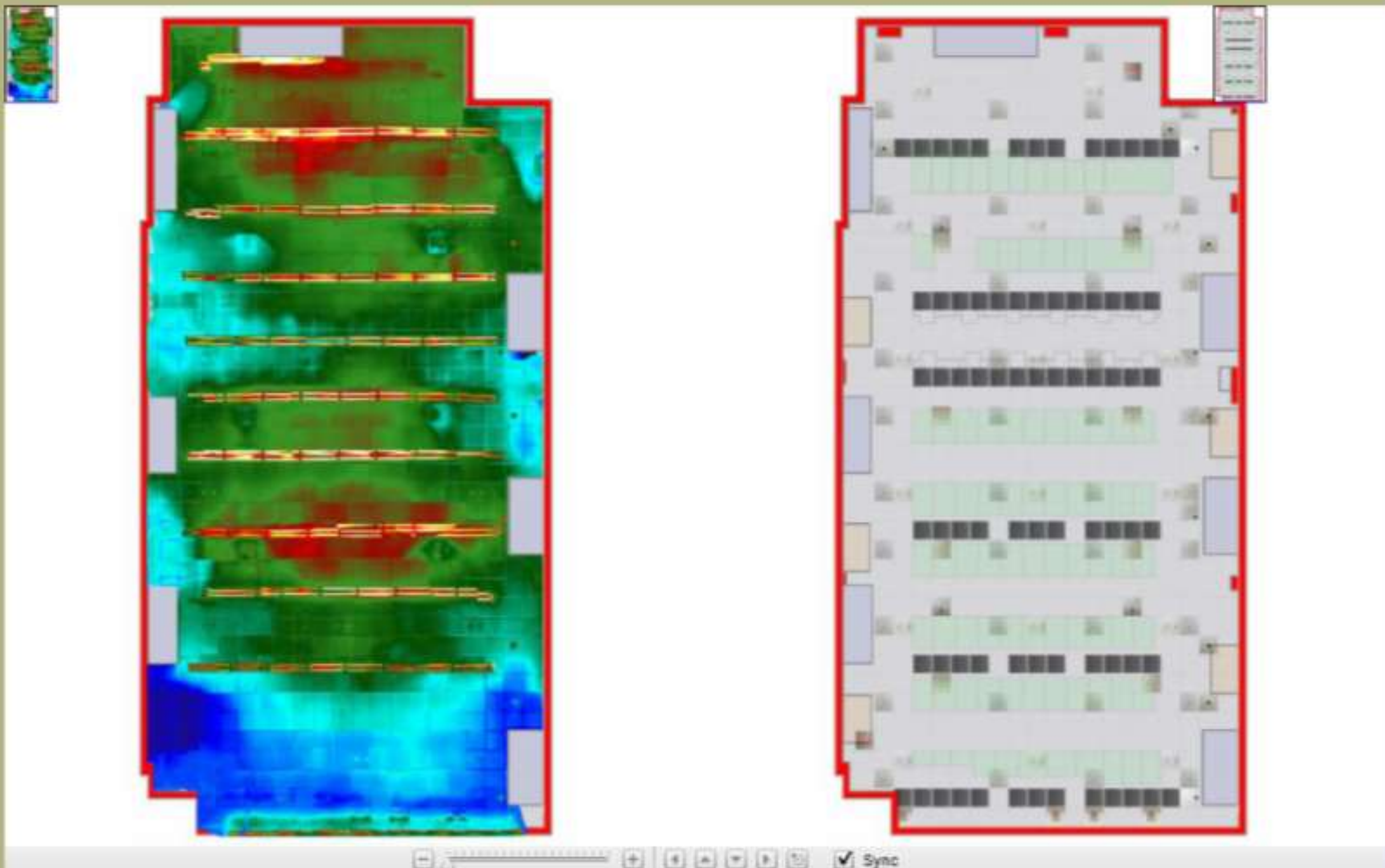
2D Thermal Mapping – The Construct



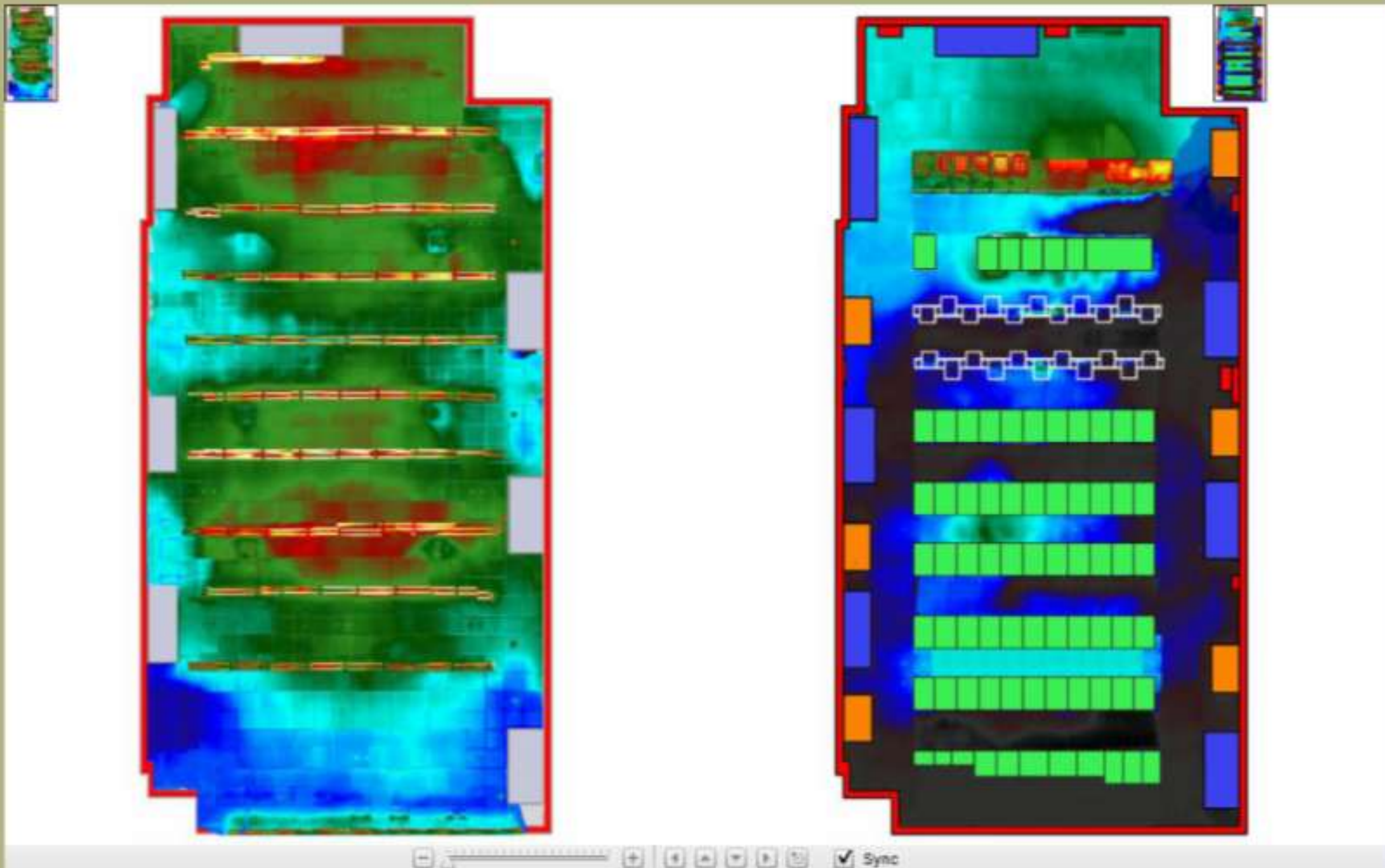
2D Thermal Mapping – Floor Mapping



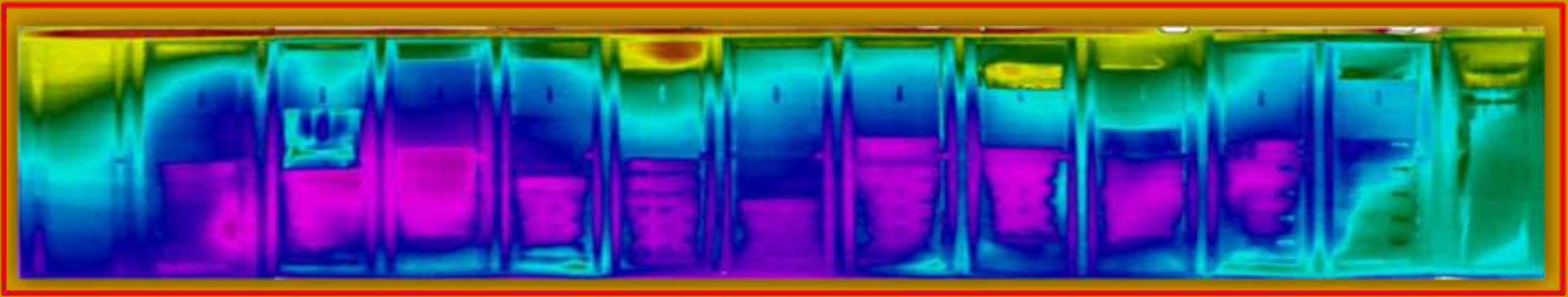
2D Thermal Mapping – Ceiling Mapping



2D Thermal Mapping – Ceiling & Floor Compared

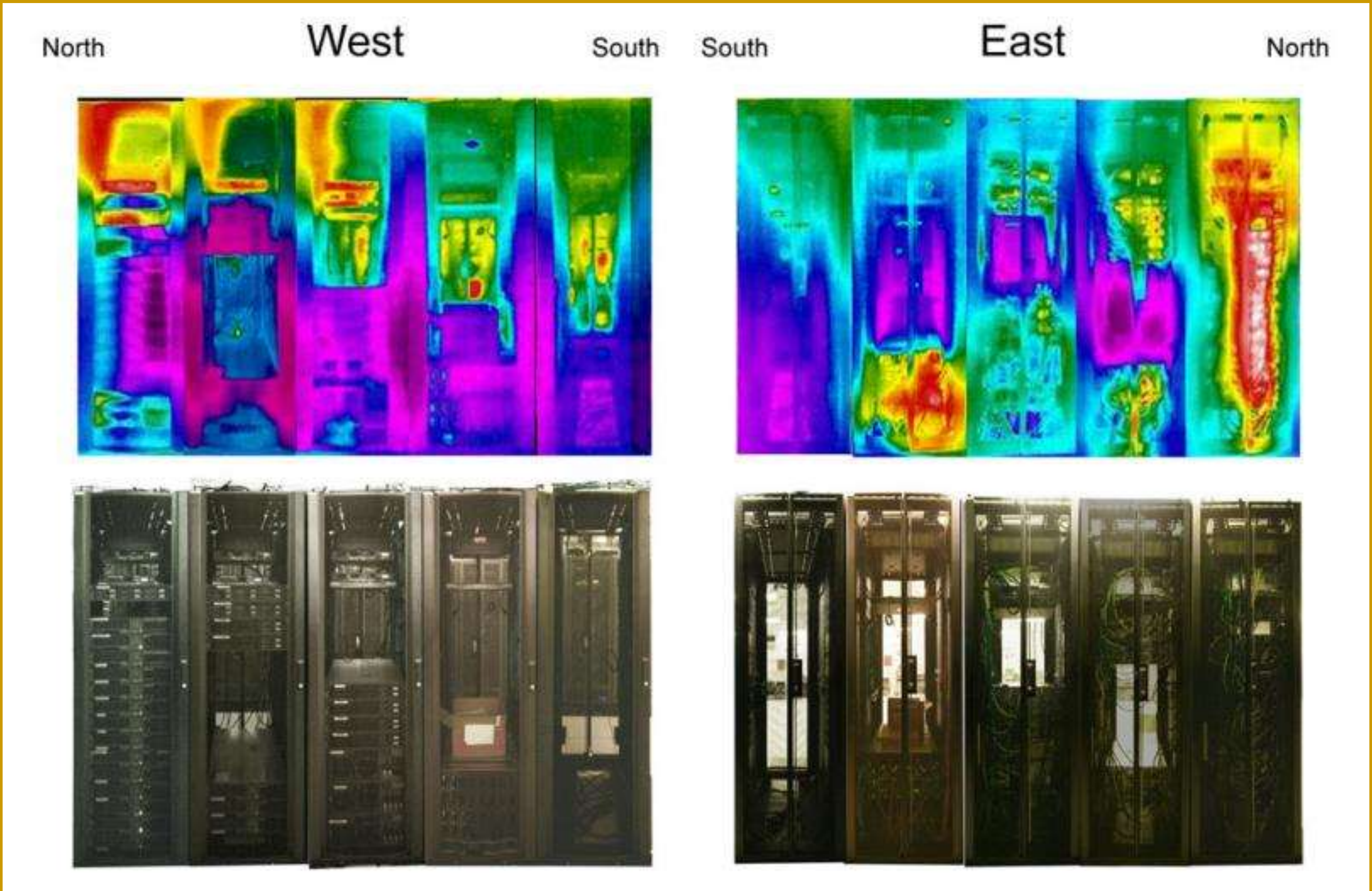


2D Thermal Mapping – Server Imaging

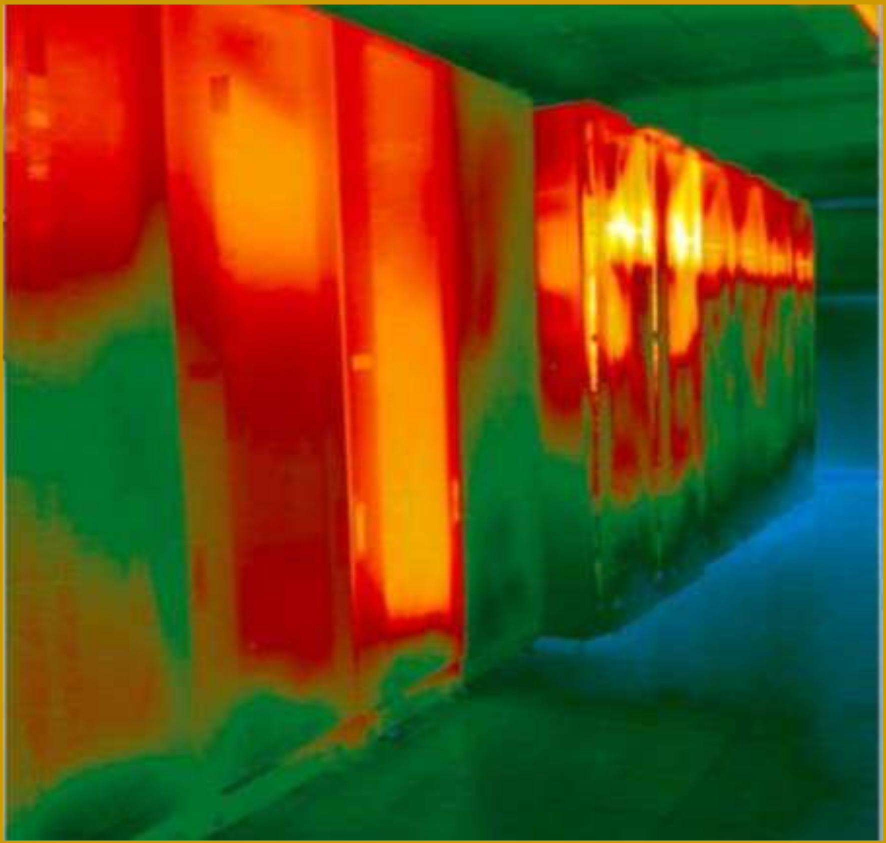


2D Thermal Mapping – Server Imaging

2D Thermal Mapping – Server Imaging Comparisons

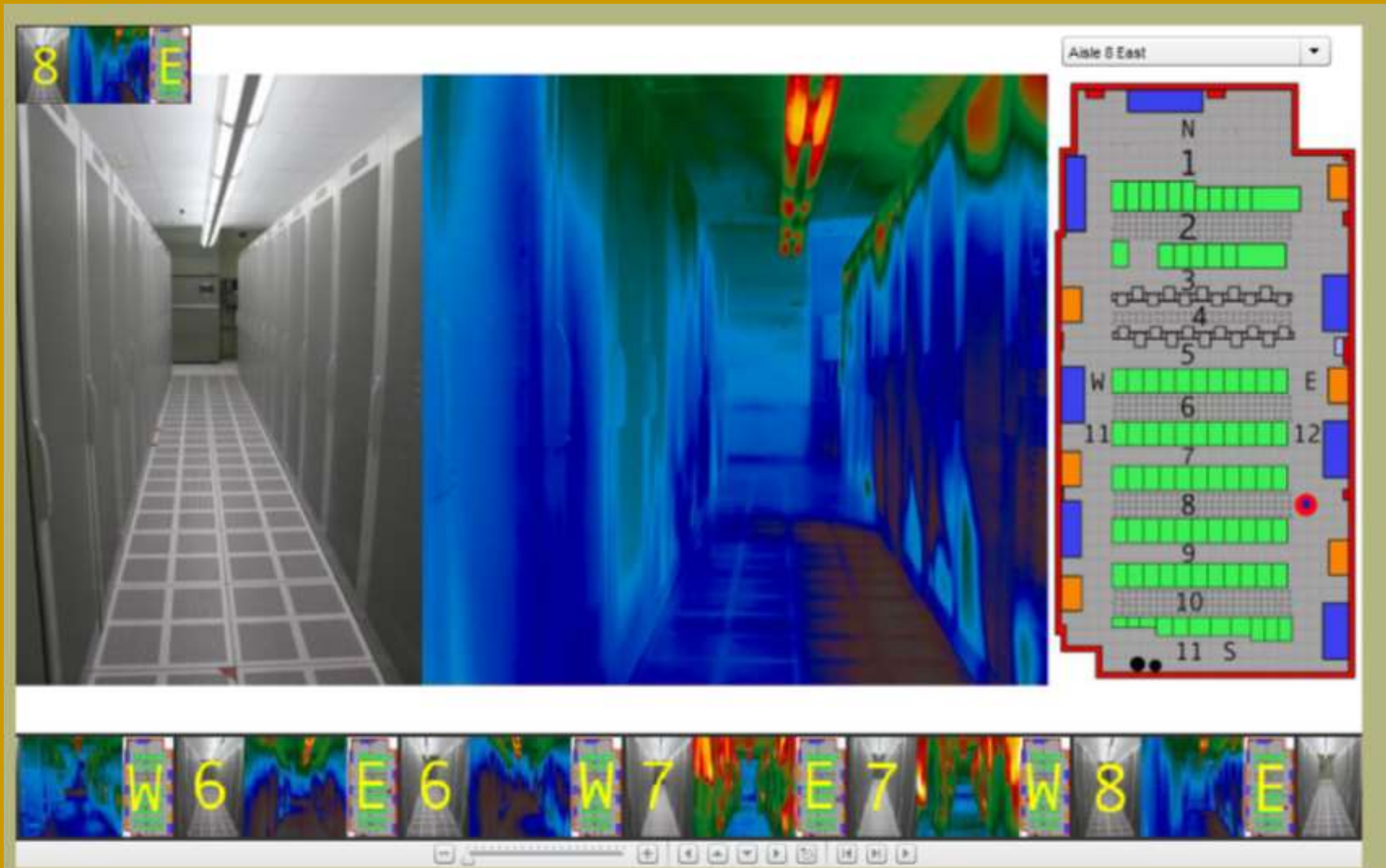


2D Thermal Mapping – Oblique "Down the Aisles"

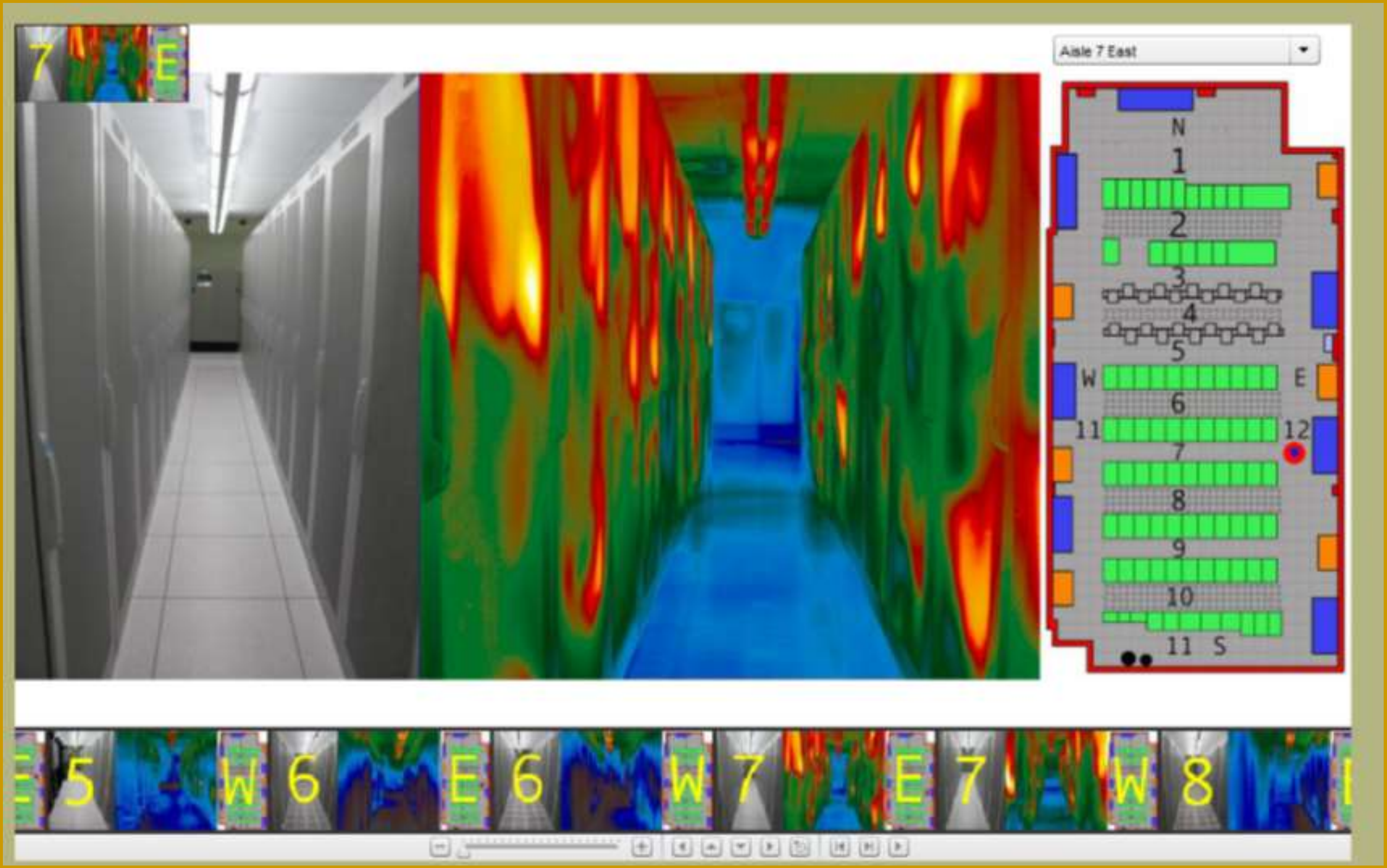


"Down the Aisles" IR imaging has very limited use in diagnosis of problems, but is simple enough for any amateur to mess-up.

2D Thermal Mapping – Oblique "Down the Aisles"

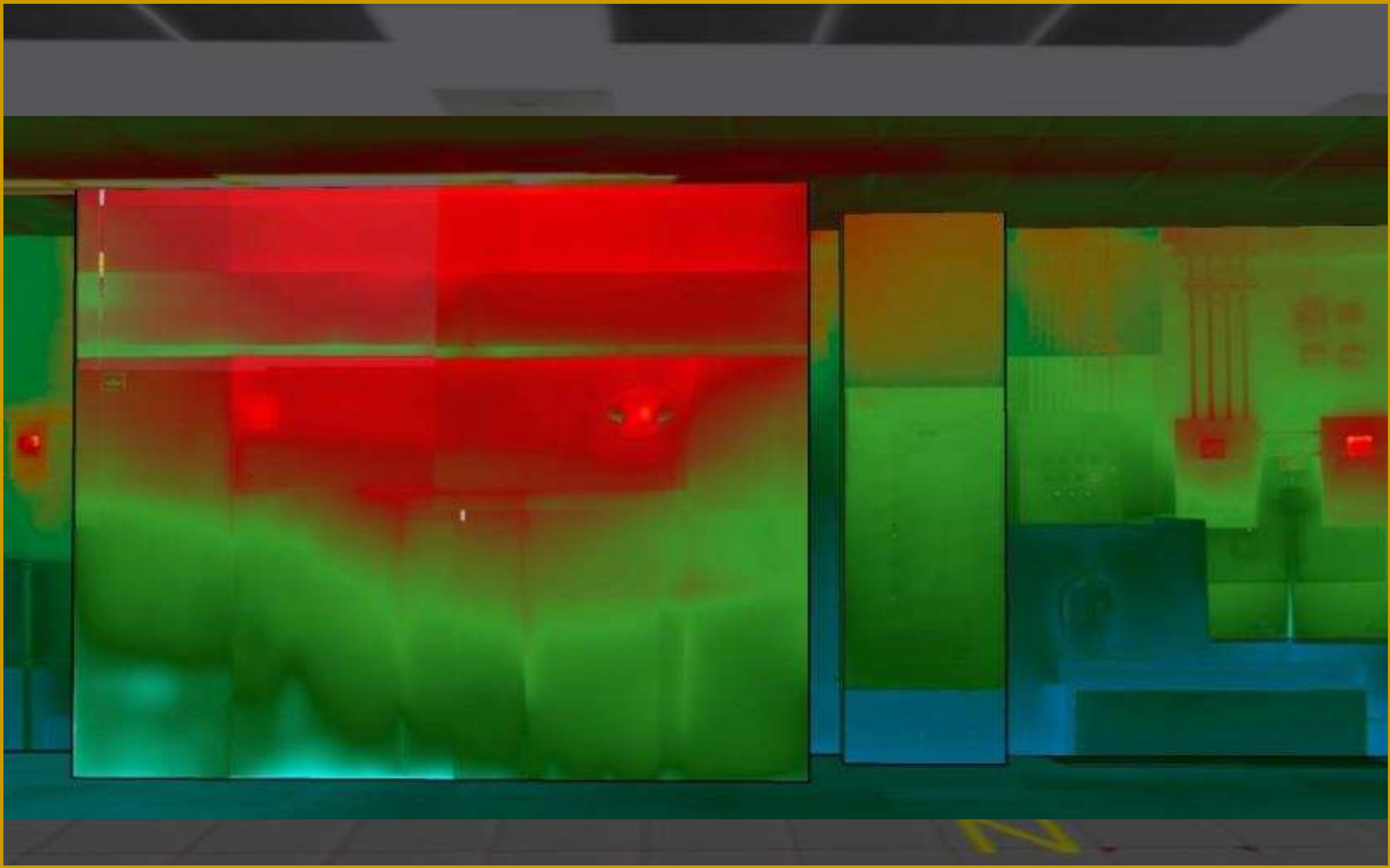


2D Thermal Mapping – Oblique "Down the Aisles"

