IR Cameras and Building Insulation Performance

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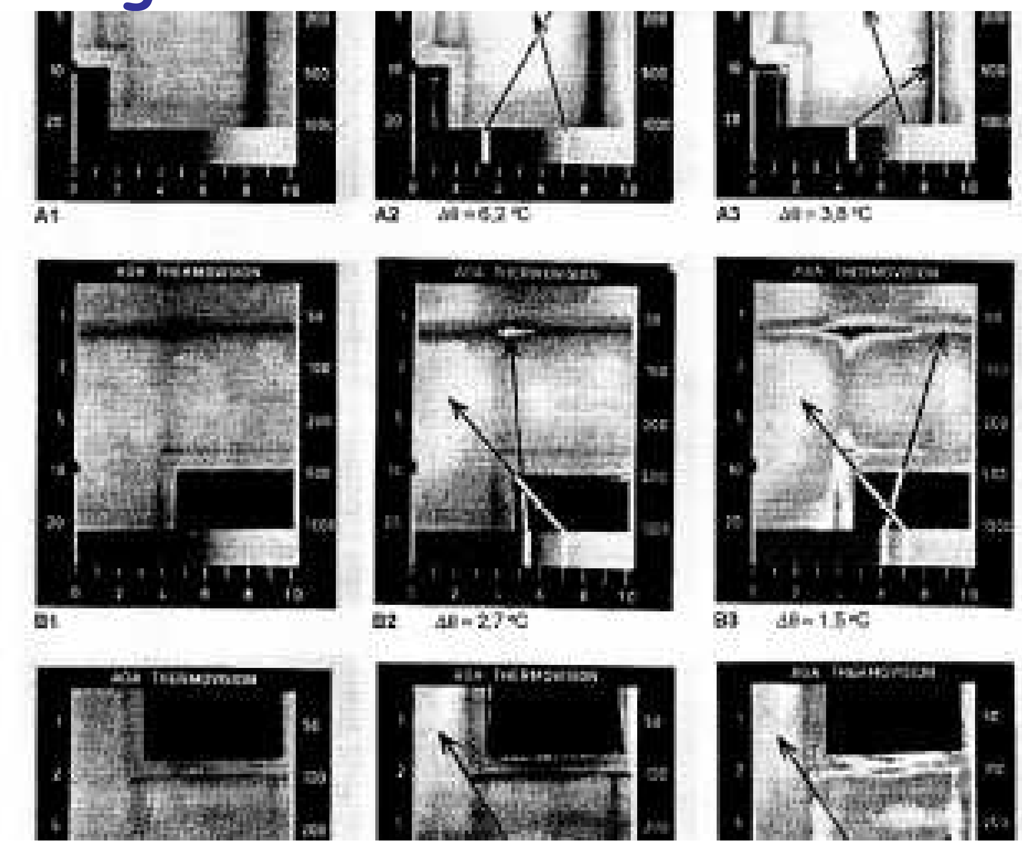
FLIR Systems, Inc

Cameras

Some cameras are simply easier to use!!!

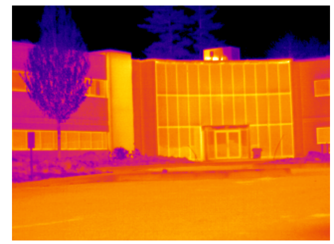
Camera

Sample Images from AGA 680 Circa 1972

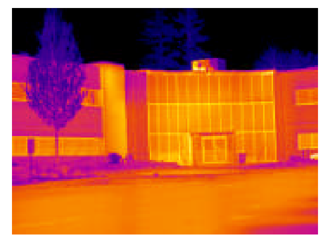


Camera Detectors

1 IR Image



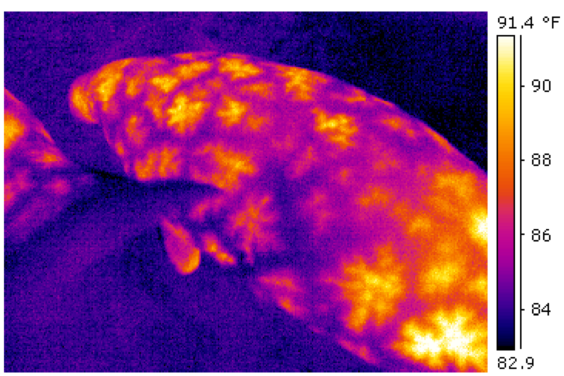
4 IR Images
(1/2 the distance to get same resolution)

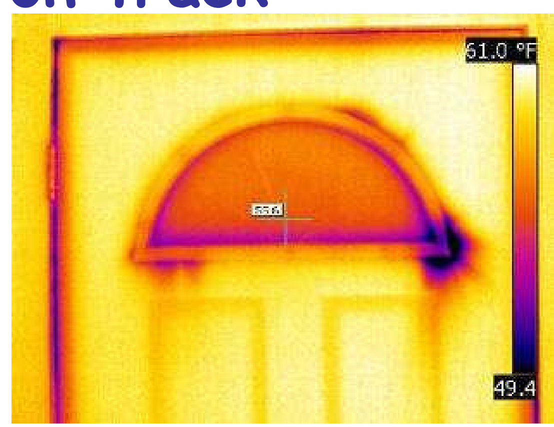


16 IR images
(1/4 the distance to get same resolution)

Sometimes you can't make it simple

- IR images are easy to get, often difficult to interpret
- The obvious isn't always obvious
- Don't try to make IR easy with simple (but wrong) shortcuts
- Good training can keep you on track





IR is Magic

- Just point the IR camera at a target
- Move the tool to where you want it
- Get an accurate temperature
- It's that easy

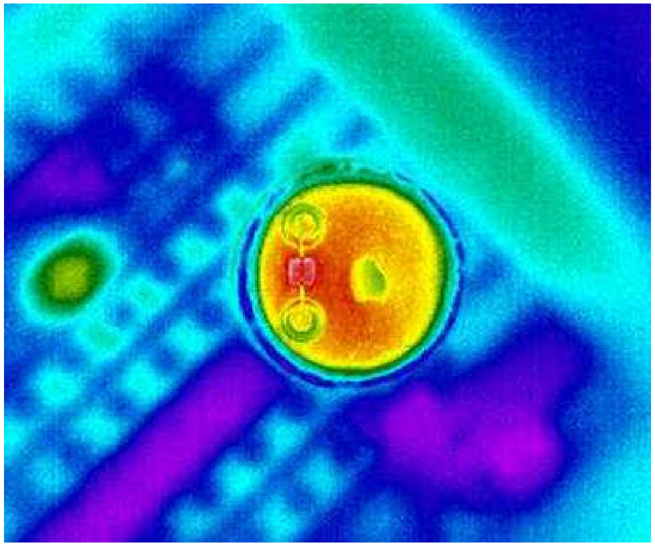
Or is it?

Thermographic Cameras

- Must be within a correct distance
- Must be focused thermally and optically
- Must enter measured object emissivity
- Must enter reflected temperature
- Must be in the correct range

Target Resolution or Spot Size

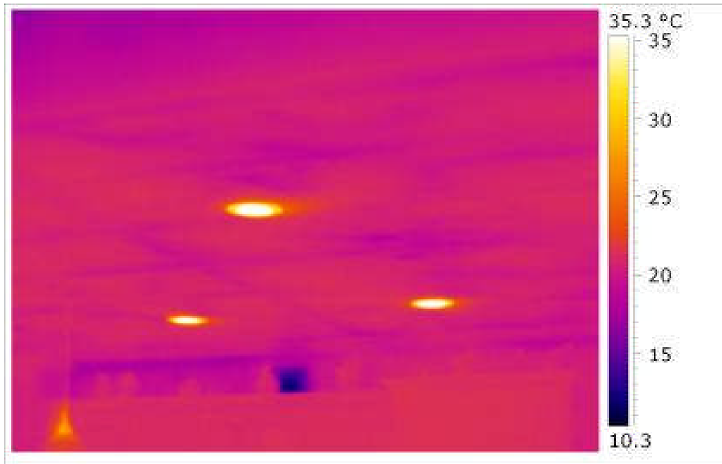
Small targets



Large targets

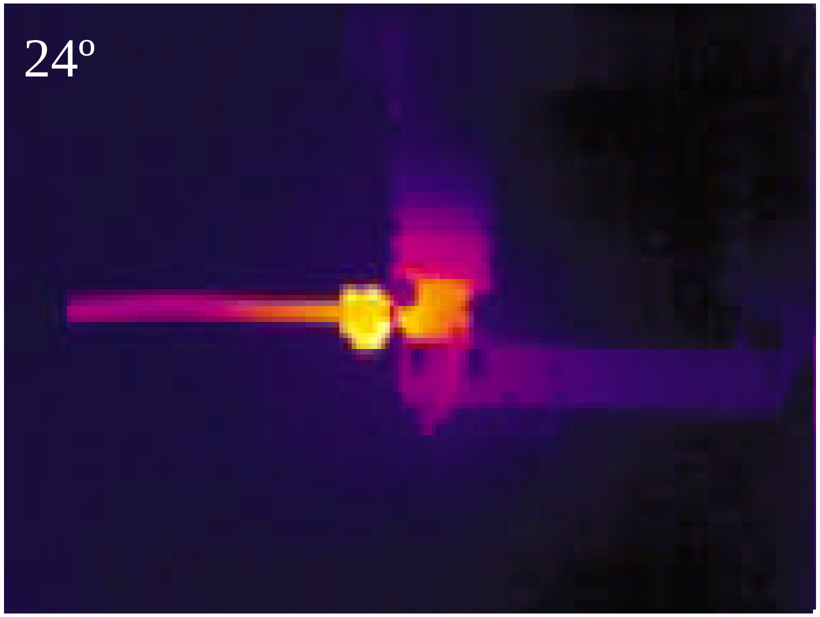
Thermal Tuning and Focus

Proper Tuning



Inadequate Tuning

Lens Change for Distance

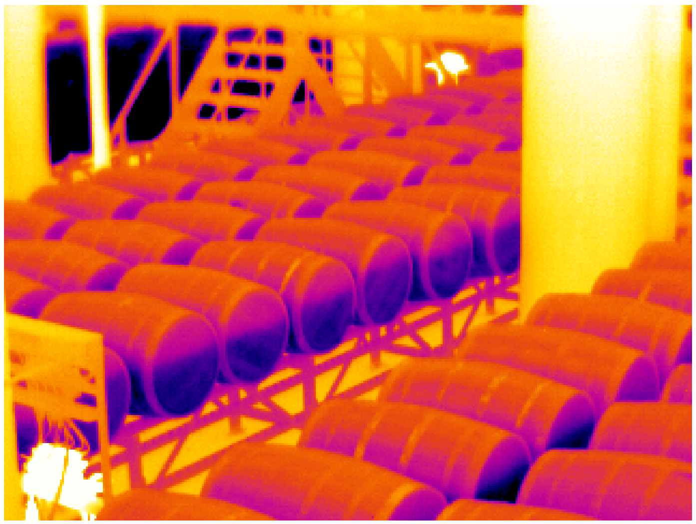


Some cameras are able to change lenses to assist resolution.

