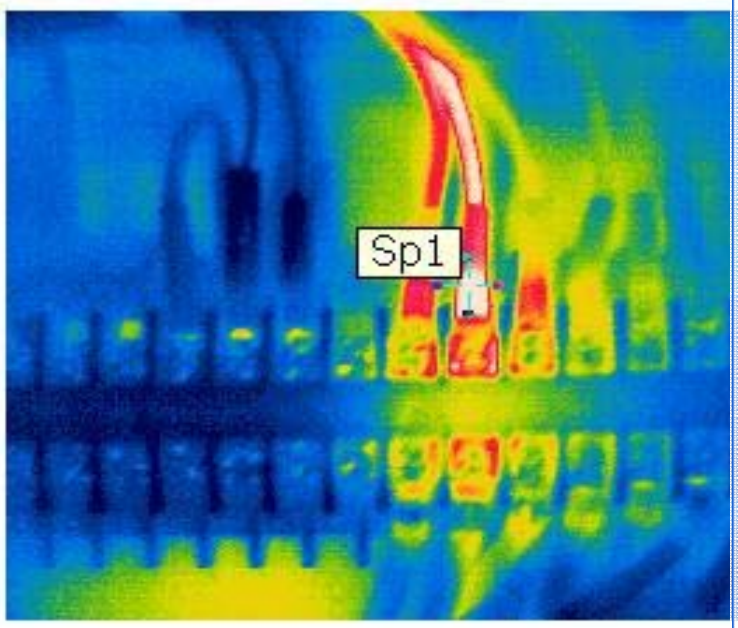
Introduction to Infrared Thermography



Jeff Beard

IT 570

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Contents

Welcome to the world of infrared thermography!

Infrared thermography is a proactive troubleshooting and predictive maintenance tool. In the hands of a thermographer an infrared camera can be used to make the world that is invisible to the human eye come to life.

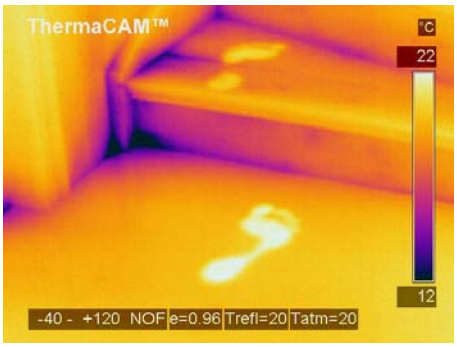
The purpose of this module is to get you to a point where you are comfortable with the basic operation of the FLIR ThermaCAM™ E45 Infrared Camera and be able to generate reports using ThermaCAM™ Reporter 2000 software. In order to use the camera and software effectively you will need to gain a general understanding of the science behind infrared thermography. This module will expose you to the terminology and skills needed to begin using the infrared camera as part of your job.

To complete this module you will need a FLIR ThermaCAM™ E45 Infrared Camera and a computer with ThermaCAM™ Reporter 2000 software.

After working through this module and the practice activities, you should be able to do the following:

- Given a list of infrared thermography and camera terms, you will be able to explain the meaning and function of each.
- Using this guide, you will be able to power on the infrared camera, adjust the emissivity setting, and capture a focused image.
- Using the ThermaCAM™ reporter software, you will be able to correctly complete a report.

Thinking Thermally…



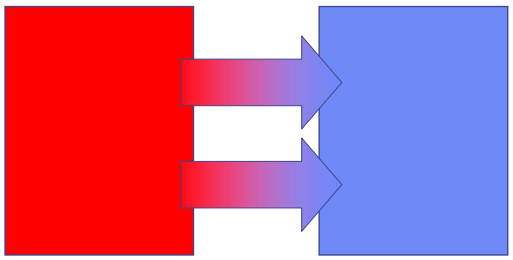
…one step at a time.

Section 1: Infrared Thermography Basics

This section will present you with general information about infrared thermography and infrared camera functions.

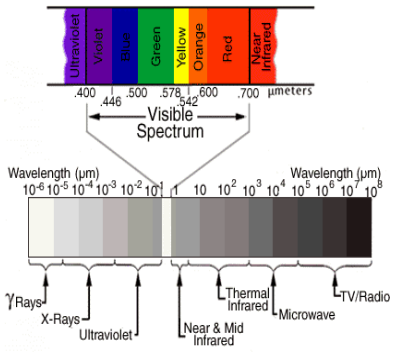
By the end of this section you will be able to:

- Take a list of infrared thermography and camera terms and be able to explain the meaning and function of each.



1. Infrared Thermography Basics

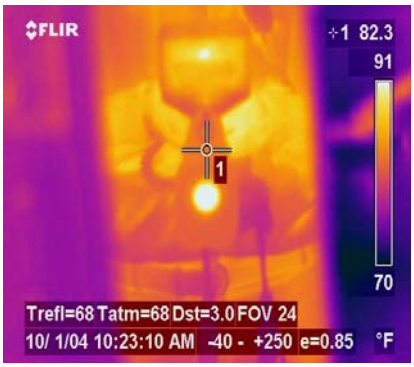
1.1 Infrared Thermography Terminology



What is Infrared Thermography?

- Infrared- below last visible color (red)
- Therm- Greek word for heat
- Graph- writing or representation for a specified process

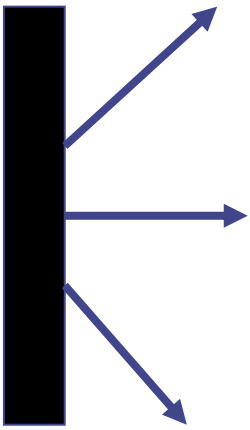
❖ *Basically a graphical representation of heat*



Kirchoff's Law: E+T+R=1

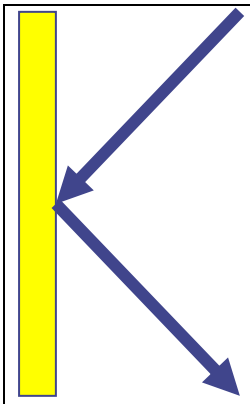
- Emitted Energy + Transmitted Energy + Reflected Energy = 1
- In most cases E+R=1

❖ *Good Emitter = Poor Reflector*
❖ *Good Reflector = Poor Emitter*



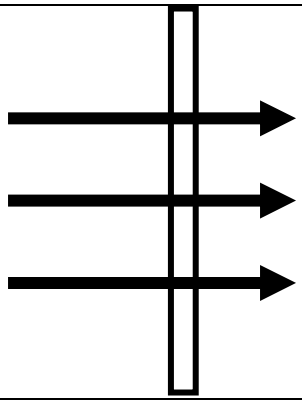
Emittance

- A perfect emitter is referred to as a Black body and E = 1.
- All bodies in nature are *colored bodies* and have an E<1.
- Human skin is .98
- A good emitter is a good absorber of energy.



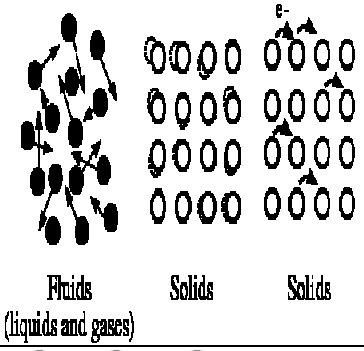
Reflectance

- The amount of light reflected from an object.
- Aluminum tape R=.98 E=.02
- A first surface mirror is a good reflector.



