RESEARCH TOOLS FOR ASSESSING THERMAL BRIDGING

Portland State University | ZGF Zimmer Gunsul Frasca Architects LLP

Objective

Compile knowledge developed from the use of building analysis tools, their applicability and limitations, for the refrence of future needs.

Project Overview

Large modern buildings consume immense quantities of energy to manage temperature, humidity and ventilation. This consumption has well-documented economic and ecological effects to building owners and occupants, as well as, on a much wider scale, the planet's changing climate. As such, improvements and innovations to building envelopes or mechanical systems can yield economic dividends to owners and operators. Building envelope systems, whether they be curtain walls or more traditional pieces of the structural system, are often locations of energy inefficiency through the existence of thermal bridges.

Advances in building science technology have provided architects and engineers a variety of methods for detecting and predicting both the location and magnitude of thermal bridges in building envelopes. Our research compares several different methods design professionals can used to detect thermal bridges including contact-based thermocouples, laser thermometers, infrared thermography, and digital modeling software. Best practices for each of these techniques and comparison of their performance are discussed and recommendations for when and how to use each technology are included below.

Conclusions and Recommendations

Although IR cameras may seem simple to use for building research science, it is important for to understand how the technology works and under what conditions it may provide inaccurate results. Direct contact thermocouples can provide in-depth data and track temperature changes over time, but are limited by the fact that their readings are only valid for an individual place. Literature-based research found that computer-aided modeling software packages like THERM and WUFI can be powerful tools for predicting thermal behavior in a structure.

These software programs can reveal more of a building's system's thermal bridging, than site based research tools can. As always, it is important to cross reference an array of building systems research tools to develop a greater understanding of the systems in use.

ZGF Architects
Nicolas Papaefthimiou | Liz Rhodes | Chris Chatto

PSU Graduate Students
Kevin Chavez | Gorgon Chen | Tyler Williams

PSU School of Architecture Advisors
Corey Griffin | Kalina Vander Poel

Methodology

WEEK 1

INITIAL RESEARCH PROJECT PROPOSAL
Attain an understanding of thermal performance of unitized curtain wall systems for the improvement of their design

WEEK 2

ATTEMPT 1 → BUILDING COMPONENT + RESEARCH TOOL + SPECIFIC SITE CONDITIONS → COLLECTED DATA → ASSESSMENT OF DATA → INCONCLUSIVE FINDINGS

WEEK 3

ATTEMPT 2 → BUILDING COMPONENT + RESEARCH TOOL + SPECIFIC SITE CONDITIONS → COLLECTED DATA → ASSESSMENT OF DATA → INCONCLUSIVE FINDINGS

WEEK 4

ATTEMPT 3 → BUILDING COMPONENT + RESEARCH TOOL + SPECIFIC SITE CONDITIONS → COLLECTED DATA → ASSESSMENT OF DATA → INCONCLUSIVE FINDINGS

WEEK 5

ATTEMPT 4 → BUILDING COMPONENT + RESEARCH TOOL + SPECIFIC SITE CONDITIONS → COLLECTED DATA → ASSESSMENT OF DATA → INCONCLUSIVE FINDINGS

WEEK 6

ATTEMPT 5 → BUILDING COMPONENT + RESEARCH TOOL + SPECIFIC SITE CONDITIONS → COLLECTED DATA → ASSESSMENT OF DATA → INCONCLUSIVE FINDINGS

WEEK 7

DEVELOPED RESEARCH PROJECT PROPOSAL
Compile knowledge developed from site visits on the applicability and limitations of building analysis tools

WEEK 8

ATTEMPT 6 → BUILDING COMPONENT + RESEARCH TOOL + SPECIFIC SITE CONDITIONS → COLLECTED DATA → ASSESSMENT OF DATA → DEVELOPED KNOWLEDGE OF TOOL

WEEK 9

ATTEMPT 7 → BUILDING COMPONENT + RESEARCH TOOL + SPECIFIC SITE CONDITIONS → COLLECTED DATA → ASSESSMENT OF DATA → DEVELOPED KNOWLEDGE OF TOOL

WEEK 10

COMPILE KNOWLEDGE OF RESEARCH TOOLS

INFRARED THERMOGRAPHY

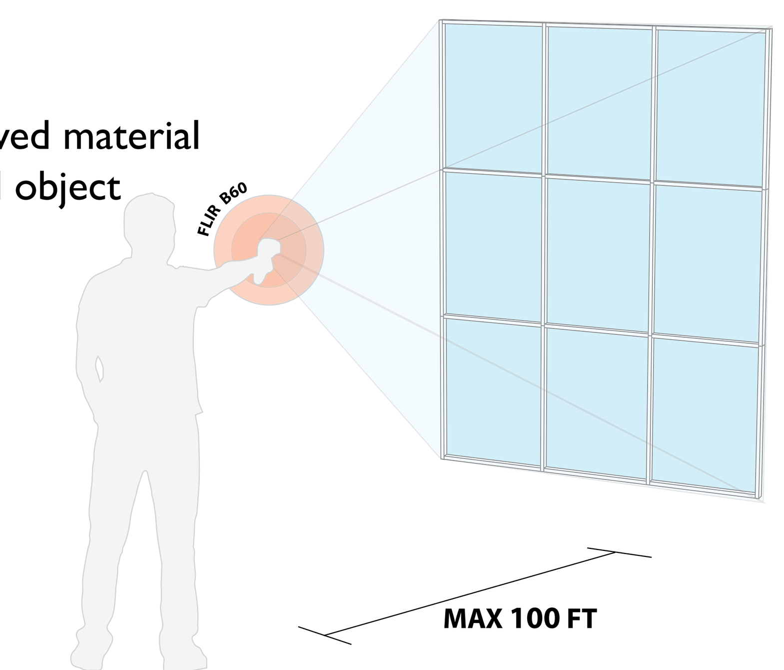
FLIR B60

Overview

The FLIR B60 is a larger science-grade inferared thermographer (IR). IR measures the non-visible electromagnetic waves radiating from a structure to determine the amount of energy passing through a solid surface. This particular model has capability to take both thermal and digital color images. It allows for manual temperature range inputs and can switch between Celsius and Fahrenheit. Usability is simple as point and click if using the automatic range finder feature.