Thermal Emissivity

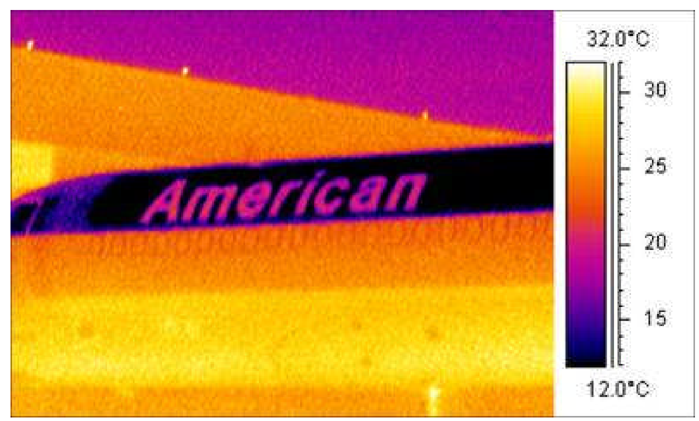
- Efficiency of an object as a radiator of heat
- For opaque objects: Emissivity (ε) plus reflectivity (ρ) equals one
- High ε means low ρ and vice versa

Target Surfaces

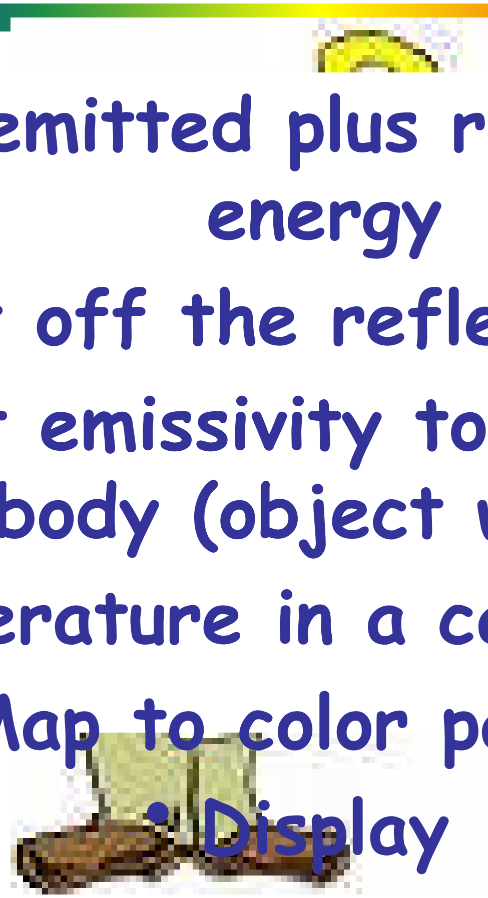


Wood Barrels – High Emissivity

Shiny Metal – High Reflective



IR Camera Workings

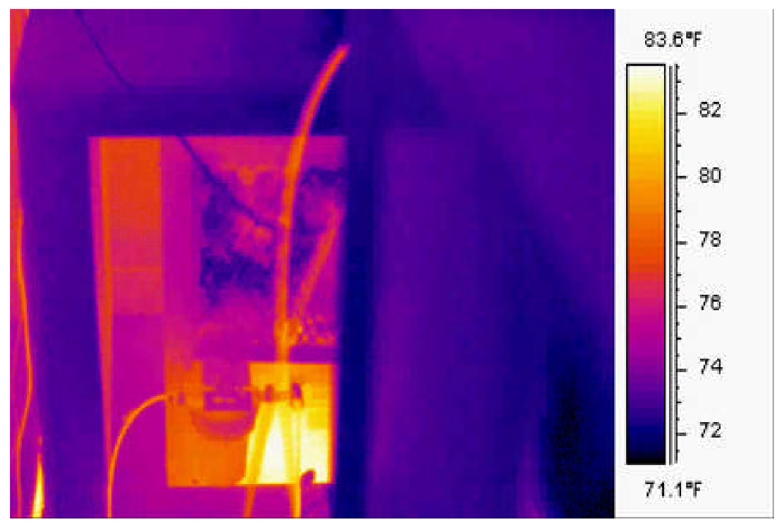


- Capture emitted plus reflected heat energy
- Subtract off the reflected energy,
- Use object emissivity to normalize to a blackbody (object with ε=1),
- Find temperature in a calibration table
- Map to color palette
- Display

