

Infrared Camera Skills for the Building Thermographer



Presented By
Wyatt Nease



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Wyatt Nease



Instructor & Consultant
The Snell Group



- Joined The Snell Group in 2014
- Instructor Level I
- Performs IR inspections for a wide variety of customers.

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Who is The Snell Group?



- Established 1986
- Headquarters in Barre, VT
- Offices around North America
- Training, inspection & consulting services provided world-wide:
 - Infrared Thermography (IR)
 - Electric Motor Testing (EMT)
- Full-time support staff
- Free customer support after training
- www.thesnellgroup.com



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We are Vendor-Neutral...Period!



- The Snell Group is independent of equipment sales
- We work with ALL vendors and their customers.



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Qualities of a Good Image



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Focus



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Focus

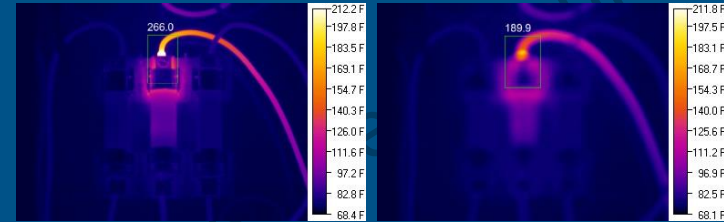


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Focus & Temperature



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Brightness & Contrast

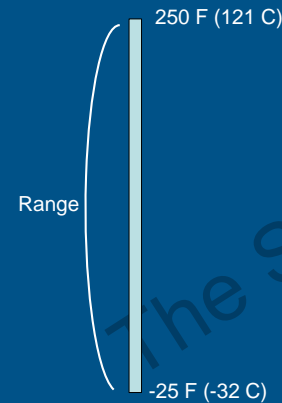


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Thermal Range



- Range of temperatures that your thermal imager can detect
- Size of Range varies from model to model
- Most IR building cameras have one range.



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Dynamic Range

- Data storage:
 - 8-bit data: 256 divisions
 - 12-bit data: 4096 divisions
 - 14-bit data: 16,384 divisions

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Dynamic Range

- Data storage:
 - 8-bit data: 256 divisions
 - 12-bit data: 4096 divisions
 - 14-bit data: 16,384 divisions
- Older infrared cameras only captured 8-bits of data at a time

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Dynamic Range

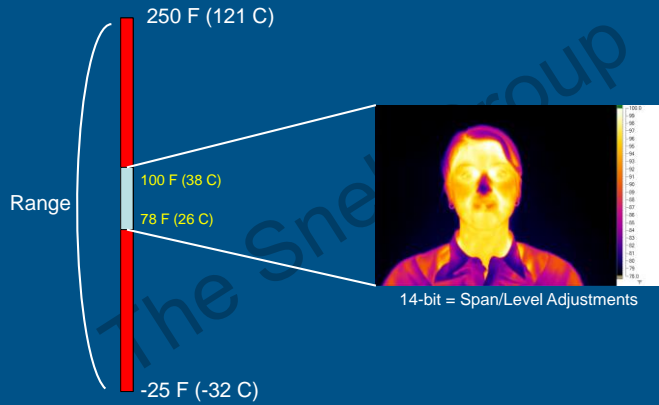
- Data storage:
 - 8-bit data: 256 divisions
 - 12-bit data: 4096 divisions
 - 14-bit data: 16,384 divisions
- Older infrared cameras only captured 8-bits of data at a time
- 12 or 14-bit systems capture the entire thermal range, allowing you to save and (later) see data that is not displayed.

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Dynamic Range

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Dynamic Range

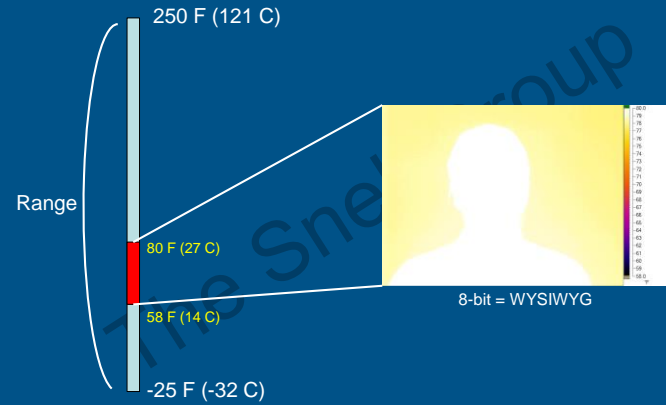


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Dynamic Range



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Contrast & Brightness



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Thermal Contrast & Brightness



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Thermal Span

250 F (121 C)

Span

40 F (4 C)

20 F (-7 C)

-25 F (-32 C)

- Similar to **visual contrast**
- Span is the portion of the Range that you are looking at during any given moment
- Think of it as a smaller "range" of temperatures within the Range

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Thermal Span

250 F (121 C)

Span

40 F (4 C)

20 F (-7 C)

-25 F (-32 C)

- Adjust the Span's width to change thermal contrast and optimize the image.
- Object is to put the maximum number of colors or shades on the area of interest

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Thermal Span – Too Wide

250 F (121 C)

Span

80 F (27 C)

0 F (-18 C)

-25 F (-32 C)

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Thermal Span – Too Narrow

250 F (121 C)

Span

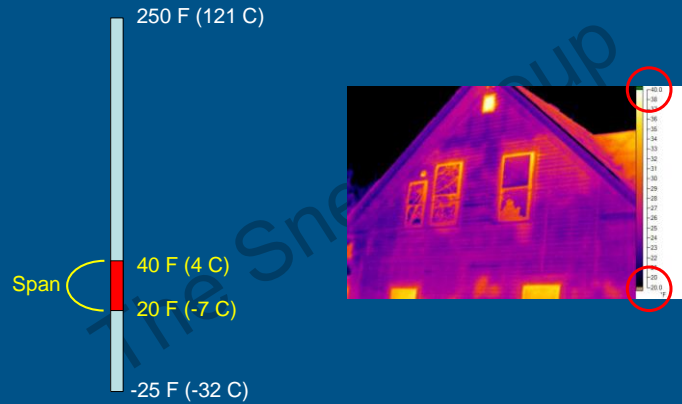
32 F (0 C)

28 F (-2 C)

-25 F (-32 C)

