THERMAL IMAGING - LEVEL 1



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Thermal Imaging - Level 1

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This text was compiled on 06/15/2026

Preface

Thermography has become one of the most widely used nondestructive testing (NDT) methods across industries, including electrical maintenance, mechanical systems, building diagnostics, energy efficiency, and infrastructure inspection. As the field continues to evolve, so too must the way thermography is taught, particularly at the foundational Level I stage, where proper habits, discipline, and professional boundaries are established.

This textbook was developed to provide a **comprehensive, ASNT CP-105–aligned Thermography Level I curriculum** that reflects both traditional inspection practices and modern field realities. In addition to covering core infrared theory, heat transfer, camera operation, inspection techniques, safety, and documentation, this book uniquely integrates **drone-based thermography** as a legitimate inspection platform within the Level I scope.

Unmanned Aircraft Systems (UAS) are now routinely used for roof inspections, solar photovoltaic surveys, building envelope assessments, and infrastructure screening. Despite this widespread adoption, very few thermography texts address aerial data acquisition in a structured, standards-aligned manner, especially at Level I. This textbook fills that gap by treating drone thermography as an **application context**, not a separate certification, while strictly adhering to American Society for Nondestructive Testing (ASNT) role boundaries and professional practice expectations.

A key emphasis throughout this book is that **data quality is determined at capture**, not in software. Concepts such as **Focus, Range, and Distance (FoRD),** environmental influences, solar loading, flat-field correction, and quality control are reinforced repeatedly to ensure students develop sound inspection habits early in their training. Supplemental materials, including hands-on lab work with **FLIR Thermal Studio**, provide students with practical exposure to professional workflows without crossing into interpretation or diagnostic decision-making.

This text is intended for:

· Students enrolled in Thermography Level I training programs

· Apprentices and workforce trainees completing Related Supplemental Instruction (RSI)

· Community college and university technical programs

· Industry training providers seeking CP-105 alignment

· Professionals preparing for ASNT Level I certification

By combining foundational thermography education with modern inspection platforms and rigorous professional boundaries, this book prepares students not only to meet certification requirements but also to operate safely, ethically, and effectively in real-world inspection environments.

Acknowledgments

This textbook reflects the collective knowledge and practices of the thermography, nondestructive testing, and unmanned systems communities.

The author acknowledges the contributions of:

· **The American Society for Nondestructive Testing (ASNT)** for establishing the standards and training frameworks that guide professional thermographic practice.

· Industry professionals, educators, and technicians whose real-world experience continues to shape best practices in infrared inspection.

· Software and equipment manufacturers whose tools support modern thermography workflows, including thermal imaging systems and analysis platforms.

· Academic institutions and workforce partners who are committed to advancing technical education, applied learning, and ethical professional practice.

Special recognition is extended to the students and trainees whose questions, fieldwork, and curiosity helped inform the clarity, structure, and practical emphasis of this book.

Any errors or omissions remain the responsibility of the author.

Disclaimer

This textbook is intended for **educational and training purposes only**.

The content of this book is designed to align with **ASNT CP-105 Thermography Level I training requirements** and to support formal instruction, hands-on training, and practical assessment. Completion of coursework using this textbook does **not**, by itself, grant certification or authorization to perform thermographic inspections.

Thermography Level I personnel are limited to:

· Equipment setup and verification

· Safe and compliant data acquisition

· Recognition and documentation of thermal patterns

· Quality control and data handling

Interpretation of thermographic data, severity classification, root-cause analysis, repair recommendations, and final reporting decisions are the responsibility of **Thermography Level II or Level III personnel**, as defined by applicable standards and employer certification programs.

Drone operations referenced in this textbook must be conducted in compliance with all applicable aviation regulations and under the authority of a properly designated Remote Pilot in Command (RPIC). This book does not constitute flight training or regulatory authorization.

The author and publisher assume no liability for the use or misuse of the information contained herein. Users are responsible for complying with all applicable safety standards, regulations, and organizational procedures.

TABLE OF CONTENTS

Licensing

1: Introduction to Nondestructive Testing (NDT) and Infrared Thermography

- 1.1: What Is Nondestructive Testing (NDT)?
- 1.2: Common NDT Methods
- 1.3: Infrared Thermography as an NDT Method
- 1.4: Advantages and Limitations of Thermography
- 1.5: The Role of the Thermography Level I Technician
- 1.6: Ethics and Professional Responsibility
- 1.7: Safety Considerations in Thermographic Inspections
- 1.8: Summary
- 1.9: Review Questions

2: Fundamentals of Heat Transfer

- 2.1: Introduction
- 2.2: Heat vs. Temperature
- 2.3: The Three Modes of Heat Transfer
- 2.4: Steady-State and Transient Heat Conditions
- 2.5: Thermal Mass and Heat Storage
- 2.6: Solar Loading
- 2.7: Heat Generation Sources
- 2.8: Environmental Influences on Heat Transfer
- 2.9: Practical Implications for Thermography
- 2.10: Summary
- 2.11: Review Questions

3: Infrared Theory and Physics

- 3.1: Introduction
- 3.2: The Electromagnetic Spectrum
- 3.3: Infrared Wavelength Bands
- 3.4: Blackbody Radiation
- 3.5: Relationship Between Temperature and Infrared Radiation
- 3.6: Emission, Reflection, and Transmission
- 3.7: Apparent Temperature
- 3.8: Atmospheric Effects on Infrared Radiation
- 3.9: Infrared Detectors and Image Formation
- 3.10: Spatial Resolution and Measurement Accuracy
- 3.11: Practical Implications for Level I Thermographers
- 3.12: Summary
- 3.13: Review Questions

4: Emissivity, Reflectivity, and Transmissivity

- 4.1: Introduction
- 4.2: Emissivity
- 4.3: Reflectivity

- 4.4: Transmissivity
- 4.5: Relationship Between Emissivity, Reflectivity, and Transmissivity
- 4.6: Viewing Angle and Measurement Error
- 4.7: Practical Camera Setup Considerations
- 4.8: Common Errors Related to Surface Properties
- 4.9: Summary
- 4.10: Review Questions

5: Infrared Camera Systems

- 5.1: Introduction
- 5.2: Basic Components of an Infrared Camera
- 5.3: Infrared Detector Types
- 5.4: Key Camera Performance Specifications
- 5.5: Image Display and Color Palettes
- 5.6: Focus and Image Clarity
- 5.7: Camera Calibration and Accuracy
- 5.8: Handheld vs. Drone-Mounted Infrared Cameras
- 5.9: Care, Handling, and Maintenance
- 5.10: Summary
- 5.11: Review Questions
- 5.12: Drone Thermography Specification Tables

6: Camera Controls and Setup

- 6.1: Introduction
- 6.2: Importance of Proper Camera Setup
- 6.3: Focus Control
- 6.4: Temperature Range Selection
- 6.5: Level and Span Controls
- 6.6: Color Palettes
- 6.7: Emissivity Input
- 6.8: Reflected Apparent Temperature
- 6.9: Distance and Atmospheric Inputs
- 6.10: Image Capture Settings
- 6.11: Drone-Specific Camera Setup Considerations
- 6.12: Common Setup Errors
- 6.13: Documentation of Camera Settings
- 6.14: Summary
- 6.15: Review Questions
- 6.16: Step-by-Step Camera Setup Checklists

7: Image Types and Data Handling

- 7.1: Introduction
- 7.2: Thermal Image Types
- 7.3: Still Images vs. Video
- 7.4: File Formats
- 7.5: Metadata and Embedded Information
- 7.6: File Naming and Organization
- 7.7: Data Storage and Backup
- 7.8: Data Transfer and Handoff
- 7.9: Data Integrity and Ethics
- 7.10: Drone-Specific Data Handling Considerations

- 7.11: Quality Control Checks
- 7.12: Summary
- 7.13: Review Questions
- 7.14: Inspection Log Template

8: Inspection Techniques

- 8.1: Introduction
- 8.2: Passive and Active Thermography
- 8.3: Qualitative vs. Quantitative Inspections
- 8.4: Steady-State and Transient Inspection Conditions
- 8.5: Comparative Inspection Techniques
- 8.6: Distance, Angle, and Access Considerations
- 8.7: Environmental and Operating Condition Considerations
- 8.8: Electrical Inspection Techniques (Level I Scope)
- 8.9: Mechanical Inspection Techniques (Level I Scope)
- 8.10: Building and Infrastructure Inspection Techniques
- 8.11: Drone-Based Inspection Techniques
- 8.12: Common Inspection Errors
- 8.13: Summary
- 8.14: Review Questions

9: Safety in Thermographic Inspections

- 9.1: Introduction
- 9.2: General Safety Principles
- 9.3: Electrical Safety
- 9.4: Mechanical and Industrial Safety
- 9.5: Working at Heights
- 9.6: Environmental and Outdoor Safety
- 9.7: Drone-Based Thermography Safety
- 9.8: Personal Protective Equipment (PPE)
- 9.9: Emergency Preparedness
- 9.10: Safety Documentation
- 9.11: Common Safety Mistakes
- 9.12: Summary
- 9.13: Review Questions
- 9.14: Job Hazard Analysis (JHA) Templates

10: Common Sources of Error

- 10.1: Introduction
- 10.2: Measurement vs. Indication Errors
- 10.3: Emissivity-Related Errors
- 10.4: Reflection Errors
- 10.5: Atmospheric and Environmental Errors
- 10.6: Thermal Loading and Operating Condition Errors
- 10.7: Motion and Stability Errors
- 10.8: Focus, Range and Distance (FoRD) Errors
- 10.9: Viewing Angle Errors
- 10.10: Camera Setup and Configuration Errors
- 10.11: Data Handling Errors
- 10.12: Human Factors and Procedural Errors
- 10.13: Summary

- 10.14: Review Questions

11: Electrical Systems Thermography

- 11.1: Introduction
- 11.2: Basic Electrical Concepts (Level I Overview)
- 11.3: Common Electrical Components Inspected
- 11.4: Typical Thermal Patterns in Electrical Systems
- 11.5: Comparative Inspection Techniques
- 11.6: Inspection Conditions and Timing
- 11.7: Inspection Workflow (Level I)
- 11.8: Safety Considerations Specific to Electrical Thermography
- 11.9: FoRD Considerations in Electrical Inspections
- 11.10: Environmental Influences
- 11.11: Documentation and Reporting (Level I Role)
- 11.12: Common Errors in Electrical Thermography
- 11.13: Summary
- 11.14: Review Questions

12: Mechanical Systems Thermography

- 12.1: Introduction
- 12.2: Basic Mechanical Concepts (Level I Overview)
- 12.3: Common Mechanical Components Inspected
- 12.4: Typical Thermal Patterns in Mechanical Systems
- 12.5: Comparative Inspection Techniques
- 12.6: Inspection Conditions and Timing
- 12.7: Inspection Workflow (Level I)
- 12.8: Safety Considerations Specific to Mechanical Thermography
- 12.9: FoRD Considerations in Mechanical Inspections
- 12.10: Environmental Influences
- 12.11: Documentation and Reporting (Level I Role)
- 12.12: Common Errors in Mechanical Thermography
- 12.13: Summary
- 12.14: Review Questions

13: Building and Infrastructure Thermography

- 13.1: Introduction
- 13.2: Heat Transfer in Buildings (Level I Review)
- 13.3: Common Building and Infrastructure Applications
- 13.4: Building Envelope Thermography
- 13.5: Inspection Conditions and Timing for Buildings
- 13.6: Roof Thermography (Ground-Based)
- 13.7: Drone-Based Roof Thermography
- 13.8: Solar Panel (PV) Thermography
- 13.9: Infrastructure Thermography
- 13.10: Documentation and Reporting (Level I Role)
- 13.11: Common Errors in Building and Infrastructure Thermography
- 13.12: Summary
- 13.13: Review Questions

14: Introduction to Drone-Based Thermography

- 14.1: Introduction
- 14.2: Why Use Drones for Thermography?
- 14.3: Limitations of Drone-Based Thermography
- 14.4: Typical Applications of Drone Thermography
- 14.5: Drone Platforms Used for Thermography
- 14.6: Thermal Sensors and Payloads
- 14.7: Flat Field Correction (FFC)
- 14.8: Focus, Range, and Distance (FoRD) in Drone Thermography
- 14.9: Mission Planning Fundamentals (Level I Awareness)
- 14.10: Regulatory and Compliance Awareness
- 14.11: Safety Considerations in Drone Thermography
- 14.12: Environmental Influences on Aerial Thermography
- 14.13: Data Collection and Documentation (Level I Role)
- 14.14: Ground-Based vs. Drone-Based Thermography
- 14.15: Common Errors in Drone Thermography
- 14.16: Summary
- 14.17: Review Questions

15: UAS Platforms and Thermal Payloads

- 15.1: Introduction
- 15.2: Thermal Sensor Resolution and Pixel Count
- 15.3: Lens Field of View (FOV) and Resolution
- 15.4: Mid-Wave vs. Long-Wave Infrared (MWIR vs. LWIR)
- 15.5: Atmospheric Effects on MWIR and LWIR
- 15.6: Radiometric vs. Non-Radiometric Thermal Payloads
- 15.7: Gimbal Stabilization and Image Quality
- 15.8: FoRD Considerations for UAS Payloads
- 15.9: Typical Payload Configurations
- 15.10: Documentation and Payload Identification
- 15.11: Summary
- 15.12: Review Questions

16: Regulatory and Operational Considerations

- 16.1: Introduction
- 16.2: Overview of Applicable Regulatory Frameworks
- 16.3: Aviation Regulations for Drone-Based Thermography
- 16.4: Roles and Responsibilities in Drone Operations
- 16.5: Operational Planning and Briefings
- 16.6: Site Access and Permissions
- 16.7: Electrical and Industrial Regulatory Awareness
- 16.8: Privacy and Data Protection Considerations
- 16.9: Operational Limitations Affecting Thermography
- 16.10: International and Non-U.S. Operations (Awareness)
- 16.11: Documentation and Compliance Records
- 16.12: Common Regulatory and Operational Errors
- 16.13: Summary
- 16.14: Review Questions

17: Mission Planning for Aerial Thermography

- 17.1: Introduction
- 17.2: Defining the Inspection Objective
- 17.3: Target Characteristics and Resolution Requirements
- 17.4: Altitude Selection and Ground Sample Distance (GSD)
- 17.5: Flight Path and Coverage Planning
- 17.6: Viewing Angle and Sensor Orientation
- 17.7: Focus, Range, and Distance (FoRD) Verification
- 17.8: Environmental Assessment
- 17.9: Time-of-Day Considerations
- 17.10: Safety Planning and Risk Mitigation
- 17.11: Coordination and Communication
- 17.12: Pre-Flight Briefing Participation (Level I Role)
- 17.13: In-Flight Data Collection Considerations
- 17.14: Post-Flight Review and Documentation
- 17.15: Common Mission Planning Errors
- 17.16: Summary
- 17.17: Review Questions
- 17.18: Mission Planning Worksheets (Aerial Thermography)

18: Aerial Thermal Image Acquisition

- 18.1: Introduction
- 18.2: Pre-Flight Camera and Payload Verification
- 18.3: Focus, Range, and Distance (FoRD) Verification
- 18.4: Test Image Capture (Before Full Mission)
- 18.5: In-Flight Image Acquisition Techniques
- 18.6: Viewing Angle and Sensor Orientation
- 18.7: Environmental Monitoring During Flight
- 18.8: Communication During Image Acquisition
- 18.9: Managing Multiple Sensors (Thermal + Visual)
- 18.10: Post-Flight Image Review (Initial QC)
- 18.11: Documentation and Metadata Recording
- 18.12: Common Aerial Image Acquisition Errors
- 18.13: Data Handling and Handoff
- 18.14: Summary
- 18.15: Review Questions
- 18.16: Quality Control (QC) Checklists for Aerial Thermography

19: Post-Flight Data Handling and Preparation

- 19.1: Introduction
- 19.2: Immediate Post-Flight Actions
- 19.3: Initial Image Quality Review (QC Confirmation)
- 19.4: Data Transfer from Aircraft to Storage
- 19.5: Preservation of Original Data
- 19.6: File Organization and Folder Structure
- 19.7: File Naming and Identification
- 19.8: Metadata Verification
- 19.9: Data Backup and Redundancy
- 19.10: Flight Logs and Supporting Data
- 19.11: Documentation of Limitations and Anomalies
- 19.12: Preparing Data for Analysis and Handoff

- 19.13: Data Security and Confidentiality
- 19.14: Common Post-Flight Data Handling Errors
- 19.15: Summary
- 19.16: Review Questions

20: Review, Documentation, and Professional Practice

- 20.1: Introduction
- 20.2: Review of Collected Data (Level I Role)
- 20.3: Documentation Standards
- 20.4: Use of Images in Documentation
- 20.5: Handling Limitations and Uncertainty
- 20.6: Data Integrity and Chain of Custody
- 20.7: Professional Conduct and Ethics
- 20.8: Communication and Teamwork
- 20.9: Continuous Improvement and Professional Development
- 20.10: Regulatory and Standards Awareness
- 20.11: Common Documentation and Professional Practice Errors
- 20.12: Summary
- 20.13: Comprehensive Review Questions

21: Practice Level I Practical Examination

- 21.1: Purpose and Instructions
- 21.2: SECTION 1- Equipment Setup and Pre-Inspection Verification
- 21.3: SECTION 2- FoRD Validation (Critical Section)
- 21.4: SECTION 3- Handheld Thermal Image Acquisition
- 21.5: SECTION 4- Aerial Thermography
- 21.6: SECTION 5- Thermal Tuning Awareness (Software Review)
- 21.7: SECTION 6- Quality Control (QC)
- 21.8: SECTION 7- Documentation Practice
- 21.9: SECTION 8- Safety and Professional Judgment
- 21.10: SECTION 9- Final Self-Assessment

Index

Glossary

Detailed Licensing

Appendix

References and Standards

Detailed Licensing

Licensing

*A detailed breakdown of this resource's licensing can be found in **Back Matter/Detailed Licensing**.*

CHAPTER OVERVIEW

1: Introduction to Nondestructive Testing (NDT) and Infrared Thermography

1.1: What Is Nondestructive Testing (NDT)?
1.2: Common NDT Methods
1.3: Infrared Thermography as an NDT Method
1.4: Advantages and Limitations of Thermography
1.5: The Role of the Thermography Level I Technician
1.6: Ethics and Professional Responsibility
1.7: Safety Considerations in Thermographic Inspections
1.8: Summary
1.9: Review Questions

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1.1: What Is Nondestructive Testing (NDT)?

The ability to see, identify, and understand heat is a kind of superpower. You get to see and understand things most people cannot. As the saying goes, with great power comes great responsibility. You need to fully understand the aspects of this new ability. Now, let's get started. Nondestructive Testing (NDT) refers to a group of inspection methods used to evaluate materials, components, or systems without causing damage or altering their future usability. Unlike destructive testing, which stresses a specimen to failure, NDT allows inspections to be performed while equipment remains in service or is ready for service.

NDT is widely used across industries such as aerospace and aviation, electrical power generation and distribution, manufacturing and advanced manufacturing, infrastructure and civil engineering, oil, gas, and petrochemical industries, and facilities maintenance and energy management

The primary objectives of NDT include:

- Detecting defects or irregularities
- Monitoring condition and degradation
- Improving safety and reliability
- Reducing downtime and maintenance costs
- Supporting quality control and compliance

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1.2: Common NDT Methods

Several established NDT methods are used depending on the material, application, and inspection goal. Common methods include:

- **Visual Testing (VT)** – Direct or indirect visual examination
- **Ultrasonic Testing (UT)** – High-frequency sound waves to detect internal flaws
- **Radiographic Testing (RT)** – X-rays or gamma rays to image internal structures
- **Magnetic Particle Testing (MT)** – Detection of surface and near-surface flaws in ferromagnetic materials
- **Liquid Penetrant Testing (PT)** – Detection of surface-breaking defects
- **Eddy Current Testing (ET)** – Electromagnetic induction for conductive materials
- **Infrared Thermography (IRT)** – Detection of thermal patterns and temperature differences

Each method has specific strengths and limitations. Infrared thermography is unique because it is non-contact, can be performed from a distance, and often allows rapid inspection of large areas.

The Laws of Thermodynamics and Thermal Imaging

Thermal imaging is grounded in the fundamental principles of thermodynamics, which describe how energy behaves and how heat is generated, transferred, and observed. Understanding these principles helps thermographers recognize why thermal patterns appear on a surface and why thermal imaging reflects **energy behavior**, not just temperature.

Zeroth Law of Thermodynamics

Definition:
If two objects are each in thermal equilibrium with a third object, they are in thermal equilibrium with each other.

Relevance to Thermal Imaging:
The Zeroth Law establishes the concept of **temperature measurement**. Thermal cameras rely on the assumption that temperature differences indicate differences in thermal energy. When surfaces are in thermal equilibrium, little or no thermal contrast will be visible in a thermogram.

First Law of Thermodynamics (Conservation of Energy)

Definition:
Energy cannot be created or destroyed—only transferred or converted from one form to another.

Relevance to Thermal Imaging:
Thermal imaging detects heat that results from **energy conversion**, such as electrical energy converting to heat due to resistance or mechanical energy converting to heat due to friction. Thermal cameras do not create heat; they observe energy that has been transformed and emitted as infrared radiation.

Second Law of Thermodynamics

Definition:
Heat naturally flows from warmer objects to cooler objects, and energy systems tend toward increased disorder.

Relevance to Thermal Imaging:
This law explains why heat spreads from a hot component to its surroundings and why thermal patterns change over time. Thermal imaging captures these **heat flow patterns**, helping thermographers visualize gradients, dissipation, and thermal imbalance.

Third Law of Thermodynamics

Definition:
As the temperature of a system approaches absolute zero, the motion of particles approaches a minimum.

Relevance to Thermal Imaging:
All objects above absolute zero emit infrared radiation. Thermal imaging is possible because real-world objects always have some level of particle motion and emit detectable infrared energy.

Forms of Energy Relevant to Thermal Imaging

Understanding basic forms of energy helps explain the sources of heat observed in thermography.

Kinetic Energy
Energy associated with motion. In thermography, increased particle motion within a material result in higher temperatures and greater infrared emission.

Potential Energy
Stored energy due to position or configuration, such as elevated components or compressed systems. When potential energy is released, it may convert to kinetic energy and then to heat.

Stored Energy
Energy contained within a system that can be released over time, such as chemical energy in batteries or elastic energy in mechanical components. As stored energy is released or dissipated, it often converts to heat detectable by thermal imaging.

Common Units of Energy and Heat Measurement

Energy can be measured in several units, depending on the application, industry, and measurement system used. In thermography, understanding these units provides context for how heat energy is quantified, even though thermal cameras typically display **temperature** rather than total energy.

Joule (J)

Definition:
The **joule** is the standard unit of energy in the International System of Units (SI). One joule is the amount of energy transferred when a force of one newton moves an object one meter.

Context for Thermography:
Joules represent total energy, whereas thermal cameras measure temperature distribution. Heat energy detected by a thermal camera is related to energy transfer but not displayed directly in joules.

Calorie (cal)

Definition:
A **calorie** is the amount of energy required to raise the temperature of one gram of water by one degree Celsius.

Context for Thermography:
Calories are commonly used in chemistry and nutrition. In thermography, the concept helps explain how much energy is required to change temperature, even though cameras display temperature rather than energy.

Kilocalorie (kcal)

Definition:
A **kilocalorie** equals 1,000 calories and is commonly referred to as a “food calorie.”

Context for Thermography:
Kilocalories illustrate energy storage and conversion in biological and chemical systems, which ultimately dissipate heat that may be detectable in thermal imaging applications.

British Thermal Unit (BTU)

Definition:
A **British Thermal Unit (BTU)** is the amount of energy required to raise the temperature of one pound of water by one degree Fahrenheit.

Context for Thermography:
BTUs are widely used in HVAC and building systems. Understanding BTUs helps thermographers contextualize heat loads and energy transfer in buildings and mechanical systems.

Watt (W) (Rate of Energy Transfer)

Definition:
A **watt** is a unit of power equal to one joule per second.

Context for Thermography:
Thermal cameras do not measure watts directly, but electrical power dissipated as heat often appears as elevated temperatures in thermograms.

Kilowatt-Hour (kWh)

Definition:
A **kilowatt-hour** is a unit of energy equal to the use of one kilowatt of power for one hour.

Context for Thermography:
Kilowatt-hours are used to quantify electrical energy consumption. Energy losses or inefficiencies measured in kWh often manifest as heat detectable during thermal inspections.

Electronvolt (eV) (Advanced Context)

Definition:
An **electronvolt** is a very small unit of energy used at the atomic and subatomic level.

Context for Thermography:
While not used directly in applied thermography, electronvolts help explain energy transitions that produce electromagnetic radiation, including infrared.

Important Energy Distinction

Thermal cameras measure temperature distribution, not total energy.
Units such as joules, BTUs, and calories describe energy quantities, while thermography visualizes how that energy appears as heat on a surface.

Quick Reference Summary

Unit	Measures	Common Use
Joule (J)	Energy	Scientific / SI
Calorie (cal)	Heat energy	Chemistry
Kilocalorie (kcal)	Energy	Nutrition
BTU	Heat energy	HVAC / Buildings
Watt (W)	Power (energy per time)	Electrical systems
kWh	Energy over time	Electrical consumption

Energy Units in Context: Applied Thermography Examples

HVAC Systems (BTU, kWh, Watt)

Context:
HVAC systems are commonly rated and designed using **BTUs** and **kilowatt-hours (kWh),** which represent heat transfer and energy consumption over time.

Thermography Connection:
During an HVAC inspection, thermal imaging may reveal uneven temperature distribution across ducts, coils, or building zones. Although the thermal camera displays **surface temperature,** the underlying issue may involve inefficient heat transfer (measured in **BTUs)** or excessive energy consumption (measured in **kWh)**.

Level I Takeaway:
Thermography visualizes *where* heat transfer is occurring, while BTUs and kWh describe *how much* energy the system is moving or consuming.

Electrical Systems (Watt, Joule, kWh)

Context:
Electrical systems convert electrical energy (measured in **joules** or **kilowatt-hours**) into useful work, with losses dissipated as heat. Power flow is measured in **watts**.

Thermography Connection:
When inspecting energized electrical equipment, a thermal camera may show localized heating on conductors, breakers, or connections. This heat represents **electrical power (watts) being converted into thermal energy**due to resistance.

Level I Takeaway:
Elevated temperature patterns indicate energy loss as heat, but thermography shows temperature, not watts or joules, and does not quantify electrical load.

Mechanical Systems (Joule, Calorie, Watt)

Context:
Mechanical systems involve moving parts where **kinetic energy** is converted into heat through friction. This energy conversion can be described in **joules** or **calories**, and the rate of conversion in **watts**.

Thermography Connection:
During a mechanical inspection, bearings, couplings, or motors may appear warmer than surrounding components. The thermal image reflects **mechanical energy being dissipated as heat**, often due to friction or inefficiency.

Level I Takeaway:
Thermography detects the surface result of energy conversion, not the mechanical cause or energy quantity.

Level I Concept Summary

Energy units (BTU, joule, watt, kWh) describe energy quantity and rate.
Thermal imaging shows how that energy appears as heat on a surface.

Thermography complements energy measurements by providing **spatial insight** into where energy is being transferred, lost, or dissipated, without directly measuring total energy.

One-Line Exam Aid

- **BTU / kWh** → How much heat or energy
- **Watt** → How fast energy is being used
- **Thermal image** → Where heat appears

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1.3: Infrared Thermography as an NDT Method

Infrared thermography is an NDT method that detects infrared radiation emitted by objects and converts it into a visible image representing temperature differences. These images, known as thermal images or thermograms, allow inspectors to observe thermal patterns that may indicate abnormal conditions.

Unlike some NDT methods that require physical contact or surface preparation, thermography is non-contact, can be performed while systems are energized or operating, allows inspection of inaccessible or hazardous areas, and provides immediate visual results.

Thermography does not see through objects. Instead, it detects surface temperature patterns that may be related to internal or surface conditions.

Typical Applications of Thermography

At the Level I scope, thermography is commonly used for screening and condition monitoring rather than for diagnosis. Typical applications include:

Electrical Systems

- Electrical panels and switchgear
- Transformers
- Circuit breakers
- Connections and terminations

Abnormal heating may indicate increased resistance, loose connections, or imbalanced loads.

Mechanical Systems

- Bearings
- Motors
- Pumps
- Gearboxes

Heat patterns may be associated with friction, misalignment, or lubrication issues.

Building and Infrastructure

- Insulation performance
- Air leakage
- Moisture intrusion
- Roof condition

Thermal patterns can reveal areas of heat loss or moisture-related anomalies.

Industrial and Manufacturing Processes

- Process monitoring
- Quality control
- Heat distribution in components

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1.4: Advantages and Limitations of Thermography

As with any technology used for testing, there are advantages and limitations.

Advantages

- Non-contact and non-intrusive
- Can be performed at a safe distance
- Rapid inspection of large areas
- Real-time results
- Effective for energized systems

Limitations

- Measures surface temperature only
- Influenced by emissivity and reflections
- Environmental conditions affect results
- Cannot identify root cause without further analysis
- Requires proper training and procedure adherence

Understanding these limitations is essential for avoiding incorrect conclusions.

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1.5: The Role of the Thermography Level I Technician

According to ASNT guidelines, a Thermography Level I technician is qualified to:

- Perform specific calibrations and tests
- Follow written inspection procedures
- Set up and operate infrared equipment
- Collect thermal images and data
- Recognize and document thermal anomalies

A Level I technician does not:

- Select inspection methods
- Interpret results beyond recognizing patterns
- Make accept/reject decisions
- Modify procedures
- Issue final diagnostic conclusions

The Level I role is critical because accurate data collection directly affects the reliability of subsequent analysis.

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1.6: Ethics and Professional Responsibility

Thermography technicians are expected to maintain high ethical and professional standards. This includes:

- Reporting observations accurately and honestly
- Avoiding over-interpretation of results
- Following established procedures
- Maintaining data integrity
- Respecting safety requirements
- Understanding the limits of one’s certification

Misrepresentation of findings or exceeding one’s certification authority can result in safety risks and professional consequences.

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1.7: Safety Considerations in Thermographic Inspections

Although thermography is non-contact, inspections often occur in potentially hazardous environments, including:

- Energized electrical systems
- Elevated work areas
- Industrial machinery
- Outdoor and weather-exposed locations

Level I technicians must follow all applicable safety protocols, including:

- Use of personal protective equipment (PPE)
- Compliance with electrical safety standards
- Situational awareness
- Following site-specific safety rules

Safety is always the highest priority.

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1.8: Summary

In this chapter, you learned that:

- NDT allows inspection without damaging components
- Infrared thermography is a powerful NDT method for detecting thermal patterns
- Thermography is widely used across multiple industries
- Level I technicians focus on equipment operation, data collection, and documentation
- Understanding limitations and ethical responsibilities is essential

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1.9: Review Questions

1. What is the primary purpose of nondestructive testing?
2. List three advantages of infrared thermography.
3. Why is thermography considered a non-contact inspection method?
4. What are the responsibilities of a Thermography Level I technician?
5. Why is it important to understand the limitations of thermography?

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CHAPTER OVERVIEW

2: Fundamentals of Heat Transfer

2.1: Introduction
2.2: Heat vs. Temperature
2.3: The Three Modes of Heat Transfer
2.4: Steady-State and Transient Heat Conditions
2.5: Thermal Mass and Heat Storage
2.6: Solar Loading
2.7: Heat Generation Sources
2.8: Environmental Influences on Heat Transfer
2.9: Practical Implications for Thermography
2.10: Summary
2.11: Review Questions

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2.1: Introduction

Heat transfer is the movement of thermal energy from one object or area to another due to a difference in temperature. All thermographic inspections are based on the principle that temperature differences create measurable thermal patterns.

