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Problem Identification / Analyze Needs to Identify Goals

OVERVIEW
Denso has two IR (infrared) cameras that can be used for troubleshooting various problems. The cost of both cameras is seventy thousand dollars and requires a basic knowledge of thermodynamics and camera operation skills to operate effectively. There are three levels of certification in IR Thermography and the cost is two thousand dollars per class, travel expenses, and a week away from work per technician.

ASSESSMENT

STATEMENT OF THE PROBLEM
Technicians are unable to use IR cameras for troubleshooting problems.

DISCREPANCIES

• What is the existing situation?
  Technicians (non-certified) are unable to capture an IR image for troubleshooting.

• What is the desired goal?
  The goal is for non-certified technicians to be able to operate the IR camera and capture a clear image for troubleshooting problems.

• What is the gap?
  Technicians do not know thermal theory and do not know how to operate the IR camera and download data to a computer to analyze.

REASON FOR THE PROBLEM/DISCREPANCIES? SPECIFICALLY, WHY ARE PEOPLE NOT PERFORMING AS DESIRED?
There is not an introduction class or materials available to instruct the technicians on the basics of IR thermography and how to use the IR camera and software.

GOAL ANALYSIS

AIM
To be able to effectively operate an infrared camera to capture an image that can be used for troubleshooting purposes.

SET AND REFINE GOALS

• Understand what the camera is actually reading
• Identify and understand basic infrared thermography principles
• Be able to turn camera on
• Determine how infrared can be used to help technicians do their jobs
• Identify basic camera functions and be able to use them
• Know what heat transfer is and the three basic modes of transfer
• Understand what infrared is and be able to define what infrared thermography means
Introduction to Infrared Thermography

- Prepare for image evaluation by downloading ThermaCAM™ software
- Identify correct report to use and be able to complete, save to correct location, and print a hard copy
- Be able to use ThermaCAM™ software
- Be able to understand what emissive, reflective, and transmittance means and how it affects infrared thermography.
- Know the elements of an accurate image.
- Be able to focus on a desired image and capture it
- Be able to define heat and temperature and know the difference between the two
- Identify focus, range, and distance on the camera operation
- Understand what “delta T” means and its effect on infrared thermography

RANK THE GOALS
1. Understand what infrared is and be able to define what infrared thermography means
2. Identify and understand basic infrared thermography principles
3. Identify basic camera functions and be able to use them
4. Be able to focus on a desired image and capture it
5. Be able to use ThermaCAM™ software
6. Determine how infrared can be used to help technicians do their jobs

RECOMMENDED SOLUTION FOR INSTRUCTION
To develop an “Introduction to Infrared Thermography” module that will be taught in-house in less than 8 hours. The course and materials will involve instruction and “hands-on” experience that will enable technicians to capture a good image for troubleshooting problems using an infrared camera.

Analyze Learners and Context

LEARNER ANALYSIS

GENERAL CHARACTERISTICS
- Gender: Male
- Age: 30-60 years old
- Education and Literacy: All high school graduates, most have an A.A. degree, some have apprenticeship or journeyman training
- Work experience: Minimum of 6 years in a technical field
- Ethnicity: African American, Caucasian
- Language: English
SPECIFIC ENTRY CHARACTERISTICS

- **Prerequisite skills**: basic computer skills, familiar with connecting and synchronizing external devices to a computer, familiar with digital cameras, technical background

- **Attitudes and aptitudes**: desire to learn new things, willingness to use new tools

LEARNING STYLES

- **Perceptual Preferences and Strengths**: auditory, visual, tactile, and kinesthetic. Learners with a technical background generally like visual and audio instruction combined with hands-on time to practice what is taught. Generally open to new technologies, but prefer clear and concise instruction.

- **Information Processing Habits**: Adult learners with technical backgrounds typically prefer a structured format with instructors that are prepared to answer challenging questions. Technical learners generally prefer interactive instruction that stimulates them to compare new information to previous knowledge or experience.