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Thermal Span - Optimized

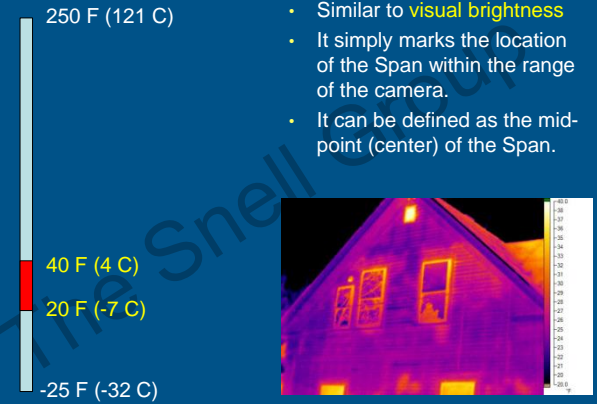


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Thermal Level

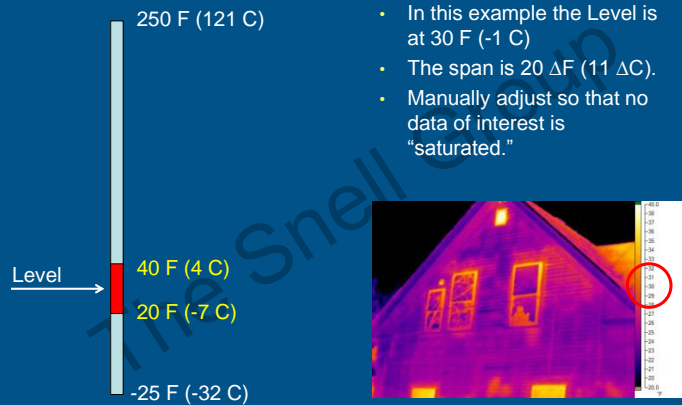


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Thermal Level

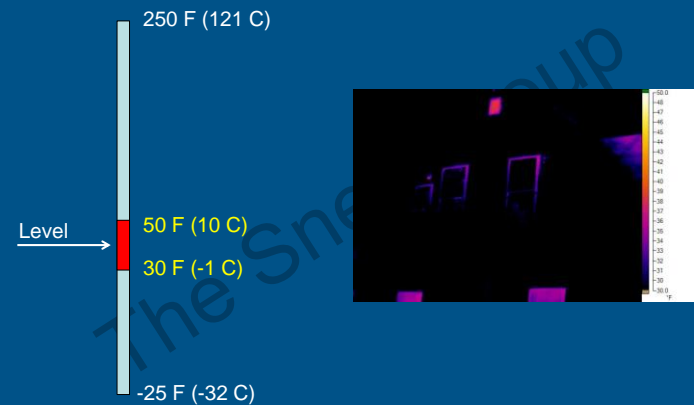


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Thermal Level – Too High

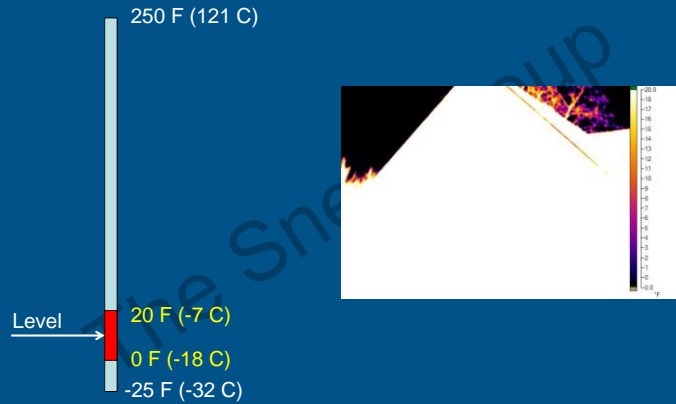


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Thermal Level – Too Low

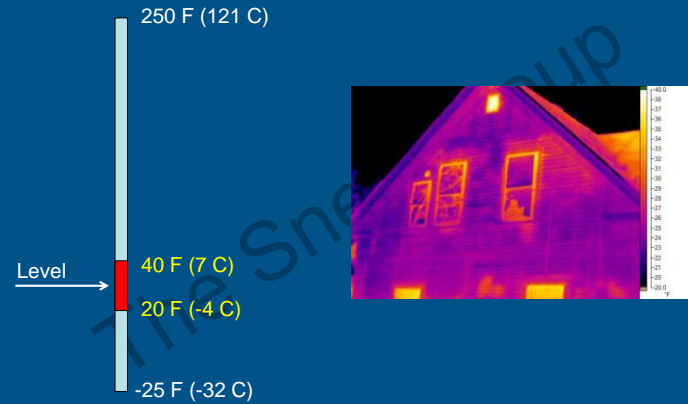


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Thermal Level – Optimized

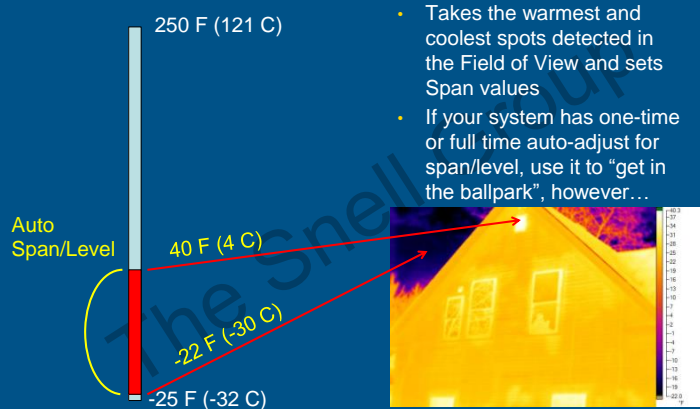


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Span/Level Auto Adjust

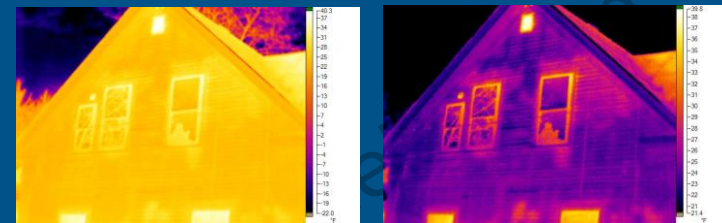


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Auto Adjustment - Outside



Auto

Manual

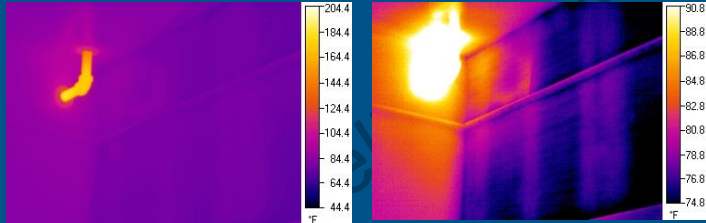
- Try to exclude extraneous hot and cold areas from the image such as wood stoves, radiators/pipes and cold windows or the sky.
- If unable, you'll need to manually adjust your image.

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Auto Adjustment - Inside



Auto

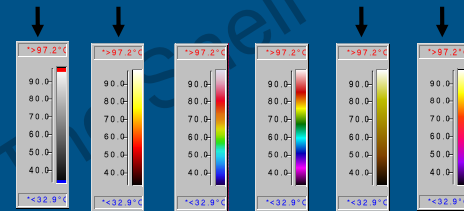
Manual

- Try to exclude extraneous hot and cold areas from the image such as wood stoves, radiators/pipes and cold windows or the sky.
- If unable, you'll need to manually adjust your image.