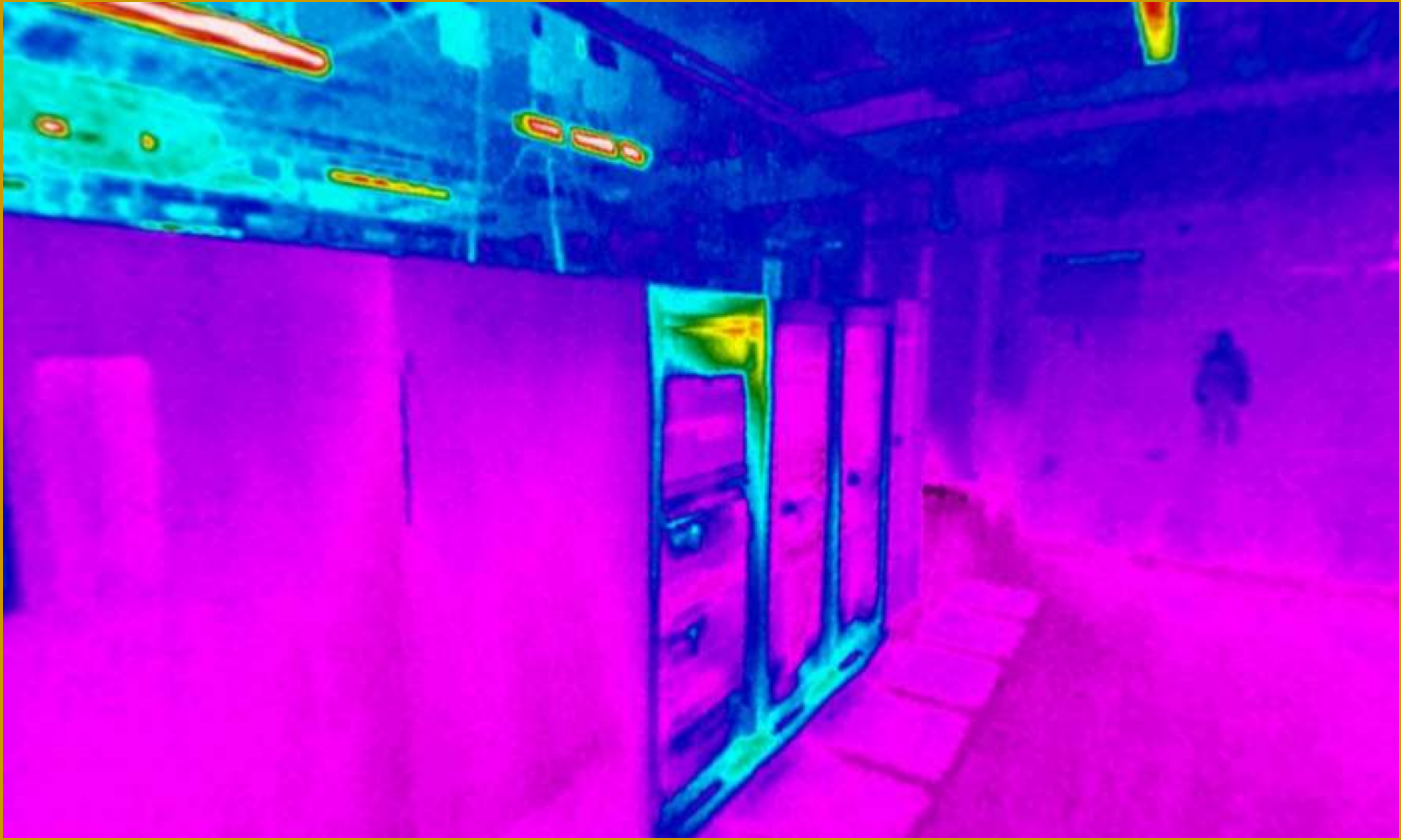


3D Thermal Mapping – Wall Imaging

3D Thermal Mapping – Wall Imaging

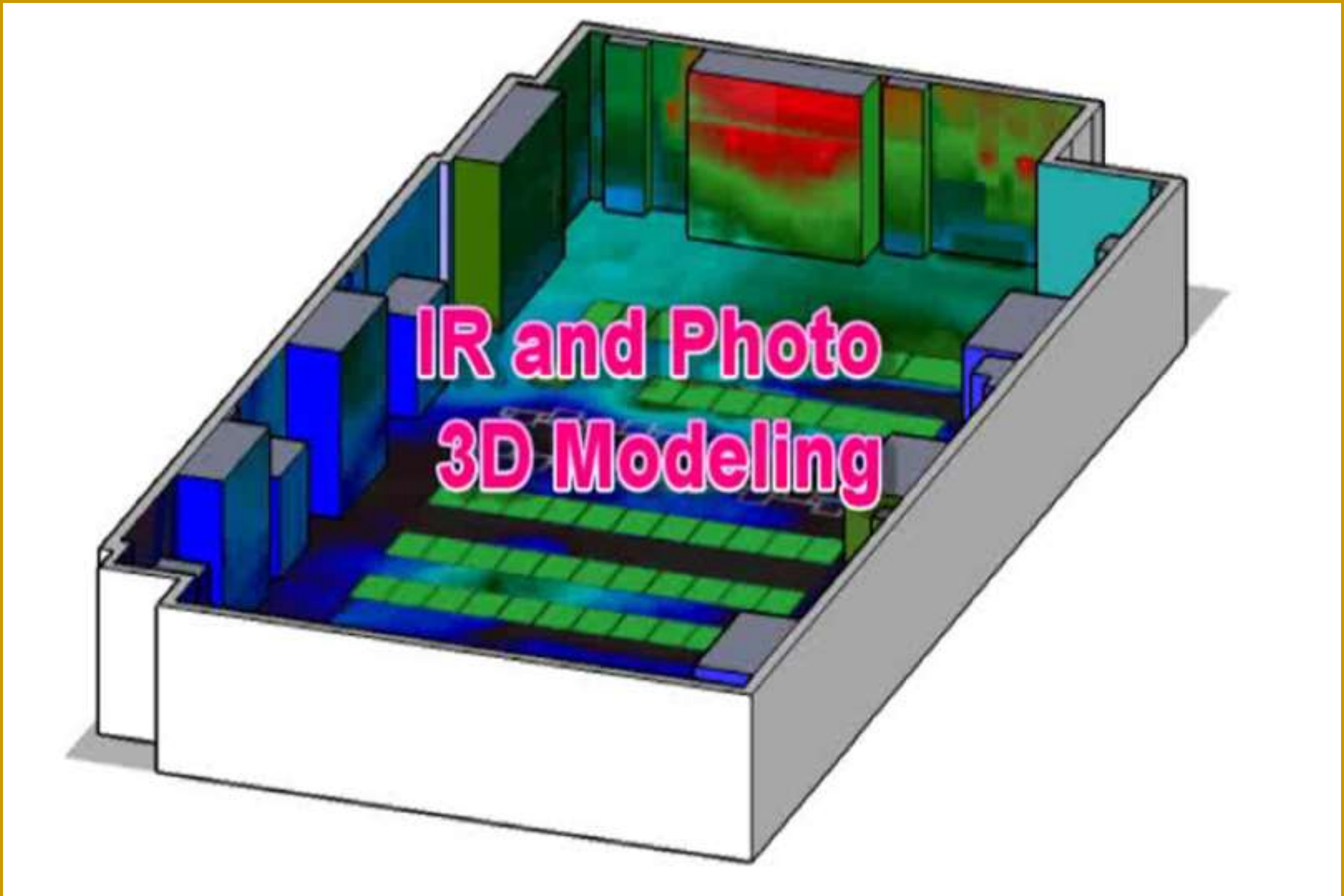


3D Thermal Mapping – 360 Mapping

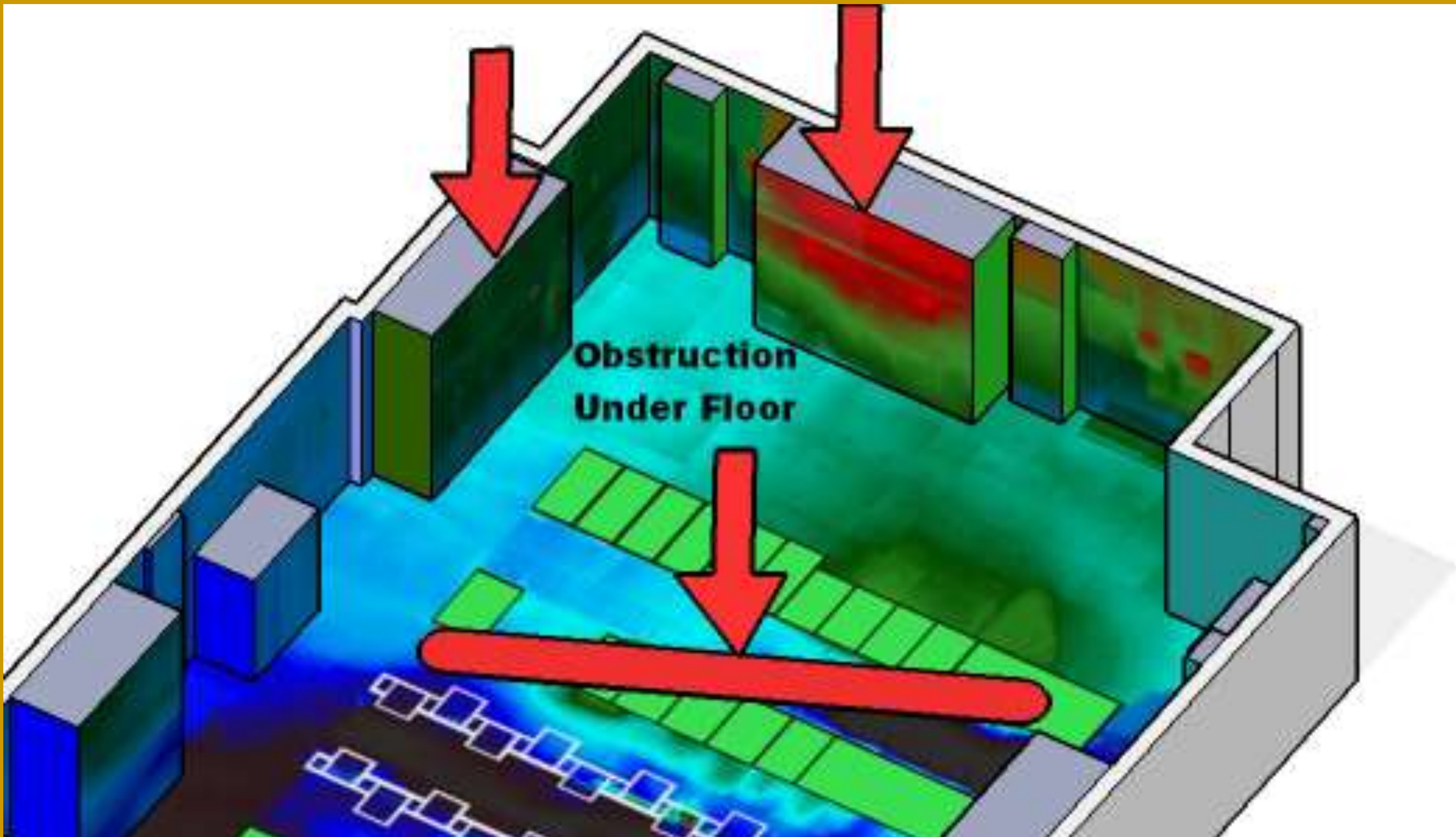


3D Thermal Mapping – 360 Mapping

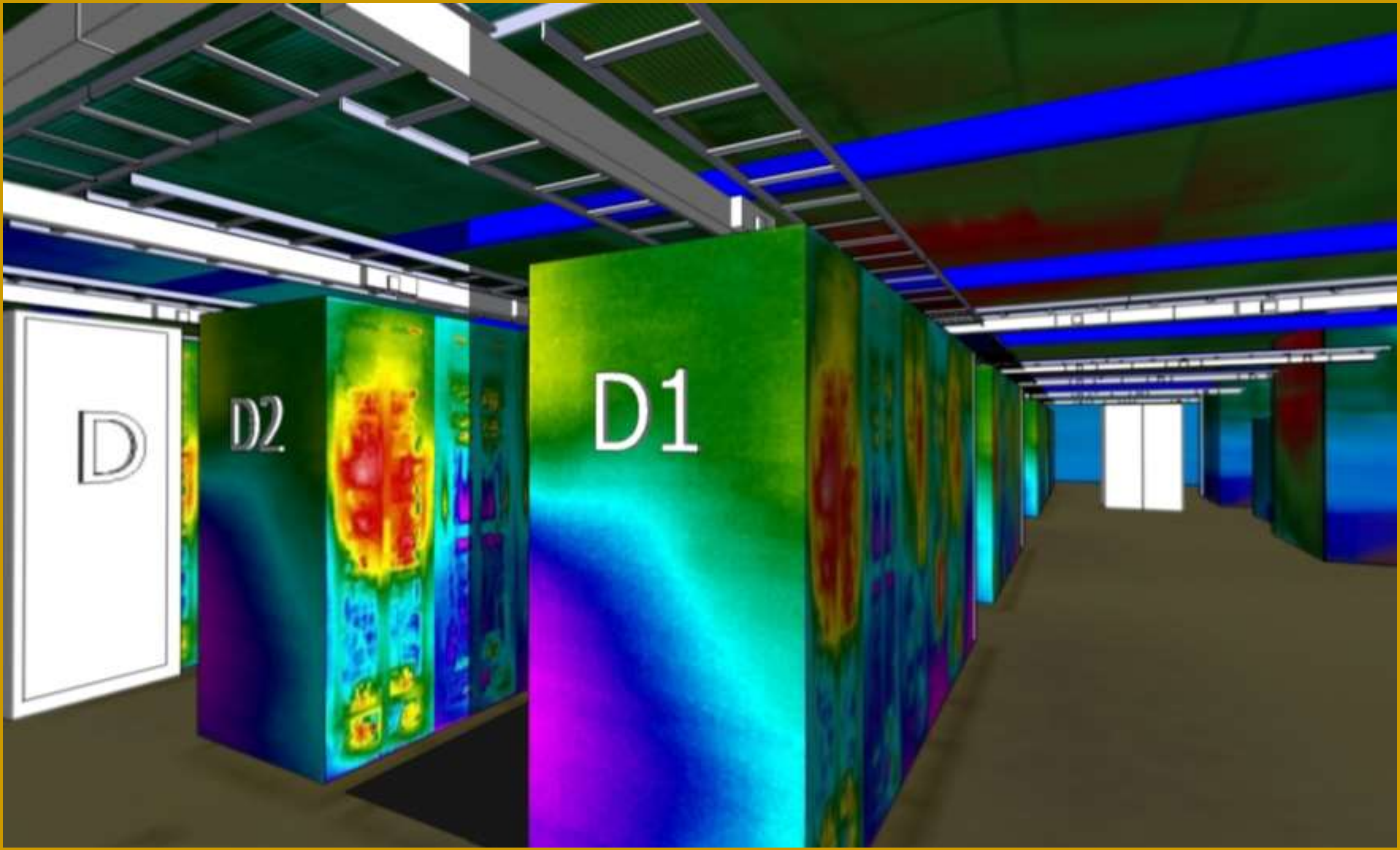
3D Thermal Mapping – 3D Modeling



3D Thermal Mapping – 3D Modeling



3D Thermal Mapping – 3D Virtual Presentation

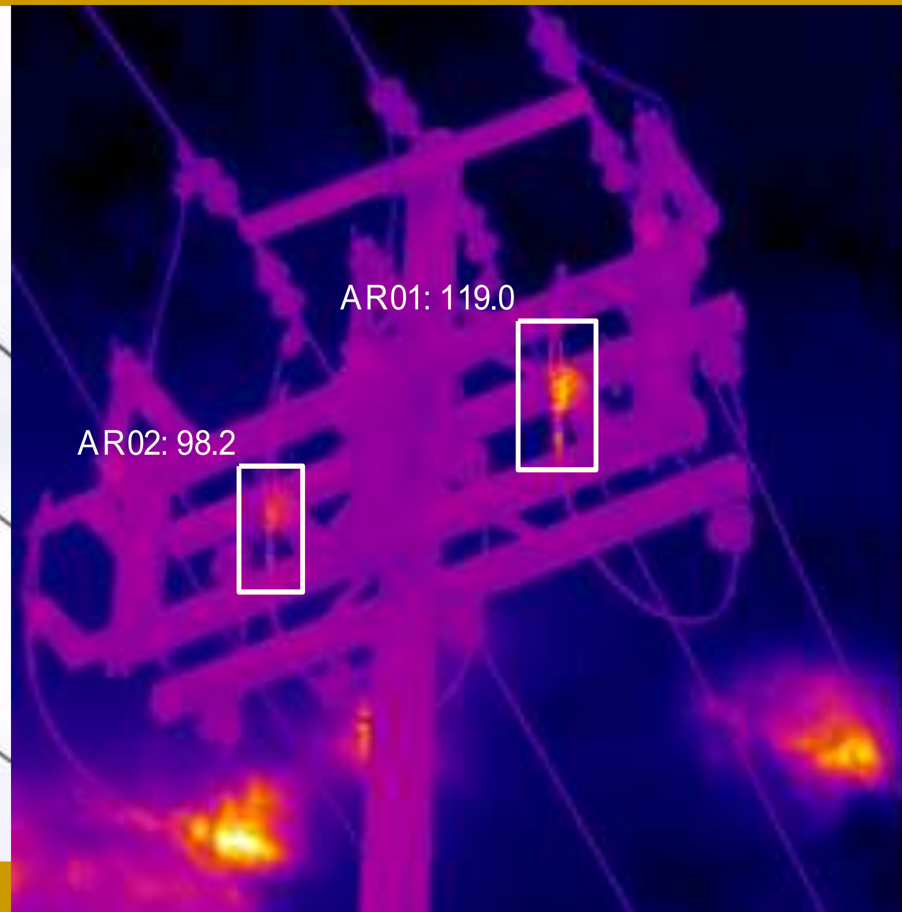


3D Thermal Mapping – 3D Virtual Presentation

Electrical Infrared

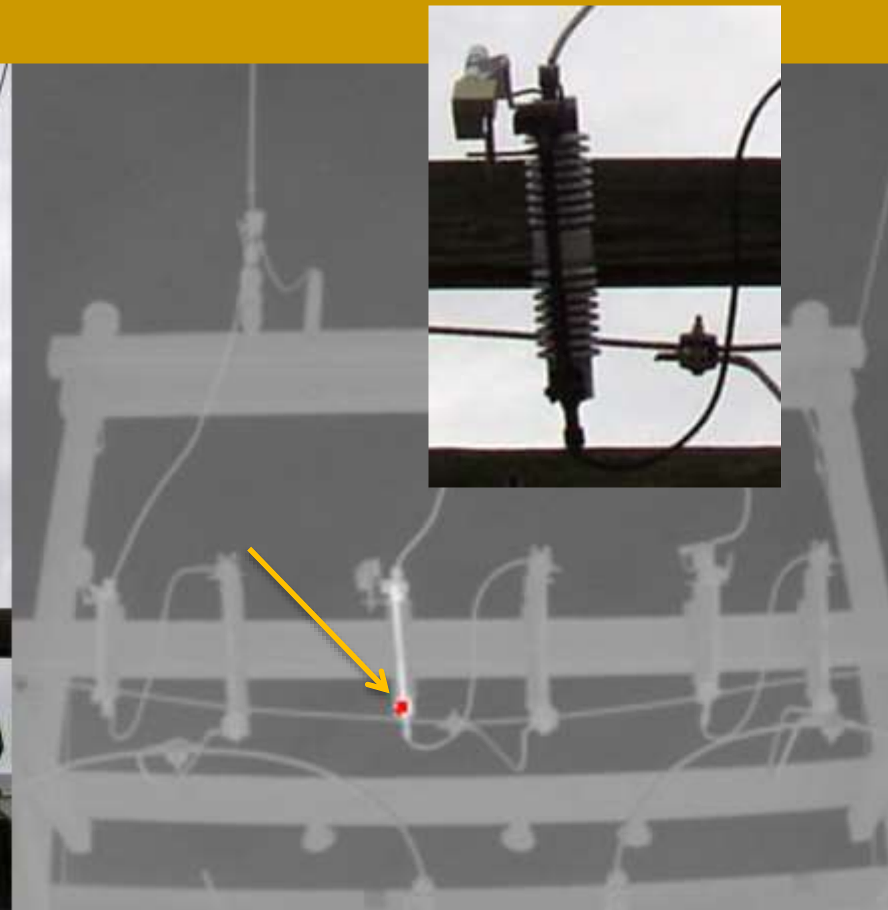
NORTHERN OHIO CHAPTER

Electrical Infrared



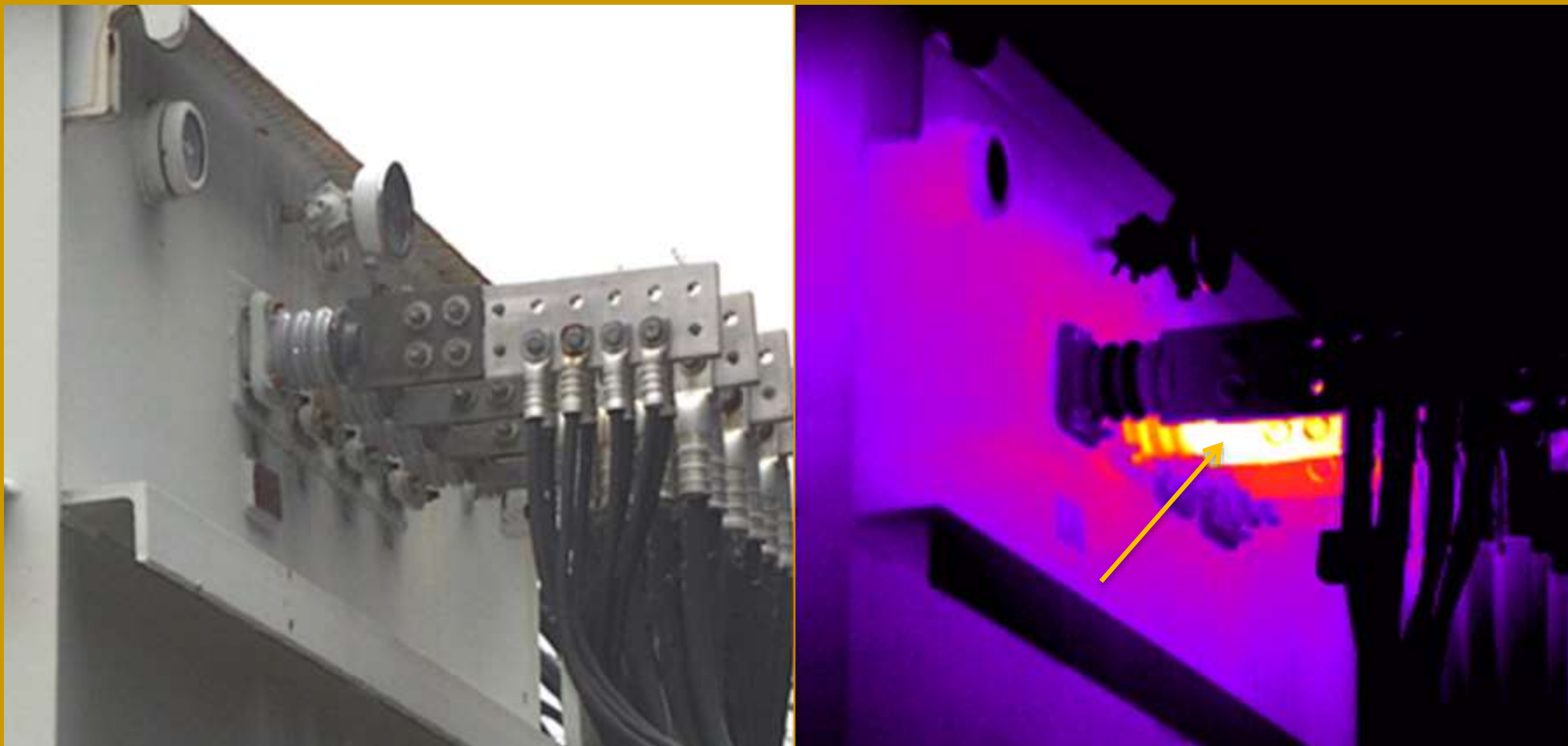
Fuse knives, phases center and right as indicated.

Electrical Infrared



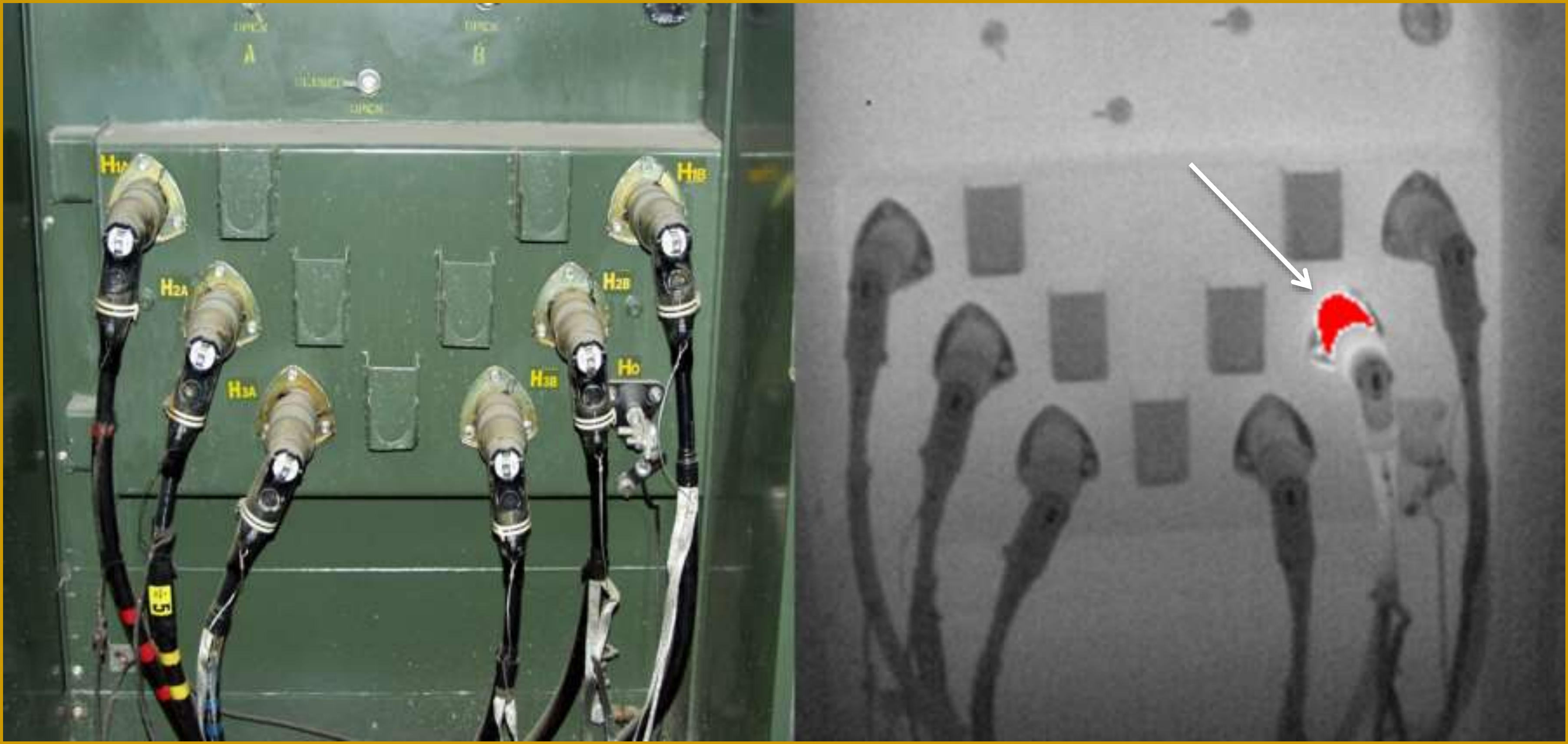
Lightning arrestor, phase B, load side.

Electrical Infrared



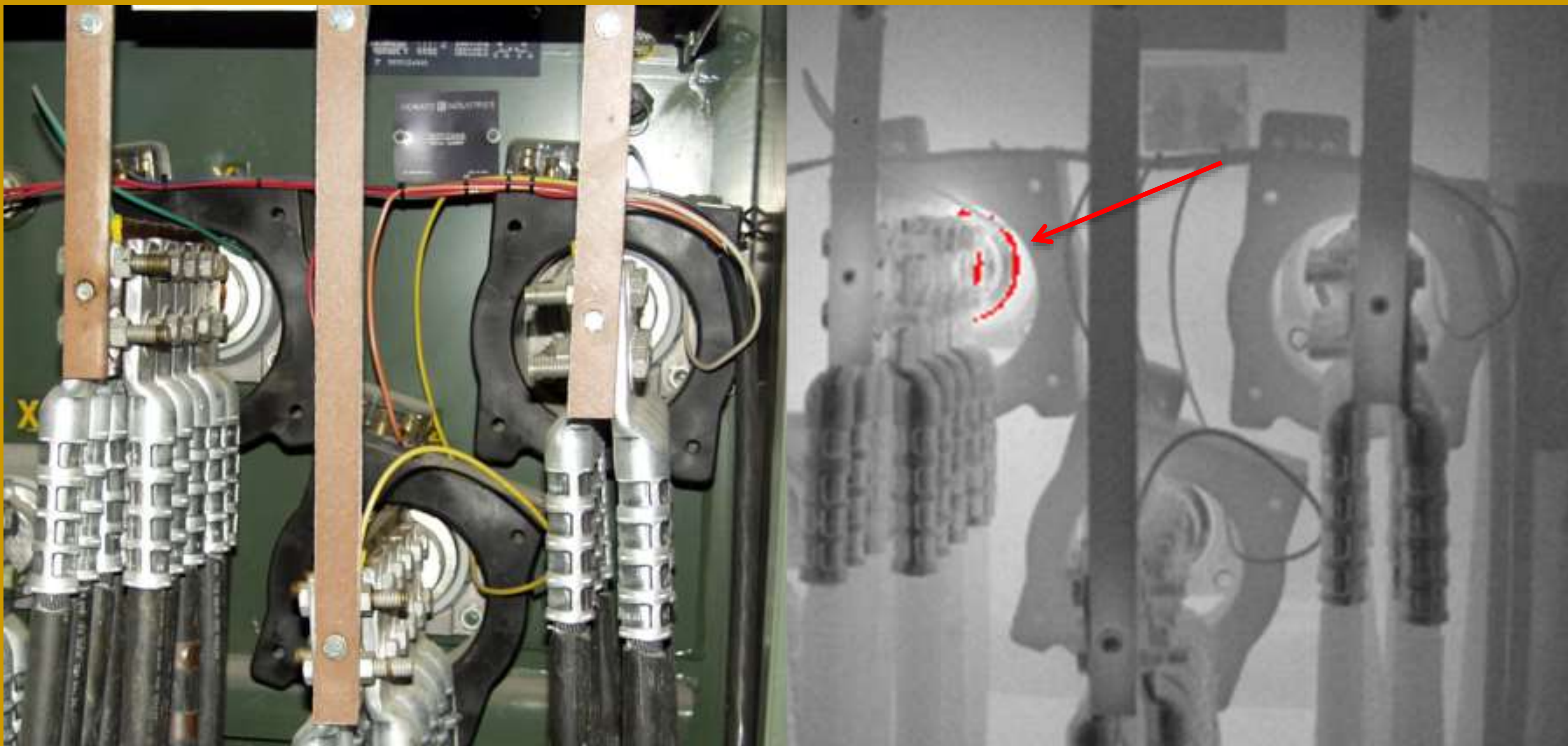
Transformer, load side stab arm bolted connectors, phase A.

