The Use of Thermal Imaging Technology

Greg Stockton

Anchor Elite, LLC

Infrared Thermographic Services
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.
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
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 travel at the speed of light ($c$), and are characterized by frequency ($\nu$) or wavelength ($\lambda$) 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 $E = h c / \lambda$.

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 nanometers

- 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

\[ \Delta U = Q - W \]

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

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

Heat Transfer

Convection

Radiation

Conduction

Ludwig Boltzmann
Infrared Imager History and Current Technology

1940
- PbS, Tl₂S

1950
- PbSe, PbTe

1960
- Ge:X, InSb
- HgCdTe
- PbSnTe
- Si:X

1970
- Silicide Schottky-barrier detectors
- Si:X/CCD
- HgCdTe, PbSnTe/CCD
- HgCdTe SPRITE
- InGaAs
- QWIP
- Multirow (TDI function) second/third (staring) generation MCT hybrid arrays

1980

1990
- FPAs
- Uncooled Microbolometers
- In the Future --- Thin Films

2000

Next...photodiode and phototransistor
The Use of Thermal Imaging Technology

Infrared Imager History and Current Technology
The Use of Thermal Imaging 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.

*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 iPhone® or iPad®, 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.
The Use of Thermal Imaging Technology

Infrared Imager History and Current Technology

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 into detailed reports on the go.

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

Related Products

- 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.
Infrared Imager History and Current Technology

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.
Infrared Imager Selection For a Particular Project

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?
Infrared Imager Selection For a Particular Project

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?
The Use of Thermal Imaging Technology

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
Oblique IR Imaging Showing Varying Amounts of Heat Loss
The Use of Thermal Imaging Technology

Oblique IR Imaging Showing Varying Amounts of Heat Loss
Oblique IR Imaging Showing Varying Amounts of Heat Loss
Oblique IR Imaging Showing Varying Amounts of Heat Loss
NADIR & Oblique IR Imaging Required for 3D Imaging
Oblique IR Imaging Showing Building Survey Done Too Early
Oblique IR Imaging Showing Building Survey Done Too Early
The Use of Thermal Imaging Technology

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
Typical Large Building Air Leakage Testing
Typical Large Building Air Leakage Testing
Typical Large Building Air Leakage Testing

Before Pressurization

After Pressurization
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 survey

- 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 survey

- RTU-15
- RTU-14
- RTU-13
- RTU-12
- RTU-11
- RTU-5
- RTU-4
- RTU-3
- RTU-2
- RTU-1
The Use of Thermal Imaging Technology

Typical Large Building Air Leakage Testing

Representation of the heat distribution throughout the building
Typical Large Building Air Leakage Testing

Before Pressurization

After Pressurization

Heat loss occurring mainly around gaps in board insulation

Heat loss and many air leaks around board insulation and seems
Typical Large Building Air Leakage Testing
Typical Large Building Air Leakage Testing

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
Typical Large Building Air Leakage Testing
Typical Hotel Air and Heat Loss
Typical Hotel Air and Heat Loss

East area with outside wall is 3F degrees warmer with 8% higher humidity

(East) 85F RH = 55%
(North) 82F RH = 47%
Typical Hotel Air and Heat Loss
Typical Large Building Heat Loss
Missing Insulation in a Convention Center

Dark areas indicate heat loss from improperly placed fiberglass batts.
Improperly Installed Batt Insulation in a Commercial Building
Institutional Building - Air Stratification

The Use of Thermal Imaging Technology
Apartment Building Heat Loss Findings

The Use of Thermal Imaging Technology
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
The Use of Thermal Imaging Technology

Grouted Cells in Concrete Block Walls

Grouted Cells
Empty Cells
Insulated Cells
Finding Insulated Cells in Concrete Block Walls
Building IR (Interior Moisture from a Pipe Leak)

84.1°F
86
88
90
92
93.9°F

84.1°F
86
92

“Duck Soup”
Building IR (Interior Moisture from a Pipe 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)

Moisture in sheetrock wall coming from attic (see below)

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

Water Leaks from Piping

Shows mold/mildew damage on and in pipe insulation.