Display Palettes



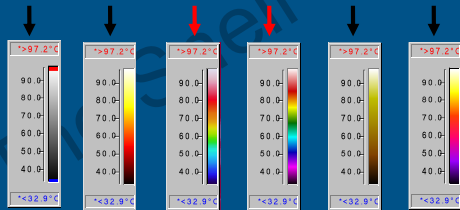
- Different palettes can show different image detail
- Palettes vary widely from brand model to brand model
- Know all your palettes and use them appropriately
- Gray and monochromatic color are typically best for day-to-day work.



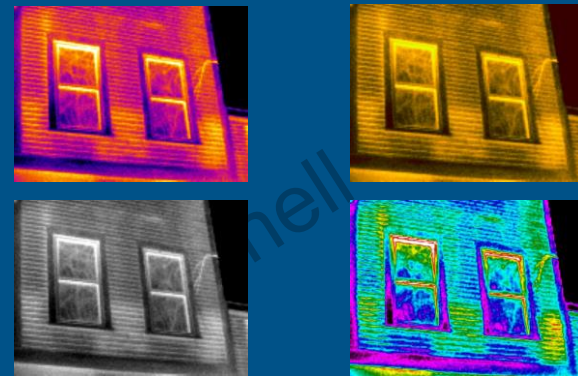
Display Palettes



- Different palettes can show different image detail
- Palettes vary widely from brand model to brand model
- Know all your palettes and use them appropriately
- Gray and monochromatic color are typically best for day-to-day work
- **Rainbow best used sparingly for high contrast needs and marketing.**



Display Palettes



Which palette works best of your imager?

Resolution and Thermography



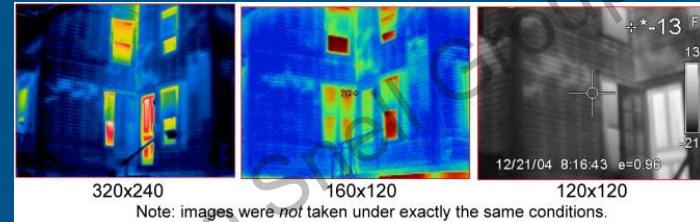
- We need to see detail of various sizes at various distances
- We may also need to measure radiometric temperatures
- Applications may also have requirements for a particular field of view at a given distance.
- Affected by array size and lens

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Size is *Not* Everything!



320x240

160x120

120x120

Note: images were *not* taken under exactly the same conditions.

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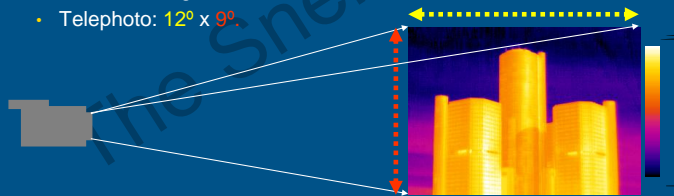
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Field of View (FOV)



- FOV describes the width and height (as angles) of the area being viewed through the lens
- Example:
 - Normal: 24° x 18°
 - Wide angle: 48° x 36°
 - Ultra wide angle: 60° x 60°
 - Telephoto: 12° x 9°



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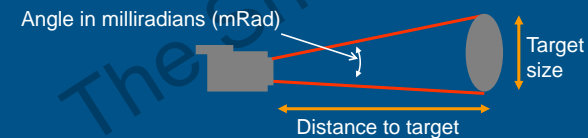
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Two Kinds of Resolution



- IFOV is *spatial* resolution = what you can see
 - This is on your camera's spec sheet
- IFOV_{meas} is *measurement* resolution = what you can measure
 - This is NOT on your camera's spec sheet
 - Roughly 3X less than spatial
- Both can be specified either as an angle (in units of milliradians) or as a ratio of distance to spot (target) size.



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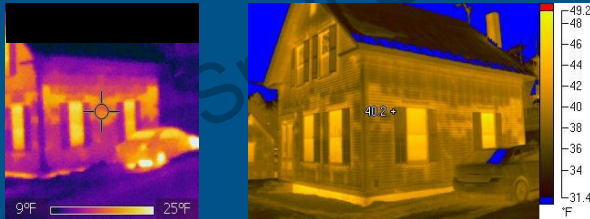
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An Example - IFOV



- “Can I see framing and small insulation voids at the distance I am working from?”
- You need to have a good idea of what the limits are for your imaging system.



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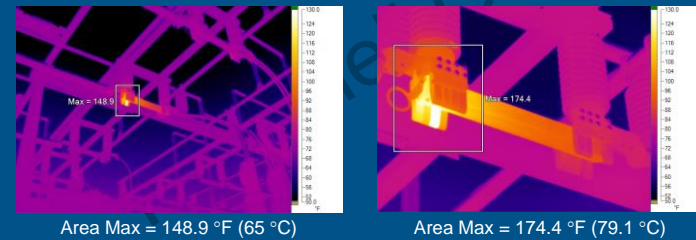
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An Example – IFOVmeas



- “Can I confidently measure the temperature of a hot spot at the distance I am working from?”
- You need to have a good idea of what the limits are for your imaging system.



Area Max = 148.9 °F (65 °C)

Area Max = 174.4 °F (79.1 °C)

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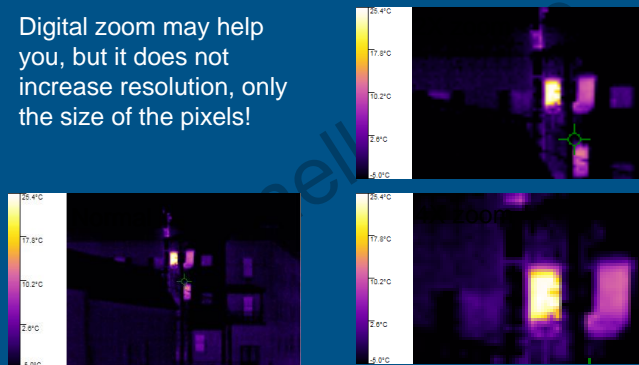
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Digital Zoom



- Digital zoom may help you, but it does not increase resolution, only the size of the pixels!



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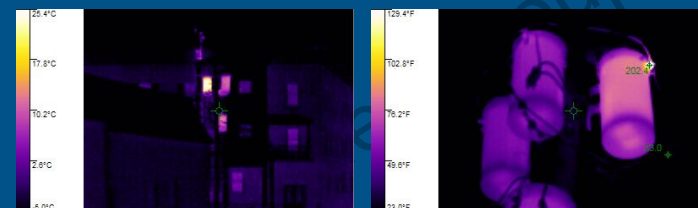
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Distance Considerations



- When possible, the simple solution may be to move closer!



