How to Evaluate Thermography Cameras

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Today there are more choices then ever before when evaluating thermography cameras. Each model features unique capabilities, specifications and price points.

Regardless of your specific preferences there are a number of basic system characteristics that you can evaluate to compare units. This guide is designed to help you establish a method to critically evaluate systems based on your requirements.

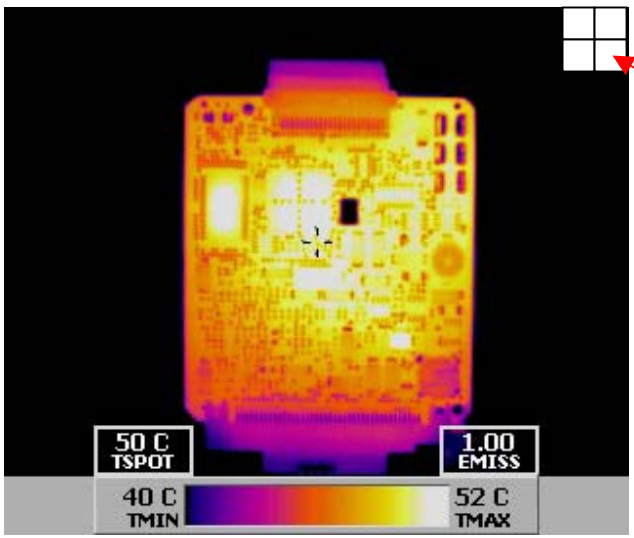
Camera Selection Guide

- Image Quality
  - Image Resolution
  - Measurement Spot Size
  - Sensitivity
  - Frame Rate
- Measurement Performance
  - Measurement Accuracy
  - Analysis
  - Ambient Temperature Range
  - Temperature Range
  - Object Parameter Compensation
- Ergonomics
  - Weight
  - User Interface
  - Display Issues
- Camera Functionality
  - Image Recording
  - Voice Recording
  - Visible Image Capture
  - Electronic Zoom
  - AGC
  - Report Generation
- Cost of Ownership
  - Acquisition Costs
  - Ongoing Costs
  - Service Costs

Image Quality - Resolution

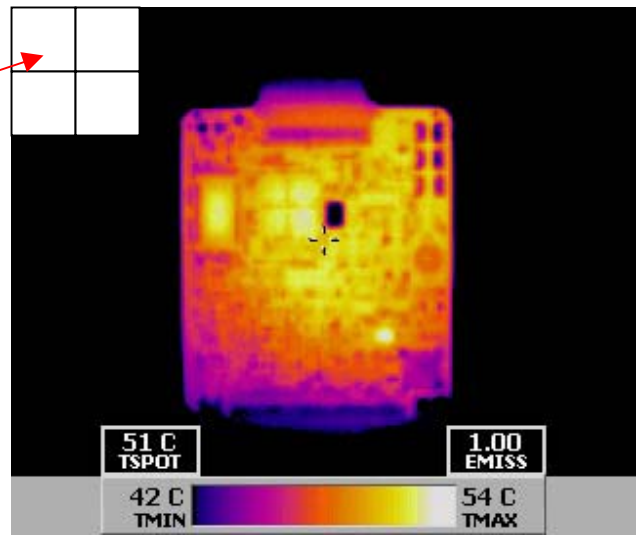
Two levels of resolution currently available

- 320x240 pixel arrays (76,800 total pixels) ¼ VGA Resolution
- 160x120 pixel arrays (19,200 total pixels) 1/16 VGA Resolution



320x240 Image Quality

Pixel Size
Relative
Comparison



160x120 Image Quality
Pixels are 4X larger!

Pixel Count Makes a Difference!