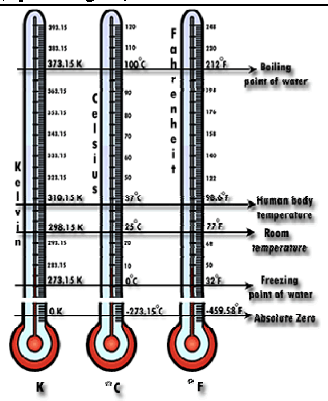
Transmittance

- The heat transmitted through an object to the camera.
- Thin plastics are transmissive.
- Opaque objects will not transmit energy. (Ex. metals, woods, concrete)



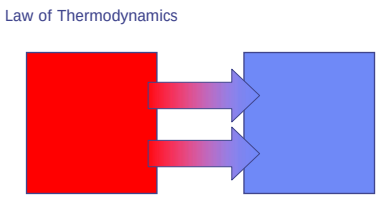
Heat

- Heat may be defined as a form of energy created by the molecular motions of an object.
- Heat, unlike temperature, is a measure of the total kinetic energy of all the molecules in the objects.



Temperature

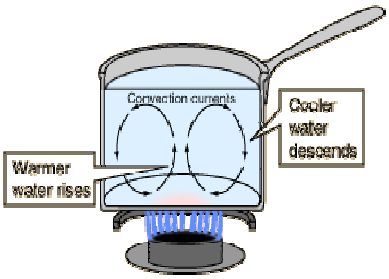
- Temperature is a measure of the thermal energy contained by an object; the degree of hotness or coldness of an object (e.g. atmosphere, living body) measurable by any of a number of relative scales.
- A measure of the quantity of heat present in something.



Heat Transfer

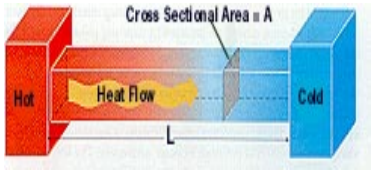
- Heat energy will transfer from an object of high temperature to an object or region of lower temperature unless it is blocked.

3 Modes of Heat Transfer



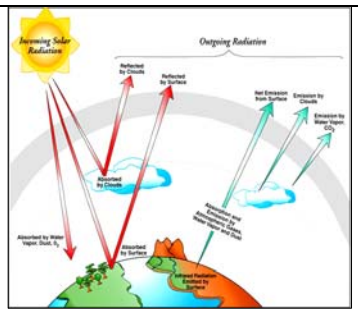
1. Convection

- Heat transfer through a fluid (e.g. air, water, gas).
- *Natural* convection involves the force of gravity.
- *Forced* convection involves a mechanism like a fan or pump.



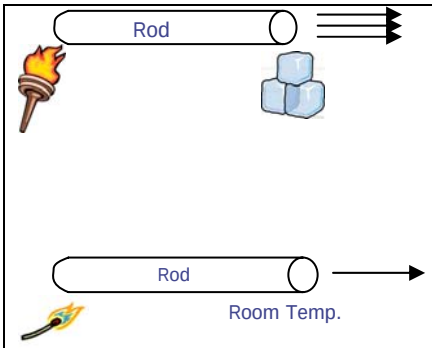
2. Conduction

- Transfer of energy from higher energy particles to lower energy particles. (i.e. one end of rod to other)
- Transfer of heat through or between two solids.



3. Radiation

- Transfer of energy through electromagnetic waves. (i.e. heat from fireplace warms you)

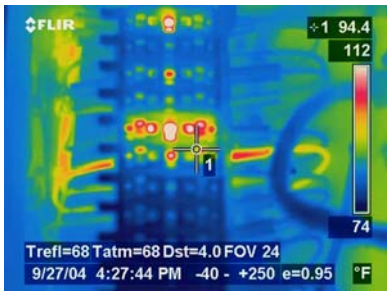


Delta T

- Difference in temperature.
- Increasing temperature differences will increase heat transfer rates.
- The bigger the delta T, the more heat is being transferred.

FoRD

- Focus- use focus ring to clarify image
- Range- press SEL to auto adjust
- Distance- make sure intended area is in image captured



Anomalie

- Something that is different than usual.
- Usually determined to be one of two conditions
  - ❖ No good condition
  - ❖ Different, but okay condition

Now that you have been exposed to some infrared thermography terminology and concepts, let's take a moment to practice your new knowledge with the practice activity on the next page.

PRACTICE ACTIVITY 1.1

For this review activity, place the letter of the term in the blank next to the correct definition. Check your answers in the appendix on page 38 (see Section 1, Practice Activity 1.1).

A. IR Thermography	B. Kirchoff's Law	C. Emitter
D. Reflector	E. Transmitter	F. Heat
G. Temperature	H. Heat Transfer	I. Convection
J. Conduction	K. Radiation	L. Delta T
M. FoRD	N. Anomolie	

1._____Heat detected through an object.

2._____Energy created by molecular motion.

3._____Basically a graphical representation of heat.

4._____A good absorber of energy.

5._____E+T+R=1

6._____A poor emitter of energy.

7._____Heat transfer through a fluid.

8._____Heat transfer between two solids.

9._____Higher temperature moving to lower temperature.

10.____Measure of quantity of heat in something.

11.____Difference in temperature.

12.____Something that is different than usual.

13.____Transfer of energy through electromagnetic waves.

14.____Focus, Range, and Distance.

Now that you have successfully completed this review of what you have learned so far, the next step is learning the camera terminology. Please proceed to the next page.

1.2 FLIR THERMACAM™ E45 INFRARED CAMERA TERMINOLOGY

Front View

Figure 1.1

Lens- Detects infrared image

Lens Cap- Protects lens from dust and damage

Focus Ring- Used to make image clear

Hand Strap- Used to attach carrying strap

Bottom View

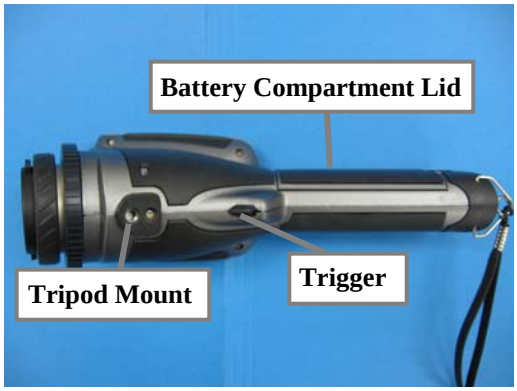


Figure 1.2

Tripod Mount- Used to attach tripod and use camera hands-free

Trigger- Press to perform function that has been designated

Battery Lid- Battery is behind this lid

End View

Figure 1.3

Power Supply Port- Top port (LCD screen up)

USB/ RS-232 Port- Middle port

Video Port- Bottom port (LCD screen up)

*__Note__- There is a description of the functions on page 12

Top View

Figure 1.4

LCD screen-	Image and menu options appear here
SEL-	Press to auto adjust or switch between screen objects
SAVE/ FRZ-	Press briefly to freeze image or >1 second to save an image
Navigation Pad-	Used to move up/down and left/right
LED-	Indicates that power is on
PWR/ NO-	Press to power on or to cancel selection in dialog box
MENU/ Yes-	Press to display vertical menu or to confirm selection in dialog boxes

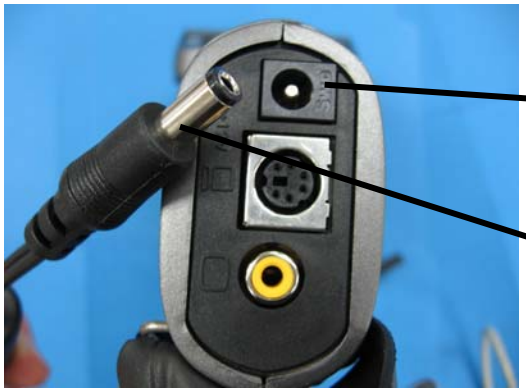


Figure 1.5

Power Supply

Power supply port- Plug the power supply cable into this port to charge or use without a battery.

Power supply cable- Connects the camera to the power outlet.