100m (325ft)

10m (32.5ft)

The same lens used at two different distances

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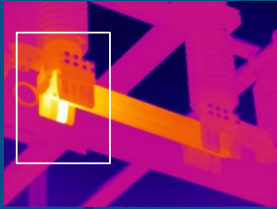
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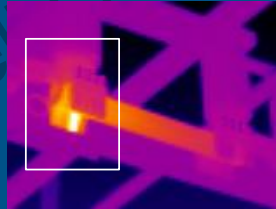
Digital Zoom?



- Does not improve resolution
- It simply electronically magnifies a portion of the array
- The only way to truly zoom is via an optional lens.



Area Max = 174.4F



Area Max = 148.9F

Resolution



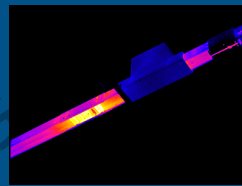
- If we cannot see a "target,"
- Is it just not there?
- Are we too far away?
- Or, is it too small?



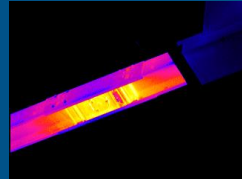
Optional Lenses



- Use the right lens for the job
- The right lens pays for itself.



Telephoto & Normal Lens



Optional Lenses

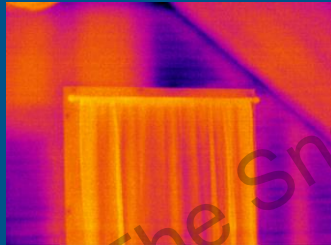


46° x 34°
Wide Angle

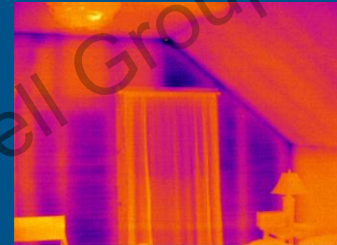
23° x 17°
Standard

11.5° x 8.7°
Telephoto

Optional Lenses



Standard Lens



Wide-Angle Lens

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Checking Camera Functionality



You should regularly check how well your infrared camera is functioning!



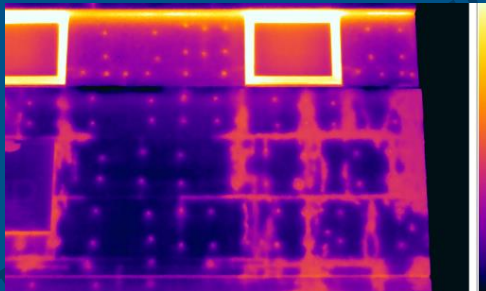
- Set camera to Range 1
- Adjust emissivity to 0.98
- Adjust background temperature
- Focus on face at 1m (\approx 3 ft)
- Put cross-hair or box on tear duct
- Save/freeze image
- Value should read \approx 34-36C (93-97F)
- We suggest you do this each time you use your camera. **Also check...**
 - Color palette polarity
 - Data file type (IS2 vs. JPEG)
 - Other measurement parameters (i.e. transmissivity setting, lens type)

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Moisture



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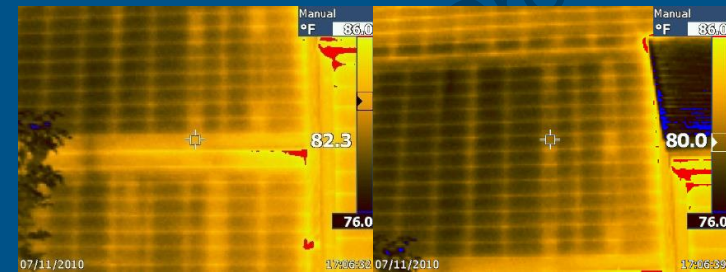
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Framing



- Framing is slow to change temperature due to its larger thermal capacitance.



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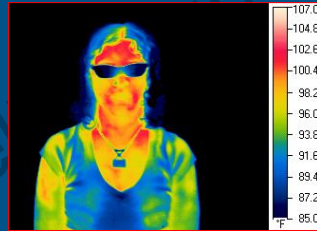
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Evaporative Cooling



- When we sweat, we feel cool
- When surfaces are wet, even inside the walls of our buildings, they may be cooled below ambient air temperatures.



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Evaporative Cooling



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Fourier's Law of Conduction



$$Q = \frac{k}{L} \cdot \Delta T \cdot A$$

- The amount of heat conducted depends on:
 - Conductivity (k) and thickness (L)
 - Temperature difference (from one side to the other)
 - Area.

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Difference in L (Thickness)



- How do differences in thickness (L) affect conductive heat flow?

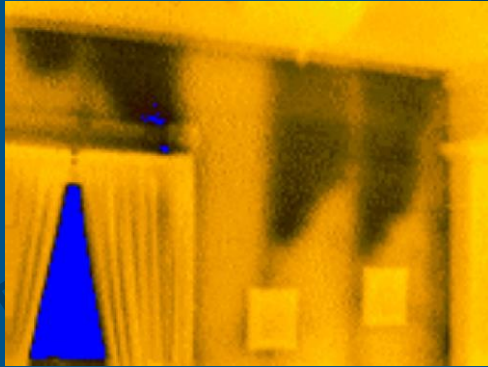


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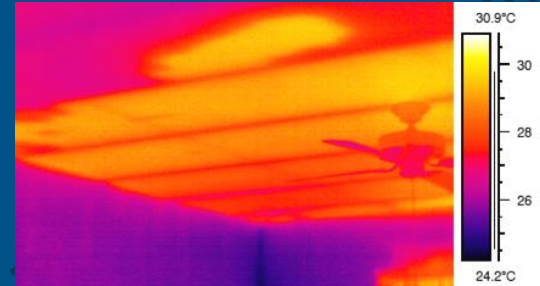
Blown Cellulose



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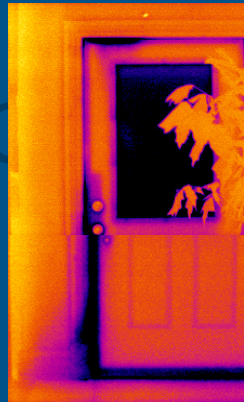
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Convection



- Occurs in fluids (non-solids)
- A process of conduction & mixing
- Results in differences in density.