Consider

- Reflectance of observed material
- Distance of observed object
- Index of refraction
- Weather conditions
- Temperature range



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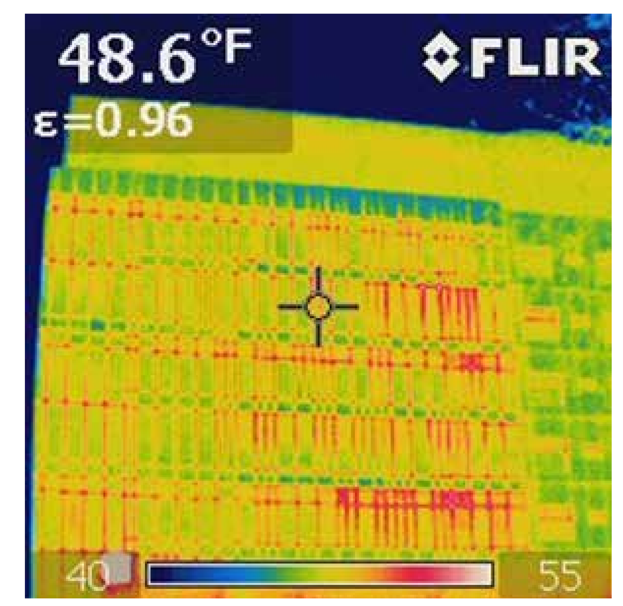
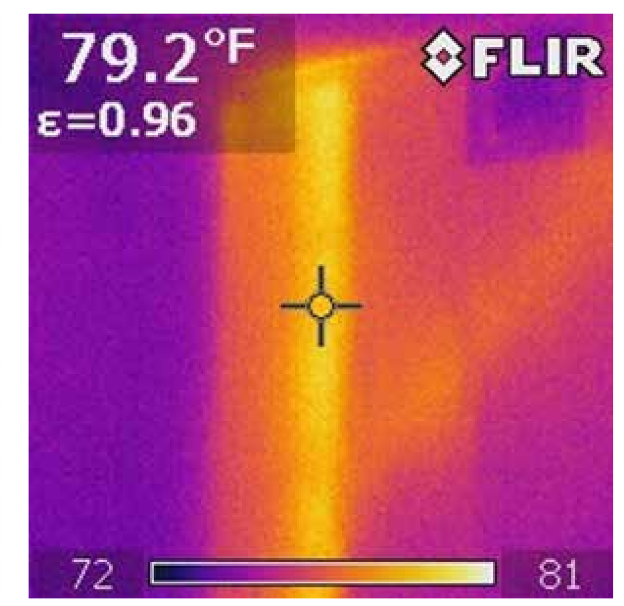


Nighttime exterior thermograph (FLIR B60)



Interior thermograph of plumbing wall (FLIR B60)

Results

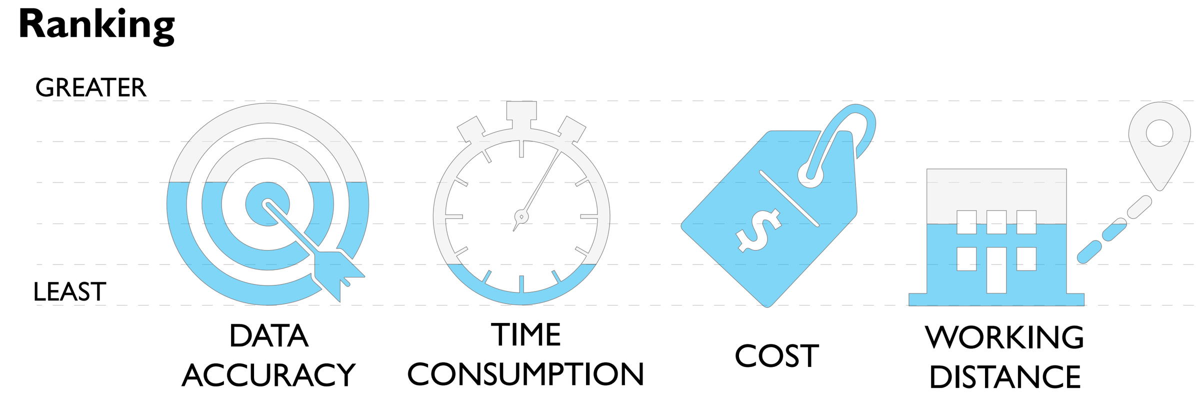
Conclusions

The FLIR B60 camera was able to detect some evidence of thermal bridging at long distance and was also not clear enough to identify individual components that caused the bridge. This unit is also highly sensitive to outdoor influences which requently cause misreadings.