Infrared thermography does not directly measure heat transfer. Instead, it detects infrared radiation emitted from surfaces, which is influenced by how heat is generated, stored, and transferred within a material or system. Understanding basic heat transfer concepts allows thermography technicians to recognize why certain thermal patterns appear and under what conditions they are most visible.

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2.2: Heat vs. Temperature

Although often used interchangeably, **heat** and **temperature** are not the same.

- **Temperature** is a measure of how hot or cold an object is, related to the average kinetic energy of its molecules.
- **Heat** is thermal energy in motion, transferred from a higher-temperature object to a lower-temperature object.

In thermography:

- Cameras display **apparent surface temperature**
- Thermal images represent **relative temperature differences**
- Heat transfer explains *why* those temperature differences exist

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2.3: The Three Modes of Heat Transfer

Heat transfer occurs through three primary mechanisms:

1. Conduction
2. Convection
3. Radiation

Each mode plays a role in thermographic inspections.

Conduction

Conduction is the transfer of heat through a material or between materials that are in direct physical contact. Heat flows from warmer regions to cooler regions within the material.

Examples relevant to thermography include:

- Heat traveling along an electrical conductor
- Thermal flow through a metal bearing housing
- Heat loss through a building wall

Factors affecting conduction include:

- Material type (metal vs. insulation)
- Thickness
- Contact quality between materials

In thermography, conduction often explains heat spreading patterns, such as:

- Elongated warm areas along conductors
- Heat spreading away from a hot mechanical component

Convection

Convection is the transfer of heat through the movement of fluids, including liquids and gases. As fluid is heated, it becomes less dense and rises, while cooler fluid moves in to replace it.

Examples include:

- Warm air rising inside a building
- Cooling airflow around electrical components
- Heated fluid circulating in a pipe

Convection affects thermographic inspections by:

- Carrying heat away from components
- Masking or reducing surface temperature differences
- Creating uneven thermal patterns

Wind and airflow can significantly alter thermographic results, particularly during outdoor or aerial inspections.

Radiation

Radiation is the transfer of heat through electromagnetic waves, without requiring physical contact or a medium. All objects above absolute zero emit infrared radiation.

Thermography is based on detecting radiated energy from object surfaces. The amount of radiation emitted depends on:

- Surface temperature
- Emissivity of the material
- Surface condition

Radiation is the only heat transfer mode directly measured by an infrared camera.

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2.4: Steady-State and Transient Heat Conditions

Steady-State Heat Transfer

Steady-state conditions exist when temperatures remain relatively constant over time. In these conditions:

- Heat input and heat loss are balanced
- Thermal patterns remain stable

Examples:

- Energized electrical panels under constant load
- Operating industrial machinery at normal conditions

Steady-state conditions are ideal for many thermographic inspections because patterns are easier to compare and repeat.

Transient Heat Transfer

Transient conditions occur when temperatures change over time. These conditions are common during:

- Equipment startup or shutdown
- Changing electrical loads
- Heating or cooling cycles

Transient conditions may:

- Enhance thermal contrast
- Make patterns harder to interpret
- Require careful timing during inspections

Level I technicians must determine whether an inspection is occurring under steady-state or transient conditions and document this in inspection records.

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2.5: Thermal Mass and Heat Storage

Thermal mass refers to a material's ability to absorb and store heat. Materials with high thermal mass:

- Heat up slowly
- Cool down slowly

Materials with low thermal mass:

- Heat up quickly
- Cool down quickly

Examples:

- Concrete and brick have high thermal mass
- Thin metals and plastics have low thermal mass

Thermal mass affects:

- How quickly thermal patterns develop
- How long anomalies remain visible
- Timing of inspections, especially in building and infrastructure applications

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2.6: Solar Loading

Solar loading is the heating of a surface caused by the absorption of solar radiation from the sun. When sunlight strikes a material, some of the energy is absorbed and converted into heat, raising the surface temperature independently of internal heat sources.

Solar Loading in Thermography

In thermography, solar loading can significantly affect surface temperatures and may create thermal patterns unrelated to internal conditions or defects. The degree of solar loading depends on factors such as time of day, sun angle, cloud cover, surface color, material properties, and exposure duration. Dark or absorptive materials typically experience greater solar loading than light-colored or reflective surfaces.

Because solar loading affects surface temperature distribution, it must be recognized, managed, and documented during thermographic inspections. Failure to account for solar loading can lead to misleading thermal images or false indications.

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2.7: Heat Generation Sources

Heat detected during thermographic inspections may originate from several sources, including:

- Electrical resistance
- Mechanical friction
- Chemical reactions
- Environmental exposure (sun, weather)

Not all heat indicates a problem. Level I technicians must understand that thermography detects **temperature differences**, not defect causes.

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2.8: Environmental Influences on Heat Transfer

Environmental conditions can strongly influence heat transfer and thermographic results. Important factors include:

- Ambient temperature
- Wind speed
- Solar loading
- Humidity
- Rain or moisture

Examples:

- Sunlight can heat surfaces unevenly (due to factors like shadows)
- Wind can cool components through convection
- Moisture can alter surface temperatures

These factors should always be noted during inspections.

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2.9: Practical Implications for Thermography

Understanding heat transfer helps technicians:

- Recognize valid thermal patterns
- Avoid false indications
- Choose appropriate inspection timing
- Understand why thermal contrast may be weak or strong

At Level I, this understanding supports accurate data collection, not interpretation.

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2.10: Summary

In this chapter, you learned that:

- Heat transfer causes temperature differences detected in thermography
- Heat and temperature are related but not the same
- Heat is transferred through conduction, convection, and radiation
- Steady-state conditions produce stable thermal patterns
- Transient conditions involve changing temperatures
- Environmental factors significantly affect inspections

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2.11: Review Questions

1. What is the difference between heat and temperature?
2. Name the three modes of heat transfer.
3. Which heat transfer mode is directly detected by an infrared camera?
4. How does convection affect outdoor thermographic inspections?
5. Why is thermal mass important when planning inspections?

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CHAPTER OVERVIEW

3: Infrared Theory and Physics

3.1: Introduction
3.2: The Electromagnetic Spectrum
3.3: Infrared Wavelength Bands
3.4: Blackbody Radiation
3.5: Relationship Between Temperature and Infrared Radiation
3.6: Emission, Reflection, and Transmission
3.7: Apparent Temperature
3.8: Atmospheric Effects on Infrared Radiation
3.9: Infrared Detectors and Image Formation
3.10: Spatial Resolution and Measurement Accuracy
3.11: Practical Implications for Level I Thermographers
3.12: Summary
3.13: Review Questions

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3.1: Introduction

Infrared thermography detects infrared (IR) radiation emitted by objects due to their temperature. All objects with a temperature above absolute zero emit electromagnetic radiation. The amount and characteristics of this radiation depend primarily on the object's temperature and surface properties.

An infrared camera does not measure temperature directly. Instead, it detects infrared radiation emitted from a surface and converts it into an image representing apparent surface temperature differences.

Understanding basic infrared theory helps Level I thermographers:

- Properly configure equipment
- Recognize valid thermal patterns
- Avoid common measurement errors
- Understand the limits of infrared measurements

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3.2: The Electromagnetic Spectrum

The electromagnetic spectrum includes all forms of electromagnetic energy, arranged by wavelength or frequency. Common regions of the spectrum include:

- Gamma rays
- X-rays
- Ultraviolet (UV)
- Visible light
- Infrared (IR)
- Microwaves
- Radio waves

Infrared radiation lies just beyond visible red light and is invisible to the human eye.

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3.3: Infrared Wavelength Bands

Infrared radiation is typically divided into wavelength bands:

- **Near Infrared (NIR):** Approximately 0.7 to 1.4 micrometers (µm)
- **Short-Wave Infrared (SWIR):** Approximately 1.4 to 3 µm
- **Mid-Wave Infrared (MWIR):** Approximately 3 to 5 µm
- **Long-Wave Infrared (LWIR):** Approximately 8 to 14 µm

Most handheld and drone-mounted thermographic cameras used for industrial inspections operate in the long-wave infrared (LWIR) band. This range is well-suited for detecting temperatures commonly encountered in electrical, mechanical, and building inspections.

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3.4: Blackbody Radiation

A **blackbody** is a theoretical object that absorbs all incident radiation and emits the maximum possible radiation at a given temperature. Although perfect blackbodies do not exist in the real world, they serve as an important reference in infrared physics.

Key characteristics of a blackbody:

- Emits radiation based solely on temperature
- Has an emissivity of 1.0
- Provides a reference for comparing real materials

Infrared cameras are calibrated using blackbody sources to ensure measurement accuracy.

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3.5: Relationship Between Temperature and Infrared Radiation

As an object's temperature increases:

- The total amount of infrared radiation emitted increases
- The peak wavelength of emission shifts toward shorter wavelengths

Several physical laws describe this behavior. At Level I, it is sufficient to understand these relationships conceptually.

Stefan–Boltzmann Law (Conceptual)

This law describes how total radiated energy increases rapidly as temperature increases.

Wien's Displacement Law (Conceptual)

This law explains why hotter objects emit radiation at shorter wavelengths.

These laws explain why infrared cameras can detect small temperature differences and why camera sensitivity is critical.

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3.6: Emission, Reflection, and Transmission

When infrared radiation interacts with a surface, it can be:

- **Emitted**
- **Reflected**
- **Transmitted**

The sum of these three components equals 100% of the incident energy.

Emission

Emission is infrared radiation generated by the object itself. This is the desired signal in thermography.

Reflection

Reflection occurs when infrared radiation from surrounding objects reflects off a surface. Reflections can cause false indications if not recognized.

Transmission

Transmission occurs when infrared radiation passes through a material. Most solid materials used in industrial inspections are opaque in the infrared range, meaning transmission is minimal.

Understanding these interactions is essential for accurate data collection.

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3.7: Apparent Temperature

Infrared cameras display **apparent temperature**, which is influenced by:

- True surface temperature
- Emissivity of the surface
- Reflected apparent temperature
- Atmospheric effects

Because of these factors, the temperature shown on the camera is not always the true temperature of the object. Level I technicians must understand this limitation and ensure camera settings are properly configured.

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3.8: Atmospheric Effects on Infrared Radiation

Infrared radiation emitted by an object and traveling to the camera can be affected by the atmosphere. Factors include:

- Distance between the camera and the object
- Humidity
- Air temperature
- Gases and particulates

Atmospheric absorption increases with distance and can reduce measurement accuracy, especially during outdoor or aerial inspections.

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3.9: Infrared Detectors and Image Formation

Infrared cameras use specialized detectors to convert infrared radiation into an electrical signal. Common detector types include:

- **Uncooled microbolometers** (most common in Level I applications)
- **Cooled detectors** (used in higher-performance systems)

The detector signal is processed and displayed as a thermogram, where colors or shades represent relative temperature differences.

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3.10: Spatial Resolution and Measurement Accuracy

Important concepts related to image quality include:

- **Spatial resolution:** Ability to distinguish small objects
- **Instantaneous Field of View (IFOV):** The area represented by a single pixel
- **Distance-to-spot ratio:** Relationship between distance and measurement area

As distance increases:

- Each pixel represents a larger area
- Small targets may not be measured accurately

This is particularly important in drone-based thermography.

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3.11: Practical Implications for Level I Thermographers

Understanding infrared theory helps Level I technicians:

- Choose appropriate inspection distances
- Properly adjust emissivity and reflected temperature settings
- Recognize reflections and environmental influences
- Collect consistent and repeatable data

Level I personnel are responsible for **accurate image acquisition**, not analysis or diagnosis.

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3.12: Summary

In this chapter, you learned that:

- Infrared radiation is part of the electromagnetic spectrum
- All objects emit infrared radiation based on temperature
- Most thermographic inspections use the long-wave infrared band
- Blackbodies provide a reference for camera calibration
- Apparent temperature is influenced by multiple factors
- Atmospheric conditions and distance affect measurements
- Infrared cameras convert radiation into thermal images

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3.13: Review Questions

1. Where does infrared radiation fall within the electromagnetic spectrum?
2. Which infrared wavelength band is most commonly used for industrial thermography?
3. What is a blackbody, and why is it important?
4. Why does an infrared camera measure apparent temperature rather than true temperature?
5. How does distance affect spatial resolution and measurement accuracy?

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CHAPTER OVERVIEW

4: Emissivity, Reflectivity, and Transmissivity

4.1: Introduction
4.2: Emissivity
4.3: Reflectivity
4.4: Transmissivity
4.5: Relationship Between Emissivity, Reflectivity, and Transmissivity
4.6: Viewing Angle and Measurement Error
4.7: Practical Camera Setup Considerations
4.8: Common Errors Related to Surface Properties
4.9: Summary
4.10: Review Questions

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4.1: Introduction

Accurate thermographic measurements depend on understanding how infrared radiation interacts with object surfaces. Three fundamental surface properties determine this interaction:

- **Emissivity**
- **Reflectivity**
- **Transmissivity**

These properties determine how much infrared energy a material **emits**, **reflects**, or **transmits**. Because infrared cameras detect radiation rather than temperature, incorrect assumptions about these properties can lead to inaccurate readings.

For Level I thermographers, understanding these concepts is essential for

- Proper camera setup
- Recognizing sources of error
- Collecting consistent and repeatable data

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4.2: Emissivity

Definition of Emissivity

Emissivity is a measure of a material's ability to emit infrared radiation compared to a perfect blackbody at the same temperature. Emissivity values range from **0.0 to 1.0**.

- **High emissivity (close to 1.0):** Emits most of its thermal energy
- **Low emissivity (close to 0.0):** Emits little energy and reflects more

Most non-metallic materials have relatively high emissivity, while many bare metals have low emissivity.

Kirchhoff's Law ($\epsilon = \alpha$)
Kirchhoff's law of thermal radiation states that at thermal equilibrium, an object's ability to **emit** thermal radiation (emissivity, ϵ) equals its ability to **absorb** that radiation (absorptivity, α) at the same wavelength and temperature; essentially, good absorbers are good emitters, and poor absorbers (good reflectors) are poor emitters.

Emissivity Common Materials

Approximate emissivity values for common materials include:

- Painted surfaces: High emissivity
- Rubber and plastics: High emissivity
- Wood and concrete: High emissivity
- Oxidized metals: Moderate emissivity
- Polished or shiny metals: Low emissivity

Surface condition is often more important than base material.

Factors Affecting Emissivity

Emissivity can change based on:

- Surface finish (polished vs. rough)
- Oxidation
- Paint or coatings
- Dirt, grease, or corrosion
- Viewing angle

Because emissivity varies, it should be treated as an adjustable camera parameter rather than a fixed value.

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4.3: Reflectivity

Definition of Reflectivity

Reflectivity is the ability of a surface to reflect infrared radiation from surrounding objects. Highly reflective surfaces act like mirrors in the infrared spectrum.

Reflected radiation can cause:

- False hot or cold spots
- Apparent temperatures that do not represent the object itself

Sources of Reflected Infrared Energy

Common sources of reflected infrared radiation include:

- The sun
- Heated equipment
- Hot pipes or machinery
- The thermographer's body
- Sky and surrounding structures

Reflectivity is especially important when inspecting:

- Shiny metals
- Electrical bus bars
- Polished mechanical components

Reflected Apparent Temperature – T-refl

Infrared cameras allow users to enter reflected apparent temperature (T-refl), which represents the average temperature of surrounding reflected sources (such as the sky, sun, or nearby hot surfaces) that bounce off the target surface and are picked up by the camera, appearing as an incorrect temperature reading. Correctly accounting for T-refl, often by entering its value into the camera settings or using specific techniques such as changing viewing angles, is crucial for subtracting this background noise and accurately measuring the target's true emitted temperature.

Why It Matters

Accuracy: Without correcting for T-refl, you get false temperature readings, especially for low-emissivity materials (like polished metal) or in bright sunlight.

Outdoor Measurements: The "cold sky" or bright sun can create significant T-refl, making outdoor measurements challenging.

How to Handle T-refl

Camera Setting: Input the measured or estimated T-refl into the camera's emissivity/reflection menu.

Change View Angle: Physically move or change the camera's angle; reflections will shift or disappear, while true hot spots remain.

Use a Card/Shield: Place a non-reflective card in front of the target to block reflections and measure the card's temperature, using that as your T-refl.

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4.4: Transmissivity

Definition of Transmissivity

Transmissivity describes how much infrared radiation passes through a material. Transmissivity values range from **0.0 to 1.0**.

In most industrial thermography applications:

- Solid materials are opaque in the infrared range
- Transmissivity is close to zero

Materials That Transmit Infrared Radiation

Some materials allow partial transmission of infrared radiation, including:

- Certain plastics
- Thin films
- Specialized infrared windows

Common materials such as standard glass are opaque in the long-wave infrared range and do not transmit thermal radiation effectively.

Infrared Windows

Infrared-transparent windows are used to allow thermographic inspection while maintaining safety. These windows:

- Are made of specialized materials
- Have known transmissivity values
- Must be properly maintained and documented

Level I technicians should use manufacturer-provided transmissivity values and follow established inspection procedures.

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4.5: Relationship Between Emissivity, Reflectivity, and Transmissivity

For any surface, the relationship can be summarized as:

Emission + Reflection + Transmission = 1.0

Understanding this relationship helps explain why low-emissivity surfaces tend to reflect more radiation.

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4.6: Viewing Angle and Measurement Error

As the viewing angle becomes more oblique:

- Apparent emissivity decreases
- Reflectivity increases
- Measurement error increases

Best practice is to:

- Inspect surfaces as close to perpendicular as possible
- Document angles when deviations are unavoidable

This is especially important in aerial thermography, where camera angles may vary.

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4.7: Practical Camera Setup Considerations

Level I thermographers must properly configure camera settings before data collection, including:

- Emissivity value
- Reflected apparent temperature
- Distance to target
- Atmospheric conditions

Improper settings can result in misleading temperature readings, even when thermal patterns appear clear.

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4.8: Common Errors Related to Surface Properties

Common mistakes include:

- Assuming emissivity is constant for all materials
- Ignoring reflections from nearby heat sources
- Attempting to measure temperature through standard glass
- Failing to document surface conditions

Recognizing these errors is a key responsibility at Level I.

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4.9: Summary

In this chapter, you learned that:

- Emissivity determines how efficiently a surface emits infrared radiation
- Reflectivity can introduce false thermal indications
- Transmissivity describes how radiation passes through materials
- Surface condition strongly affects emissivity
- Viewing angle and environment influence measurement accuracy
- Proper camera setup is essential for reliable data collection

The next chapter will focus on infrared camera systems, including detectors, optics, and key performance specifications.

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4.10: Review Questions

1. What is emissivity, and why is it important in thermography?
2. Why do shiny metal surfaces often produce inaccurate temperature readings?
3. What is reflected apparent temperature?
4. Why is standard glass not suitable for most thermographic inspections?
5. How does viewing angle affect emissivity and reflectivity?

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CHAPTER OVERVIEW

5: Infrared Camera Systems

5.1: Introduction
5.2: Basic Components of an Infrared Camera
5.3: Infrared Detector Types
5.4: Key Camera Performance Specifications
5.5: Image Display and Color Palettes
5.6: Focus and Image Clarity
5.7: Camera Calibration and Accuracy
5.8: Handheld vs. Drone-Mounted Infrared Cameras
5.9: Care, Handling, and Maintenance
5.10: Summary
5.11: Review Questions
5.12: Drone Thermography Specification Tables

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5.1: Introduction

Infrared thermography relies on specialized cameras that detect infrared radiation and convert it into a visible image. Although the internal technology of these systems can be complex, a Thermography Level I technician must understand the basic components, functions, and limitations of infrared camera systems to collect accurate, repeatable data.

This chapter introduces the primary components of an infrared camera, common detector types, key performance specifications, and practical considerations for field use, including handheld and drone-mounted systems.

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5.2: Basic Components of an Infrared Camera

Most infrared cameras consist of the following major components:

- **Infrared detector**
- **Optical system (lens)**
- **Electronics and signal processing**
- **Display and user interface**
- **Power and data storage systems**

Each component plays a role in the quality and reliability of the thermographic image.

Infrared Detector

The detector is the core of the infrared camera. It senses incoming infrared radiation and converts it into an electrical signal.

Detectors are arranged in a grid known as a focal plane array (FPA). Each element in the array corresponds to a pixel in the thermal image.

Optical System

The optical system focuses infrared radiation onto the detector. Infrared lenses are made from specialized materials that transmit infrared energy, not visible glass.

Common infrared lens materials include:

- Germanium
- Chalcogenide glass

Infrared lenses are fragile and require careful handling to avoid damage or contamination.

Electronics and Signal Processing

The camera's electronics amplify and process the detector signal. This processing:

- Converts electrical signals into temperature data
- Applies calibration and correction algorithms
- Generates the displayed thermal image

Level I technicians are not responsible for modifying internal processing parameters but should understand that image quality depends on proper camera operation and setup.

Display and User Interface

The display presents thermal images using color palettes or grayscale. The user interface allows the operator to:

- Adjust settings
- Capture images or video
- Review stored data

Understanding menu navigation and control functions is essential for efficient field work.

Power and Data Storage

Infrared cameras use batteries for portable operation and store data internally or on removable media. Proper battery management and data backup are critical to successful inspections.

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5.3: Infrared Detector Types

Uncooled Detectors

Most Level I thermographic inspections use **uncooled microbolometer detectors**.

Characteristics include:

- Operate at ambient temperature
- Lower cost and maintenance
- Adequate sensitivity for most industrial applications
- Common in handheld and drone-mounted cameras

Cooled Detectors

Cooled detectors use cryogenic cooling to improve sensitivity and response time.

These systems:

- Are more complex and expensive
- Are typically used in specialized or research applications
- Are beyond Level I operational responsibility

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5.4: Key Camera Performance Specifications

Understanding camera specifications helps Level I technicians select appropriate equipment for a given inspection, when directed by procedures.

Thermal Sensitivity (NETD)

Noise Equivalent Temperature Difference (NETD) describes the camera's ability to detect small temperature differences.

- Lower NETD values indicate better sensitivity
- Important for detecting subtle thermal contras

Table 5-1: Thermal Sensitivity (NETD) Comparison

NETD Value (mK)	Sensitivity Description	Typical Applications	Level I Relevance
< 30 mK	Very high sensitivity	Research, precision inspections	Awareness only
30–50 mK	High sensitivity	Electrical, mechanical, building inspections	Ideal for Level I
50–80 mK	Moderate sensitivity	General condition monitoring	Acceptable for training
> 80 mK	Low sensitivity	Limited applications	May miss subtle anomalies

Note: Lower NETD values allow detection of smaller temperature differences.

Table 5-3: Infrared Camera Spectral Range

Spectral Range	Wavelength (µm)	Common Applications	Notes
SWIR	1–3	High-temperature, specialty	Rare in Level I
MWIR	3–5	Gas detection, high-temp targets	Typically cooled systems
LWIR	8–14	Electrical, mechanical, building, drone	Most Level I cameras

Spatial Resolution

Spatial resolution refers to the number of pixels in the detector array, such as:

- 160 × 120
- 320 × 240
- 640 × 480

Higher resolution allows better detail and smaller target detection, especially at greater distances.

Table 5-2: Infrared Camera Detector Resolution Comparison

Detector Resolution	Typical Use Cases	Advantages	Limitations	Level I Notes
160 × 120	Basic inspections, training, short-range work	Lower cost, simple operation	Limited detail, small targets difficult to resolve	Suitable for introductory labs
320 × 240	General industrial inspections	Balanced resolution and cost	Reduced effectiveness at long distances	Common Level I field camera

Detector Resolution	Typical Use Cases	Advantages	Limitations	Level I Notes
640 × 480	Electrical, mechanical, building, aerial inspections	High detail, better small-target detection	Higher cost, larger data files	Preferred for drone thermography

Instantaneous Field of View (IFOV)

IFOV describes the angular size of a single pixel. Smaller IFOV values mean each pixel represents a smaller area of the target.

IFOV is critical when inspecting small components or when working at long distances, including aerial inspections.

Table 5-4: IFOV and Distance Impact on Measurement

Distance to Target	IFOV Impact	Measurement Risk	Level I Guidance
Close range	Small pixel area	Low	Preferred when possible
Medium range	Moderate pixel area	Moderate	Verify target fills pixels
Long range	Large pixel area	High	Risk of averaging errors

Key Principle: The target must fill multiple pixels for reliable measurement.

Distance-to-Spot Ratio

Distance-to-spot ratio describes how distance affects the minimum size of a measurable object.

As distance increases:

- The measurement area increases
- Small targets may be averaged with surrounding areas

Spectral Range

Most industrial cameras operate in the 8–14 micrometer (µm) long-wave infrared range. This range is well suited for typical inspection temperatures and environmental conditions.

Wide, Standard, Telephoto Lenses

In photography, there are different types of lenses that provide an array of different perspectives. In thermal imaging, lens choice (wide, standard, telephoto) dictates your Field of View (FOV) and magnification, crucial for matching the camera to the task: wide-angle (large FOV) captures big scenes or close objects; standard (medium FOV) is versatile for general use; and telephoto (narrow FOV) zooms in on small, distant targets like power lines, enabling safe, detailed inspection from afar. The right lens makes the subject fill the frame for best resolution, balancing distance and detail.

Lens Types & Applications

Wide-Angle Lens

Characteristics: Larger FOV (e.g., 45°+), shorter focal length.

Best For: Scanning large areas (roofs, walls), tight spaces, or getting detailed views of nearby objects (thermal windows).

Example Use: Home inspections, large industrial scans, finding heat leaks in buildings.

Standard Lens

Characteristics: Moderate FOV (around 25°), good balance.

Best For: General-purpose inspections where you don't need extreme wide or narrow views.

Example Use: General electrical inspections, most everyday tasks.

Telephoto Lens

Characteristics: Narrower FOV, longer focal length, higher magnification.

Best For: Viewing small targets from a significant distance safely.

Example Use: Inspecting overhead power lines, high-voltage equipment, or distant ductwork from the ground.

Table 5-6: Common Infrared Lens Options

Lens Type	Field of View	Typical Applications	Limitations
Wide-angle	Large area coverage	Building surveys, roofs	Reduced spatial detail
Standard	Balanced	General inspections	Limited long-range
Telephoto	Narrow	Distant targets	Sensitive to motion

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5.5: Image Display and Color Palettes

Infrared images are displayed using color palettes that represent temperature differences.

Common palettes include:

- Iron
- Rainbow
- Grayscale
- High-contrast palettes

Color palettes do not change the measured temperature, only how it is displayed. Level I technicians should select palettes that enhance contrast and visibility of thermal patterns.

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5.6: Focus and Image Clarity

Proper focus is essential for accurate thermographic measurements.

Out-of-focus images:

- Reduce apparent temperature differences
- Lower measurement accuracy
- Can mask small anomalies

Focus should be checked and adjusted frequently, particularly when distance to the target changes

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5.7: Camera Calibration and Accuracy

Infrared cameras are calibrated by the manufacturer using blackbody references. Level I technicians:

- Do not perform calibration adjustments
- Should verify calibration status
- Must report suspected calibration issues

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5.8: Handheld vs. Drone-Mounted Infrared Cameras

Handheld Systems

Handheld cameras are commonly used for:

- Electrical inspections
- Mechanical inspections
- Building diagnostics

They offer flexibility and ease of use in close-range inspections.

Drone-Mounted Systems

Drone-mounted thermal cameras are used for:

- Roof inspections
- Solar arrays
- Large-area surveys
- Infrastructure inspections

Key considerations include:

- Vibration and motion effects
- Altitude and resolution tradeoffs
- Stabilization and gimbal performance

Level I technicians may operate these systems under established procedures and supervision.

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5.9: Care, Handling, and Maintenance

Proper care extends camera life and ensures reliable performance.

Best practices include:

- Keeping lenses clean
- Using protective cases
- Avoiding thermal shock
- Protecting cameras from moisture and dust
- Avoid touching lens with fingers
- NEVER point at the sun

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5.10: Summary

In this chapter, you learned that:

- Infrared cameras consist of detectors, optics, electronics, and displays
- Uncooled microbolometers are common in Level I applications
- Camera specifications affect image quality and accuracy
- Focus and spatial resolution are critical
- Color palettes affect image visibility, not temperature
- Both handheld and drone-mounted systems require careful operation

Level I Reminder:
Specifications help explain *why* images look the way they do, but Level I thermographers follow written procedures and do not select inspection methods or acceptance criteria.

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5.11: Review Questions

1. What is the primary function of an infrared detector?
2. Why are infrared lenses made from special materials?
3. What does NETD indicate about camera performance?
4. Why is focus critical in thermographic inspections?
5. How does distance affect spatial resolution?

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5.12: Drone Thermography Specification Tables

Table 5-8: Ground Sample Distance (GSD) Concept for Thermal Sensors

Term	Description	Level I Relevance
Ground Sample Distance (GSD)	The real-world ground area represented by one pixel in a thermal image	Determines smallest detectable feature
Smaller GSD	Higher detail per pixel	Preferred for inspections
Larger GSD	Less detail per pixel	Risk of averaging errors
GSD Dependency	Affected by altitude, sensor resolution, and lens	Must be considered before flight

Key Principle:
If a target does not occupy multiple pixels, its temperature reading may be unreliable.

Table 5-9: Typical Thermal Sensor Configurations Used on Drones

Sensor Resolution	Common Lens FOV	Typical Platforms	Level I Notes
320 × 256	~45°	Entry-level UAS	Limited small-target detection
640 × 512	~45°	Professional UAS	Preferred for inspections
640 × 512	~25° (telephoto)	Industrial UAS	Better detail at altitude

Table 5-10: Altitude vs. Approximate Thermal GSD (320 × 256 Sensor, ~45° Lens)

Flight Altitude (AGL)	Approx. GSD	Practical Impact
65 ft	~6–7 cm / pixel	Good for small components
130 ft	~12–14 cm / pixel	Moderate detail
200 ft	~18–20 cm / pixel	Small anomalies may be lost
260 ft	~25–28 cm / pixel	Pattern recognition only

Level I Guidance:
At higher altitudes, thermography becomes a qualitative screening tool, not a measurement-focused one.

Table 5-11: Altitude vs. Approximate Thermal GSD (640 × 512 Sensor, ~45° Lens)

Flight Altitude (AGL)	Approx. GSD	Practical Impact
65 ft	~3–4 cm / pixel	High detail
130 ft	~6–7 cm / pixel	Reliable inspections
200 ft	~9–10 cm / pixel	Moderate detail
260 ft	~12–14 cm / pixel	Acceptable screening

Instructor Note:
A 640-resolution sensor roughly doubles usable inspection altitude compared to 320 sensors.

Table 5-12: Effect of Telephoto Lenses on Thermal GSD (640 × 512 Sensor)

Lens FOV	Altitude	Approx. GSD	Benefit	Limitation
45°	40 m	~6–7 cm	Wide coverage	Less detail
25°	40 m	~3–4 cm	High detail	Narrow coverage

Lens FOV	Altitude	Approx. GSD	Benefit	Limitation
25°	80 m	~6–7 cm	Maintains detail	Reduced situational awareness

Table 5-13: Minimum Target Size vs. Pixel Coverage Rule

Pixel Coverage	Measurement Reliability	Level I Interpretation
< 1 pixel	Invalid	Do not report
1–2 pixels	Poor	Screening only
3–5 pixels	Fair	Caution advised
5+ pixels	Good	Preferred

Best Practice:
Targets should fill at least 5 × 5 pixels for meaningful temperature data.

Table 5-15: Common Drone Thermography Applications and Recommended GSD

Application	Recommended GSD	Typical Altitude (640 Sensor)
Electrical components	≤ 5 cm	20–30 m
Solar modules	5–10 cm	30–60 m
Roof inspections	8–15 cm	40–80 m
Building envelopes	10–20 cm	50–100 m
Large infrastructure	≥ 15 cm	80+ m

Level I Reminder – Drone Thermography
Altitude, resolution, and lens choice directly affect thermal image quality.
Level I thermographers follow approved flight and inspection procedures and document altitude, sensor type, and environmental conditions.