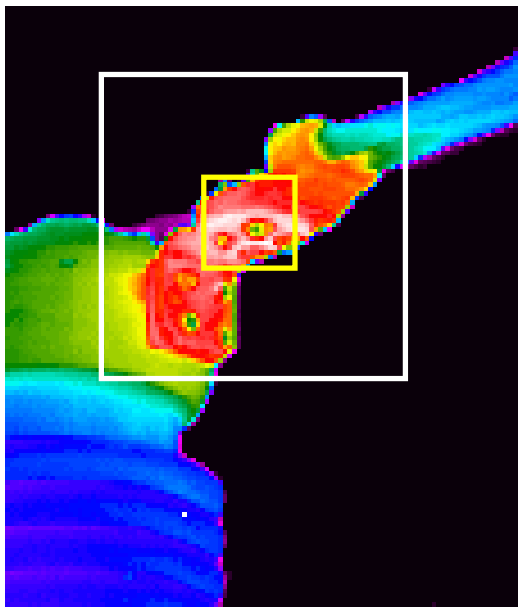
Image Quality – Resolution

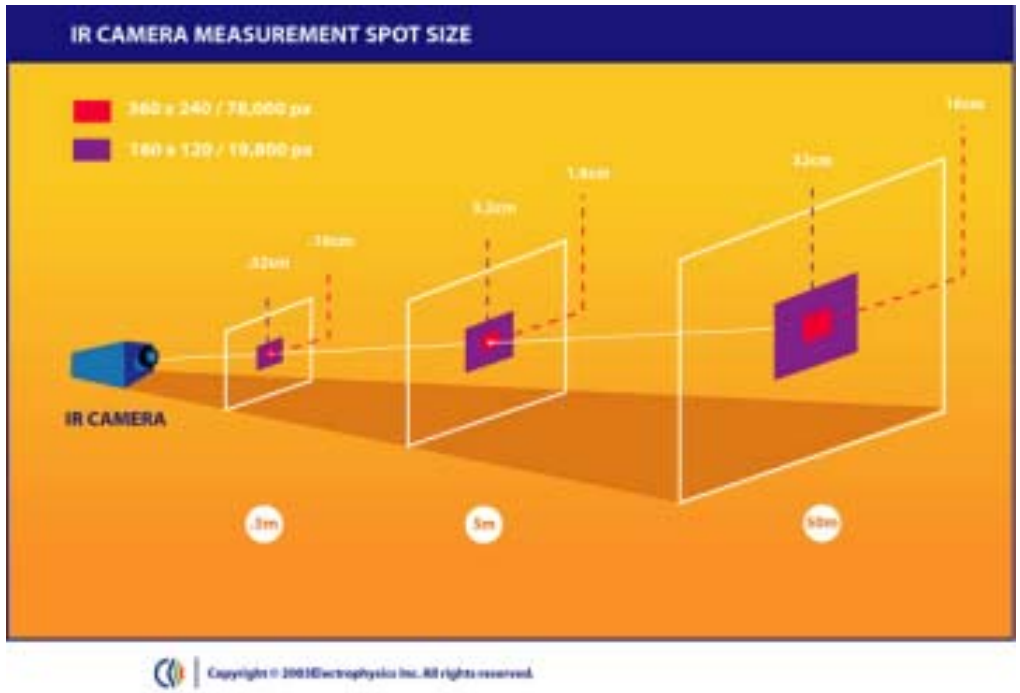
Does it Make a Difference When Making Measurements?

320x240 Spot Size[1] 300:1

160x120 Spot Size[2] 90:1

YES



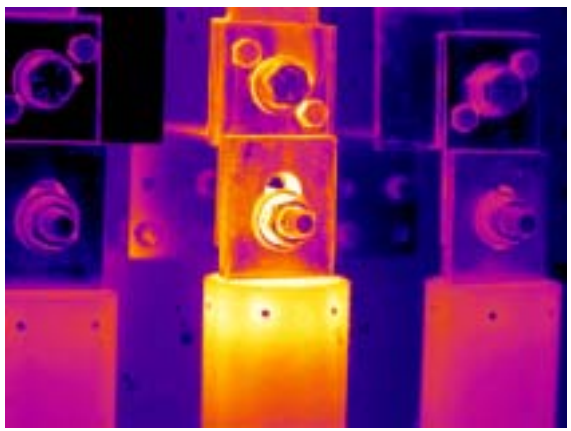


1. 25° field of view (EZTherm)
2. 18° field of view (Raytek Ti30)

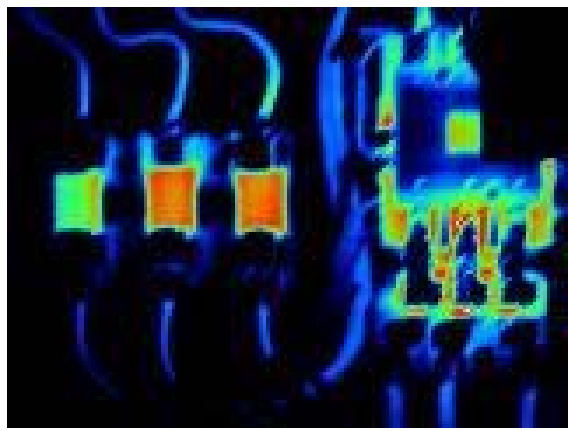
Make Certain You Have the Resolution you Need !

Image Quality – Thermal Sensitivity

The ability to discern temperature differences is fundamental to the performance of a thermal imaging camera. The most often used specification to quantify sensitivity is NETD or *Noise Equivalent Temperature Difference*. Manufactures use sophisticated test equipment to image two different temperature targets. As the temperature difference between to two targets is reduced around a reference temperature (usually 25°) at some point the signal output from the sensor can no longer "see" the temperature difference between the two targets. At this point the actual temperature difference between the two targets is measured and determines the NETD specification.



0.08° (80mK) Sensitivity



0.2° (200mK) Sensitivity

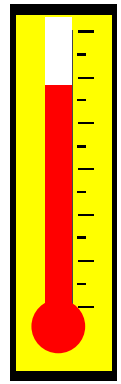
Sensitivity Really Makes a Difference!