- **Motivational Factors**: Want to be more effective and efficient in their job performance, desire to master new things, and thrive on learning new technologies.

- **Physiological Factors**: There are no disabilities or deficiencies to accommodate for.

CONTEXT ANALYSIS

ORIENTING CONTEXT

- **Goals**: To become a more valuable member of the maintenance team, become a more knowledgeable about a new technology, and ability to find the root cause of problems.

- **Utility**: Students will find the training useful to aid in their daily job.

- **Accountability**: Workers want the instruction because of the usefulness of the new knowledge. Students realize that not being able to use this technology will result in being viewed as lacking technical skills. There will be an assessment test and students know that they will eventually take certification training and tests.

LEARNING ENVIRONMENT

- **Lighting**: More than adequate in the classroom as well as the factory.

- **Noise**: No noise in the classroom, but there will be noise in the factory during hands-on training that will not affect the instruction.

- **Temperature**: Controlled environment with ability to adjust classroom, but not in the factory (factory temperature is 70~75 F and 40% humidity).

- **Seating**: More than adequate seating and room to move and practice.

- **Tools**: Camera and tools will be provided. Will need to bring company provided laptop.
Introduction to Infrared Thermography

Task Analysis

**TOPIC ANALYSIS**

I. Infrared Thermography Basics
   A. What is IR Thermography?
      1. Infrared- below last visible color
      2. Therm- Greek word for heat
      3. Graph- writing or representation for a specified process
      4. Basically a graphical representation of heat
   B. Kirchoff’s Law $E+T+R=1$
      1. Emitted Energy + Transmitted Energy + Reflected Energy $= 1$
      2. In most cases $E+R=1$
         a. Good Emitter = Poor Reflector
         b. Good Reflector = Poor Emitter
   C. Emittance
      1. A perfect emitter is referred to as a Black body and $E = 1$.
      2. All bodies in nature are **colored bodies** and have an $E<1$.
      3. Human skin is .98
      4. A good emitter is a good absorber of energy.
   D. Reflectance
      1. The amount of light reflected from an object.
      2. Aluminum tape $R=.98$ $E=.02$
      3. A first surface mirror is a good reflector.
   E. Transmittance
      1. The heat transmitted through an object to the camera.
      2. Thin plastics are transmissive.
      3. Opaque objects will not transmit energy.
         a. Ex. metals, woods, concrete
   F. Heat defined
      1. Heat may be defined as a form of energy created by the molecular motions of an object.
      2. Heat, unlike temperature, is a measure of the total kinetic energy of all the molecules in the objects.
   G. Temperature defined
      1. 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.
      2. A measure of the quantity of heat present in something.
   H. Heat Transfer
      1. Heat energy will transfer from an object of high temperature to an object or region of lower temperature unless it is blocked.
   I. Modes of Heat Transfer
      1. Convection
         a. Heat transfer through a fluid (e.g. air, water, gas).
         b. *Natural* convection involves the force of gravity.
Introduction to Infrared Thermography

2. Conduction
   a. Transfer of energy from higher energy particles to lower energy particles. (i.e. one end of rod to other)
   b. Transfer of heat through or between two solids.
3. Radiation- Transfer of energy through electromagnetic waves. (i.e. heat from fireplace warms you)

J. Delta T
   1. Difference in temperature.
   2. Increasing temperature differences will increase heat transfer rates.
   3. The bigger the delta T, the more heat is being transferred.