Before removing ceiling tile
Shows Mold/Mildew Damage on Wallpaper Wall
Mold/Mildew Damage to Inner Wall and Insulation

The Use of Thermal Imaging Technology

Anchor Elite, LLC
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.
The Use of Thermal Imaging Technology

Building Roof Moisture

NORTHERN OHIO CHAPTER
The Use of Thermal Imaging Technology

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
The Use of Thermal Imaging Technology

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

Good tool for verifying wet... once found with infrared

Dielectric Capacitance Meters measure differences in dielectric constants
Roof Moisture Surveying

Non-Destructive Testing – Nuclear

Nuclear Density Gauges count slowed neutrons
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.
The Use of Thermal Imaging Technology
The Use of Thermal Imaging Technology
The Use of Thermal Imaging Technology
The Use of Thermal Imaging Technology

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
The Use of Thermal Imaging Technology

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
The Use of Thermal Imaging Technology

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

The infrared method is based on pattern recognition
Wet substrates have higher mass, therefore higher thermal conductivity and specific heat capacity.
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.
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

- Wet Insulation = Higher Mass
- Dry Insulation = Lower Mass
Under-Roof Moisture Surveying

Entrained Water in Vinyl-backed Fiberglass
Under-Roof Moisture Surveying

Entrained Water in Vinyl-backed Fiberglass

The Use of Thermal Imaging Technology
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
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) Total area ~231.398 ft²

Photograph w/Cad Overlay
Probable wet area (~39,696 ft², 17.11%) Possible wet area (NONE)

Total area ~231.398 ft²
Aerial Roof Moisture Surveying

The Use of Thermal Imaging Technology
Aerial Roof Moisture Surveying

Key to Sectional Reports
- Top Left
- Top Right
- Center Left
- Center Right
- Bottom Left
- Bottom Right

Key to Drawings

CAD Drawing

Thermograph

Photograph

Thermograph with CAD Overlay

Photograph with CAD Overlay

The Use of Thermal Imaging Technology
Aerial Roof Moisture Surveying

Key to Sectional Reports:
- Top Left
- Top Right
- Center Left
- Center Right
- Bottom Left
- Bottom Right

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)
The Use of Thermal Imaging Technology

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

Nuclear Power Plant
Thermal Mapping of Photovoltaic Solar Fields
Thermal Mapping of Photovoltaic Solar Fields
Thermal Mapping of Photovoltaic Solar Fields

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Delta Temperature (Degrees Celsius)
Aerial Infrared Imagery of Industrial Complexes
Aerial Infrared Imagery of Industrial Complexes
Aerial Infrared Imagery of Industrial Complexes
Aerial Infrared Imagery of Industrial Complexes

Cursor (0, 0) = -90.435365
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
The Use of Thermal Imaging Technology

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

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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

Failed Insulation
Steam and Condensate Return Lines Heat the Ground Above The Line
Steam and Condensate Return Lines Heat the Ground Above The Line

Steam Line Leak
The Use of Thermal Imaging Technology

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
Visible Map of NAX-JAX
Aerial Infrared Surveying of Steam, Hot Water & Chilled Water Systems

Thermal Map of NAX-J AX
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
DCs use around 3% of all electricity consumed...
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.
The Use of Thermal Imaging Technology

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

Before

After
Three different types of Thermal Imaging Possible

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

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

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 Comparisons
"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
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.
Transformer load side bushing (internal), phase X1.
Main switch, phase B, line side bus connector. Phases A & C also.
Electrical Infrared

Main bus, bolted connection (rear) as shown.
Main bus insulator heating from induction.
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.
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.
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.
Control panel mercury switch #8, switch and lug, phase C.
Battery charger at battery #22, connector heating as indicated.
Control panel, main fuses, circuit F4, lug connections, load side.

Electrical Infrared
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.
Control panel, circuit labeled #22, fuse holder as indicated.
Steam Systems and Infrared