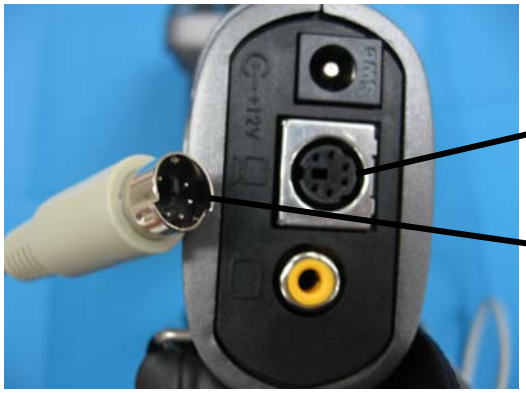


Figure 1.6

RS-232

RS-232 port- Plug the USB/ RS-232 cable into this port to communicate with a laptop or PC.

USB/ RS-232 Cable- Connects camera to laptop or PC.

Figure 1.7

Video

Video Port- Plug the video cable into this port to view an image on a monitor.

Video Cable- Connects camera to a monitor.

Now that you have been exposed to some infrared camera terminology and concepts, let's take a moment to practice your new knowledge with the practice activity on the next page.

PRACTICE ACTIVITY 1.2

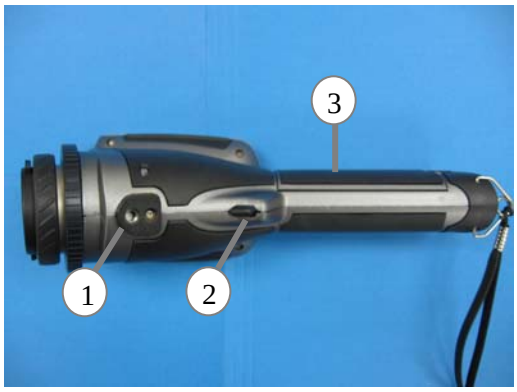
For this review activity, place the number in the blank next to the correct description. Check your answers in Section 1 (pages 10-12).

___Focus Ring

___Lens

___Hand Strap

___Lens Cap



___Trigger

___Battery Lid

___Tripod Mount

___MENU/ YES

___LED indicator

___Navigation Pad

___LCD Screen

___PWR/ NO

___SEL button

___ SAVE/ FRZ

___USB/ RS-232 Port

___Video Port

___Power Supply Port

Now that you have successfully completed this review of what you have learned so far about camera terminology, now it is time to test your knowledge on infrared thermography. Please proceed to the next page.

one step at a time

TEST YOUR KNOWLEDGE

This practice test includes matching, multiple choice and true/ false. Try to answer with out referring back to the materials. Check your answers in the appendix on page 38 (see Section 1, Test Your Knowledge).

1. Match the definition with the term:

Definition:	*Term:*
___An object that heat goes through is a	a. Reflector
___A good reflector is a poor	b. Tramsmitter
___A good emitter is a poor	c. Emitter

2. The bigger the delta T, the _____.

a. less heat is transferred
b. more heat is transferred
c. same heat is transferred

3. A good thermogram contains qualitative and quantitative information.

True

False

4. Infrared Thermography is _____.

a. a graphical representation of heat
b. an accurate measurement of temperature
c. a photographic representation of heat

5. Match the definition with the term:

Definition:	*Term:*
___Heat transfers through movement of a fluid	a. Radiation
___Transfer of heat between two solids	b. Conduction
___Transfer of energy through electromagnetic waves	c. Convection

6. Heat transfers from a lower temperature to a higher temperature unless it is blocked.

True

False

7. What does the Mnemonic FoRD represent?

a. Fix or Repair Daily
b. Focus, Reading, Distance
c. Focus, Range, Distance
d. Focus, Results, Delta

8. An anomolie is when you have a normal operating condition.

True

False

9. Heat is a form of _____and temperature is a _____of energy.

a. temperature, form
b. kinetic energy, molecule
c. energy, measurement

10. The infrared camera detects wavelengths below the last visible color.

True

False

Now that you have successfully completed this section on infrared thermography terminology, now it is time to learn how to use the FLIR ThermaCAM™ E45 Infrared Camera . Please proceed to the next page.

Section 2: Camera Operation

This section will step you through the basic operation of the FLIR ThermaCAM™ E45 Infrared Camera functions.

By the end of this section you will be able to:

- Use this guide to power on the infrared camera, adjust the emissivity setting, and capture a focused image.

2. Camera Operation

2.1 Powering on/off ThermaCAM™ E45 Camera

1. Pick up camera with right or left hand.
2. Press **PWR/NO** button (Figure 2.1). Screen display will resemble Figure 2.2.

Figure 2.1

Figure 2.2

3. Remove **Lens Cap** (Figure 2.3- lens cap on, Figure 2.4 - lens cap removed).


Figure 2.3


Figure 2.4

4. Press **PWR/NO** button (Figure 2.5) and hold > 2 seconds to **power off**. Screen will display "Shutting down in 2 seconds, 1 second, powering down" (Figure2.6).

Figure 2.5

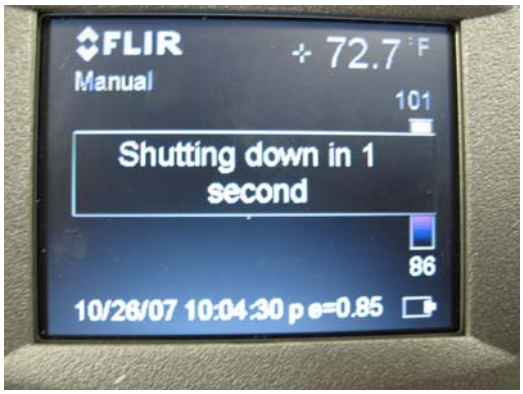


Figure 2.6

2.2 Setting Emissivity

After powering on you must determine the emissivity value. There are tables that will give specific values for various materials and there are methods to determine the emissivity for each situation. However, for now use the default value of **0.85** and it should work fine.

1. Press **MENU/YES** button (Figure 2.7). Then menu opens (Figure 2.8).

Figure 2.7

Figure 2.8

2. Press **Navigation Pad up/down** button (Figure 2.9) to move down yellow highlight until "Emissivity" is highlighted (Figure 2.10).

Figure 2.9

Figure 2.10

3. Press **MENU/YES** button (Figure 2.11). Emissivity value is highlighted (Figure 2.12).

Figure 2.11

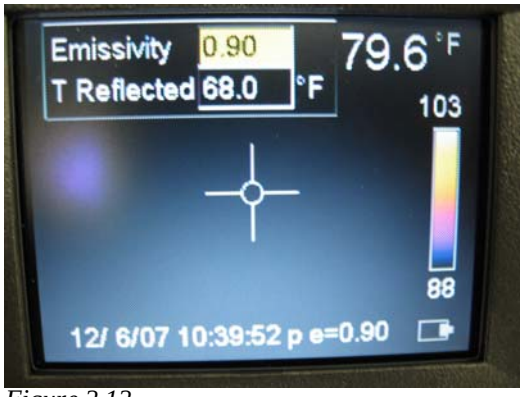


Figure 2.12

4. Press **Navigation Pad right/left button** (Figure 2.13) until 0.85 is achieved (Figure 2.14).

Figure 2.13

Figure 2.14

5. Press **MENU/YES** button (Figure 2.15). Screen should now have **e=0.85** at the bottom (Figure 2.16)

Figure 2.15

Figure 2.16

Now you are ready to capture a focused image!

2.3 Capturing a Focused Image

1. Point camera at object of interest.
2. Press **SEL** (Figure 2.17) and hold for >2 seconds to auto adjust temperature scale (bar on right side of Figure 2.18).

Figure 2.17

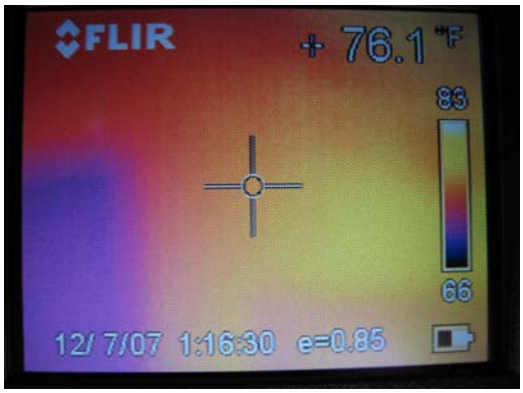


Figure 2.18

3. Press **SEL** (Figure 2.17) and auto adjust as many times as needed until contrast allows for discernable image (Figure 2.19 is better, but Figure 2.20 is even better).