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CHAPTER OVERVIEW

6: Camera Controls and Setup

6.1: Introduction
6.2: Importance of Proper Camera Setup
6.3: Focus Control
6.4: Temperature Range Selection
6.5: Level and Span Controls
6.6: Color Palettes
6.7: Emissivity Input
6.8: Reflected Apparent Temperature
6.9: Distance and Atmospheric Inputs
6.10: Image Capture Settings
6.11: Drone-Specific Camera Setup Considerations
6.12: Common Setup Errors
6.13: Documentation of Camera Settings
6.14: Summary
6.15: Review Questions
6.16: Step-by-Step Camera Setup Checklists

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6.1: Introduction

Proper camera setup is critical to successful thermographic inspections. Even the most advanced infrared camera can produce misleading results if it is not configured correctly. A Thermography Level I technician must be proficient in adjusting camera controls, verifying settings, and ensuring consistent image quality before and during inspections.

This chapter covers the essential camera controls used in infrared thermography, including focus, temperature range, level and span, emissivity input, reflected apparent temperature, and image capture settings. Mastery of these controls ensures accurate and repeatable data collection.

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6.2: Importance of Proper Camera Setup

Infrared cameras detect radiation, not temperature directly. Camera settings determine how that radiation is processed and displayed. Improper setup can:

- Reduce thermal contrast
- Mask anomalies
- Introduce measurement errors
- Produce non-repeatable results

Level I technicians are responsible for verifying camera setup before image acquisition and documenting key parameters as required by procedure.

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6.3: Focus Control

Manual Focus

Manual focus is one of the most important controls in thermography. Proper focus ensures:

- Maximum spatial resolution
- Accurate temperature measurement
- Clear definition of thermal patterns

Focus should be adjusted:

- At the inspection distance
- Whenever distance changes
- Before capturing images

An out-of-focus image can significantly reduce apparent temperature differences and should not be used for reporting.

Auto Focus

Some cameras offer autofocus features. While convenient, autofocus:

- May lock onto incorrect surfaces
- Can be affected by low contrast scenes
- Should always be visually verified

Level I technicians must confirm that autofocus has achieved proper image clarity before capturing data.

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6.4: Temperature Range Selection

Infrared cameras operate within selectable temperature ranges. Choosing the correct range:

- Improves measurement accuracy
- Maximizes image contrast
- Prevents saturation or clipping

Best practices include:

- Selecting the narrowest range that includes expected temperatures
- Adjusting range when inspecting different components
- Avoiding overly wide ranges that reduce sensitivity.

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6.5: Level and Span Controls

Level

The **level** control sets the midpoint temperature displayed on the screen. Adjusting the level shifts the entire temperature scale up or down.

Span

The **span** control determines the width of the temperature range displayed. A smaller span increases contrast, while a larger span reduces contrast.

Practical Use of Level and Span

For Level I inspections:

- Reduce span to enhance contrast
- Adjust level to center the temperature range on the area of interest
- Avoid over-adjustment that exaggerates noise

Level and span adjustments affect **image appearance only**, not actual temperature data.

High-Range vs. Low-Range Thermal Cameras

Thermal cameras are commonly configured with either low-temperature ranges or high-temperature ranges, and the selected range directly affects thermal sensitivity, image contrast, and appropriate inspection applications.

Low-Range Thermal Cameras

Description

- Optimized for temperatures near ambient conditions
- Designed to detect small temperature differences with high sensitivity

Positives

- Higher thermal sensitivity (better ability to resolve small ΔT)
- Improved image contrast for low-temperature inspections
- Better suited for subtle thermal patterns

Negatives

- Limited maximum temperature capability
- Hot targets may saturate or lose detail
- Not suitable for very high-temperature applications

Common Use Cases

- Building envelope inspections
- Roof moisture surveys
- Mechanical equipment inspections
- Solar photovoltaic (PV) inspections
- Energy audits

High-Range Thermal Cameras

Description

- Designed to measure elevated and extreme temperatures
- Commonly used in industrial and electrical environments

Positives

- Capable of measuring very high temperatures
- Reduced risk of saturation on hot components

- Suitable for energized electrical and process equipment

Negatives

- Lower sensitivity at near-ambient temperatures
- Reduced contrast for subtle temperature differences
- Less effective for low-temperature building applications

Common Use Cases

- Electrical inspections of energized equipment
- Furnaces and kilns
- Refractory and process monitoring
- High-temperature industrial assets

Level I Selection Reminder

Selecting the appropriate temperature range is essential.
Using a range that is too high or too low for the application can reduce image quality and may lead to misleading thermograms, even when the camera is operating correctly.

Quick-Reference Comparison: High-Range vs. Low-Range Thermal Cameras

Feature	Low-Range Thermal Camera	High-Range Thermal Camera
Primary Design Purpose	Detect small temperature differences near ambient	Measure elevated and extreme temperatures
Typical Temperature Range	Near ambient to moderate temperatures	Moderate to very high temperatures
Thermal Sensitivity	Higher sensitivity (better for small ΔT)	Lower sensitivity at ambient temperatures
Image Contrast (Low ΔT)	Excellent	Reduced
Risk of Saturation	Higher when viewing hot targets	Low
Best For	Subtle thermal patterns	Hot components and energized equipment
Common Applications	Building envelopes, roofs, mechanical systems, solar PV	Electrical inspections, furnaces, refractory systems
Limitations	Cannot accurately measure very hot objects	Poor resolution of small temperature differences
Typical Inspection Environment	Ambient or slightly elevated temperatures	High-energy or industrial environments

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6.6: Color Palettes

Color palettes convert temperature data into visual color patterns. Common palettes include:

- Iron
- Rainbow
- Grayscale
- High-contrast palettes

Guidelines for Level I use:

- Choose palettes that highlight contrast
- Use consistent palettes for similar inspections
- Avoid palettes that obscure detail

Palette selection does not change measured temperature values.

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6.7: Emissivity Input

Setting Emissivity

Emissivity input enables the camera to correct for surface emissivity. Level I technicians must:

- Set emissivity based on known or estimated values
- Follow established procedures
- Document emissivity used during inspection

Incorrect emissivity settings can significantly affect displayed temperatures

Adjusting for Surface Conditions

Surface coatings, oxidation, and contamination can alter emissivity. Technicians should:

- Visually inspect surfaces
- Note surface conditions
- Adjust emissivity if required by the procedure

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6.8: Reflected Apparent Temperature

Reflected apparent temperature represents the average temperature of surrounding reflected sources.

Level I technicians should:

- Estimate reflected apparent temperature using approved methods
- Input the value into the camera
- Document the method used

Ignoring reflected temperature can result in false hot or cold indications, especially on reflective surfaces.

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6.9: Distance and Atmospheric Inputs

Some cameras allow input of:

- Distance to target
- Ambient air temperature
- Relative humidity

These inputs help correct for atmospheric attenuation, particularly for:

- Long-distance inspections
- Outdoor environments
- Drone-based thermography

Level I technicians should follow procedures regarding when these inputs are required.

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6.10: Image Capture Settings

Radiometric vs. Non-Radiometric Images

- **Radiometric images** store full temperature data for each pixel
- **Non-radiometric images** store only a visual representation

Radiometric images are preferred whenever post-processing or review by Level II personnel is required.

Still Images vs. Video

- Still images are used for documentation and reporting
- Video may be used to capture transient conditions

Level I technicians should use the format specified by procedure.

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6.11: Drone-Specific Camera Setup Considerations

For drone-mounted thermography, additional setup considerations include:

- Gimbal stabilization
- Focus verification prior to flight
- Fixed vs. dynamic focus
- Synchronization of visual and thermal sensors
- Pre-flight camera checks

Camera settings should be verified before takeoff whenever possible.

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6.12: Common Setup Errors

Common camera setup mistakes include:

- Failing to refocus after changing distance
- Using incorrect emissivity values
- Ignoring reflected temperature
- Selecting overly wide temperature ranges
- Relying on autofocus without verification

Recognizing and correcting these errors is a key Level I responsibility.

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6.13: Documentation of Camera Settings

Inspection records should include:

- Camera model and serial number
- Lens used
- Emissivity value
- Reflected apparent temperature
- Distance to target
- Environmental conditions
- Date and time

Accurate documentation supports traceability and repeatability.

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6.14: Summary

In this chapter, you learned that:

- Proper camera setup is essential for reliable thermography
- Focus, range, level, and span strongly affect image quality
- Emissivity and reflected temperature inputs influence measurement accuracy
- Color palettes affect visibility, not temperature
- Drone-based inspections require additional setup verification
- Documentation is a critical part of Level I responsibilities

The next chapter will focus on image types and data handling, including radiometric data, file formats, and data management practices.

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6.15: Review Questions

1. Why is focus one of the most critical camera controls?
2. How do level and span affect thermal image appearance?
3. Why must emissivity be set correctly?
4. What is reflected apparent temperature, and when is it important?
5. Why are radiometric images preferred for many inspections?

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6.16: Step-by-Step Camera Setup Checklists

The responsibility of the Level I thermographer is accurate, repeatable data collection.
Proper camera setup and documentation are critical to ensuring that Level II and III personnel can perform valid analysis.

Checklist 6-1: Pre-Inspection Camera Setup (All Thermography)

Before arriving on site or before powering up the camera:

☐ Verify camera model and serial number
☐ Confirm calibration status is current
☐ Inspect lens for dirt, moisture, or damage
☐ Verify correct lens is installed
☐ Check battery level (primary and spare)
☐ Confirm sufficient storage space
☐ Set correct date and time
☐ Confirm correct temperature units (°C or °F)
☐ Review inspection procedure and scope

Checklist 6-2: Initial Camera Power-On Setup

After powering on the camera:

☐ Allow camera to stabilize (per manufacturer guidance)
☐ Select correct temperature range
☐ Set emissivity to initial value per procedure
☐ Input reflected apparent temperature (if required)
☐ Enter distance to target (if applicable)
☐ Enter ambient temperature and humidity (if required)
☐ Select radiometric image capture mode
☐ Select approved color palette

Checklist 6-3: Focus and Image Quality Verification

Before capturing inspection images:

☐ Adjust focus at inspection distance
☐ Confirm sharp edges and clear thermal detail
☐ Re-focus after any change in distance
☐ Verify autofocus accuracy (if used)
☐ Check for motion blur or vibration effects
☐ Confirm target fills multiple pixels
☐ Adjust level and span to enhance contrast

Reminder:
Out-of-focus images are not acceptable for reporting.

Checklist 6-4: Emissivity and Reflection Control

For each surface inspected:

☐ Identify surface material and condition
☐ Confirm emissivity value used
☐ Adjust emissivity if surface condition changes
☐ Identify potential reflective sources
☐ Estimate reflected apparent temperature
☐ Adjust camera angle to minimize reflections
☐ Document surface condition and assumptions

Checklist 6-5: Environmental Verification

At the inspection location:

☐ Record ambient air temperature
☐ Note wind or airflow conditions
☐ Note solar loading or shadowing
☐ Check for rain, moisture, or condensation
☐ Verify equipment is under normal operating load (if required)
☐ Document any conditions that may affect results

Checklist 6-6: Image Capture Checklist (Handheld Thermography)

For each inspection image:

☐ Verify focus immediately before capture
☐ Confirm correct temperature range
☐ Confirm emissivity and reflected temperature
☐ Adjust level and span for clarity
☐ Capture radiometric image
☐ Capture corresponding visual image (if required)
☐ Verify image saved successfully
☐ Add notes or annotations (if permitted)

Checklist 6-7: Drone Thermography – Pre-Flight Camera Setup

Before takeoff:

☐ Confirm thermal sensor resolution and lens
☐ Verify gimbal stabilization operation
☐ Confirm thermal and visual sensor alignment
☐ Verify focus (manual or fixed)
☐ Set emissivity and reflected temperature
☐ Select radiometric capture mode
☐ Set image or video format per procedure
☐ Verify storage capacity
☐ Perform test image capture on ground

Checklist 6-8: Drone Thermography – In-Flight Verification

During flight (as applicable):

☐ Maintain planned altitude and standoff distance
☐ Monitor image clarity and focus
☐ Watch for motion blur or vibration
☐ Maintain appropriate viewing angle
☐ Avoid excessive yaw or pitch during capture
☐ Ensure target fills sufficient pixels
☐ Capture overlapping images if required

Checklist 6-9: Post-Capture Verification (All Inspections)

Immediately after image capture:

☐ Review images for focus and clarity
☐ Confirm thermal contrast is visible
☐ Verify radiometric data is present
☐ Confirm metadata recorded correctly

☐ Re-capture images if quality is insufficient
☐ Back up data per procedure

Checklist 6-10: Documentation Checklist (Level I Responsibility)

☐ Camera model and serial number
☐ Lens type
☐ Emissivity value(s) used
☐ Reflected apparent temperature
☐ Distance to target
☐ Environmental conditions
☐ Date and time
☐ Inspection location and component ID
☐ Operator name and Level I designation

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CHAPTER OVERVIEW

7: Image Types and Data Handling

7.1: Introduction
7.2: Thermal Image Types
7.3: Still Images vs. Video
7.4: File Formats
7.5: Metadata and Embedded Information
7.6: File Naming and Organization
7.7: Data Storage and Backup
7.8: Data Transfer and Handoff
7.9: Data Integrity and Ethics
7.10: Drone-Specific Data Handling Considerations
7.11: Quality Control Checks
7.12: Summary
7.13: Review Questions
7.14: Inspection Log Template

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7.1: Introduction

Thermographic inspections rely on accurate image capture and responsible data handling. The quality of collected data directly affects the ability of Level II and Level III personnel to analyze and interpret results. A Thermography Level I technician must understand the types of images produced by infrared cameras and follow established procedures for storing, organizing, and transferring thermographic data.

This chapter covers common image types, file formats, metadata, storage practices, and data integrity considerations for both handheld and drone-based thermography.

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7.2: Thermal Image Types

Infrared cameras can produce several types of images. Understanding the differences between these image types is critical for proper documentation and downstream analysis.

Radiometric Thermal Images

Radiometric images store temperature data for every pixel in the image. This allows:

- Post-processing
- Temperature measurement after capture
- Review by Level II or III personnel

Radiometric images are the preferred format for most professional thermographic inspections.

Level I Responsibility:
Ensure radiometric capture mode is enabled when required by procedure.

Non-Radiometric (Visualized) Images

Non-radiometric images store only the visual representation of the thermal scene. They:

- Do not contain temperature data
- Cannot be re-analyzed for measurement

These images may be used for training or general documentation but are typically insufficient for formal inspections.

Visual (RGB) Images

Many infrared cameras and drone payloads capture visual images alongside thermal data. Visual images help:

- Identify components
- Provide context
- Correlate thermal patterns to physical features

When required, visual images should be captured at the same time and from a similar viewpoint as thermal images

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7.3: Still Images vs. Video

Still Images

Still images are commonly used for:

- Documentation
- Reporting
- Comparison over time

They provide high-resolution, static records of thermal conditions.

Thermal Video

Thermal video captures a sequence of images over time and may be useful for:

- Observing transient conditions
- Monitoring changes during startup or shutdown
- Reviewing dynamic events

Video files are typically larger and may not store full radiometric data unless specifically configured.

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7.4: File Formats

Infrared cameras save data in various file formats, depending on manufacturer and settings.

Proprietary Radiometric Formats

Common proprietary formats include:

- FLIR (.jpg with embedded data, .seq)
- DJI radiometric formats
- Manufacturer-specific raw files

These formats preserve full thermal data and metadata.

Standard Image Formats

Formats such as .jpg or .png may be used for:

- Visual documentation
- Sharing images without thermal data

When converted from radiometric files(.rjpg), these formats lose temperature information.

Video Formats

Thermal video formats may include:

- Proprietary sequences
- Standard video containers with thermal overlays

Level I technicians should follow procedures specifying acceptable formats.

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7.5: Metadata and Embedded Information

Thermal images often contain embedded metadata, including:

- Date and time
- Camera model and serial number
- Lens information
- Emissivity setting
- Reflected apparent temperature
- Distance to target
- Environmental conditions

Metadata is essential for traceability and repeatability.

Level I Responsibility:
Verify metadata accuracy and completeness.

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7.6: File Naming and Organization

Consistent file naming and organization improve data usability and reduce errors.

File Naming Conventions

A typical naming convention may include:

- Inspection date
- Location or asset ID
- Component identifier
- Image sequence number

Example:

2025-03-12_BldgA_Panel3_PhaseB_Img001

Folder Structure

Recommended folder organization:

- Project or site name
- Date
- Inspection type
- Thermal images
- Visual images
- Supporting documentation

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7.7: Data Storage and Backup

Thermographic data must be stored securely and backed up according to procedure.

Best practices include:

- Backing up data as soon as practical
- Using redundant storage locations
- Protecting data from unauthorized modification
- Following employer or client data policies

Data loss or corruption can invalidate an inspection.

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7.8: Data Transfer and Handoff

Level I technicians often transfer data to Level II or III personnel for analysis.

Handoff should include:

- Radiometric image files
- Visual images
- Metadata
- Inspection notes
- Environmental observations

Incomplete handoff can limit the effectiveness of analysis.

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7.9: Data Integrity and Ethics

Maintaining data integrity is a professional responsibility.

Level I technicians must:

- Avoid altering original data
- Preserve original files
- Clearly identify any copies or exports
- Follow chain-of-custody requirements

Misrepresentation or modification of data is unethical and may have serious consequences.

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7.10: Drone-Specific Data Handling Considerations

Drone-based thermography introduces additional data management challenges, including:

- Large data volumes
- Multiple sensors
- Flight log integration
- Geolocation data

Level I technicians should ensure:

- Thermal and visual data are properly synchronized
- Flight data is retained when required
- File naming reflects flight segments or altitudes

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7.11: Quality Control Checks

Before submitting data for review, Level I technicians should perform basic quality checks:

- Verify focus and clarity
- Confirm thermal contrast
- Ensure radiometric data is present
- Confirm metadata accuracy
- Identify any limitations or anomalies

Images that do not meet quality standards should be flagged or re-captured if possible.

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7.12: Summary

In this chapter, you learned that:

- Radiometric images preserve temperature data and are preferred
- Non-radiometric images are limited in usefulness
- Metadata supports traceability and repeatability
- Proper file naming and organization are essential
- Data integrity is a professional and ethical responsibility
- Drone thermography requires additional data management steps

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7.13: Review Questions

1. What is the difference between radiometric and non-radiometric images?
2. Why is metadata important in thermographic inspections?
3. What risks are associated with poor data handling?
4. Why should original image files not be altered?
5. What additional data considerations apply to drone-based thermography?

Level I Reminder – Data Integrity

Level I thermographers are responsible for accurate capture, organization, and documentation of thermographic data.

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7.14: Inspection Log Template

Inspection Log – Thermography Level I

Field	Entry
Inspection Date	
Location / Site	
Asset ID	
Component	
Camera Model / Serial #	
Lens	
Emissivity	
Reflected Apparent Temp	
Distance to Target	
Ambient Temp	
Wind / Airflow	
Solar Loading	
Image File Names	
Notes / Observations	
Operator Name	
Certification Level	

7.X.5 Environmental Conditions Log Template

Environmental Conditions Record

Parameter	Value
Ambient Air Temperature	
Relative Humidity	
Wind Speed / Direction	
Cloud Cover	
Surface Condition (dry/wet)	
Time of Day	
Notes	

7.X.6 Image Quality Control Checklist (Post-Capture)

☐ Image is in focus
☐ Radiometric data present
☐ Correct emissivity recorded
☐ Reflected apparent temperature recorded
☐ Adequate thermal contrast
☐ Target fills sufficient pixels
☐ Metadata verified

☐ Visual image available (if required)
☐ File named correctly

7.X.7 Drone Thermography Mission Data Template

Drone Thermography Mission Record

Field	Entry
Date	
Location	
Drone Platform	
Thermal Sensor	
Sensor Resolution	
Lens FOV	
Flight Altitude (AGL)	
Overlap	
Time On Target	
Weather Conditions	
Image File Range	
Operator	

7.X.8 Level II / III Data Handoff Checklist

Before transferring data:

☐ Original radiometric files included
☐ Visual images included
☐ Metadata intact
☐ Inspection log completed
☐ Environmental conditions documented
☐ Limitations noted
☐ Data packaged read-only or zipped

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CHAPTER OVERVIEW

8: Inspection Techniques

8.1: Introduction
8.2: Passive and Active Thermography
8.3: Qualitative vs. Quantitative Inspections
8.4: Steady-State and Transient Inspection Conditions
8.5: Comparative Inspection Techniques
8.6: Distance, Angle, and Access Considerations
8.7: Environmental and Operating Condition Considerations
8.8: Electrical Inspection Techniques (Level I Scope)
8.9: Mechanical Inspection Techniques (Level I Scope)
8.10: Building and Infrastructure Inspection Techniques
8.11: Drone-Based Inspection Techniques
8.12: Common Inspection Errors
8.13: Summary
8.14: Review Questions

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8.1: Introduction

Thermographic inspection techniques are the methods used to collect thermal data in a consistent, repeatable, and meaningful way. The effectiveness of an infrared inspection depends not only on the camera and its settings, but also on how and when the inspection is performed.

A Thermography Level I technician must understand common inspection techniques, recognize appropriate inspection conditions, and follow established procedures. This chapter introduces fundamental thermographic inspection approaches used across electrical, mechanical, building, and aerial applications.

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8.2: Passive and Active Thermography

Thermographic inspections can be broadly categorized as passive or active, based on how thermal energy is introduced into the object being inspected.

Passive Thermography

Passive thermography relies on naturally occurring temperature differences. No external heat source is applied by the inspector.

Common examples include:

- Energized electrical systems
- Operating mechanical equipment
- Buildings under normal heating or cooling conditions
- Solar-heated surfaces

Passive thermography is the most common method used in Level I inspections.

Level I Focus:

Verify normal operating conditions and document load or usage state.

Active Thermography

Active thermography involves intentionally introducing a heat source to create thermal contrast.

Examples include:

- Heating or cooling a surface
- Using controlled load changes
- Applying external energy sources under supervision

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8.3: Qualitative vs. Quantitative Inspections

Qualitative Thermography

Qualitative inspections focus on observing thermal patterns rather than measuring exact temperatures.

Applications include:

- Identifying relative hot or cold areas
- Comparing similar components
- Screening large areas for anomalies

Most Level I inspections are qualitative in nature.

Quantitative Thermography

Quantitative inspections involve measuring temperature values and comparing them to reference data or criteria.

Quantitative measurements require:

- Accurate emissivity settings
- Controlled conditions
- Defined procedures

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8.4: Steady-State and Transient Inspection Conditions

Steady-State Inspections

Steady-state inspections are conducted when system temperatures remain relatively stable over time.

Examples:

- Electrical panels under constant load
- Continuous-process machinery

Steady-state conditions produce stable thermal patterns and are preferred when possible.

Transient Inspections

Transient inspections are conducted during changing conditions, such as:

- Equipment startup or shutdown
- Load changes
- Environmental changes

Transient conditions may enhance thermal contrast but require careful timing and documentation.

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8.5: Comparative Inspection Techniques

Comparative techniques involve comparing:

- Similar components
- Phases or circuits
- Adjacent areas
- Historical data (when available)

Examples include:

- Comparing electrical phases
- Comparing identical motors
- Comparing insulated vs. uninsulated areas

Level I technicians should capture images that allow clear comparison and document any observed differences without interpretation.

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8.6: Distance, Angle, and Access Considerations

Distance to Target

Distance affects:

- Spatial resolution
- Measurement accuracy
- Safety

Technicians should:

- Maintain consistent inspection distances
- Avoid exceeding camera resolution limits
- Document distance when required

Viewing Angle

Best practice is to view surfaces as close to perpendicular as possible.

Oblique angles can:

- Reduce apparent emissivity
- Increase reflections
- Introduce measurement error

Viewing angle should be noted when deviations are unavoidable

Access Limitations

Some components may be:

- Enclosed
- Elevated
- Obstructed

Level I technicians must follow safety rules and never compromise safety to obtain an image.

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8.7: Environmental and Operating Condition Considerations

Environmental conditions can strongly influence thermographic inspections.

Important factors include:

- Ambient temperature
- Wind and airflow
- Solar loading
- Moisture or precipitation
- Time of day

Technicians should:

- Note conditions
- Avoid inspections under unsuitable conditions when possible
- Document any limitations

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8.8: Electrical Inspection Techniques (Level I Scope)

Common Level I electrical inspection practices include:

- Inspecting under load
- Maintaining safe approach distances
- Scanning systematically from source to load
- Capturing comparative images of phases

Level I technicians recognize thermal patterns but do not diagnose causes.

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8.9: Mechanical Inspection Techniques (Level I Scope)

Mechanical inspections often involve:

- Scanning bearings, motors, and couplings
- Comparing similar components
- Observing heat distribution patterns

Equipment should be operating normally during inspection unless otherwise directed.

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8.10: Building and Infrastructure Inspection Techniques

Building inspections may include:

- Scanning building envelopes
- Identifying insulation inconsistencies
- Detecting moisture-related patterns
- Inspecting roofs and façades

Environmental conditions and timing are especially important for building thermography.

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8.11: Drone-Based Inspection Techniques

Drone thermography is used for:

- Roofs
- Solar arrays
- Large-area surveys
- Infrastructure inspections

Key Level I considerations include:

- Maintaining planned altitude and angle
- Ensuring sufficient image overlap
- Managing motion and vibration
- Documenting flight parameters

Drone inspections must follow aviation regulations and approved procedures.

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8.12: Common Inspection Errors

Common mistakes include:

- Inspecting under insufficient load
- Ignoring environmental influences
- Inconsistent distances or angles
- Poor focus or camera setup
- Inadequate documentation

Recognizing and avoiding these errors improves inspection reliability.

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8.13: Summary

In this chapter, you learned that:

- Inspection techniques affect data quality
- Passive thermography is most common at Level I
- Qualitative inspections focus on patterns
- Steady-state conditions are preferred
- Comparative techniques improve reliability
- Environmental and access factors must be considered
- Drone-based inspections require additional controls

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8.14: Review Questions

1. What is the difference between passive and active thermography?
2. Why are steady-state conditions preferred for many inspections?
3. What is the purpose of comparative inspections?
4. How do distance and viewing angle affect thermographic data?
5. What additional considerations apply to drone-based inspections?

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CHAPTER OVERVIEW

9: Safety in Thermographic Inspections

9.1: Introduction
9.2: General Safety Principles
9.3: Electrical Safety
9.4: Mechanical and Industrial Safety
9.5: Working at Heights
9.6: Environmental and Outdoor Safety
9.7: Drone-Based Thermography Safety
9.8: Personal Protective Equipment (PPE)
9.9: Emergency Preparedness
9.10: Safety Documentation
9.11: Common Safety Mistakes
9.12: Summary
9.13: Review Questions
9.14: Job Hazard Analysis (JHA) Templates

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9.1: Introduction

Safety is the highest priority in all thermographic inspections. While infrared thermography is a non-contact inspection method, inspections are often conducted in hazardous environments, including energized electrical systems, operating machinery, elevated work areas, and outdoor locations.

A Thermography Level I technician must recognize hazards, follow established safety procedures, and never compromise safety to obtain an image. This chapter introduces common safety hazards and safe work practices associated with thermographic inspections, including handheld and drone-based operations.

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9.2: General Safety Principles

The following safety principles apply to all thermographic inspections:

- Follow employer and site-specific safety policies
- Comply with applicable codes and standards
- Use appropriate personal protective equipment (PPE)
- Maintain situational awareness at all times
- Stop work if conditions become unsafe

Level I technicians must report unsafe conditions to appropriate personnel.

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9.3: Electrical Safety

Electrical inspections are among the most common thermographic applications and present significant hazards.

Energized Electrical Equipment

Many thermographic inspections are performed on energized systems to observe load-related heating. Hazards include:

- Electric shock
- Arc flash
- Arc blast
- Burns

Level I technicians must:

- Maintain required approach distances
- Follow lockout/tagout procedures when applicable
- Never defeat safety interlocks
- Use insulated tools and PPE as required

Electrical PPE

Common electrical PPE may include:

- Arc-rated clothing
- Insulated gloves
- Face shields
- Safety glasses
- Hard hats

PPE requirements are determined by hazard assessments and site procedures.

Access and Panel Safety

When inspecting electrical panels:

- Do not open panels unless authorized
- Ensure panels are properly secured
- Maintain stable footing
- Avoid contact with live parts

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9.4: Mechanical and Industrial Safety

Thermographic inspections often occur near operating machinery.

Moving Machinery

Hazards include:

- Rotating shafts
- Belts and pulleys
- Fans
- Pinch points

Technicians must:

- Maintain safe distances
- Avoid loose clothing
- Secure tools and equipment
- Follow lockout/tagout when required

Hot Surfaces and Fluids

Heat sources may include:

- Hot pipes
- Steam lines
- Exhaust systems
- Heated process equipment

Avoid direct contact and be aware of radiant heat exposure.

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9.5: Working at Heights

Some thermographic inspections require working at elevated locations

Ladders and Platforms

When using ladders or platforms:

- Inspect equipment before use
- Use an appropriate ladder type
- Maintain three points of contact
- Do not overreach

Fall Protection

Fall protection may include:

- Guardrails
- Harnesses
- Anchor points

Follow site-specific fall protection requirements.

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9.6: Environmental and Outdoor Safety

Outdoor inspections introduce additional hazards.

Weather Conditions

Hazards may include:

- Wind
- Rain
- Extreme temperatures
- Lightning

Inspections should be postponed during unsafe weather conditions.

Terrain and Access

Uneven terrain, rooftops, and confined spaces require:

- Proper footwear
- Awareness of footing
- Use of spotters when needed

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9.7: Drone-Based Thermography Safety

Drone thermography introduces aviation-specific safety considerations.

Operational Safety

Level I personnel involved in drone operations must:

- Follow FAA Part 107 or applicable regulations
- Maintain visual line of sight (VLOS)
- Avoid flying over people unless authorized
- Conduct pre-flight safety checks

Site Safety

Drone inspections require:

- Establishing a safe launch and recovery area
- Maintaining separation from bystanders
- Coordinating with site personnel

Electrical and Infrastructure Hazards

When flying near:

- Power lines
- Substations
- Towers

Extra caution must be exercised to avoid collision or electromagnetic interference.

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9.8: Personal Protective Equipment (PPE)

PPE selection depends on the inspection environment and hazard assessment.

Common PPE includes:

- Safety glasses
- Gloves
- Hard hats
- High-visibility vests
- Hearing protection

PPE must be properly fitted and maintained.

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9.9: Emergency Preparedness

Level I technicians should:

- Know emergency procedures
- Identify exits and assembly points
- Carry communication devices
- Know how to summon help

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9.10: Safety Documentation

Safety documentation may include:

- Job hazard analyses (JHA)
- Permit-to-work forms
- PPE checklists
- Safety briefings

Accurate documentation supports safe operations and compliance.

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9.11: Common Safety Mistakes

Common safety errors include:

- Ignoring approach distances
- Inadequate PPE
- Poor situational awareness
- Working alone in hazardous environments
- Rushing inspections

Safety must never be compromised for data collection.

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9.12: Summary

In this chapter, you learned that:

- Thermographic inspections often involve hazardous environments
- Electrical safety is critical during energized inspections
- Mechanical and industrial hazards must be managed
- Working at heights requires proper equipment and training
- Outdoor and drone-based inspections introduce additional risks
- PPE and emergency preparedness are essential
- Safety documentation supports safe operations

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9.13: Review Questions

1. Why is safety a primary concern in thermographic inspections?
2. What hazards are associated with energized electrical equipment?
3. What precautions should be taken when working at heights?
4. How do drone inspections introduce additional safety considerations?
5. Why is safety documentation important?