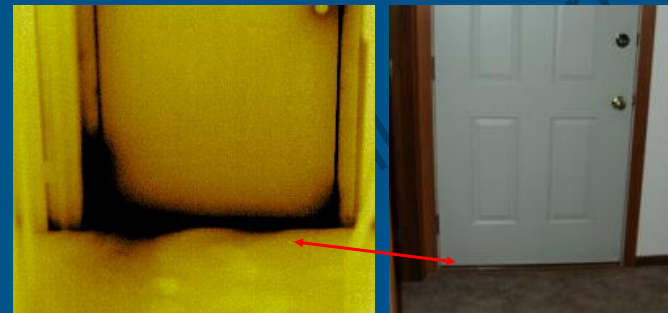


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Air Leakage

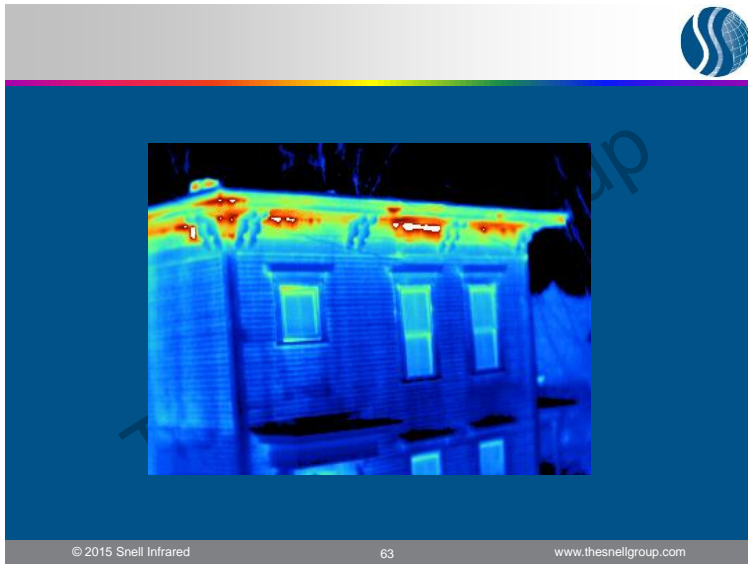


Cold air infiltration past a poorly adjusted threshold seal.

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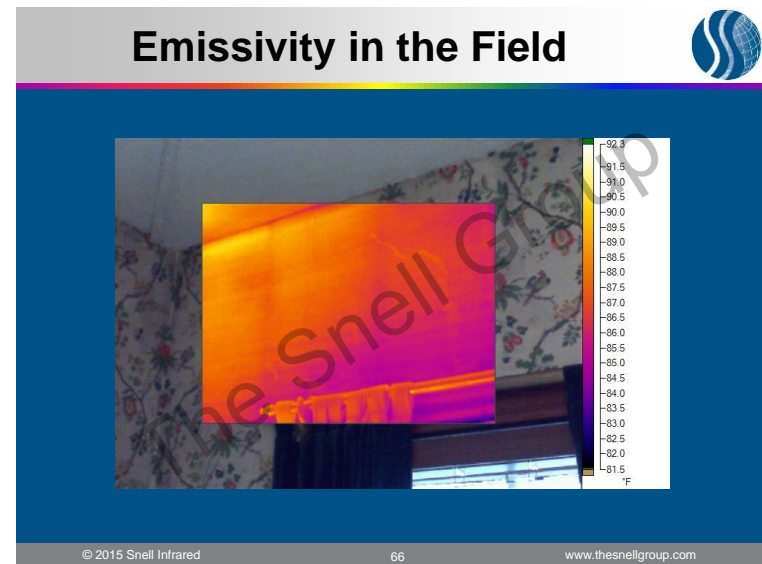
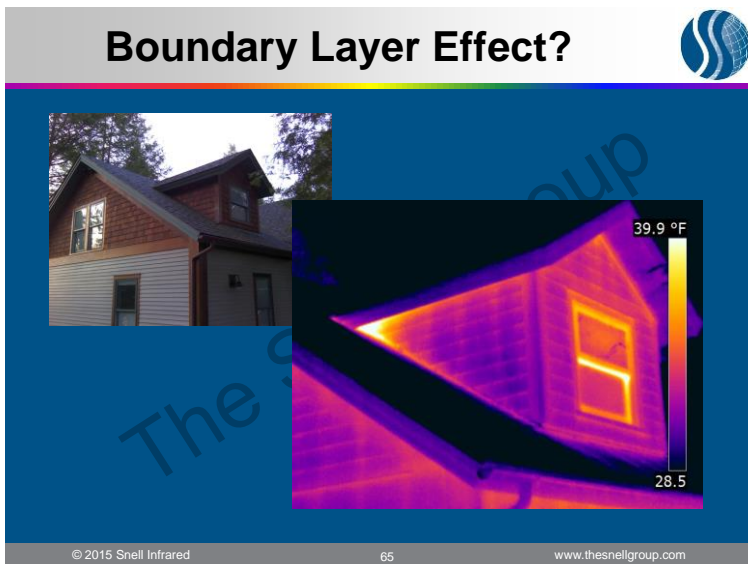
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Films or Boundary Layers

- Slow fluid velocity
 - Films are thick
 - Heat transfer is reduced
- Fast fluid velocity
 - Films are thin
 - Heat transfer is increased.

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Emissivity in the Field



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Emissivity is Independent of Color



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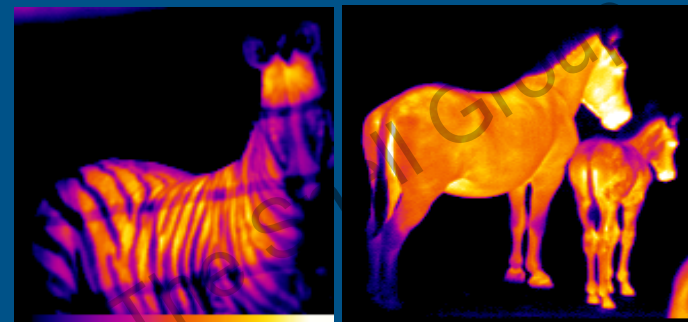
Emissivity is Independent of Color?



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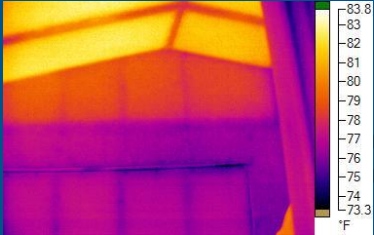



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Reflections

- Specular 
- Diffuse 


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Reflections in the Field



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Reflections & Angle of View



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Reflections & Angle of View



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Angle of View - Windows



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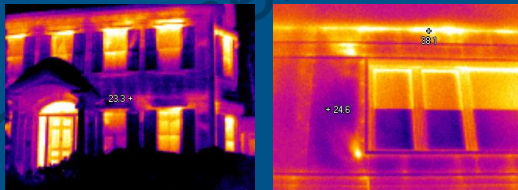
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Building Inspections



- A complete IR building inspection is often actually *two* inspections in one:
 - Insulation
 - Air leakage
- Typically these are *qualitative* inspections.