Target Interpretation

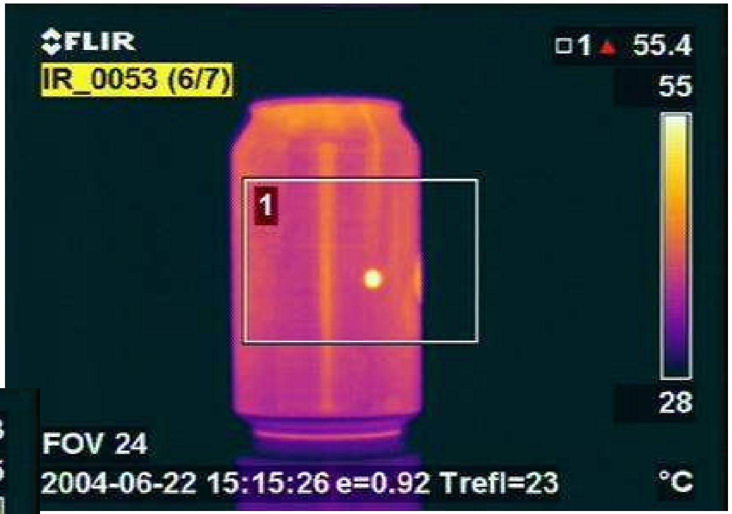
Still or static

Moving or dynamic



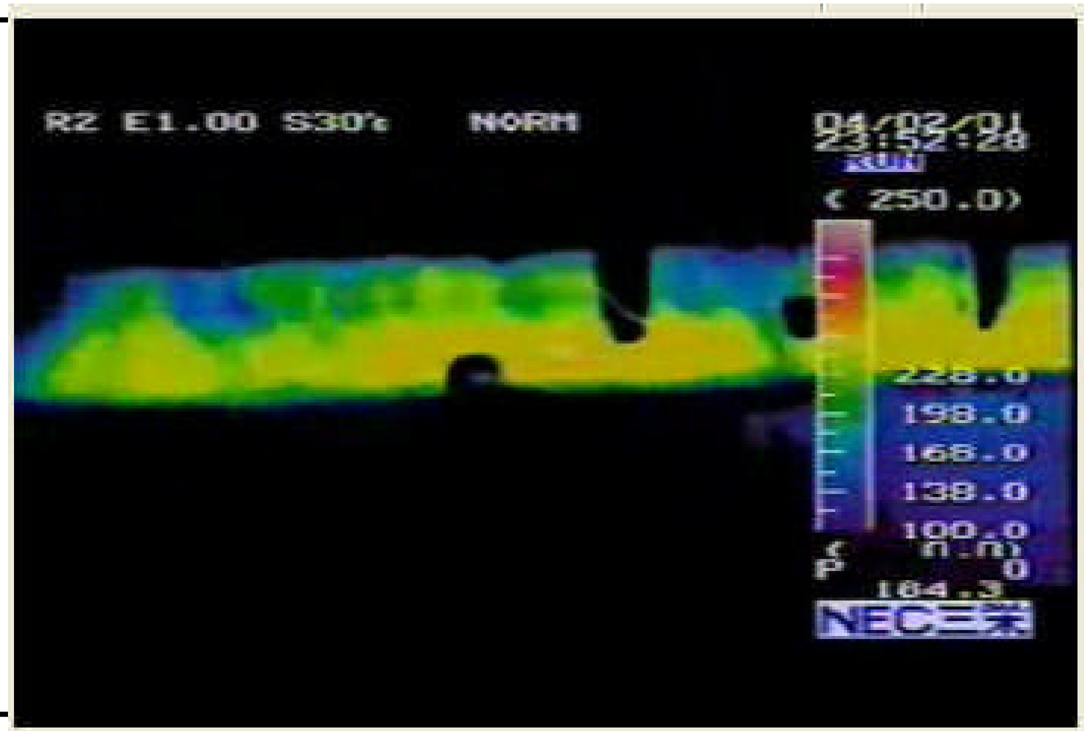
Focus

Focused =
Accurate



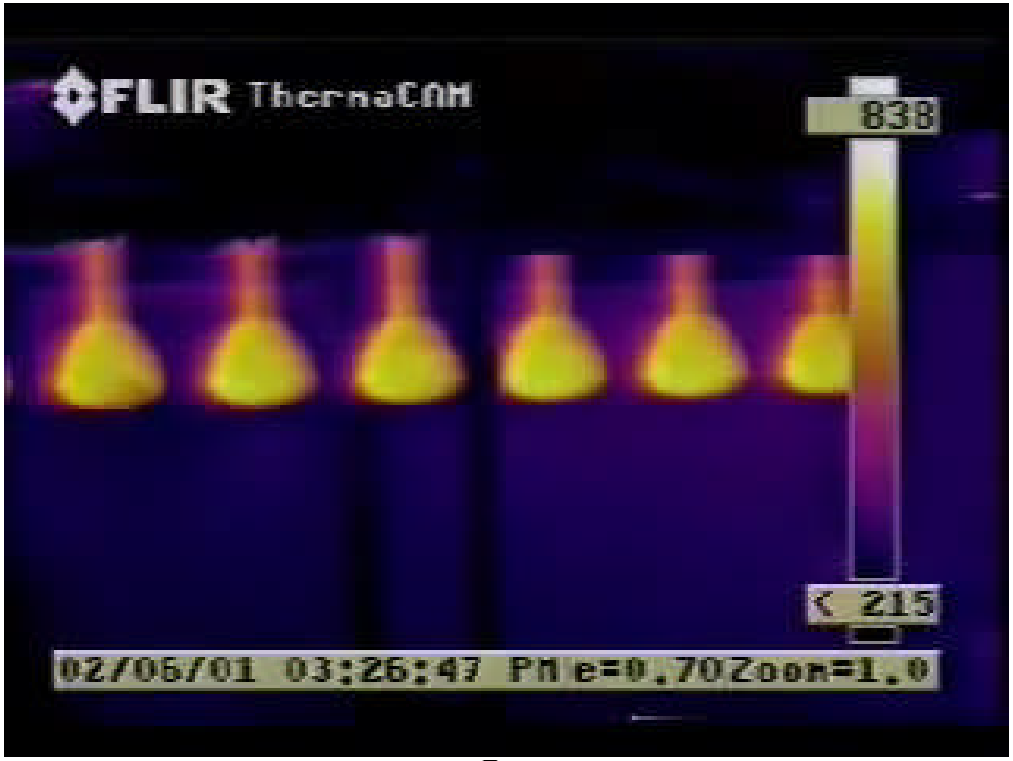
Unfocused =
Inaccurate

Scan Rate



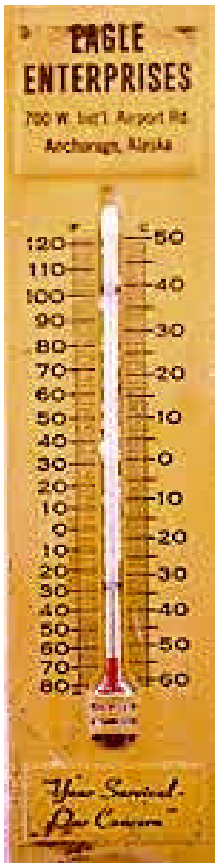
Too Slow

Scan Rate



Better

Environmental Accuracy



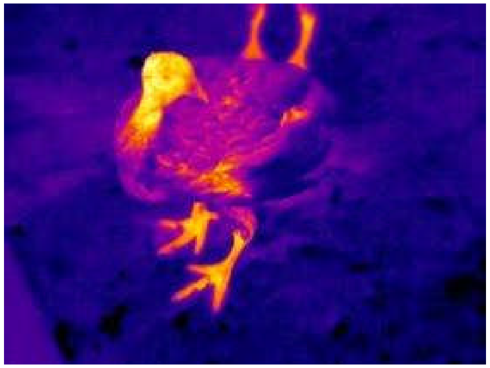
From this

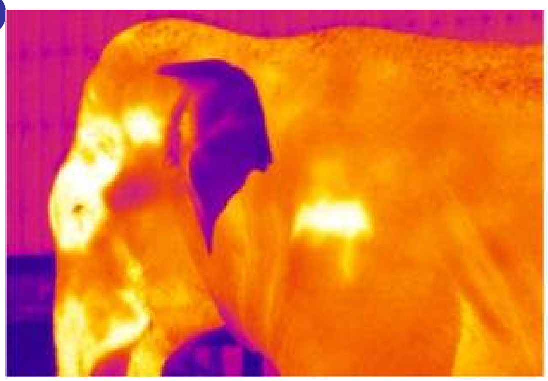
To this

Camera should remain accurate through it's entire operating range

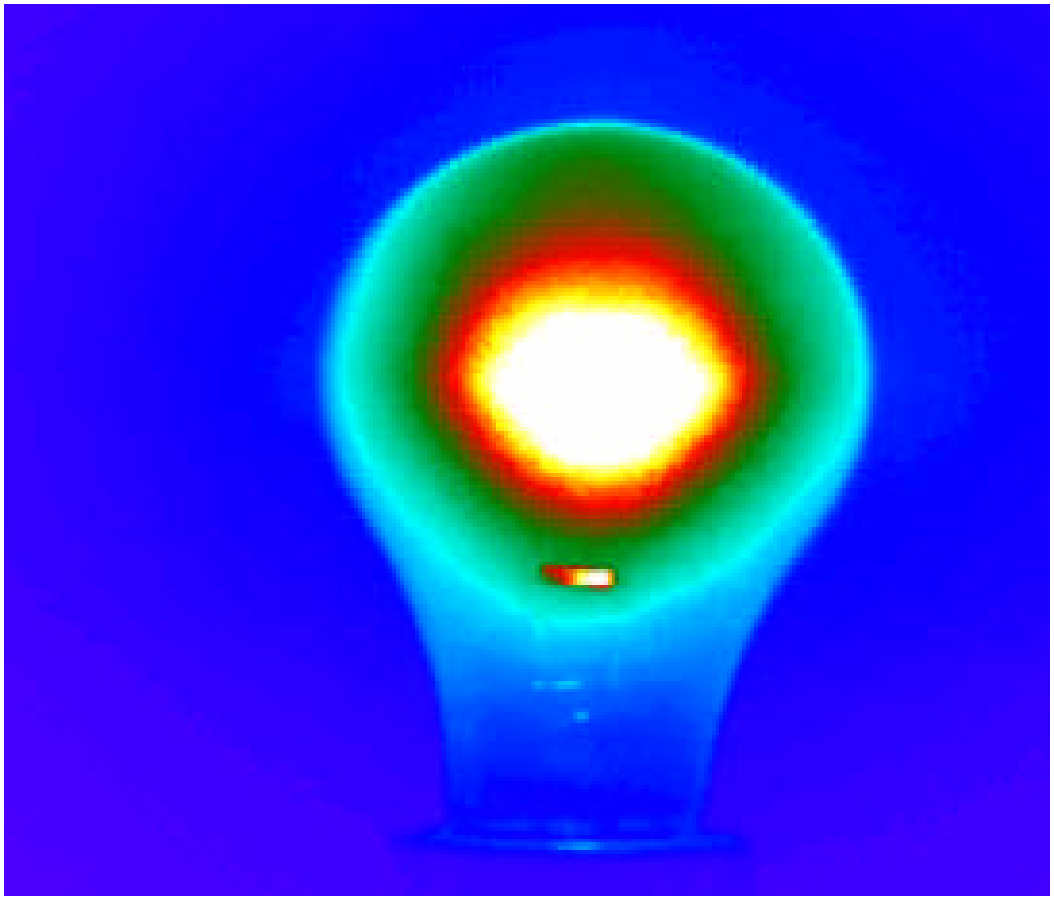
Review

- Today's cameras are easy to operate
- Understanding IR is as important as understanding your equipment
- You need proper training to be a thermographer
- Experiment!
- Practice!





Need Ideas?



Typical Existing Homes

Use Of IR/Thermal Camera For…

- Building Shell Analysis:
  - Identifying framing and insulation integrity of the building envelope
  - Air leakage out of and movement through the building shell
- QA/QC of Corrective Measures
  - addressing Building Shell issues
    - (i.e. installation of insulation and infiltration reduction measures)

Viewing Thermal Images Of Buildings

- Image is only the surface temperatures of object in picture (but beware!)
- It is the effect of the materials beneath the surface on the surface temperature that make you think you are seeing through materials. You may think you see an image of something beneath the surface but you are viewing the surface only.
- It is our ability to interpret the images and the information that is of value!

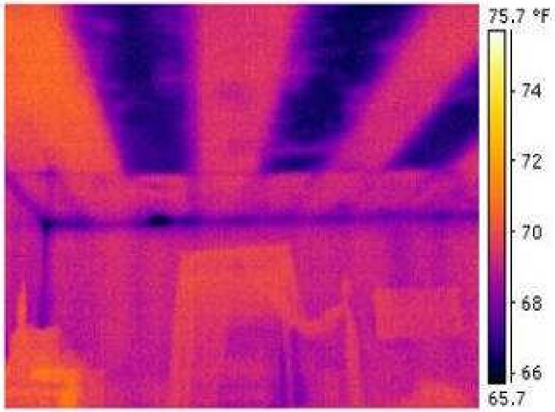
Use Caution When Evaluating Exterior Wall Images

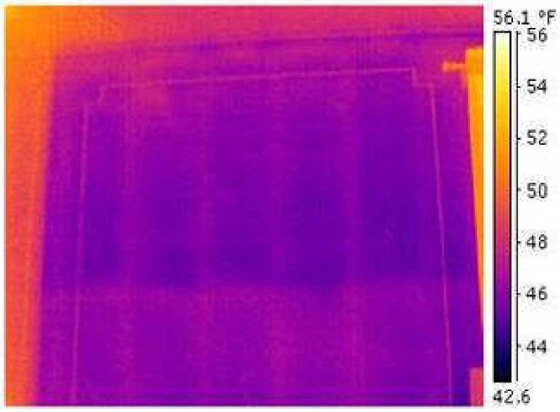
- Insulating sheathing materials can skew interpretation by moderating the surface temperature of the interior wall. This is particularly true with a brick façade.
  - Examples of Insulating Sheathing:
    - Urethane Panels
    - Celetex
    - Extruded Polystyrene
- BOTTOM LINE: You still need to do selective sampling to physically determine what is in the wall cavity!!!

Analyzing Shell Framing And Insulation

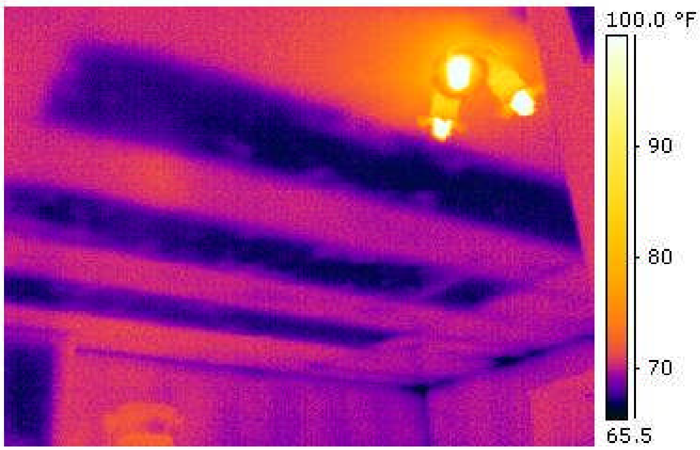
- Look For Inconsistencies In The Thermal Boundary
  - Images show how framing appears when observed with the IR/Thermal camera
  - In a well insulated wall, the framing may not be as obvious. However, you will notice a dark line where 2 or more surfaces meet (wall – ceiling, wall-wall, and at corners). This is common point of thermal boundary issues leading to ice damming and moisture issues.

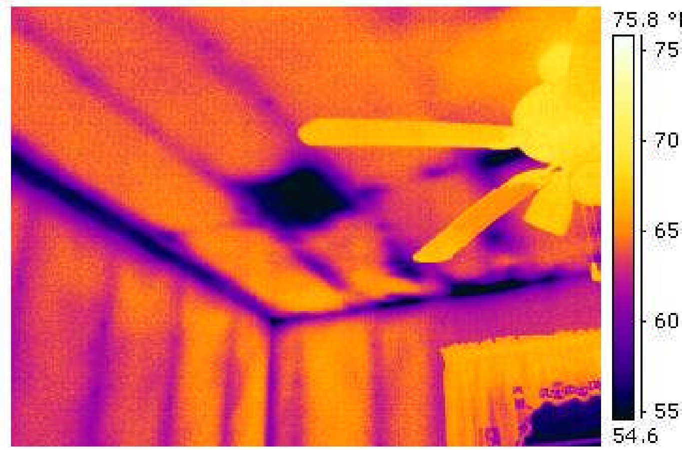
Walls And Ceilings



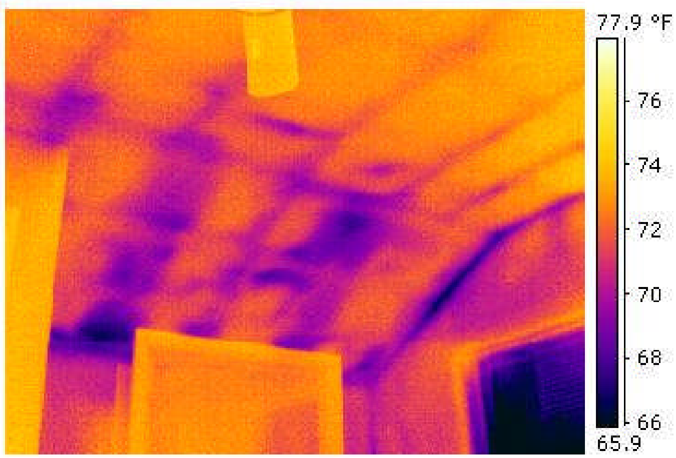


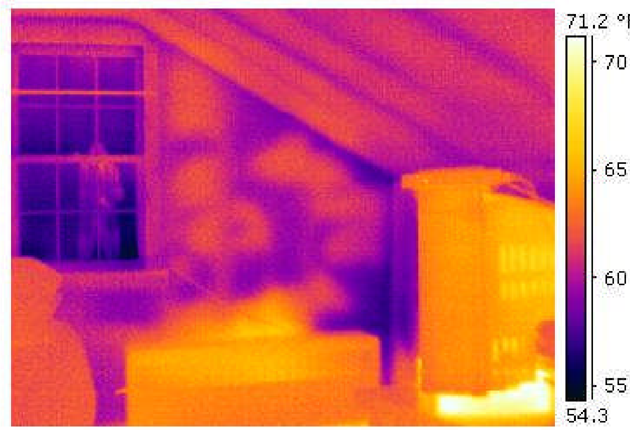
Missing Insulation Is Evident With The IR Camera



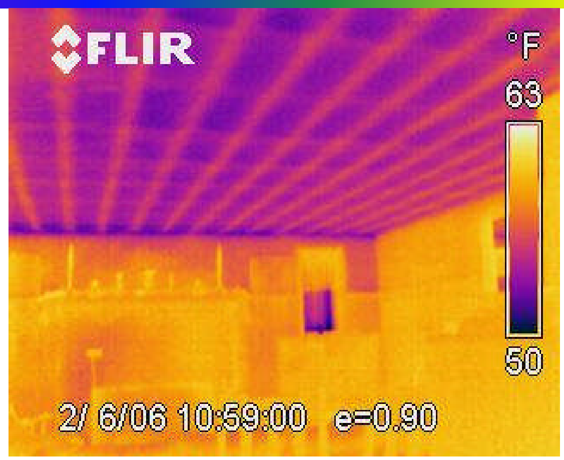


Poorly Installed Fiberglass Batt and Blown Insulation





No Insulation In Attic



Dormers!