Image Quality – Frame Rate

The frame rate of a camera is primarily determined by the design of the uncooled sensor. For applications such as predictive maintenance inspection of electrical, mechanical and building infrastructure frame rates fast enough to permit real-time focus are usually adequate. Slow scan cameras are difficult to focus and images can be distorted by any movement of the camera during the frame scan.

Nearly all cameras currently available feature frame rates above 20 frames per second which is adequate for “real-time” operation and focusing.

Measurement Performance - Accuracy



There are many factors that contribute to making accurate temperature measurements. The inherent accuracy of the thermographic camera is the responsibility of the camera vendor. Object variables and understanding their effects on measurements is the responsibility of the user.

Most thermographic cameras provide ± 2% absolute accuracy. Many users concern themselves primarily with temperature rise and some cameras feature a delta measurement feature.

The greatest source of measurement error is setting an a correct emissivity value. While there are emissivity tables available, most users typically estimate the emissivity value since an exact determination of any surface's properties is nearly impossible in the field.

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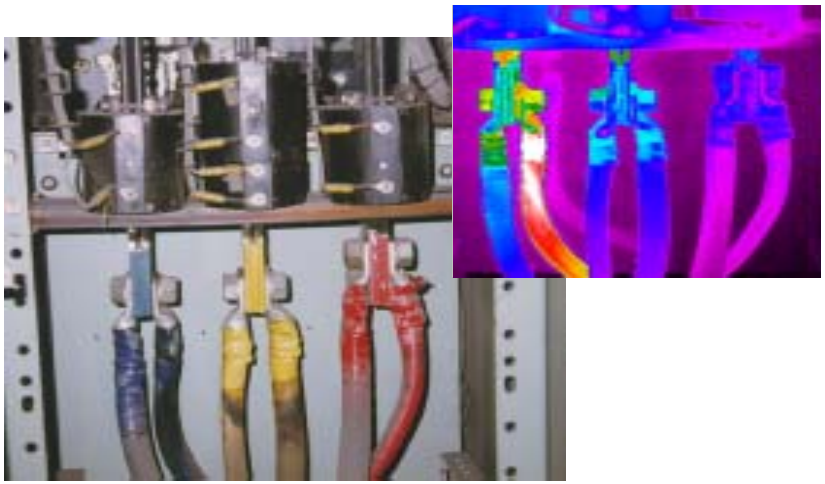
How to Evaluate a Thermography Camera

What's my emissivity?

Emissivity - *The ratio of power radiated by a substance to the power radiated by a blackbody at the same temperature.*



Emissivity Experiment	
Emissivity	Temperature Reading
1.0	305° F
0.95	325° F
0.8	350° F
0.7	388° F
0.6	425° F
0.5	483° F

Actual temperature of metal test object was measured with a contact probe and the emissivity was determined to 0.7. The table shows the error resulting from incorrect emissivity value entry.

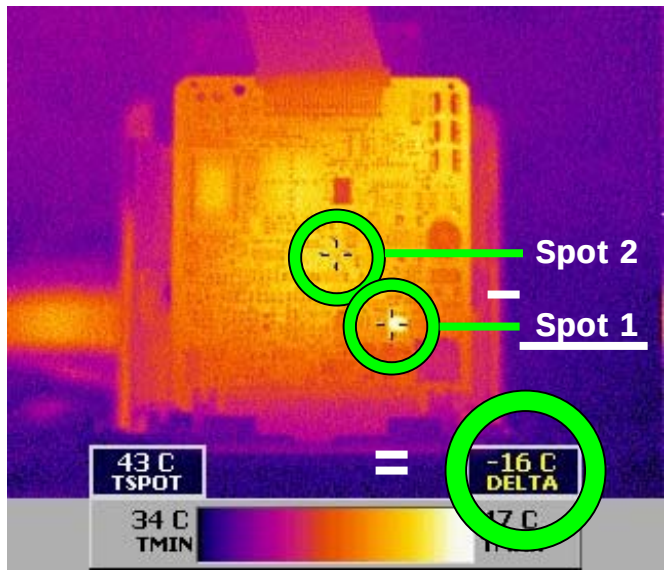
Emissivity Table	
Aluminium, bright-rolled 170 °C	0.04
Cotton 20 °C	0.77
Concrete 25 °C	0.93
Ice, smooth 0 °C	0.97
Iron, emeried 20 °C	0.24
Iron with cast skin 100 °C	0.8
Iron with rolled skin 20 °C	0.77
Gypsum 20 °C	0.9
Glass 90 °C	0.94
Rubber, hard 23 °C	0.94
Rubber, softgrey 23 °C	0.89
Wood 70 °C	0.94
Cork 20 °C	0.7
Heat sink, black anodised 50 °C	0.98
Copper, lightly tarnished 20 °C	0.04
Copper, oxidised 130 °C	0.76
Plastics (PE, PP, PVC) 20 °C	0.94
Brass, oxidised 200 °C	0.61
Paper 20 °C	0.97
Porcelain 20 °C	0.92
Black paint (matt) 80 °C	0.97
Steel (heat-treated surface) 200 °C	0.52
Steel oxidised 200 °C	0.79
Clay, fired 70 °C	0.91
Transformer paint 70 °C	0.94
Brick, mortar, plaster 20 °C	0.93

Measurement Performance - Analysis

Temperature analysis can be performed in the field during inspections using the camera's analysis functionality or at a PC using a image analysis/report generation software.