II. FLIR ThermaCAM™ E45 Infrared Camera
A. Camera parts
   1. Front view
      a. Lens- Detects infrared image
      b. Lens Cap- Protect lens from dust and damage
      c. Focus Ring- Used to make image clear
      d. Hand Strap Ring- Used to attach carrying strap
   2. Bottom view
      a. Tripod Mount- Used to attach tripod and use hands-free
      b. Trigger- Press to perform function designated
      c. Battery Compartment Lid- Battery is behind this lid
   3. Top view
      a. LCD screen- Image and menu options appear here
      b. SEL button
         i. Press to auto adjust camera
         ii. Press to switch between screen objects
      c. SAVE/FRZ button
         i. Press briefly to freeze image to display
         ii. Press for > 1 second to save image
      d. Navigation Pad- Used to move up/down and left/right
      e. LED indicator- Indicates power is on
      f. MENU/YES button
         i. Press to display vertical menu
         ii. Press to confirm selections in dialog boxes
      g. PWR/NO button
         i. Press to power on
         ii. Press to cancel selections in dialog boxes
   4. End view
      a. Power supply port- with LCD screen up, top port
      b. USB/ RS-232 port- middle port
      c. Video port- LCD screen up, bottom port

B. Camera program
   1. Result table
      a. Spot- Used to mark a specific location on an image
      b. Max- Maximum area temperature
Introduction to Infrared Thermography

2. System messages
   a. Frozen- Displayed when image is frozen
   b. Manual- Camera is manual adjust mode
   c. Please wait- Displayed during operations that take time
   d. Restarting- Displayed when software is restarted
   e. Saving as- displayed when image is being saved
   f. Battery low- battery level is below a critical level
   g. Shutting down- Camera will switch off immediately
   h. Shutting down in 2 seconds- Camera will switch off in 2 seconds

3. Menu system
   a. Press MENU/YES
      i. To display the vertical menu bar
      ii. To confirm selections in menus and dialog boxes
   b. Press PWR/NO
      i. To exit the menu system
      ii. To cancel selections in menus and dialog boxes
   c. Press Navigation Pad
      i. Up/down- to move up and down in menus, submenus, and dialog boxes
      ii. Right/left- to move right and left in menus and submenus, and to change values in dialog boxes

C. Electrical power system
   1. Battery
      a. Removable and rechargeable
      b. Operation time approximately 1.5~2 hours
   2. Power supply- Power cord plugged into power outlet and camera
   3. Battery Charger
      a. Battery can be removed from camera and charged
      b. Battery can be charged in camera when power cord is attached

D. Capturing a good image
   1. FoRD
      a. Focus- use focus ring to clarify image
      b. Range- press SEL to auto adjust
      c. Distance- make sure intended area is in image captured
   2. Techniques
      a. Use different angles to verify hot area is full size and not a reflection of something else
      b. Compare with another same kind of object to use as a reference

E. Connecting camera components
   a. Power supply cable- Connects camera to power outlet
   b. USB/ RS-232 cable- Connects camera to laptop or PC
   c. Video cable- Connects camera to video monitor

III. ThermaCam™ Reporter
A. Connecting camera
   1. Cable- Use USB/ RS-232 cable
   2. Ports- Cable connects to middle port on camera and USB port on laptop or PC
B. Software
   1. ThermoCam™ Reporter 2000 Professional (or newest version)
   2. If not downloaded see supervisor for assistance
C. Report Wizard- step-by-step process that prompts user next step to take
D. Reports
   1. Denso SINGLE PAGE- used for most reporting
   2. Denso Before_After- used when comparing
E. Saving Reports
   1. Report Wizard will indicate when finished
   2. Select “save” from “file” menu selection
   3. Save icon- software button that looks like a “floppy disk” can be selected
   4. Location to be saved to can be selected from “save in:” options

IV. Anomalie
   A. Something that is different than usual.
   B. Usually determined to be on of two conditions
      1. No good condition
      2. Different, but okay condition

PROCEDURAL ANALYSIS

I. Power on ThermaCam™ E45 Camera
   A. Pick up camera with right or left hand
   B. Press PWR/NO button using thumb of hand holding camera

Visual cue: LED turns green and LCD screen comes on with multiple colors and then goes black. FLIR logo is in upper left portion of screen and other data is present on various locations of the screen

C. Remove Lens Cap with hand not holding camera
D. Press SEL button using thumb of hand holding camera (hold for two seconds and release)