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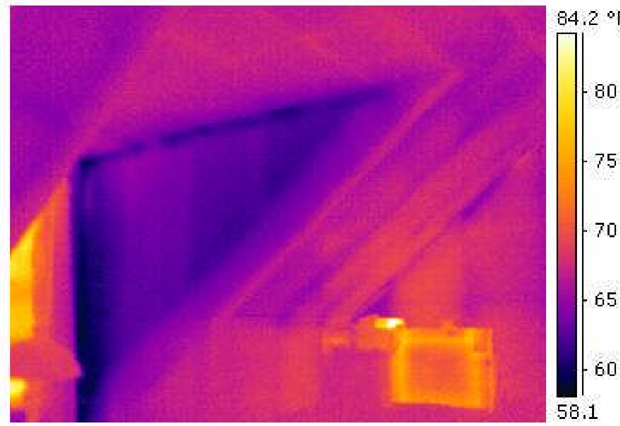
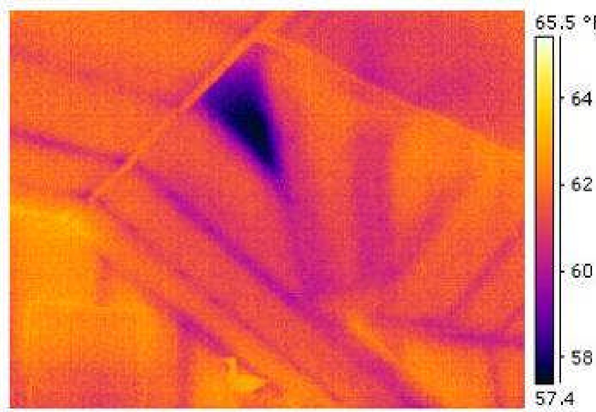
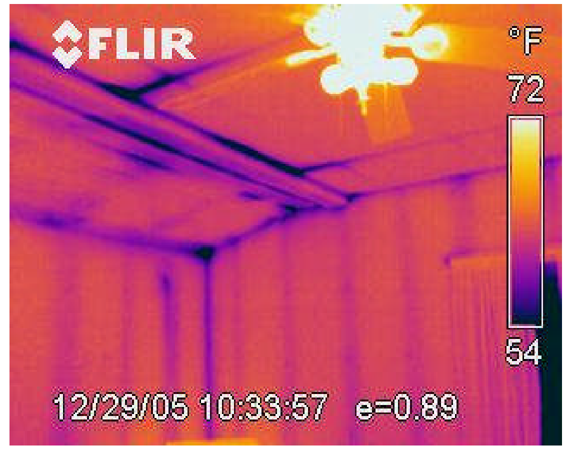


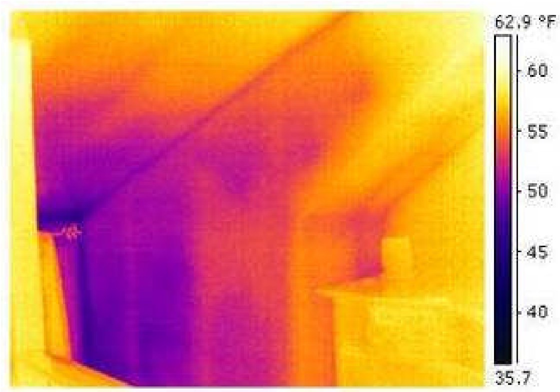


Knee Walls

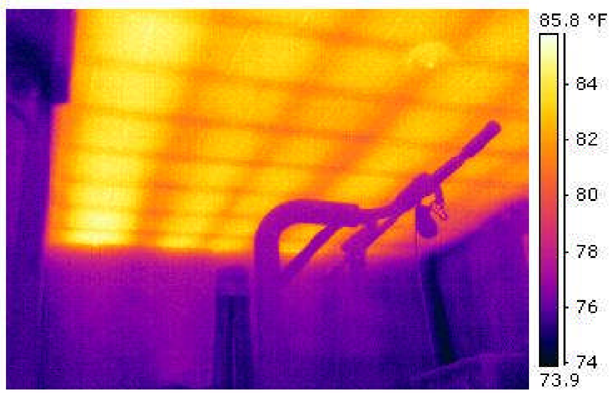

FLIR
°F
84
61

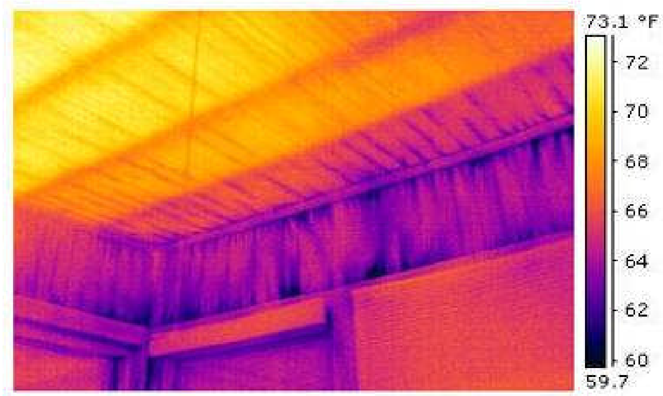

FLIR
°F
72
54
12/29/05 10:33:57 e=0.89


69.1 °F
65
60
55.4


62.9 °F
60
55
50
45
40
35.7

Flat Roof Images





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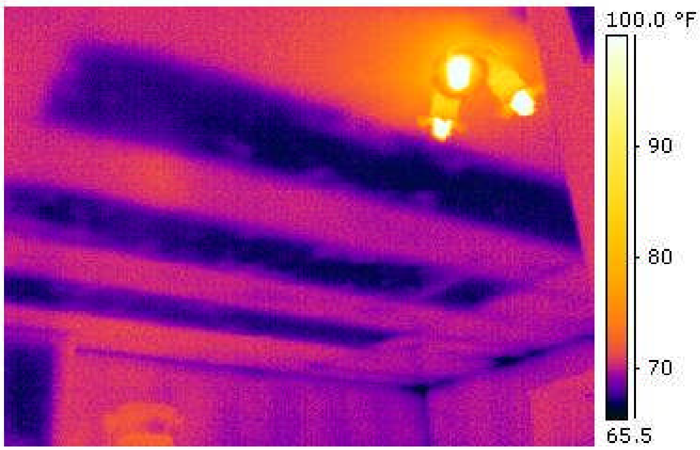

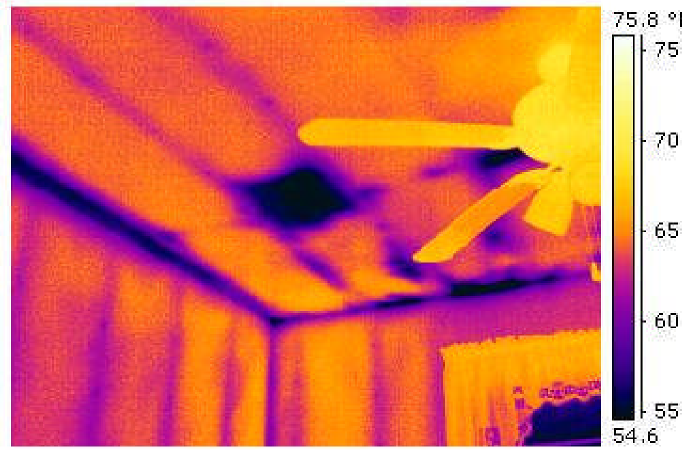

Attic Hatches

- The top image is a pull-down stairway.
- The bottom image is also a pull-down staircase.
- Why are these images different?

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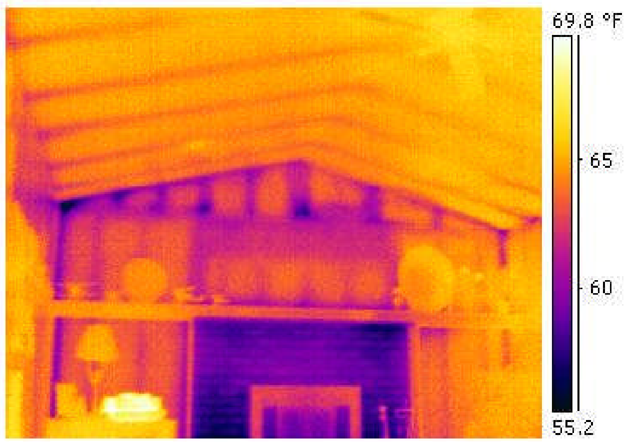
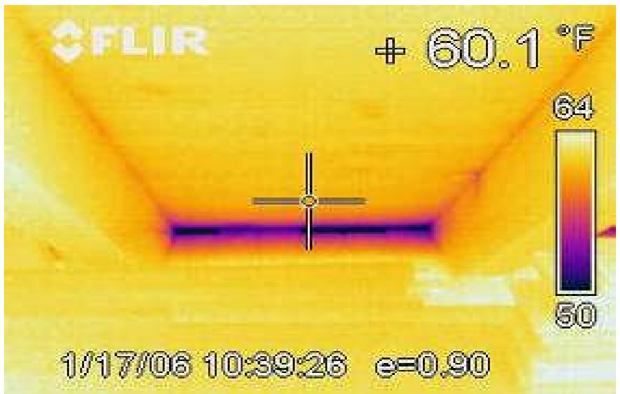
Fireplaces And Intersections With Exterior Walls

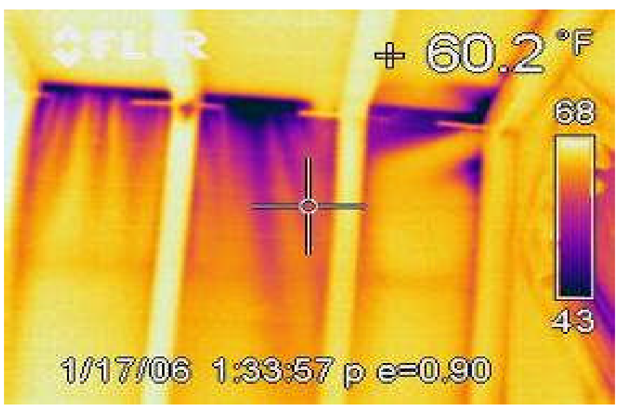


Air Infiltration = Heat Exfiltration

- Common sources of air infiltration or Stack Effect of a Residential home:
  - Around Doors
  - Balloon Framing
  - Rim Joists at the top of Foundation Walls
  - Exterior Wall Outlets and Switches
  - Bath and Kitchen Exhausts
  - Vertical Intersection of Walls and Horizontal Intersection of Walls and Ceilings
  - Plumbing and Electrical Chases