Electrical Infrared



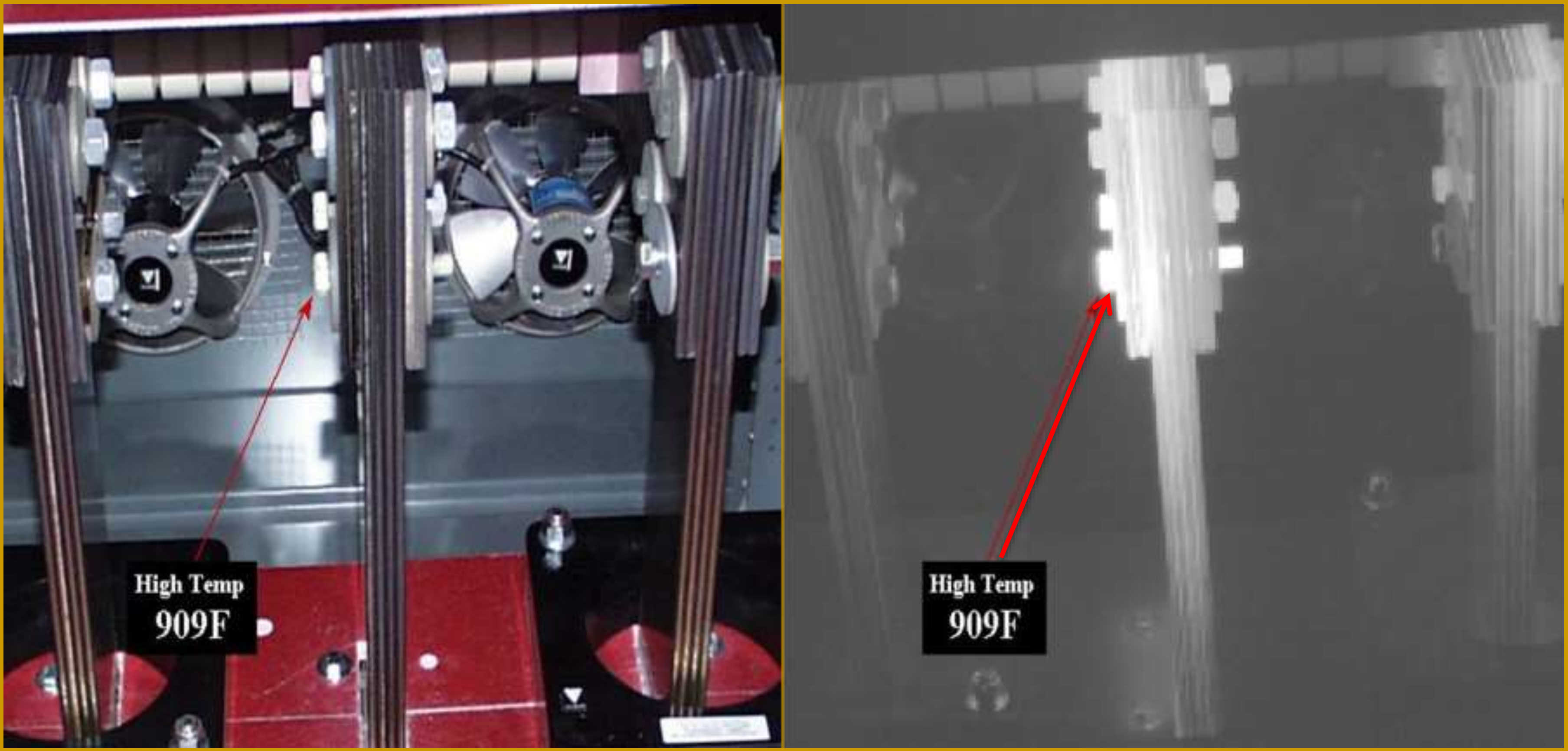
Transformer, load side feed H2B bushing connection.

Electrical Infrared



Transformer load side bushing (internal), phase X1.

Electrical Infrared

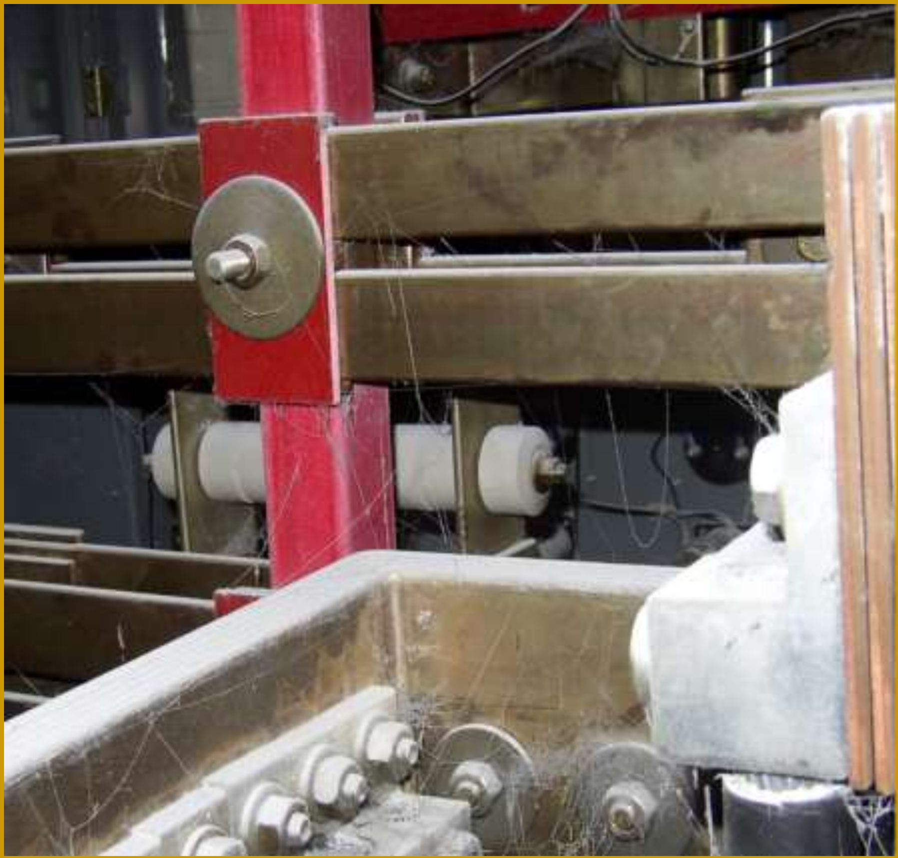


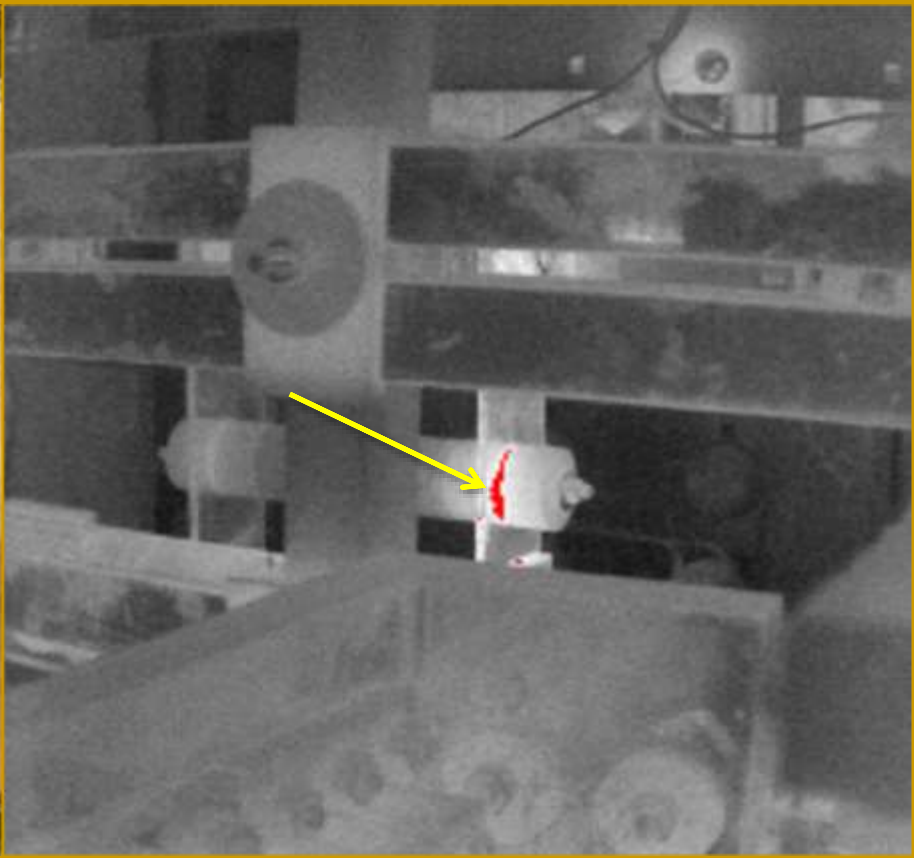
Main switch, phase B, line side bus connector. Phases A & C also.

Electrical Infrared

Main bus, bolted connection (rear) as shown.

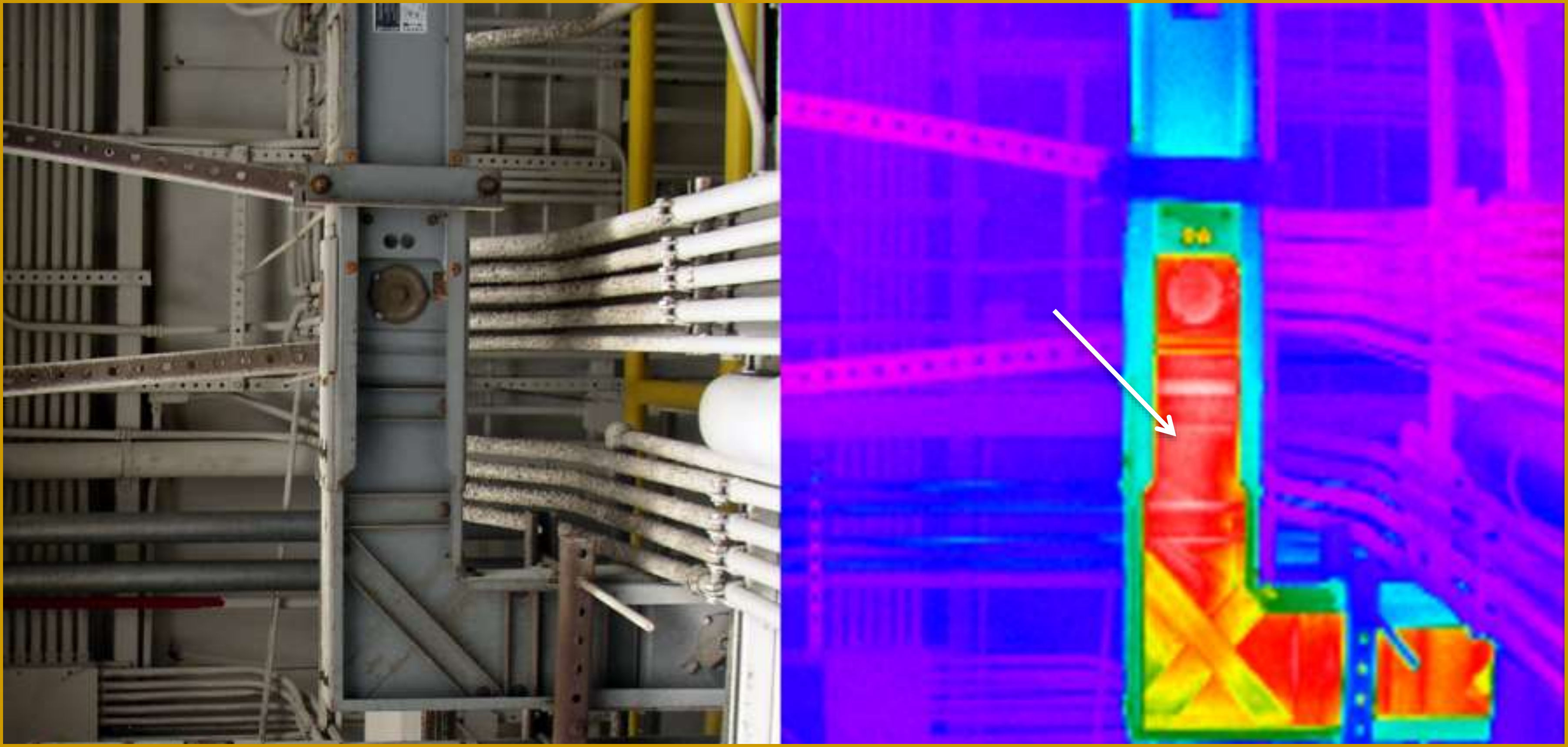
Electrical Infrared





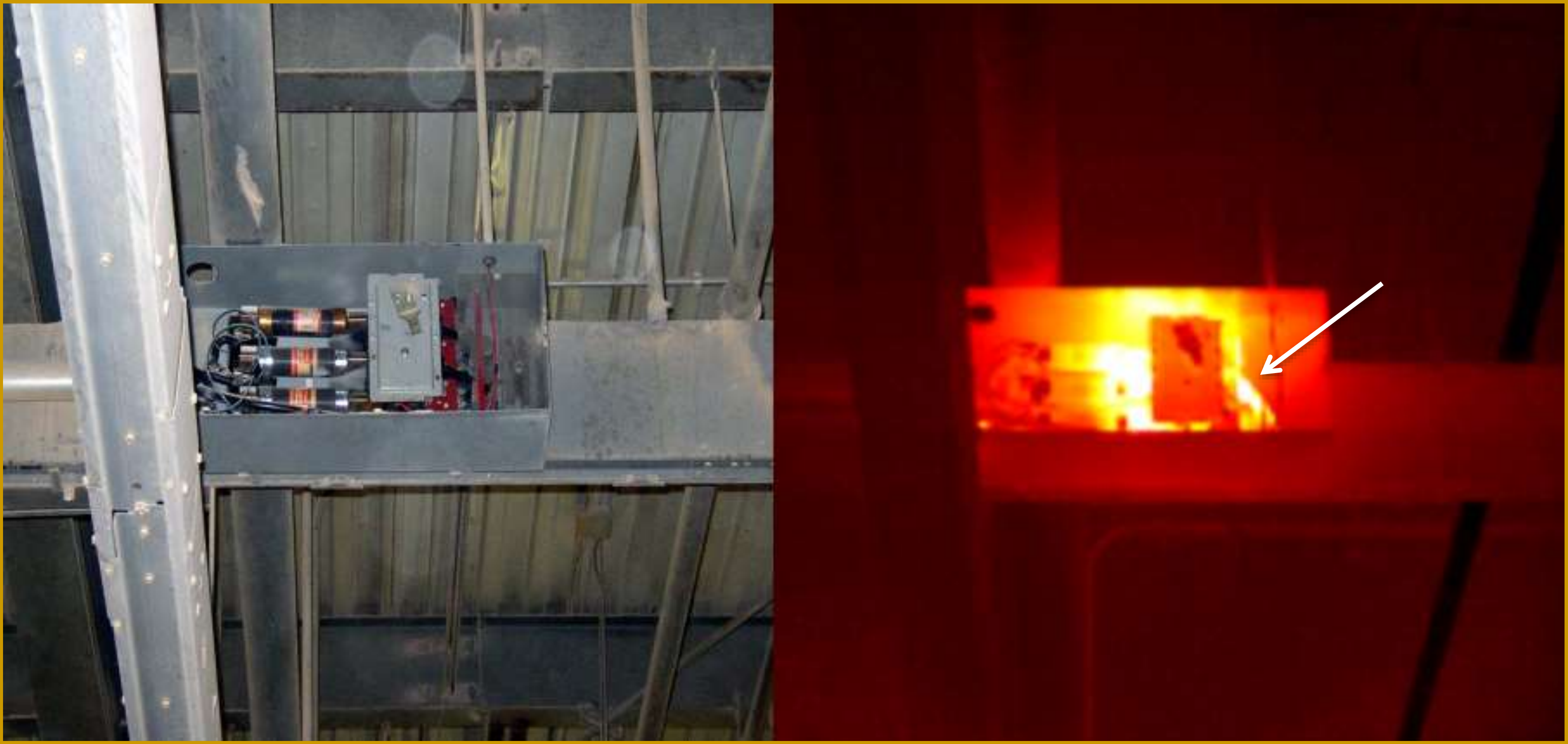
Main bus insulator heating from induction.

Electrical Infrared



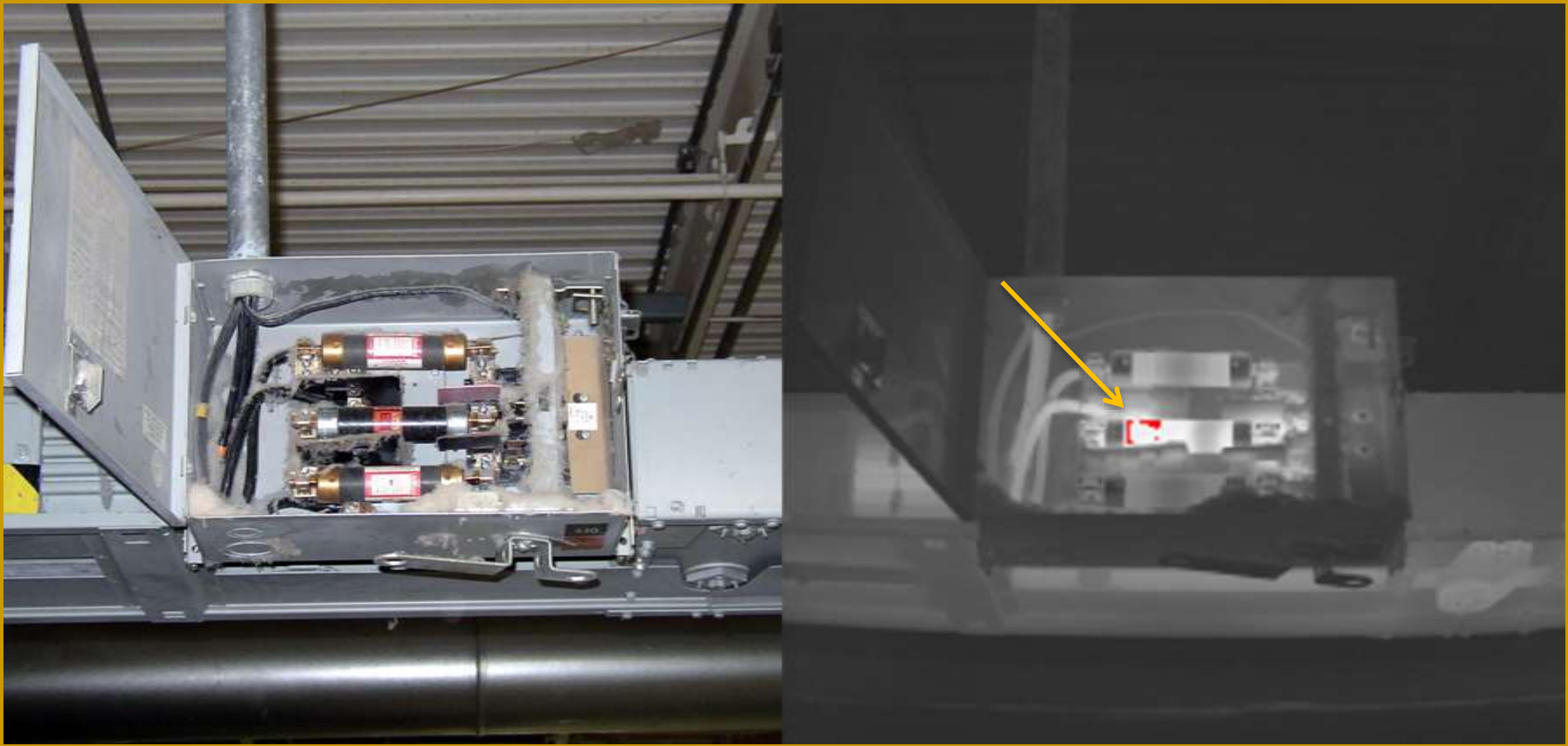
Bus duct overheating at right angle connector.

Electrical Infrared



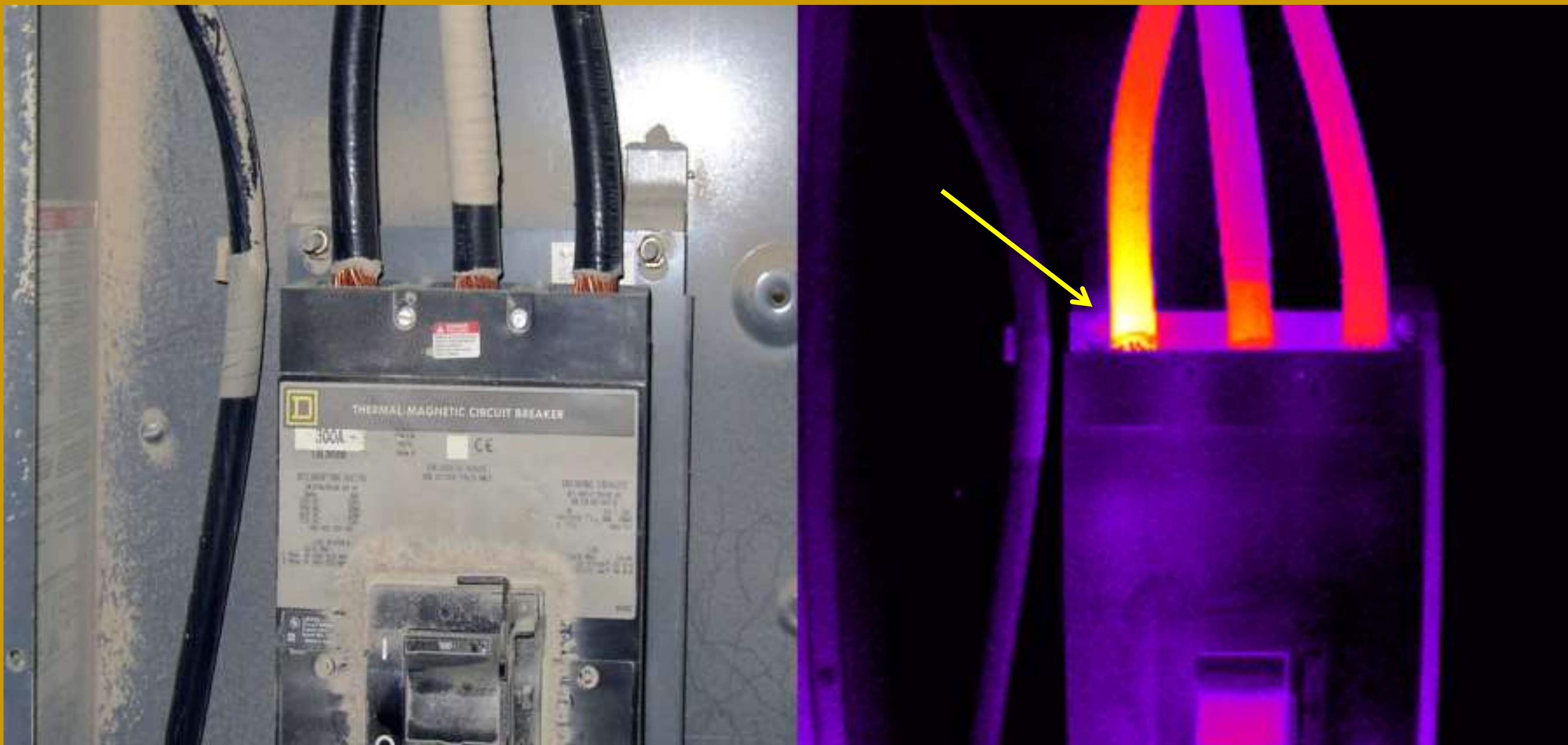
Bus disconnect, switch and line side connections.

Electrical Infrared



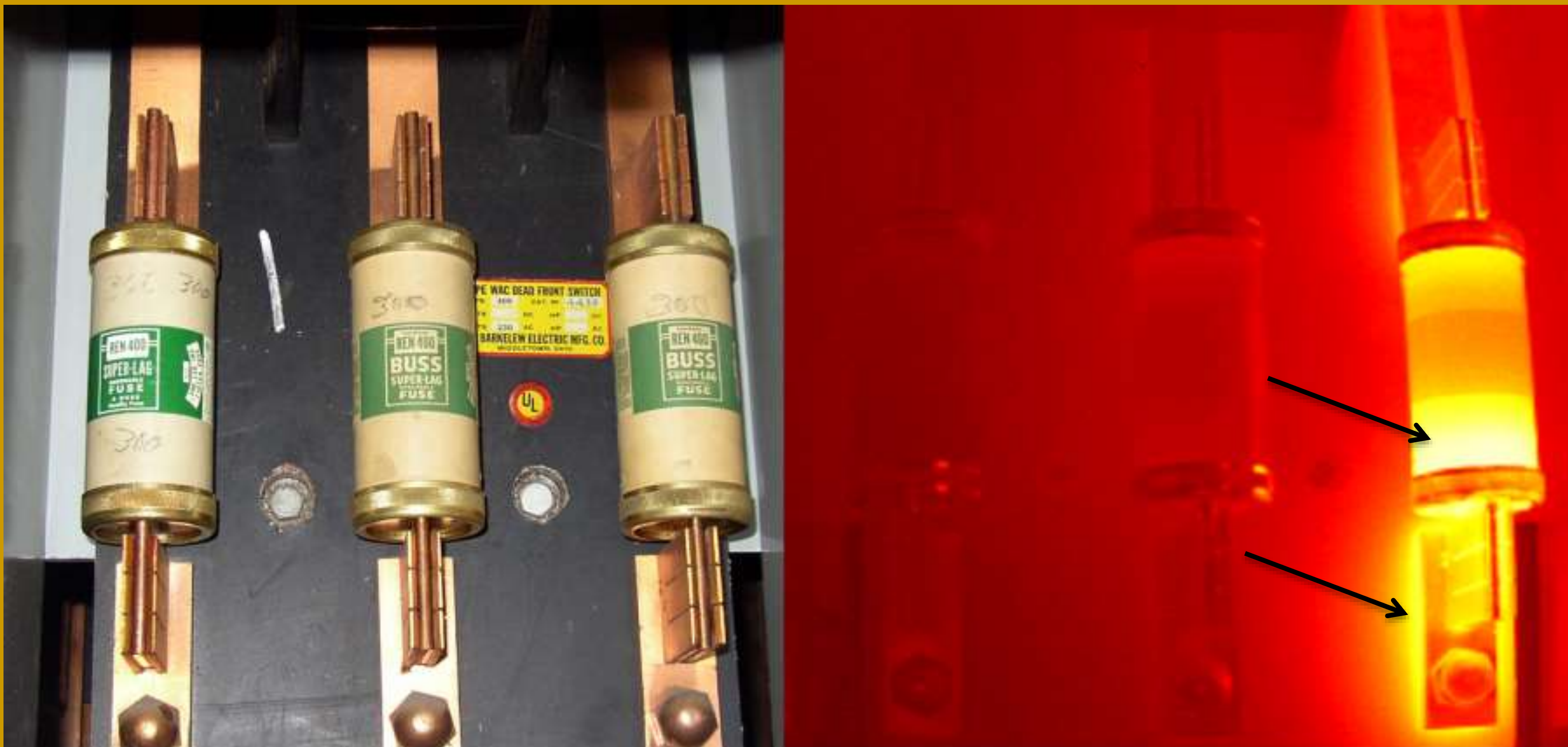
Bus disconnect, fuse and fuse knife, phase B, load side.