II. Determine emissivity setting
   A. When in doubt use a default value of 0.85
   B. Look up emissivity tables
      1. Use resources available in infrared manuals in department library
         (Level 1, 2, and 3 training manuals or camera manual)
      2. Find a table on a website
   C. Measure using a contact thermometer
      1. Use the thermometer to measure a specific point
      2. Use camera to point at the same specific point.
3. Adjust the emissivity settings until the same temperature reading appears.
   D. Use a known emittance component
      1. Place 3M electrical tape or black spray paint on a surface
      2. Set emissivity level in camera to $e=0.96$ for black electrical tape.
      3. Get a temperature reading where the paint or tape is located
      4. Go to surface beside the tape or paint and adjust emissivity until the temperature reads the same as the where the paint or tape is located with the emissivity set for them.

III. Set Emissivity
   A. Press MENU/YES button using thumb of hand holding camera
   B. Press Navigation Pad up/down button using thumb of hand holding camera to move down yellow highlight until Emissivity is highlighted
   C. Press MENU/YES button using thumb of hand holding camera
   D. Use Navigation Pad and press right/left button using thumb of hand holding camera until desire number is achieved (e.g. 0.85)
   E. Press MENU/YES button using thumb of hand holding camera

      Visual cue: bottom of LCD screen should have date, time, and then emissivity value (e.g. $e=0.85$)

IV. Capture a focused image
   A. Point camera at object of interest
   B. Press SEL using thumb of hand holding camera and hold for 2 seconds to auto adjust temperature scale
   C. Press SEL using thumb of hand holding camera and auto adjust as many times as needed until contrast allows for discernable image

      Visual cue: color contrast should allow for image to be seen

   D. Make sure that distance between camera and desired object allows for all of desired object to appear on LCD screen
   E. Grab Focus Ring with index finger and thumb of hand not holding camera
   F. Adjust focus by twisting the Focus Ring both directions until image is clear

      Visual Cue: Straight edges visually seen on object should appear straight and be clear, not blurry, on LCD screen

   G. Press SAVE/FRZ using thumb of hand holding camera to capture image of object

      Visual cue: on the LCN screen under FLIR logo the word “Frozen” appears and across the bottom “SAVE-Save” and “NO-Cancel” appears

   H. Press SAVE/FRZ button to save the image or PWR/NO button to cancel using thumb of hand holding camera
I. Repeat steps A through H as needed to capture the best image or as many images as desired

V. Use ThermaCAM™ software to make a report
   A. Upload image(s) to laptop or PC
      1. Connect camera using USB/RS-232 cable
         a. Plug round end of cable into middle port on camera
         b. Plug the USB end into USB port on computer
      2. Press PWR/ON button on camera
      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
   B. Open "ThermaCAM™ Reporter 2000 Professional" by selecting icon on desktop of laptop
      1. When "ThermaCAM™ Reporter 2000 Professional" opens the selection box gives new report options or template options
      2. Under the “Use Template” options
         a. Select "Denso Before_After" if it is a before and after repair situation
         b. Select "Denso SINGLE PAGE" if it is a problem being reported.
      3. Follow the Report Wizard and select NEXT
      4. Click on "Select IR"
      5. Then select "View thumbnails" box to see images
      6. Then "double click" the folder that the images are in
      7. Then select the desired image and then click OK
      8. The desired image should appear, if not then select “back” and do step 7
      9. If okay and no additional pictures are needed then select "next"
   10. If okay and more images are being used in the report then click on "Select IR" and repeat steps 5-7.
   11. If a digital photo was taken, then "select photo" can be selected and the photo can be obtained
   12. Make sure that the correct photo is displayed and then select "next"
   13. Type in the information in the "value" boxes.
   14. When information is entered in all of the boxes and information is verified correct, Select "Next"
   15. The wizard then prompts you to select "Finish"
   16. The report should now be displayed

Visual cue: The completed report should now appear with Denso logo in the upper left corner