Limitations

OBSERVABLE DISTANCE
WEATHER INTERFERENCE
READINGS MUST NOT BE AT ANGLES
INABILITY TO READ SMALL COMPONENTS

Ranking



INFRARED THERMOGRAPHY

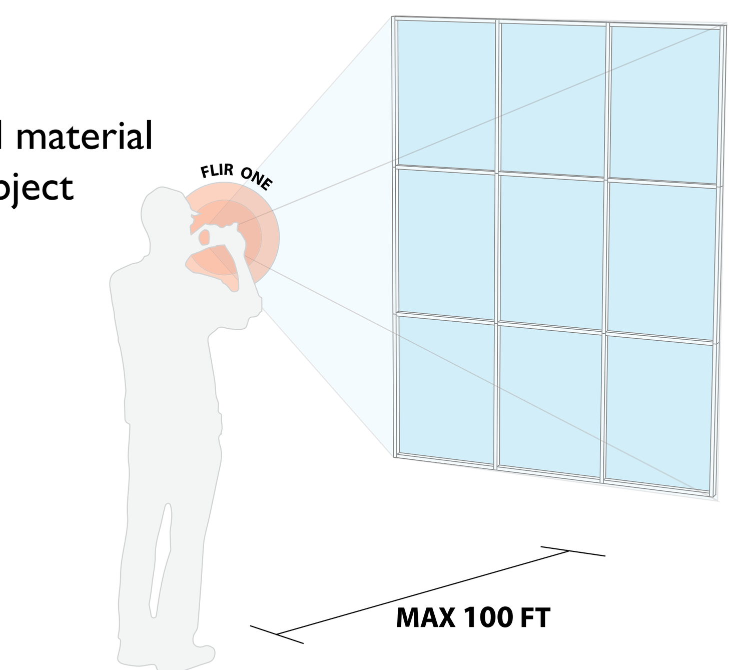
FLIR ONE

Overview

The FLIR One is a compact and inexpensive infrared thermograph camera that integrates with a smartphone to take pictures. Its slim design allows for quick and convenient use on the go. Usability is simple as point and click, yet there is no ability to preset temperature ranges.

Consider

- Reflectance of observed material
- Distance of observed object
- Index of refraction
- Weather conditions



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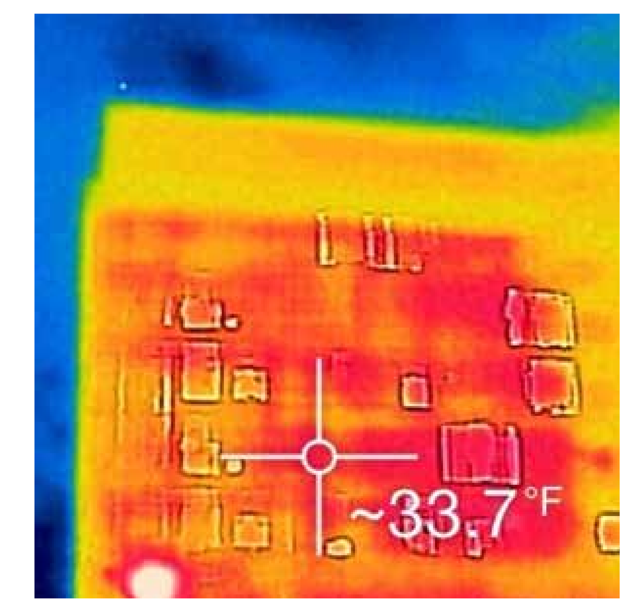
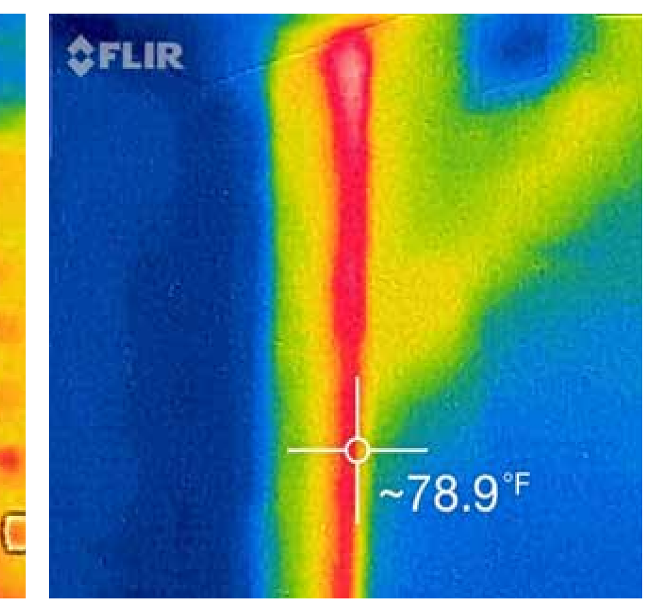


Nighttime exterior thermograph (FLIR One)



Interior thermograph of plumbing wall (FLIR One)