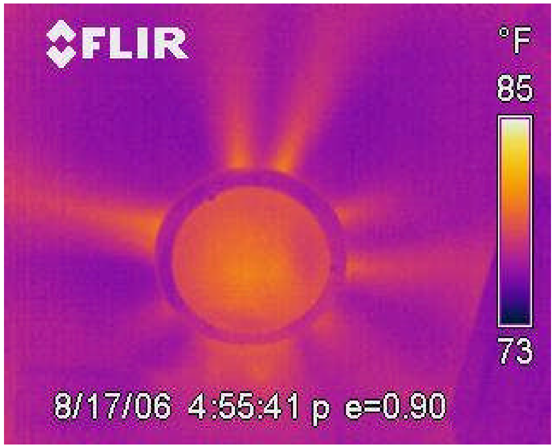
Air Infiltration:
With And Without The Blower Door

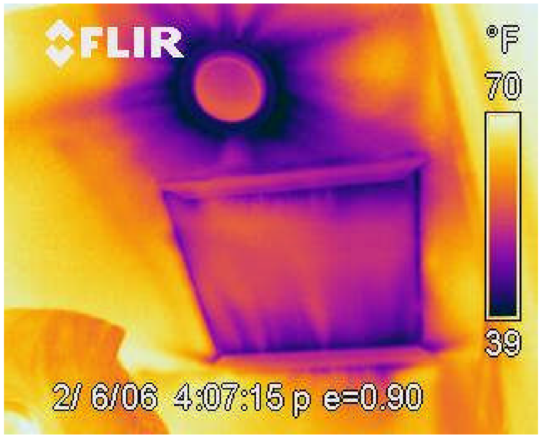


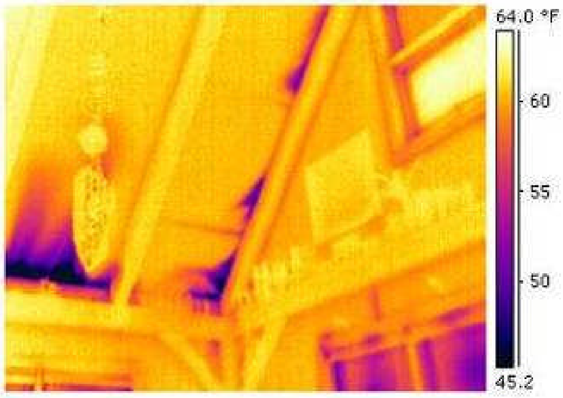


- Infrared image doesn't show air leakage at top of cathedral ceiling. Why?
- Because air leaking out shows no temperature difference from inside
- Use of a Blower door can aid in detecting air leaking out of a home
- With Blower door, air leakage becomes obvious because air leakage is reversed

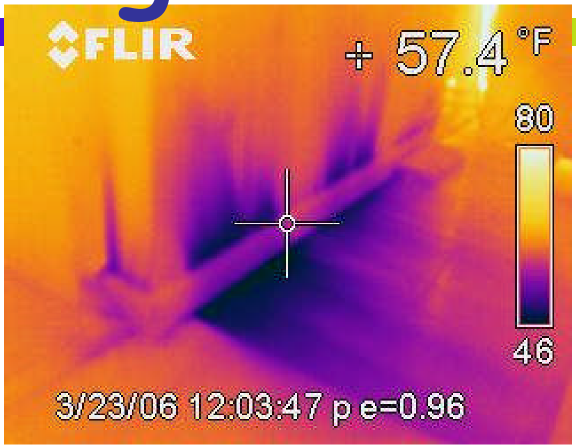
Blower Door Enhanced Images

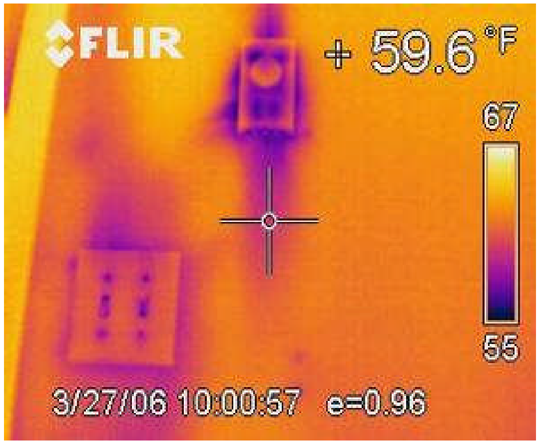






Blower Door Enhanced Images



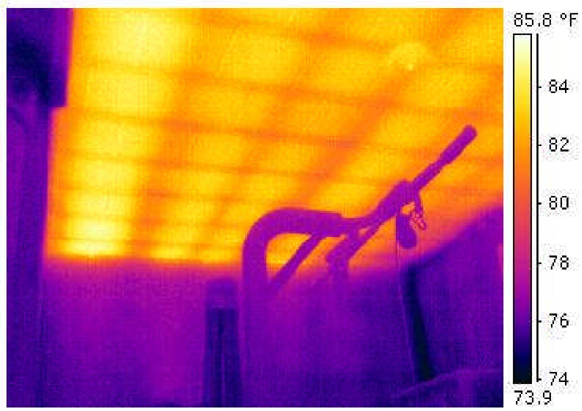


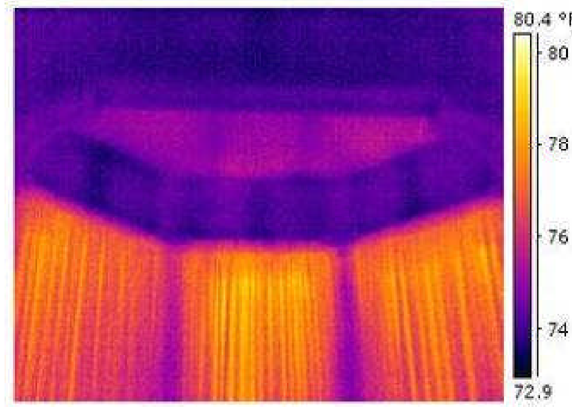
Images courtesy of Energy Construction, LLC.
Used with permission.

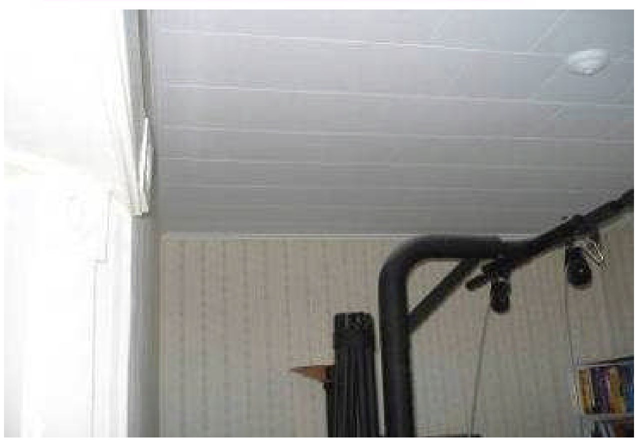
Its Not Always Winter!!!

- When outside temperature rise above indoor temperatures infrared images completely change.
- Exterior temperature differences will no longer be darker.
- Awareness of this is critical in making correct interpretations

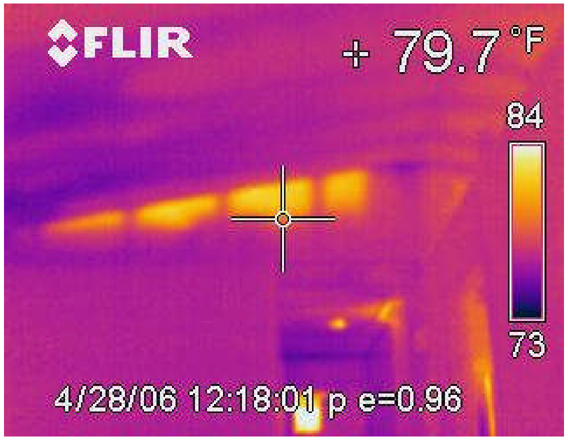
Summer Changes Everything







Wall And Ceiling Interface For Both Flat Ceiling And Cathedral Ceilings



Watch for "Solar Loading"

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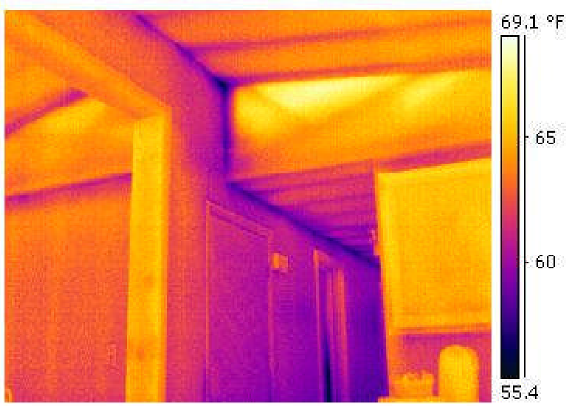
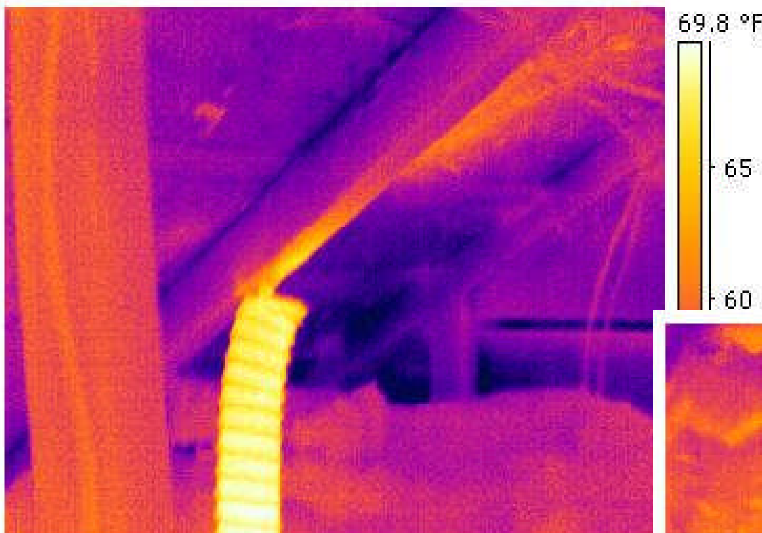
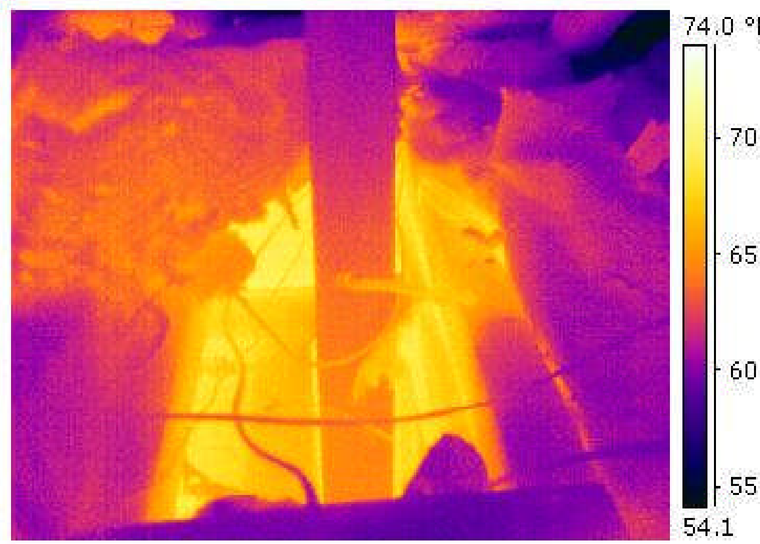
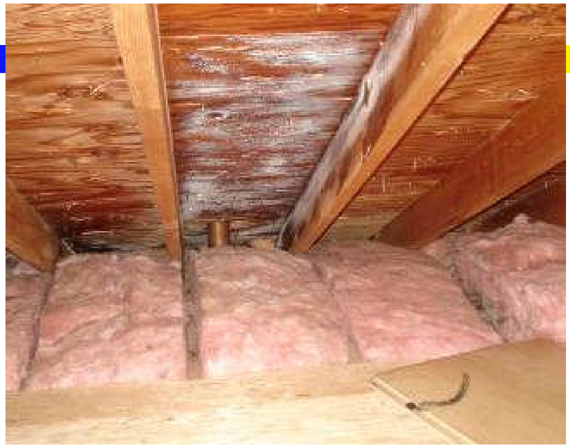