Figure 2.19

Figure 2.20

4. Grab **Focus Ring** with index finger and thumb of hand not holding camera (Figure 2.21).


Figure 2.21


Figure 2.22

5. Adjust focus by twisting the **Focus Ring** (Figure 2.22) both directions until image is clear (Figure 2.23 is out of focus and Figure 2.24 is focused).

Figure 2.23

Figure 2.24

6. Press **SAVE/FRZ** (Figure 2.25). On the LCD screen under FLIR logo the word "Frozen" appears, across the bottom "SAVE-Save, NO-Cancel" appears (Figure 2.26).

Figure 2.25

Figure 2.26

7. Press **SAVE/FRZ** button (Figure 2.27) to save the image or **PWR/NO** button (Figure 2.28) to cancel.

Figure 2.27

Figure 2.28

8. Repeat steps 1 through 7 as needed to capture the best image or as many images as desired.

PRACTICE ACTIVITY

For this review activity, complete the missing steps for preparing the FLIR ThermaCAM™ E45 Infrared Camera for operation. Check your answers in the appendix on page 38 (see Section 2, Practice Activity).

Powering on/off the camera:

1. Pick up _____ with right or left hand.
2. Press _____ button.
3. Remove _____.
4. Press _____ and hold for more than two seconds to power off.

Setting the emissivity:

5. Press _____The menu opens.
6. Press _____ button to move down yellow highlight until "Emissivity" is highlighted.
7. Press _____ Emissivity value is highlighted.
8. Press _____ until 0.85 is achieved.
9. Press _____ Screen should display *e*=0.85.

Capturing a focused image:

10. Point _____at object of interest.
11. Press _____ and hold for 2 seconds to auto adjust temperature scale.
12. Press _____ and auto adjust as many times as needed until contrast allows for discernable image.
13. Grab _____ with index finger and thumb of hand not holding camera
14. Adjust focus by twisting the _____ both directions until image is clear.
15. Press _____ to capture image of object.
16. Press _____ to save the image or _____ button to cancel.

Now that you have successfully completed this review on operating the FLIR ThermaCAM™ E45 Infrared Camera, now verify you knowledge. Please proceed to the next page.

TEST YOUR KNOWLEDGE

Complete the following self-evaluation checklist to verify that you have the knowledge required to operate the infrared camera.

☐ **Yes** ☐ **No**	I know how to power on the camera.
☐ **Yes** ☐ **No**	I know how to remove the lens cap.
☐ **Yes** ☐ **No**	I know how to set the emissivity level.
☐ **Yes** ☐ **No**	I know how to verify that the correct emissivity level is set.
☐ **Yes** ☐ **No**	I know how to focus the camera on an image.
☐ **Yes** ☐ **No**	I know how to auto adjust the camera.
☐ **Yes** ☐ **No**	I know how to capture an image on the camera.
☐ **Yes** ☐ **No**	I know how to save an image on the camera.
☐ **Yes** ☐ **No**	I know how to connect the camera to power.
☐ **Yes** ☐ **No**	I know how to connect the camera to a laptop or PC.

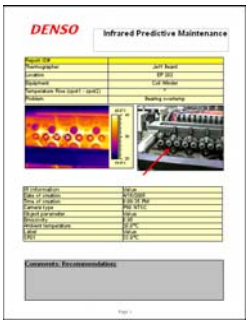
Once you can answer Yes to all of the questions above pertaining to operating the FLIR ThermaCAM™ E45 Infrared Camera, you can proceed to the next page.

Section 3: Reporting Results

This section will step you through using ThermaCAM™ Reporter 2000 Professional software.

By the end of this section you will be able to:

- Use the ThermaCAM™ Reporter 2000 Professional software to correctly complete a report.



3. Report Software

3.1 Use ThermaCAM™ software to make a report

Upload image(s) to laptop or PC

1. Connect camera using **USB/ RS-232 cable** (Figure 1.6, page 12).

    - Plug round end of cable into middle port on camera
    - Plug the USB end into USB port on computer

2. Press **PWR/ON** button on camera (Figure 2.1, page 18).
3. ThermaCAM™ software will automatically open and link the camera to the computer.
4. Instruction box will open on computer screen and give option to where to upload image(s).
5. Allow images to go to default location.

After uploading image(s)

6. Open "ThermaCAM™ Reporter 2000 Professional" by selecting icon (Figure 3.1) on desktop of laptop or PC

Figure 3.1

7. When "ThermaCAM™ Reporter 2000 Professional" opens the selection box gives new report options or template options (Figure 3.2).

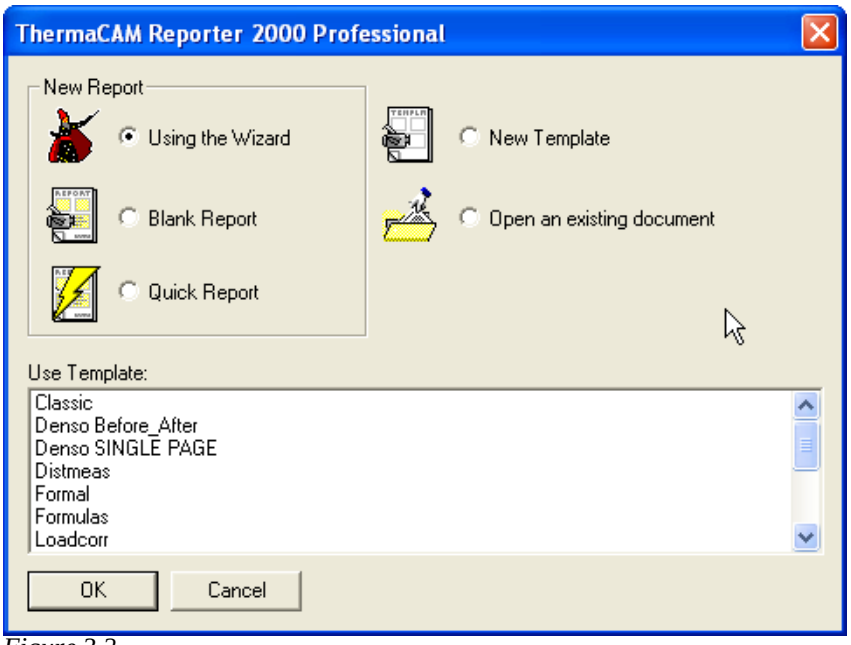


Figure 3.2

8. Under the **Use Template** options (Figure 3.3).
   - Select **Denso Before_After** if it is a before and after repair situation.
   - Select **Denso SINGLE PAGE** if it is a problem being reported.