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9.14: Job Hazard Analysis (JHA) Templates

General Thermography JHA Template (Level I)

Project / Site: _____
Date: _____ **Time:** _____
Location: _____
Task Description: _____
Technician Name: _____
Certification Level: ☐ Level I
Supervisor / Lead: _____

Task Breakdown & Hazard Controls

Task Step	Potential Hazards	Risk Level (L/M/H)	Controls / Mitigations	PPE Required
Camera setup	Trip hazards, dropped equipment			
Approach to inspection area	Slips, electrical proximity			
Image acquisition	Arc flash, hot surfaces			
Data review	Distraction in hazardous area			

Environmental Conditions:
☐ Indoor ☐ Outdoor ☐ Wind ☐ Rain ☐ Heat ☐ Cold ☐ Poor lighting

Stop-Work Triggers (Check all that apply):
☐ Unexpected energized parts
☐ Inadequate PPE
☐ Weather deterioration
☐ Loss of situational awareness
☐ Unauthorized access required

Signatures:
Technician: _____ Date: _____
Supervisor: _____ Date: _____

Electrical Thermography JHA Template

Inspection Type: ☐ Switchgear ☐ Panel ☐ Transformer ☐ Bus Bars
System Status: ☐ Energized ☐ De-energized
Load Condition (if energized): _____

Electrical Hazard Assessment

Hazard	Yes/No	Control Measures
Arc flash potential		Arc-rated PPE, distance
Shock exposure		Insulated gloves, barriers
Limited access		Authorized personnel only
Panel removal required		Supervisor approval

Required PPE (Check all):
☐ Arc-rated clothing (Rating: _____)

☐ Insulated gloves
☐ Face shield
☐ Safety glasses
☐ Hard hat

Approach Distance Verified: ☐ Yes ☐ No
NFPA 70E / Site Rules Reviewed: ☐ Yes ☐ No

Mechanical / Industrial Thermography JHA Template

Equipment Inspected: _____
Operating Condition: ☐ Normal ☐ Startup ☐ Shutdown

Mechanical Hazard Assessment

Hazard	Present (Y/N)	Controls
Rotating components		Guards, distance
Pinch points		Barriers, awareness
Hot surfaces		No-contact inspection
Noise		Hearing protection

Lockout/Tagout Required? ☐ Yes ☐ No
If Yes, Authorized by: _____

Working at Heights JHA Template

Work Location: ☐ Ladder ☐ Lift ☐ Roof ☐ Platform
Height: _____ ft / m

Fall Hazard Controls

Hazard	Control
Fall exposure	Harness / guardrails
Ladder instability	Proper ladder type
Overreach	Reposition equipment
Weather exposure	Delay inspection

Fall Protection Used: ☐ Harness ☐ Guardrails ☐ Spotter
Access Equipment Inspected: ☐ Yes ☐ No

Outdoor / Environmental Thermography JHA Template

Weather Conditions:
☐ Clear ☐ Windy ☐ Hot ☐ Cold ☐ Rain ☐ Lightning Risk

Environmental Hazard Assessment

Hazard	Risk	Controls
Heat stress		Breaks, hydration
Cold exposure		PPE, time limits
Slips / uneven terrain		Footwear, awareness
Reduced visibility		Delay inspection

Inspection Proceed? ☐ Yes ☐ No
If delayed, reason: _____

Drone-Based Thermography JHA Template (Level I Support Role)

For use by Level I personnel assisting or supporting UAS thermography under an authorized Remote Pilot in Command (RPIC).

Drone Platform: _____
Thermal Payload: _____
Altitude (AGL): _____
Visual Line of Sight Maintained: ☐ Yes ☐ No

UAS Hazard Assessment

Hazard	Present (Y/N)	Controls
People in area		Establish safety buffer
Power lines		Standoff distance
Wind / gusts		Adjust flight / abort
GPS interference		Manual control readiness

Roles Defined:
☐ RPIC ☐ Visual Observer ☐ Sensor Operator (Level I)

Emergency Procedures Reviewed: ☐ Yes ☐ No

Pre-Task Safety Brief Checklist (Tailgate Brief)

☐ Task scope reviewed
☐ Hazards identified
☐ Controls discussed
☐ PPE verified
☐ Emergency procedures reviewed
☐ Stop-work authority confirmed
☐ Communication plan established

Instructor / Textbook Callout Box

Level I Reminder – Safety Authority
Level I thermographers are responsible for **hazard recognition, PPE compliance, and stop-work authority**.
Engineering controls, acceptance criteria, and procedural changes are the responsibility of Level II, Level III, or site management.

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CHAPTER OVERVIEW

10: Common Sources of Error

10.1: Introduction
10.2: Measurement vs. Indication Errors
10.3: Emissivity-Related Errors
10.4: Reflection Errors
10.5: Atmospheric and Environmental Errors
10.6: Thermal Loading and Operating Condition Errors
10.7: Motion and Stability Errors
10.8: Focus, Range and Distance (FoRD) Errors
10.9: Viewing Angle Errors
10.10: Camera Setup and Configuration Errors
10.11: Data Handling Errors
10.12: Human Factors and Procedural Errors
10.13: Summary
10.14: Review Questions

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10.1: Introduction

Infrared thermography is a powerful inspection tool, but it is also highly sensitive to errors. Many common errors occur not because of equipment failure, but due to improper setup, environmental influences, or incorrect inspection techniques.

A Thermography Level I technician must be able to recognize potential sources of error, understand how they affect thermal images, and take corrective action before or during data collection. This chapter addresses the most common thermographic errors encountered in field inspections and explains how to avoid them.

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10.2: Measurement vs. Indication Errors

Thermographic errors can be grouped into two broad categories:

- **Measurement errors** – Affect the accuracy of temperature values
- **Indication errors** – Create false or misleading thermal patterns

Some errors affect both measurement and indication. Level I technicians are responsible for identifying and documenting these limitations.

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10.3: Emissivity-Related Errors

Incorrect emissivity settings are one of the most common sources of thermographic error.

Common causes include:

- Assuming emissivity is constant for all materials
- Ignoring surface coatings or oxidation
- Failing to adjust for surface condition changes

Impact:

- Incorrect temperature readings
- Apparent hot or cold spots

Prevention:

- Verify material and surface condition
- Use approved emissivity values
- Document assumptions

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10.4: Reflection Errors

Reflective surfaces can introduce infrared radiation from surrounding objects.

Common reflective sources include:

- Sunlight
- Hot equipment
- The thermographer's body

Impact:

- False hot or cold indications
- Misleading thermal patterns

Prevention:

- Adjust viewing angle
- Estimate and input reflected apparent temperature
- Identify reflective sources in the scene

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10.5: Atmospheric and Environmental Errors

Infrared radiation can be absorbed or altered by the environment.

Common environmental influences include:

- Wind and airflow
- Humidity
- Rain or moisture
- Solar loading

Impact:

- Reduced thermal contrast
- Temperature attenuation

Prevention:

- Document conditions
- Avoid inspections under unsuitable conditions
- Adjust inspection timing

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10.6: Thermal Loading and Operating Condition Errors

Thermography depends on sufficient thermal contrast.

Errors occur when:

- Electrical systems are under low load
- Mechanical equipment is not operating normally
- Buildings are not under heating or cooling stress

Impact:

- Hidden anomalies
- False negatives

Prevention:

- Verify operating conditions
- Document load or usage state
- Follow inspection procedures

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10.7: Motion and Stability Errors

Motion during image capture can degrade image quality.

Common causes include:

- Hand movement
- Vibration
- Drone motion or wind gusts

Impact:

- Blurred images
- Reduced spatial resolution

Prevention:

- Stabilize camera
- Use gimbals for drone operations
- Capture multiple images if needed

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10.8: Focus, Range and Distance (FoRD) Errors

(Critical – Cannot Be Corrected with Thermal Tuning)

Overview of FoRD

Focus, Range, and Distance (FoRD) represent three fundamental physical constraints in thermography:

- **Focus** – Optical sharpness of the image
- **Range** – Selected temperature measurement range
- **Distance** – Separation between camera and target

FoRD errors are especially critical because they permanently affect the data at the moment of capture and cannot be corrected through thermal tuning, software adjustment, or post-processing.

Focus Errors

Improper focus reduces spatial resolution and alters temperature readings.

Causes:

- Failure to manually focus
- Relying on autofocus without verification
- Changing distance without refocusing

Impact:

- Averaging of hot and cold areas
- Reduced apparent temperature differences
- Masked small anomalies

Key Principle:
An out-of-focus image cannot be fixed later.

Prevention:

- Manually focus at inspection distance
- Verify focus visually
- Re-focus whenever distance changes

Range Errors

Selecting an incorrect temperature range reduces measurement resolution.

Causes:

- Using overly wide ranges
- Failing to adjust range for different components

Impact:

- Reduced sensitivity
- Flattened thermal contrast
- Increased noise

Key Principle:
Thermal tuning adjusts display appearance, **not sensor resolution**.

Prevention:

- Select the narrowest appropriate range
- Re-adjust range when conditions change

Distance Errors

Distance directly affects spatial resolution and measurement accuracy.

Causes:

- Excessive standoff distance
- Inspecting small targets from too far away
- Ignoring IFOV and GSD limits

Impact:

- Pixel averaging
- Missed small anomalies
- Invalid temperature readings

Key Principle:
If a target does not fill enough pixels, no amount of software correction can recover the data.

Prevention:

- Reduce distance when possible
- Use higher-resolution sensors or appropriate lenses
- Document distance limitations

FoRD vs. Thermal Tuning

Thermal tuning (level, span, palette changes) affects image appearance only.

FoRD Factor	Can Thermal Tuning Fix It?
Out-of-focus image	❌ No
Excessive distance	No
Incorrect range resolution	No
Poor contrast	⚠️ Appearance only

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10.9: Viewing Angle Errors

Oblique viewing angles reduce apparent emissivity and increase reflections.

Impact:

- Measurement inaccuracies
- False patterns

Prevention:

- Inspect as close to perpendicular as possible
- Document angle deviations

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10.10: Camera Setup and Configuration Errors

Errors may include:

- Incorrect emissivity
- Incorrect reflected temperature
- Incorrect distance input
- Wrong capture mode

Prevention:

- Follow setup checklists
- Verify settings before capture
- Document all parameters

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10.11: Data Handling Errors

Errors in data management can invalidate inspections.

Examples include:

- Saving non-radiometric images
- Overwriting original files
- Poor file naming
- Loss of metadata

Prevention:

- Follow data handling procedures
- Perform quality checks
- Maintain backups

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10.12: Human Factors and Procedural Errors

Human factors include:

- Rushing inspections
- Distraction
- Overconfidence
- Failure to follow procedures

Prevention:

- Use checklists
- Maintain situational awareness
- Respect certification limits

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10.13: Summary

In this chapter, you learned that:

- Many thermographic errors are preventable
- Emissivity, reflection, and environment affect measurements
- Operating conditions influence detectability
- FoRD errors permanently affect data and cannot be corrected later
- Thermal tuning affects display, not physics
- Documentation and discipline are essential

The next chapter will focus on electrical systems thermography, introducing common components and Level I inspection practices.

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10.14: Review Questions

1. What is the difference between measurement errors and indication errors?
2. Why are FoRD errors considered permanent?
3. Why can’t thermal tuning correct focus or distance errors?
4. How does excessive distance affect pixel coverage?
5. What steps can a Level I technician take to prevent common errors?

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CHAPTER OVERVIEW

11: Electrical Systems Thermography

11.1: Introduction
11.2: Basic Electrical Concepts (Level I Overview)
11.3: Common Electrical Components Inspected
11.4: Typical Thermal Patterns in Electrical Systems
11.5: Comparative Inspection Techniques
11.6: Inspection Conditions and Timing
11.7: Inspection Workflow (Level I)
11.8: Safety Considerations Specific to Electrical Thermography
11.9: FoRD Considerations in Electrical Inspections
11.10: Environmental Influences
11.11: Documentation and Reporting (Level I Role)
11.12: Common Errors in Electrical Thermography
11.13: Summary
11.14: Review Questions

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11.1: Introduction

Electrical systems thermography is one of the most common and valuable applications of infrared inspection. Electrical components generate heat as a normal result of current flow. Abnormal heat patterns may indicate conditions that warrant further evaluation by qualified personnel.

A Thermography Level I technician’s role is to safely collect thermal data, recognize abnormal thermal patterns, and document observations according to established procedures. Diagnosis, severity assessment, and corrective recommendations are the responsibility of Level II or Level III personnel.

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11.2: Basic Electrical Concepts (Level I Overview)

A basic understanding of electrical principles helps explain why heat is generated in electrical systems.

Current, Voltage, and Resistance

- **Current** is the flow of electrical charge.
- **Voltage** is the electrical potential that drives current.
- **Resistance** opposes current flow.

Heat in electrical systems is commonly related to resistance. Increased resistance can result in increased heat generation.

Electrical Load

Electrical load refers to the amount of current being drawn by a system or component.

- Higher load generally produces more heat.
- Low-load conditions may mask thermal anomalies.

Level I Requirement:
Verify and document load conditions when required by procedure.

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11.3: Common Electrical Components Inspected

Electrical thermography is applied to a wide range of components, including:

- Switchgear
- Electrical panels
- Circuit breakers
- Fuses
- Bus bars
- Transformers
- Disconnects
- Contactors
- Cable terminations

Understanding component function helps with systematic inspection.

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11.4: Typical Thermal Patterns in Electrical Systems

Thermographic inspections focus on pattern recognition, not diagnosis.

Normal Thermal Patterns

Normal conditions may include:

- Uniform heating across similar components
- Symmetrical heating between phases
- Gradual temperature gradients

Abnormal Thermal Patterns

Abnormal patterns may include:

- Localized hot spots
- Uneven heating between phases
- Unexpected temperature gradients
- Isolated heating at connections

Level I technicians document these patterns.

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11.5: Comparative Inspection Techniques

Comparative techniques are essential in electrical thermography.

Examples include:

- **Phase-to-phase comparison** - involves visually comparing the thermal images of the three phases (A, B, C) in a three-phase system to spot temperature anomalies, revealing issues like high resistance, unbalanced loads, or overloaded components, where a hotter phase indicates a fault, though sometimes the colder phase can be the problem, requiring analysis with electrical knowledge and proper load conditions for accurate diagnosis.
- **Load-side vs. line-side comparison** - The primary distinction between the line side (incoming power source) and the load side (outgoing power to equipment) is crucial for accurate diagnosis and safety. By observing whether the heat is localized at the connection point or travels down the wire, a thermographer can better diagnose the nature of the problem (e.g., loose connection vs. overloaded circuit).
- **Similar component comparison** - is a core qualitative method where you scan identical components (like fuses, breakers, or bus bars) under similar loads, expecting uniform temperatures; a significant temperature difference (delta T) indicates a fault, such as loose connections, corrosion, or phase imbalance, often requiring immediate action per standards like NFPA 70B or NETA guidelines

Comparisons help identify deviations under similar operating conditions.

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11.6: Inspection Conditions and Timing

Electrical thermography should be performed:

- Under load (as specified by procedure)
- During stable operating conditions
- When access and safety permit

Low-load or transient conditions may reduce detectability of anomalies.

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11.7: Inspection Workflow (Level I)

A typical Level I electrical thermography workflow includes:

1. Review the inspection scope and safety requirements
2. Verify load and operating conditions
3. Perform camera setup and focus
4. Inspect systematically from source to load
5. Capture radiometric thermal images
6. Capture corresponding visual images
7. Document observations and conditions

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11.8: Safety Considerations Specific to Electrical Thermography

Electrical thermography presents significant hazards.

Key reminders:

- Maintain required approach distances
- Use appropriate PPE
- Never open energized equipment unless authorized
- Follow site-specific safety procedures

Safety requirements take precedence over data collection.

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11.9: FoRD Considerations in Electrical Inspections

Electrical components are often small and closely spaced.

FoRD challenges include:

- Limited access
- Small targets
- Reflective surfaces
- Safety-driven standoff distances

Level I Guidance:

- Ensure adequate pixel coverage
- Maintain proper focus
- Document distance limitations

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11.10: Environmental Influences

Environmental factors affecting electrical thermography include:

- Ambient temperature
- Airflow from cooling fans
- Outdoor weather conditions

These influences should be noted in inspection records.

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11.11: Documentation and Reporting (Level I Role)

Level I documentation should include:

- Image identification
- Component identification
- Observed thermal patterns
- Load and environmental conditions
- Inspection limitations

Avoid:

- Diagnosing causes
- Assigning severity
- Recommending corrective actions

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11.12: Common Errors in Electrical Thermography

Common errors include:

- Inspecting under insufficient load
- Poor focus or excessive distance
- Ignoring reflections
- Inconsistent comparison conditions

Use checklists and procedures to minimize errors.

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11.13: Summary

In this chapter, you learned that:

- Electrical systems generate heat under normal operation
- Abnormal thermal patterns may indicate potential issues
- Comparative inspection is essential
- Proper load and operating conditions are critical
- Safety and FoRD considerations strongly influence data quality
- Level I technicians document patterns, not diagnoses

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11.14: Review Questions

1. Why is load important in electrical thermography?
2. What is the difference between recognizing a pattern and diagnosing a fault?
3. Why are comparative techniques used in electrical inspections?
4. How do FoRD considerations affect electrical inspections?
5. What information should Level I technicians include in documentation?

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CHAPTER OVERVIEW

12: Mechanical Systems Thermography

12.1: Introduction
12.2: Basic Mechanical Concepts (Level I Overview)
12.3: Common Mechanical Components Inspected
12.4: Typical Thermal Patterns in Mechanical Systems
12.5: Comparative Inspection Techniques
12.6: Inspection Conditions and Timing
12.7: Inspection Workflow (Level I)
12.8: Safety Considerations Specific to Mechanical Thermography
12.9: FoRD Considerations in Mechanical Inspections
12.10: Environmental Influences
12.11: Documentation and Reporting (Level I Role)
12.12: Common Errors in Mechanical Thermography
12.13: Summary
12.14: Review Questions

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12.1: Introduction

Mechanical systems thermography uses infrared imaging to observe surface temperature patterns associated with mechanical operation. Heat in mechanical systems is commonly generated by. Abnormal thermal patterns may indicate conditions that require further evaluation.

A Thermography Level I technician’s role is to safely collect thermal data, recognize unusual thermal patterns, and document observations in accordance with written procedures.

Mechanical thermography at Level I is focused on recognizing and documenting thermal patterns.

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12.2: Basic Mechanical Concepts (Level I Overview)

Understanding basic mechanical concepts helps explain why heat appears in mechanical systems.

Friction and Heat Generation

Friction occurs when two surfaces move against each other. Friction generates heat, which may be detected by infrared thermography.

Examples include:

- Bearings
- Gears
- Sliding surfaces
- Couplings

Load and Mechanical Stress

Mechanical load refers to the forces acting on a component during operation.

- Increased load generally increases heat generation
- Uneven load distribution may create localized heating

Speed and Motion

Operating speed influences heat generation:

- Higher speeds may increase friction
- Changes in speed can create transient thermal conditions

Level I technicians should note operating conditions during inspection.

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12.3: Common Mechanical Components Inspected

Mechanical thermography is applied to a wide range of equipment, including:

- Bearings (rolling and plain)
- Electric motors
- Pumps
- Fans and blowers
- Gearboxes
- Couplings
- Conveyors
- Compressors

Understanding component layout supports systematic inspection.

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12.4: Typical Thermal Patterns in Mechanical Systems

Thermographic inspections focus on pattern recognition, not fault diagnosis.

Normal Thermal Patterns

Normal conditions may include:

- Even heat distribution across similar components
- Gradual temperature gradients
- Symmetrical heating on paired components

Abnormal Thermal Patterns

Abnormal patterns may include:

- Localized hot spots
- Asymmetrical heating
- Unexpected temperature gradients
- Heat is concentrated at interfaces or joints

Level I technicians document observed patterns.

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12.5: Comparative Inspection Techniques

Comparative techniques are especially useful in mechanical inspections.

Examples include:

- Comparing similar bearings
- Comparing drive-side vs. non-drive-side components
- Comparing identical machines under similar load

Comparisons help identify deviations from expected behavior.

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12.6: Inspection Conditions and Timing

Mechanical thermography should be performed:

- While equipment is operating
- Under normal load and speed
- During stable operating conditions when possible

Startup or shutdown inspections may reveal transient patterns and should be documented as such.

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12.7: Inspection Workflow (Level I)

A typical Level I mechanical thermography workflow includes:

1. Review inspection scope and safety requirements
2. Verify operating condition and load
3. Perform camera setup and focus
4. Inspect components systematically
5. Capture radiometric thermal images
6. Capture corresponding visual images
7. Document observations and conditions

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12.8: Safety Considerations Specific to Mechanical Thermography

Mechanical inspections present hazards such as:

- Rotating components
- Pinch points
- Hot surfaces
- Noise and vibration

Level I technicians must:

- Maintain safe distances
- Avoid loose clothing
- Follow lockout/tagout when required
- Use appropriate PPE

Safety takes precedence over inspection completeness.

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12.9: FoRD Considerations in Mechanical Inspections

Mechanical components are often small and closely spaced.

FoRD challenges include:

- Limited access
- Motion blur
- Small targets
- Guarding and enclosures

Level I Guidance:

- Ensure proper focus
- Minimize distance when safe
- Capture images quickly to reduce motion effects
- Document limitations

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12.10: Environmental Influences

Environmental factors affecting mechanical thermography include:

- Ambient temperature
- Airflow from fans
- Radiant heat from nearby equipment

These factors should be recorded in inspection documentation.

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12.11: Documentation and Reporting (Level I Role)

Level I documentation should include:

- Component identification
- Observed thermal patterns
- Operating condition and load
- Environmental influences
- Inspection limitations

Avoid:

- Diagnosing faults
- Assigning severity levels
- Recommending repairs

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12.12: Common Errors in Mechanical Thermography

Common errors include:

- Inspecting equipment at idle
- Motion-induced blur
- Poor focus or excessive distance
- Ignoring airflow effects
- Inconsistent comparison conditions

Using checklists and standardized procedures reduces error risk.

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12.13: Summary

In this chapter, you learned that:

- Mechanical systems generate heat through friction and load
- Thermography reveals surface temperature patterns
- Comparative inspection is essential
- Proper operating conditions are critical
- Safety and FoRD strongly influence data quality
- Level I technicians document patterns, not diagnoses

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12.14: Review Questions

1. Why does friction generate heat in mechanical systems?
2. What are common mechanical components inspected using thermography?
3. Why are comparative techniques important in mechanical inspections?
4. How does motion affect thermographic image quality?
5. What documentation is required from a Level I technician?

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CHAPTER OVERVIEW

13: Building and Infrastructure Thermography

13.1: Introduction
13.2: Heat Transfer in Buildings (Level I Review)
13.3: Common Building and Infrastructure Applications
13.4: Building Envelope Thermography
13.5: Inspection Conditions and Timing for Buildings
13.6: Roof Thermography (Ground-Based)
13.7: Drone-Based Roof Thermography
13.8: Solar Panel (PV) Thermography
13.9: Infrastructure Thermography
13.10: Documentation and Reporting (Level I Role)
13.11: Common Errors in Building and Infrastructure Thermography
13.12: Summary
13.13: Review Questions

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13.1: Introduction

Building and infrastructure thermography applies infrared imaging to evaluate the thermal performance of structures and building systems. Thermography is commonly used to identify temperature patterns associated with heat loss, insulation performance, air leakage, moisture intrusion, and roof or solar panel anomalies.

At the Level I scope, the thermographer’s role is to collect accurate thermal data, recognize abnormal thermal patterns, and document conditions and limitations.

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13.2: Heat Transfer in Buildings (Level I Review)

Building thermography is influenced by heat transfer mechanisms discussed earlier in this text:

- **Conduction** through walls, roofs, and structural elements
- **Convection** from air movement within and around buildings
- **Radiation** from surfaces exposed to sunlight or sky cooling

Understanding these mechanisms helps explain why certain thermal patterns appear during inspections.

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13.3: Common Building and Infrastructure Applications

Thermography is commonly applied to:

- Building envelopes
- Roof systems
- Insulation and thermal barriers
- Windows and doors
- Structural elements (concrete, masonry)
- Solar photovoltaic (PV) systems

Each application requires appropriate inspection conditions and techniques.

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13.4: Building Envelope Thermography

Walls, Insulation, and Thermal Bridging

Thermal imaging may reveal:

- Missing or compressed insulation
- Thermal bridges through structural members
- Inconsistent insulation performance

Normal patterns often show gradual temperature transitions, while abnormal patterns may appear as localized warm or cool areas.

Air Leakage and Infiltration

Air leakage may appear as:

- Linear patterns near joints or seams
- Temperature anomalies around windows and doors
- Irregular shapes influenced by wind or pressure differences

Environmental conditions strongly affect air leakage visibility.

Moisture-Related Thermal Patterns

Moisture may influence thermal behavior through evaporation and differences in heat capacity.

Thermal patterns may include:

- Cooler areas with diffuse boundaries
- Patterns that change over time

Level I technicians document these patterns.

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13.5: Inspection Conditions and Timing for Buildings

Building thermography is sensitive to:

- Indoor–outdoor temperature difference
- Solar loading
- Wind conditions
- Time of day

Inspections are often scheduled:

- Early morning or evening
- During heating or cooling operation

Conditions should always be documented.

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13.6: Roof Thermography (Ground-Based)

Ground-based roof thermography is used to observe:

- Heat retention differences
- Insulation inconsistencies
- Moisture-influenced thermal patterns

Best results often occur:

- After solar heating
- During evening cooling

Level I technicians follow written procedures and do not determine roof condition or repair needs.

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13.7: Drone-Based Roof Thermography

Advantages of Drone-Based Roof Inspections

Drone thermography allows:

- Access to large or complex roofs
- Reduced need for rooftop access
- Improved safety
- Rapid data collection

Operational Considerations (Level I Scope)

Drone roof inspections require:

- Stable flight and gimbal control
- Appropriate altitude to achieve sufficient GSD
- Overlapping image capture
- Consistent viewing angles

Focus, Range, and Distance (FoRD) are critical due to altitude and motion.

Environmental and Timing Factors

Drone roof inspections are strongly influenced by:

- Solar loading
- Cloud cover
- Wind
- Roof material type

Thermal patterns may change rapidly as conditions change.

Safety and Regulatory Awareness

Drone operations must:

- Comply with aviation regulations
- Maintain visual line of sight
- Avoid people and obstacles
- Follow site-specific safety plans

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13.8: Solar Panel (PV) Thermography

Introduction to Solar PV Thermography

Thermography is widely used to screen solar photovoltaic systems for abnormal thermal patterns that may indicate performance issues.

At Level I, the focus is on image acquisition and pattern recognition, not electrical diagnosis or performance analysis.

Typical Solar PV Thermal Patterns

Thermal patterns that may be observed include:

- Localized hot areas on modules
- Temperature differences between modules
- Linear or spot-like heating patterns

Level I technicians can document these patterns without determining cause.

Inspection Conditions for Solar PV Systems

Solar PV thermography typically requires:

- Adequate solar irradiance
- Systems under load
- Minimal cloud cover
- Consistent inspection angles

Low irradiance may reduce thermal contrast.

Drone-Based Solar Panel Inspections

Drone thermography is commonly used for:

- Large rooftop arrays
- Ground-mounted solar farms
- Utility-scale installations

Key Level I considerations include:

- Maintaining consistent altitude
- Achieving sufficient pixel coverage of individual cells or modules
- Capturing overlapping imagery
- Pairing thermal and visual data

FoRD Considerations for Solar Inspections

Solar modules contain small features that require:

- Proper focus
- Appropriate altitude
- Adequate resolution

Excessive distance may result in missed cell-level anomalies.

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13.9: Infrastructure Thermography

Thermography may be applied to infrastructure elements such as:

- Concrete structures
- Bridges
- Pavements
- Utility corridors

Thermal patterns may relate to material differences, moisture presence, or environmental effects.

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13.10: Documentation and Reporting (Level I Role)

Level I documentation for building and infrastructure inspections should include:

- Location and component identification
- Inspection method (ground-based or drone-based)
- Environmental conditions
- Observed thermal patterns
- Inspection limitations

Avoid diagnostic conclusions or repair recommendations.

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13.11: Common Errors in Building and Infrastructure Thermography

Common errors include:

- Inspecting during unfavorable environmental conditions
- Ignoring solar loading effects
- Excessive altitude in drone inspections
- Poor focus or insufficient pixel coverage
- Inadequate documentation

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13.12: Summary

In this chapter, you learned that:

- Building thermography reveals thermal performance patterns
- Environmental conditions strongly affect results
- Roof inspections can be ground-based or drone-based
- Drone thermography improves access and safety
- Solar PV inspections rely on adequate load and irradiance
- FoRD is critical for roof and solar inspections
- Level I technicians document patterns, not diagnoses

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13.13: Review Questions

1. Why are environmental conditions critical in building thermography?
2. What advantages do drone-based roof inspections provide?
3. Why is solar irradiance important for PV thermography?
4. How does FoRD affect solar panel inspections?
5. What are Level I documentation responsibilities in building thermography?

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CHAPTER OVERVIEW

14: Introduction to Drone-Based Thermography

14.1: Introduction
14.2: Why Use Drones for Thermography?
14.3: Limitations of Drone-Based Thermography
14.4: Typical Applications of Drone Thermography
14.5: Drone Platforms Used for Thermography
14.6: Thermal Sensors and Payloads
14.7: Flat Field Correction (FFC)
14.8: Focus, Range, and Distance (FoRD) in Drone Thermography
14.9: Mission Planning Fundamentals (Level I Awareness)
14.10: Regulatory and Compliance Awareness
14.11: Safety Considerations in Drone Thermography
14.12: Environmental Influences on Aerial Thermography
14.13: Data Collection and Documentation (Level I Role)
14.14: Ground-Based vs. Drone-Based Thermography
14.15: Common Errors in Drone Thermography
14.16: Summary
14.17: Review Questions

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14.1: Introduction

Drone-based thermography combines infrared imaging with unmanned aircraft systems (UAS) to inspect large, elevated, or inaccessible areas. By mounting thermal cameras on drones, inspectors can safely collect thermal data over rooftops, solar arrays, infrastructure, and other expansive assets.

At the Thermography Level I scope, drone-based thermography focuses on proper equipment setup, safe and compliant operation, accurate image acquisition, and thorough documentation.

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14.2: Why Use Drones for Thermography?

Drone-based thermography offers several advantages over ground-based methods:

- Access to rooftops, towers, and elevated assets
- Rapid inspection of large areas
- Reduced need for ladders, lifts, or scaffolding
- Improved safety by minimizing exposure to hazards
- Ability to capture consistent overhead perspectives

These advantages make drone thermography especially valuable for building, roof, solar, and infrastructure inspections.

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14.3: Limitations of Drone-Based Thermography

Despite its advantages, drone-based thermography has limitations:

- Increased inspection distance affects resolution
- Motion and vibration can degrade image quality
- Environmental conditions have greater impact
- Fixed-focus systems may limit flexibility
- Regulatory and airspace constraints apply

Understanding these limitations helps prevent misuse of the technology.

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14.4: Typical Applications of Drone Thermography

Common applications include:

- Roof inspections
- Solar photovoltaic (PV) inspections
- Building envelope surveys
- Electrical substations (authorized areas only)
- Infrastructure and utility corridors
- Emergency response and damage assessment

Each application requires appropriate planning and procedures.

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14.5: Drone Platforms Used for Thermography

Multirotor Platforms

Multirotor drones are the most common platforms for thermographic inspections due to:

- Vertical takeoff and landing
- Hover capability
- Precise positioning

Compatibility with gimbal-mounted sensors

Fixed-Wing Platforms (Overview Only)

Fixed-wing drones:

- Cover large areas efficiently
- Require more space for launch and recovery
- Are less common for detailed thermographic inspections

Fixed-wing operations are typically beyond Level I involvement.

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14.6: Thermal Sensors and Payloads

Drone thermography uses compact infrared cameras designed for aerial use.

Key sensor characteristics include:

- Detector resolution (e.g., 320×256, 640×512)
- Spectral range (typically LWIR)
- Radiometric capability
- Lens field of view
- Gimbal stabilization

Level I technicians should be familiar with the payload in use and its limitations.