NORTHERN OHIO CHAPTER
The Use of Thermal Imaging Technology

**Thermodynamic Properties of Saturated Steam**

<table>
<thead>
<tr>
<th>Gage Pressure</th>
<th>Temperature deg. Fahr.</th>
<th>% Heat of Liquid</th>
<th>Latent Heat of Evaporation</th>
<th>Total Heat of Steam</th>
<th>Specific Volus cu ft/lb</th>
<th>1000 lb Steam</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>104</td>
<td>64</td>
<td>1037</td>
<td>1101</td>
<td>4.60</td>
<td>64</td>
</tr>
<tr>
<td>20</td>
<td>106</td>
<td>66</td>
<td>1040</td>
<td>1106</td>
<td>4.63</td>
<td>66</td>
</tr>
<tr>
<td>40</td>
<td>108</td>
<td>68</td>
<td>1043</td>
<td>1111</td>
<td>4.66</td>
<td>68</td>
</tr>
<tr>
<td>60</td>
<td>110</td>
<td>70</td>
<td>1046</td>
<td>1116</td>
<td>4.69</td>
<td>70</td>
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<tr>
<td>80</td>
<td>112</td>
<td>72</td>
<td>1049</td>
<td>1121</td>
<td>4.72</td>
<td>72</td>
</tr>
<tr>
<td>100</td>
<td>114</td>
<td>74</td>
<td>1052</td>
<td>1126</td>
<td>4.75</td>
<td>74</td>
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<tr>
<td>120</td>
<td>116</td>
<td>76</td>
<td>1055</td>
<td>1131</td>
<td>4.78</td>
<td>76</td>
</tr>
<tr>
<td>140</td>
<td>118</td>
<td>78</td>
<td>1058</td>
<td>1136</td>
<td>4.81</td>
<td>78</td>
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<tr>
<td>160</td>
<td>120</td>
<td>80</td>
<td>1061</td>
<td>1141</td>
<td>4.84</td>
<td>80</td>
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<tr>
<td>180</td>
<td>122</td>
<td>82</td>
<td>1064</td>
<td>1146</td>
<td>4.87</td>
<td>82</td>
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<tr>
<td>200</td>
<td>124</td>
<td>84</td>
<td>1067</td>
<td>1151</td>
<td>4.90</td>
<td>84</td>
</tr>
<tr>
<td>220</td>
<td>126</td>
<td>86</td>
<td>1070</td>
<td>1156</td>
<td>4.93</td>
<td>86</td>
</tr>
<tr>
<td>240</td>
<td>128</td>
<td>88</td>
<td>1073</td>
<td>1161</td>
<td>4.96</td>
<td>88</td>
</tr>
<tr>
<td>260</td>
<td>130</td>
<td>90</td>
<td>1076</td>
<td>1166</td>
<td>4.99</td>
<td>90</td>
</tr>
<tr>
<td>280</td>
<td>132</td>
<td>92</td>
<td>1079</td>
<td>1171</td>
<td>5.02</td>
<td>92</td>
</tr>
<tr>
<td>300</td>
<td>134</td>
<td>94</td>
<td>1082</td>
<td>1176</td>
<td>5.05</td>
<td>94</td>
</tr>
<tr>
<td>320</td>
<td>136</td>
<td>96</td>
<td>1085</td>
<td>1181</td>
<td>5.08</td>
<td>96</td>
</tr>
<tr>
<td>340</td>
<td>138</td>
<td>98</td>
<td>1088</td>
<td>1186</td>
<td>5.11</td>
<td>98</td>
</tr>
<tr>
<td>360</td>
<td>140</td>
<td>100</td>
<td>1091</td>
<td>1191</td>
<td>5.14</td>
<td>100</td>
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</tbody>
</table>

**Steam Pipe Capacities**

<table>
<thead>
<tr>
<th>Dia. w.p.</th>
<th>150 lb Steam</th>
<th>300 lb Steam</th>
<th>150 lb Steam</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/8</td>
<td>100</td>
<td>200</td>
<td>100</td>
</tr>
<tr>
<td>3/8</td>
<td>200</td>
<td>400</td>
<td>200</td>
</tr>
<tr>
<td>1/2</td>
<td>400</td>
<td>800</td>
<td>400</td>
</tr>
<tr>
<td>5/8</td>
<td>800</td>
<td>1600</td>
<td>800</td>
</tr>
<tr>
<td>3/4</td>
<td>1600</td>
<td>3200</td>
<td>1600</td>
</tr>
<tr>
<td>1</td>
<td>3200</td>
<td>6400</td>
<td>3200</td>
</tr>
</tbody>
</table>

**Notes:**
- Values in pounds per hour (using 105 psi) and 480 psi steam.

**Or Infrared Camera**

**FUNDAMENTALS OF STEAM**
The Use of Thermal Imaging Technology

Cost of $team

The opportunity is improved efficiency
### Cost of Steam Leaks

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

#### Input Section

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steam pressure</td>
<td>250 psig</td>
</tr>
<tr>
<td>Steam temperature</td>
<td>460 Deg F</td>
</tr>
<tr>
<td>Amount of superheat</td>
<td>57 Deg F</td>
</tr>
<tr>
<td>Facility steam value</td>
<td>9.00 $/Klb</td>
</tr>
<tr>
<td>Leak orifice flow coefficient</td>
<td>0.61</td>
</tr>
<tr>
<td>Hours/year in service</td>
<td>8760</td>
</tr>
</tbody>
</table>

#### 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.
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.)

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

The Steam Trap Handbook
The Use of Thermal Imaging Technology

Heat Resistant Paint
The Use of Thermal Imaging Technology

Missing Boiler Header Trap

Area2
Min   Mean   Max
97.9   108.3  291.7

*>188.8°F

*<80.9°F
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Missing Boiler Header Trap

* >152.1°F

* <=94.7°F
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

The Use of Thermal Imaging Technology

FLIR
07/25/2012 2:11 PM
FOV 24 T atm = 28.1 Dist = 3.3 T refl = 33.7 ε = 1.00

Mechanical Trap
100 psi
Closed
203°F
90 psi
Open
240°F

Permanent Orifice
100 psi
Always
Open
203°F
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!
Questions ???

NORTHERN OHIO CHAPTER
The Use of Thermal Imaging Technology
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