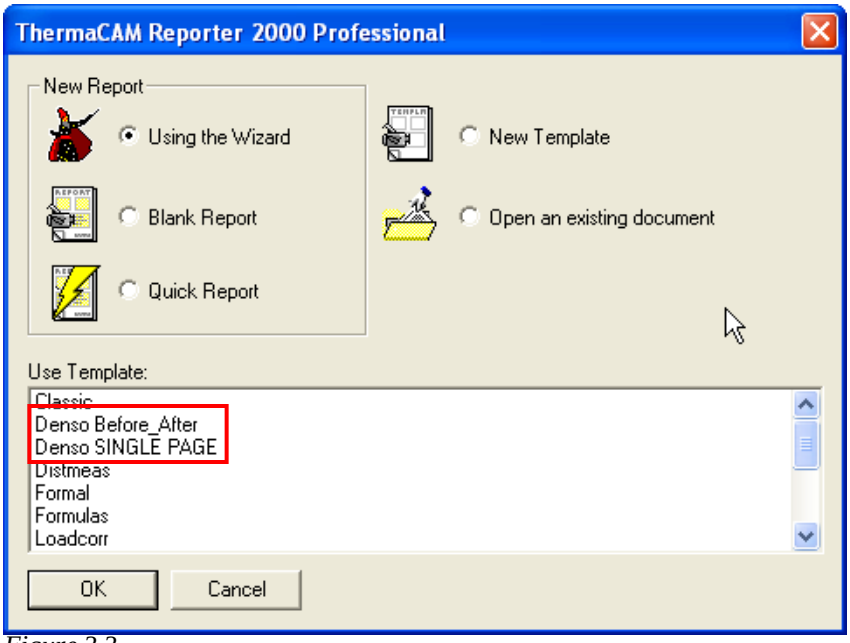


Figure 3.3

9. Follow the Report Wizard and select **Next** (Figure 3.4)

Figure 3.4

10. Click on **Select IR** (Figure 3.5).

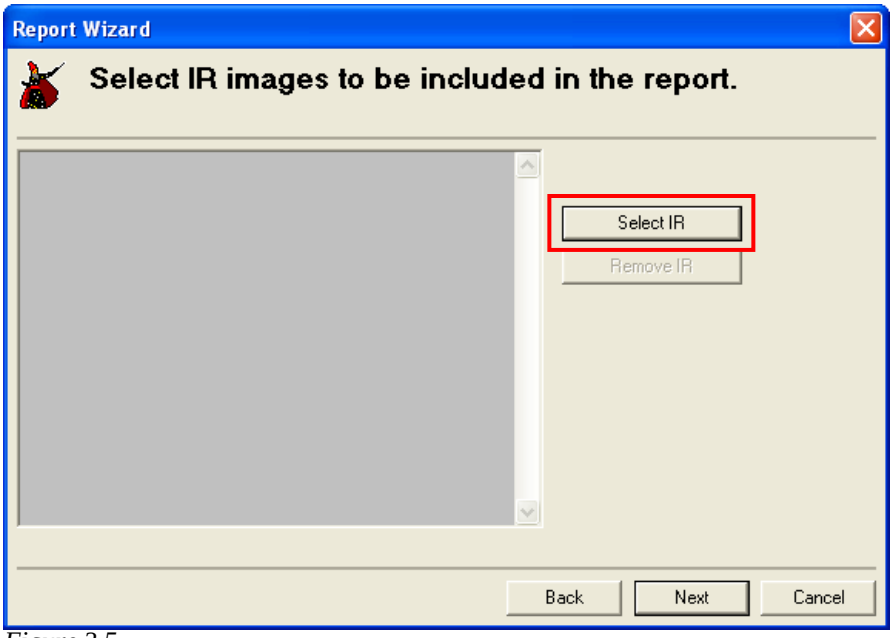


Figure 3.5

11. Then select the **View Thumbnails** box (Figure 3.6) to see images.

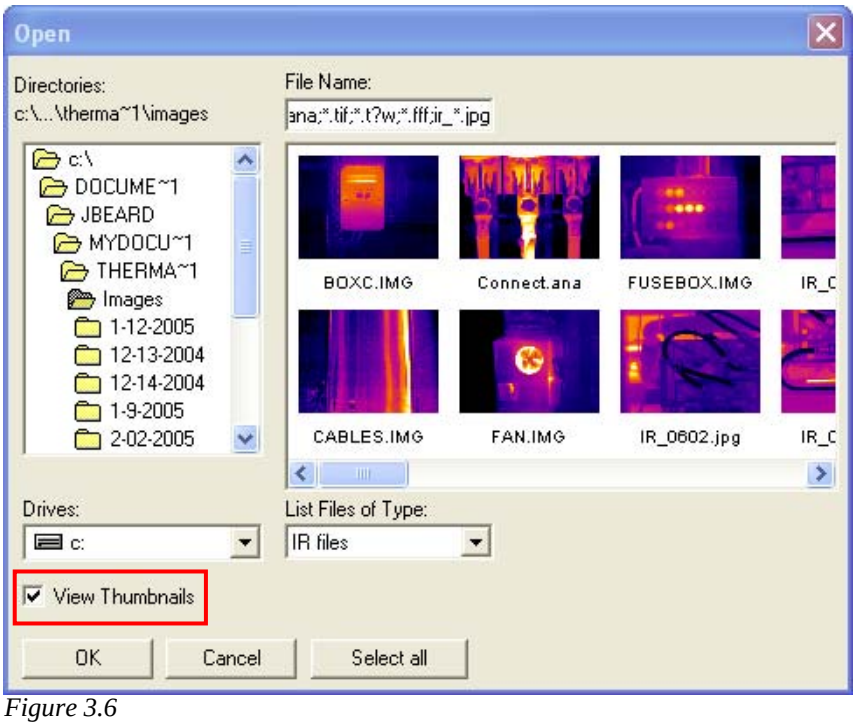


Figure 3.6

12. Then "**double click**" the folder that the images are in (Figure 3.7).

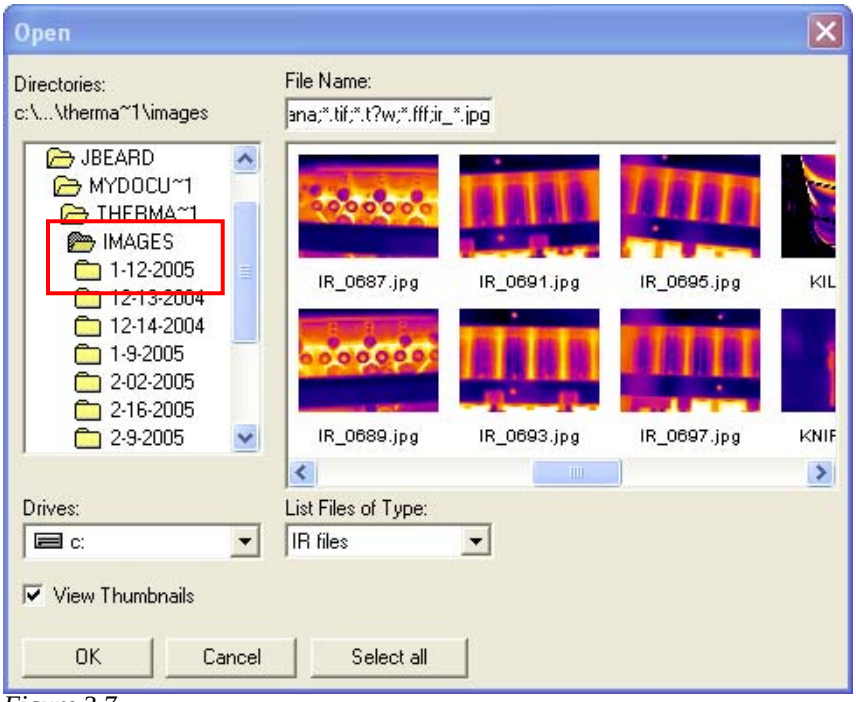


Figure 3.7

13. Then select the desired image and then click **OK** (Figure 3.8).

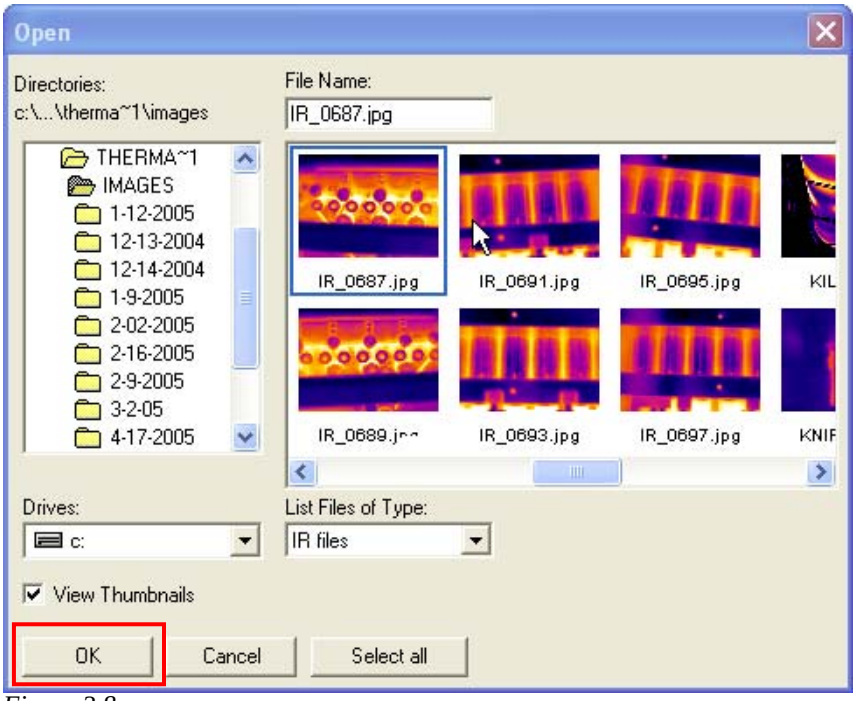


Figure 3.8