Results

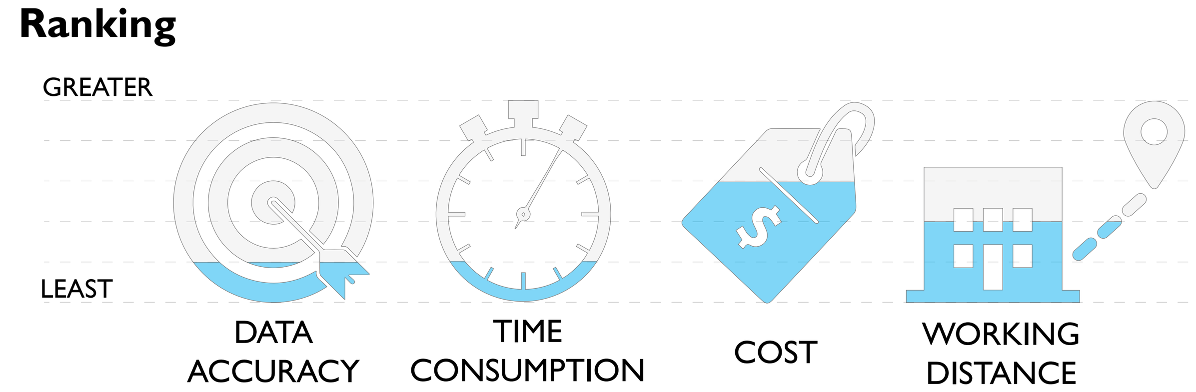
Conclusions

The less advanced FLIR One was incapable of producing localized results at long range. Images were of low resolution and unable to separately distinguish building components. This unit seemed to be more suited for an indoor usage.

Limitations

OBSERVABLE DISTANCE
WEATHER INTERFERENCE
READINGS MUST NOT BE AT ANGLES
INABILITY TO READ SMALL COMPONENTS
INDISTINQUISABLE RESOLUTION

Ranking



LASER THERMOMETER

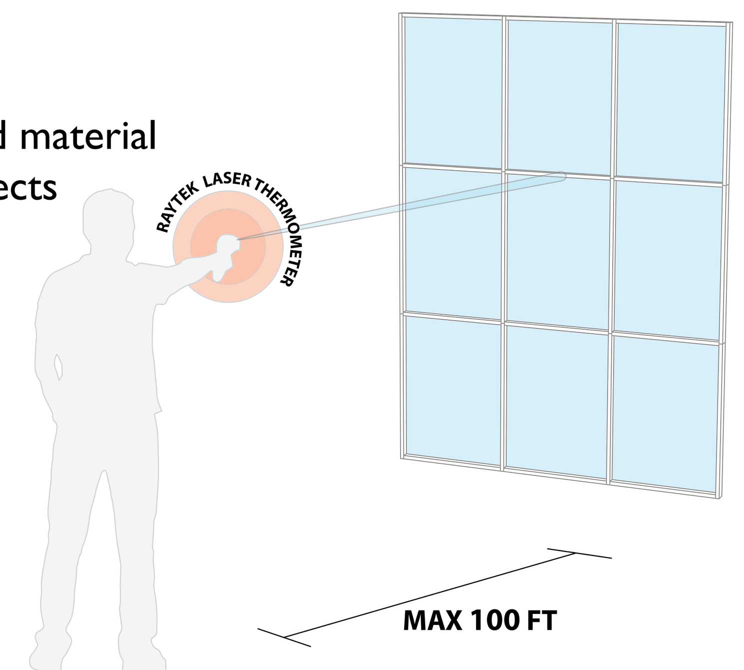
RAYTEK

Overview

A laser thermometer, also called non-contact thermometer or temperature gun, is a thermometer which infers temperature from a portion of the thermal radiation emitted by the object being measured. A lens focuses the infrared thermal radiation on to a detector, which converts the radiant power to an electrical signal displayed as a unit of temperature. To use, simply point and click.

Consider

- •Reflectance of observed material
- •Surrounding colder objects



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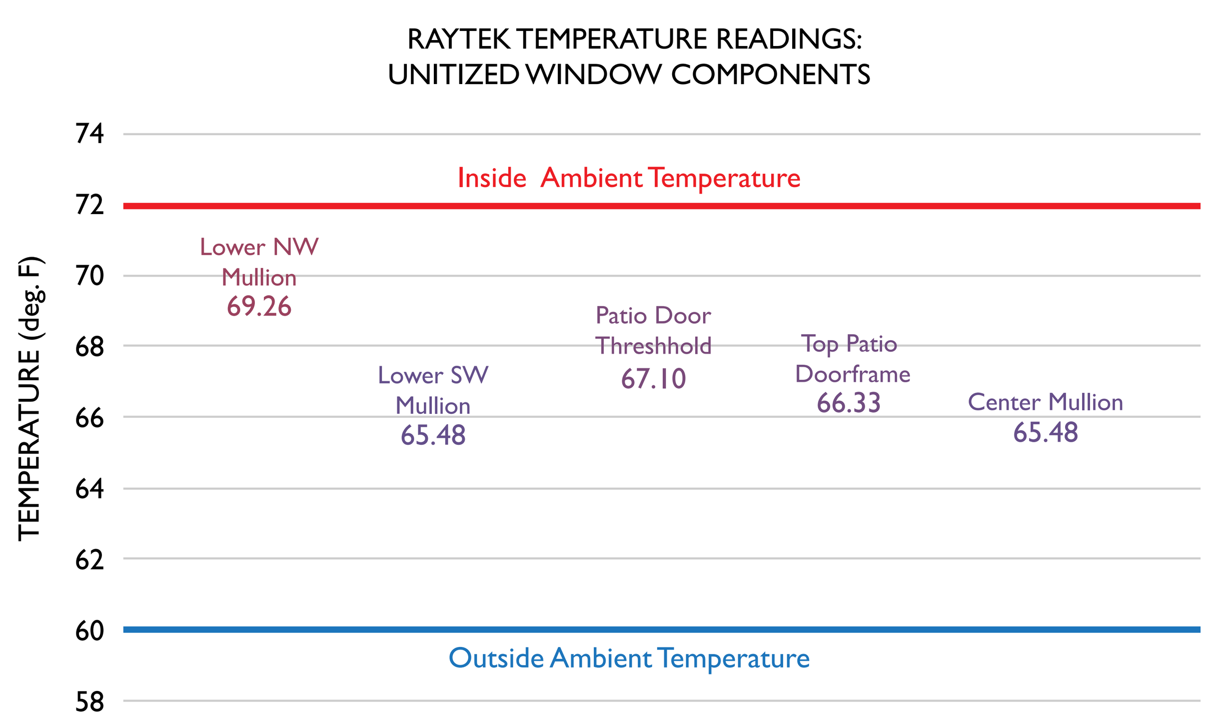


Quantitative temperature measurements (Raytek Laser Thermometer).