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14.7: Flat Field Correction (FFC)

FFC is essential for maintaining **image quality and measurement consistency**. Without proper correction, thermal images may display non-uniform patterns such as streaking, shading, or blotchy areas that are unrelated to the actual temperature of the target. These artifacts can obscure real thermal patterns or be mistaken for valid indications.

Because detector response can drift due to **ambient temperature changes, camera warm-up, or changing scene conditions,** periodic FFC helps ensure that the camera's output remains reliable during an inspection.

FFC and Thermal Image Data Acquisition

Flat Field Correction affects how thermal data is **captured**, not how it is interpreted. Performing FFC at appropriate times:

· Improves image clarity and uniformity

· Reduces sensor-induced artifacts

· Supports consistent temperature measurement across the field of view

Failure to allow FFC to occur, especially during large temperature changes or long inspections, can degrade image quality and reduce confidence in the data.

Level I Operational Awareness

At the Thermography Level I level:

· Be aware when FFC is occurring (automatic or manual)

· Allow FFC to complete before capturing critical images

· Avoid capturing images during an FFC cycle

· Document unusual image artifacts if FFC was delayed or disabled

FFC **does not correct** focus errors, excessive distance, motion blur, or improper temperature range selection. It is a sensor stabilization process, not a substitute for proper inspection technique.

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14.8: Focus, Range, and Distance (FoRD) in Drone Thermography

FoRD considerations are especially critical in aerial inspections.

- **Focus:** Often fixed or set prior to flight
- **Range:** Must be appropriate for expected temperatures
- **Distance:** Determined by altitude and standoff

FoRD errors at capture cannot be corrected later, making pre-flight verification essential.

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14.9: Mission Planning Fundamentals (Level I Awareness)

While mission planning is often led by a Remote Pilot in Command (RPIC), Level I thermographers should understand key planning elements:

- Inspection objectives
- Planned altitude and GSD
- Flight path and overlap
- Environmental conditions
- Safety buffers and exclusion zones

Understanding the plan supports effective data collection.

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14.10: Regulatory and Compliance Awareness

Drone operations must comply with applicable aviation regulations, such as:

- FAA Part 107
- Visual line-of-sight requirements
- Airspace authorization
- Operational limitations

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14.11: Safety Considerations in Drone Thermography

Drone thermography introduces unique safety concerns:

- Rotating propellers
- Loss of control
- Collision with structures
- Interaction with people or vehicles

Pre-flight safety checks, controlled work areas, and clear communication are essential.

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14.12: Environmental Influences on Aerial Thermography

Environmental factors have a significant impact on aerial thermography:

- Wind affects stability and blur
- Solar loading influences surface temperatures
- Cloud cover changes thermal contrast
- Ambient temperature affects cooling rates

Conditions should be monitored and documented throughout the mission.

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14.13: Data Collection and Documentation (Level I Role)

Level I responsibilities include:

- Verifying camera settings before flight
- Capturing radiometric thermal images
- Capturing paired visual imagery
- Documenting flight parameters
- Noting environmental conditions
- Identifying inspection limitations

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14.14: Ground-Based vs. Drone-Based Thermography

Aspect	Ground-Based	Drone-Based
Access	Limited by height	Elevated access
Distance	Shorter	Longer
Resolution	Higher	Dependent on altitude
Safety	Climbing hazards	Reduced fall risk
Coverage	Limited	Wide-area

Both methods may be used together to support comprehensive inspections.

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14.15: Common Errors in Drone Thermography

Common errors include:

- Flying too high for sensor resolution
- Failing to verify focus
- Insufficient image overlap
- Ignoring environmental changes
- Overreliance on thermal tuning

Recognizing these errors helps prevent invalid data collection.

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14.16: Summary

In this chapter, you learned that:

- Drone-based thermography expands inspection capability
- Multirotor platforms are most common for thermal inspections
- Sensor resolution and FoRD are critical
- Mission planning and regulatory compliance are essential
- Environmental factors strongly influence results
- Level I technicians focus on data acquisition and documentation

The next chapter will focus on UAS platforms and thermal payloads, providing deeper familiarity with the equipment used in drone thermography.

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14.17: Review Questions

1. What advantages do drones provide for thermographic inspections?
2. What are key limitations of drone-based thermography?
3. Why is FoRD especially important in aerial inspections?
4. What role does a Level I thermographer play in drone missions?
5. How do environmental conditions affect drone thermography?

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CHAPTER OVERVIEW

15: UAS Platforms and Thermal Payloads

15.1: Introduction
15.2: Thermal Sensor Resolution and Pixel Count
15.3: Lens Field of View (FOV) and Resolution
15.4: Mid-Wave vs. Long-Wave Infrared (MWIR vs. LWIR)
15.5: Atmospheric Effects on MWIR and LWIR
15.6: Radiometric vs. Non-Radiometric Thermal Payloads
15.7: Gimbal Stabilization and Image Quality
15.8: FoRD Considerations for UAS Payloads
15.9: Typical Payload Configurations
15.10: Documentation and Payload Identification
15.11: Summary
15.12: Review Questions

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15.1: Introduction

Unmanned Aircraft Systems (UAS) equipped with thermal payloads have become essential tools for aerial thermographic inspections. The quality and usefulness of thermographic data collected by a drone depend heavily on the platform, the thermal sensor, and how well these components match the inspection objective.

At the Thermography Level I scope, the emphasis is on understanding sensor capabilities, recognizing limitations, and operating equipment properly.

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15.2: Thermal Sensor Resolution and Pixel Count

A thermal payload typically includes:

- Infrared sensor (detector)
- Lens and optical assembly
- Gimbal stabilization system
- Electronics and data interface
- Power and cooling systems (if applicable)

Each component influences image quality and data reliability.

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15.3: Lens Field of View (FOV) and Resolution

Understanding Pixel Count

The pixel count of a thermal sensor refers to the number of individual detector elements in the sensor array, commonly expressed as:

- 320 × 256 (~82,000 pixels)
- 640 × 512 (~327,000 pixels)

Each pixel measures the infrared radiation from a portion of the scene. More pixels provide:

- Higher spatial resolution
- Smaller Ground Sample Distance (GSD) at a given altitude
- Improved ability to resolve small features

Impact of Pixel Count on Inspection Quality

Pixel count directly affects:

- Minimum detectable target size
- Measurement reliability
- Maximum usable inspection altitude

Key Level I Principle:
If a target does not occupy enough pixels, its temperature reading may be inaccurate or invalid.

Pixel Count vs. Altitude

At higher altitudes:

- Each pixel covers a larger area
- Small features may be averaged with surrounding areas

Higher-resolution sensors allow inspections to be conducted at greater altitudes while maintaining acceptable detail.

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15.4: Mid-Wave vs. Long-Wave Infrared (MWIR vs. LWIR)

The lens determines how the sensor’s pixels are projected onto the scene.

- **Wide FOV lenses** cover large areas but reduce spatial detail
- **Narrow FOV (telephoto) lenses** improve detail but reduce coverage

Pixel count and lens selection together determine effective resolution.

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15.5: Atmospheric Effects on MWIR and LWIR

Overview of Infrared Bands

Thermal sensors used in thermography typically operate in either:

- **Mid-Wave Infrared (MWIR): ~3–5 micrometers (µm)**
- **Long-Wave Infrared (LWIR): ~8–12 micrometers (µm)**

Understanding the differences between these bands helps explain sensor performance and application suitability.

MWIR (3–5 µm) Characteristics

MWIR sensors:

- Often use cooled detectors
- Provide high sensitivity and fast response
- Perform well in high-temperature applications
- Are less affected by some atmospheric absorption

However, MWIR systems:

- Are more expensive
- Require cooling systems
- Are less common in routine Level I inspections

LWIR (8–12 µm) Characteristics

LWIR sensors:

- Commonly use uncooled microbolometers
- Are widely used in industrial and building thermography
- Perform well at ambient temperatures
- Are cost-effective and robust

Most drone-based thermography for buildings, roofs, and solar inspections uses LWIR sensors.

Practical Comparison: MWIR vs. LWIR

Feature	MWIR	LWIR
Wavelength	~3–5 µm	~8–12 µm
Detector Type	Typically cooled	Typically uncooled
Cost	High	Moderate
Typical Use	High-temp, specialty	Building, solar, electrical
Level I Use	Limited	Common

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15.6: Radiometric vs. Non-Radiometric Thermal Payloads

Atmospheric absorption varies by wavelength.

- LWIR performs well through humidity and haze at short-to-moderate distances
- MWIR may perform better for certain long-distance or high-temperature applications

Environmental conditions should always be documented.

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15.7: Gimbal Stabilization and Image Quality

Radiometric payloads:

- Store temperature data per pixel
- Support post-flight analysis
- Are preferred for professional inspections

Non-radiometric payloads:

- Display thermal imagery only
- Limit post-processing capability

Level I technicians should verify payload capability before flight.

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15.8: FoRD Considerations for UAS Payloads

Gimbal systems:

- Stabilize the sensor
- Reduce motion blur
- Maintain consistent viewing angles

Poor stabilization can degrade image quality regardless of sensor resolution.

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15.9: Typical Payload Configurations

FoRD is influenced by:

- Fixed-focus designs
- Flight altitude
- Sensor resolution
- Lens selection

FoRD errors in drone thermography cannot be corrected after capture and must be managed before flight.

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15.10: Documentation and Payload Identification

Level I documentation should include:

- Sensor resolution
- Spectral band (MWIR or LWIR)
- Lens FOV
- Radiometric capability
- Gimbal type

This information supports traceability and downstream analysis.

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15.11: Summary

In this chapter, you learned that:

- UAS platforms and payloads strongly influence data quality
- Pixel count determines spatial resolution and usable altitude
- Lens FOV affects coverage and detail
- MWIR and LWIR sensors serve different applications
- LWIR sensors are most common in Level I thermography
- Radiometric payloads are preferred for inspection work
- FoRD must be managed before data capture

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15.12: Review Questions

1. How does pixel count affect thermal inspection quality?
2. Why are higher-resolution sensors preferred for aerial thermography?
3. What are the main differences between MWIR and LWIR sensors?
4. Why are LWIR sensors commonly used for building and solar inspections?
5. How do lens selection and pixel count work together to determine resolution?

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CHAPTER OVERVIEW

16: Regulatory and Operational Considerations

16.1: Introduction
16.2: Overview of Applicable Regulatory Frameworks
16.3: Aviation Regulations for Drone-Based Thermography
16.4: Roles and Responsibilities in Drone Operations
16.5: Operational Planning and Briefings
16.6: Site Access and Permissions
16.7: Electrical and Industrial Regulatory Awareness
16.8: Privacy and Data Protection Considerations
16.9: Operational Limitations Affecting Thermography
16.10: International and Non-U.S. Operations (Awareness)
16.11: Documentation and Compliance Records
16.12: Common Regulatory and Operational Errors
16.13: Summary
16.14: Review Questions

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16.1: Introduction

Thermographic inspections, especially those conducted with unmanned aircraft systems (UAS), are governed by a combination of regulatory requirements, operational procedures, and site-specific rules. Compliance with these requirements is essential for safety, legal compliance, and data integrity.

At the Thermography Level I scope, technicians are expected to understand applicable regulations, follow approved procedures, and operate within their defined roles and authorizations. Regulatory interpretation, waiver applications, and operational approvals are the responsibility of management, the employer, or the Remote Pilot in Command (RPIC).

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16.2: Overview of Applicable Regulatory Frameworks

Thermographic inspections may be subject to multiple regulatory frameworks, depending on the application.

Common frameworks include:

- Aviation regulations (for drone operations)
- Workplace safety regulations
- Electrical safety standards
- Site-specific policies and permits

Level I technicians must comply with all applicable requirements and report any conflicts or uncertainties.

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16.3: Aviation Regulations for Drone-Based Thermography

FAA Part 107 Overview

In the United States, most commercial drone operations are conducted under FAA Part 107.

Key Part 107 concepts relevant to thermography include:

- Commercial operation definition
- Requirement for a Remote Pilot Certificate
- Aircraft registration
- Operating limitations

Level I thermographers do not need to be certificated remote pilots unless acting as the RPIC, but must operate under the authority and supervision of an RPIC.

Operating Limitations (Awareness Level)

Common Part 107 operating limitations include:

- Visual Line of Sight (VLOS)
- Daylight or civil twilight operations (unless authorized)
- Maximum altitude limits
- Avoidance of people and moving vehicles
- Yielding right of way to crewed aircraft

Level I technicians supporting drone operations must understand these limitations and immediately notify the RPIC if a limitation is at risk of being exceeded.

Airspace Awareness

Drone operations may require:

- Airspace authorization
- Coordination with facility operators
- Temporary flight restrictions (TFR) awareness

Airspace approval and coordination are the responsibility of the RPIC.

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16.4: Roles and Responsibilities in Drone Operations

Clear role definitions are essential for safe and compliant operations.

Common roles include:

- **Remote Pilot in Command (RPIC):** Overall authority and responsibility for the flight
- **Visual Observer (VO):** Assists RPIC in maintaining situational awareness
- **Sensor Operator / Thermographer:** Operates thermal payload and collects data

A Level I thermographer may serve as a sensor operator, observer or RPIC (if properly certificated).

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16.5: Operational Planning and Briefings

Pre-Flight Planning (Level I Awareness)

The RPIC leads mission planning. Level I personnel should understand:

- Mission objectives
- Planned flight altitude and path
- Inspection targets
- Safety buffers
- Emergency procedures

Understanding the plan ensures effective data collection and communication.

Pre-Task Safety Briefings

Before inspections, teams should conduct a briefing covering:

- Scope of work
- Identified hazards
- Roles and responsibilities
- Communication protocols
- Stop-work authority

Level I technicians have stop-work authority if unsafe conditions arise.

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16.6: Site Access and Permissions

Thermographic inspections often require:

- Facility access authorization
- Work permits
- Coordination with site personnel
- Lockout/tagout or escort requirements

Level I technicians must not bypass access controls or safety systems.

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16.7: Electrical and Industrial Regulatory Awareness

Electrical and industrial thermography may involve compliance with:

- Electrical safety programs
- Arc flash requirements
- Lockout/tagout procedures
- Confined space rules

Level I technicians must follow site-specific safety programs and never assume authorization beyond what is explicitly granted.

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16.8: Privacy and Data Protection Considerations

Thermographic data may include:

- Images of private property
- Sensitive infrastructure
- Personally identifiable information (PII)

Level I technicians must:

- Follow data handling policies
- Avoid unnecessary data capture
- Secure data appropriately
- Transfer data only to authorized personnel

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16.9: Operational Limitations Affecting Thermography

Operational constraints may limit inspection effectiveness, including:

- Minimum standoff distances
- Restricted access areas
- Environmental conditions
- Time-of-day restrictions

Such limitations should be documented as part of inspection records.

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16.10: International and Non-U.S. Operations (Awareness)

Outside the United States, drone and inspection regulations vary by country.

Key considerations include:

- Local aviation authority rules
- Operator certification requirements
- Import/export of equipment
- Data sovereignty laws

Regulatory compliance for international operations is managed by the employer or project lead.

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16.11: Documentation and Compliance Records

Level I technicians may be required to contribute to compliance documentation, including:

- Inspection logs
- Safety brief acknowledgments
- Flight records (as applicable)
- Incident or near-miss reports

Accurate documentation supports compliance and accountability.

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16.12: Common Regulatory and Operational Errors

Common errors include:

- Operating outside authorized roles
- Assuming permissions without confirmation
- Ignoring operating limitations
- Poor communication with RPIC or site personnel
- Inadequate documentation

Awareness and discipline help prevent these issues

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16.13: Summary

In this chapter, you learned that:

- Thermography operations are governed by multiple regulatory frameworks
- Drone-based inspections require compliance with aviation regulations
- Clear role definition is essential for safe operations
- Level I technicians operate under approved procedures and supervision
- Site access, safety rules, and privacy considerations must be respected
- Documentation supports compliance and operational integrity

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16.14: Review Questions

1. Why is regulatory awareness important in thermographic inspections?
2. What role does the RPIC play in drone-based thermography?
3. What responsibilities may a Level I thermographer have during a drone mission?
4. Why is documentation important for regulatory compliance?
5. What should a Level I technician do if operational limits are about to be exceeded?

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CHAPTER OVERVIEW

17: Mission Planning for Aerial Thermography

17.1: Introduction
17.2: Defining the Inspection Objective
17.3: Target Characteristics and Resolution Requirements
17.4: Altitude Selection and Ground Sample Distance (GSD)
17.5: Flight Path and Coverage Planning
17.6: Viewing Angle and Sensor Orientation
17.7: Focus, Range, and Distance (FoRD) Verification
17.8: Environmental Assessment
17.9: Time-of-Day Considerations
17.10: Safety Planning and Risk Mitigation
17.11: Coordination and Communication
17.12: Pre-Flight Briefing Participation (Level I Role)
17.13: In-Flight Data Collection Considerations
17.14: Post-Flight Review and Documentation
17.15: Common Mission Planning Errors
17.16: Summary
17.17: Review Questions
17.18: Mission Planning Worksheets (Aerial Thermography)

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17.1: Introduction

Mission planning is a critical step in successful aerial thermographic inspections. Proper planning ensures that thermal data is collected safely, legally, and with sufficient quality to meet inspection objectives. Unlike ground-based inspections, aerial thermography introduces additional variables, including altitude, flight path, environmental conditions, and sensor limitations.

At the Thermography Level I scope, mission planning focuses on understanding the inspection objective, verifying that the plan meets data quality requirements, and executing data collection in accordance with the approved mission plan. Final mission approval and flight authority remain the responsibility of the Remote Pilot in Command (RPIC).

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17.2: Defining the Inspection Objective

Every aerial thermography mission begins with a clear inspection objective. Examples include:

- Roof moisture screening
- Solar photovoltaic (PV) module inspection
- Building envelope survey
- Infrastructure assessment

Understanding the objective helps determine:

- Required resolution and GSD
- Target size and spacing
- Appropriate altitude and lens selection
- Image overlap requirements

Level I technicians should review the stated objective and confirm that it aligns with the planned mission parameters.

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17.3: Target Characteristics and Resolution Requirements

Mission planning must account for the physical characteristics of the target, including:

- Size of features of interest
- Spacing between components
- Thermal contrast expectations

Key Level I Principle:
Targets must occupy sufficient pixels in the thermal image to produce valid data. If the planned altitude does not meet pixel coverage requirements, the mission plan should be adjusted before flight.

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17.4: Altitude Selection and Ground Sample Distance (GSD)

Altitude directly affects GSD and image resolution.

- Lower altitude = smaller GSD = higher detail
- Higher altitude = larger GSD = reduced detail

Mission planning should ensure that the selected altitude:

- Meets resolution requirements
- Maintains safety and regulatory compliance
- Allows stable flight and overlap

Level I technicians should verify planned altitude against sensor resolution and lens FOV.

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17.5: Flight Path and Coverage Planning

Flight Path Design

Flight paths are designed to:

- Systematically cover the inspection area
- Maintain consistent viewing angles
- Ensure repeatable image capture

Common patterns include:

- Grid patterns for roofs and solar arrays
- Linear passes for long structures
- Point-of-interest or orbit patterns for localized assets

Image Overlap

Image overlap ensures complete coverage and supports post-processing when required.

Typical overlap considerations include:

- Forward overlap
- Side overlap

Insufficient overlap may result in gaps or incomplete inspection coverage.

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17.6: Viewing Angle and Sensor Orientation

Thermal data quality is influenced by viewing angle.

Best practices include:

- Maintaining near-nadir (straight down) views for roofs and solar arrays
- Avoiding steep oblique angles when possible
- Keeping sensor orientation consistent throughout the mission

Viewing angle deviations should be documented.

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17.7: Focus, Range, and Distance (FoRD) Verification

FoRD must be verified **before flight**.

Mission planning should include:

- Focus verification procedures
- Selected temperature range appropriate for expected conditions
- Planned altitude that maintains valid distance limits

FoRD errors at capture cannot be corrected later.

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17.8: Environmental Assessment

Environmental conditions can significantly affect aerial thermography.

Mission planning should consider:

- Ambient temperature
- Wind speed and direction
- Solar loading
- Cloud cover
- Recent weather events

Inspections may need to be delayed or rescheduled if conditions are unfavorable.

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17.9: Time-of-Day Considerations

Time of day influences thermal contrast, particularly for buildings and roofs.

Examples:

- Early morning or evening for roof moisture surveys
- Midday for solar PV inspections
- Avoiding rapidly changing conditions

The planned mission time should align with the inspection objective.

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17.10: Safety Planning and Risk Mitigation

Mission planning includes identifying and mitigating risks such as:

- Obstacles (power lines, towers, structures)
- People and vehicles
- Restricted areas
- Emergency landing zones

Level I technicians should be aware of identified hazards and follow safety protocols during execution.

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17.11: Coordination and Communication

Clear communication is essential during aerial thermography missions.

Planning should establish:

- Roles and responsibilities
- Communication methods
- Hand signals or verbal cues
- Emergency procedures

Level I thermographers should know who to communicate with and how.

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17.12: Pre-Flight Briefing Participation (Level I Role)

Level I technicians typically participate in pre-flight briefings covering:

- Mission objectives
- Flight plan
- Hazards and controls
- Weather conditions
- Emergency procedures

Questions or concerns should be raised before flight.

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17.13: In-Flight Data Collection Considerations

During flight, Level I thermographers may:

- Monitor image quality
- Verify focus and clarity
- Confirm coverage and overlap
- Communicate issues to the RPIC

If data quality is compromised, corrective action should be taken immediately.

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17.14: Post-Flight Review and Documentation

Mission planning continues after flight through:

- Reviewing captured data for completeness
- Confirming image quality
- Documenting deviations from the plan
- Noting environmental or operational limitations

Incomplete or compromised data should be identified early.

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17.15: Common Mission Planning Errors

Common errors include:

- Flying too high for sensor resolution
- Ignoring environmental conditions
- Insufficient image overlap
- Poor communication
- Failure to verify FoRD before flight

Recognizing these errors improves future mission success.

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17.16: Summary

In this chapter, you learned that:

- Mission planning is essential for aerial thermography
- Inspection objectives drive planning decisions
- Altitude, GSD, and target size are closely related
- Viewing angle and overlap affect data quality
- Environmental and timing factors influence results
- FoRD must be verified before flight
- Level I technicians support and execute approved mission plans

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17.17: Review Questions

1. Why is defining the inspection objective critical in mission planning?
2. How does altitude affect GSD and image resolution?
3. Why is image overlap important in aerial thermography?
4. What environmental factors should be considered during planning?
5. What role does a Level I thermographer play during mission execution?

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17.18: Mission Planning Worksheets (Aerial Thermography)

Worksheet 17-A: Mission Overview & Inspection Objective

Project / Site Name: _____
Date: _____ **Planned Time:** _____
Location: _____

Inspection Type (check one):
☐ Roof inspection
☐ Solar PV inspection
☐ Building envelope
☐ Infrastructure
☐ Other: _____

Inspection Objective (brief):

Primary Targets (components / areas):

Level I Confirmation:
☐ Objective reviewed and understood
☐ Scope aligns with Level I responsibilities

Worksheet 17-B: Target Characteristics & Resolution Planning

Smallest Feature of Interest (approx.):
☐ < 5 cm
☐ 5–10 cm
☐ 10–20 cm
☐ > 20 cm

Required Pixel Coverage (goal):
☐ ≥ 5 × 5 pixels
☐ Screening only

Notes on Target Layout / Spacing:

Worksheet 17-C: Sensor & Payload Information

Drone Platform: _____
Thermal Payload Model: _____

Parameter	Entry
Sensor Resolution (pixels)	
Spectral Band	☐ LWIR ☐ MWIR
Lens FOV	
Radiometric Capture	☐ Yes ☐ No
Gimbal Stabilization	☐ Yes ☐ No

Level I Check:
☐ Payload supports inspection objective

Worksheet 17-D: Altitude, Distance & GSD Planning (FoRD)

Planned Flight Altitude (AGL): _____

Item	Value

Item	Value
Estimated GSD	
Target Pixel Coverage Adequate?	☐ Yes ☐ No
Focus Verified Pre-Flight?	☐ Yes ☐ No
Temperature Range Selected	

FoRD Risk Assessment:
☐ Low
☐ Moderate
☐ High

If Moderate or High, explain mitigation:

Worksheet 17-E: Flight Path & Coverage Plan

Flight Pattern (check one):
☐ Grid
☐ Linear passes
☐ Orbit / POI
☐ Manual / custom

Planned Overlap:

- Forward overlap: _____ %
- Side overlap: _____ %

Coverage Notes:

Worksheet 17-F: Viewing Angle & Sensor Orientation

Primary Viewing Angle:
☐ Nadir (straight down)
☐ Slight oblique
☐ Oblique (explain): _____

Angle Consistency Plan:



Potential Reflection Risks Identified? ☐ Yes ☐ No
If yes, list sources: _____

Worksheet 17-G: Environmental & Timing Assessment

Condition	Expected
Ambient Temperature	
Wind Speed / Direction	
Cloud Cover	
Solar Loading	
Recent Weather (rain, fog, etc.)	

Time-of-Day Justification:

Proceed as Planned? ☐ Yes ☐ No
If no, explain: _____

Worksheet 17-H: Safety & Risk Awareness (Level I)

Identified Hazards (check all that apply):

☐ People in area
☐ Power lines
☐ Structures / obstacles
☐ Traffic / vehicles
☐ Weather changes

Mitigation Measures:

Emergency Procedures Reviewed? ☐ Yes ☐ No

Worksheet 17-I: Roles, Communication & Authority

Role	Name
RPIC	
Visual Observer	
Sensor Operator (Level I)	

Primary Communication Method:

☐ Verbal
☐ Radio
☐ Hand signals

Stop-Work Authority Confirmed? ☐ Yes ☐ No

Worksheet 17-J: Pre-Flight FoRD & Data Quality Checklist

☐ Focus verified
☐ Correct temperature range selected
☐ Planned altitude meets GSD requirement
☐ Emissivity set (if applicable)
☐ Reflected apparent temperature set
☐ Radiometric capture enabled
☐ Test image reviewed

Worksheet 17-K: Post-Flight Data Completeness Check

☐ Full coverage achieved
☐ No major gaps
☐ Image quality acceptable
☐ Metadata intact
☐ Environmental conditions documented
☐ Limitations noted

Reflight Required? ☐ Yes ☐ No
If yes, reason: _____

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CHAPTER OVERVIEW

18: Aerial Thermal Image Acquisition

18.1: Introduction
18.2: Pre-Flight Camera and Payload Verification
18.3: Focus, Range, and Distance (FoRD) Verification
18.4: Test Image Capture (Before Full Mission)
18.5: In-Flight Image Acquisition Techniques
18.6: Viewing Angle and Sensor Orientation
18.7: Environmental Monitoring During Flight
18.8: Communication During Image Acquisition
18.9: Managing Multiple Sensors (Thermal + Visual)
18.10: Post-Flight Image Review (Initial QC)
18.11: Documentation and Metadata Recording
18.12: Common Aerial Image Acquisition Errors
18.13: Data Handling and Handoff
18.14: Summary
18.15: Review Questions
18.16: Quality Control (QC) Checklists for Aerial Thermography

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18.1: Introduction

Aerial thermal image acquisition is the process of collecting infrared data from a drone-mounted thermal sensor during flight. The quality of the collected data depends on proper pre-flight preparation, in-flight technique, and post-flight verification. Unlike ground-based inspections, aerial thermography introduces challenges related to altitude, motion, environmental variability, and limited opportunities for re-capture.

At the Thermography Level I scope, aerial image acquisition focuses on accurate, repeatable data capture in accordance with the approved mission plan. Interpretation and diagnostic conclusions are the responsibility of Level II or Level III personnel.

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18.2: Pre-Flight Camera and Payload Verification

Before takeoff, the thermal payload must be verified to ensure it is properly configured.

Pre-flight checks include:

- Confirming correct thermal sensor and lens
- Verifying gimbal operation and stabilization
- Checking camera calibration status
- Confirming radiometric capture mode
- Setting emissivity and reflected apparent temperature (if applicable)
- Selecting appropriate temperature range

Failure to verify camera settings before flight may result in unusable data.

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18.3: Focus, Range, and Distance (FoRD) Verification

FoRD must be verified **before** the aircraft leaves the ground.

18.3.1 Focus Verification

- Verify focus at the planned inspection distance
- Confirm sharp image detail using test captures
- Understand whether the system is fixed-focus or adjustable
- Re-verify focus if altitude or payload configuration changes

Out-of-focus aerial images cannot be corrected after capture.

Temperature Range Verification

- Select a range appropriate for expected surface temperatures
- Avoid overly wide ranges that reduce sensitivity
- Confirm that expected temperatures fall well within the selected range

Distance and Altitude Confirmation

- Verify planned altitude matches mission planning worksheets
- Confirm expected GSD meets target resolution requirements
- Ensure targets will occupy sufficient pixels

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18.4: Test Image Capture (Before Full Mission)

Whenever possible, capture one or more test images before proceeding with full coverage.

Test image review should confirm:

- Focus and clarity
- Adequate thermal contrast
- Correct temperature range
- Proper metadata recording

If test images do not meet quality requirements, corrective action should be taken immediately.

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18.5: In-Flight Image Acquisition Techniques

Stable Flight and Motion Control

Stable flight is critical for image clarity.

Best practices include:

- Maintaining steady airspeed
- Avoiding abrupt maneuvers
- Minimizing yaw during image capture
- Using gimbal stabilization effectively

Motion blur reduces spatial resolution and measurement reliability.

Maintaining Planned Altitude and Speed

During data collection:

- Maintain planned altitude to preserve GSD
- Maintain consistent speed to ensure even coverage
- Avoid rapid altitude changes unless directed

Altitude deviations should be documented.

Image Overlap and Coverage

Ensure sufficient:

- Forward overlap between images
- Side overlap between flight lines

Overlap helps ensure complete coverage and reduces the risk of missed areas.

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18.6: Viewing Angle and Sensor Orientation

Maintain consistent viewing angles throughout the mission.

- Use near-nadir orientation for roofs and solar arrays
- Avoid excessive oblique angles
- Keep gimbal orientation consistent across passes

Inconsistent angles can introduce emissivity and reflection errors.

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18.7: Environmental Monitoring During Flight

Environmental conditions can change rapidly.

During flight, monitor:

- Wind speed and gusts
- Cloud cover changes
- Shifts in solar loading
- Temperature changes

If conditions degrade, pause or terminate the mission and notify the RPIC.

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18.8: Communication During Image Acquisition

Clear communication between team members is essential.

Level I thermographers should:

- Communicate image quality concerns to the RPIC
- Report deviations from the plan
- Confirm completion of coverage areas

Use established communication protocols at all times.

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18.9: Managing Multiple Sensors (Thermal + Visual)

Many payloads capture both thermal and visual imagery.

Best practices include:

- Synchronizing capture of thermal and visual images
- Maintaining similar viewpoints
- Verifying both data streams are recording correctly

Visual images provide context and aid downstream analysis.

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18.10: Post-Flight Image Review (Initial QC)

Immediately after landing:

- Review a sample of images for focus and clarity
- Confirm coverage completeness
- Verify radiometric data presence
- Check metadata accuracy

Early review allows timely re-flight if necessary.

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18.11: Documentation and Metadata Recording

Level I documentation should include:

- Flight date and time
- Location and asset identification
- Sensor resolution and lens
- Flight altitude and pattern
- Environmental conditions
- Observed limitations or anomalies

Accurate documentation supports traceability and analysis.

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18.12: Common Aerial Image Acquisition Errors

Common errors include:

- Flying too high for sensor resolution
- Failing to verify focus
- Insufficient image overlap
- Ignoring environmental changes
- Overreliance on thermal tuning

Recognizing these errors improves inspection reliability.