In the Field Analysis - Typical

- Spot Measurement
  - Delta and Multiple
- Temperature Rise
- Range and Span Optimization
- Palette Selection
- Emissivity Entry
- Load (Electrical Inspection)
- Background Temperature
- Preliminary Diagnosis



Automatic Delta Display

Measurement Performance – Ambient Temperature Range

The operating ambient temperature range of a thermographic camera is determined by both the electronics and the techniques used to calibrate cameras so that they produce accurate measurements over the entire operating temperature range.

What effects camera operation?

1. The liquid in an LCD is made up of glass, organic sealant, organic fluid and polymer based polarizers that have a limited operating temperature range.
2. Electronics. All the components is a systems must meet the camera operating temperature specifications.
3. Environmental temperature change. Cameras taken from a warn ambient into very cold conditions are subject to condensation formation on optical surfaces even frost.

What effects the camera calibration?

1. Over 80% of the infrared radiation the camera detector receives comes from non-scene sources. The camera housing contribution is significant and properly designed systems employ sophisticated ambient temperature compensation that incorporate multiple temperature sensors and factory calibrations that utilize precision black bodies and environmental temperature chambers.

Measurement Performance –Temperature Range

Thermography cameras are available that provide varying temperature range capabilities. For the majority of applications, thermographic systems that measure temperature up to 500°C (932°F) are adequate.

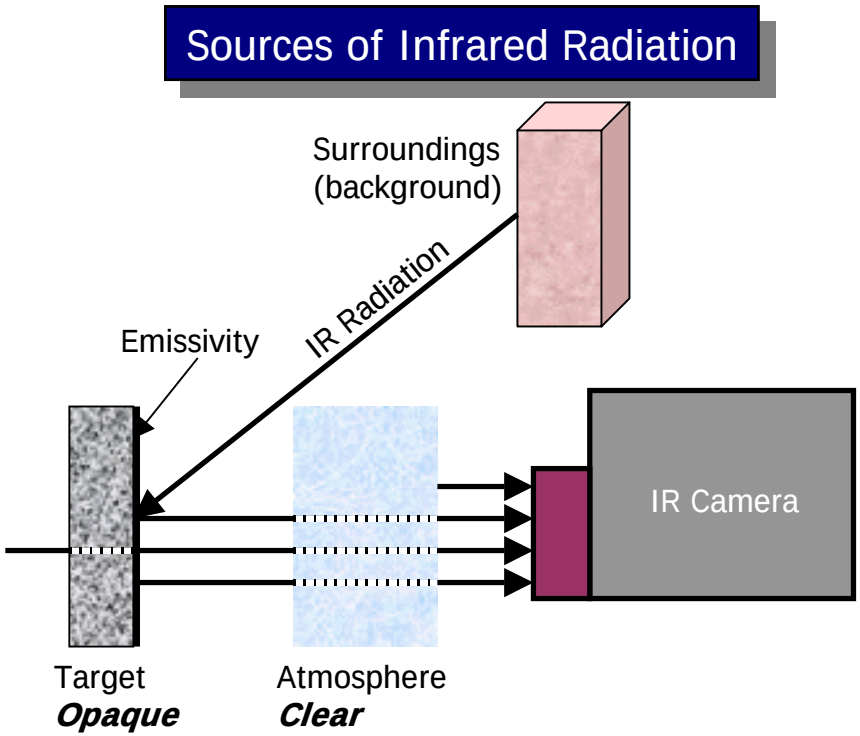
- ***Low Temperature Models*** - up to 250°C
- ***Standard Temperature Range Models*** – up to 500°C (932°F)
- ***High Temperature Range Models*** – up to 2000°C

Low Temperature	Standard	High Temperature

• Electrical Inspection
  • Low Voltage
• Mechanical
	• Electrical (All)
	• Mechanical
	• Refractory
	• Process Monitoring
	  • Non metals
		• Electrical
		• Mechanical
		• Refractory (All)
		• Furnace Tubes[1]
		• Process Monitoring

1 – With proper spectral band pass filter

Measurement Performance –Object Parameters



Target	**Object to be measured. It is assumed to be opaque.**
Atmosphere	**The environment the IR energy passes through is assumed to be 100% transparent.**
Surroundings	**Energy emitted by the background reflected off the target relative to the target's emissivity.**
Emissivity	**The ratio of power radiated by a substance to the power radiated by a blackbody at the same temperature.**

The camera sees all sources of radiation but relies on user input to correct for the all the sources of infrared.