Results

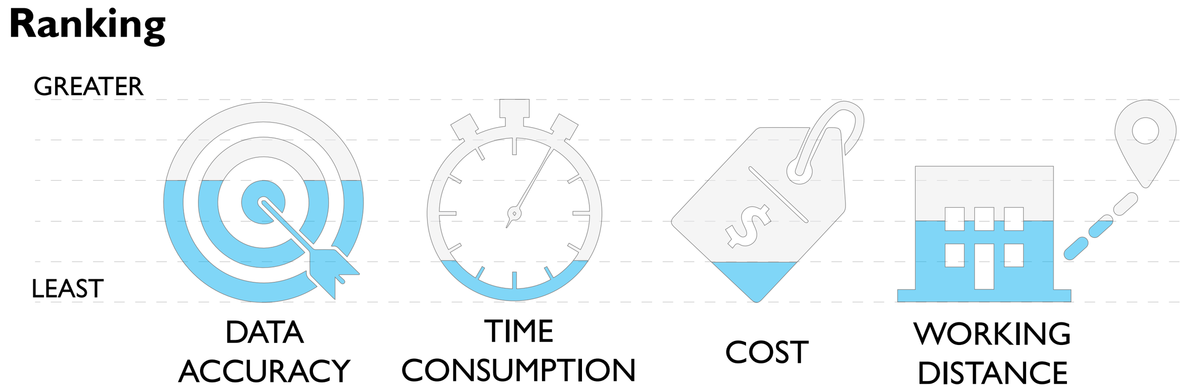
Conclusions

A laser thermometer is useful for measuring temperature under circumstances where thermocouples or other probe-type sensors cannot be used, or do not produce accurate data. Yet, they do not illustrate temperature distribution of a building system as well as an infrared thermography camera would/

Limitations

SINGLE POINT READING
DOES NOT SHOW TEMPERATURE DISTRIBUTION

Ranking



CONTACT-BASED THERMOCOUPLES

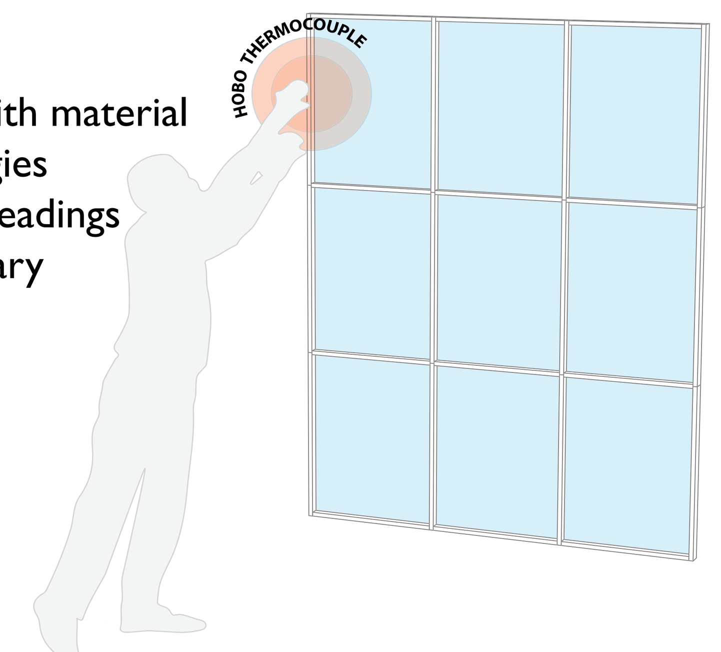
HOBO DATA LOGGERS

Overview

A thermocouple is an electrical device consisting of two different conductors forming electrical junctions at differing temperatures. Thermocouplers produces a temperature-dependent voltage as a result of the thermoelectric effect which can be interpreted to measure temperature. These data loggers must be physically attached to envelope materials to measure temperature.

Consider

- •Coupler must contact with material
- •Coupler adhesive strategies
- •Accessing locations for readings
- •Multiple readings necessary