Electrical Infrared



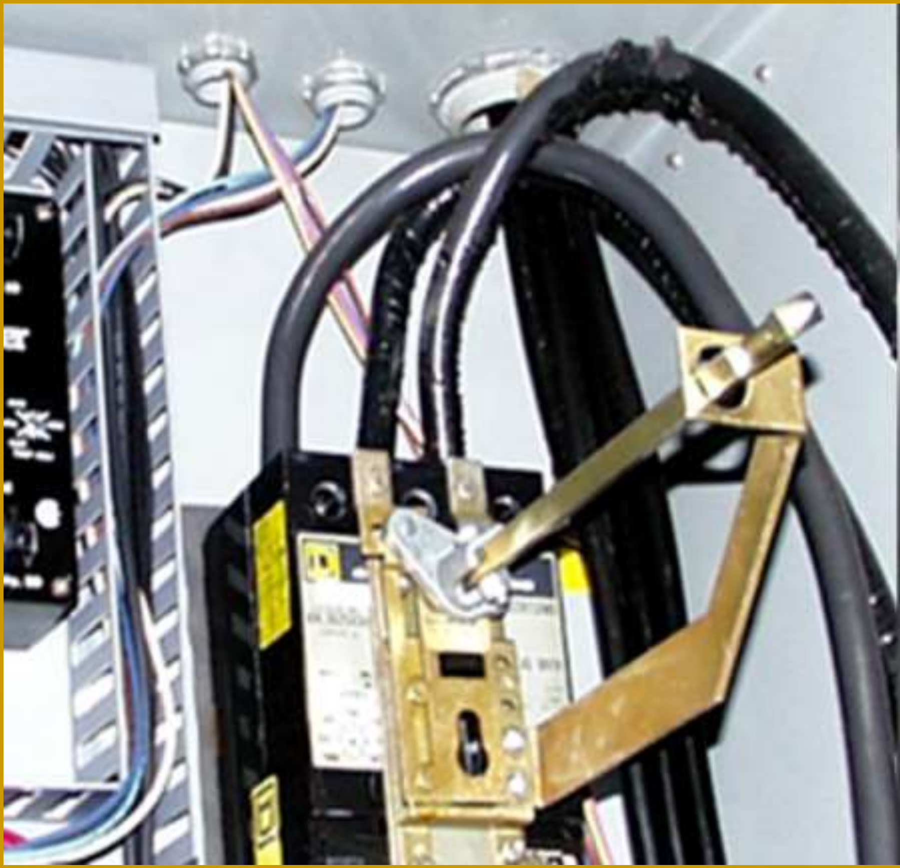
Breaker lug, phase A, line side.

Electrical Infrared



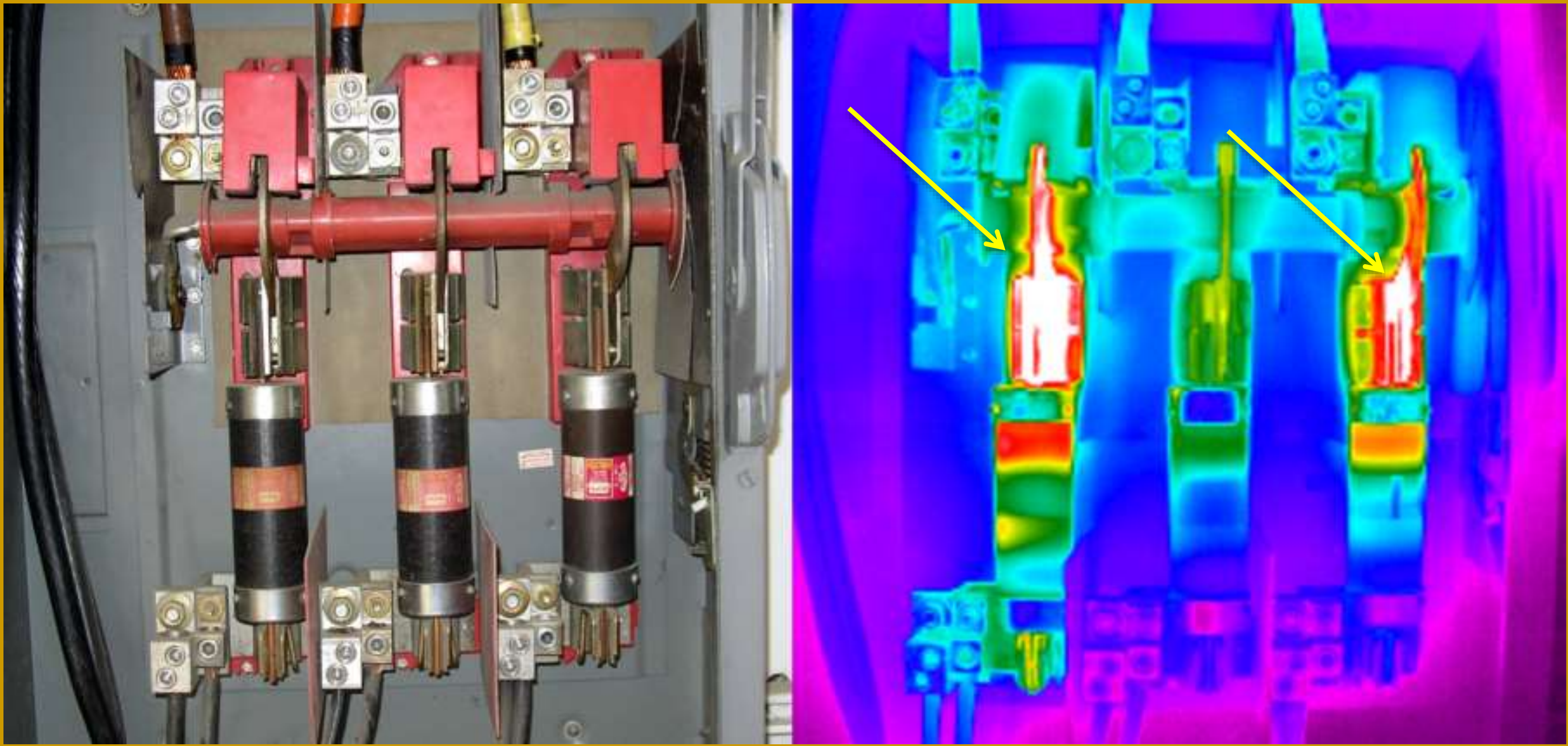
Main switch fuse knife connection and fuse, phase C, load side.

Electrical Infrared



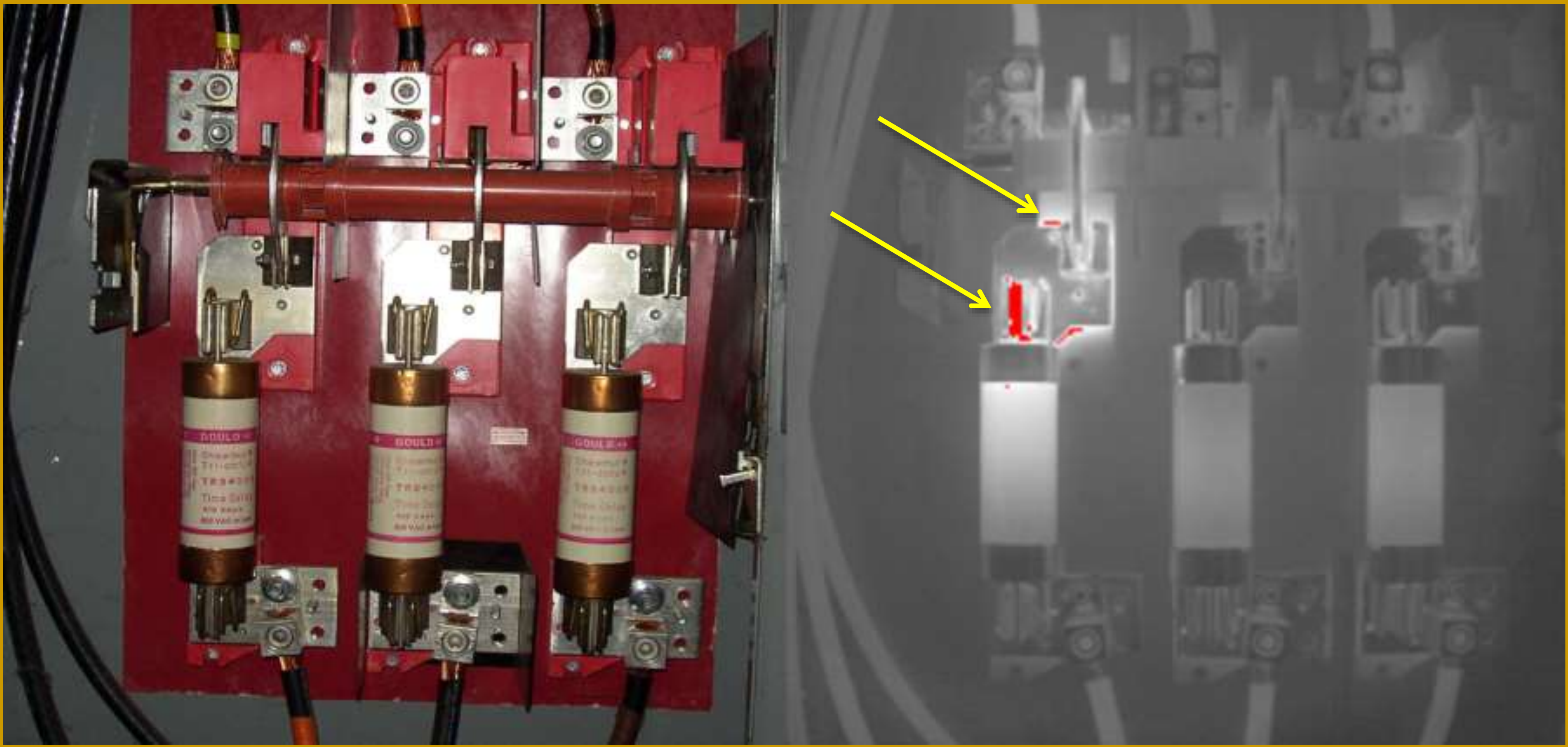
Breaker lug, phase B, line side.

Electrical Infrared



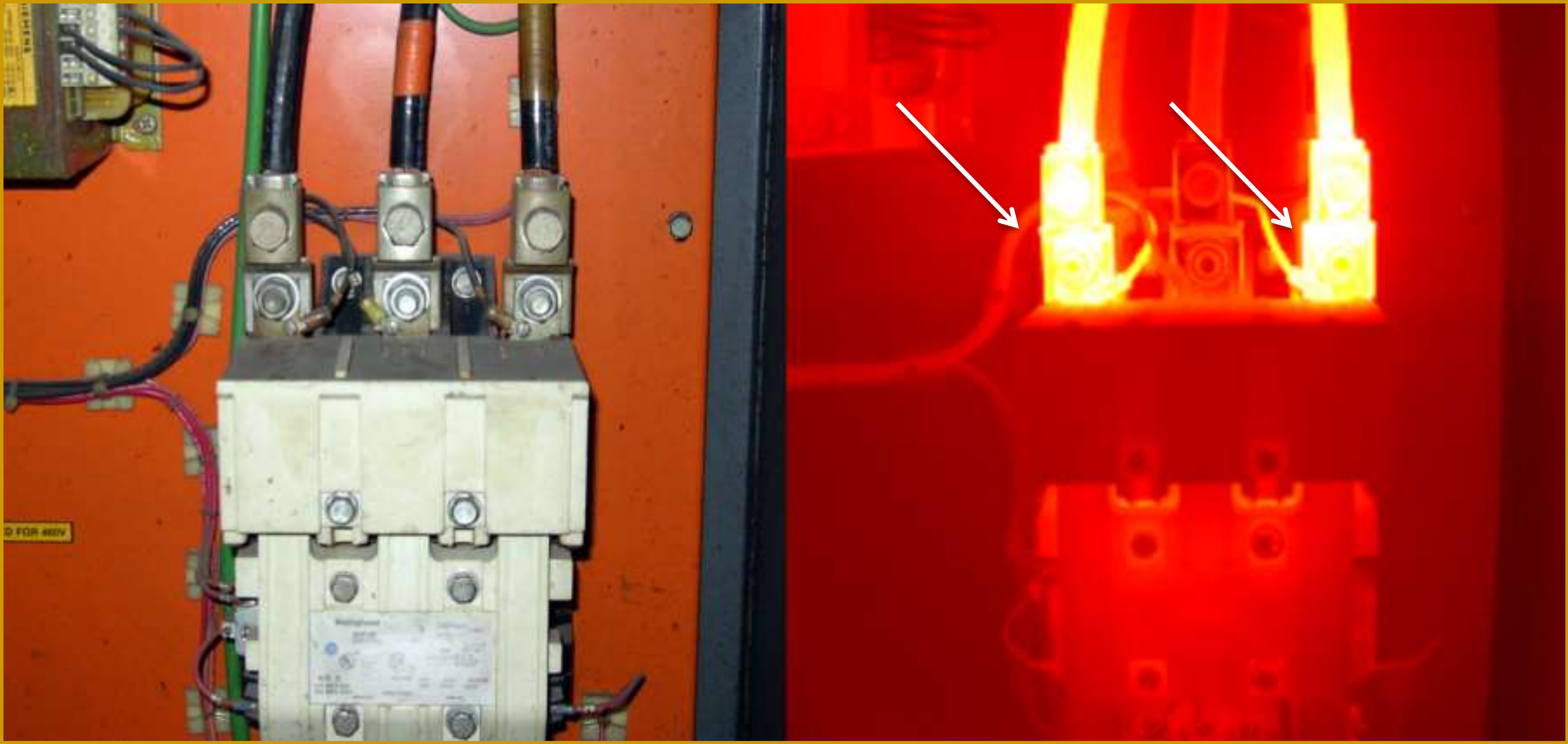
Main disconnect, switch and knives, phases A & C, line sides.

Electrical Infrared



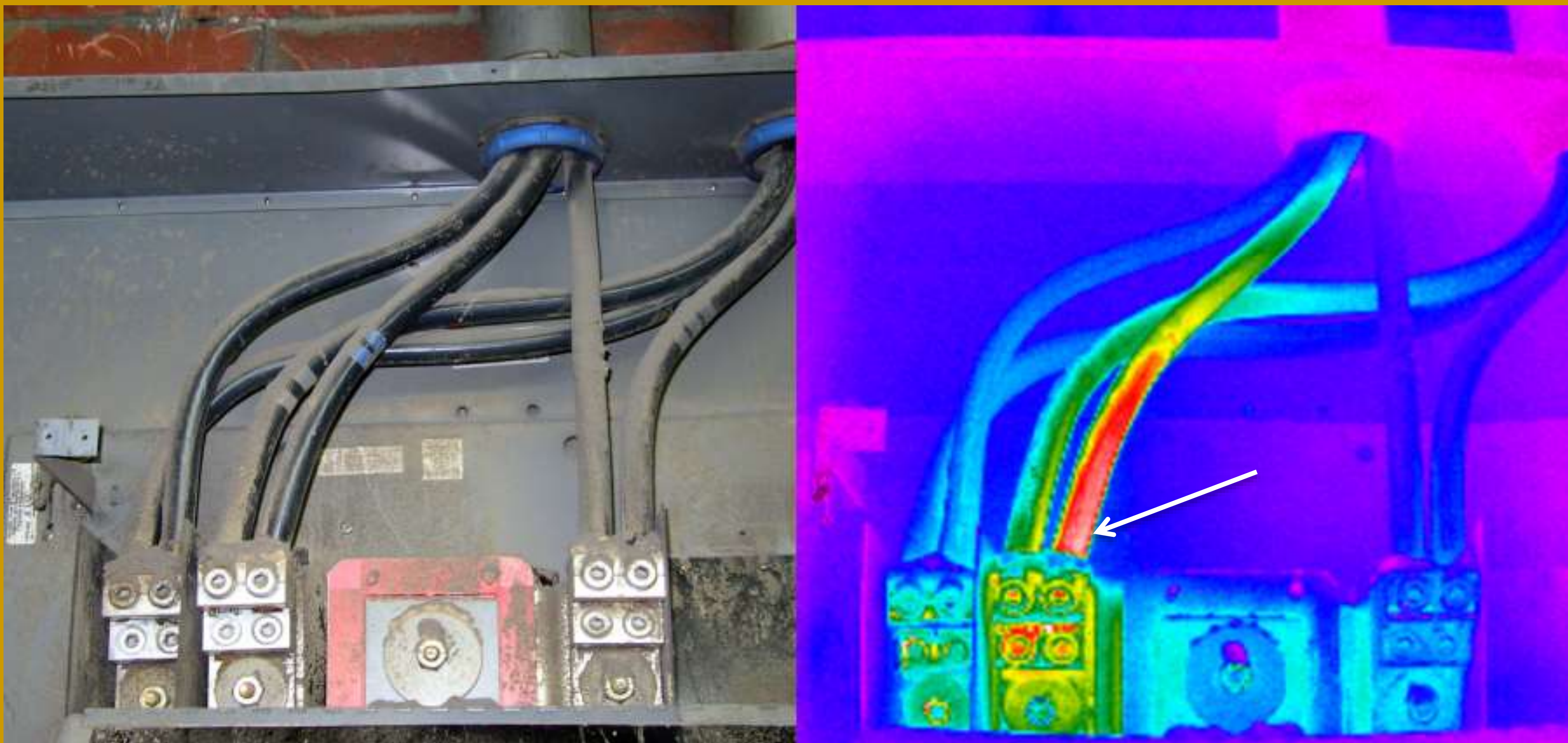
Main disconnect switch, fuse, and knife connection, phase A.

Electrical Infrared



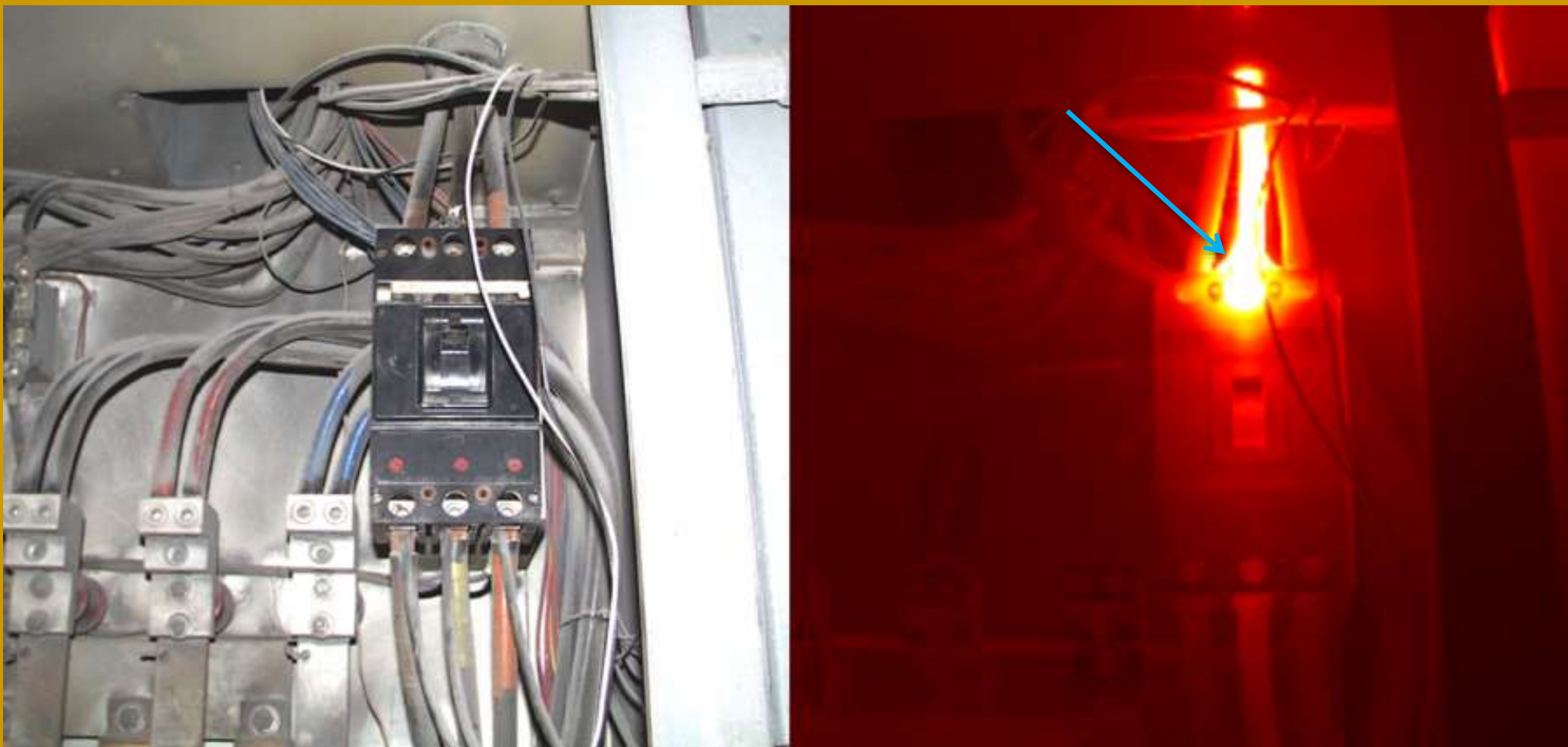
Contactor lugs and wires, phases A & C.

Electrical Infrared



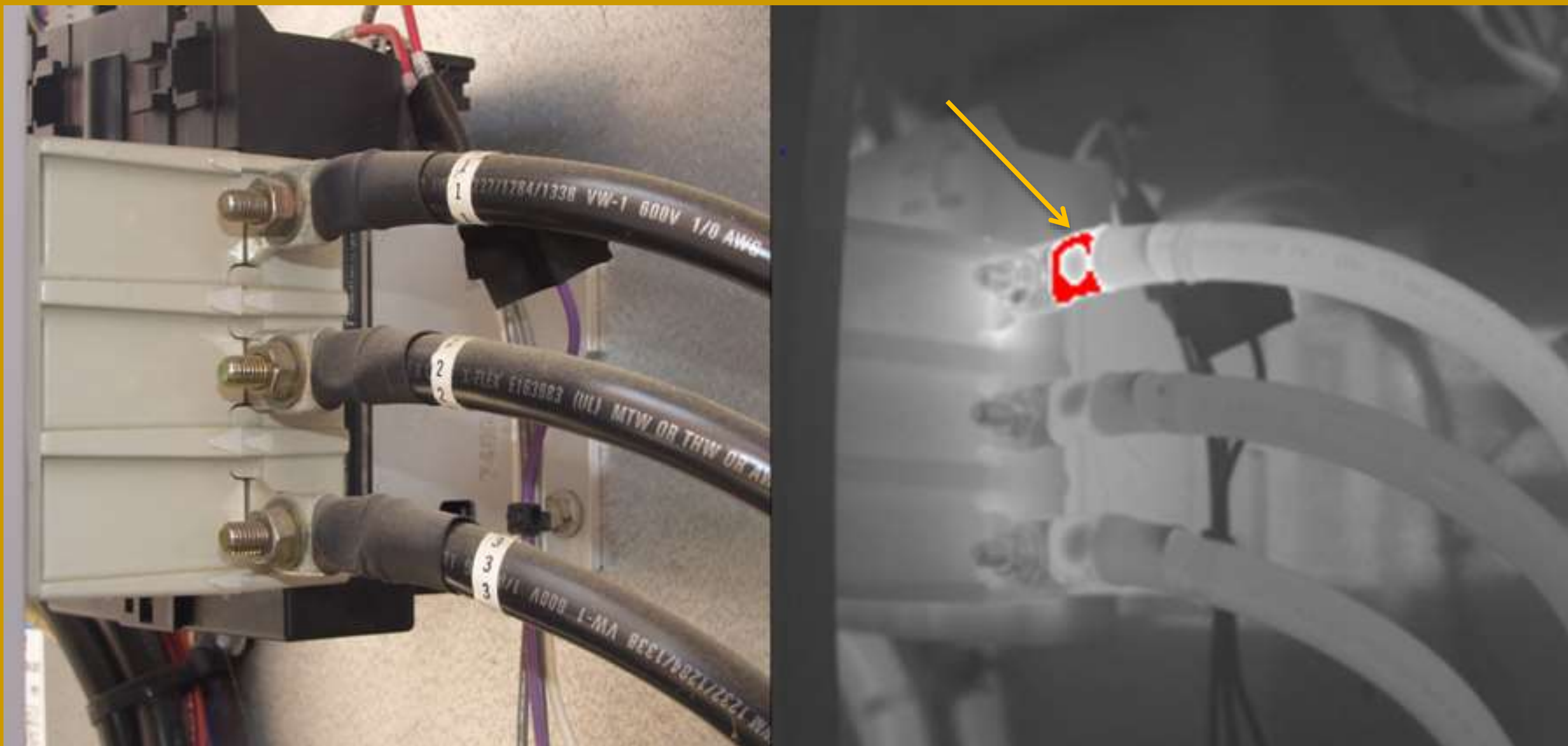
Main panel incoming feed, phase B, line side

Electrical Infrared



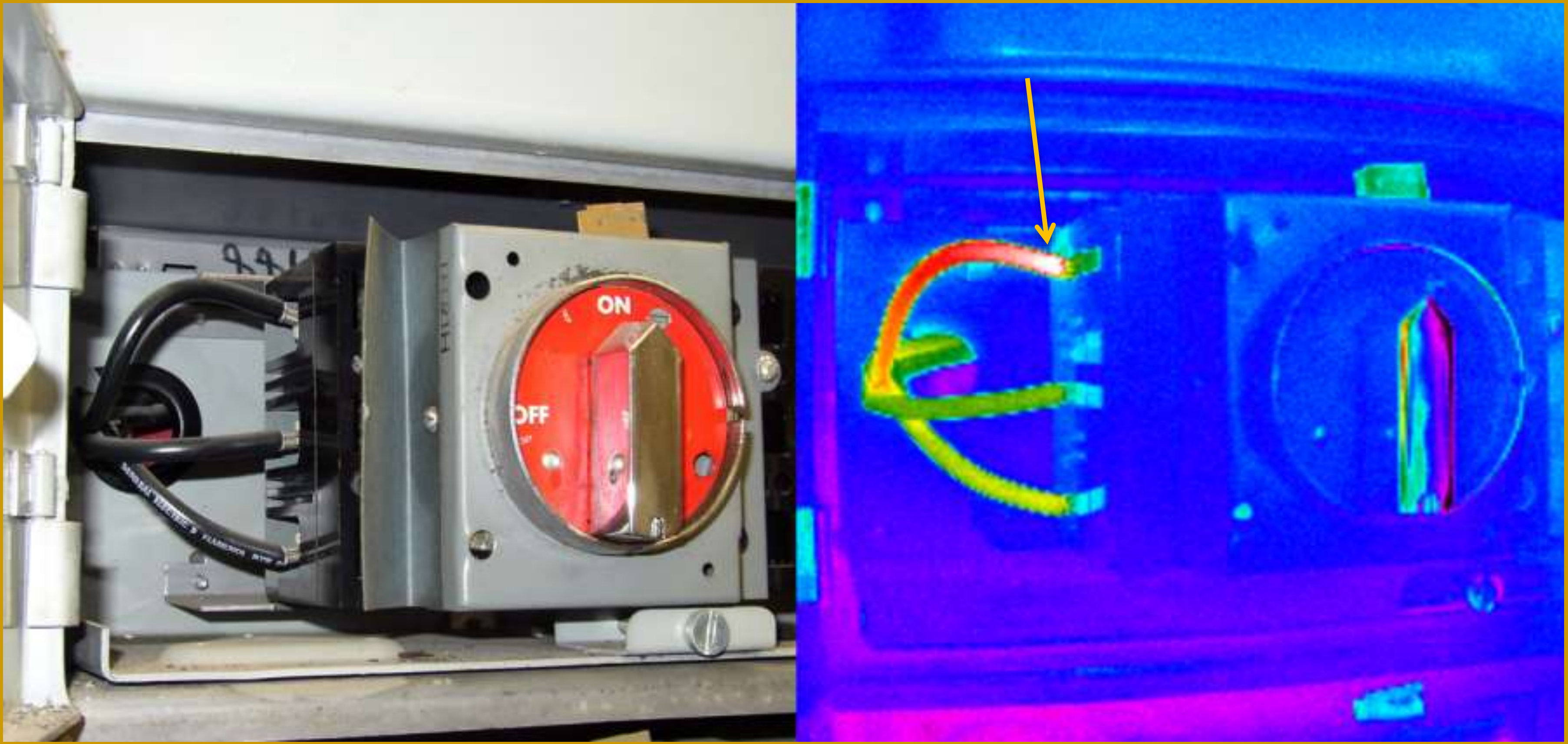
Breaker, lug and wire, phase B, line side.

Electrical Infrared



Contactor connector, phase A, load side. Note: not the lug.