14. The desired image should appear, if not then select **Remove IR** (Figure 3.9) and start again at step 10 on page 28 (Figure 3.5).

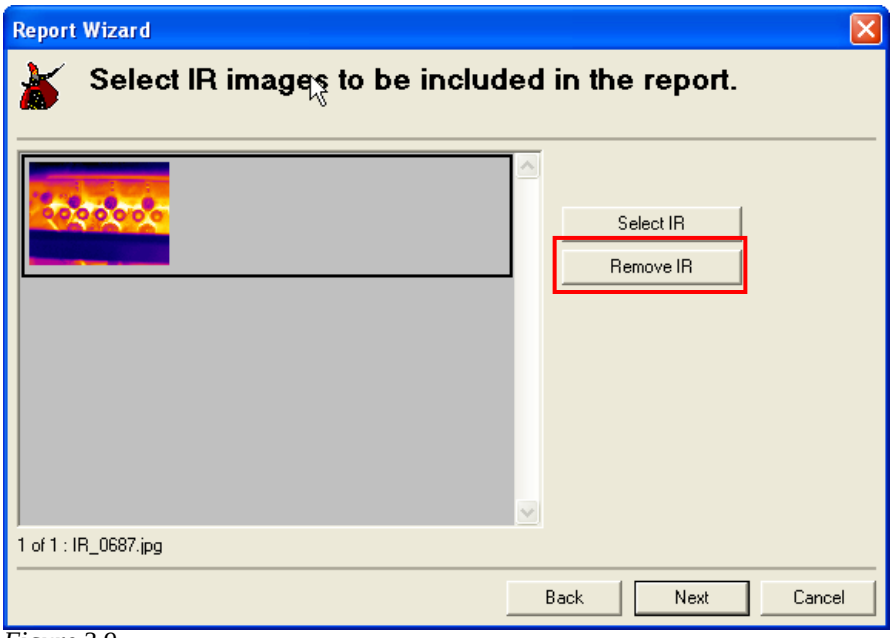


Figure 3.9

15. If okay and no additional images are needed then select **Next** (Figure 3.10).

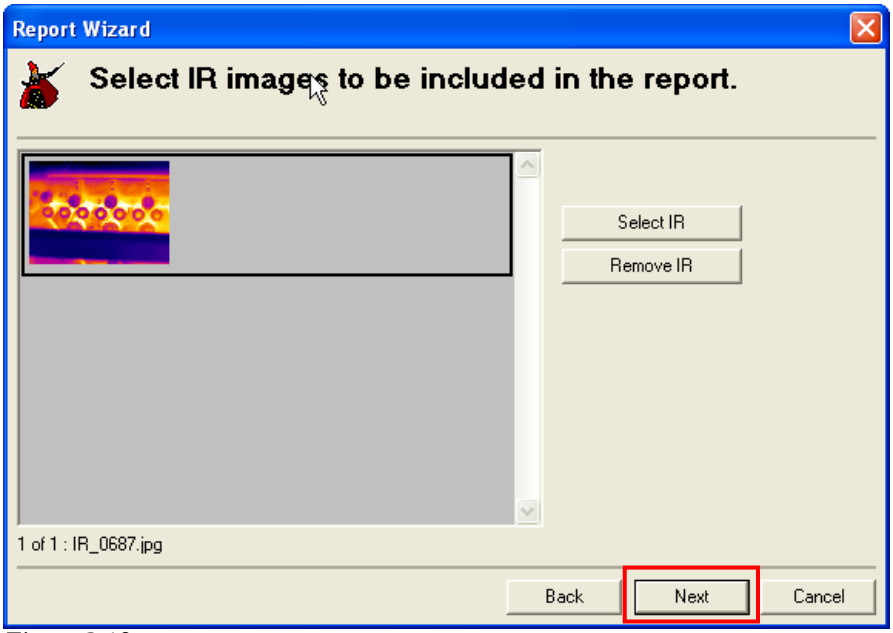


Figure 3.10

16. If okay and more images are being used in the report then click on **Select IR** and repeat steps 12-14 until all desired images are selected and then go to step 15.

17. If a digital photo was taken, then **Select photo** (Figure 3.11) can be selected and the photo can be obtained following the same method as selecting an IR image in steps 11-15.