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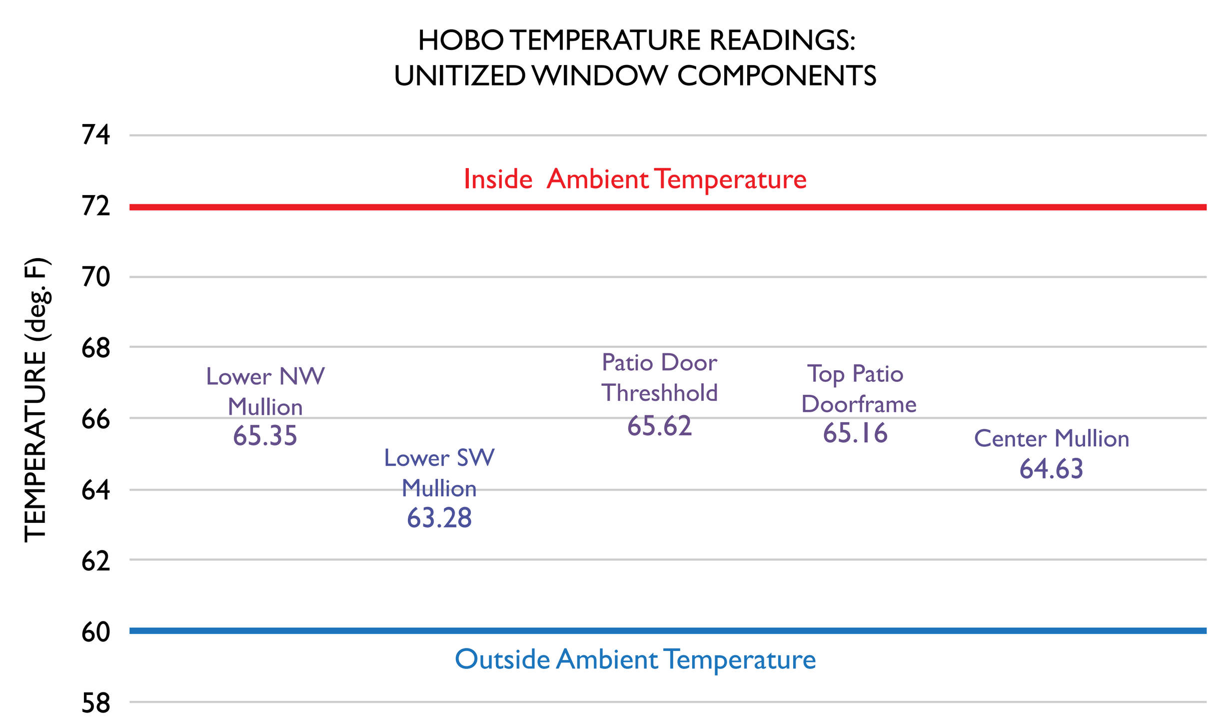


Quantitative temperature measurements (HOBO Thermocouple)

Results

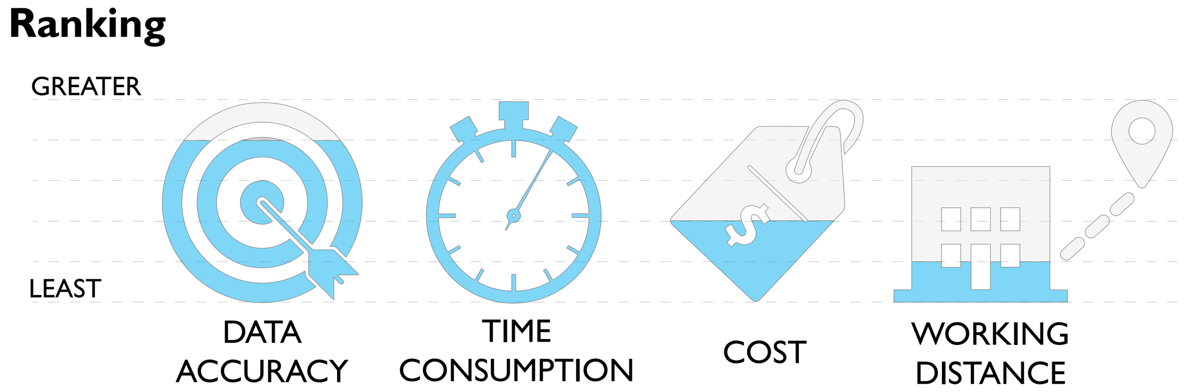
Conclusions

We found that contact-based thermocouples are the preferred tool if temperature data is required for a single, discrete, physically accessible point. However, many contact points are necessary for a greater resolution of a building system. This process can be a tedious and time consuming.

Limitations

MULTPLE READINGS ARE NESSESARY
MUST BE CONTACT-BASED
LOCATIONS OF READINGS MUST BE ACCESSIBLE

Ranking



THERMAL MODELING SOFTWARE

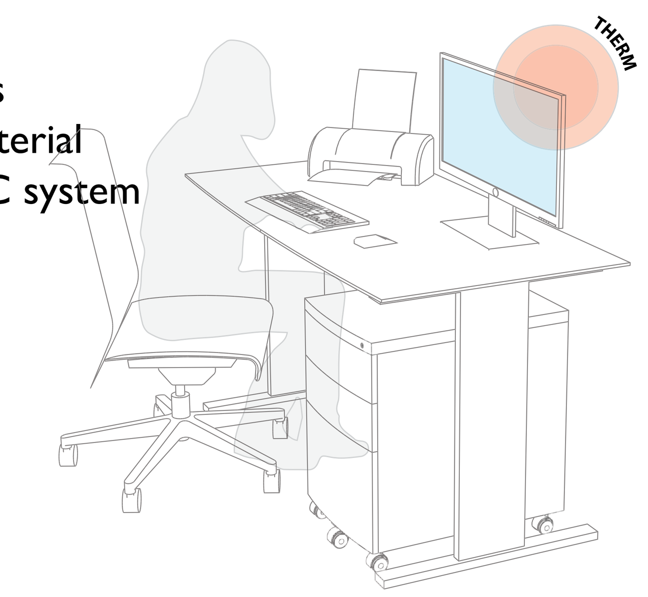
THERM

Overview

THERM is an open-access computer modeling program that allows the user to analyze heat transfer through window and curtain wall assemblies. It allows the user to draw two-dimensional sections of a curtain wall and assign different material properties and boundary conditions associated with the design. A thermal visualization is the product of this analysis.