Electrical Infrared

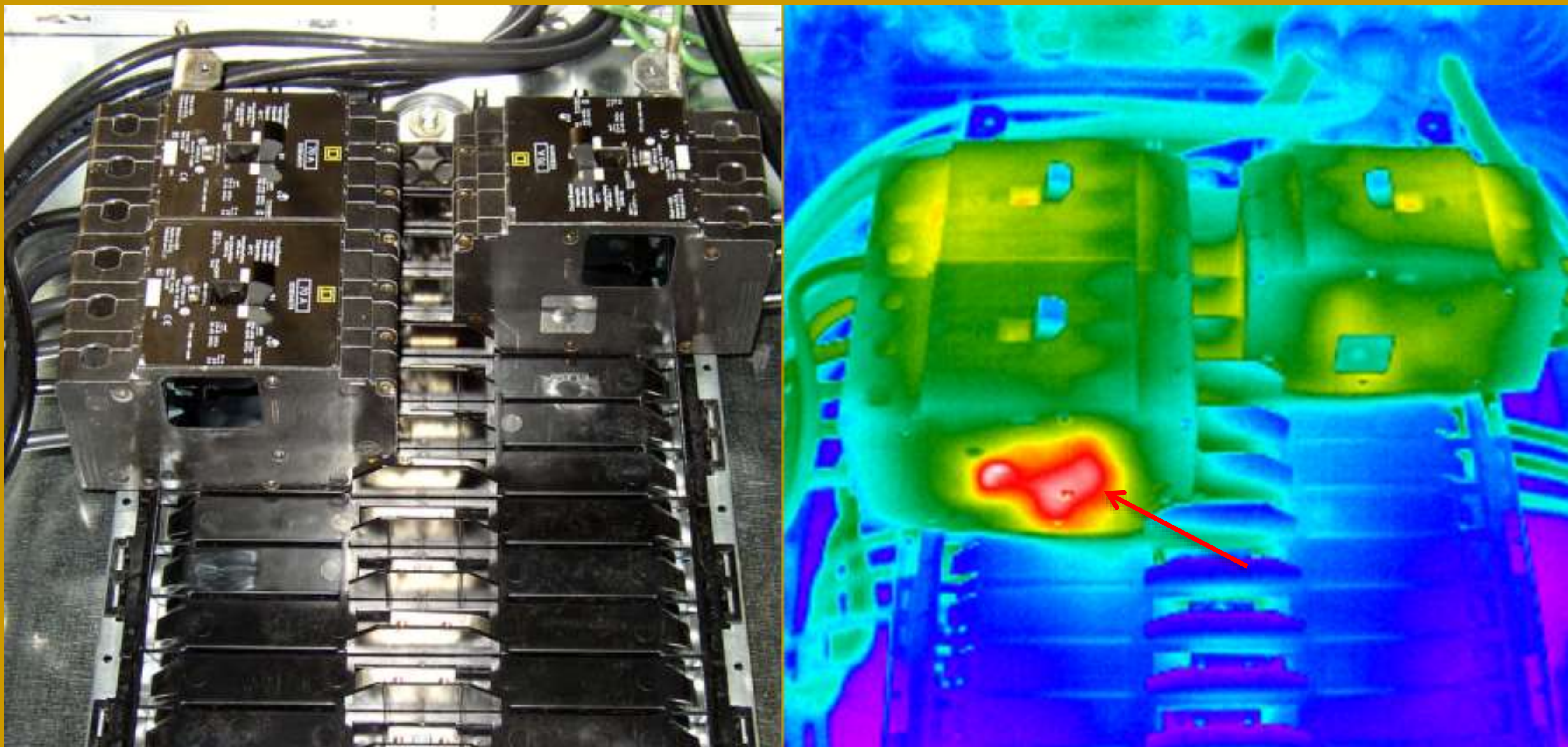


MCC cubicle, breaker lug, phase A, load side.

Electrical Infrared

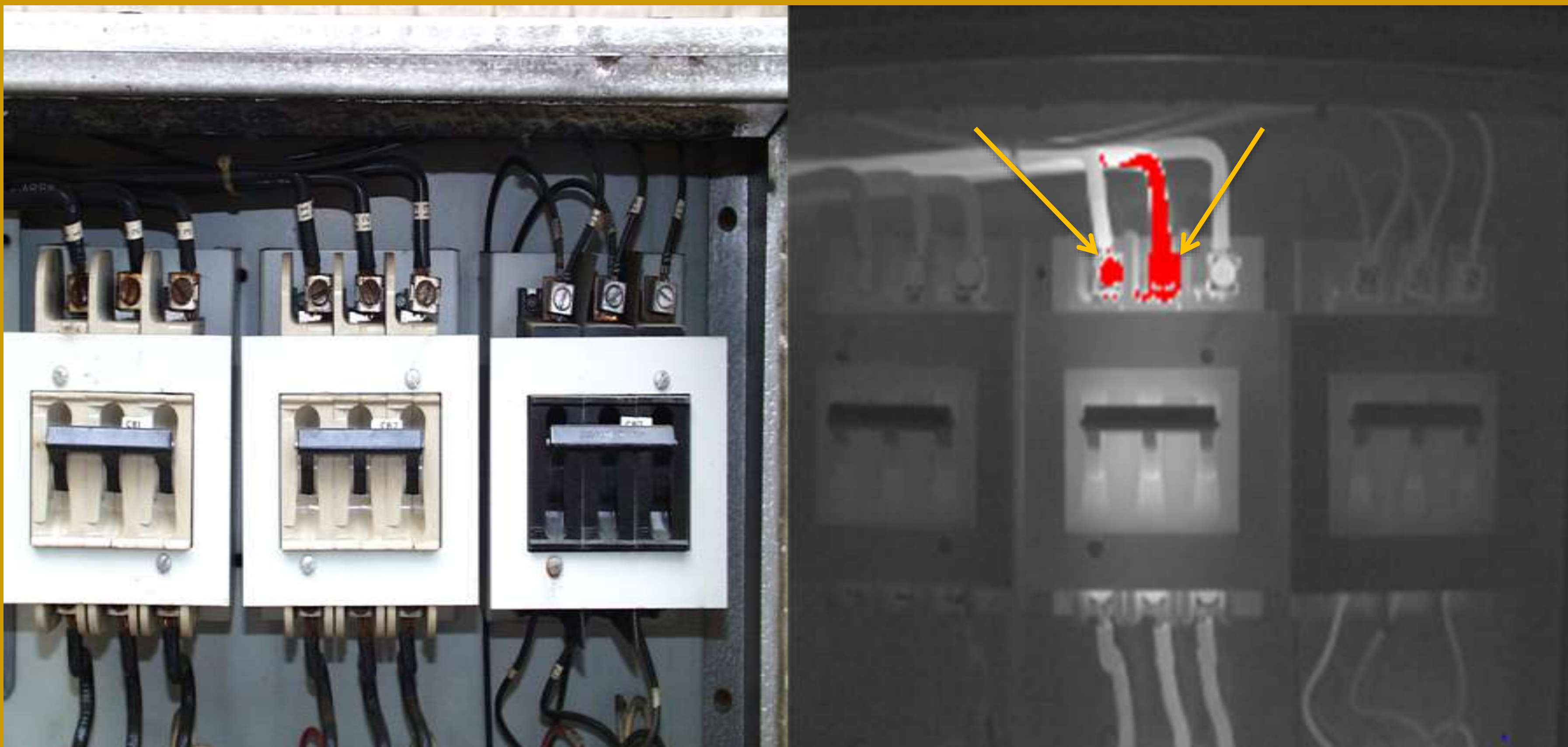
Combination starter panel main fuse, knife, phase A, line side.

Electrical Infrared



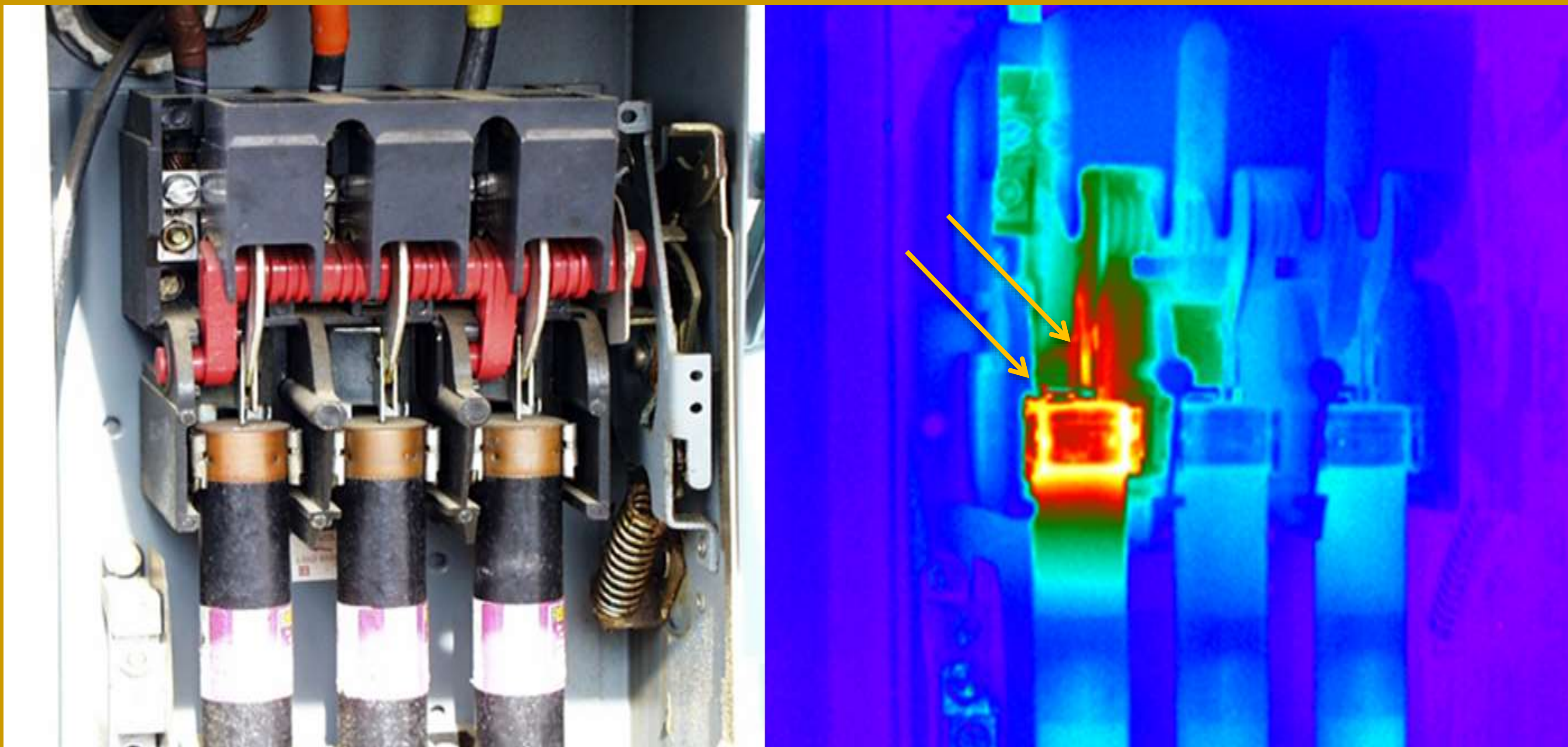
Breaker 21, breaker heating internally.

Electrical Infrared



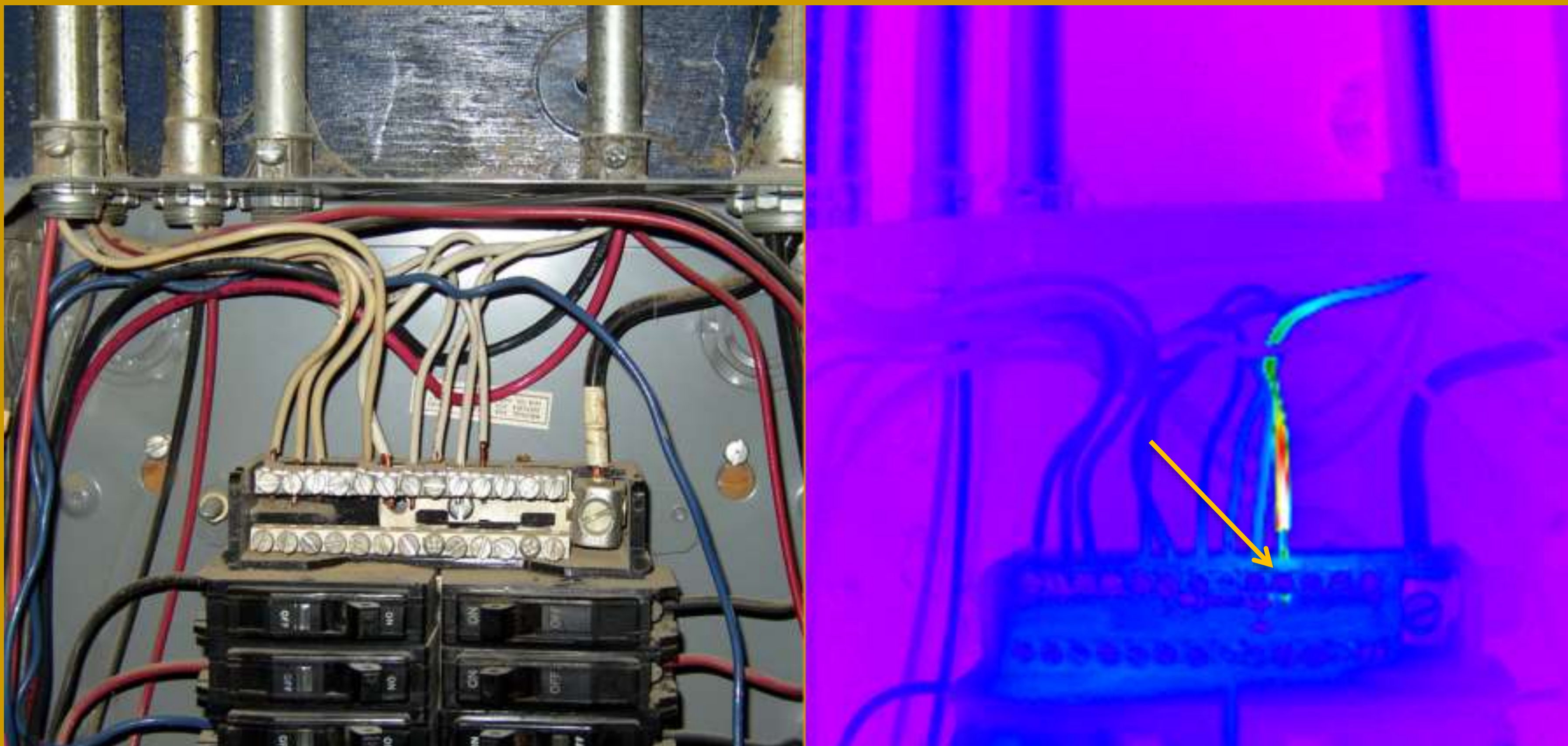
Center breaker, lug connections, phases A & B, line sides.

Electrical Infrared



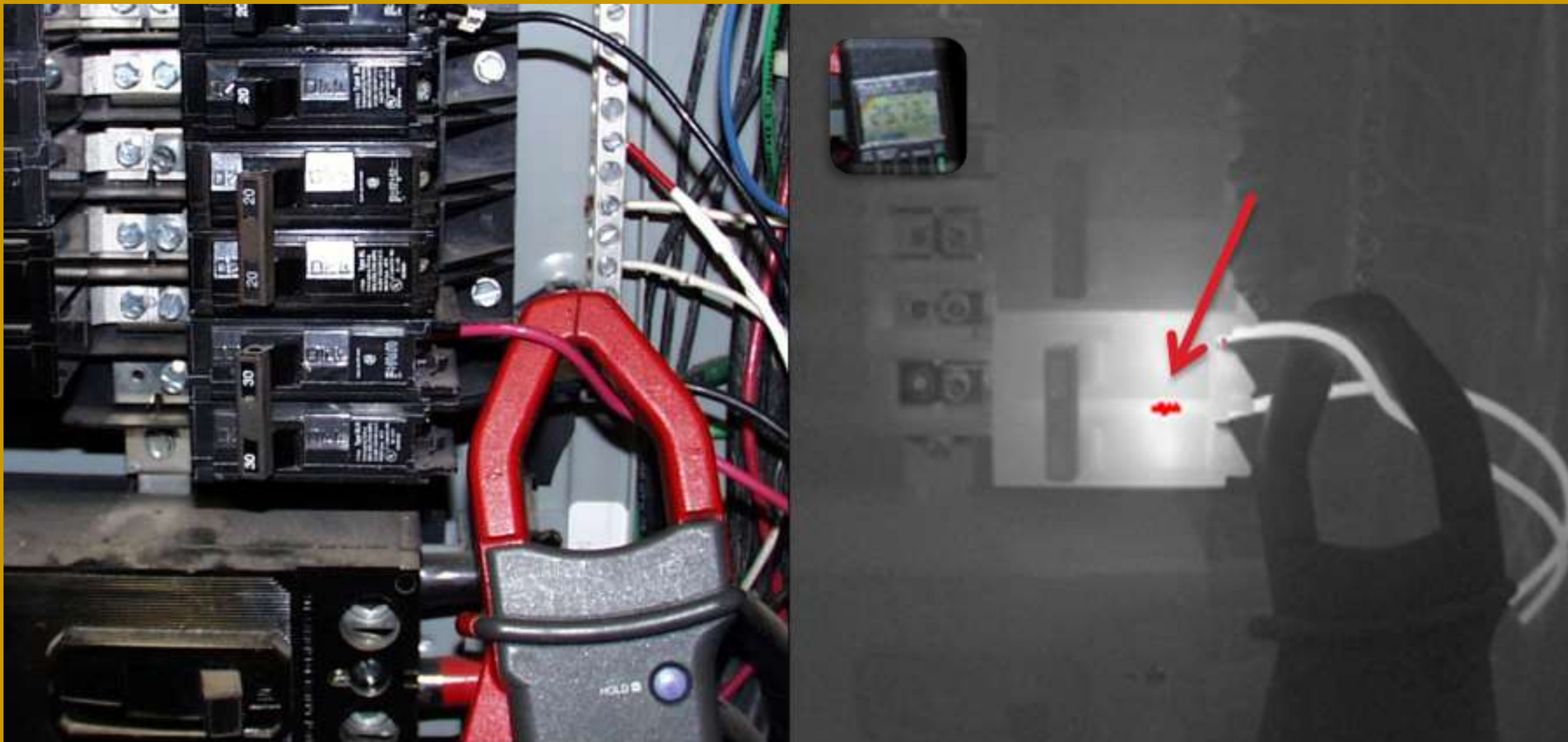
Disconnect fuse, fuse clip and switch knife, phase A.

Electrical Infrared



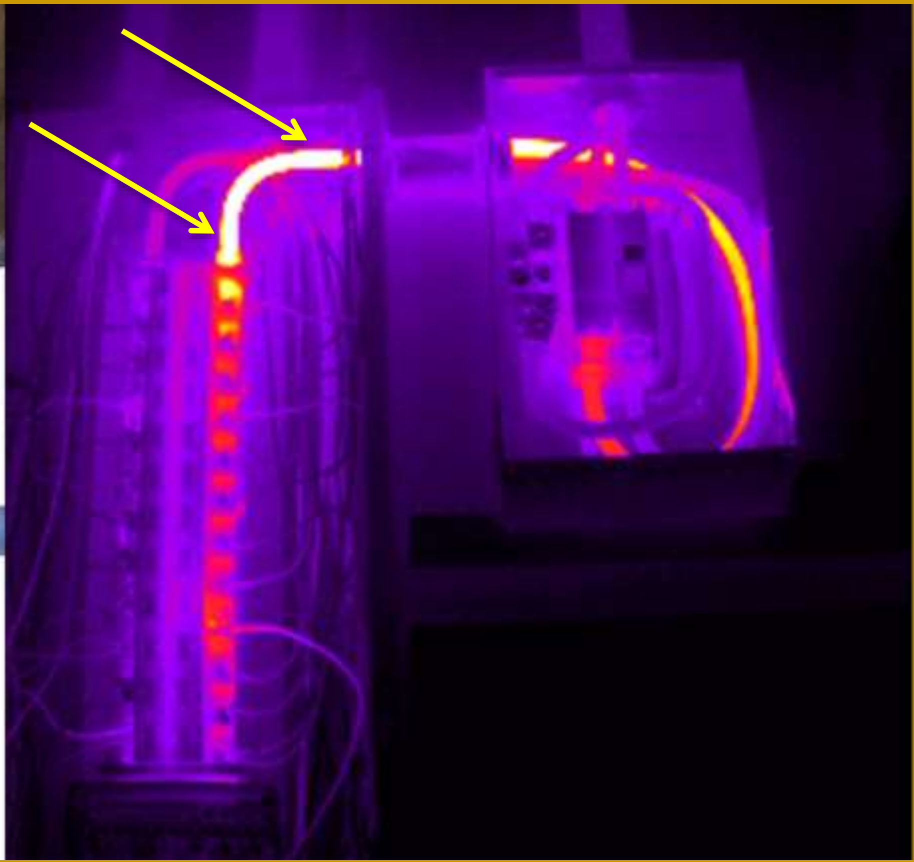
Panel neutral bar at circuit #16 connection.

Electrical Infrared



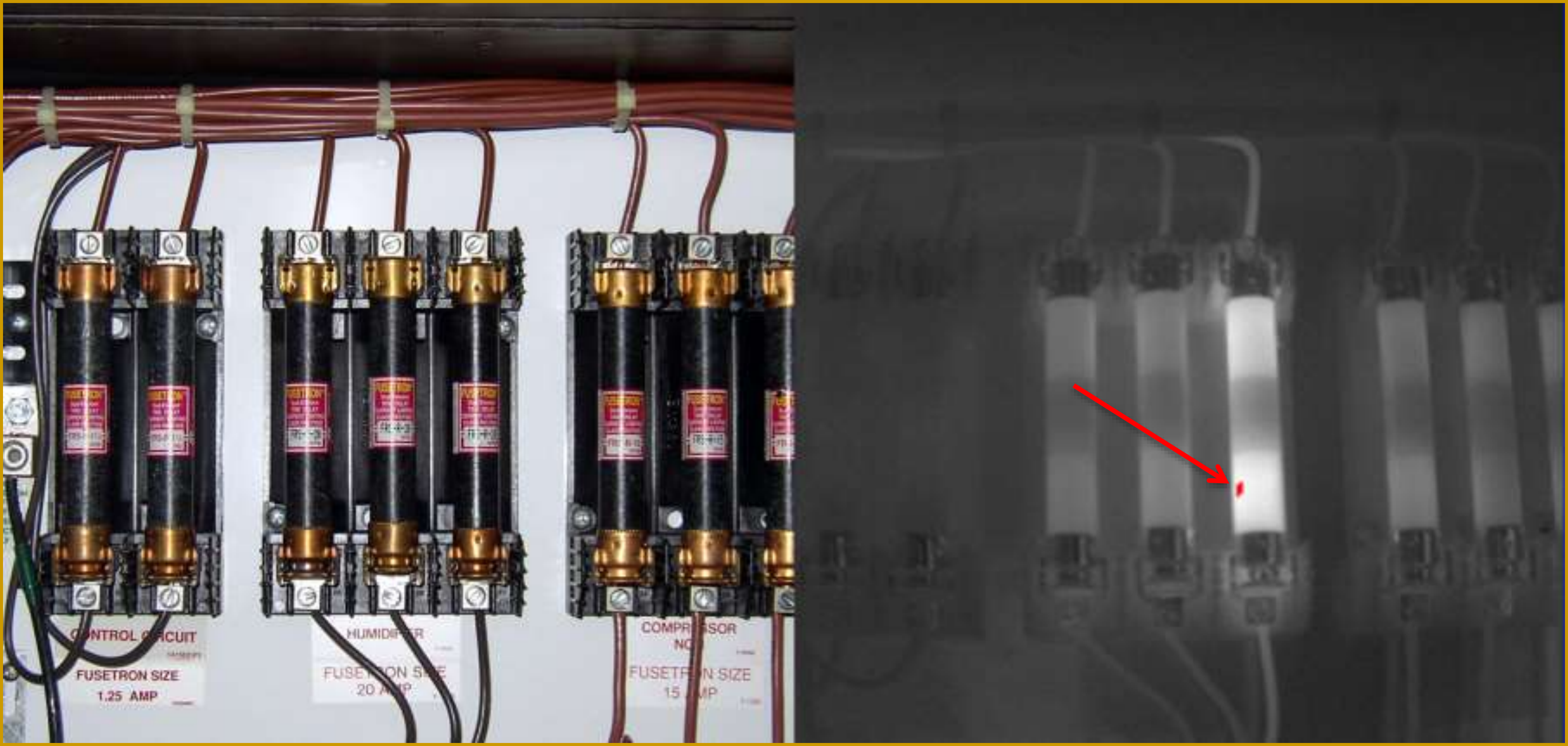
Breaker, circuit 22/24, internally heating due to 80%+ load.

Electrical Infrared



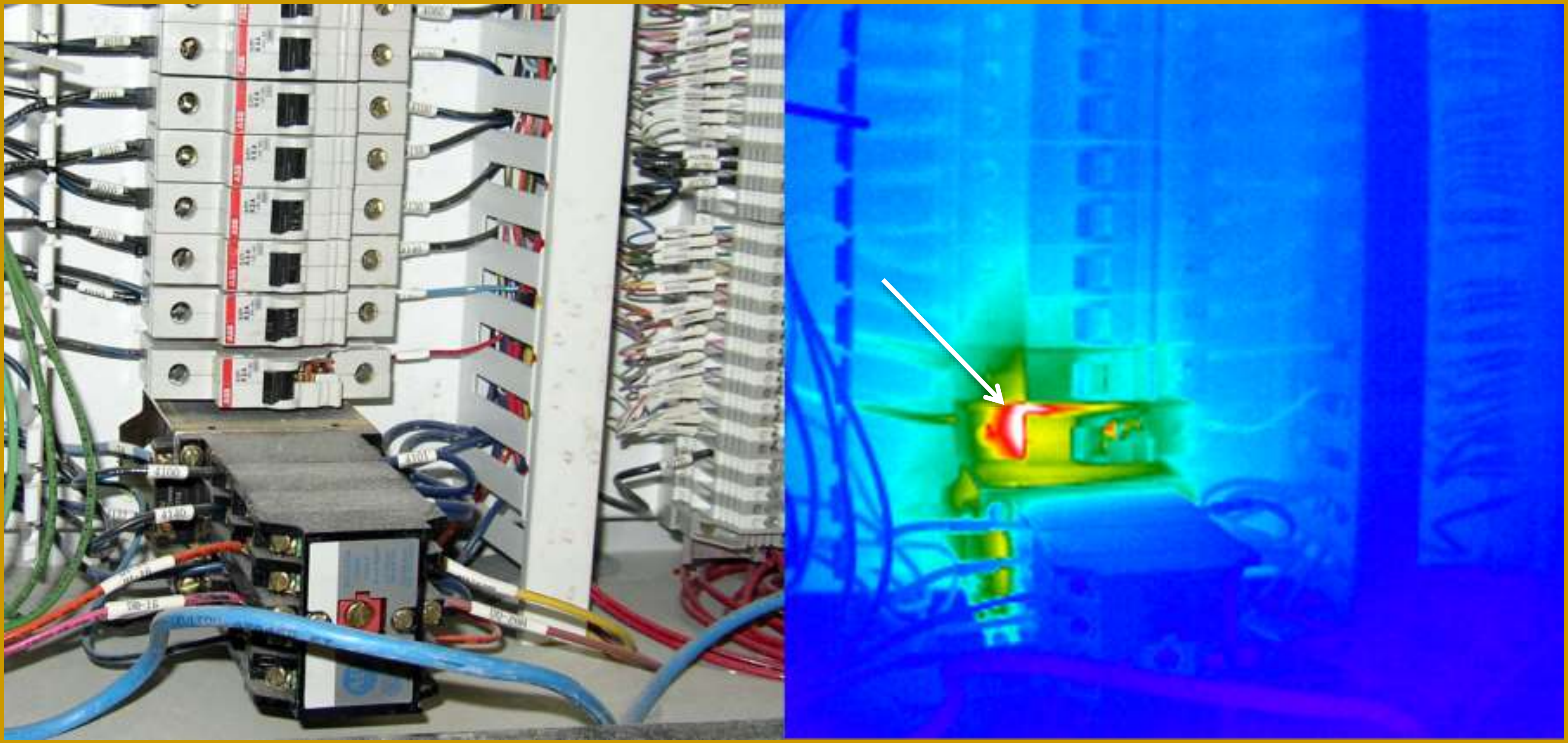
Panel main incoming feed lug and wire, phase right, line side.