Figure 3.11

18. Make sure that the correct photo is displayed and then select **Next** (Figure 3.12).

Figure 3.12

19. Type in the information in the **Value** boxes (Figure 3.13).

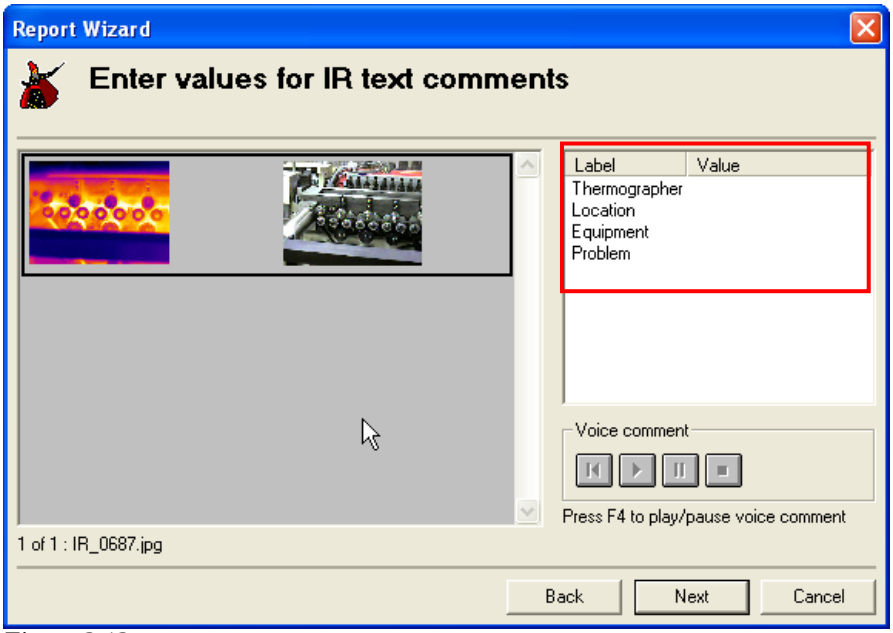


Figure 3.13

20. When data is entered in all of the boxes and data is verified correct, Select **Next** (Figure 3.14).

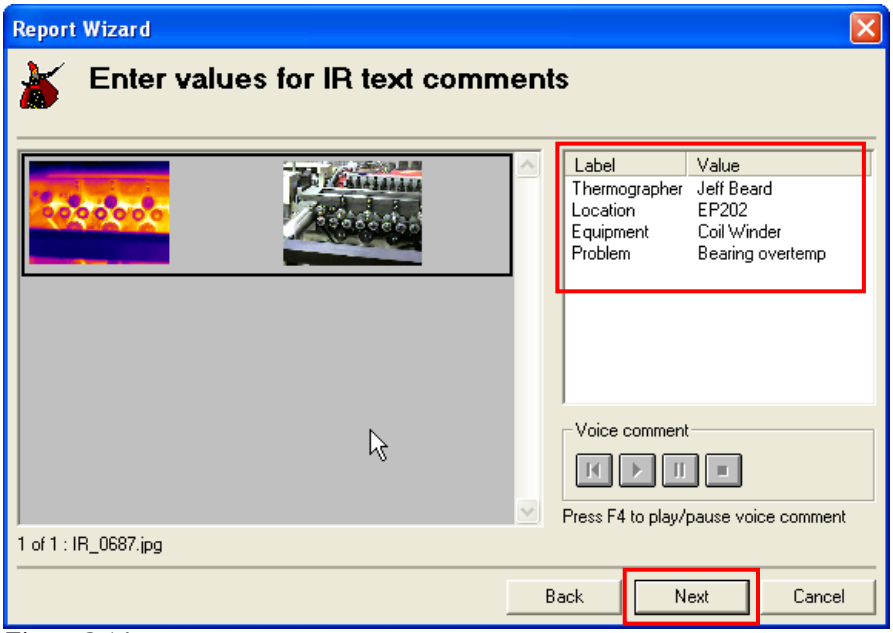


Figure 3.14

21. The wizard then prompts you to select **Finish** (Figure 3.15).

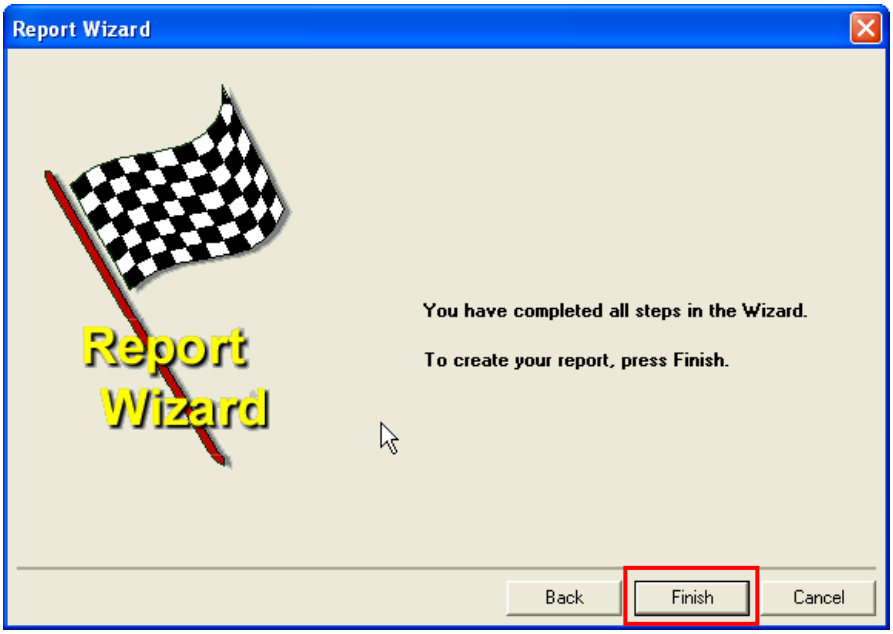


Figure 3.15

22. The report should now be displayed (Figure 3.16).

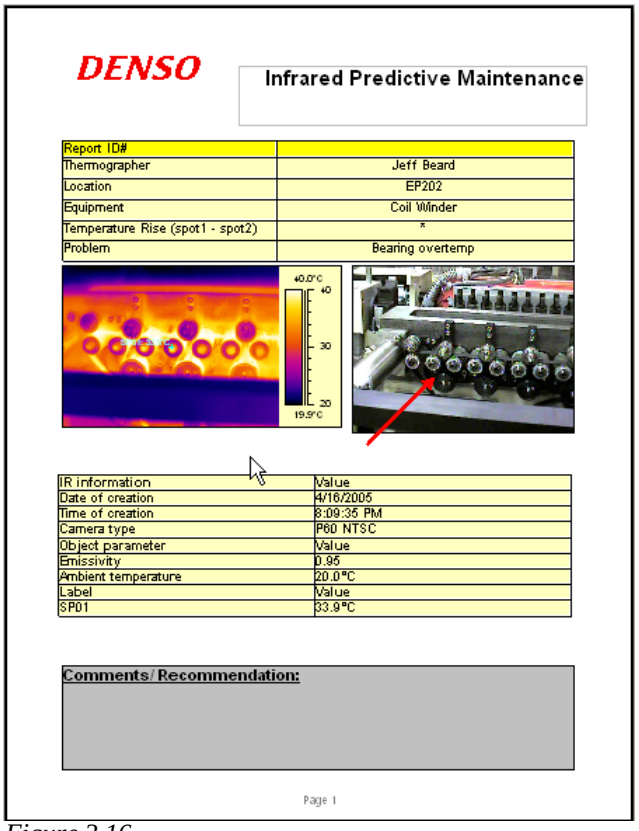


Figure 3.16

3.2 Saving A Report

1. Select the **save icon** or select **File** and then **Save** from the task menu (Figure 3.17).
2. Location to be saved to can be selected from "**Save in:**" options (Figure 3.17).

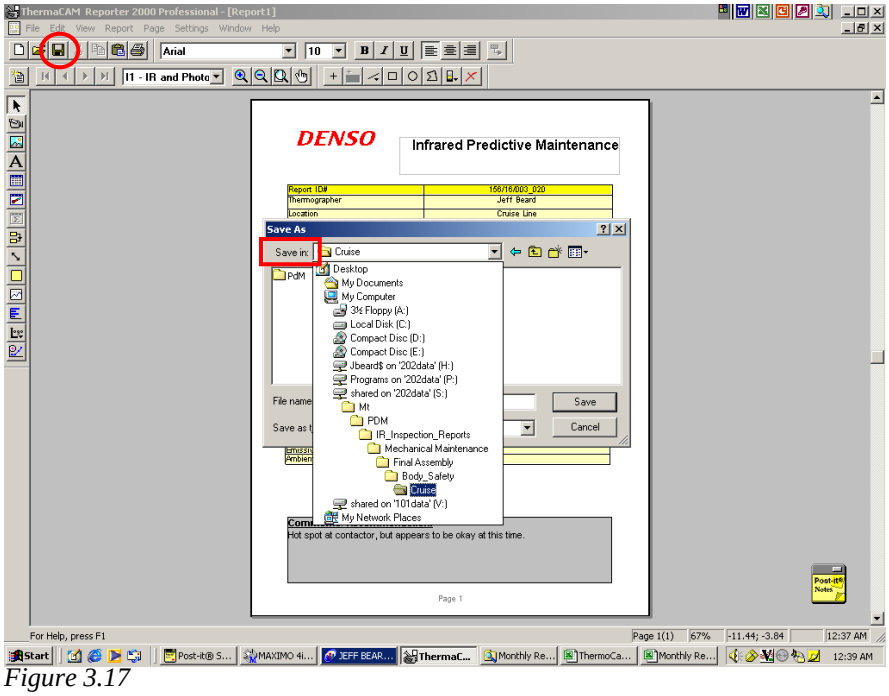


Figure 3.17

Evaluating Infrared Images

- Becoming an infrared thermographer with the ability to effectively evaluate an infrared image requires extensive training and experience.
- However, one can make basic evaluations by benchmarking.
  - Compare image with other same situations (e.g. exact location on other same type of equipment).
  - Verify that situation is good and capture image for future comparison.
  - Capture image of no good situation and capture new image when repair is made to compare.
- Use images in camera manual, online examples, and Level 1, 2, and 3 training manuals in department library to compare and learn from.
- Obtain the aid of certified infrared thermographers in maintenance department.