Consider

- •Access to construction details
- •Knowledge of component material
- •Knowledge of building's HVAC system



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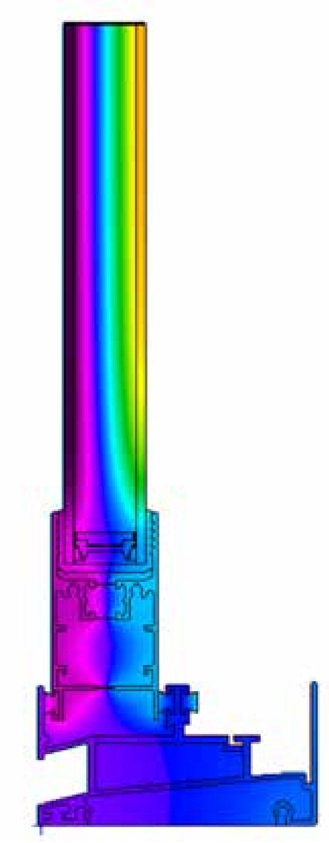
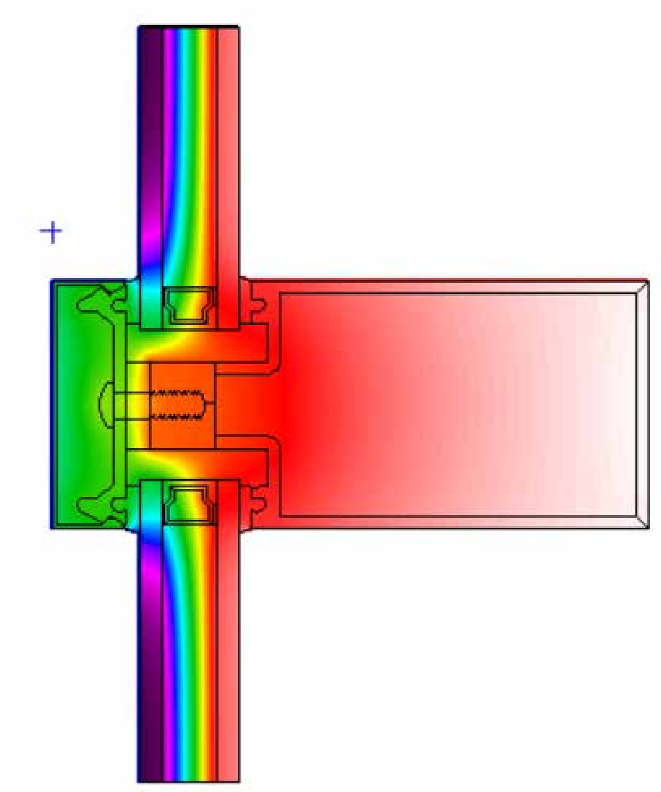


Sample section infrared results of aluminum slider window frame

(THERM)



Sample curtainwall with bolt cross section with infrared results

(THERM)

Results

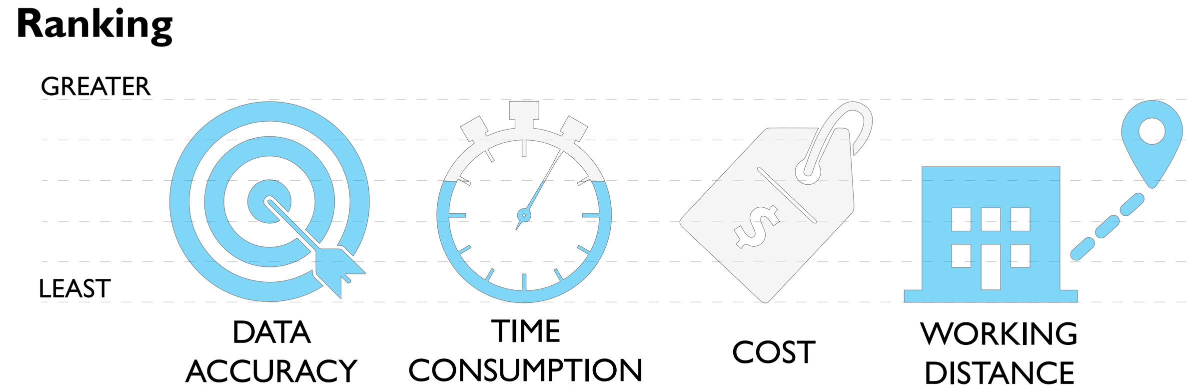
Conclusions

This tool is effective for analyzing movement of heat through walls, windows, and floors. It is powerful, quick and produces visuals of the thermal effects of changing connection types, or building assemblies. Yet, it is limited in its ability to model dew point changes and is only capable of simulating two-dimensional steady state conditions.