Electrical Infrared



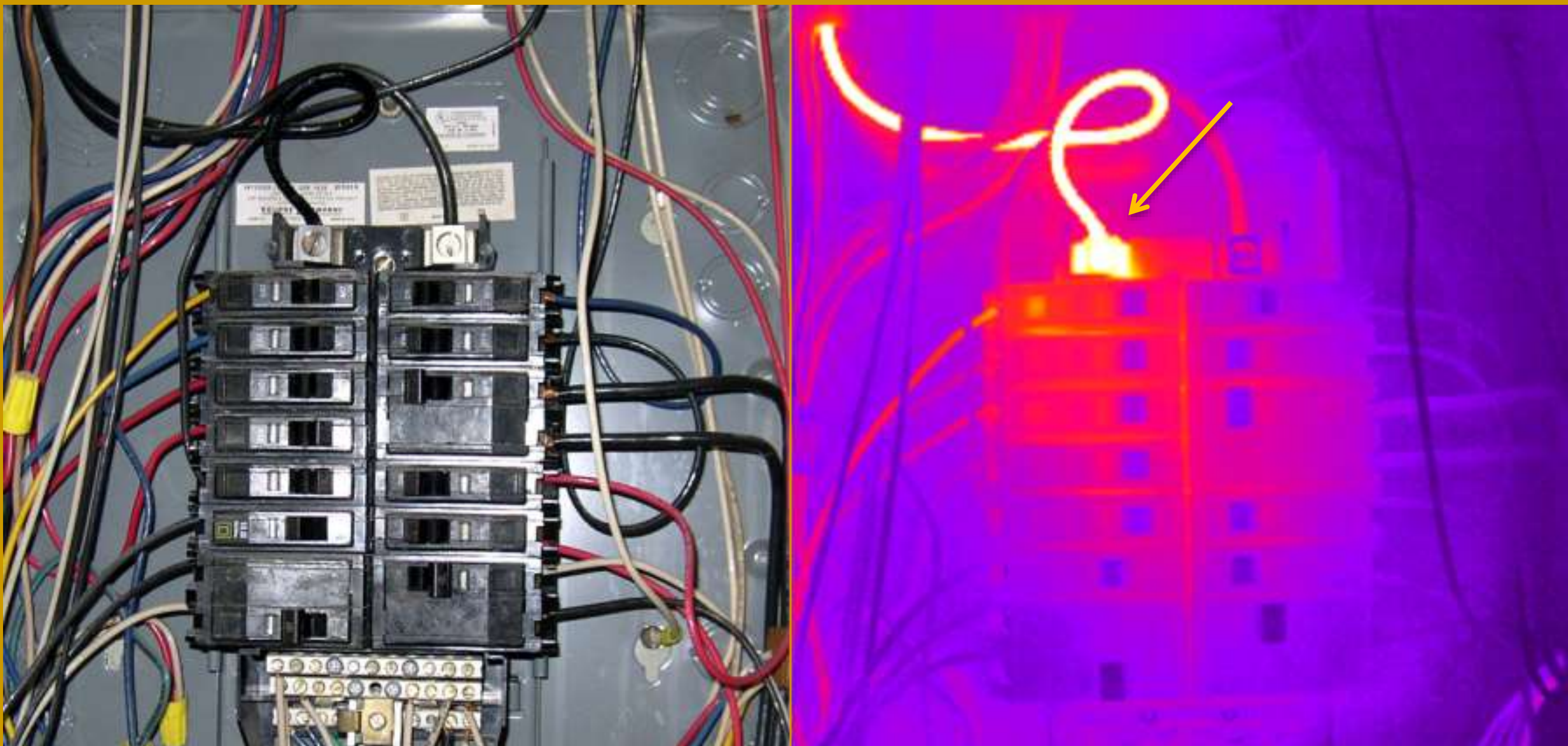
Control panel fuse block for humidifier, Phase C fuse damaged.

Electrical Infrared



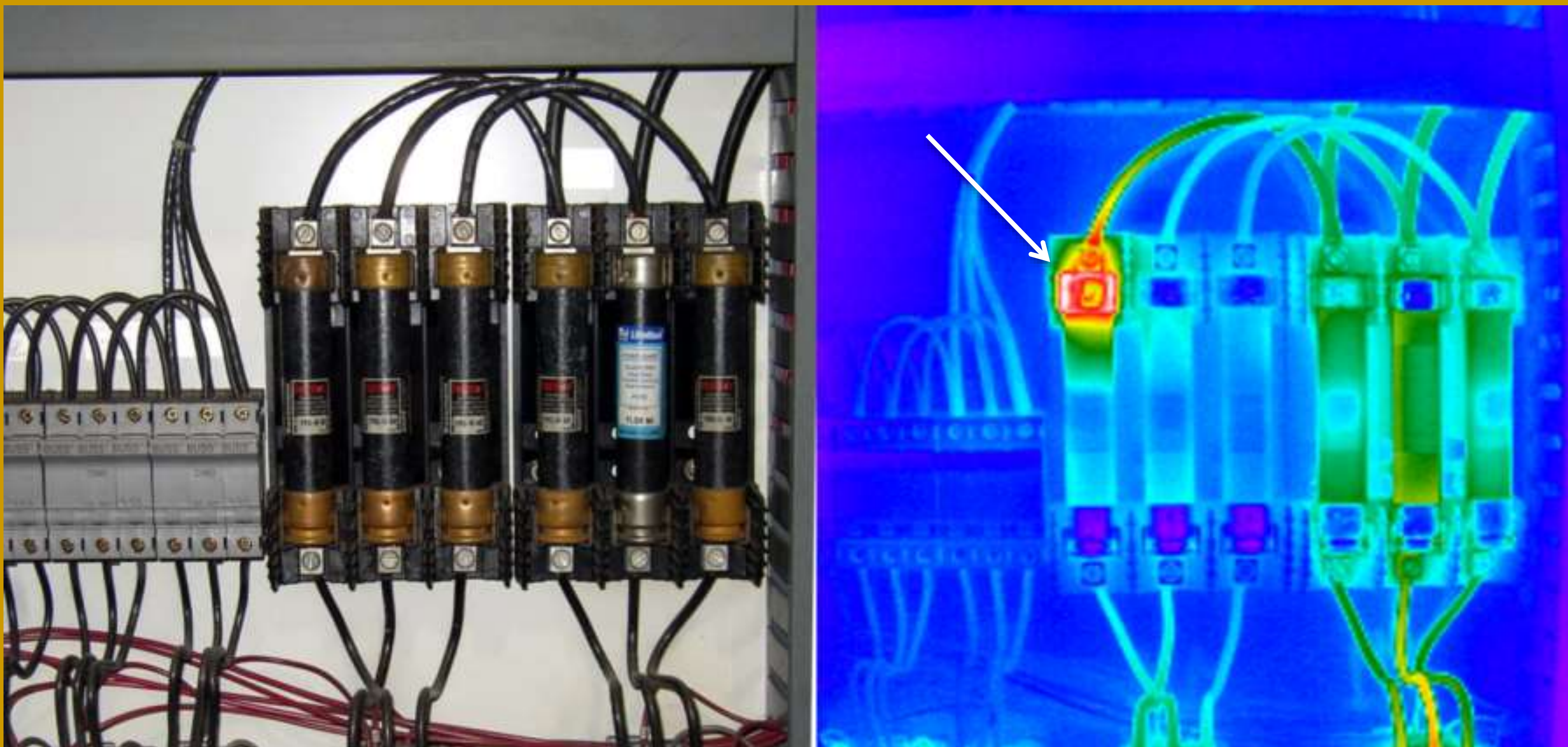
Breaker for circuit 4150 physically damaged with exposed parts.

Electrical Infrared



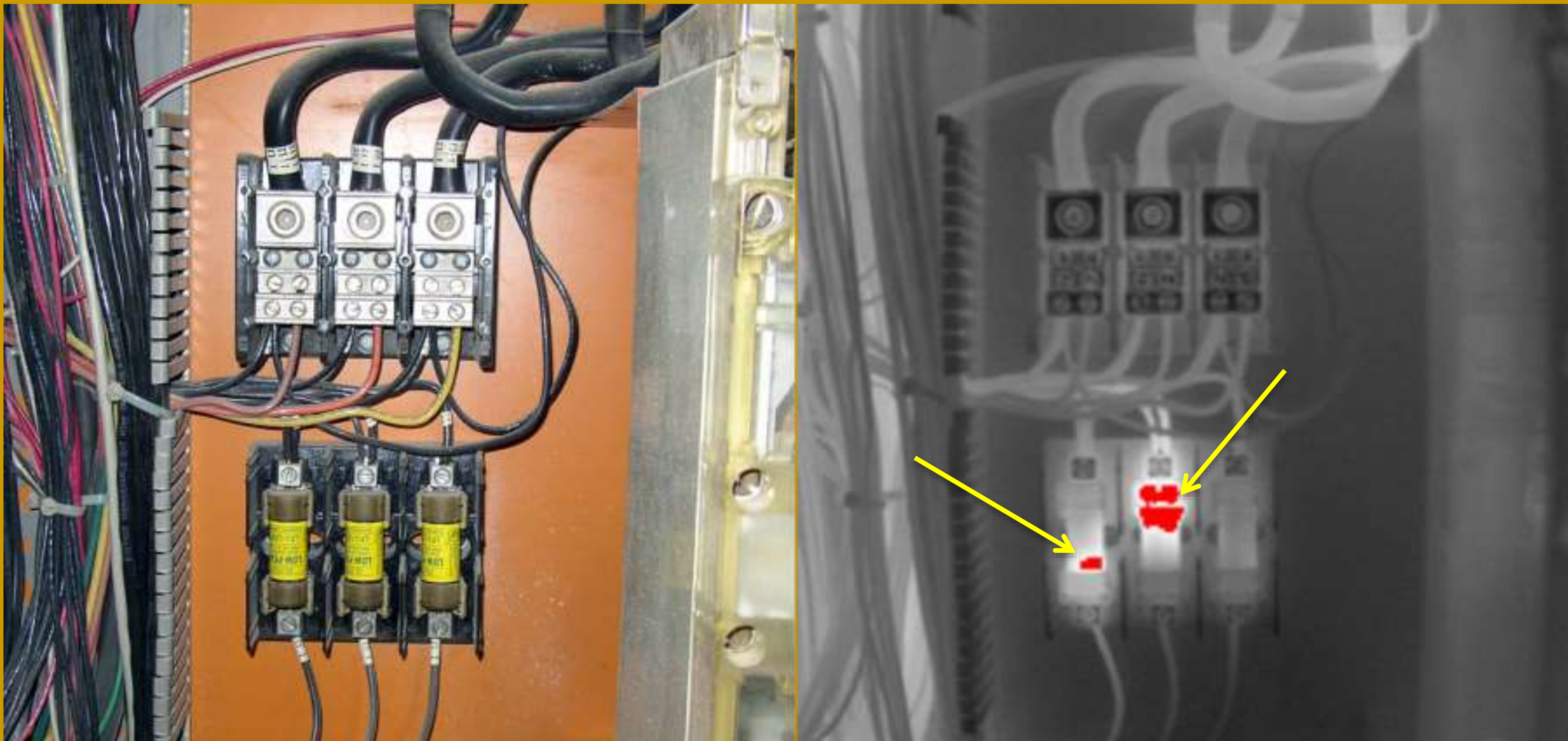
Panel main incoming lug and wire, phase left, line side.

Electrical Infrared



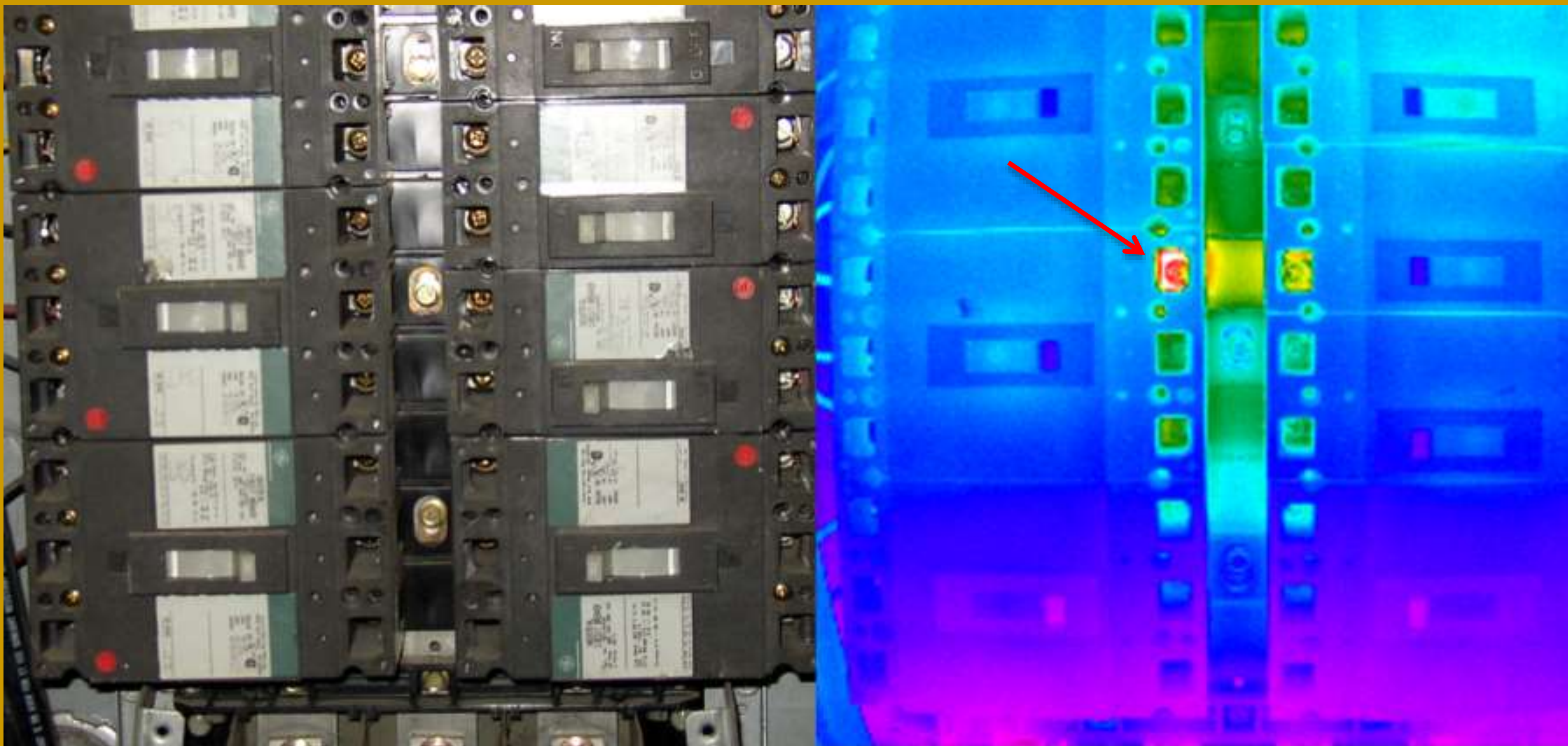
Panel fuse block for 6J, fuse clip, phase A, line side.

Electrical Infrared



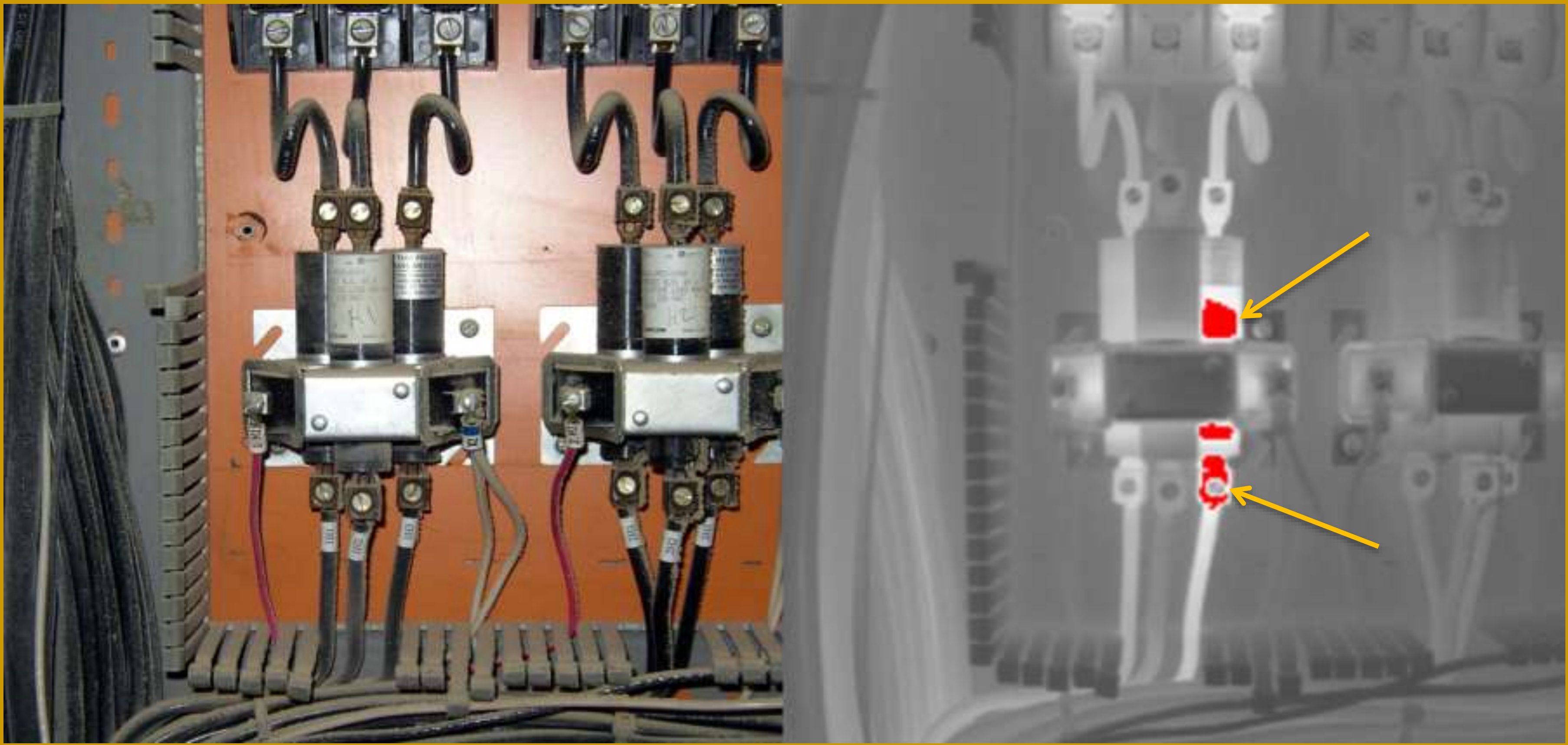
Control panel main fuses, lug & fuse on phase B / fuse on phase A.

Electrical Infrared



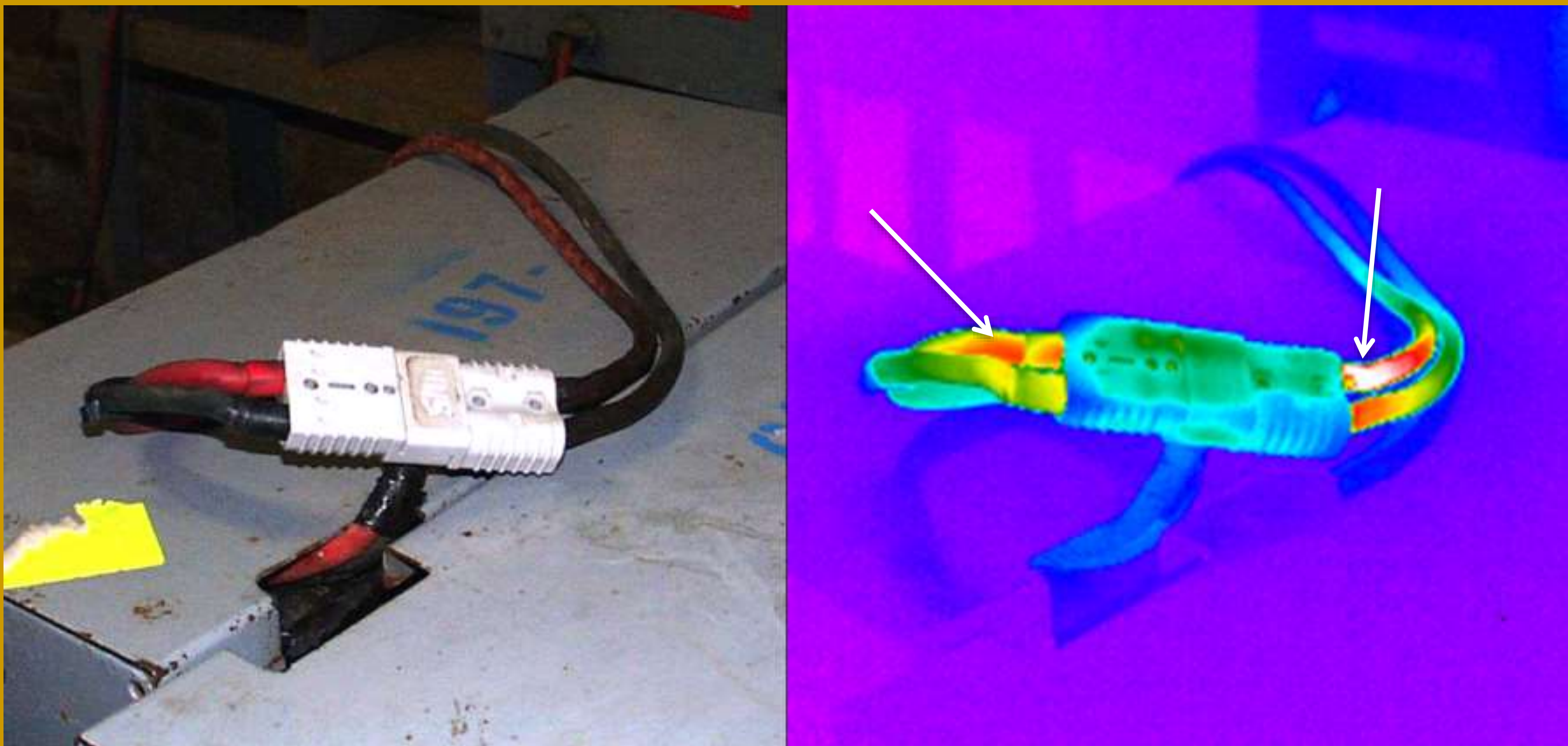
Panel breaker #5, line side connection to main bus, phase A.

Electrical Infrared



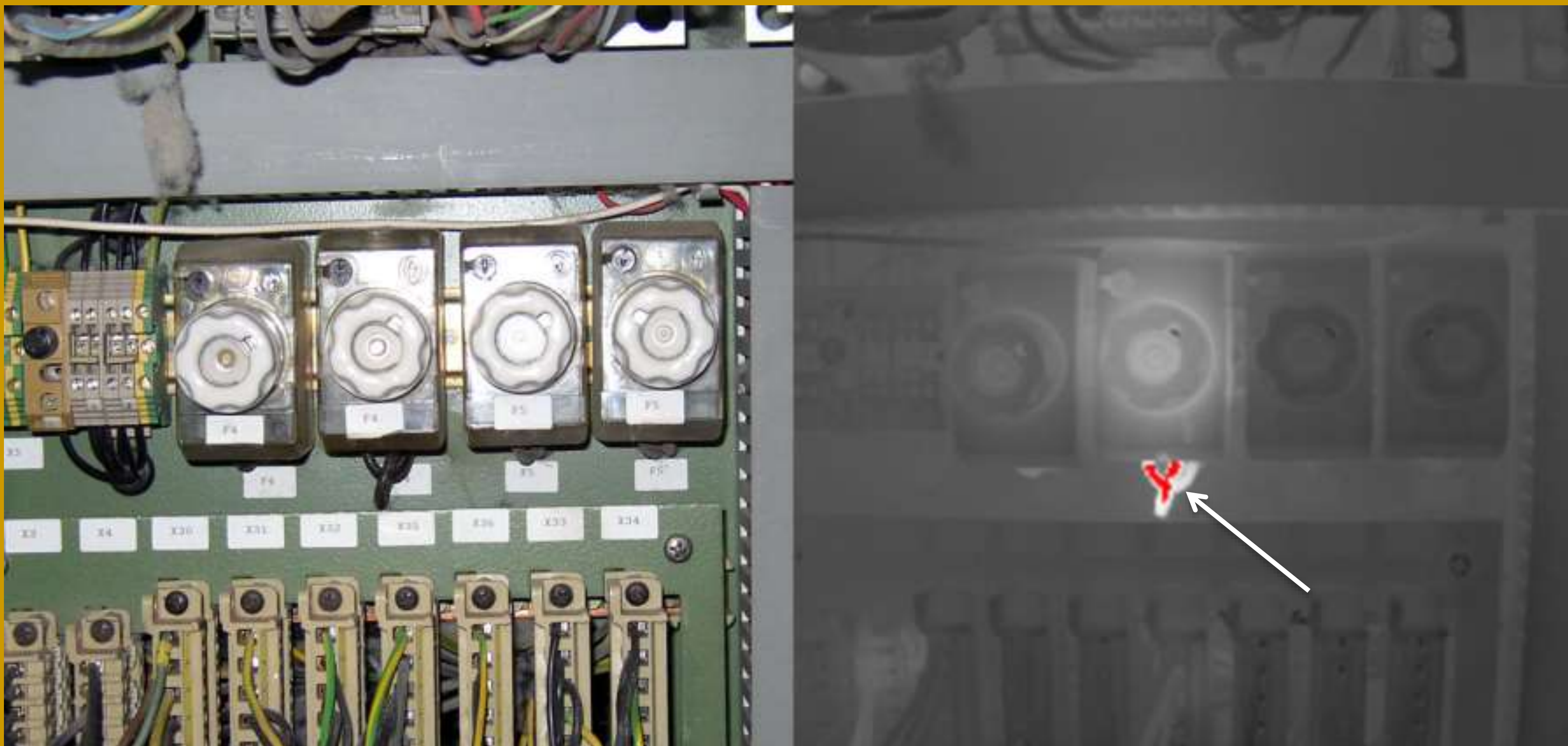
Control panel mercury switch #8, switch and lug, phase C.

Electrical Infrared



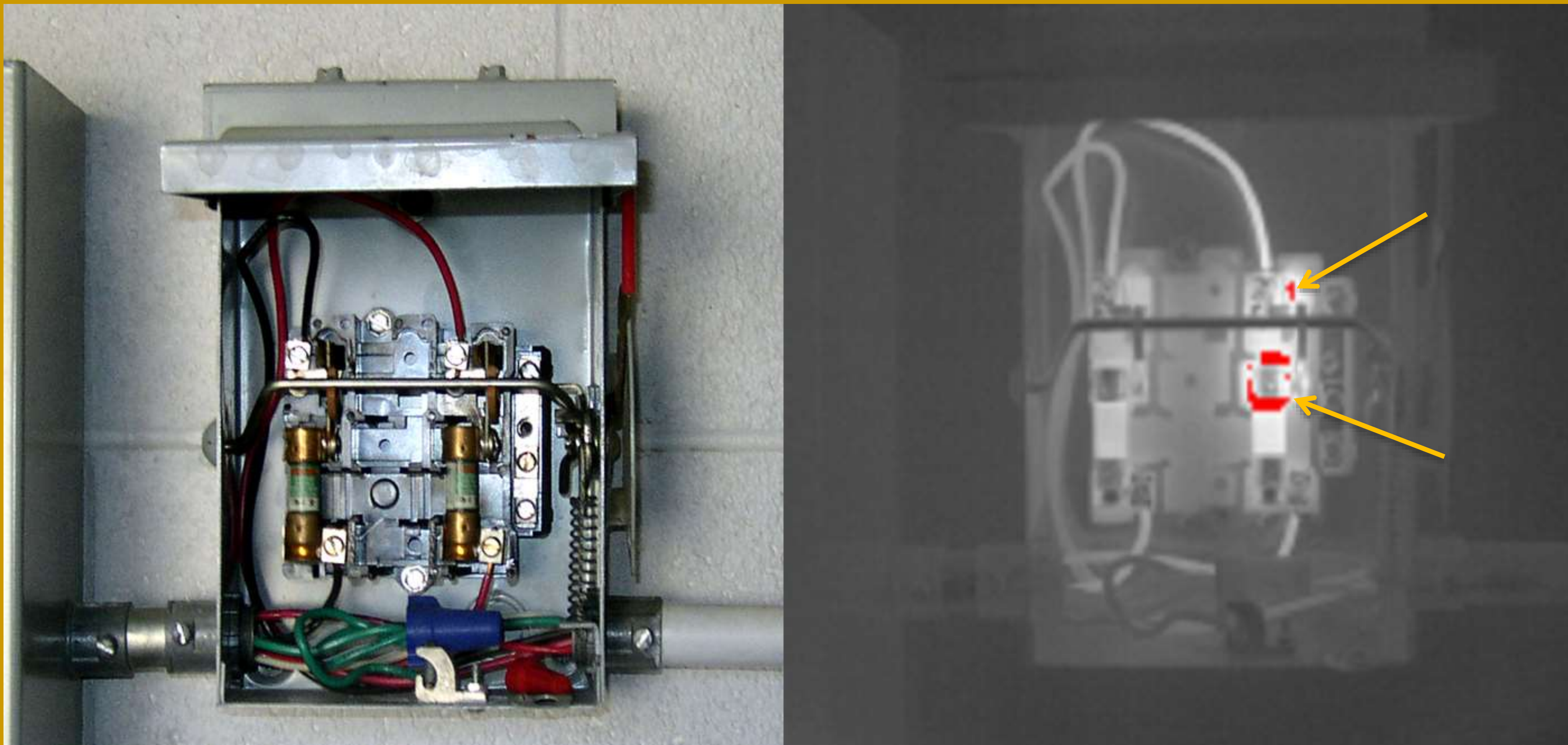
Battery charger at battery #22, connector heating as indicated.