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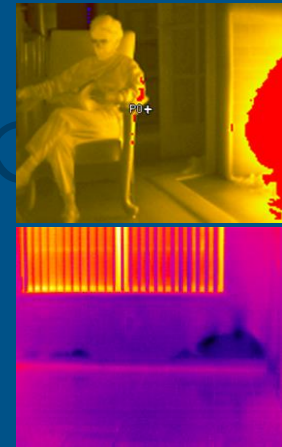
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Building Inspections



- Could also include:
 - Air movement within or outside the enclosure
 - Moisture inspections
 - Structural inspections
 - Human thermal comfort investigations



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Conduction Inspection



- Conduction losses & gains are controlled by adding insulation that performs effectively
- A conduction inspection can provide:
 - Determination of the presence of insulation
 - Define thermal envelope of building
 - Location of structural members prior to insulating
 - Verification of the placement of insulation
 - Performance testing of insulation
 - Locate possible moisture intrusion and damage.

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The Keys to the Signature



- Shape
- Location
- Intensity



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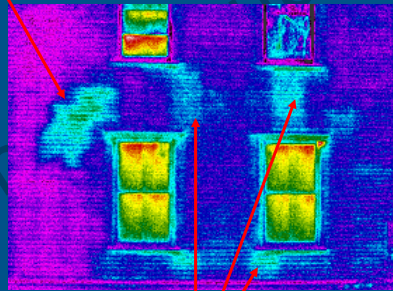
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The Keys to the Signature



- Shape
- Location
- Intensity

Fireplace chimney against the wall.



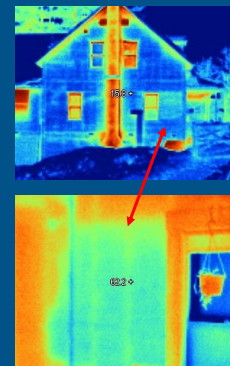
Missing insulation

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Conduction Inspections



- Perform conduction inspection before inducing any air leakage
- 10° C (18° F) or greater stable ΔT
- View both sides of the wall
- Inside is usually best view
- Outside gives "big picture"
- Account for wind & sun
- Know the type of insulation.

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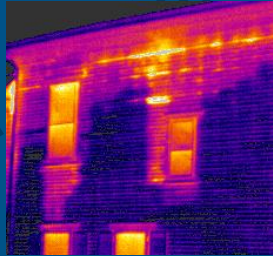
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When to Inspect?



- Good inspections can be done:
 - Early in the morning
 - On a cloudy day
- However, the sun's effects can last:
 - 3 hours on light frame
 - 8 hours on masonry
- Afternoon/evening inspections may prove difficult due to transient conditions.



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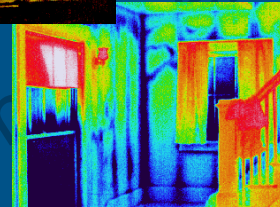
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Inside/Outside Views



- Often the exterior signature is not as pronounced as the inside one
 - Weather
 - More thermally disconnected



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Difficulties Outside



- Excessive wind
- Sun
- Brick-faced
- Vinyl/aluminum siding
- Exterior insulation
- Double wall or back-plastered walls
- Moisture on walls
- Extremely low temperatures
- Distance/Angle of view
- Access to all sides and roof/attic.



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Solar Loading



- Quickly "masks" over the exterior thermal signature that shows heat loss/gain
- Solar loading often results in changes to the thermal signature *on the inside*.



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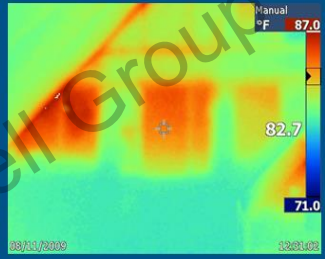
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What Direction is Heat Flow?



Winter



Summer

Summer - Insulated



Inside view



Winter - Not insulated



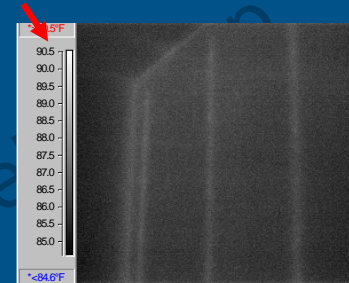
Inside view



Similar Patterns



Inside view
Winter
Not insulated



Inside view
Summer
Insulated

Conduction Patterns



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Fiberglass Batts

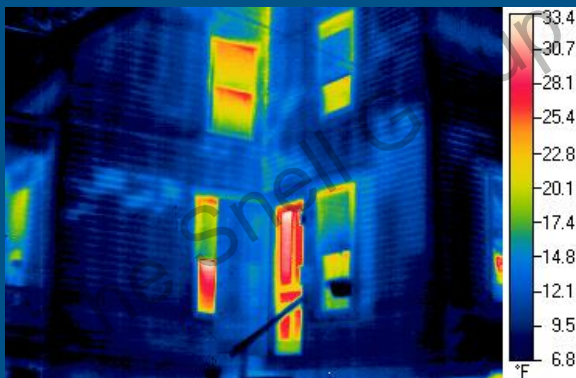


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Blown Rock Wool



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Foundations / Slab Edges



- High conductive losses
- Basement temperatures are often high, even if not actively heated
- Watch for residual solar heating! Go to north side.

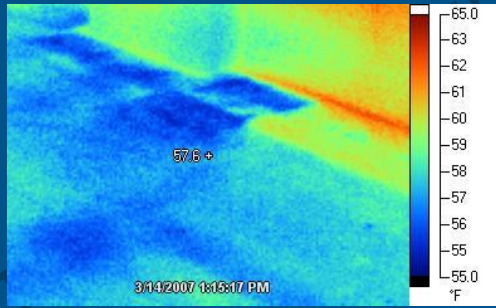


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Moisture in Sub-floor

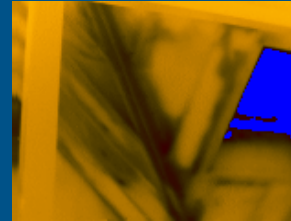


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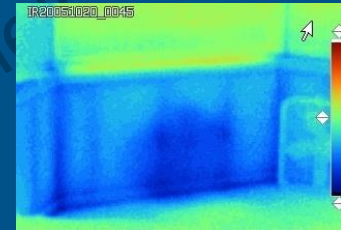
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Moisture



- Pay attention to cold areas, visual indications, and suspect structural details like kick flashings and valleys.



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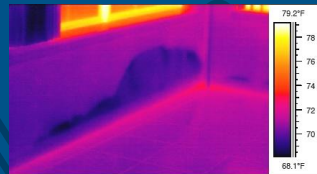
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Moisture Signatures



- Thermal signature based on:
 - Evaporative cooling
 - Thermal capacitance
 - Extra conductive heat transfer
- These can occur either on surfaces or behind them or both
- What are the conditions?
- Whenever possible, verify with a moisture meter.