Limitations

TEMPERATURE DISTRIBUTION IS 2D VISUALIZATION ONLY
NO ABILITY TO MODEL DEW POINT
INABILITY TO CALCULATE SITE SPECIFIC CONDITIONS

Ranking



THERMAL MODELING SOFTWARE

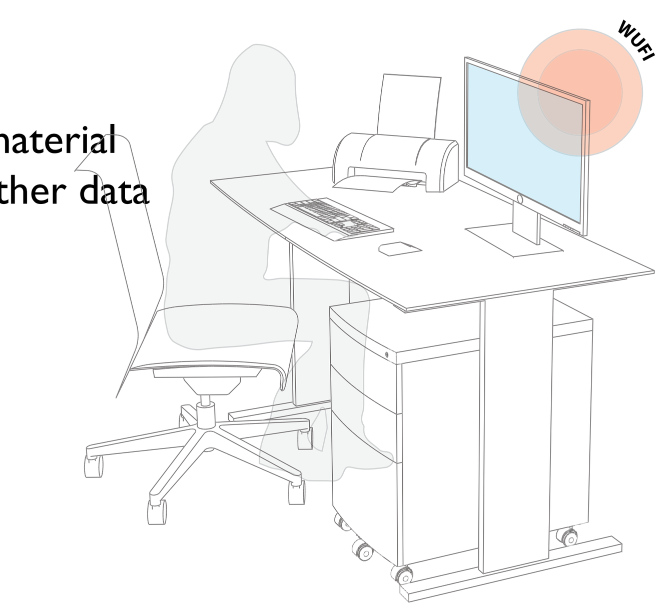
WUFI

Overview

WUFI is suite of digital modeling programs that simulates one-dimensional assemblies to measure hydrothermal performance in walls, assemblies or even entire buildings. Using historical weather data, this program can calculate changes in a building's thermal efficiency and dew point over time and can locate areas of moisture accumulation. Simulations are represented graphically to illustrate time and weather-dependent changes.

Consider

- •Access to building details
- •Knowledge of component material
- •Knowledge of sourcing weather data



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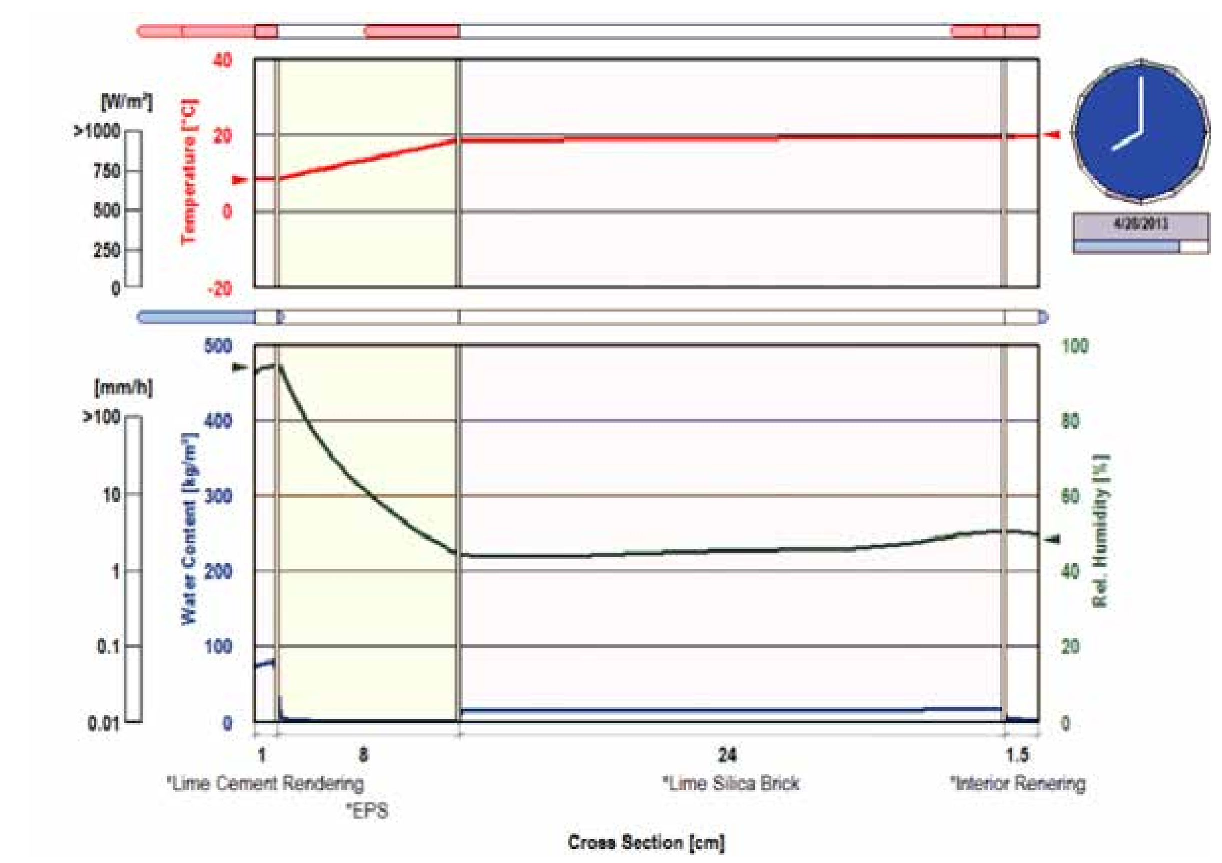

Example of a produced cross section analysis (WUFI)

Results

Conclusions

While WUFI can quickly find possible material deterioration locations and probability of mold propagation, it does little to help understand thermal bridging in building assemblies. WUFI was found to be more useful in conjunction with THERM to predict dew point fluctuations, moisture buildup, and possible mold issues early in the design process.

Limitations

PREDICTIVE TOOL ONLY
DOES NOT ADDRESS THERMAL BRIDGING
DOES NOT PRODUCE CONTEXTUAL VISUAL AIDS

Ranking