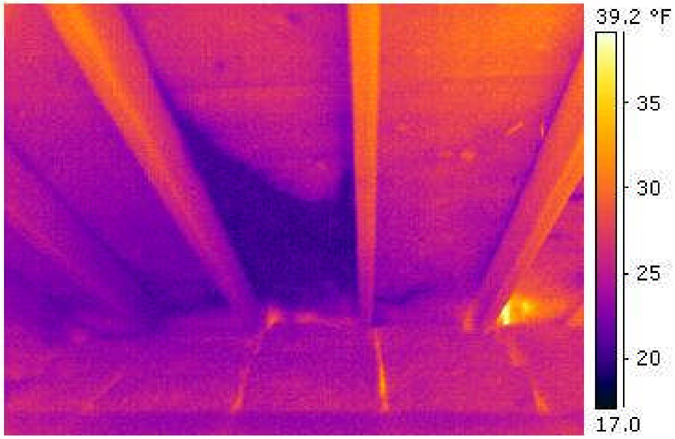
Heat And Moisture Escaping Into Attic



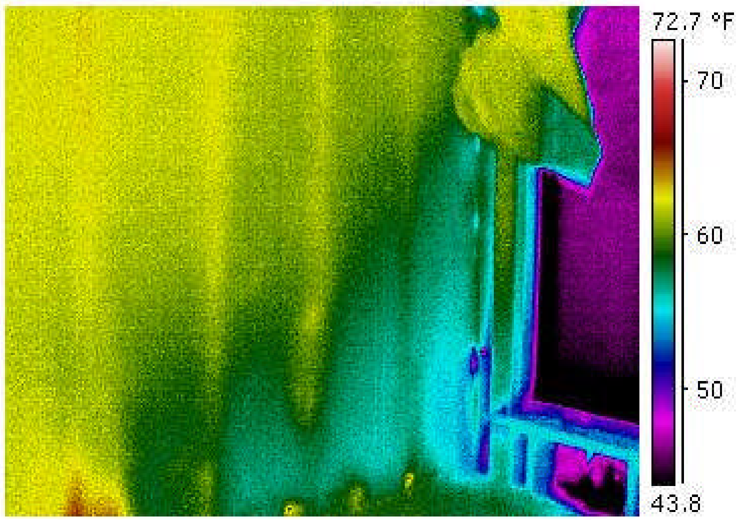


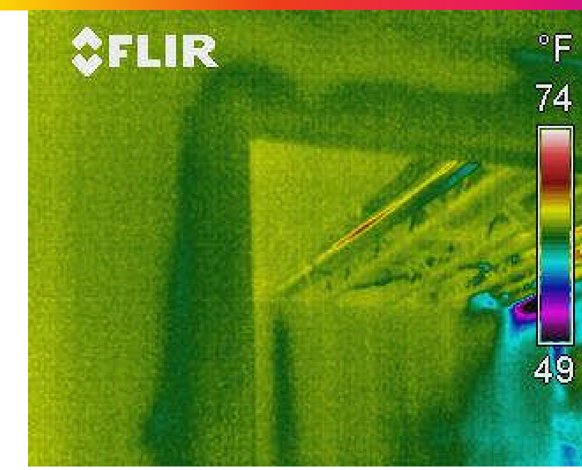
Moisture In An Attic



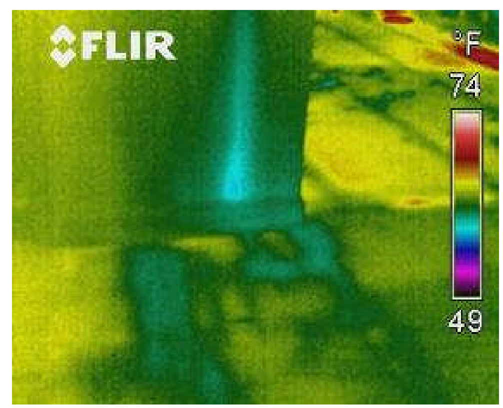


IR Camera Easily Identifies Moisture Within Building Materials

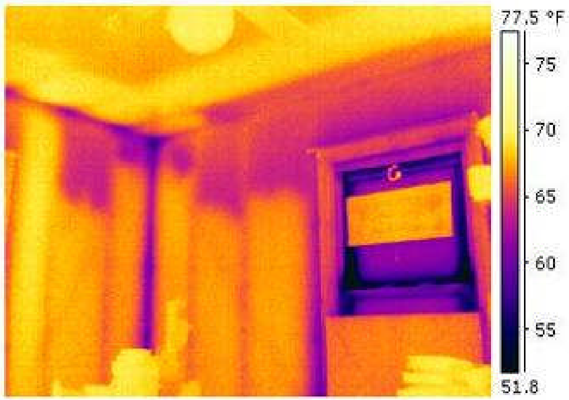


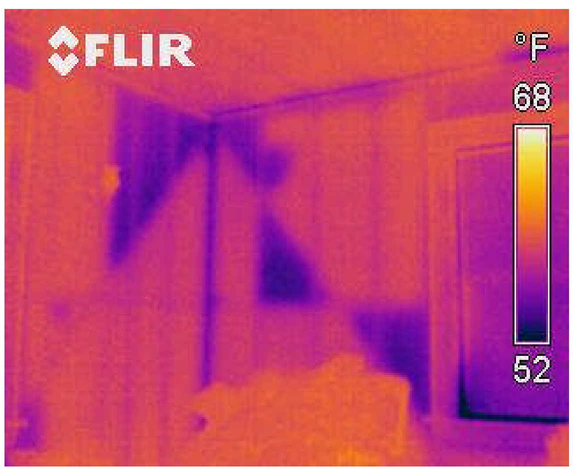


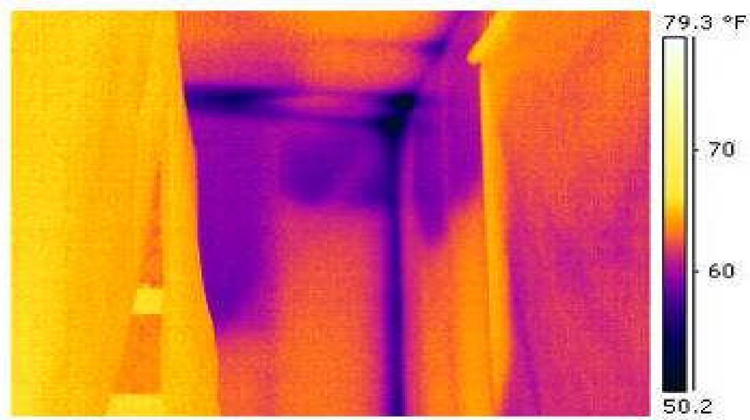
The key to remember is that moisture can be mistaken for cold air infiltration. Therefore, you have to validate those “dark” areas for the presence of moisture!!!



Improperly Blown & Differential Settling of Cellulose

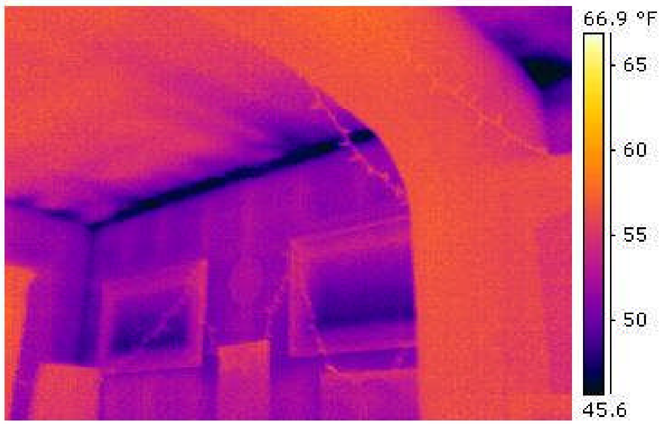


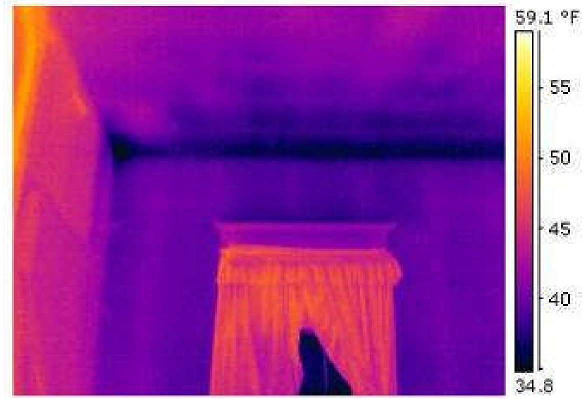




More Improperly Blown Wall Cavities

Check for Continuity of Thermal Boundary And Eliminate Problems "Down the Road"





Standards

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C1153.5035-1 Location of Wet Insulation in Roofing Systems Using Infrared Imaging

C1060.5903-1 Thermographic Inspection of Insulation Installations in Envelope Cavities of Frame Buildings

E1186.6605-1 Air Leakage Site Detection in Building Envelopes and Air

ASTM INTERNATIONAL Designation: C 1060 – 90 (Reapproved 2003)

Standard Practice for
Thermographic Inspection of Insulation Installations in Envelope Cavities of Frame Buildings[1]

This standard is issued under the fixed designation C 1060; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice is a guide to the proper use of infrared imaging systems for conducting qualitative thermal inspections of building walls, ceilings, roofs, and floors, framed in wood or metal, that may contain insulation in the spaces between framing members. This procedure allows the detection of cavities where insulation may be inadequate or missing and allows identification of areas with apparently adequate insulation.

1.2 This practice offers reliable means for detecting suspected missing insulation. It also offers the possibility of detecting partial-thickness insulation, improperly installed insulation, or insulation damaged in service. Proof of missing insulation or a malfunctioning envelope requires independent validation. Validation techniques, such as visual inspection or *in-situ R*-value measurement, are beyond the scope of this practice.