It is practical to make some assumptions about "real world" applications and the number of object parameters can be reduced to two.

1. The object is opaque.
2. Since we are imaging in the 8-12 micron band, the atmosphere is considered transparent.

In most cases the background temperature and the ambient temperature are the same. In cases where the background is hot, the user turns around and measures the area and then enters the background temperature into the user menu.

Thermography Camera Evaluation – Ergonomics

How well the user interfaces with a product determines in large measure to how well the product will work for each individually.

Weight	Display Angle	User Interface

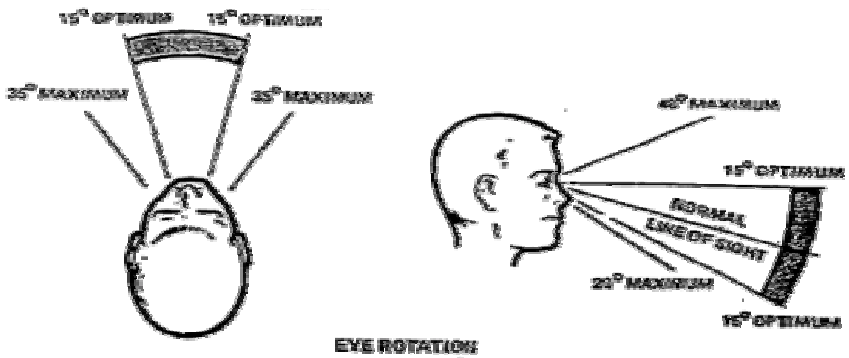
• What are your expectations?
• Make certain you "add up" all the components you intend to use.
  • Batteries
  • LCD Display and battery (if necessary)
  • Visible camera
	Is the display angle adjustable?
	• Can you adjust for different viewing angles
	  • Floor level
	  • Overhead
	• What about reflections?
	• What about a viewfinder for outdoor direct sunlight conditions?
		• Does the camera have a proper hand grip and strap?
		• Do the button inputs make sense? Are they intuitive?
		• Are there multiple inputs
		  • Onscreen menu
		  • Touch screen
		• DO THEY MAKE SENSE

Display Angle

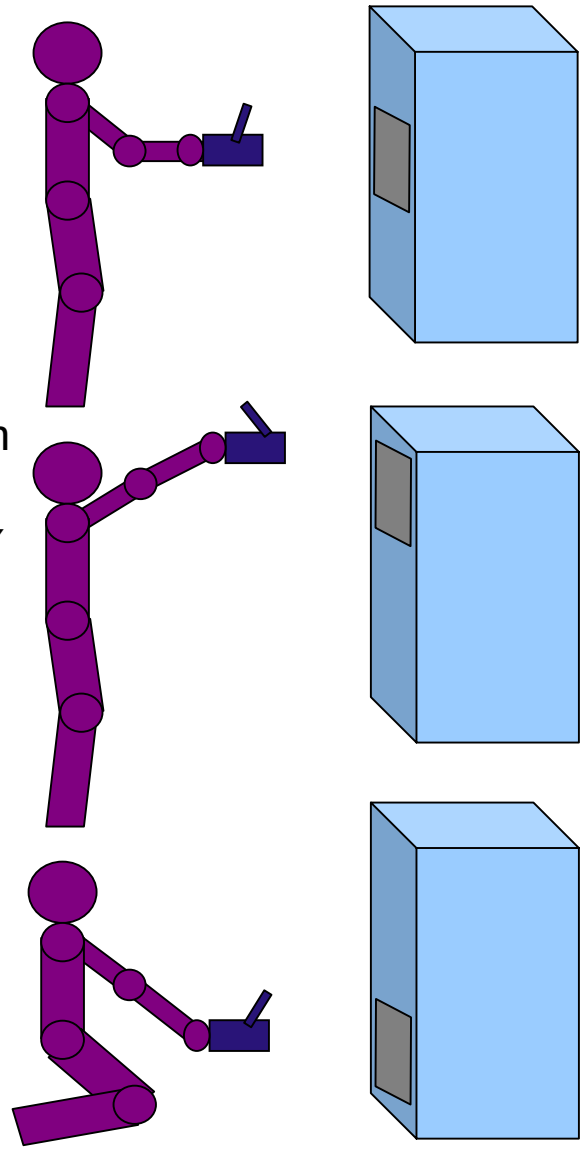
There are two issues related to display angle optimization.

1. Maintaining the most comfortable angle when viewing object at different heights
2. An LCD display has an optimal viewing angle. Issues like brightness and ambient light reflection should be evaluated.

Units with fixed viewing angles potentially will cause operator fatigue and cause the operator to assume dangerous positions.



Human Factors Specification mil-std 1472f



Display Angle

Point and Shoot style cameras require the user to position themselves relative to objects due to no display angle adjustment.