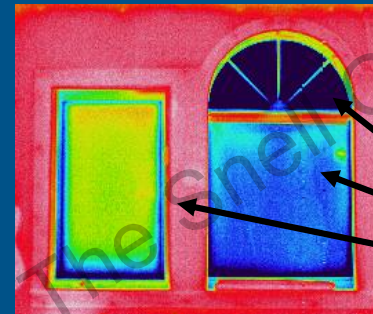


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Window Temperatures



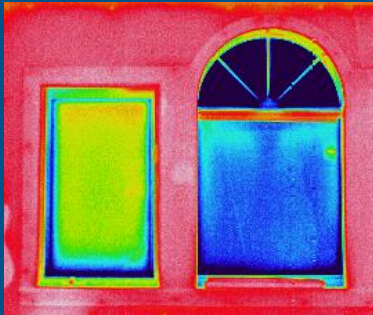
- Outside = 5° F
- Inside = 70° F
- Single = 35° F
- Double = 45° F
- Low E = 62° F

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Window Temperatures



Note: accurately measuring radiometric temperature of windows is not simple due to their high reflectance!
Increasing emissivity is recommended when possible.

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Aluminum or Vinyl Siding



There is still heat loss! The sided portion is simply more "thermally disconnected" than the un-sided portion.

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Air Leakage



- Some air exchange *is* necessary:
 - Health
 - Moisture control
 - Odor control
- Most buildings have far too much resulting in:
 - Frozen plumbing
 - Excessive energy consumption
 - Dry winter conditions
 - Condensation inside walls.



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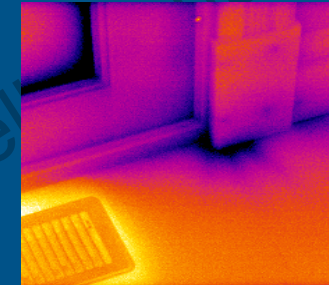
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Conditions for Air Leakage Inspection



- ASTM 1186-03 suggests a 5°C (9°F) inside to outside ΔT to check for air leakage
- A larger ΔT is better
- It may also be possible to detect issues with less
- Understand all building pressure differences
 - Wind
 - Mechanical systems
 - Height of structure
 - Closed/open doors.



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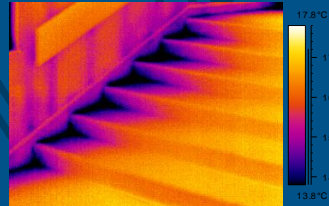
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Conditions for Air Leakage Inspection



- When possible, control direction of flow:
 - Blower door
 - Exhaust fans
 - HVAC System
- Inspect from both inside (infiltration) and outside (exfiltration)
- Do conduction inspection first and air leakage last.



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Blower Door



- Direction of air flow is controlled and uniform
- Air flow rates can be measured
- Building performance can be validated or predicted
- Also useful in fire sealing applications
- In large buildings HVAC can be adjusted to give similar results.

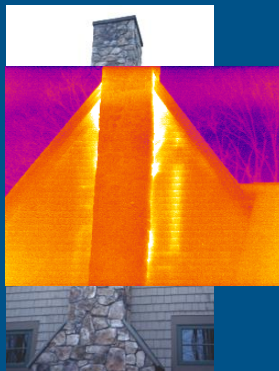


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Exfiltration

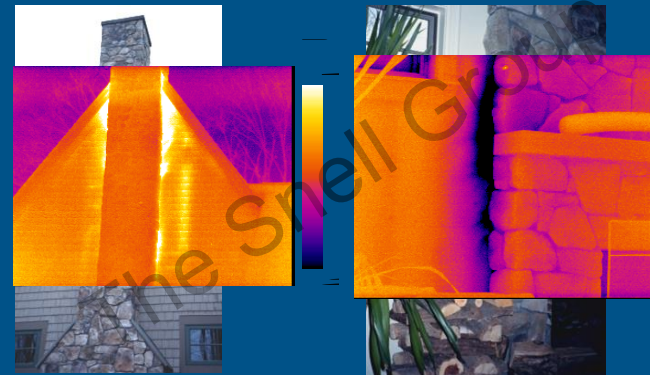


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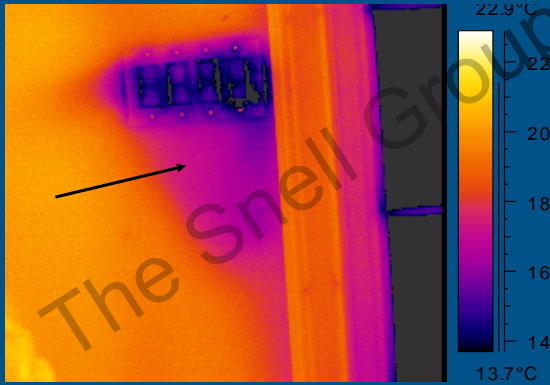
Exfiltration & Infiltration



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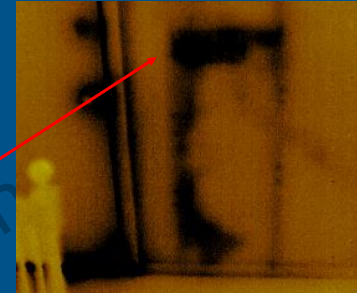
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Infiltration through fiberglass insulation at electrical receptacles and wiring.

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Running Blower Door

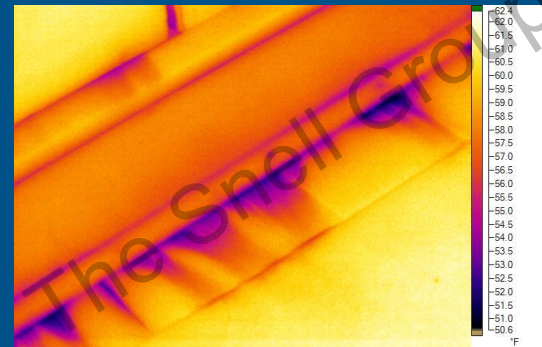


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Running Blower Door

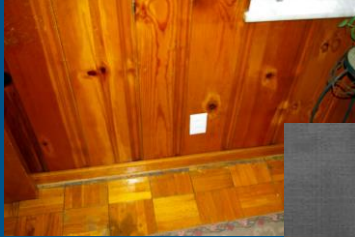


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Running Blower Door



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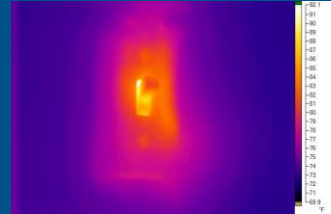
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Electrical Inspections - Residential



- Be "thermally aware" of your surroundings



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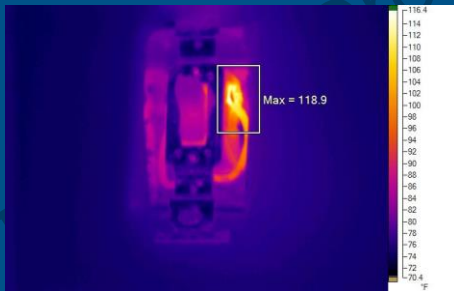
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Electrical Inspections - Residential



- A fire hazard? Why risk it! Have someone who is qualified investigate further.