1.3 This practice is limited to frame construction even though thermography can be used on all building types.[2,3]

1.4 Instrumentation and calibration required under a variety of environmental conditions are described. Instrumentation requirements and measurement procedures are considered for inspections from both inside and outside the structure. Each vantage point offers visual access to areas hidden from the other side.

1.5 The values stated in SI units are to be regarded as standard. The inch-pound units given in parentheses are for information only.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* In particular, caution should be taken in the handling of any cryogenic liquids or pressurized gases required for use in this practice. Specific precautionary statements are given in Note 1 and Note 3.

2. Referenced Documents

2.1 *ASTM Standards:*
C 168 Terminology Relating to Thermal Insulation[4]
E 1213 Test Method for Minimum Resolvable Temperature Difference for Thermal Imaging Systems[5]

3. Terminology

3.1 *Definitions*—Definitions pertaining to insulation are defined in Terminology C 168.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *anomalous thermal image*—an observed thermal pattern of a structure that is not in accordance with the expected thermal pattern.

3.2.2 *envelope*—the construction, taken as a whole or in part, that separates the indoors of a building from the outdoors.

3.2.3 *field-of-view (FOV)*—the total angular dimensions, expressed in degrees or radians, within which objects can be imaged, displayed, and recorded by a stationary imaging device.

3.2.4 *framing spacing*—distance between the centerlines of joists, studs, or rafters.

3.2.5 *infrared imaging system*—an instrument that converts the spatial variations in infrared radiance from a surface into a two-dimensional image of that surface, in which variations in radiance are displayed as a range of colors or tones.

3.2.6 *infrared thermography*—the process of generating thermal images that represent temperature and emittance variations over the surfaces of objects.

3.2.7 *instantaneous field of view (IFOV)*—the smallest angle, in milliradians, that can be instantaneously resolved by a particular infrared imaging system.

[1] This practice is under the jurisdiction of ASTM Committee C16 on Thermal Insulation and is the direct responsibility of Subcommittee C16.30 on Thermal Measurement.

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[2] *ISO/TC 163/SC 1/WG N31E Thermal Insulation—Qualitative Detection of Thermal Irregularities in Building Envelopes—Infrared Method*, available from American National Standards Institute, 25 W. 43rd St., 4th Floor, New York, NY 10036.

[3] *Guidelines for Specifying and Performing Infrared Inspections*, Infraspection Institute, Shelburne, VT, 1988.

[4] *Annual Book of ASTM Standards*, Vol 04.06.

[5] *Annual Book of ASTM Standards*, Vol 03.03.

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Standard Practice for
Location of Wet Insulation in Roofing Systems Using Infrared Imaging[1]

Standards

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- Time of day considerations (non sunny)
- Minimum temp differential (18F)
- Minimum distance to size of target or MFOV
- Wind speed considerations (none)
- Angle of view (perpendicular)

R Value

Thermal conductivity

	W / m K	BTU inch / hour-foot^2-°F
• Diamond (natural)	1000	6938.11
• Silver	429	2976.44
• Copper	401	2782.18
• Gold	293	2032.86
• Aluminium	237	1644.33
• Steel	50	346.90
• Ice	2	13.86
• Glass (window)	0.9	6.24
• Water	0.6	4.16
• Brick	0.18	1.24
• Snow	0.16	1.11
• Wood	0.14	0.97
• Fiberglas	0.04	0.27
• Styrofoam	0.03	0.20
• Air (still)	0.025	0.17
• Xenon	0.0051	0.03

Based on thermal conductivity

- Why are toilet seats cold even if the air in the bathroom isn't?
- Why can you hold your hands in a hot oven for the few seconds it takes to remove a roast without feeling any ill effects, but if you touch the roasting pan for even a split second you'll wind up with a burn?
- How did the Eskimos keep warm if they build shelters out of snow? Isn't snow cold?

Factors Affecting Conductivity

1. Type of material or k = (Thermal Conductivity)
2. Cross sectional Area or A
3. Path length or thickness of material or L
4. Temperature difference or T1-T2
5. Steady State conduction through a solid in 1 dimension

$$q = \frac{kA(T_1 - T_2)}{L}$$

Conductivity and R value

R value or thermal resistance

The higher the number the better insulator.

$$R = {}^{d}/_{k}$$

d = distance in inches

k = thermal conductivity in BTU inch/hour-foot^2-°F

Conductivity and R value

- If the **insulation material** has **k = 0.27** BTU inch/hour-foot^2-°F
- d = distance or the insulation depth (stud bay 3.5")

If $R = {}^{d}/_{k}$

Then:

- Insulation material has an R value of:
  3.5 inch/ 0.27 BTU inch/hour-foot^2-°F =
  R = 13(12.96) for 3.5" **insulation material**

Conductivity and R value

- If the **<u>wooden stud</u>** has **k** = 0.97 BTU inch/hour-foot^2-°F
- d = distance or the stud depth (stud 3.5")

If R=$^d/_k$

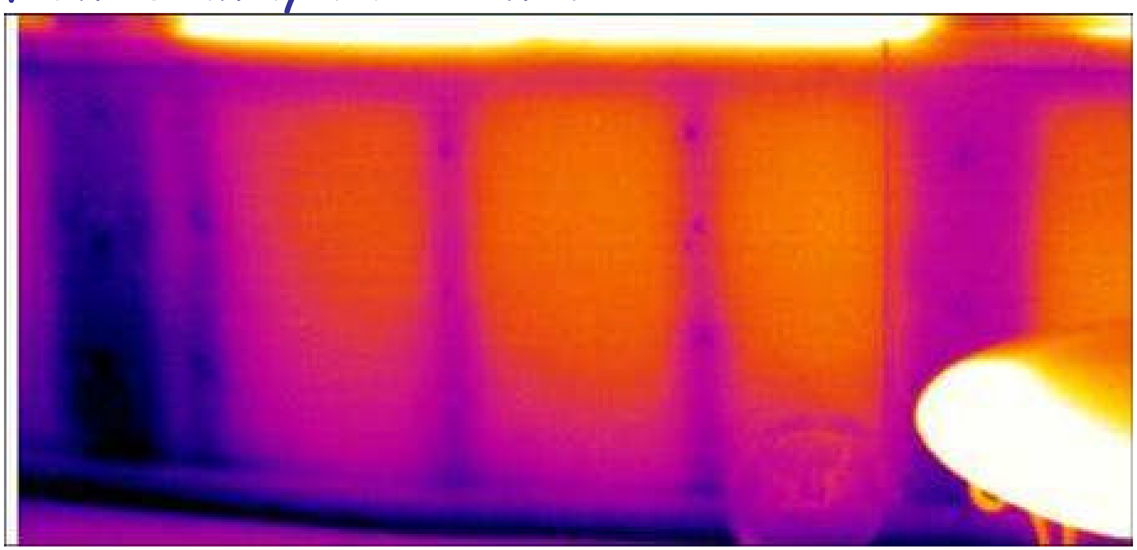
Then:

- Wooden stud has an R value of: 3.5/.97

R = 3.6 for 3.5" **<u>wooden stud</u>**

Conductivity and R value

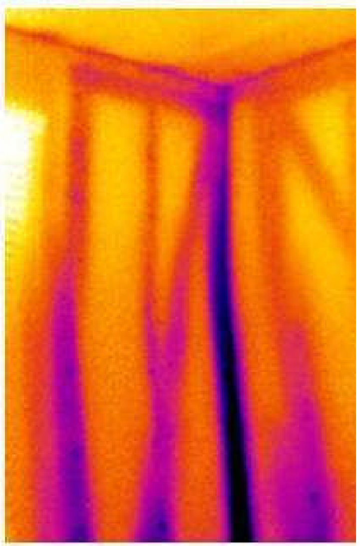
- Insulation material has k=.27 or R=13
- Wooden stud has k=0.97 or R=3.6
- Wooden studs conducts more energy than the insulation – appears cold on the inside when the heat flow is away the viewer



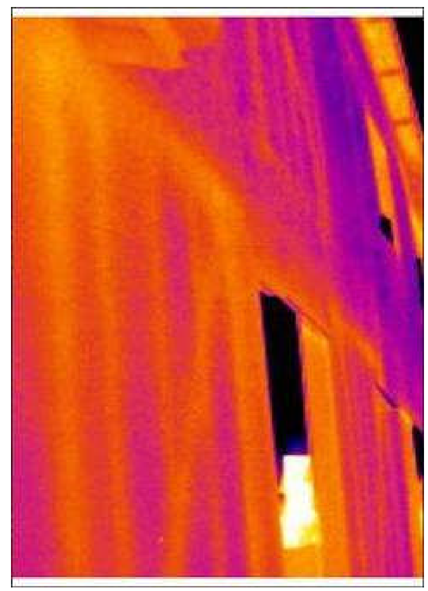
Conductivity

- Insulation material has a low k=.27
- Metal stud has a high k=346.9
- Metal studs conducts more energy than the insulation – appears cold on the inside

Cold on the inside?



Hot on the outside?



Example: Wall area

- Heated houses in winter, -10°F
- Same temperature inside, 70 °F
- Same wall thickness (4") and material (k=0.25)
- Small house: 1000 ft^2
- Big house: 4000 ft^2

$$q = \frac{kA(T_1 - T_2)}{L}$$

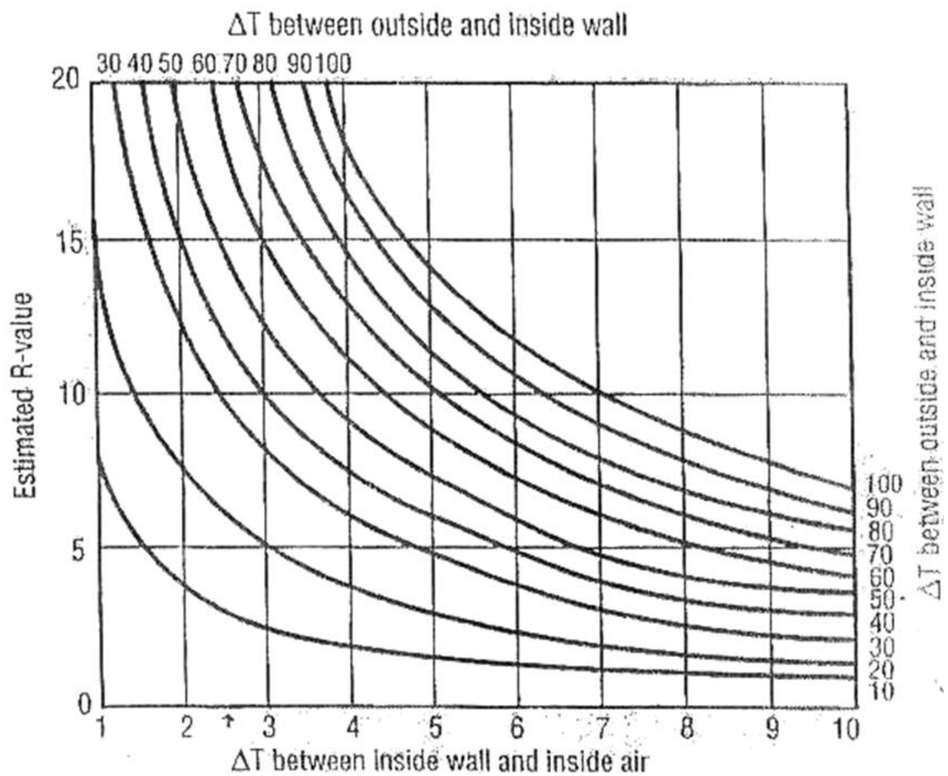
Example: Wall area

- Small house:
  - Delta T = 80F
  - L = 4"
  - k = 0.25 BTU inch/hour-foot^2-°F
  - A = 1000 ft^2
  - Result:

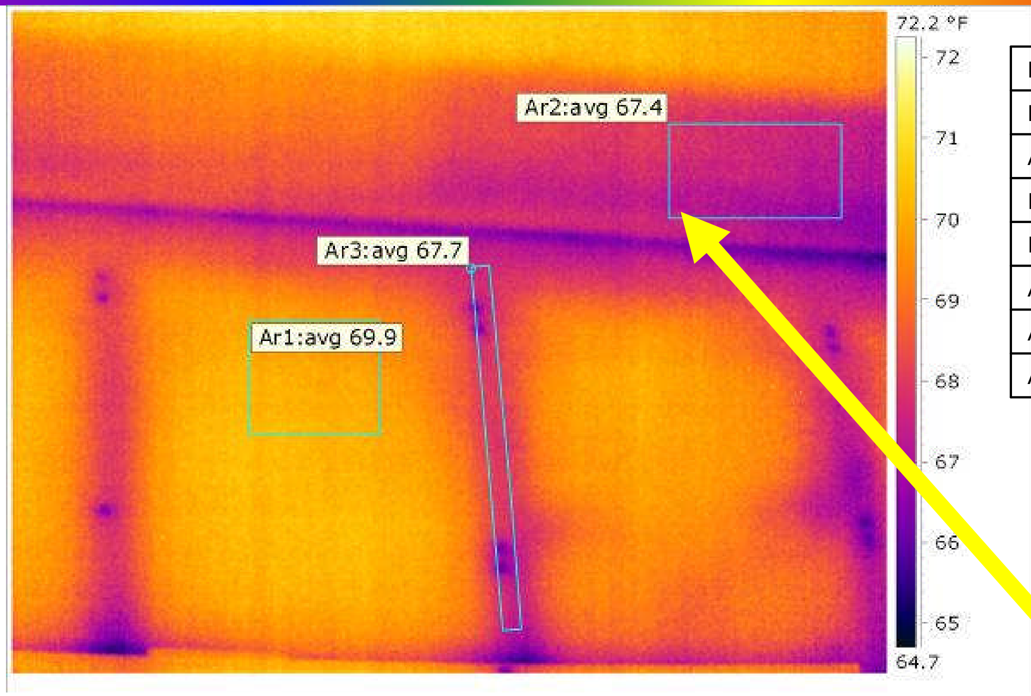
    The heat loss is 5,000 BTU/hr
- Big house:
  - Delta T = 80F
  - L = 4"
  - k = 0.25 BTU inch/hour-foot2-°F
  - A = 4000 ft^2
  - Result:
  - The heat loss is 20,000 BTU/hr

$$q = \frac{kA(T_1 - T_2)}{L}$$

R value estimates using Temp Diff



Temp Diff Example



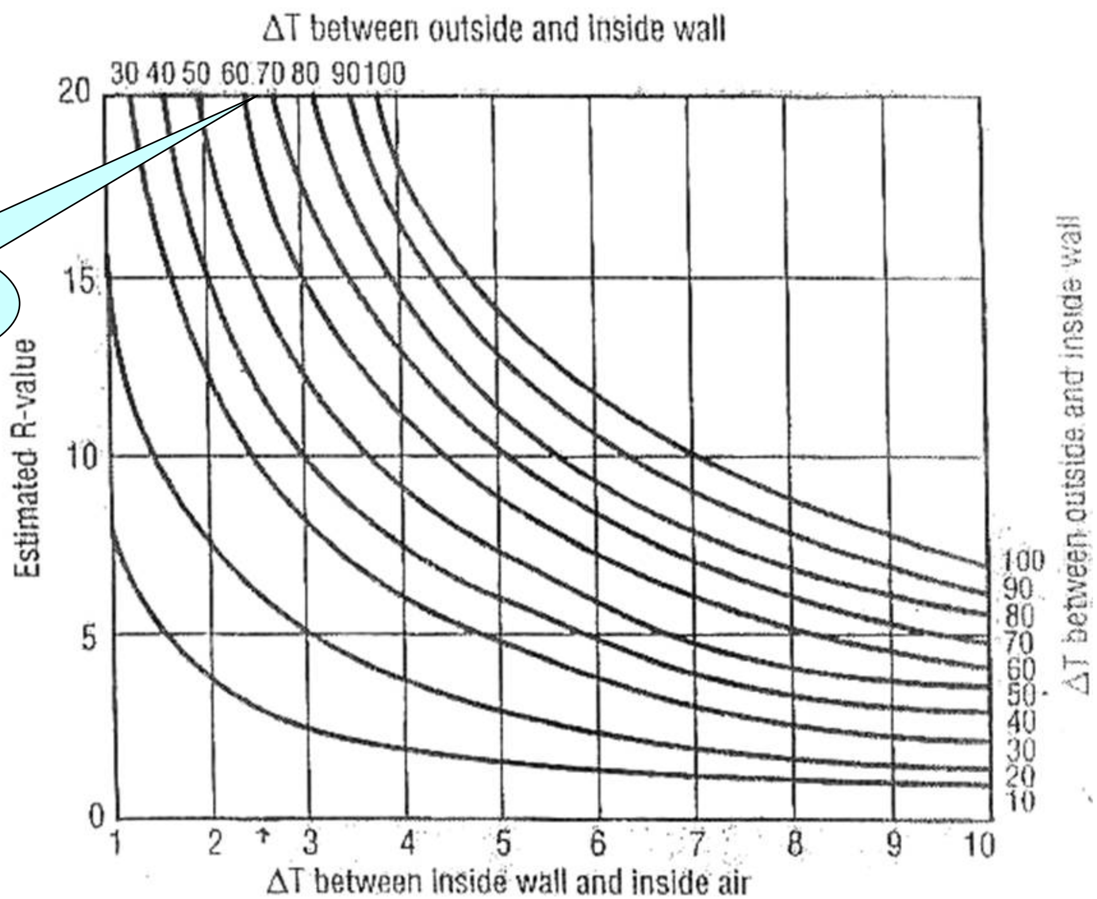
Emissivity	0.93
Reflected Apparent Temperature	70.0 °F
Atmospheric Temperature	70.0 °F
Image Date	1/19/2008
Image Time	9:10:07 AM
Ar1 Average Temperature	69.9 °F
Ar2 Average Temperature	67.4 °F
Ar3 Average Temperature	67.7 °F

Outside air = -5 ^{o}F

Temp diff O – I=-5 – 70 = 75
IW-IA = 70-67.4= 2.6

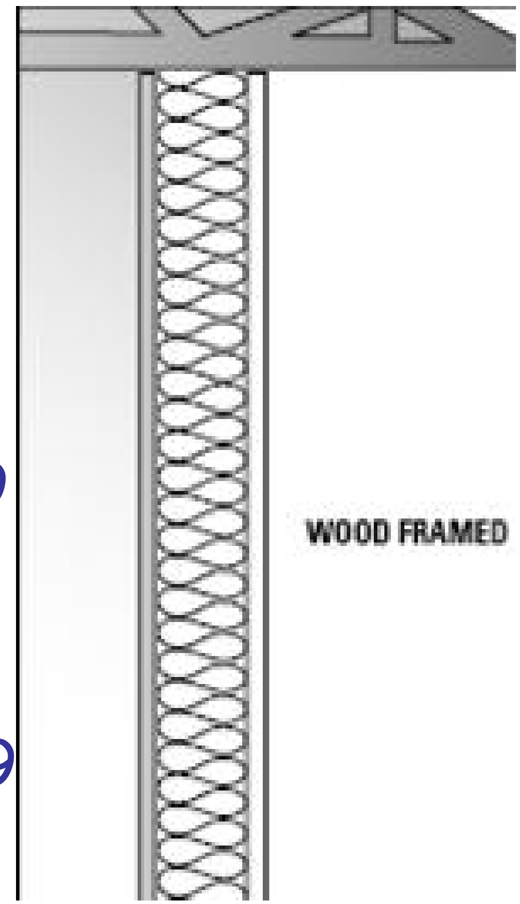
R value estimates using Temp Diff

2.6 & 75



R value Estimates

	Wall	Stud
Interior air boundary	0.68	.68
Wallboard	0.45	.45
Insulated Sheathing	7.1	7.1
Wood siding	0.59	.59
Exterior air boundary	0.17	.17
Insulation 3.5"	13	3.6
Total =	21.99	12.59



R Value Summary

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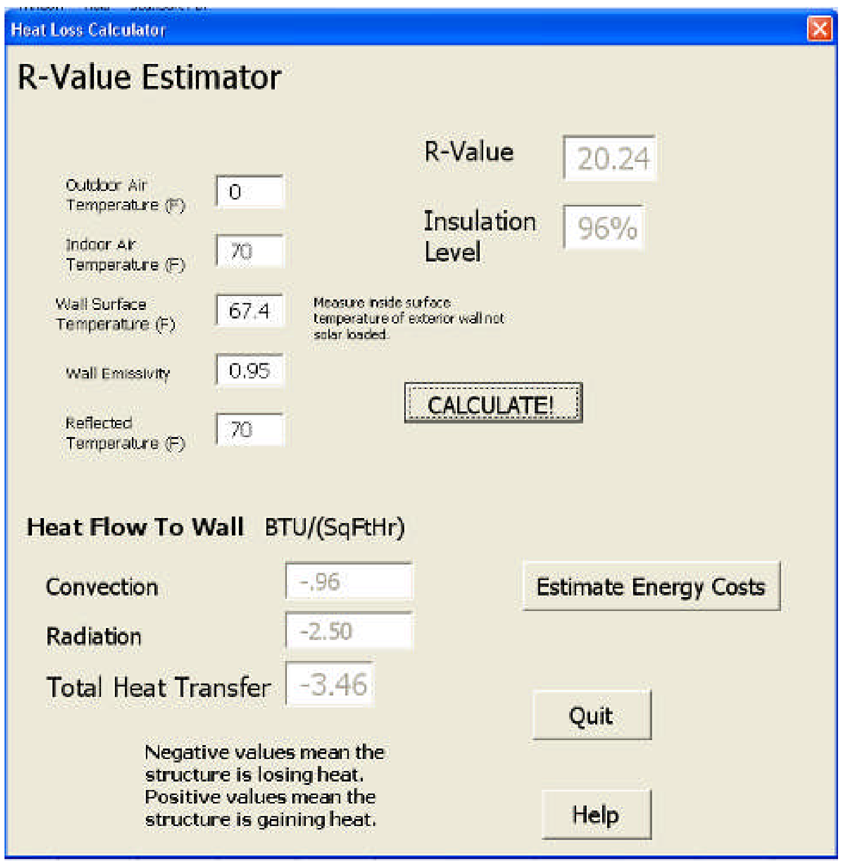
- Very Difficult to do
- Prone to error
- R value is not useful in this interpretation
- Image could have infiltration or a thermal bridge involved.

An R Calculator



Developed by Dr. Bob Madding at Infrared Training Center

Thank You Very Much!

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