17. Select the "save icon" or "file" and "save"
18. Location to be saved to can be selected from “save in:” options
VI. Evaluate Image  
A. Becoming an infrared thermographer with the ability to effectively evaluate an infrared image requires extensive training and experience  
B. However, one can make basic evaluations by benchmarking  
   1. Compare image with other same situations (e.g. exact location on other same type of equipment)  
   2. Verify that situation is good and capture image for future comparison  
   3. Capture image of no good situation and capture new image when repair is made to compare  
C. Use images in camera manual, online examples, and Level 1, 2, and 3 training manuals in department library to compare and learn from  
D. Obtain the aid of certified infrared thermographers in department

### Instructional Objectives

<table>
<thead>
<tr>
<th>Objective</th>
<th>Content</th>
<th>Recall</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Given a list of infrared thermography and camera terms, the learner will explain the meaning and function of each.</td>
<td>Fact</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>2. Using the guide, the learner will power on the infrared camera, adjust the emissivity setting, and capture a focused image.</td>
<td>Procedure</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>3. Using the ThermaCAM™ reporter software, the learner will correctly complete a report.</td>
<td>Procedure</td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

### Instructional Sequence

**LEARNING-RELATED SEQUENCING: IDENTIFIABLE PREREQUISITE**

The learning-related sequencing is based on identifiable prerequisite because the learner must know the infrared thermography and camera terminology before they are capable of completing the task.

**WORLD-RELATED SEQUENCING: TEMPORAL**

The world-related sequencing is based on the temporal phenomena because of the orderly sequence of steps. The learner will power on the camera, adjust emissivity settings, use the camera, and complete a report.
Instructional Strategies

Objective 1

*Given a list of infrared thermography and camera terms, the learner will be able to explain the meaning and function of each.*

<table>
<thead>
<tr>
<th>Classification</th>
<th>Fact/Recall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Presentation</td>
<td>The learner will be presented with infrared thermography and camera illustrations along with a list of definitions in a table format.</td>
</tr>
<tr>
<td>Generative Strategy</td>
<td>Rehearsal/Practice</td>
</tr>
<tr>
<td>Activity</td>
<td>Shown the visual illustrations, the learner will match the definitions associated with the illustration or term.</td>
</tr>
</tbody>
</table>

Objective 2

*Using the guide, the learner will power on the infrared camera, adjust the emissivity setting, and capture a focused image.*

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Initial Presentation</td>
<td>The learner will be presented with a step-by-step procedure on how to power on the camera, adjust the emissivity setting, and capturing a focused image. A demonstration on how to use the infrared camera will be done using example information and illustrations from a real-life situation.</td>
</tr>
<tr>
<td>Generative Strategy</td>
<td>Demonstration/ Practice</td>
</tr>
<tr>
<td>Activity</td>
<td>Using the guide, the learner will be given information about a scenario and they will list the necessary steps to operate the infrared camera in the correct sequence.</td>
</tr>
</tbody>
</table>

Objective 3

*Using the ThermaCAM™ reporter software, the learner will correctly complete a report.*

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<tbody>
<tr>
<td>Initial Presentation</td>
<td>The learner will be presented with a step-by-step procedure on how to complete a report. A demonstration on how to use the ThermaCAM™ reporter software will be done using example information and illustrations from a real-life situation.</td>
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<td>Generative Strategy</td>
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<tr>
<td>Activity</td>
<td>Using the guide, the learner will be given information about a scenario and they will list the necessary steps to complete a report in the correct sequence.</td>
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</table>
Preinstructional Strategy

OBJECTIVES

I chose this strategy based on table 8-1 on page 171 in the textbook. The learners are new to this topic and therefore, this strategy will prepare them for each learning task. The learners are higher-ability students learning factual information. Using this method, each section will begin with objectives that will clearly indicate the concepts and skills that the learner is expected to master at the end of each unit.

Designing the Evaluation

FORMATIVE EVALUATION

PURPOSE

The purpose of this evaluation is to improve the material and determine the time requirements to complete the module. The feedback will be used to improve this module during the design phase, as well as continually refining the module for use with future students.