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Normal Thermal Patterns



- However, you will always encounter electrical components in a residence that are normally warm.



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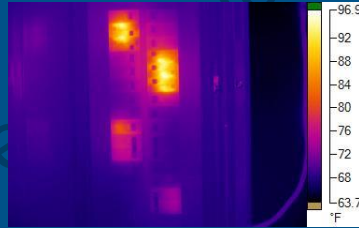
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Normal Thermal Patterns???



- Load?
- Breaker Type?
 - Standard
 - GFCI
 - AFCI
- What is the circuit feeding?
- Warm doesn't necessarily mean you have a problem.

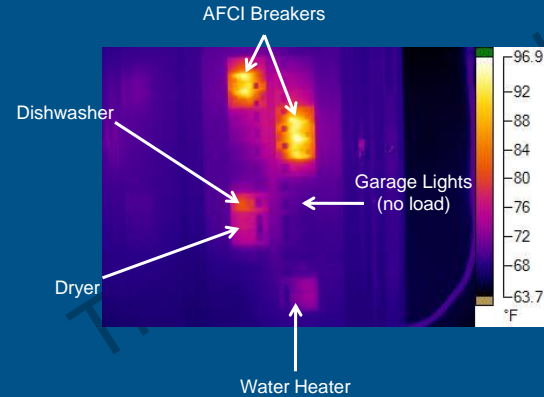


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Yes...Normal Thermal Patterns



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Roof Moisture Inspections



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Why Use Infrared?



- Locates the moisture trapped in insulation
 - Survey may not locate exact point of entry
 - Leak is typically associated with wet insulation
- IR is much faster than other technologies
 - Nuclear (shown right) or capacitance
 - These can be used to confirm moisture
- 100% coverage of the roof surface
- Can be done from the air for large or complex roofs.

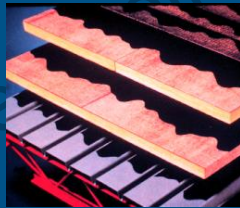


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Built-up Roof (BUR) Construction



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Insulation Types



- Absorbent types
 - Perlite
 - Wood fiber
 - Fiberglass
- Most often used in BURs and modified bitumen roof systems.



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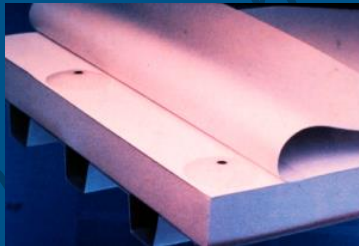
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Insulation Types



- Slow Wetting Insulation
 - Urethane
 - Isocyanurate
 - Styrofoam
 - Poly-urethane foam (PUF)
- Most common in single-ply roofs.



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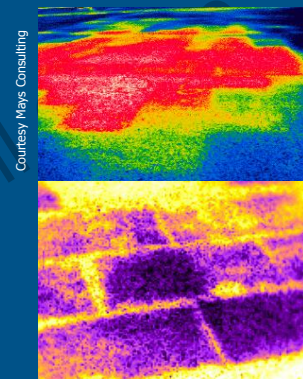
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The Two Common Patterns



- Board-stock pattern (absorbent)
- Picture-frame pattern (slow-wetting)



Courtesy Mays Consulting

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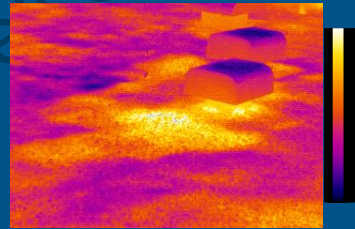
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Absorbent Insulation



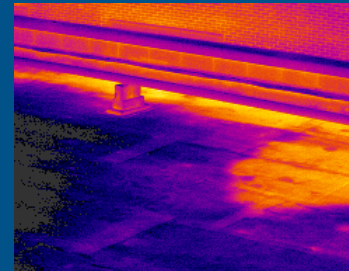
- Board-stock patterns



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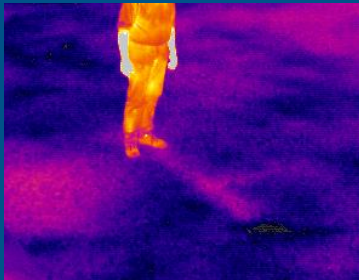


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Slow-Wetting Insulation



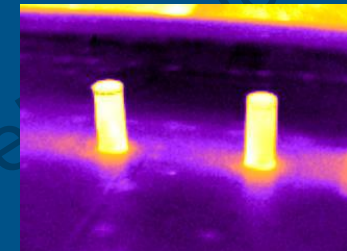
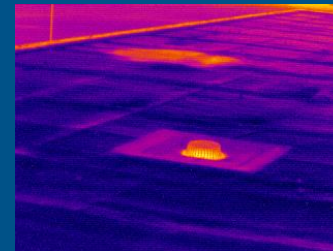
- Single-ply systems typically use slow-wetting insulations
 - Picture-frame pattern
 - Patterns are often indistinct
 - Pattern may come and go rapidly.

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Other Thermal Patterns



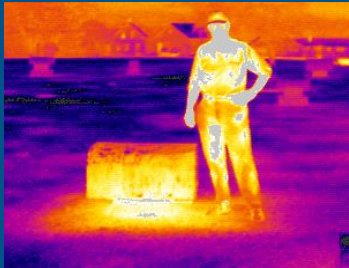
- Drains and vents

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Other Thermal Patterns



- Warm/cold air exhausting onto the roof

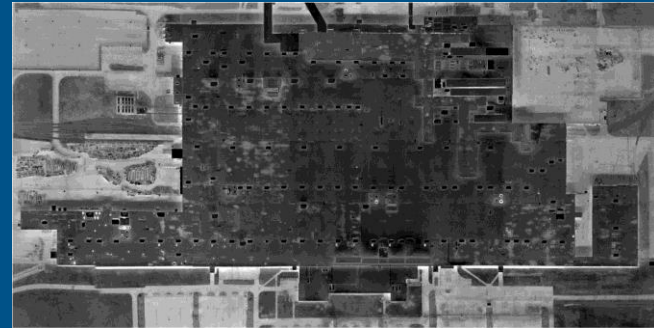


- Structural elements

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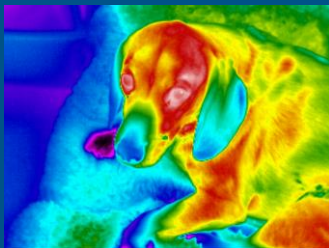


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Questions?



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