Electrical Infrared



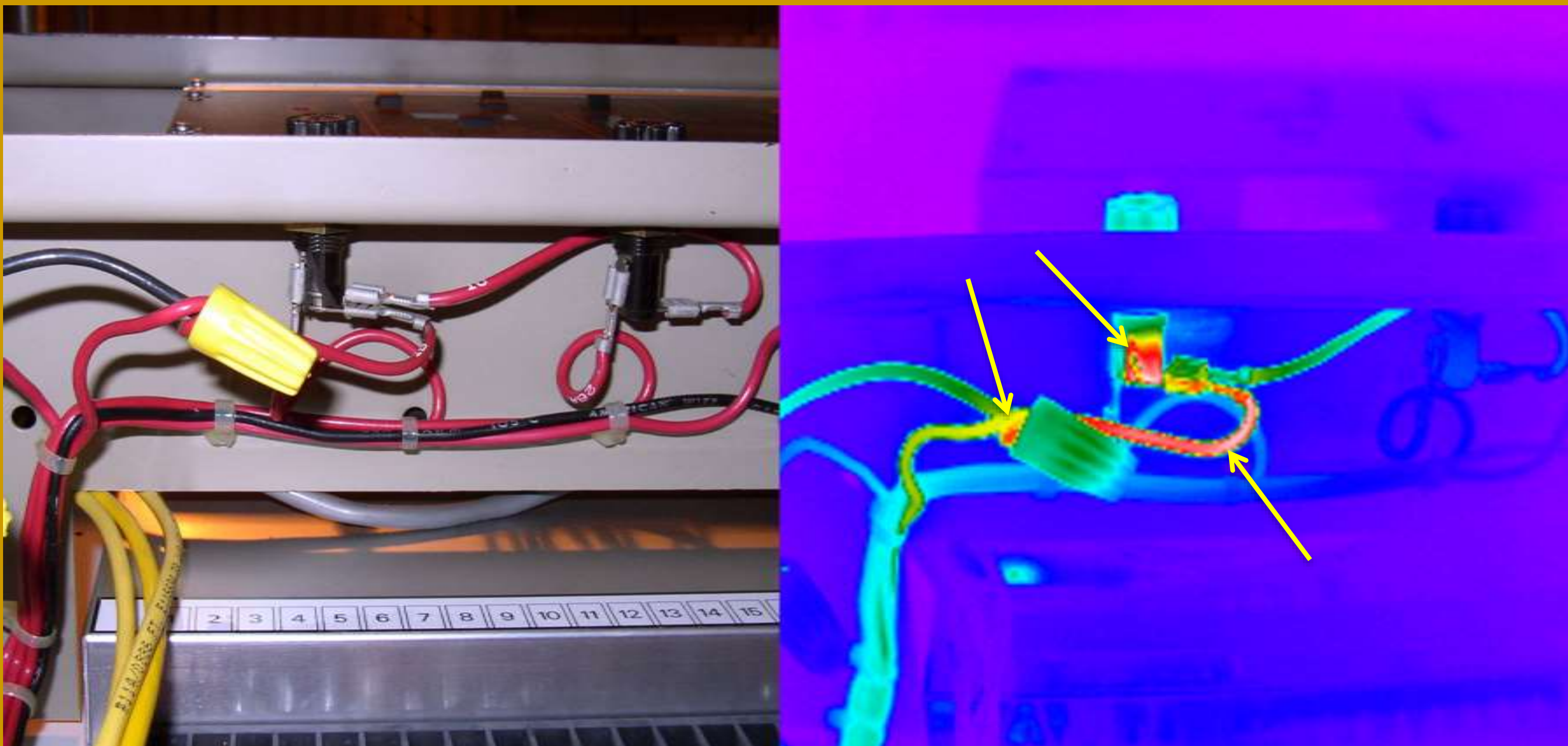
Control panel, main fuses, circuit F4, lug connections, load side.

Electrical Infrared



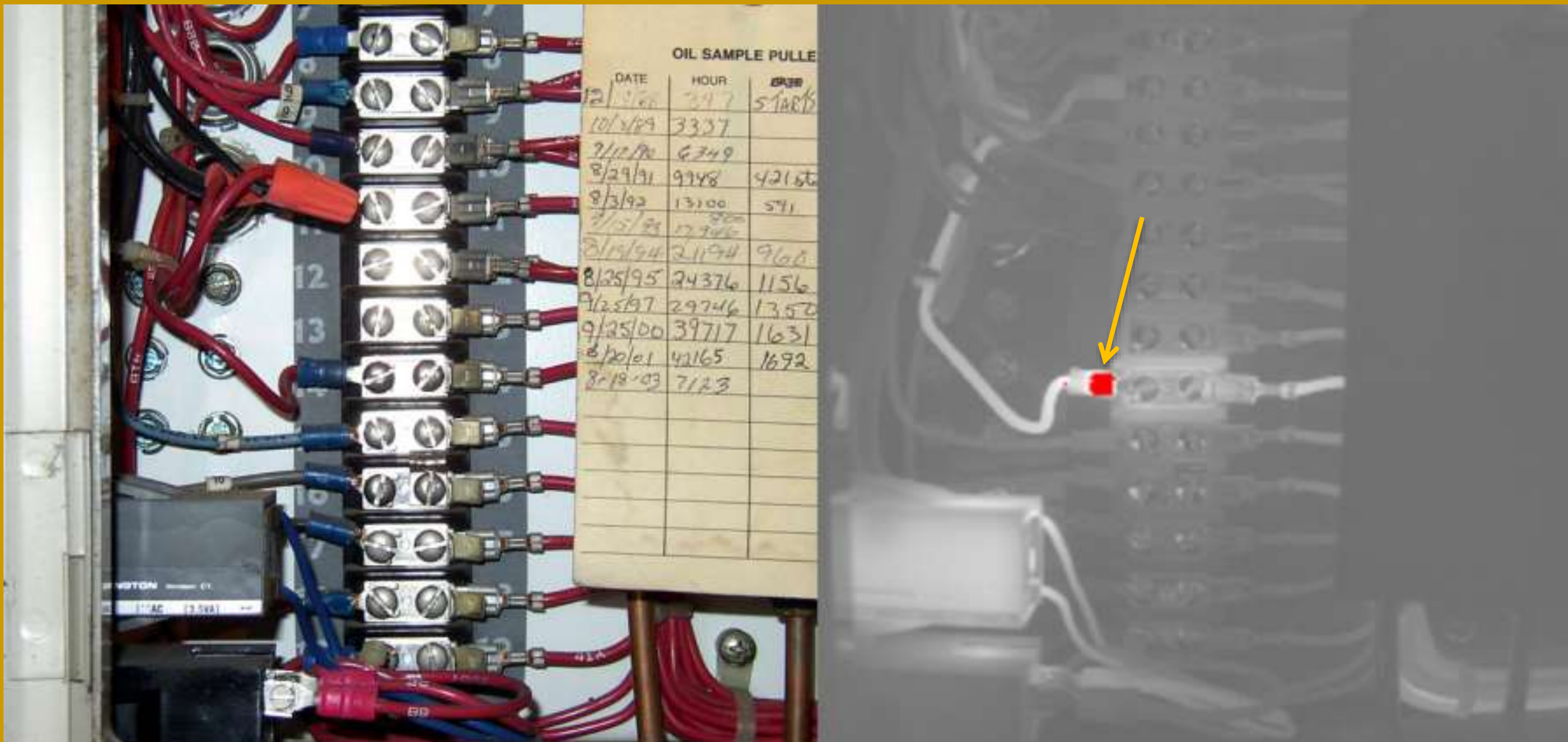
Disconnect, main incoming lug and fuse clip, phase right.

Electrical Infrared



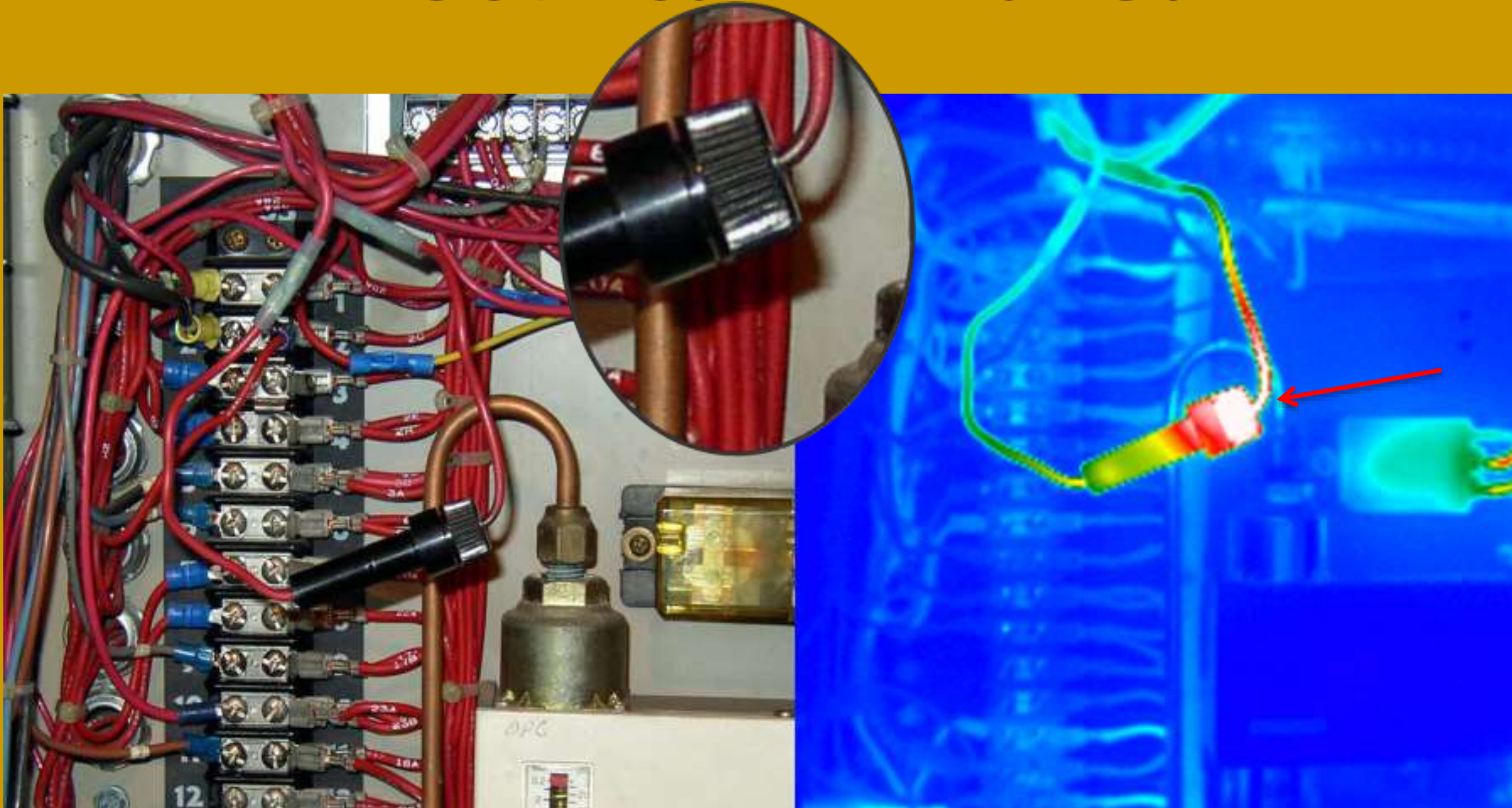
Control panel connectors, wire, and wire nut as indicated.

Electrical Infrared



Control panel, circuit 14, sta-con connector, load side.

Electrical Infrared

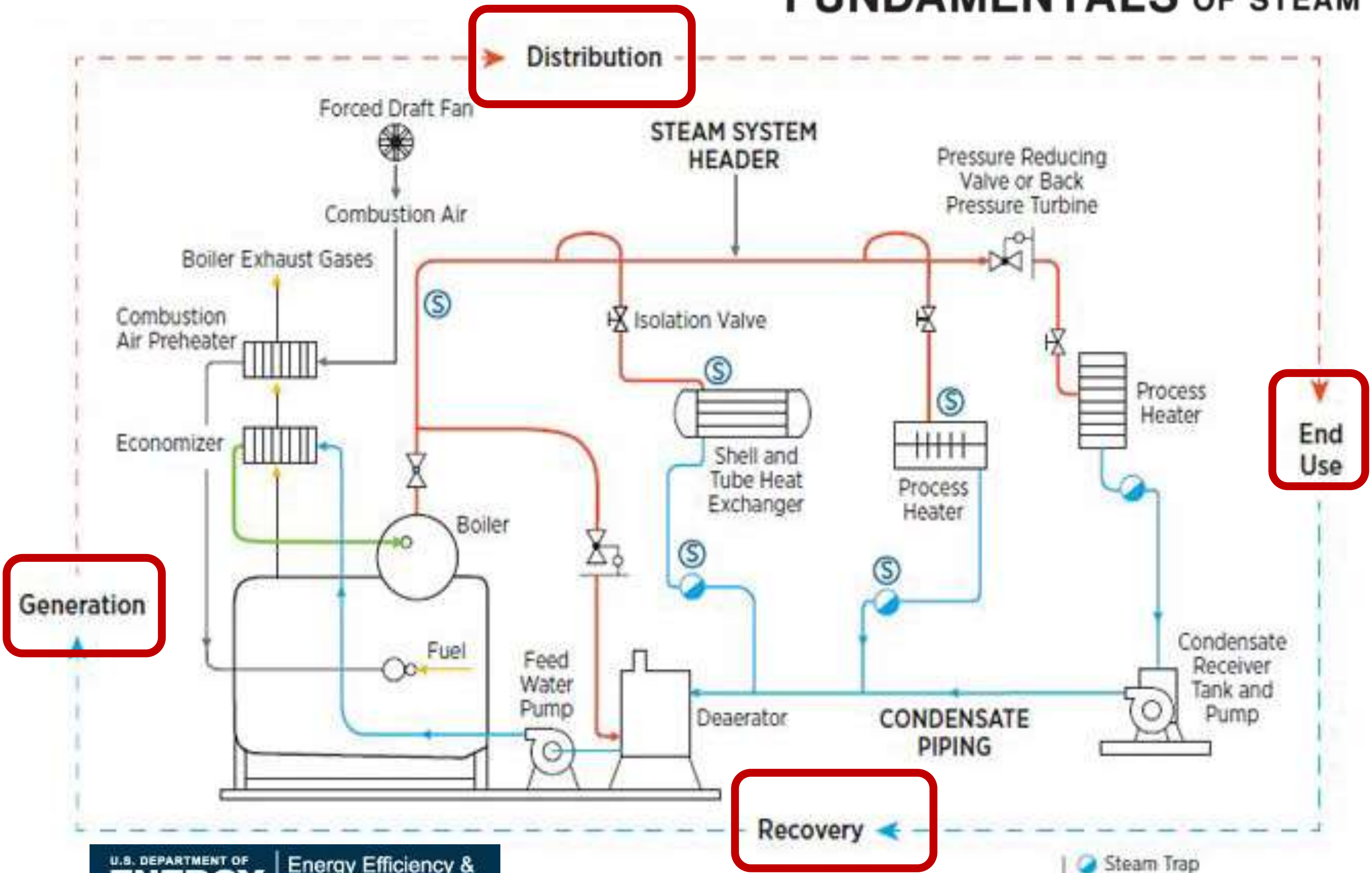


Control panel, circuit labeled #22, fuse holder as indicated.

Steam Systems and Infrared

NORTHERN OHIO CHAPTER

FUNDAMENTALS OF STEAM



U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

FUNDAMENTALS OF STEAM

Thermodynamic Properties of Saturated Steam

Fig. 87-1 To facilitate trap calculations, values in this table are shown in nearest even digits

GAGE PRESSURE psig	TEMPERATURE deg. Fahr.	Btu/lb Heat of Liquid	Btu/lb Latent Heat of Evaporation	Btu/lb Total Heat of Steam	SPECIFIC VOLUME cu ft/lb sat. vapor
28 (Vacuum, In Hg)	101	68	1037	1105	339
26	126	93	1023	1116	177
24	141	109	1014	1122	121
22	152	120	1007	1127	92
20	162	130	1001	1131	75
18	169	137	997	1134	63
16	176	144	993	1137	55
14	182	150	989	1139	48
12	187	155	986	1141	43
10	192	160	983	1143	39
8	197	165	980	1145	36
6	201	169	977	1146	33
4	205	173	975	1148	31
2 (Vacuum, In Hg)	209	177	972	1149	29
0	212	180	970	1150	27
1	216	183	968	1151	25
2	219	187	965	1152	24
3	222	190	964	1154	22.5
4	224	193	962	1155	21.0
5	227	195	961	1156	20.0
6	230	198	959	1157	19.5
7	232	201	957	1158	18.5
8	235	203	956	1159	18.0
9	237	206	954	1160	17.0
10	240	208	952	1160	16.5
15	250	218	945	1163	14.0
20	259	227	940	1167	12.0
25	267	236	934	1170	10.5
30	274	243	929	1172	9.5
35	281	250	924	1174	8.5
40	287	256	920	1176	8.0
45	292	262	915	1177	7.0
50	298	267	912	1179	6.7
55	303	272	908	1180	6.2
60	307	277	905	1182	5.8
65	312	282	901	1183	5.5
70	316	286	898	1184	5.2
75	320	290	895	1185	4.9
80	324	294	892	1186	4.7
85	328	298	889	1187	4.4
90	331	302	886	1188	4.2
95	335	306	883	1189	4.0
100	338	309	881	1190	3.9
110	344	316	876	1192	3.6
120	350	322	871	1193	3.3
125	353	325	868	1193	3.2
130	356	328	866	1194	3.1
140	361	334	861	1195	2.9
150	366	339	857	1196	2.7
160	371	344	853	1197	2.6
170	375	348	849	1197	2.5
180	380	353	845	1198	2.3
190	384	358	841	1199	2.2
200	388	362	837	1199	2.1
220	395	370	830	1200	2.0
240	403	378	823	1201	1.8
250	406	381	820	1201	1.75
260	409	385	817	1202	1.7
280	416	392	811	1203	1.6
300	422	399	805	1204	1.5
350	436	414	790	1204	1.3
400	448	428	776	1204	1.1
450	460	441	764	1205	1.0
500	470	453	751	1204	0.90
600	489	475	728	1203	0.75

Steam Pipe Capacities

Fig. 87-2 for 30 psig and 150 psig Steam Systems capacity in pounds per hour (using sch 40 iron pipe)

Std Pipe Size-In	30 psig System			150 psig System		
	Drop in Pressure — Lb/100 Ft Length					
	¼ Lb	½ Lb	1 Lb	¼ Lb	½ Lb	1 Lb
¾	22	31	45	41	58	82
1	46	63	89	82	117	165
1¼	100	141	199	185	262	370
1½	154	219	309	287	407	575
2	313	444	627	583	825	1170
2½	516	730	1030	959	1360	1920
3	940	1330	1880	1750	2480	3500
3½	1410	2000	2830	2630	3720	5250
4	2000	2830	4000	3720	5260	7430
5	3640	5230	7390	6880	9730	13800
6	6030	8590	12100	11300	16000	22600
8	12600	17900	25300	23500	33200	47000

From — Heating, Ventilating, Air Conditioning Guide 1958, p. 544.
Note. While the pressure drop to use depends on individual circumstances, a drop of 1/2 lb ...

Temp. Reading Sensor Spot Radiometer

Or Infrared Camera


Cost of $team
The opportunity is
improved efficiency

Cost of Blowing Steam Traps

Flow of High Quality Steam Vapor, Sharp Edge Orifice

Cost of Steam Leaks

Pressure (psig)	Flow Value	Equivalent Orifice Diameter (inches)										
		1/64	**1/32**	**1/16**	**1/8**	**1/4**	**3/8**	**1/2**	**5/8**	**3/4**	**7/8**	**1**
250	lb/hr	1.8	7.3	29.2	116.8	467.3	1,051.3	1,869.1	2,920.4	4,205.4	5,724.0	7,476.2
	$/year	***144***	***576***	***2,302***	***9,210***	***36,839***	***82,888***	***147,357***	***230,245***	***331,553***	***451,280***	***589,427***

Input Section	*site data entry*	
Steam pressure =	**250**	psig
Steam temperature =	**460**	Deg F
Amount of superheat =	**57**	Deg F
Facility steam value =	**9.00**	$/Klb
Leak orifice flow coefficient =	**0.61**	
Hours/year in service =	**8760**	

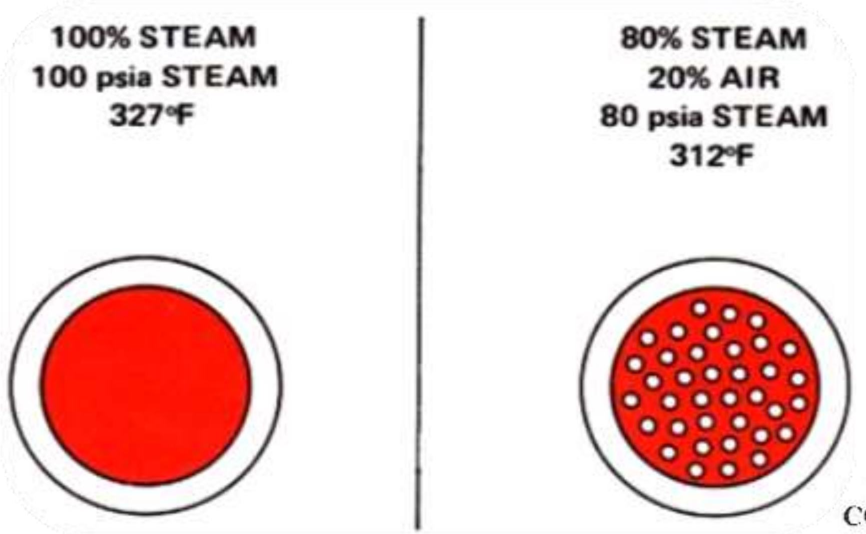
Directions -

1) Determine the steam pressure and temperature in the vicinity of the leak you are concerned with.
2) Estimate the equivalent diameter of the system leak.
3) Apply the input values for your facility, including amount of superheat if any.

CKG CONSULTING, LLC

Cost of Blowing Steam Traps

Flow of High Quality Steam Vapor, Sharp Edge Orifice



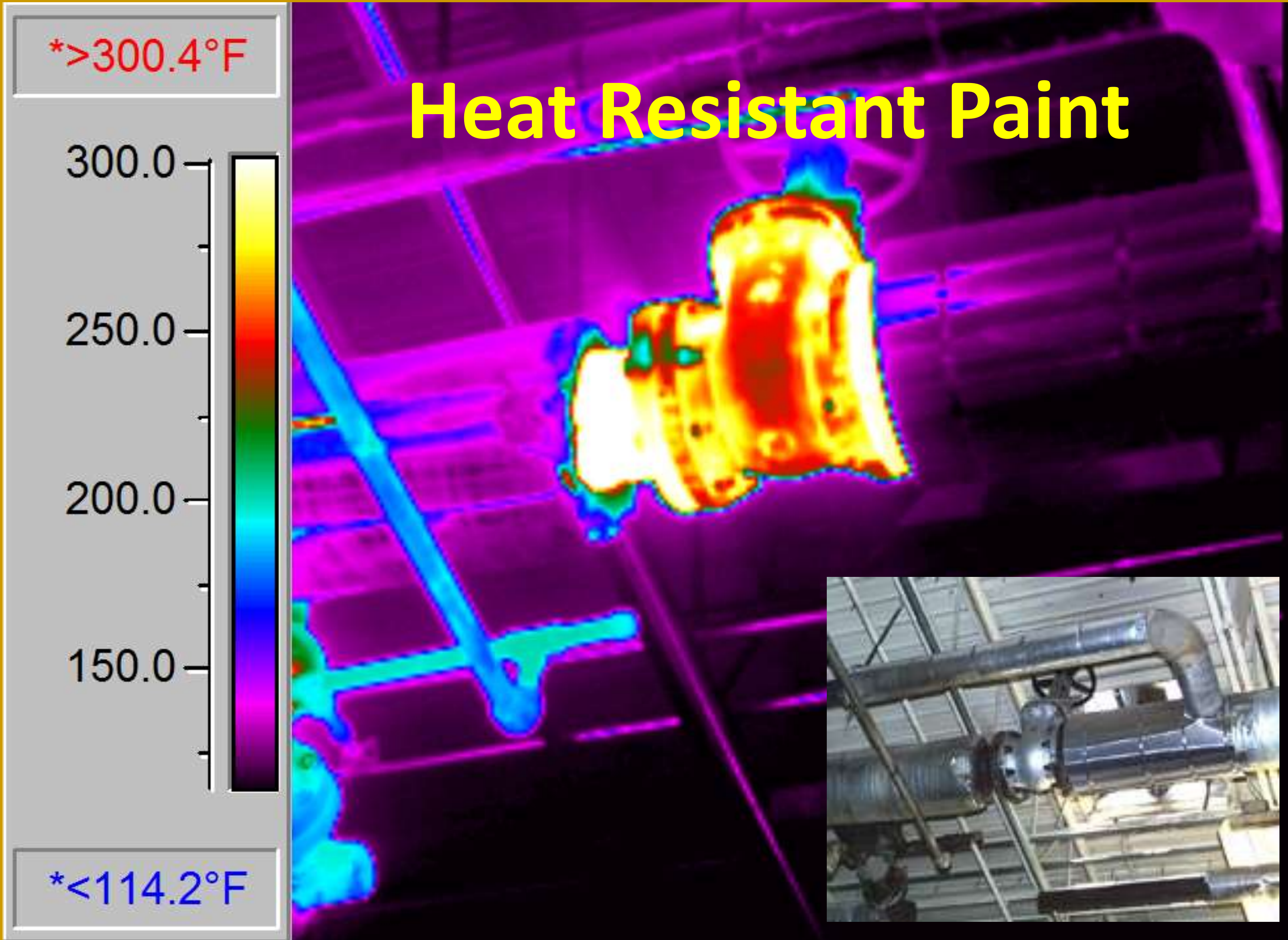
Flexitallic Gasket Co. Inc.

COST OF VARIOUS SIZED STEAM TRAP LEAKS AT 100 PSI
(assuming steam costs $5.00/1,000 lbs.)