- How do you image objects near floor level?
- How do you image object overhead?

Point and Shoot style cameras require that the camera be held at arms length to achieve optimal viewing angle. Many require two hand operation. This may cause significant operator fatigue.

Point and Shoot Cameras

Make sure you experience holding the camera at different elevations!

Camera Functions

- Image Recording
- Voice Recording
- Visible Image Camera
- Electronic Zoom
- AGC
- Palette Selection
- Report Generation

- Image Recording
- Voice Recording
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Image Capture

Today's thermographic systems offer image recording to either internal memory or removable media. Depending on your requirements you should consider the following issues.

- *Do I wish to be able to remove my recorded images from the camera so that it can be returned to the field or is connecting the camera to a serial (or USB) cable acceptable?*
- *Is the memory capacity provided adequate for my needs?*
    - *Don't forget about voice files and visible image files*
- *How secure is the cameras memory?*
    - *Removable memory cards are extremely reliable.*
- *How expensive is it to upgrade (if available) to additional memory.*
- *Will I ever need to carry an image library into the field for comparison analysis?*

SD Media

Compact Flash Media

Voice Recording

Many systems incorporate a voice recording feature. Since nearly all thermographic cameras have a limited data input capability, voice notes are a practical way to record a wide range of field observations.

Voice Recording Feature Issues

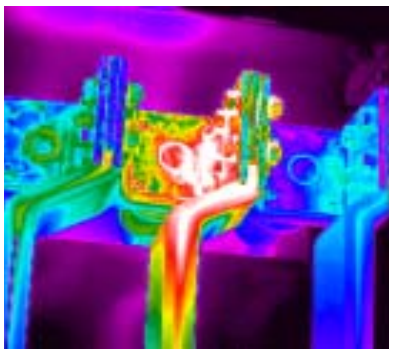
1. Is the voice file a standard .wav format that can be played back in Microsoft Office applications and reports?
2. Is the voice recording duration adequate for your needs?
3. Is an external microphone required? If yes, is being tethered to the camera acceptable?
4. What are your expectations for recording in high ambient noise conditions? Generally the quality of voice recordings in high ambient noise conditions is poor. You should have the system voice recording and playback capability demonstrated in the facility under conditions typical of normal operations.

Visible Image Recording

- Image Recording
- Voice Recording
- Visible Image Camera
- Electronic Zoom
- AGC
- Report Generation

Visible reference image recording has become a standard practice in infrared inspection and many cameras incorporate a visible camera. What to consider:

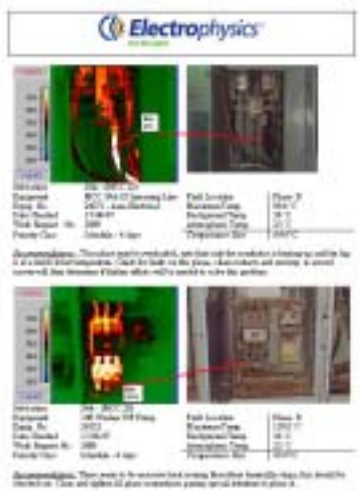
1. **Does the visible camera feature a flash?**
2. **How is the visible camera output displayed?**
3. **How is the visible camera controlled?**
4. **Are there user selected setting for resolution levels and flash control?**
5. **How the visible images recorded? How are they named?**



Thermal

Visible

Picture in Picture Display



Report Generation

Visible Image Recording

- Image Recording
- Voice Recording
- Visible Image Camera
- Electronic Zoom
- AGC
- Report Generation

The majority of infrared inspections is of electrical cabinets. Typically electrical apparatus is inside a cabinet while the lighting is high overhead. Without a flash your control photos maybe too dark to be a good reference image.

With Flash

Without Flash

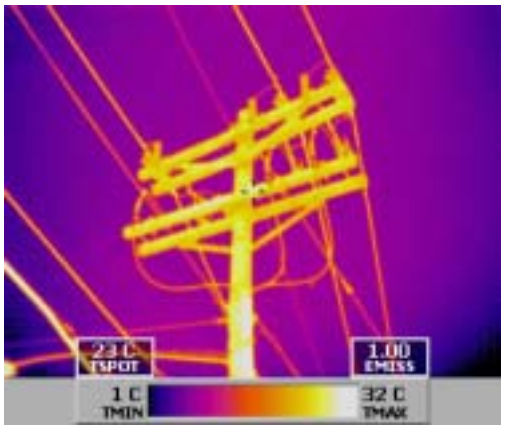
A FLASH Unit Really Makes a Difference!