AUDIENCE

The results from the evaluations will be analyzed by Level III certified thermographers (the SME and the instructional designer for this module). Improvements will be made as needed until the SME and the instructional designer feel that they have improved the instruction and determined the time requirements for completing the course.

ISSUES

- Given the objectives for the unit, is the level of learning acceptable? What weaknesses are apparent?
- Are learners able to use the knowledge or perform the skills to do their job? Are any weaknesses indicated?
- How much time did the instruction and learning require? Is this acceptable?
- Did the activities seem appropriate and manageable to the instructor and learners?
- Were the materials convenient and easy to locate and use?
- What were the learners’ reactions to the method of study, activities, materials, and evaluation methods?
- Do the tests and other outcome measures satisfactorily assess the instructional objectives?
- What revisions in the program seem necessary (content, format, etc.)?
- Is the instructional approach appropriate?
RESOURCES

• Trainees/ students
• Instructor
• SME
• Copies of materials
• Infrared Camera
• Computer

EVIDENCE

This “Introduction to Infrared Thermography” module will be tested at three stages during the design process. Stage one will be conducted on Level II certified infrared thermographers during the development phase in one-on-one trials. Stage two will be conducted on different Level II certified thermographers during the preliminary/draft version phase in small groups. Stage three will involve field trials with new learners once the module is completed in realistic training sessions. Data gathered from each stage will be reviewed by the SME and the instructional designer. Future results will be evaluated for continuous content improvement.

DATA-GATHERING TECHNIQUES

Observations, surveys, and interviews will be conducted in order to determine the try-out impressions of students who are knowledgeable about the content. Observations and performances will be used to identify strengths and weaknesses with other students who are also knowledgeable about the content.

ANALYSIS

Qualitative results will be the primary type of analysis used. Although some quantitative data will be collected, the learners’ perceptions will be most heavily considered. The learners will provide feedback based on the usefulness of the module for actual job application.

REPORTING

Results will be reported by the SME and the instructional designer and final revisions will be made if needed. The following format will be used.

I. Executive summary
II. Purposes of evaluation
   A. Evaluation objects
   B. Description of target course/unit
III. Methodology
   A. Participants
   B. Instruments
IV. Results
   A. Analyses
   B. Findings
V. Conclusions and recommendations
SUMMATIVE EVALUATION

Objective 1
Given a list of infrared thermography and camera terms, the learner will be able to explain the meaning and function of each.

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<tr>
<td>Activity</td>
<td>Shown the visual illustrations, the learner will match the definitions associated with the illustration or term.</td>
</tr>
<tr>
<td>Test Items</td>
<td>At the end of the first objective, the learner will complete an objective self-test that will include matching, multiple choice, and true and false. The learner may refer back to the module as needed, but will be encouraged to “test their knowledge” without referring.</td>
</tr>
</tbody>
</table>

Objective 2
Using the guide, the learner will power on the infrared camera, adjust the emissivity setting, and capture a focused image.

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<td>Demonstration/ Practice</td>
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<tr>
<td>Activity</td>
<td>Using the guide, the learner will be given information about a scenario and they will list the necessary steps to operate the infrared camera in the correct sequence.</td>
</tr>
<tr>
<td>Test Items</td>
<td>At the end of the second objective, the learner will be given a checklist so that the learner can verify that they are completing the camera operation steps in the correct order.</td>
</tr>
</tbody>
</table>

Objective 3
Using the Thermacam™ reporter software, the learner will correctly complete a report.

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<td>Demonstration/ Practice</td>
</tr>
<tr>
<td>Activity</td>
<td>Using the guide, the learner will be given information about a scenario and they will list the necessary steps to complete a report in the correct sequence.</td>
</tr>
<tr>
<td>Test Items</td>
<td>At the end of the third objective, the learner will be given a checklist so that the learner can verify that they are completing the steps in the correct order.</td>
</tr>
</tbody>
</table>