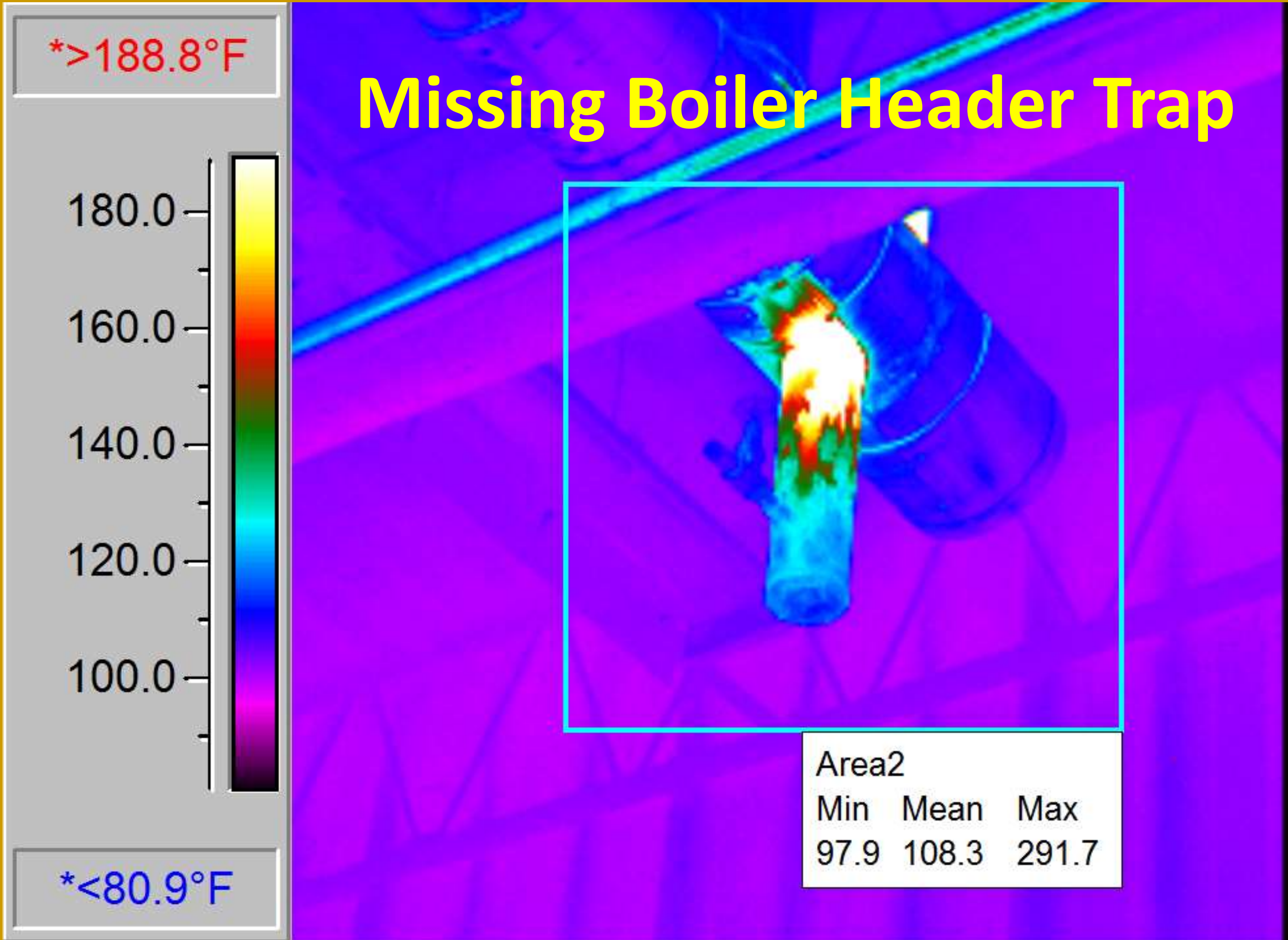
SIZE OF ORIFICE(in)	LBS STEM WASTED PER MONTH	TOTAL COST PER MONTH	TOTAL COST PER YEAR
1/2	835,000	$4,175.00	$50,100.00
7/16	637,000	3,185.00	38,220.00
3/8	470,000	2,350.00	28,200.00
5/16	325,000	1,625.00	19,500.00
1/4	210,000	1,050.00	12,600.00
3/16	117,000	585.00	7,020.00
1/8	52,500	262.00	3,150.00

The Steam Trap Handbook

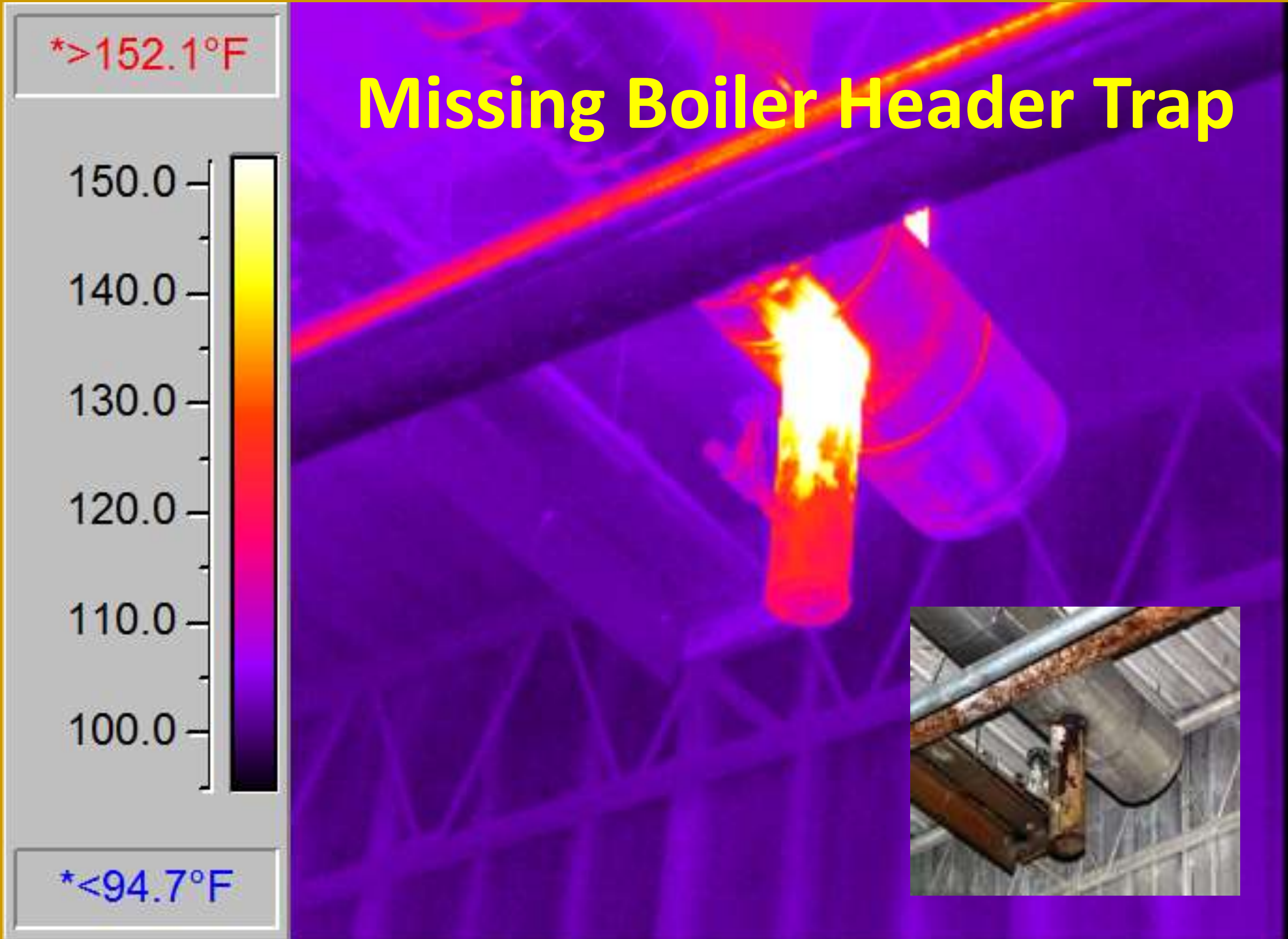
Heat Resistant Paint

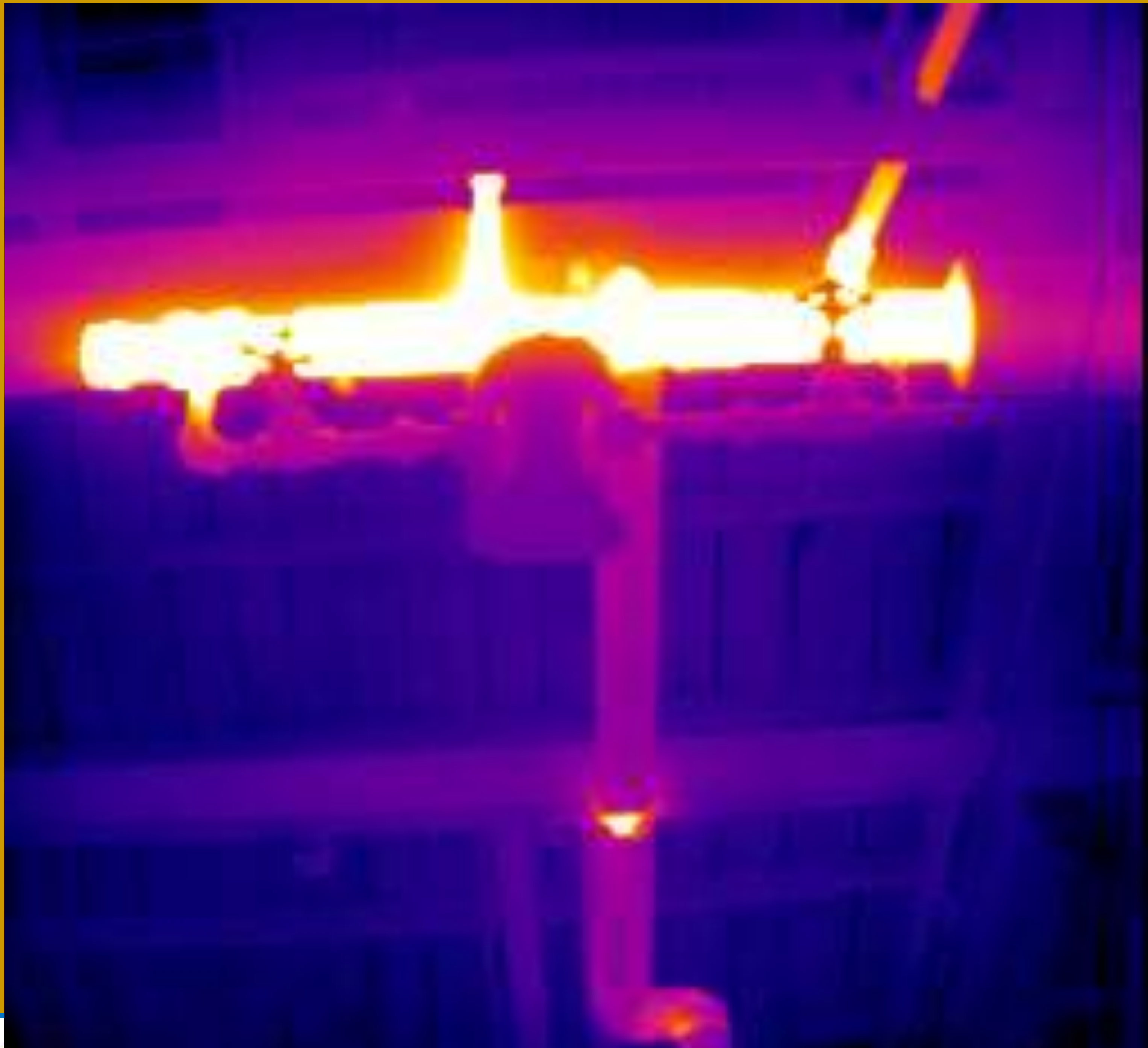


Missing Boiler Header Trap



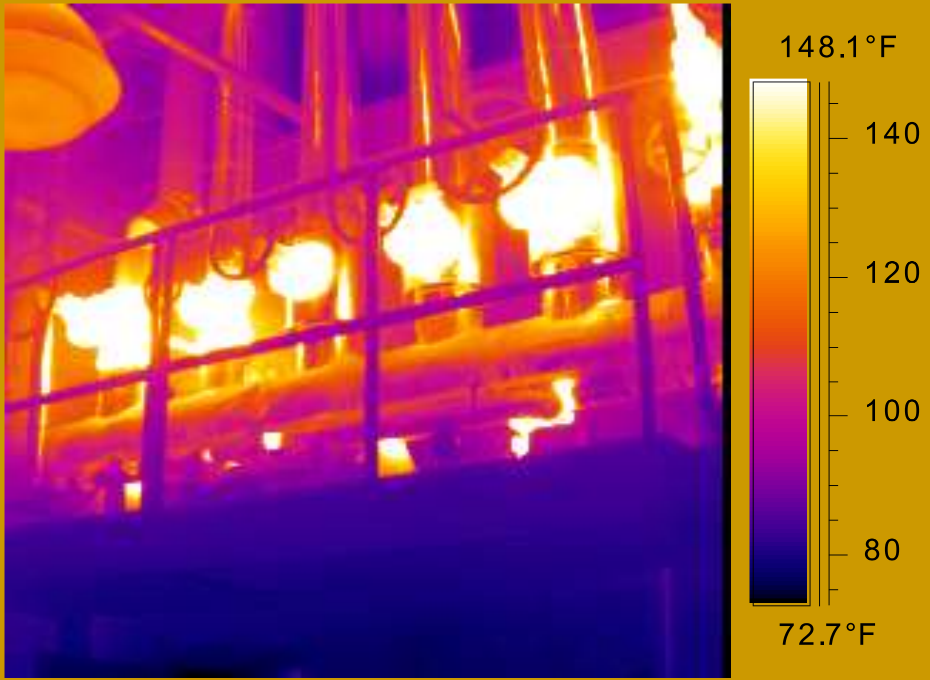
Missing Boiler Header Trap





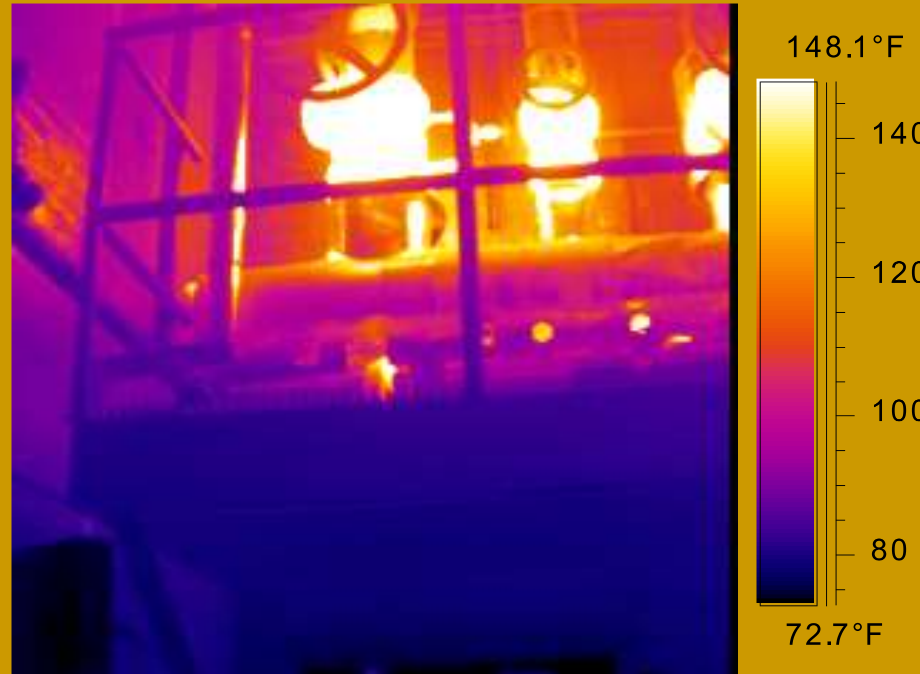
17

7 9



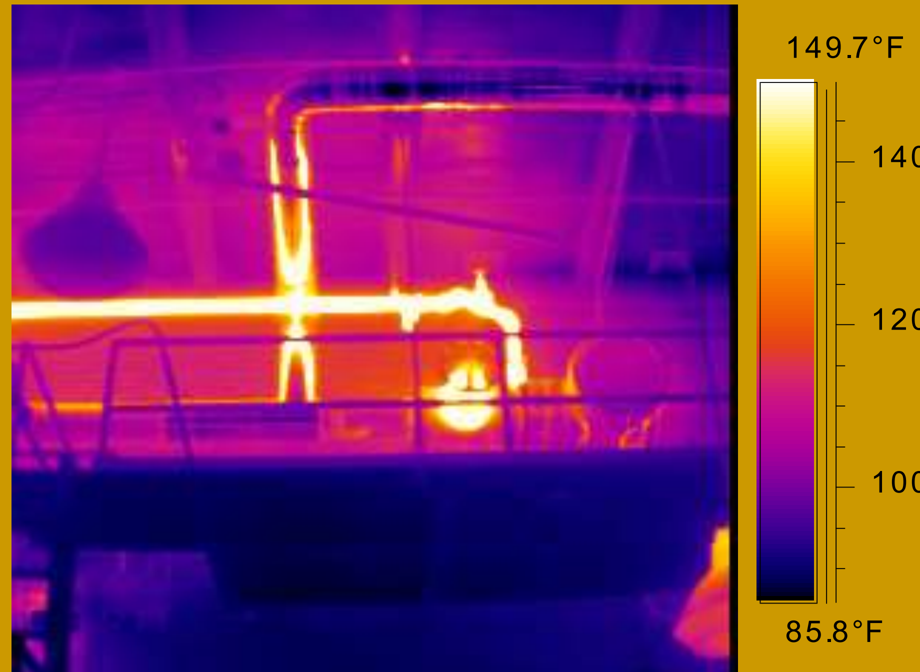
Boiler Room/Main Steam Header

Boiler header trap – failed.



Boiler Room/Main Steam Header

Boiler header trap – failed.

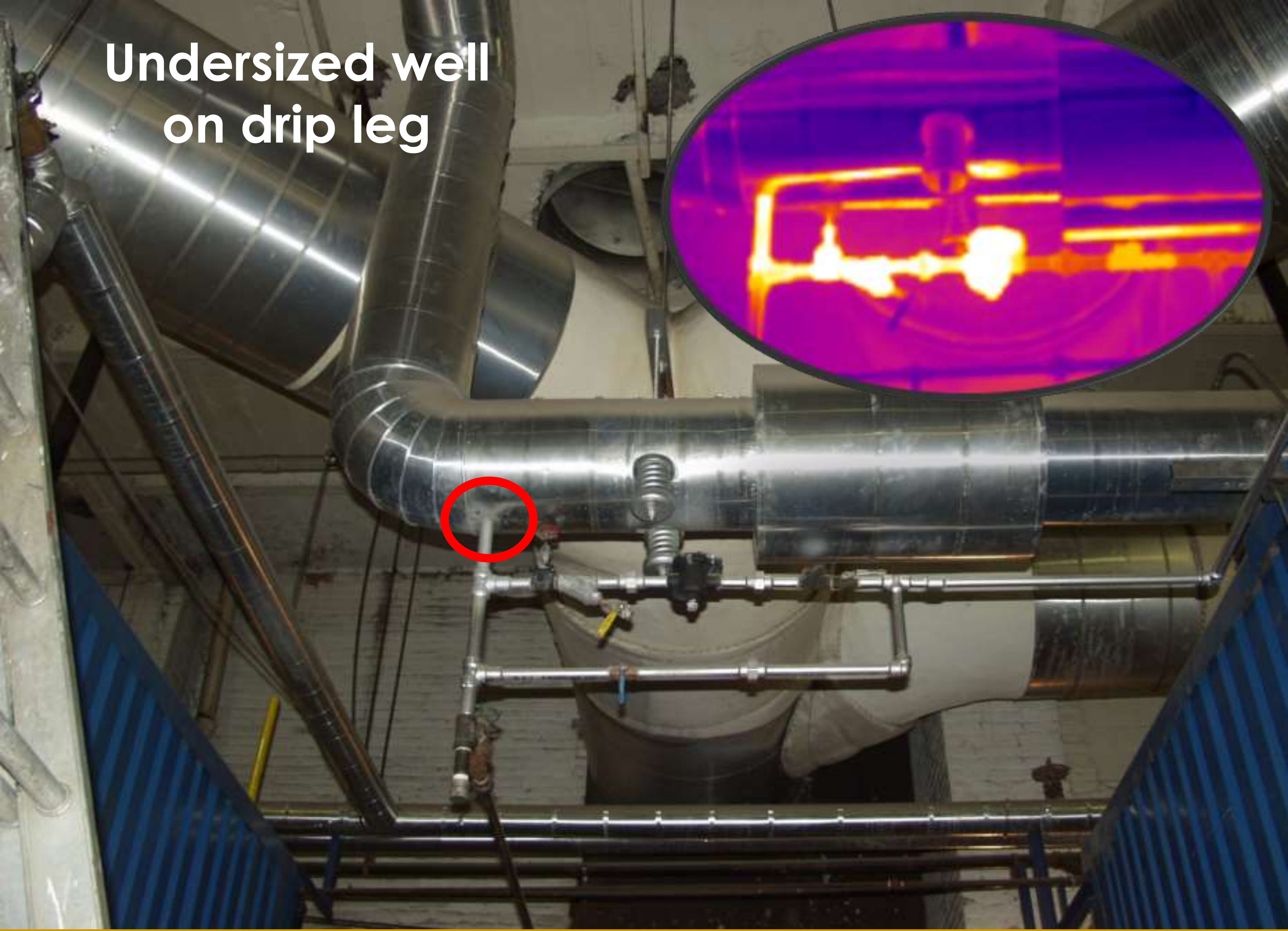


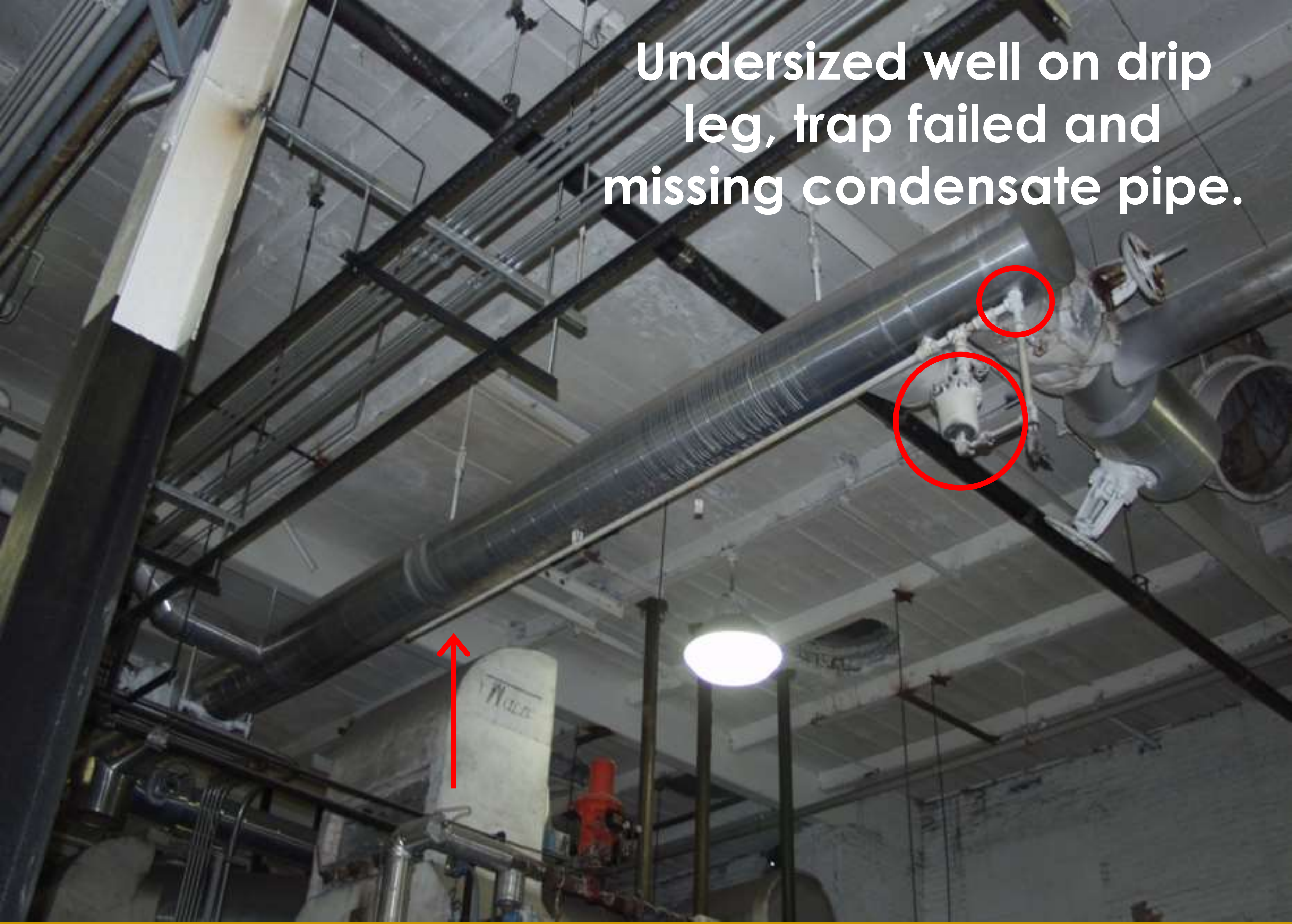
Boiler Room/Main Distribution

Main line is uninsulated.

Uninsulated lines and missing drip leg

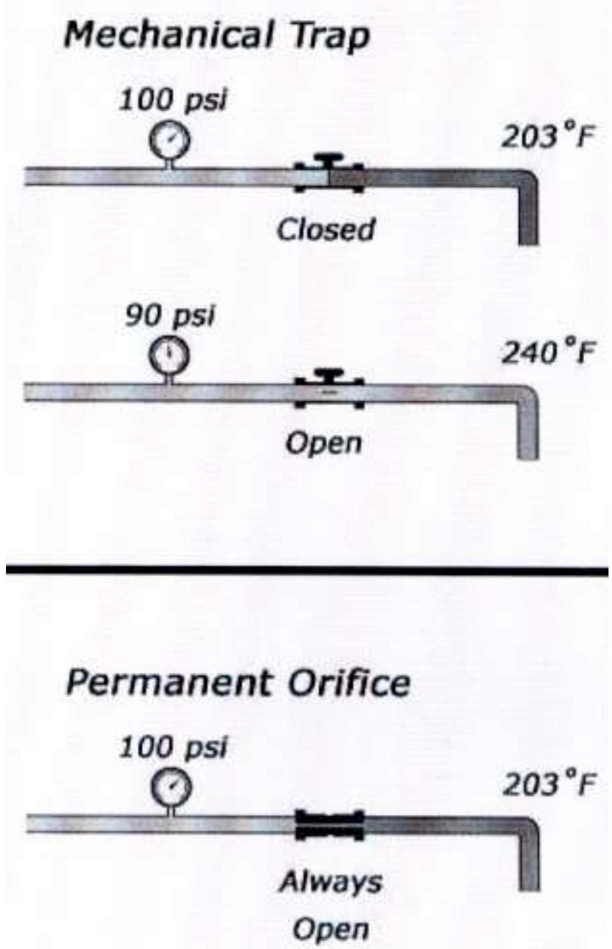
Undersized well on drip leg



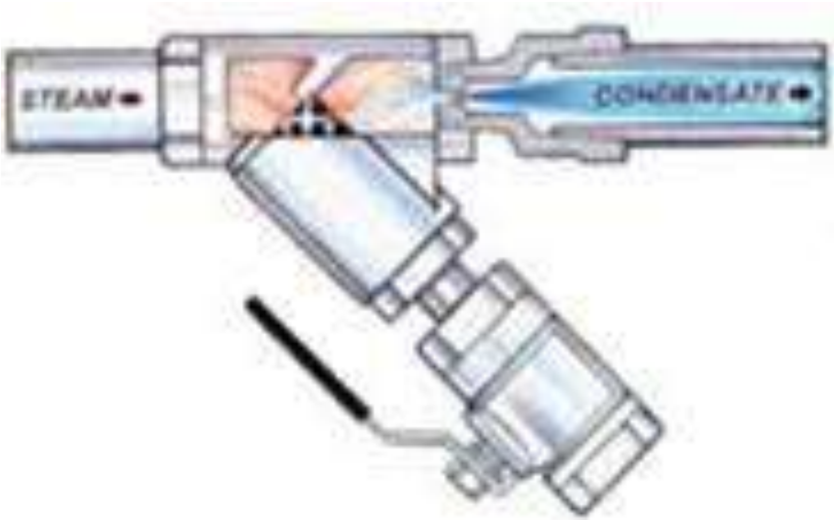


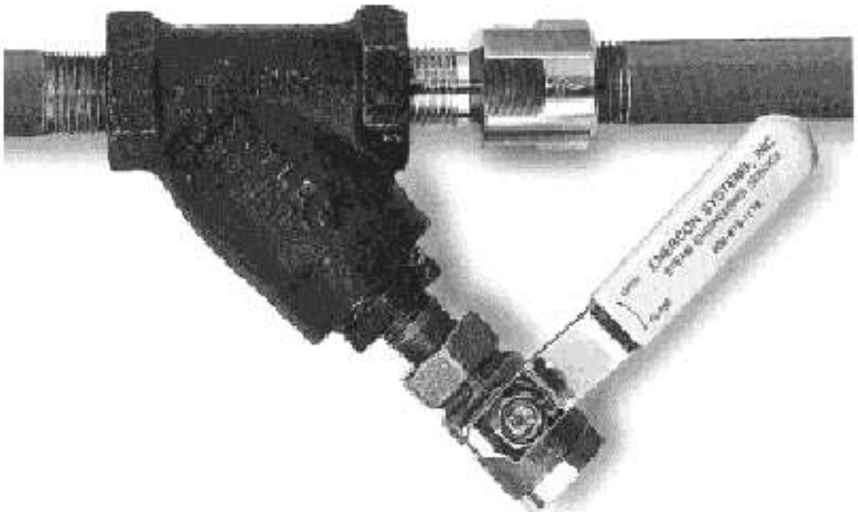
Undersized well on drip
leg, trap failed and
missing condensate pipe.

Pressure Drop Experiment



Venturi Orifice Trap





Venturi Orifice Trap

- Improved Thermal Efficiency
- Reduced Steam Consumption
- Virtually No Maintenance
- Response to load fluctuations: instantaneous.
- Discharge is fully controlled at all condensate loads.
- Requires expert engineering and precise sizing.

Thank you for your kind attention!

NORTHERN OHIO CHAPTER

Questions ???

NORTHERN OHIO CHAPTER

- Thermography Training and Online Classes
- Infrared Thermographer Support Portal
- Annual Infrared Users Conference (June 2014)

United Infrared, Inc.

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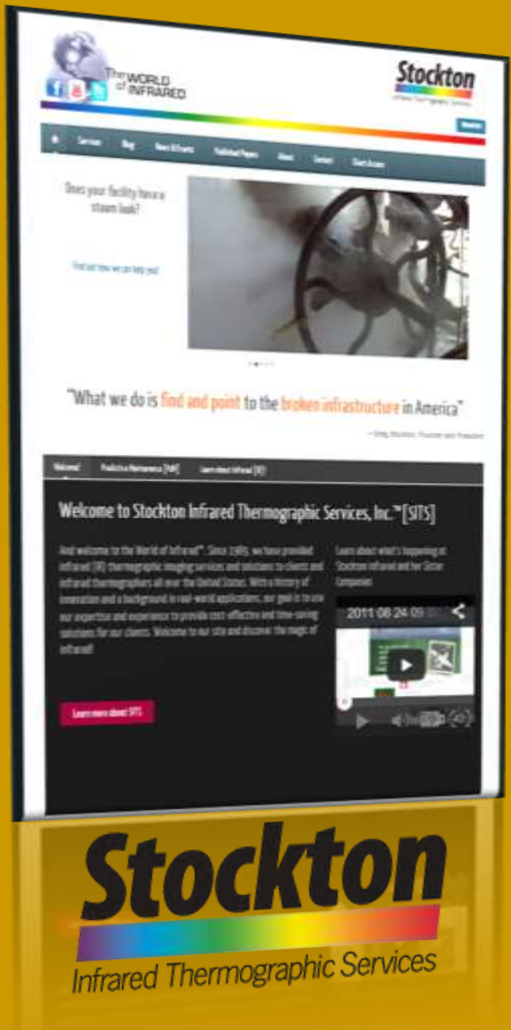

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