Electronic Zoom

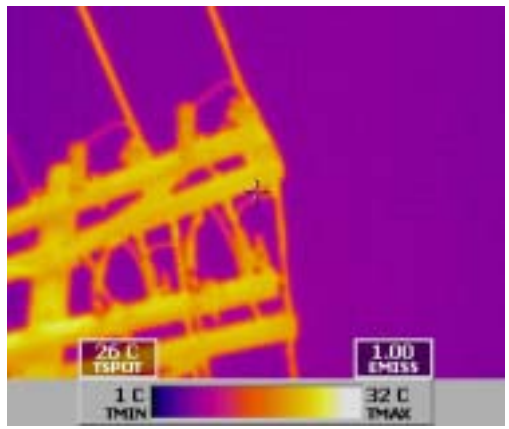
- Image Recording
- Voice Recording
- Visible Image Camera
- Electronic Zoom
- AGC
- Report Generation

Electronic zoom is a useful feature when conducting inspections at distances greater than 15 feet. A 320x240 camera at 2X zoom provides the same image as a 160x120 with no electronic zoom.

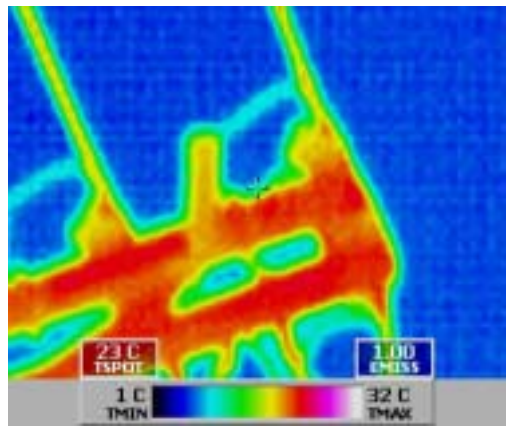
For most applications the imagery at magnification level beyond 4X creates images with too much pixelization. Be aware that electronic zoom is not the same as an optical zoom. The measurement and image resolution remains the same regardless of electronic zoom power.



320x240 Pixel with a 25° Lens
No Magnification



320x240 Pixel with a 25° Lens
2X Magnification



320x240 Pixel with a 25° Lens
4X Magnification

Automatic Gain Control (AGC)

Most of today's cameras feature an automatic gain control feature. Think of AGC as the auto exposure function in your camcorder. AGC simplifies the operators' need to set camera controls and enables users not fully trained or with experience to conduct thermographic inspections and collect good data.

1. Does the camera you are evaluating offer AGC?
2. If yes, what type? Continuous, momentary or both.

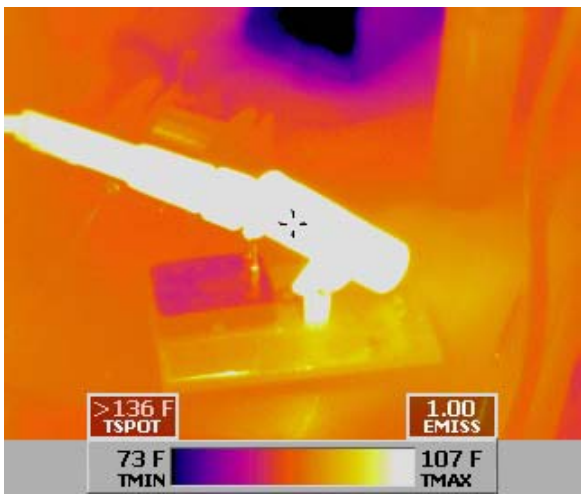
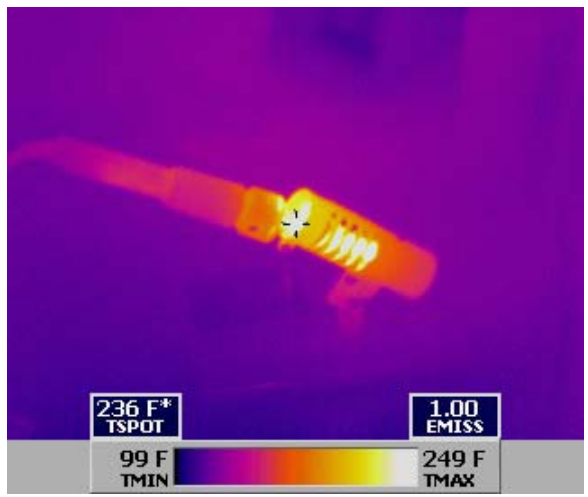