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18.13: Data Handling and Handoff

After acquisition:

- Secure original radiometric files
- Organize data according to established folder structures
- Transfer data to Level II/III personnel
- Preserve metadata and flight logs

Do not alter original data files.

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18.14: Summary

In this chapter, you learned that:

- Aerial thermal image acquisition requires careful execution
- Pre-flight camera verification is essential
- FoRD must be correct before flight
- Stable flight and consistent altitude preserve data quality
- Environmental conditions must be monitored throughout the mission
- Post-flight QC ensures data completeness
- Level I technicians focus on data capture and documentation

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18.15: Review Questions

1. Why is FoRD verification critical before aerial image acquisition?
2. What should be checked during pre-flight camera setup?
3. How does flight stability affect thermal image quality?
4. Why is immediate post-flight image review important?
5. What documentation is required from a Level I thermographer?

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18.16: Quality Control (QC) Checklists for Aerial Thermography

QC-1: Pre-Flight Aerial Thermography QC Checklist

(Completed before takeoff)

Payload & Camera Configuration

☐ Correct thermal payload installed
☐ Sensor resolution verified
☐ Spectral band confirmed (LWIR / MWIR)
☐ Radiometric capture enabled
☐ Lens FOV verified
☐ Gimbal stabilization operational

FoRD Verification

☐ Focus verified at planned altitude
☐ Temperature range appropriate for expected targets
☐ Planned altitude supports required GSD
☐ Target expected to fill sufficient pixels

QC Hold Point:
❌ Do not fly if focus or altitude/GSD is not confirmed.

Mission Parameters

☐ Mission objective reviewed
☐ Planned flight altitude confirmed
☐ Planned flight speed confirmed
☐ Planned overlap confirmed
☐ Viewing angle defined (nadir / oblique)



Environmental Conditions

☐ Wind within acceptable limits
☐ Solar loading appropriate for inspection type
☐ Cloud cover acceptable
☐ No precipitation present

Documentation

☐ Mission planning worksheet completed
☐ Roles defined (RPIC, VO, Sensor Operator)
☐ Emergency procedures reviewed

QC-2: Test Image Verification Checklist

(Completed after test capture, before full mission)

☐ Image in focus
☐ Adequate thermal contrast visible
☐ No motion blur present
☐ Correct temperature range confirmed
☐ Radiometric data present
☐ Metadata recording correctly

Test Image Accepted? ☐ Yes ☐ No
If no, corrective action taken: _____

QC-3: In-Flight Image Acquisition QC Checklist

(Monitored during flight)

Flight Stability

☐ Altitude maintained within plan
☐ Speed consistent
☐ Minimal yaw during capture
☐ Gimbal maintaining orientation

Coverage & Overlap

☐ Forward overlap maintained
☐ Side overlap maintained
☐ No visible coverage gaps

FoRD Monitoring

☐ Focus appears consistent
☐ Targets remain adequately resolved
☐ No altitude creep reducing resolution

Environmental Monitoring

☐ Wind conditions stable
☐ Solar loading stable
☐ No sudden cloud changes

QC Trigger:
⛔ Pause or abort mission if FoRD or environmental limits are exceeded.

QC-4: Immediate Post-Flight Image Quality Check

(Completed immediately after landing)

☐ Sample images reviewed
☐ Focus acceptable across dataset
☐ No significant motion blur
☐ Thermal contrast adequate
☐ Radiometric data intact
☐ Metadata present

Re-flight Required? ☐ Yes ☐ No
If yes, reason: _____

QC-5: Aerial Data Completeness Checklist

(Before leaving site)

☐ All planned areas covered
☐ No missing flight lines
☐ All targets captured
☐ Thermal + visual images paired
☐ Flight logs saved

QC-6: FoRD-Specific QC Audit

(Critical Level I QC step)

FoRD Element	Acceptable?	Notes
Focus	☐ Yes ☐ No	

FoRD Element	Acceptable?	Notes
Range	☐ Yes ☐ No	
Distance / Altitude	☐ Yes ☐ No	

FoRD Rule:
❌ If any FoRD element is unacceptable, the data is **not valid** and must be flagged.

QC-7: Data Integrity & Handling Checklist

☐ Original radiometric files preserved
☐ No files overwritten
☐ File naming correct
☐ Folder structure followed
☐ Backup created
☐ Data ready for Level II/III handoff

QC-8: Limitations & Exceptions Documentation

☐ Environmental limitations noted
☐ Access or altitude constraints noted
☐ FoRD limitations documented
☐ Deviations from plan recorded

QC-9: Level II / III Handoff Readiness Checklist

☐ Radiometric thermal images included
☐ Visual images included
☐ Metadata intact
☐ Mission planning worksheet included
☐ Environmental conditions documented
☐ QC checklists completed

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CHAPTER OVERVIEW

19: Post-Flight Data Handling and Preparation

19.1: Introduction
19.2: Immediate Post-Flight Actions
19.3: Initial Image Quality Review (QC Confirmation)
19.4: Data Transfer from Aircraft to Storage
19.5: Preservation of Original Data
19.6: File Organization and Folder Structure
19.7: File Naming and Identification
19.8: Metadata Verification
19.9: Data Backup and Redundancy
19.10: Flight Logs and Supporting Data
19.11: Documentation of Limitations and Anomalies
19.12: Preparing Data for Analysis and Handoff
19.13: Data Security and Confidentiality
19.14: Common Post-Flight Data Handling Errors
19.15: Summary
19.16: Review Questions

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19.1: Introduction

Post-flight data handling is a critical phase of aerial thermographic inspections. Even when high-quality images are captured in flight, improper handling, organization, or documentation of data can compromise the usefulness of the inspection.

At the Thermography Level I scope, post-flight responsibilities focus on preserving original data, verifying completeness and quality, organizing files consistently, and preparing datasets for transfer to client or senior personnel.

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19.2: Immediate Post-Flight Actions

Immediately after landing and securing the aircraft, the following actions should be taken:

- Power down and secure the thermal payload
- Verify that data recording was completed successfully
- Confirm that the storage media is intact
- Ensure flight logs were saved (if applicable)

Delaying post-flight checks increases the risk of unnoticed data loss or corruption.

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19.3: Initial Image Quality Review (QC Confirmation)

A brief but systematic review of captured data should be conducted as soon as practical.

Image Quality Verification

Review a representative sample of images to confirm:

- Focus and sharpness
- Adequate thermal contrast
- Absence of excessive motion blur
- Proper temperature range selection
- Presence of radiometric data

If significant issues are identified and conditions allow, a re-flight should be considered before leaving the site.

Coverage Verification

Confirm that:

- All planned areas were covered
- No gaps exist in flight lines
- Key targets were captured

Incomplete coverage should be documented.

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19.4: Data Transfer from Aircraft to Storage

Thermal data should be transferred carefully from onboard storage to secure media.

Best practices include:

- Using manufacturer-recommended transfer methods
- Avoiding interruption during transfer
- Verifying file sizes and counts after transfer
- Retaining original files on the source media until backups are confirmed

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19.5: Preservation of Original Data

Original radiometric files are the authoritative inspection record.

Level I technicians must:

- Never overwrite original files
- Avoid altering file formats
- Clearly distinguish originals from copies or exports
- Preserve metadata embedded in files

Any derived files should be stored separately and clearly labeled.

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19.6: File Organization and Folder Structure

Consistent organization improves traceability and usability.

Post-flight data should be organized using established folder structures, such as:

- Project or site name
- Inspection date
- Thermal images (radiometric)
- Visual images
- Flight logs
- Documentation and QC records

Adhering to standardized structures reduces errors during analysis.

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19.7: File Naming and Identification

Files should be named using approved naming conventions that include:

- Date
- Location or asset identifier
- Component or area
- Sequence number

Clear naming prevents confusion and misinterpretation.

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19.8: Metadata Verification

Metadata should be reviewed to confirm accuracy and completeness.

Key metadata elements include:

- Date and time
- Camera model and serial number
- Sensor resolution and lens
- Emissivity setting
- Reflected apparent temperature
- Distance or altitude (if recorded)

Missing or incorrect metadata should be noted in inspection documentation.

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19.9: Data Backup and Redundancy

Thermal inspection data should be backed up promptly.

Recommended practices include:

- Maintaining at least two copies
- Storing copies on separate media
- Protecting data from unauthorized access
- Following organizational data retention policies

Data loss may invalidate the inspection.

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19.10: Flight Logs and Supporting Data

Drone-based inspections often generate additional data, such as:

- Flight logs
- Mission plans
- GPS tracks

These files support traceability and should be retained with the inspection dataset.

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19.11: Documentation of Limitations and Anomalies

Level I technicians should document:

- Environmental conditions affecting data
- Deviations from the mission plan
- FoRD limitations
- Safety or access constraints
- Any observed data quality concerns

Clear documentation helps personnel understand context and limitations.

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19.12: Preparing Data for Analysis and Handoff

Before transferring data, ensure that:

- All required files are included
- Folder structure is complete
- Naming conventions are followed
- QC checklists are completed
- Documentation is included

Data may be packaged in a read-only or compressed format to preserve integrity.

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19.13: Data Security and Confidentiality

Thermographic data may involve sensitive infrastructure or private property.

Level I technicians must:

- Follow data security policies
- Limit access to authorized personnel
- Avoid sharing data through unsecured channels
- Protect physical and digital storage media

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19.14: Common Post-Flight Data Handling Errors

Common errors include:

- Overwriting original files
- Incomplete data transfer
- Poor file organization
- Missing metadata
- Failure to back up data
- Inadequate documentation

Using checklists and standardized procedures reduces these risks.

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19.15: Summary

In this chapter, you learned that:

- Post-flight data handling is critical to inspection success
- Immediate QC checks help identify issues early
- Original radiometric data must be preserved
- Consistent organization and naming improve usability
- Metadata supports traceability and analysis
- Backups protect against data loss
- Level I technicians prepare data for analysis, not interpretation

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19.16: Review Questions

1. Why is immediate post-flight data review important?
2. What should never be done to original radiometric files?
3. Why is consistent file organization important?
4. What supporting data should accompany aerial thermography files?
5. What information should be documented as inspection limitations?

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CHAPTER OVERVIEW

20: Review, Documentation, and Professional Practice

20.1: Introduction
20.2: Review of Collected Data (Level I Role)
20.3: Documentation Standards
20.4: Use of Images in Documentation
20.5: Handling Limitations and Uncertainty
20.6: Data Integrity and Chain of Custody
20.7: Professional Conduct and Ethics
20.8: Communication and Teamwork
20.9: Continuous Improvement and Professional Development
20.10: Regulatory and Standards Awareness
20.11: Common Documentation and Professional Practice Errors
20.12: Summary
20.13: Comprehensive Review Questions

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20.1: Introduction

Professional thermographic inspections require more than technical skill. Consistent review, thorough documentation, and adherence to professional practice standards ensure that thermographic data is reliable, traceable, and useful to decision-makers.

At the Thermography Level I scope, the technician’s role is to verify data quality, document observations and conditions, and maintain professional and ethical conduct. Interpretation, diagnosis, and recommendations remain the responsibility of Level II or Level III personnel.

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20.2: Review of Collected Data (Level I Role)

Purpose of Review

The purpose of data review at Level I is to:

- Confirm image quality
- Verify completeness
- Identify limitations
- Ensure documentation accuracy

Review is not analysis or interpretation.

Image Quality Review

Level I review includes checking:

- Focus and clarity
- Adequate thermal contrast
- Correct temperature range
- Absence of excessive blur or artifacts
- Radiometric data presence

Images that do not meet quality requirements should be flagged.

Coverage and Completeness Review

Confirm that:

- All planned areas were inspected
- Required overlap was achieved
- No critical targets were missed

Incomplete inspections must be documented.

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20.3: Documentation Standards

Purpose of Documentation

Documentation ensures:

- Traceability
- Repeatability
- Accountability
- Regulatory compliance

Clear documentation supports downstream analysis and reporting.

Required Documentation Elements (Level I)

Typical Level I documentation includes:

- Inspection date and time
- Location and asset identification
- Camera and sensor information
- Inspection method (ground or aerial)
- Environmental conditions
- Observed thermal patterns
- Inspection limitations

Language and Terminology

Documentation should:

- Use objective, descriptive language
- Avoid diagnostic terms
- Avoid severity classifications
- Avoid repair recommendations

Example:

- Acceptable: “Localized area of elevated temperature observed”
- Not acceptable: “Loose connection causing overheating”

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20.4: Use of Images in Documentation

Thermal Images

Thermal images should:

- Be properly labeled
- Retain original color scales and ranges
- Include scale bars and reference information

Do not modify original images for documentation purposes.

Visual Images

Visual images provide context and should:

- Match the thermal viewpoint when possible
- Clearly identify inspected components
- Be labeled consistently with thermal images

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20.5: Handling Limitations and Uncertainty

All inspections have limitations.

Level I technicians should document:

- Environmental influences
- Access constraints
- FoRD limitations
- Deviations from procedures

Transparency about limitations supports accurate interpretation.

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20.6: Data Integrity and Chain of Custody

Maintaining data integrity is a professional responsibility.

Level I technicians must:

- Preserve original data
- Prevent unauthorized access
- Maintain chain-of-custody records when required
- Clearly identify copies or exports

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20.7: Professional Conduct and Ethics

Ethical Responsibilities

Ethical thermographic practice includes:

- Honest representation of findings
- Avoiding overstatement or speculation
- Respecting certification boundaries
- Protecting confidential information

Misrepresentation of data undermines trust and safety.

Working Within Certification Limits

Level I technicians must:

- Perform only tasks authorized at Level I
- Seek guidance when unsure
- Avoid offering opinions beyond their certification

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20.8: Communication and Teamwork

Thermographic inspections often involve multidisciplinary teams.

Professional communication includes:

- Clear reporting of observations
- Timely data transfer
- Respectful interaction with clients and colleagues
- Clear escalation of concerns

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20.9: Continuous Improvement and Professional Development

Thermography is an evolving field.

Professional development may include:

- Additional training
- Higher certification levels
- Equipment familiarization
- Participation in professional organizations

Continuous learning improves inspection quality and career opportunities.

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20.10: Regulatory and Standards Awareness

Professional practice includes awareness of:

- Applicable standards
- Regulatory requirements
- Organizational procedures

Level I technicians should follow current standards and report outdated or conflicting guidance.

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20.11: Common Documentation and Professional Practice Errors

Common errors include:

- Incomplete documentation
- Use of diagnostic language
- Poor image labeling
- Inadequate data security
- Failure to document limitations

Checklists and peer review help prevent these issues.

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20.12: Summary

In this chapter, you learned that:

- Review ensures data quality and completeness
- Documentation supports traceability and analysis
- Objective language is essential
- Limitations must be clearly recorded
- Data integrity is a professional obligation
- Ethical conduct builds trust
- Level I technicians operate within defined boundaries

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20.13: Comprehensive Review Questions

1. What is the purpose of data review at Level I?
2. What documentation elements are required for a Level I inspection?
3. Why must diagnostic language be avoided in Level I reports?
4. How should inspection limitations be handled?
5. Why is ethical conduct essential in thermographic practice?

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CHAPTER OVERVIEW

21: Practice Level I Practical Examination

21.1: Purpose and Instructions
21.2: SECTION 1- Equipment Setup and Pre-Inspection Verification
21.3: SECTION 2- FoRD Validation (Critical Section)
21.4: SECTION 3- Handheld Thermal Image Acquisition
21.5: SECTION 4- Aerial Thermography
21.6: SECTION 5- Thermal Tuning Awareness (Software Review)
21.7: SECTION 6- Quality Control (QC)
21.8: SECTION 7- Documentation Practice
21.9: SECTION 8- Safety and Professional Judgment
21.10: SECTION 9- Final Self-Assessment

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21.1: Purpose and Instructions

(Thermography – Student Review Version)

Purpose of This Practice Examination

This practice examination is provided to help students **master the skills and decision-making expected of a Thermography Level I technician**. Completing this exercise will help you:

- Build confidence with equipment setup and data capture
- Reinforce Focus, Range, and Distance (FoRD) principles
- Practice quality control (QC) habits
- Use professional, Level I–appropriate language
- Recognize (not diagnose) inspection limitations

This practice exam emphasizes process over answers.

Practice Exam Instructions

- Work through each section in order
- Use real equipment, recorded datasets, or instructor-provided files
- Do **not** diagnose faults or recommend repairs
- Use objective, professional language
- Treat this as if it were a real inspection

Practice Exam Takeaway

If you can correctly perform these steps and explain your decisions without diagnosing problems, you are operating at the Thermography Level I level.

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21.2: SECTION 1- Equipment Setup and Pre-Inspection Verification

Scenario

You are preparing to perform a thermographic inspection using a thermal camera (handheld or drone payload). The inspection objective is **general condition screening**.

Task 1.1 – Camera Setup Checklist

Complete the checklist before proceeding:

☐ Camera powered on and warmed up
☐ Correct lens verified
☐ Sensor resolution noted
☐ Radiometric capture enabled
☐ Emissivity set as instructed
☐ Reflected apparent temperature set
☐ Temperature range appropriate for expected targets
☐ Focus verified at inspection distance
☐ Flat Field Correction (FFC) completed

Reflection Question 1.1

Why must focus and temperature range be verified **before** image capture?

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21.3: SECTION 2- FoRD Validation (Critical Section)

Task 2.1 – FoRD Check

For your inspection target, record the following:

- **Focus:** ☐ Acceptable ☐ Not acceptable
- **Range:** ☐ Appropriate ☐ Too wide ☐ Too narrow
- **Distance:** ☐ Adequate pixel coverage ☐ Insufficient

Mandatory Practice Question

Can thermal tuning correct an out-of-focus or distance-limited image?

☐ Yes
☐ **No**

Explain your answer:

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21.4: SECTION 3- Handheld Thermal Image Acquisition

Scenario

You are inspecting one electrical component, one mechanical component, and one building-related feature.

Task 3.1 – Image Capture

For each target, capture:

- One thermal image
- One corresponding visual image

Target Type	Focus Acceptable?	Viewing Angle Appropriate?	Notes
Electrical	☐ Yes ☐ No	☐ Yes ☐ No	
Mechanical	☐ Yes ☐ No	☐ Yes ☐ No	
Building	☐ Yes ☐ No	☐ Yes ☐ No	

Reflection Question 3.1

Why is it important to capture a visual image along with the thermal image?

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21.5: SECTION 4- Aerial Thermography

Task 4.1 – Mission Review

☐ Planned altitude reviewed
☐ Sensor resolution noted
☐ GSD appropriate for target size
☐ Viewing angle consistent
☐ Environmental conditions noted

Task 4.2 – Image Acceptance

Review provided aerial thermal images.

Image	Acceptable for Use?	Reason (FoRD, blur, coverage, etc.)
Image A	☐ Yes ☐ No	
Image B	☐ Yes ☐ No	
Image C	☐ Yes ☐ No	

Reflection Question 4.1

Why is it especially important to verify FoRD **before flight** during aerial inspections?

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21.6: SECTION 5- Thermal Tuning Awareness (Software Review)

Task 5.1 – Thermal Tuning Controls

Using FLIR Thermal Studio or similar software:

☐ Adjust level and span
☐ Change color palette
☐ Apply and remove an isotherm
☐ Add and remove a spot measurement

Critical Thinking Question 5.1

What changed when you adjusted level and span:

- The **data**, or
- The **visual presentation**?

Explain:

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21.7: SECTION 6- Quality Control (QC)

Task 6.1 – QC Checklist

Before accepting the inspection data:

☐ Focus acceptable
☐ Adequate thermal contrast
☐ No excessive motion blur
☐ Complete coverage achieved
☐ Environmental conditions documented
☐ Limitations identified

Reflection Question 6.1

Why is QC an essential responsibility of a Level I thermographer?

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21.8: SECTION 7- Documentation Practice

Task 7.1 – Objective Observation Writing

Write one **Level I–appropriate** observation for a thermal image:

✔ Example format:
“Localized area of elevated temperature observed on [component].”

Your observation:

Boundary Check (Circle One)

Which statement is appropriate for Level I?

A. “The overheating is caused by a loose connection.”
B. **“An area of elevated temperature was observed.”**

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21.9: SECTION 8- Safety and Professional Judgment

Scenario

During an inspection, you encounter an unsafe condition.

Practice Question

What is the correct Level I response?

☐ Continue inspection carefully
☐ Adjust camera settings
☐ **Stop work and notify appropriate personnel**

Explain why:

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21.10: SECTION 9- Final Self-Assessment

Check all statements you can confidently explain:

☐ FoRD and why it matters
☐ Why thermal tuning cannot fix bad data
☐ Difference between high-range and low-range cameras
☐ Effects of solar loading
☐ Importance of documentation
☐ Level I professional boundaries

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Index

A

abnormal heat patterns
- 11.1: Introduction

abnormal thermal patterns
- 11.4: Typical Thermal Patterns in Electrical Systems

abrupt maneuvers
- 18.5: In-Flight Image Acquisition Techniques

absorption
- 3.8: Atmospheric Effects on Infrared Radiation

absorptivity
- 4.2: Emissivity

Access
- 9.6: Environmental and Outdoor Safety
- 12.9: FoRD Considerations in Mechanical Inspections
- 14.14: Ground-Based vs. Drone-Based Thermography
- 16.6: Site Access and Permissions
- 19.13: Data Security and Confidentiality

access constraints
- 19.11: Documentation of Limitations and Anomalies
- 20.5: Handling Limitations and Uncertainty

access factors
- 8.13: Summary

accountability
- 16.11: Documentation and Compliance Records
- 20.3: Documentation Standards

accuracy
- 5.6: Focus and Image Clarity
- 5.10: Summary
- 10.2: Measurement vs. Indication Errors
- 19.8: Metadata Verification

accurate data capture
- 7.13: Review Questions

accurate documentation
- 16.11: Documentation and Compliance Records
- 18.11: Documentation and Metadata Recording

accurate imaging
- 3.11: Practical Implications for Level I Thermographers

accurate measurement
- 4.3: Reflectivity

acquisition
- 18.13: Data Handling and Handoff
- 18.14: Summary
- 21: Practice Level I Practical Examination

active thermography
- 8.2: Passive and Active Thermography
- 8.14: Review Questions

adjustable focus
- 18.3: Focus, Range, and Distance (FoRD) Verification

adjustments
- 6.7: Emissivity Input

advantages
- 1.4: Advantages and Limitations of Thermography
- 14.17: Review Questions

advantages of thermography
- 1: Introduction to Nondestructive Testing (NDT) and Infrared Thermography
- 1.9: Review Questions

aerial
- 14.6: Thermal Sensors and Payloads
- 17.2: Defining the Inspection Objective
- 18.14: Summary
- 18.16: Quality Control (QC) Checklists for Aerial Thermography
- 21: Practice Level I Practical Examination

aerial image acquisition
- 18.15: Review Questions

aerial imagery
- 18: Aerial Thermal Image Acquisition

aerial imaging
- 14.15: Common Errors in Drone Thermography

aerial inspections
- 14.8: Focus, Range, and Distance (FoRD) in Drone Thermography
- 14.17: Review Questions
- 21.5: SECTION 4- Aerial Thermography

aerial thermal images
- 21.5: SECTION 4- Aerial Thermography

aerial thermal imaging
- 18.1: Introduction

aerial thermographic inspections
- 19.1: Introduction

aerial thermography
- 4.6: Viewing Angle and Measurement Error
- 14.12: Environmental Influences on Aerial Thermography
- 15.12: Review Questions
- 17.1: Introduction
- 17.8: Environmental Assessment
- 17.11: Coordination and Communication
- 17.16: Summary
- 17.17: Review Questions
- 19.16: Review Questions

aerialthermographicinspections
- 15.1: Introduction

air leakage
- 13.4: Building Envelope Thermography

air temperature
- 3.8: Atmospheric Effects on Infrared Radiation

aircraft
- 14.1: Introduction
- 19.2: Immediate Post-Flight Actions

airflow
- 8.7: Environmental and Operating Condition Considerations
- 10.5: Atmospheric and Environmental Errors
- 11.10: Environmental Influences
- 12.10: Environmental Influences

airspace authorization
- 14.10: Regulatory and Compliance Awareness

airspace awareness
- 16.3: Aviation Regulations for Drone-Based Thermography

airspeed
- 18.5: In-Flight Image Acquisition Techniques

altitude
- 8.11: Drone-Based Inspection Techniques
- 13.7: Drone-Based Roof Thermography
- 14.8: Focus, Range, and Distance (FoRD) in Drone Thermography
- 17.4: Altitude Selection and Ground Sample Distance (GSD)
- 17.16: Summary
- 17.17: Review Questions
- 21.5: SECTION 4- Aerial Thermography

altitude adjustment
- 17.3: Target Characteristics and Resolution Requirements

altitude changes
- 18.3: Focus, Range, and Distance (FoRD) Verification

altitude impact
- 5.12: Drone Thermography Specification Tables

altitude limits
- 16.3: Aviation Regulations for Drone-Based Thermography

ambient temperature
- 2.8: Environmental Influences on Heat Transfer
- 5.3: Infrared Detector Types
- 6.9: Distance and Atmospheric Inputs
- 7.14: Inspection Log Template
- 8.7: Environmental and Operating Condition Considerations
- 11.10: Environmental Influences
- 12.10: Environmental Influences
- 14.12: Environmental Influences on Aerial Thermography
- 17.8: Environmental Assessment

American Society for Nondestructive Testing
- References and Standards

analysis
- 20.12: Summary

angle deviations
- 10.9: Viewing Angle Errors

angles
- 4.6: Viewing Angle and Measurement Error

anomalies
- 5.6: Focus and Image Clarity
- 6.2: Importance of Proper Camera Setup
- 7.11: Quality Control Checks
- 10.6: Thermal Loading and Operating Condition Errors
- 11.6: Inspection Conditions and Timing
- 13.8: Solar Panel (PV) Thermography

anomalies detection
- 8.3: Qualitative vs. Quantitative Inspections

apparent temperatures
- 4.3: Reflectivity

Application suitability
- 15.5: Atmospheric Effects on MWIR and LWIR

applications
- 14: Introduction to Drone-Based Thermography
- 15.6: Radiometric vs. Non-Radiometric Thermal Payloads

approach distances
- 9.11: Common Safety Mistakes
- 11.8: Safety Considerations Specific to Electrical Thermography

approved methods
- 6.8: Reflected Apparent Temperature

approved procedures
- 16.13: Summary

arc
- 16.7: Electrical and Industrial Regulatory Awareness

arc blast
- 9.3: Electrical Safety

arc flash
- 9.3: Electrical Safety

area
- 19.7: File Naming and Identification

ASNT
- InfoPage
- Appendix

ASNT guidelines
- 1.5: The Role of the Thermography Level I Technician

aspect
- 14.14: Ground-Based vs. Drone-Based Thermography

assembly points
- 9.9: Emergency Preparedness

assessment
17.2: Defining the Inspection Objective
asset
19.7: File Naming and Identification
asset ID
7.6: File Naming and Organization
asset identification
18.11: Documentation and Metadata Recording
asymmetrical heating
12.4: Typical Thermal Patterns in Mechanical Systems
atmosphere
3.8: Atmospheric Effects on Infrared Radiation
atmospheric absorption
15.6: Radiometric vs. Non-Radiometric Thermal Payloads
atmospheric attenuation
6.9: Distance and Atmospheric Inputs
atmospheric conditions
4.7: Practical Camera Setup Considerations
atmospheric effects
3.7: Apparent Temperature
15: UAS Platforms and Thermal Payloads
atmospheric errors
10: Common Sources of Error
authorization
16.6: Site Access and Permissions
authorized personnel
16.8: Privacy and Data Protection Considerations
19.13: Data Security and Confidentiality
authorized tasks
20.7: Professional Conduct and Ethics
autofocus
6.3: Focus Control
6.12: Common Setup Errors
average temperature
6.8: Reflected Apparent Temperature
aviation
16.2: Overview of Applicable Regulatory Frameworks
aviation authority
16.10: International and Non-U.S. Operations (Awareness)
aviation regulations
8.11: Drone-Based Inspection Techniques
14.10: Regulatory and Compliance Awareness
16: Regulatory and Operational Considerations
16.13: Summary
aviation safety
17.7: Focus, Range, and Distance (FoRD) Verification
17.12: Pre-Flight Briefing Participation (Level I Role)
awareness
9.6: Environmental and Outdoor Safety
16.12: Common Regulatory and Operational Errors
20.10: Regulatory and Standards Awareness

B

backup
7.7: Data Storage and Backup
backup confirmation
19.4: Data Transfer from Aircraft to Storage
backups
10.11: Data Handling Errors
basic components
5: Infrared Camera Systems
bearings
8.9: Mechanical Inspection Techniques (Level I Scope)
12.2: Basic Mechanical Concepts (Level I Overview)
12.3: Common Mechanical Components Inspected
12.5: Comparative Inspection Techniques
before flight
15.7: Gimbal Stabilization and Image Quality
best practices
4.6: Viewing Angle and Measurement Error
5.9: Care, Handling, and Maintenance
6.4: Temperature Range Selection
7.7: Data Storage and Backup
17.6: Viewing Angle and Sensor Orientation
18.9: Managing Multiple Sensors (Thermal + Visual)
19.4: Data Transfer from Aircraft to Storage
best results
13.6: Roof Thermography (Ground-Based)
blackbodies
3.12: Summary
blackbody
3: Infrared Theory and Physics
3.4: Blackbody Radiation
3.13: Review Questions
4.2: Emissivity
blackbody references
5.7: Camera Calibration and Accuracy
blowers
12.3: Common Mechanical Components Inspected
blurred images
10.7: Motion and Stability Errors
boundary check
21.8: SECTION 7- Documentation Practice
brick
2.5: Thermal Mass and Heat Storage
bridges
13.9: Infrastructure Thermography
building
13.1: Introduction
13.2: Heat Transfer in Buildings (Level I Review)
13.5: Inspection Conditions and Timing for Buildings
13.13: Review Questions
14.2: Why Use Drones for Thermography?
17.2: Defining the Inspection Objective
building applications
13: Building and Infrastructure Thermography
building diagnostics
5.8: Handheld vs. Drone-Mounted Infrared Cameras
building envelope
13: Building and Infrastructure Thermography
building envelope inspections
6.5: Level and Span Controls
building envelope surveys
14.4: Typical Applications of Drone Thermography
building envelopes
13.3: Common Building and Infrastructure Applications
building inspection
8: Inspection Techniques
building inspections
8.10: Building and Infrastructure Inspection Techniques
13.10: Documentation and Reporting (Level I Role)
15.12: Review Questions
building materials
2.5: Thermal Mass and Heat Storage
building science
13.2: Heat Transfer in Buildings (Level I Review)
13.4: Building Envelope Thermography
building systems
13.1: Introduction
building thermography
8.10: Building and Infrastructure Inspection Techniques
buildings
10.6: Thermal Loading and Operating Condition Errors
13: Building and Infrastructure Thermography
17.9: Time-of-Day Considerations
bus bars
11.3: Common Electrical Components Inspected