PRACTICE ACTIVITY

For this review activity, complete the missing steps for preparing the ThermaCAM™ E45 Infrared Camera for operation. Check your answers in the appendix on page 38 (see Section 3 Practice Activity).

Upload image(s) to laptop or PC:

1. Connect camera using **_____.**
2. Press _____ .
3. Open "ThermaCAM™ Reporter 2000 Professional" by selecting _____on desktop of laptop or PC.

Using the "ThermaCAM™ Reporter 2000 Professional" Wizard:

4. Under the “Use Template” options
   - Select **Denso** _____ if it is a before and after repair situation.
   - Select **Denso** _____ if it is a problem being reported.
5. Follow the Report Wizard and select _____.
6. Click on **_____.**
7. After locating the image desired, then select the desired image and then click **_____.**
8. If okay and no additional images are needed then select _____.
9. If okay and more images are being used in the report then click on _____ and repeat steps 5-7.
10. If a digital photo was taken , then _____ can be selected and the photo can be obtained.
11. Make sure that the correct photo is displayed and then select _____.
12. Type in the information in the _____ boxes.
13. When data is entered in all of the boxes and data is verified correct, Select _____.
14. The wizard then prompts you to select _____ and then the report is displayed.

Saving the report:

15. Select the _____ or _____ and then _____.
16. Location to be saved to can be selected from _____ options.

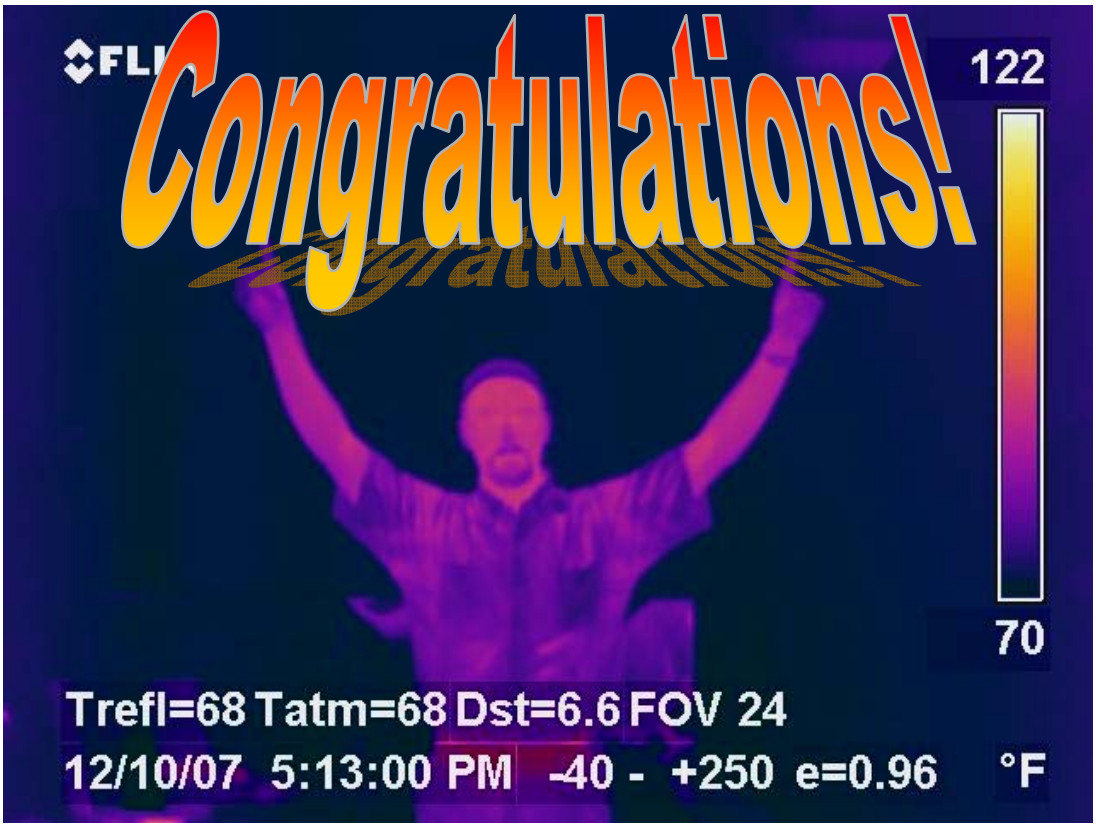
Now that you have successfully completed this review on operating the ThermaCAM™ Reporter 2000 Professional software, now verify you knowledge. Please proceed to the next page.

TEST YOUR KNOWLEDGE

Complete the following self-evaluation checklist to verify that you have the knowledge required to operate the infrared camera.

☐ **Yes** ☐ **No**	I know how to connect the camera to the laptop or PC.
☐ **Yes** ☐ **No**	I know how to open the report software.
☐ **Yes** ☐ **No**	I know how to select the desired template.
☐ **Yes** ☐ **No**	I know how to select the desired IR image.
☐ **Yes** ☐ **No**	I know how to select the desired photo.
☐ **Yes** ☐ **No**	I know how to enter the report value boxes.
☐ **Yes** ☐ **No**	I know how to complete the report.
☐ **Yes** ☐ **No**	I know how to save the report to a desired location.

Once you can answer Yes to all of the questions above pertaining to operating the ThermaCAM™ Reporter 2000 Professional software, you can proceed to the next page.



You are now ready to begin using Infrared Thermography as a proactive troubleshooting tool in your daily job!

Please take a few minutes to complete the evaluation located on the last page of this unit. Your feedback will help to improve this unit for future users.

one step at a time

APPENDIX

Section 1

PRACTICE ACTIVITY 1.1 (PAGE 9)

1. E
2. F
3. A
4. C
5. B
6. D
7. I
8. J
9. H
10. G
11. L
12. N
13. K
14. M

TEST YOUR KNOWLEDGE (PAGE 15, 16)

1. b, c, a
2. b
3. True
4. a
5. c, b, a
6. False
7. c
8. False
9. c
10. True

Section 2

PRACTICE ACTIVITY (PAGE 23)

1. camera
2. PWR/NO
3. Lens Cap
4. PWR/NO
5. MENU/YES
6. Navigation pad up/down
7. MENU/YES
8. Navigation pad right/left
9. MENU/YES
10. camera
11. SEL
12. SEL
13. Focus Ring
14. Focus Ring
15. SAVE/FRZ
16. SAVE/FRZ, PWR/NO

Section 3

PRACTICE ACTIVITY (PAGE 35)

1. USB/RS-232 cable
2. PWR/ON
3. icon
4. Before_After, SINGLE PAGE
5. Next
6. Select IR
7. OK
8. Next
9. Select IR
10. select photo
11. Next
12. value
13. Next
14. Finish
15. save icon, file, save
16. save in:

UNIT EVALUATION

Please take a few minutes to complete the following unit evaluation. Your input will help to improve this instructional unit for future users.

Please circle the category that applies to you:
Technician Engineer Production

Please circle the number that best describes your answer.

Statement	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
The instruction was presented in logical order.	1	2	3	4	5
The practice activities enhanced the understanding of the topics.	1	2	3	4	5
Each step of the instruction was easy to follow.	1	2	3	4	5
I was able to accomplish each task successfully.	1	2	3	4	5
The diagrams and screen shots clarified the information.	1	2	3	4	5
As a result of this training I feel confident that I can operate an infrared camera.	1	2	3	4	5
As a result of this training I feel confident that I can complete a report.	1	2	3	4	5
I would recommend this unit of instruction to others.	1	2	3	4	5

Please complete the following questions:

What would you change in this instructional unit?

_____
_____
_____
_____

What did you like about this instructional unit?

_____
_____
_____
_____

Thank you for taking time to participate in this evaluation!