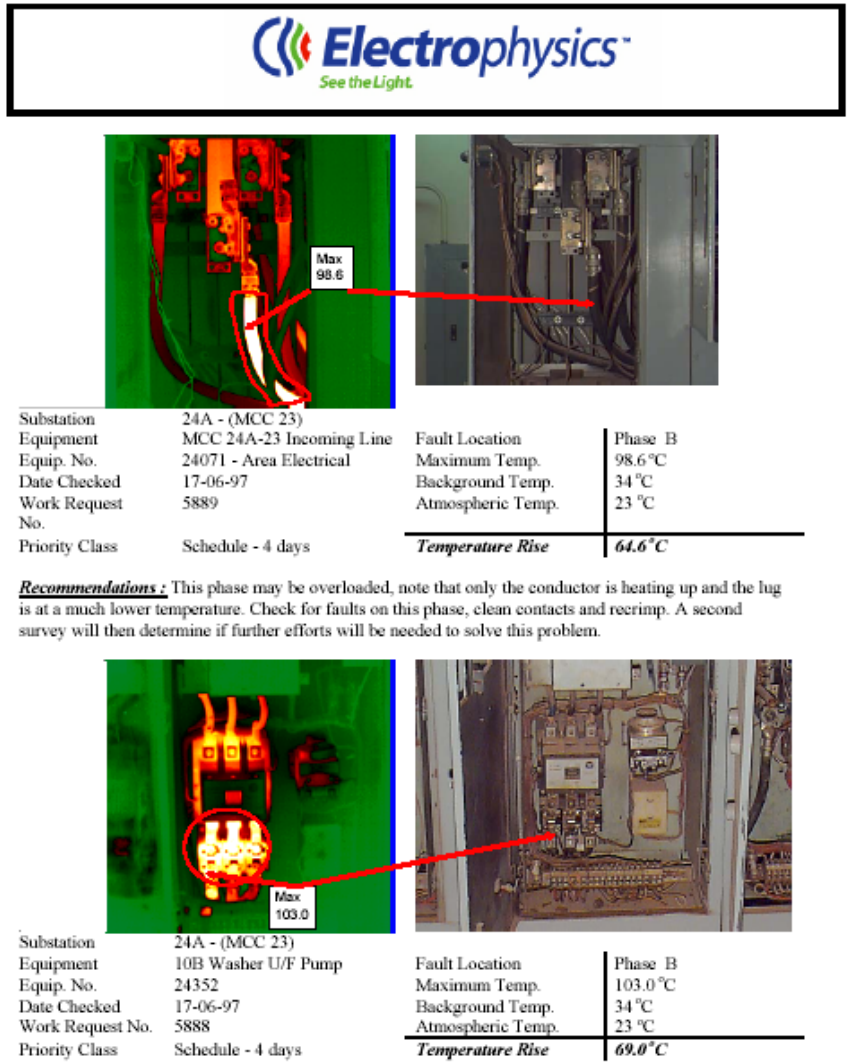
Image out of range



Auto adjust sets the proper range and level automatically

Report Generation

- Should have ability to analyze images
- Should feature a wide variety of tools
  - Spot meters
  - Isotherms
  - Area Analysis (average, SD, etc.)
  - Line Profile
  - Results table
- Easy visible and IR image loading
- Ability to rescale images and change palettes and change object parameters such as emissivity.
- Marker tools to make reports easy to read.
- Many programs run within Microsoft Office making training fairly easy.



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Substation	24A - (MCC 23)		
Equipment	MCC 24A-23 Incoming Line	Fault Location	Phase B
Equip. No.	24071 - Area Electrical	Maximum Temp.	98.6 °C
Date Checked	17-06-97	Background Temp.	34 °C
Work Request No.	5889	Atmospheric Temp.	23 °C
Priority Class	Schedule - 4 days	***Temperature Rise***	***64.6°C***

Recommendations : This phase may be overloaded, note that only the conductor is heating up and the lug is at a much lower temperature. Check for faults on this phase, clean contacts and recrimp. A second survey will then determine if further efforts will be needed to solve this problem.

Substation	24A - (MCC 23)		
Equipment	10B Washer U/F Pump	Fault Location	Phase B
Equip. No.	24352	Maximum Temp.	103.0 °C
Date Checked	17-06-97	Background Temp.	34 °C
Work Request No.	5888	Atmospheric Temp.	23 °C
Priority Class	Schedule - 4 days	***Temperature Rise***	***69.0°C***

Recommendations: There seems to be excessive heat coming from these bimetallic strips, this should be checked out. Clean and tighten all phase connections paying special attention to phase A.

Cost of Ownership

Cost to Purchase	Ongoing Cost	Service Costs
• How much does the camera cost? • Does my company capitalize such assets? • Do I want to consider criteria such as cost per pixel or other metric?	• Does the sophistication of the camera require outside training support? • If yes, how much does it cost and how often will I need to budget for it? • Are there any consumables? • Are there software licensing issues?	• What is the warranty? • What is the calibration frequency? • What does a calibration cost? • Are service contract available • What is the companies service turn around performance

Fortunately the cost trend is very positive. Full featured high resolution cameras are available for under $17,000 and uncooled sensor technology has proven to be extremely reliable.

Costs are Falling Rapidly and Reliability is Way Up!

Summary

- Image quality can be quantified
- A wide range of products are available.
- The promise of uncooled technology is finally here.
  - ***Costs are declining rapidly.***
- Two levels of resolution have become standard.
- Integrated visible cameras are becoming standard.
- Cameras while easy than ever to operate still require training to teach accurate measurement techniques.

Thank you for reviewing our thermographic camera buyers guide. If you would like a copy, please contact me or visit Electrophysics.com and request a copy.

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