C

Calibration
3.4: Blackbody Radiation
3.12: Summary
5.2: Basic Components of an Infrared Camera
5.7: Camera Calibration and Accuracy
18: Aerial Thermal Image Acquisition
Glossary
calibration adjustments
5.7: Camera Calibration and Accuracy
calibration issues
5.7: Camera Calibration and Accuracy
calibration methods
5.7: Camera Calibration and Accuracy
calibration status
5.7: Camera Calibration and Accuracy
Camera
3.1: Introduction
3.8: Atmospheric Effects on Infrared Radiation
3.12: Summary
5: Infrared Camera Systems
6.13: Documentation of Camera Settings
8.1: Introduction
11.7: Inspection Workflow (Level I)
12.7: Inspection Workflow (Level I)
18.14: Summary
18.16: Quality Control (QC) Checklists for Aerial Thermography
camera calibration
14.7: Flat Field Correction (FFC)
18.2: Pre-Flight Camera and Payload Verification
camera care
5.9: Care, Handling, and Maintenance
camera controls
6.1: Introduction
6.3: Focus Control
6.15: Review Questions
camera documentation
6: Camera Controls and Setup
camera model
7.5: Metadata and Embedded Information
19.8: Metadata Verification
camera performance
5: Infrared Camera Systems
5.9: Care, Handling, and Maintenance
5.11: Review Questions
camera resolution
8.6: Distance, Angle, and Access Considerations
camera settings
3.7: Apparent Temperature
4.7: Practical Camera Setup Considerations
14.13: Data Collection and Documentation (Level I Role)

camera setup
4: Emissivity, Reflectivity, and Transmissivity
4.1: Introduction
4.9: Summary
6: Camera Controls and Setup
6.12: Common Setup Errors
6.14: Summary
6.16: Step-by-Step Camera Setup Checklists
8.12: Common Inspection Errors
21.2: SECTION 1- Equipment Setup and Pre-Inspection Verification
camera specifications
5.4: Key Camera Performance Specifications
camera stabilization
10.7: Motion and Stability Errors
camera technology
5.1: Introduction
cameras
5.10: Summary
6.2: Importance of Proper Camera Setup
6.9: Distance and Atmospheric Inputs
14.1: Introduction
14.6: Thermal Sensors and Payloads
capability
14.5: Drone Platforms Used for Thermography
capture errors
14.8: Focus, Range, and Distance (FoRD) in Drone Thermography
capture mode
10.10: Camera Setup and Configuration Errors
career opportunities
20.9: Continuous Improvement and Professional Development
certification
InfoPage
20.9: Continuous Improvement and Professional Development
Appendix
References and Standards
certification authority
1.6: Ethics and Professional Responsibility
certification boundaries
20.7: Professional Conduct and Ethics
certification limits
10.12: Human Factors and Procedural Errors
chain of custody
20: Review, Documentation, and Professional Practice
challenges
12.9: FoRD Considerations in Mechanical Inspections
characteristics
14.6: Thermal Sensors and Payloads
checklist
18.16: Quality Control (QC) Checklists for Aerial Thermography
21.2: SECTION 1- Equipment Setup and Pre-Inspection Verification
21.7: SECTION 6- Quality Control (QC)
checklists
10.12: Human Factors and Procedural Errors
11.12: Common Errors in Electrical Thermography
12.12: Common Errors in Mechanical Thermography
19.14: Common Post-Flight Data Handling Errors
20.11: Common Documentation and Professional Practice Errors
chemical reactions
2.7: Heat Generation Sources
circuit breakers
11.3: Common Electrical Components Inspected
circuit comparison
8.5: Comparative Inspection Techniques
clarity
7.11: Quality Control Checks
17.13: In-Flight Data Collection Considerations
18.4: Test Image Capture (Before Full Mission)
18.10: Post-Flight Image Review (Initial QC)
20.2: Review of Collected Data (Level I Role)
clear documentation
19.11: Documentation of Limitations and Anomalies
clear role definitions
16.4: Roles and Responsibilities in Drone Operations
clipping
6.4: Temperature Range Selection
cloud cover
2.6: Solar Loading
14.12: Environmental Influences on Aerial Thermography
17.8: Environmental Assessment
18.7: Environmental Monitoring During Flight
codes
9.2: General Safety Principles
collected data
20: Review, Documentation, and Professional Practice
collision
14.11: Safety Considerations in Drone Thermography
color
5.5: Image Display and Color Palettes
color palette change
21.6: SECTION 5- Thermal Tuning Awareness (Software Review)
color palettes
5: Infrared Camera Systems
6: Camera Controls and Setup
6.6: Color Palettes
6.14: Summary
common errors
10.14: Review Questions
11.12: Common Errors in Electrical Thermography
12.12: Common Errors in Mechanical Thermography
13.11: Common Errors in Building and Infrastructure Thermography
14.15: Common Errors in Drone Thermography
16.12: Common Regulatory and Operational Errors
17.15: Common Mission Planning Errors
18.12: Common Aerial Image Acquisition Errors
19.14: Common Post-Flight Data Handling Errors
20.11: Common Documentation and Professional Practice Errors
common mistakes
4.8: Common Errors Related to Surface Properties
8.12: Common Inspection Errors
common safety mistakes
9: Safety in Thermographic Inspections
communication
16.5: Operational Planning and Briefings
16.12: Common Regulatory and Operational Errors
17.11: Coordination and Communication
17.15: Common Mission Planning Errors
17.18: Mission Planning Worksheets (Aerial Thermography)
18.8: Communication During Image Acquisition
20: Review, Documentation, and Professional Practice
20.8: Communication and Teamwork
communication devices
9.9: Emergency Preparedness
communication methods
17.11: Coordination and Communication
comparative images
8.8: Electrical Inspection Techniques (Level I Scope)
comparative inspection
11.13: Summary
comparative inspections
8.14: Review Questions
comparative techniques
8.5: Comparative Inspection Techniques
8.13: Summary
11.5: Comparative Inspection Techniques
11.14: Review Questions
12.5: Comparative Inspection Techniques
12.14: Review Questions
comparison
7.3: Still Images vs. Video
11.12: Common Errors in Electrical Thermography
complete coverage
17.5: Flight Path and Coverage Planning
completeness
18.10: Post-Flight Image Review (Initial QC)
19.8: Metadata Verification
20.2: Review of Collected Data (Level I Role)
compliance
1.1: What Is Nondestructive Testing (NDT)?
9.10: Safety Documentation
14: Introduction to Drone-Based Thermography
16.7: Electrical and Industrial Regulatory Awareness
16.11: Documentation and Compliance Records
16.13: Summary
compliance documentation
16.11: Documentation and Compliance Records
compliant operations
16.4: Roles and Responsibilities in Drone Operations
component
19.7: File Naming and Identification
component identification
11.11: Documentation and Reporting (Level I Role)
12.11: Documentation and Reporting (Level I Role)
component identifier
7.6: File Naming and Organization
components
8.9: Mechanical Inspection Techniques (Level I Scope)
11: Electrical Systems Thermography
12: Mechanical Systems Thermography
12.9: FoRD Considerations in Mechanical Inspections
components comparison
8.5: Comparative Inspection Techniques
components evaluation
1.1: What Is Nondestructive Testing (NDT)?
compressed format
19.12: Preparing Data for Analysis and Handoff
concept
3.5: Relationship Between Temperature and Infrared Radiation
concepts
12.2: Basic Mechanical Concepts (Level I Overview)
concerns
14.11: Safety Considerations in Drone Thermography
concrete
2.5: Thermal Mass and Heat Storage
13.3: Common Building and Infrastructure Applications
concrete structures
13.9: Infrastructure Thermography
condition monitoring
1.3: Infrared Thermography as an NDT Method
References and Standards
condition screening
21.2: SECTION 1- Equipment Setup and Pre-Inspection Verification

conditions
9.6: Environmental and Outdoor Safety
11.6: Inspection Conditions and Timing
11.7: Inspection Workflow (Level I)
13.5: Inspection Conditions and Timing for Buildings
conditions monitoring
14.12: Environmental Influences on Aerial Thermography
Conduction
2.3: The Three Modes of Heat Transfer
2.10: Summary
13.2: Heat Transfer in Buildings (Level I Review)
Glossary
confidential information
20.7: Professional Conduct and Ethics
Configuration
18.16: Quality Control (QC) Checklists for Aerial Thermography
confirm
18.10: Post-Flight Image Review (Initial QC)
conflicting guidance
20.10: Regulatory and Standards Awareness
consistent measurements
8.12: Common Inspection Errors
consistent organization
19.6: File Organization and Folder Structure
contactors
11.3: Common Electrical Components Inspected
contamination
6.7: Emissivity Input
context
20.4: Use of Images in Documentation
continuous learning
20.9: Continuous Improvement and Professional Development
continuous_process_machinery
8.4: Steady-State and Transient Inspection Conditions
contrast
6.6: Color Palettes
control
14.11: Safety Considerations in Drone Thermography
controls
17.12: Pre-Flight Briefing Participation (Level I Role)
Convection
2.3: The Three Modes of Heat Transfer
2.10: Summary
2.11: Review Questions
13.2: Heat Transfer in Buildings (Level I Review)
Glossary
conventions
19.7: File Naming and Identification
conveyors
12.3: Common Mechanical Components Inspected
Cooled detectors
3.9: Infrared Detectors and Image Formation
5.3: Infrared Detector Types
15.5: Atmospheric Effects on MWIR and LWIR
cooling
8.2: Passive and Active Thermography
13.5: Inspection Conditions and Timing for Buildings
cooling fans
11.10: Environmental Influences
cooling systems
11.10: Environmental Influences
15.2: Thermal Sensor Resolution and Pixel Count
coordination
16.6: Site Access and Permissions
copies
19.5: Preservation of Original Data
corrective action
10.1: Introduction
17.13: In-Flight Data Collection Considerations
18.4: Test Image Capture (Before Full Mission)
corrective action recommendations
11.11: Documentation and Reporting (Level I Role)
corrective recommendations
11.1: Introduction
couplings
8.9: Mechanical Inspection Techniques (Level I Scope)
12.2: Basic Mechanical Concepts (Level I Overview)
12.3: Common Mechanical Components Inspected
coverage
14.14: Ground-Based vs. Drone-Based Thermography
15.11: Summary
18.10: Post-Flight Image Review (Initial QC)
21.7: SECTION 6- Quality Control (QC)
coverage areas
18.8: Communication During Image Acquisition
coverage plan
17.18: Mission Planning Worksheets (Aerial Thermography)
coverage planning
17: Mission Planning for Aerial Thermography
coverage verification
19.3: Initial Image Quality Review (QC Confirmation)
current
11.2: Basic Electrical Concepts (Level I Overview)
current flow
11.1: Introduction
11.2: Basic Electrical Concepts (Level I Overview)
current standards
20.10: Regulatory and Standards Awareness

D

damage assessment
14.4: Typical Applications of Drone Thermography
data
7.7: Data Storage and Backup
8.1: Introduction
16.8: Privacy and Data Protection Considerations
18.14: Summary
19.10: Flight Logs and Supporting Data
20.8: Communication and Teamwork
data acquisition
14.16: Summary
18.1: Introduction
data analysis
18.9: Managing Multiple Sensors (Thermal + Visual)
19: Post-Flight Data Handling and Preparation
19.15: Summary
data backup
19: Post-Flight Data Handling and Preparation
19.9: Data Backup and Redundancy
19.14: Common Post-Flight Data Handling Errors
data backups
19.15: Summary
data capture
18.9: Managing Multiple Sensors (Thermal + Visual)
21.1: Purpose and Instructions
data collection
1.5: The Role of the Thermography Level I Technician
1.8: Summary
2.9: Practical Implications for Thermography
3.6: Emission, Reflection, and Transmission
3.11: Practical Implications for Level I Thermographers
4.7: Practical Camera Setup Considerations
6.1: Introduction
6.16: Step-by-Step Camera Setup Checklists
9.11: Common Safety Mistakes
11.8: Safety Considerations Specific to Electrical Thermography
13.7: Drone-Based Roof Thermography
14.15: Common Errors in Drone Thermography
16.5: Operational Planning and Briefings
data consistency
19.16: Review Questions
data corruption
19.2: Immediate Post-Flight Actions
data handling
6.14: Summary
7.1: Introduction
18: Aerial Thermal Image Acquisition
19.1: Introduction
data handling policies
16.8: Privacy and Data Protection Considerations
data handling procedures
10.11: Data Handling Errors
data handling risks
7.13: Review Questions
data integrity
1.6: Ethics and Professional Responsibility
7.9: Data Integrity and Ethics
7.12: Summary
7.13: Review Questions
16.1: Introduction
17.14: Post-Flight Review and Documentation
19.12: Preparing Data for Analysis and Handoff
20: Review, Documentation, and Professional Practice
20.6: Data Integrity and Chain of Custody
20.12: Summary
data interface
15.2: Thermal Sensor Resolution and Pixel Count
data loss
7.7: Data Storage and Backup
19.2: Immediate Post-Flight Actions
19.9: Data Backup and Redundancy
data management
7.10: Drone-Specific Data Handling Considerations
7.12: Summary
10.11: Data Handling Errors
19.16: Review Questions
data misrepresentation
20.7: Professional Conduct and Ethics
data organization
7.12: Summary
18.13: Data Handling and Handoff
19.15: Summary
data presentation
21.6: SECTION 5- Thermal Tuning Awareness (Software Review)
data preservation
19.1: Introduction
20.6: Data Integrity and Chain of Custody
data protection
19.9: Data Backup and Redundancy

data quality
8.13: Summary
12.13: Summary
17.13: In-Flight Data Collection Considerations
17.16: Summary
17.18: Mission Planning Worksheets (Aerial Thermography)
19.11: Documentation of Limitations and Anomalies
20.1: Introduction
20.12: Summary
data quality requirements
17.1: Introduction
data recording
19.2: Immediate Post-Flight Actions
data reliability
15.2: Thermal Sensor Resolution and Pixel Count
20.1: Introduction
data retention
19.4: Data Transfer from Aircraft to Storage
19.9: Data Backup and Redundancy
data review
17.14: Post-Flight Review and Documentation
20.2: Review of Collected Data (Level I Role)
20.13: Comprehensive Review Questions
data security
19.13: Data Security and Confidentiality
20.11: Common Documentation and Professional Practice Errors
data sovereignty
16.10: International and Non-U.S. Operations (Awareness)
data storage
7: Image Types and Data Handling
data synchronization
18.9: Managing Multiple Sensors (Thermal + Visual)
data transfer
7: Image Types and Data Handling
7.8: Data Transfer and Handoff
19: Post-Flight Data Handling and Preparation
19.4: Data Transfer from Aircraft to Storage
19.12: Preparing Data for Analysis and Handoff
data usability
7.6: File Naming and Organization
19.15: Summary
dataset preparation
19.1: Introduction
date
19.7: File Naming and Identification
19.8: Metadata Verification
date and time
7.5: Metadata and Embedded Information
daylight operations
16.3: Aviation Regulations for Drone-Based Thermography
decision making
21.1: Purpose and Instructions
defect detection
1.1: What Is Nondestructive Testing (NDT)?
defects
2.6: Solar Loading
definition
Glossary
derived
19.5: Preservation of Original Data
descriptive language
20.3: Documentation Standards
detail
15.11: Summary
detection
3.5: Relationship Between Temperature and Infrared Radiation
detection technology
5.11: Review Questions
detector elements
15.3: Lens Field of View (FOV) and Resolution
detector types
5: Infrared Camera Systems
5.1: Introduction
detectors
3.9: Infrared Detectors and Image Formation
4.9: Summary
5.10: Summary
deviation reporting
18.8: Communication During Image Acquisition
deviations
12.5: Comparative Inspection Techniques
20.5: Handling Limitations and Uncertainty
diagnoses
12.13: Summary
diagnosis
11.5: Comparative Inspection Techniques
diagnostic avoidance
11.11: Documentation and Reporting (Level I Role)
diagnostic conclusions
1.5: The Role of the Thermography Level I Technician
13.10: Documentation and Reporting (Level I Role)
diagnostic language
20.11: Common Documentation and Professional Practice Errors
20.13: Comprehensive Review Questions
diagnostics
11.1: Introduction
11.13: Summary
13.8: Solar Panel (PV) Thermography
References and Standards
differences
5.5: Image Display and Color Palettes
discipline
16.12: Common Regulatory and Operational Errors
disconnects
11.3: Common Electrical Components Inspected
distance
3.8: Atmospheric Effects on Infrared Radiation
6.9: Distance and Atmospheric Inputs
6.12: Common Setup Errors
8.6: Distance, Angle, and Access Considerations
11.12: Common Errors in Electrical Thermography
14.8: Focus, Range, and Distance (FoRD) in Drone Thermography
14.14: Ground-Based vs. Drone-Based Thermography
distance effects
5.11: Review Questions
8.14: Review Questions
distance errors
10.8: Focus, Range and Distance (FoRD) Errors
10.14: Review Questions
distance input
10.10: Camera Setup and Configuration Errors
distance limitations
11.9: FoRD Considerations in Electrical Inspections
distance limits
17.7: Focus, Range, and Distance (FoRD) Verification
distance to target
4.7: Practical Camera Setup Considerations
7.5: Metadata and Embedded Information
distances
9.4: Mechanical and Industrial Safety
distraction
10.12: Human Factors and Procedural Errors
distribution
8.9: Mechanical Inspection Techniques (Level I Scope)
DJI
7.4: File Formats
document limitations
20.11: Common Documentation and Professional Practice Errors
document method
6.8: Reflected Apparent Temperature
document parameters
10.10: Camera Setup and Configuration Errors
documentation
1.8: Summary
6.2: Importance of Proper Camera Setup
6.10: Image Capture Settings
6.13: Documentation of Camera Settings
6.14: Summary
6.16: Step-by-Step Camera Setup Checklists
7.2: Thermal Image Types
7.3: Still Images vs. Video
8.6: Distance, Angle, and Access Considerations
8.7: Environmental and Operating Condition Considerations
8.12: Common Inspection Errors
9.10: Safety Documentation
10.2: Measurement vs. Indication Errors
11: Electrical Systems Thermography
11.7: Inspection Workflow (Level I)
11.14: Review Questions
12: Mechanical Systems Thermography
12.6: Inspection Conditions and Timing
12.7: Inspection Workflow (Level I)
12.14: Review Questions
13.5: Inspection Conditions and Timing for Buildings
16.12: Common Regulatory and Operational Errors
17.6: Viewing Angle and Sensor Orientation
18.14: Summary
19: Post-Flight Data Handling and Preparation
19.11: Documentation of Limitations and Anomalies
19.12: Preparing Data for Analysis and Handoff
20.1: Introduction
20.3: Documentation Standards
20.4: Use of Images in Documentation
20.5: Handling Limitations and Uncertainty
20.12: Summary
21.10: SECTION 9- Final Self-Assessment
documentation accuracy
20.2: Review of Collected Data (Level I Role)
documentation importance
16.14: Review Questions
documentation patterns
11.13: Summary
documentation standards
19.16: Review Questions
20: Review, Documentation, and Professional Practice
documenting deviations
17.14: Post-Flight Review and Documentation
doors
13.3: Common Building and Infrastructure Applications
downstream analysis
15.10: Documentation and Payload Identification
18.9: Managing Multiple Sensors (Thermal + Visual)

drone
6.11: Drone-Specific Camera Setup Considerations
7.10: Drone-Specific Data Handling Considerations
8.11: Drone-Based Inspection Techniques
9.7: Drone-Based Thermography Safety
13.7: Drone-Based Roof Thermography
14: Introduction to Drone-Based Thermography
14.1: Introduction
14.2: Why Use Drones for Thermography?
14.3: Limitations of Drone-Based Thermography
14.6: Thermal Sensors and Payloads
14.11: Safety Considerations in Drone Thermography
16.2: Overview of Applicable Regulatory Frameworks
16.3: Aviation Regulations for Drone-Based Thermography
16.10: International and Non-U.S. Operations (Awareness)
19.10: Flight Logs and Supporting Data
drone inspection
8: Inspection Techniques
drone inspections
6.14: Summary
9.13: Review Questions
13.11: Common Errors in Building and Infrastructure Thermography
13.12: Summary
13.13: Review Questions
16.13: Summary
drone mission responsibilities
16.14: Review Questions
drone motion
10.7: Motion and Stability Errors
drone operations
14.10: Regulatory and Compliance Awareness
16: Regulatory and Operational Considerations
drone payload
21.2: SECTION 1- Equipment Setup and Pre-Inspection Verification
drone technology
18.1: Introduction
drone thermography
InfoPage
3.10: Spatial Resolution and Measurement Accuracy
5.12: Drone Thermography Specification Tables
6.9: Distance and Atmospheric Inputs
6.16: Step-by-Step Camera Setup Checklists
7.14: Inspection Log Template
14.16: Summary
14.17: Review Questions
15.9: Typical Payload Configurations
16: Regulatory and Operational Considerations
drones
14.5: Drone Platforms Used for Thermography
14.17: Review Questions
dust protection
5.9: Care, Handling, and Maintenance
dynamic events
7.3: Still Images vs. Video

E

Eddy Current Testing
1.2: Common NDT Methods
education
InfoPage
effective data collection
14.9: Mission Planning Fundamentals (Level I Awareness)
effective resolution
15.4: Mid-Wave vs. Long-Wave Infrared (MWIR vs. LWIR)
effectiveness
8.1: Introduction
effectiveness of analysis
7.8: Data Transfer and Handoff
electric motors
12.3: Common Mechanical Components Inspected
electric shock
9.3: Electrical Safety
electrical
9.12: Summary
11: Electrical Systems Thermography
11.3: Common Electrical Components Inspected
11.6: Inspection Conditions and Timing
11.7: Inspection Workflow (Level I)
11.8: Safety Considerations Specific to Electrical Thermography
16.7: Electrical and Industrial Regulatory Awareness
electrical bus bars
4.3: Reflectivity
Electrical components
11.1: Introduction
11.9: FoRD Considerations in Electrical Inspections
electrical inspection
8: Inspection Techniques
8.8: Electrical Inspection Techniques (Level I Scope)
9.14: Job Hazard Analysis (JHA) Templates
electrical inspections
3.3: Infrared Wavelength Bands
5.8: Handheld vs. Drone-Mounted Infrared Cameras
9.3: Electrical Safety
11.14: Review Questions
electrical load
11.2: Basic Electrical Concepts (Level I Overview)
electrical panels
11.3: Common Electrical Components Inspected
electrical phases
8.5: Comparative Inspection Techniques
electrical potential
11.2: Basic Electrical Concepts (Level I Overview)
electrical PPE
9.3: Electrical Safety
electrical principles
11.2: Basic Electrical Concepts (Level I Overview)
electrical regulations
16: Regulatory and Operational Considerations
electrical resistance
2.7: Heat Generation Sources
electrical safety
8.8: Electrical Inspection Techniques (Level I Scope)
9: Safety in Thermographic Inspections
electrical safety standards
1.7: Safety Considerations in Thermographic Inspections
electrical signal
3.9: Infrared Detectors and Image Formation
electrical substations
14.4: Typical Applications of Drone Thermography
electrical systems
1.3: Infrared Thermography as an NDT Method
8.2: Passive and Active Thermography
10.6: Thermal Loading and Operating Condition Errors
11.1: Introduction
11.2: Basic Electrical Concepts (Level I Overview)
11.13: Summary
electrical thermography
11.5: Comparative Inspection Techniques
11.10: Environmental Influences
11.14: Review Questions
electrical_panels
8.4: Steady-State and Transient Inspection Conditions
electromagnetic
3: Infrared Theory and Physics
3.1: Introduction
3.12: Summary
electromagnetic energy
3.2: The Electromagnetic Spectrum
electromagnetic spectrum
3.2: The Electromagnetic Spectrum
3.13: Review Questions
electronics
5.2: Basic Components of an Infrared Camera
5.10: Summary
15.2: Thermal Sensor Resolution and Pixel Count
elevated
9.5: Working at Heights
elevated assets
14.2: Why Use Drones for Thermography?
elevated temperature
21.8: SECTION 7- Documentation Practice
elevated work areas
1.7: Safety Considerations in Thermographic Inspections
emergency exits
9.9: Emergency Preparedness
emergency landing zones
17.10: Safety Planning and Risk Mitigation
emergency preparedness
9: Safety in Thermographic Inspections
emergency procedures
9.9: Emergency Preparedness
16.5: Operational Planning and Briefings
17.10: Safety Planning and Risk Mitigation
17.11: Coordination and Communication
17.12: Pre-Flight Briefing Participation (Level I Role)
emergency response
14.4: Typical Applications of Drone Thermography
emission
3: Infrared Theory and Physics
3.6: Emission, Reflection, and Transmission
4.5: Relationship Between Emissivity, Reflectivity, and Transmissivity
Emissivity
1.4: Advantages and Limitations of Thermography
3.4: Blackbody Radiation
3.7: Apparent Temperature
4: Emissivity, Reflectivity, and Transmissivity
4.1: Introduction
4.2: Emissivity
4.3: Reflectivity
4.6: Viewing Angle and Measurement Error
4.7: Practical Camera Setup Considerations
4.8: Common Errors Related to Surface Properties
4.9: Summary
4.10: Review Questions
6.1: Introduction
6.7: Emissivity Input
6.12: Common Setup Errors
6.13: Documentation of Camera Settings
6.14: Summary
6.15: Review Questions
6.16: Step-by-Step Camera Setup Checklists
10.3: Emissivity-Related Errors
10.9: Viewing Angle Errors
10.10: Camera Setup and Configuration Errors
10.13: Summary
18.2: Pre-Flight Camera and Payload Verification
Glossary
emissivity errors
10: Common Sources of Error
18.6: Viewing Angle and Sensor Orientation
emissivity input
6: Camera Controls and Setup

emissivity setting
7.5: Metadata and Embedded Information
19.8: Metadata Verification
emissivity settings
3.11: Practical Implications for Level I Thermographers
8.3: Qualitative vs. Quantitative Inspections
enclosures
12.9: FoRD Considerations in Mechanical Inspections
energized
9.12: Summary
energized electrical equipment
9.3: Electrical Safety
9.13: Review Questions
energized electrical systems
1.7: Safety Considerations in Thermographic Inspections
9.1: Introduction
energized equipment
11.8: Safety Considerations Specific to Electrical Thermography
energized systems
1.4: Advantages and Limitations of Thermography
energy
3.5: Relationship Between Temperature and Infrared Radiation
Energy Conversion
1.2: Common NDT Methods
energy efficiency
2.5: Thermal Mass and Heat Storage
13.4: Building Envelope Thermography
17.9: Time-of-Day Considerations
energy emission
4.2: Emissivity
energy interaction
3.6: Emission, Reflection, and Transmission
energy transfer
2.2: Heat vs. Temperature
environment
10.13: Summary
environmental assessment
17.18: Mission Planning Worksheets (Aerial Thermography)
environmental changes
14.15: Common Errors in Drone Thermography
18.12: Common Aerial Image Acquisition Errors
environmental conditions
1.4: Advantages and Limitations of Thermography
2.8: Environmental Influences on Heat Transfer
7.5: Metadata and Embedded Information
7.14: Inspection Log Template
8.7: Environmental and Operating Condition Considerations
8.10: Building and Infrastructure Inspection Techniques
9.14: Job Hazard Analysis (JHA) Templates
11.11: Documentation and Reporting (Level I Role)
13.10: Documentation and Reporting (Level I Role)
13.11: Common Errors in Building and Infrastructure Thermography
13.12: Summary
13.13: Review Questions
14.3: Limitations of Drone-Based Thermography
14.9: Mission Planning Fundamentals (Level I Awareness)
14.13: Data Collection and Documentation (Level I Role)
14.17: Review Questions
15.6: Radiometric vs. Non-Radiometric Thermal Payloads
16.9: Operational Limitations Affecting Thermography
17.1: Introduction
17.8: Environmental Assessment
17.15: Common Mission Planning Errors
18.7: Environmental Monitoring During Flight
18.11: Documentation and Metadata Recording
19.11: Documentation of Limitations and Anomalies
20.3: Documentation Standards
21.5: SECTION 4- Aerial Thermography
21.7: SECTION 6- Quality Control (QC)
environmental effects
13.9: Infrastructure Thermography
environmental errors
10: Common Sources of Error
environmental exposure
2.7: Heat Generation Sources
environmental factors
2.10: Summary
8.13: Summary
11.10: Environmental Influences
12.10: Environmental Influences
13.7: Drone-Based Roof Thermography
14.12: Environmental Influences on Aerial Thermography
14.16: Summary
17.16: Summary
17.17: Review Questions
environmental influences
2: Fundamentals of Heat Transfer
3.11: Practical Implications for Level I Thermographers
8.12: Common Inspection Errors
10.5: Atmospheric and Environmental Errors
11: Electrical Systems Thermography
12: Mechanical Systems Thermography
12.11: Documentation and Reporting (Level I Role)
20.5: Handling Limitations and Uncertainty
environmental limitations
17.14: Post-Flight Review and Documentation
environmental monitoring
18: Aerial Thermal Image Acquisition
environmental observations
7.8: Data Transfer and Handoff
environmental safety
9: Safety in Thermographic Inspections
environmental verification
6.16: Step-by-Step Camera Setup Checklists
environmental_changes
8.4: Steady-State and Transient Inspection Conditions
environments
9.12: Summary
equipment
3.1: Introduction
8.9: Mechanical Inspection Techniques (Level I Scope)
9.4: Mechanical and Industrial Safety
9.5: Working at Heights
9.12: Summary
12.3: Common Mechanical Components Inspected
16.10: International and Non-U.S. Operations (Awareness)
20.9: Continuous Improvement and Professional Development
21: Practice Level I Practical Examination
equipment failure
10.1: Introduction
equipment inspection
12.6: Inspection Conditions and Timing
equipment operation
1.8: Summary
equipment setup
21.1: Purpose and Instructions
equipment startup
2.4: Steady-State and Transient Heat Conditions
equipment_startup
8.4: Steady-State and Transient Inspection Conditions
equipmentoperation
15.1: Introduction
error management
15.9: Typical Payload Configurations
error reduction
7.6: File Naming and Organization
error risk
12.12: Common Errors in Mechanical Thermography
errors
6.12: Common Setup Errors
9.11: Common Safety Mistakes
10.1: Introduction
10.2: Measurement vs. Indication Errors
10.6: Thermal Loading and Operating Condition Errors
10.10: Camera Setup and Configuration Errors
11: Electrical Systems Thermography
established procedures
7.1: Introduction
estimate temperature
6.8: Reflected Apparent Temperature
ethical conduct
20.1: Introduction
20.12: Summary
20.13: Comprehensive Review Questions
ethical responsibilities
20.7: Professional Conduct and Ethics
ethical responsibility
7.12: Summary
ethical standards
1.6: Ethics and Professional Responsibility
ethics
1: Introduction to Nondestructive Testing (NDT) and Infrared Thermography
20: Review, Documentation, and Professional Practice
evaluation
12.1: Introduction
evening cooling
13.6: Roof Thermography (Ground-Based)
Example
Glossary
excessive altitude
13.11: Common Errors in Building and Infrastructure Thermography

excessive distance
12.12: Common Errors in Mechanical Thermography
exclusion zones
14.9: Mission Planning Fundamentals (Level I Awareness)
expected behavior
12.5: Comparative Inspection Techniques
exports
19.5: Preservation of Original Data

F

façade inspection
8.10: Building and Infrastructure Inspection Techniques
FAA
9.7: Drone-Based Thermography Safety
16.3: Aviation Regulations for Drone-Based Thermography
FAA Part 107
14.10: Regulatory and Compliance Awareness
facility
16.6: Site Access and Permissions
fall
9.5: Working at Heights
fall protection
9.14: Job Hazard Analysis (JHA) Templates
false indications
6.8: Reflected Apparent Temperature
10.4: Reflection Errors
false negatives
10.6: Thermal Loading and Operating Condition Errors
false patterns
10.9: Viewing Angle Errors
fans
12.3: Common Mechanical Components Inspected
fault detection
11.5: Comparative Inspection Techniques
fault diagnosis
11.14: Review Questions
12.4: Typical Thermal Patterns in Mechanical Systems
12.11: Documentation and Reporting (Level I Role)
Federal Aviation Administration
References and Standards
Federal Aviation Regulations
17.7: Focus, Range, and Distance (FoRD) Verification
FFC
14.7: Flat Field Correction (FFC)
field use
5.1: Introduction
file formats
7: Image Types and Data Handling
7.4: File Formats
file management
19.12: Preparing Data for Analysis and Handoff
file naming
7.6: File Naming and Organization
10.11: Data Handling Errors
file organization
19.1: Introduction
19.16: Review Questions
file overwriting
10.11: Data Handling Errors
file verification
19.4: Data Transfer from Aircraft to Storage
files
19.7: File Naming and Identification
first aid
9.9: Emergency Preparedness
flash
16.7: Electrical and Industrial Regulatory Awareness
Flat Field Correction
14.7: Flat Field Correction (FFC)
flight
6.11: Drone-Specific Camera Setup Considerations
14.13: Data Collection and Documentation (Level I Role)
17.13: In-Flight Data Collection Considerations
17.14: Post-Flight Review and Documentation
flight altitude
15.9: Typical Payload Configurations
16.5: Operational Planning and Briefings
18.11: Documentation and Metadata Recording
flight control
13.7: Drone-Based Roof Thermography
flight date
18.11: Documentation and Metadata Recording
flight lines
19.3: Initial Image Quality Review (QC Confirmation)
flight log
7.10: Drone-Specific Data Handling Considerations
flight logs
18.13: Data Handling and Handoff
19: Post-Flight Data Handling and Preparation
19.2: Immediate Post-Flight Actions
19.10: Flight Logs and Supporting Data
flight monitoring
18.7: Environmental Monitoring During Flight
flight parameters
8.11: Drone-Based Inspection Techniques
14.13: Data Collection and Documentation (Level I Role)
flight path
14.9: Mission Planning Fundamentals (Level I Awareness)
17: Mission Planning for Aerial Thermography
17.1: Introduction
17.18: Mission Planning Worksheets (Aerial Thermography)
flight path design
17.5: Flight Path and Coverage Planning
flight plan
17.12: Pre-Flight Briefing Participation (Level I Role)
flight records
16.11: Documentation and Compliance Records
flight segments
7.10: Drone-Specific Data Handling Considerations
flight stability
18.15: Review Questions
flight verification
17.7: Focus, Range, and Distance (FoRD) Verification
FLIR
7.4: File Formats
FLIR Thermal Studio
21.6: SECTION 5- Thermal Tuning Awareness (Software Review)
focal plane array
5.2: Basic Components of an Infrared Camera
focus
5: Infrared Camera Systems
5.6: Focus and Image Clarity
5.10: Summary
5.11: Review Questions
6.11: Drone-Specific Camera Setup Considerations
6.15: Review Questions
7.11: Quality Control Checks
11.12: Common Errors in Electrical Thermography
12.7: Inspection Workflow (Level I)
12.9: FoRD Considerations in Mechanical Inspections
14.8: Focus, Range, and Distance (FoRD) in Drone Thermography
17.13: In-Flight Data Collection Considerations
18.4: Test Image Capture (Before Full Mission)
18.10: Post-Flight Image Review (Initial QC)
19.3: Initial Image Quality Review (QC Confirmation)
20.2: Review of Collected Data (Level I Role)
focus control
6: Camera Controls and Setup
focus errors
10.8: Focus, Range and Distance (FoRD) Errors
10.14: Review Questions
focus issues
8.12: Common Inspection Errors
focus verification
18.3: Focus, Range, and Distance (FoRD) Verification
focus verification procedures
17.7: Focus, Range, and Distance (FoRD) Verification
folder structure
19.12: Preparing Data for Analysis and Handoff
folder structures
18.13: Data Handling and Handoff
19.6: File Organization and Folder Structure
footwear
9.6: Environmental and Outdoor Safety
FoRD
10.8: Focus, Range and Distance (FoRD) Errors
14.8: Focus, Range, and Distance (FoRD) in Drone Thermography
14.17: Review Questions
15.9: Typical Payload Configurations
21.10: SECTION 9- Final Self-Assessment
FoRD challenges
11.9: FoRD Considerations in Electrical Inspections
FoRD considerations
11.14: Review Questions
FoRD errors
10.13: Summary
10.14: Review Questions
17.7: Focus, Range, and Distance (FoRD) Verification
FoRD limitations
19.11: Documentation of Limitations and Anomalies
20.5: Handling Limitations and Uncertainty
FoRD verification
18.3: Focus, Range, and Distance (FoRD) Verification
18.15: Review Questions
frameworks
16.2: Overview of Applicable Regulatory Frameworks
friction
12.2: Basic Mechanical Concepts (Level I Overview)
12.13: Summary
12.14: Review Questions
Fullerton College
TitlePage
fundamental
8.1: Introduction

fuses
11.3: Common Electrical Components Inspected

G

gamma rays
3.2: The Electromagnetic Spectrum
gases
3.8: Atmospheric Effects on Infrared Radiation
gearboxes
12.3: Common Mechanical Components Inspected
gears
12.2: Basic Mechanical Concepts (Level I Overview)
generation
12.2: Basic Mechanical Concepts (Level I Overview)
geolocation
7.10: Drone-Specific Data Handling Considerations
gimbal
6.11: Drone-Specific Camera Setup Considerations
15.8: FoRD Considerations for UAS Payloads
gimbal operation
18.2: Pre-Flight Camera and Payload Verification
gimbal orientation
18.6: Viewing Angle and Sensor Orientation
gimbal stabilization
15.2: Thermal Sensor Resolution and Pixel Count
18.5: In-Flight Image Acquisition Techniques
gimbal type
15.10: Documentation and Payload Identification
glossary
Glossary
gloves
9.8: Personal Protective Equipment (PPE)
GPS tracks
19.10: Flight Logs and Supporting Data
Grayscale
5.5: Image Display and Color Palettes
Grayscale palette
6.6: Color Palettes
grid patterns
17.5: Flight Path and Coverage Planning
Ground Sample Distance
5.12: Drone Thermography Specification Tables
15.3: Lens Field of View (FOV) and Resolution
GSD
5.12: Drone Thermography Specification Tables
14.9: Mission Planning Fundamentals (Level I Awareness)
17.4: Altitude Selection and Ground Sample Distance (GSD)
17.16: Summary
17.17: Review Questions
21.5: SECTION 4- Aerial Thermography
guarding
12.9: FoRD Considerations in Mechanical Inspections
guidance
12.9: FoRD Considerations in Mechanical Inspections
guidelines
6.6: Color Palettes

H

hand movement
10.7: Motion and Stability Errors
hand signals
17.11: Coordination and Communication
handheld camera
21.2: SECTION 1- Equipment Setup and Pre-Inspection Verification
handheld cameras
5.3: Infrared Detector Types
5.8: Handheld vs. Drone-Mounted Infrared Cameras
handheld systems
5.1: Introduction
5.8: Handheld vs. Drone-Mounted Infrared Cameras
hard hats
9.8: Personal Protective Equipment (PPE)
hazard assessment
9.8: Personal Protective Equipment (PPE)
9.14: Job Hazard Analysis (JHA) Templates
hazard assessments
9.3: Electrical Safety
hazard awareness
17.10: Safety Planning and Risk Mitigation
hazardous
9.12: Summary
hazardous conditions
21.9: SECTION 8- Safety and Professional Judgment
hazardous environments
1.7: Safety Considerations in Thermographic Inspections
9.11: Common Safety Mistakes
hazards
9.1: Introduction
9.4: Mechanical and Industrial Safety
9.6: Environmental and Outdoor Safety
9.7: Drone-Based Thermography Safety
9.13: Review Questions
11.8: Safety Considerations Specific to Electrical Thermography
12.8: Safety Considerations Specific to Mechanical Thermography
17.12: Pre-Flight Briefing Participation (Level I Role)
haze
15.6: Radiometric vs. Non-Radiometric Thermal Payloads
hearing protection
9.8: Personal Protective Equipment (PPE)
heat
2: Fundamentals of Heat Transfer
2.2: Heat vs. Temperature
2.11: Review Questions
8.9: Mechanical Inspection Techniques (Level I Scope)
12.2: Basic Mechanical Concepts (Level I Overview)
12.14: Review Questions
heat absorption
2.5: Thermal Mass and Heat Storage
heat detection
2.7: Heat Generation Sources
heat distribution
12.4: Typical Thermal Patterns in Mechanical Systems
heat generation
2: Fundamentals of Heat Transfer
2.1: Introduction
11.2: Basic Electrical Concepts (Level I Overview)
11.13: Summary
12.1: Introduction
12.13: Summary
heat input
2.4: Steady-State and Transient Heat Conditions
heat loss
2.3: The Three Modes of Heat Transfer
2.4: Steady-State and Transient Heat Conditions
13.1: Introduction
heat retention differences
13.6: Roof Thermography (Ground-Based)
heat storage
2: Fundamentals of Heat Transfer
2.1: Introduction
2.5: Thermal Mass and Heat Storage
heat transfer
2: Fundamentals of Heat Transfer
2.1: Introduction
2.2: Heat vs. Temperature
2.3: The Three Modes of Heat Transfer
2.8: Environmental Influences on Heat Transfer
2.9: Practical Implications for Thermography
2.10: Summary
2.11: Review Questions
13: Building and Infrastructure Thermography
13.2: Heat Transfer in Buildings (Level I Review)
Appendix
heat transfer concepts
2.1: Introduction
heating
8.2: Passive and Active Thermography
13.5: Inspection Conditions and Timing for Buildings
high resistance
11.5: Comparative Inspection Techniques
high visibility vests
9.8: Personal Protective Equipment (PPE)
higher spatial resolution
15.3: Lens Field of View (FOV) and Resolution
historical data
8.5: Comparative Inspection Techniques
honest representation
20.7: Professional Conduct and Ethics
hot surfaces
12.8: Safety Considerations Specific to Mechanical Thermography
hover
14.5: Drone Platforms Used for Thermography
human factors
10.12: Human Factors and Procedural Errors
humidity
2.8: Environmental Influences on Heat Transfer
3.8: Atmospheric Effects on Infrared Radiation
10.5: Atmospheric and Environmental Errors
15.6: Radiometric vs. Non-Radiometric Thermal Payloads
HVAC
13.4: Building Envelope Thermography

I

identical machines
12.5: Comparative Inspection Techniques
identical motors
8.5: Comparative Inspection Techniques
identified hazards
16.5: Operational Planning and Briefings
identifier
19.7: File Naming and Identification
identify copies
7.9: Data Integrity and Ethics
20.6: Data Integrity and Chain of Custody
IFOV
3.10: Spatial Resolution and Measurement Accuracy
ignoring airflow effects
12.12: Common Errors in Mechanical Thermography
image
18.14: Summary
21: Practice Level I Practical Examination
image acceptance
21.5: SECTION 4- Aerial Thermography

image acquisition
3.11: Practical Implications for Level I Thermographers
6.2: Importance of Proper Camera Setup
18: Aerial Thermal Image Acquisition
image appearance
6.15: Review Questions
image capture
6: Camera Controls and Setup
7.1: Introduction
10.7: Motion and Stability Errors
13.7: Drone-Based Roof Thermography
17.5: Flight Path and Coverage Planning
18: Aerial Thermal Image Acquisition
image clarity
5: Infrared Camera Systems
6.3: Focus Control
18.5: In-Flight Image Acquisition Techniques
image contrast
6.4: Temperature Range Selection
6.5: Level and Span Controls
image display
5: Infrared Camera Systems
image identification
11.11: Documentation and Reporting (Level I Role)
image interpretation
18.1: Introduction
image labeling
20.11: Common Documentation and Professional Practice Errors
image overlap
8.11: Drone-Based Inspection Techniques
14.15: Common Errors in Drone Thermography
17.5: Flight Path and Coverage Planning
17.15: Common Mission Planning Errors
17.17: Review Questions
18.12: Common Aerial Image Acquisition Errors
image quality
3.10: Spatial Resolution and Measurement Accuracy
5.10: Summary
6.1: Introduction
6.14: Summary
6.16: Step-by-Step Camera Setup Checklists
10.7: Motion and Stability Errors
14.3: Limitations of Drone-Based Thermography
14.7: Flat Field Correction (FFC)
14.15: Common Errors in Drone Thermography
15.2: Thermal Sensor Resolution and Pixel Count
15.8: FoRD Considerations for UAS Payloads
17.13: In-Flight Data Collection Considerations
17.14: Post-Flight Review and Documentation
18.8: Communication During Image Acquisition
19.3: Initial Image Quality Review (QC Confirmation)
20.2: Review of Collected Data (Level I Role)
image quality control
7.14: Inspection Log Template
image quality review
19: Post-Flight Data Handling and Preparation
image resolution
17.4: Altitude Selection and Ground Sample Distance (GSD)
17.17: Review Questions
image review
18.4: Test Image Capture (Before Full Mission)
image types
7: Image Types and Data Handling
7.1: Introduction
7.2: Thermal Image Types
images
5.5: Image Display and Color Palettes
11.7: Inspection Workflow (Level I)
16.8: Privacy and Data Protection Considerations
18.10: Post-Flight Image Review (Initial QC)
imaging
5.6: Focus and Image Clarity
14.1: Introduction
imaging formats
6.10: Image Capture Settings
imaging guidelines
20.4: Use of Images in Documentation
imaging techniques
18.9: Managing Multiple Sensors (Thermal + Visual)
imaging technology
3.9: Infrared Detectors and Image Formation
18.9: Managing Multiple Sensors (Thermal + Visual)
immediately
18.10: Post-Flight Image Review (Initial QC)
import export
16.10: International and Non-U.S. Operations (Awareness)
improper setup
10.1: Introduction
inadequate documentation
13.11: Common Errors in Building and Infrastructure Thermography
19.14: Common Post-Flight Data Handling Errors
incident reports
16.11: Documentation and Compliance Records
incomplete data transfer
19.14: Common Post-Flight Data Handling Errors
incomplete documentation
20.11: Common Documentation and Professional Practice Errors
inconsistent comparison conditions
12.12: Common Errors in Mechanical Thermography
indication
10.2: Measurement vs. Indication Errors
indication errors
10: Common Sources of Error
10.14: Review Questions
indoor
13.5: Inspection Conditions and Timing for Buildings
industrial
9.12: Summary
16.7: Electrical and Industrial Regulatory Awareness
industrial applications
4.4: Transmissivity
5.3: Infrared Detector Types
References and Standards
industrial inspections
3.3: Infrared Wavelength Bands
3.6: Emission, Reflection, and Transmission
industrial machinery
1.7: Safety Considerations in Thermographic Inspections
industrial regulations
16: Regulatory and Operational Considerations
industrial safety
9: Safety in Thermographic Inspections
Industrial thermography
3.13: Review Questions
15.5: Atmospheric Effects on MWIR and LWIR
industry applications
1.8: Summary
infiltration
13.4: Building Envelope Thermography
infrared
1.3: Infrared Thermography as an NDT Method
3: Infrared Theory and Physics
3.1: Introduction
3.2: The Electromagnetic Spectrum
3.4: Blackbody Radiation
3.5: Relationship Between Temperature and Infrared Radiation
3.8: Atmospheric Effects on Infrared Radiation
3.12: Summary
4.7: Practical Camera Setup Considerations
5: Infrared Camera Systems
5.5: Image Display and Color Palettes
5.10: Summary
6.1: Introduction
6.2: Importance of Proper Camera Setup
8.1: Introduction
10.5: Atmospheric and Environmental Errors
14.1: Introduction
14.6: Thermal Sensors and Payloads
15: UAS Platforms and Thermal Payloads
15.5: Atmospheric Effects on MWIR and LWIR
Glossary
Appendix
infrared camera
2.11: Review Questions
5.4: Key Camera Performance Specifications
infrared camera systems
4.9: Summary
infrared cameras
3.7: Apparent Temperature
3.9: Infrared Detectors and Image Formation
3.13: Review Questions
4.1: Introduction
5.1: Introduction
5.2: Basic Components of an Infrared Camera
5.7: Camera Calibration and Accuracy
6.4: Temperature Range Selection
7.1: Introduction
7.2: Thermal Image Types
7.4: File Formats
infrared data
18.1: Introduction
infrared detector
5.11: Review Questions
infrared energy
4.3: Reflectivity
infrared equipment
1.5: The Role of the Thermography Level I Technician
infrared imaging
12.1: Introduction
13.1: Introduction
infrared inspection
11.1: Introduction
infrared lenses
5.11: Review Questions
infrared radiation
2.1: Introduction
2.3: The Three Modes of Heat Transfer
3.3: Infrared Wavelength Bands
3.6: Emission, Reflection, and Transmission
3.9: Infrared Detectors and Image Formation
3.13: Review Questions
4.1: Introduction
4.2: Emissivity
4.3: Reflectivity
4.4: Transmissivity
4.9: Summary
5.2: Basic Components of an Infrared Camera
10.4: Reflection Errors
15.3: Lens Field of View (FOV) and Resolution
infrared sensor
15.2: Thermal Sensor Resolution and Pixel Count

infrared theory
InfoPage
3.11: Practical Implications for Level I Thermographers
infrared thermography
1: Introduction to Nondestructive Testing (NDT) and Infrared Thermography
1.2: Common NDT Methods
1.8: Summary
1.9: Review Questions
2.1: Introduction
5.1: Introduction
9.1: Introduction
10.1: Introduction
10.3: Emissivity-Related Errors
infrared windows
4.4: Transmissivity
infrastructure
13.1: Introduction
13.9: Infrastructure Thermography
14.2: Why Use Drones for Thermography?
17.2: Defining the Inspection Objective
17.18: Mission Planning Worksheets (Aerial Thermography)
19.13: Data Security and Confidentiality
infrastructure applications
13: Building and Infrastructure Thermography
infrastructure corridors
14.4: Typical Applications of Drone Thermography
infrastructure inspections
13.10: Documentation and Reporting (Level I Role)
input value
6.8: Reflected Apparent Temperature
inspected components
20.4: Use of Images in Documentation
inspecting equipment
12.12: Common Errors in Mechanical Thermography
inspection
1.3: Infrared Thermography as an NDT Method
4.6: Viewing Angle and Measurement Error
6.4: Temperature Range Selection
6.7: Emissivity Input
6.13: Documentation of Camera Settings
7.7: Data Storage and Backup
8: Inspection Techniques
8.1: Introduction
10.9: Viewing Angle Errors
11: Electrical Systems Thermography
11.7: Inspection Workflow (Level I)
11.12: Common Errors in Electrical Thermography
12: Mechanical Systems Thermography
12.7: Inspection Workflow (Level I)
13.5: Inspection Conditions and Timing for Buildings
13.8: Solar Panel (PV) Thermography
13.11: Common Errors in Building and Infrastructure Thermography
14.1: Introduction
14.2: Why Use Drones for Thermography?
14.3: Limitations of Drone-Based Thermography
16.10: International and Non-U.S. Operations (Awareness)
17.2: Defining the Inspection Objective
17.18: Mission Planning Worksheets (Aerial Thermography)
19.5: Preservation of Original Data
20.3: Documentation Standards
21: Practice Level I Practical Examination
21.9: SECTION 8- Safety and Professional Judgment
inspection applications
6.5: Level and Span Controls
inspection area
17.5: Flight Path and Coverage Planning
inspection checklist
6.16: Step-by-Step Camera Setup Checklists
inspection data
21.7: SECTION 6- Quality Control (QC)
inspection dataset
19.10: Flight Logs and Supporting Data
inspection date
7.6: File Naming and Organization
19.6: File Organization and Folder Structure
inspection distance
6.3: Focus Control
8.6: Distance, Angle, and Access Considerations
18.3: Focus, Range, and Distance (FoRD) Verification
inspection distances
3.11: Practical Implications for Level I Thermographers
inspection documentation
12.10: Environmental Influences
20.13: Comprehensive Review Questions
inspection effectiveness
16.9: Operational Limitations Affecting Thermography
inspection environment
9.8: Personal Protective Equipment (PPE)
inspection equipment
5.4: Key Camera Performance Specifications
inspection errors
8.12: Common Inspection Errors
inspection guidelines
8.7: Environmental and Operating Condition Considerations
inspection integrity
19.9: Data Backup and Redundancy
inspection limitations
11.11: Documentation and Reporting (Level I Role)
12.11: Documentation and Reporting (Level I Role)
13.10: Documentation and Reporting (Level I Role)
14.13: Data Collection and Documentation (Level I Role)
19.16: Review Questions
20.13: Comprehensive Review Questions
21.1: Purpose and Instructions
inspection log
7.14: Inspection Log Template
inspection logs
16.11: Documentation and Compliance Records
inspection methods
1.1: What Is Nondestructive Testing (NDT)?
1.8: Summary
1.9: Review Questions
13.10: Documentation and Reporting (Level I Role)
inspection notes
7.8: Data Transfer and Handoff
inspection objective
17.9: Time-of-Day Considerations
17.17: Review Questions
inspection objectives
14.9: Mission Planning Fundamentals (Level I Awareness)
17.1: Introduction
17.16: Summary
inspection parameters
17.9: Time-of-Day Considerations
inspection practices
8.8: Electrical Inspection Techniques (Level I Scope)
10.13: Summary
inspection procedures
1.5: The Role of the Thermography Level I Technician
4.4: Transmissivity
5.12: Drone Thermography Specification Tables
10.6: Thermal Loading and Operating Condition Errors
inspection process
19.16: Review Questions
inspection quality
15.3: Lens Field of View (FOV) and Resolution
15.12: Review Questions
20.9: Continuous Improvement and Professional Development
inspection records
2.4: Steady-State and Transient Heat Conditions
11.10: Environmental Influences
16.9: Operational Limitations Affecting Thermography
inspection reliability
18.12: Common Aerial Image Acquisition Errors
inspection success
19.15: Summary
inspection targets
16.5: Operational Planning and Briefings
inspection techniques
2.7: Heat Generation Sources
6.1: Introduction
8: Inspection Techniques
8.12: Common Inspection Errors
8.13: Summary
10.1: Introduction
12: Mechanical Systems Thermography
13.12: Summary
inspection timing
2.9: Practical Implications for Thermography
inspection tool
10.1: Introduction
inspection usefulness
19.1: Introduction
inspection work
15.11: Summary
inspectionobjective
15.1: Introduction
inspections
2.8: Environmental Influences on Heat Transfer
3.12: Summary
6.15: Review Questions
8.2: Passive and Active Thermography
8.9: Mechanical Inspection Techniques (Level I Scope)
8.11: Drone-Based Inspection Techniques
8.14: Review Questions
9.2: General Safety Principles
9.4: Mechanical and Industrial Safety
9.5: Working at Heights
9.6: Environmental and Outdoor Safety
9.7: Drone-Based Thermography Safety
9.11: Common Safety Mistakes
9.12: Summary
10.11: Data Handling Errors
10.12: Human Factors and Procedural Errors
11.4: Typical Thermal Patterns in Electrical Systems
12.4: Typical Thermal Patterns in Mechanical Systems
12.14: Review Questions
13.2: Heat Transfer in Buildings (Level I Review)
14.5: Drone Platforms Used for Thermography
14.14: Ground-Based vs. Drone-Based Thermography
14.17: Review Questions
16.2: Overview of Applicable Regulatory Frameworks
16.6: Site Access and Permissions
17.8: Environmental Assessment
19.10: Flight Logs and Supporting Data
20.5: Handling Limitations and Uncertainty
20.8: Communication and Teamwork
insulated areas
8.5: Comparative Inspection Techniques
insulated tools
9.3: Electrical Safety

insulation
2.3: The Three Modes of Heat Transfer
2.5: Thermal Mass and Heat Storage
13.3: Common Building and Infrastructure Applications
13.4: Building Envelope Thermography
insulation inconsistencies
8.10: Building and Infrastructure Inspection Techniques
13.6: Roof Thermography (Ground-Based)
insulation performance
13.1: Introduction
interaction
14.11: Safety Considerations in Drone Thermography
international operations
16.10: International and Non-U.S. Operations (Awareness)
interpretation
20.1: Introduction
introduction
5: Infrared Camera Systems
10: Common Sources of Error
13: Building and Infrastructure Thermography
17: Mission Planning for Aerial Thermography
19: Post-Flight Data Handling and Preparation
20: Review, Documentation, and Professional Practice
Iron
5.5: Image Display and Color Palettes
Iron palette
6.6: Color Palettes
irradiance
13.12: Summary
isotherm application
21.6: SECTION 5- Thermal Tuning Awareness (Software Review)

J

Jay Seidel
TitlePage
job hazard analysis
9: Safety in Thermographic Inspections
9.10: Safety Documentation

K

key targets
19.3: Initial Image Quality Review (QC Confirmation)
kinetic energy
2.2: Heat vs. Temperature
Kirchhoff's law
4.2: Emissivity

L

labeling
20.4: Use of Images in Documentation
ladders
9.5: Working at Heights
landing
14.5: Drone Platforms Used for Thermography
18.10: Post-Flight Image Review (Initial QC)
19.2: Immediate Post-Flight Actions
launch
9.7: Drone-Based Thermography Safety
Laws of Thermodynamics
1.2: Common NDT Methods
lens
6.13: Documentation of Camera Settings
15.4: Mid-Wave vs. Long-Wave Infrared (MWIR vs. LWIR)
18.11: Documentation and Metadata Recording
19.8: Metadata Verification
lens cleaning
5.9: Care, Handling, and Maintenance
lens field of view
5.12: Drone Thermography Specification Tables
15: UAS Platforms and Thermal Payloads
lens FOV
15.10: Documentation and Payload Identification
15.11: Summary
lens information
7.5: Metadata and Embedded Information
lens maintenance
5.9: Care, Handling, and Maintenance
lens selection
15.4: Mid-Wave vs. Long-Wave Infrared (MWIR vs. LWIR)
15.9: Typical Payload Configurations
15.12: Review Questions
level
6.15: Review Questions
level 1
TitlePage
level control
6.5: Level and Span Controls
level controls
6: Camera Controls and Setup
Level I
2.9: Practical Implications for Thermography
4.8: Common Errors Related to Surface Properties
6.12: Common Setup Errors
8.8: Electrical Inspection Techniques (Level I Scope)
9.9: Emergency Preparedness
14.13: Data Collection and Documentation (Level I Role)
20.13: Comprehensive Review Questions
Appendix
Level I documentation
11.11: Documentation and Reporting (Level I Role)
12.11: Documentation and Reporting (Level I Role)
13.10: Documentation and Reporting (Level I Role)
13.13: Review Questions
15.10: Documentation and Payload Identification
18.11: Documentation and Metadata Recording
Level I Guidance
11.9: FoRD Considerations in Electrical Inspections
Level I inspection
10.13: Summary
Level I inspections
8.3: Qualitative vs. Quantitative Inspections
Level I observation
21.8: SECTION 7- Documentation Practice
Level I response
21.9: SECTION 8- Safety and Professional Judgment
Level I technician
1.5: The Role of the Thermography Level I Technician
10.14: Review Questions
Level I technicians
1.8: Summary
2.7: Heat Generation Sources
3.7: Apparent Temperature
3.11: Practical Implications for Level I Thermographers
6.3: Focus Control
6.8: Reflected Apparent Temperature
6.9: Distance and Atmospheric Inputs
7.8: Data Transfer and Handoff
7.9: Data Integrity and Ethics
7.11: Quality Control Checks
8.5: Comparative Inspection Techniques
9.3: Electrical Safety
11.14: Review Questions
12.4: Typical Thermal Patterns in Mechanical Systems
12.13: Summary
13.6: Roof Thermography (Ground-Based)
14.16: Summary
16.11: Documentation and Compliance Records
16.13: Summary
17.12: Pre-Flight Briefing Participation (Level I Role)
19.11: Documentation of Limitations and Anomalies
19.15: Summary
20.5: Handling Limitations and Uncertainty
20.6: Data Integrity and Chain of Custody
20.7: Professional Conduct and Ethics
20.10: Regulatory and Standards Awareness
Level I thermographer
14.17: Review Questions
21.7: SECTION 6- Quality Control (QC)
Level I thermographer documentation
18.15: Review Questions
Level I thermographer responsibilities
16.14: Review Questions
Level I thermographers
4.1: Introduction
4.7: Practical Camera Setup Considerations
17.11: Coordination and Communication
18.8: Communication During Image Acquisition
Level II
7.1: Introduction
Level II personnel
7.8: Data Transfer and Handoff
18.13: Data Handling and Handoff
Level III
7.1: Introduction
Level III personnel
7.8: Data Transfer and Handoff
18.13: Data Handling and Handoff
level span adjustment
21.6: SECTION 5- Thermal Tuning Awareness (Software Review)
LibreTexts
InfoPage
limitations
1.4: Advantages and Limitations of Thermography
1.8: Summary
7.11: Quality Control Checks
10.2: Measurement vs. Indication Errors
12.9: FoRD Considerations in Mechanical Inspections
14: Introduction to Drone-Based Thermography
14.3: Limitations of Drone-Based Thermography
14.17: Review Questions
20.2: Review of Collected Data (Level I Role)
20.5: Handling Limitations and Uncertainty
20.12: Summary
21.7: SECTION 6- Quality Control (QC)
limitations of thermography
1: Introduction to Nondestructive Testing (NDT) and Infrared Thermography
1.9: Review Questions
limited access
11.9: FoRD Considerations in Electrical Inspections

linear passes
17.5: Flight Path and Coverage Planning
Liquid Penetrant Testing
1.2: Common NDT Methods
load
11.6: Inspection Conditions and Timing
11.12: Common Errors in Electrical Thermography
11.14: Review Questions
13.12: Summary
load and speed
12.6: Inspection Conditions and Timing
load comparison
12.5: Comparative Inspection Techniques
load conditions
11.11: Documentation and Reporting (Level I Role)
load inspection
8.12: Common Inspection Errors
load_changes
8.4: Steady-State and Transient Inspection Conditions
localized heat
11.5: Comparative Inspection Techniques
localized hot spots
11.4: Typical Thermal Patterns in Electrical Systems
12.4: Typical Thermal Patterns in Mechanical Systems
location
18.11: Documentation and Metadata Recording
19.7: File Naming and Identification
location ID
7.6: File Naming and Organization
locations
9.5: Working at Heights
lockout
9.4: Mechanical and Industrial Safety
16.7: Electrical and Industrial Regulatory Awareness
lockout tagout
9.3: Electrical Safety
lower cost
5.3: Infrared Detector Types
LWIR
15: UAS Platforms and Thermal Payloads
15.6: Radiometric vs. Non-Radiometric Thermal Payloads
15.10: Documentation and Payload Identification
LWIR sensors
15.11: Summary
15.12: Review Questions

M

machinery
9.4: Mechanical and Industrial Safety
Magnetic Particle Testing
1.2: Common NDT Methods
maintenance
5.3: Infrared Detector Types
8.9: Mechanical Inspection Techniques (Level I Scope)
9.8: Personal Protective Equipment (PPE)
12.8: Safety Considerations Specific to Mechanical Thermography
manual focus
6.3: Focus Control
manufacturer recommendations
19.4: Data Transfer from Aircraft to Storage
masonry
13.3: Common Building and Infrastructure Applications
material differences
13.9: Infrastructure Thermography
material properties
2.6: Solar Loading
4.2: Emissivity
materials
3.4: Blackbody Radiation
4.4: Transmissivity
4.8: Common Errors Related to Surface Properties
materials evaluation
1.1: What Is Nondestructive Testing (NDT)?
maximum inspection altitude
15.3: Lens Field of View (FOV) and Resolution
measurement
3.4: Blackbody Radiation
10.2: Measurement vs. Indication Errors
measurement accuracy
3.10: Spatial Resolution and Measurement Accuracy
3.13: Review Questions
4.9: Summary
6.4: Temperature Range Selection
6.14: Summary
8.6: Distance, Angle, and Access Considerations
measurement consistency
14.7: Flat Field Correction (FFC)
measurement error
4: Emissivity, Reflectivity, and Transmissivity
4.6: Viewing Angle and Measurement Error
measurement errors
6.2: Importance of Proper Camera Setup
10: Common Sources of Error
10.14: Review Questions
measurement inaccuracies
10.9: Viewing Angle Errors
measurement reliability
15.3: Lens Field of View (FOV) and Resolution
18.5: In-Flight Image Acquisition Techniques
measurement resolution
10.8: Focus, Range and Distance (FoRD) Errors
measurement techniques
5.6: Focus and Image Clarity
measurements
5.6: Focus and Image Clarity
Mechanical
8.9: Mechanical Inspection Techniques (Level I Scope)
9.12: Summary
12: Mechanical Systems Thermography
12.2: Basic Mechanical Concepts (Level I Overview)
12.7: Inspection Workflow (Level I)
12.9: FoRD Considerations in Mechanical Inspections
mechanical components
12.14: Review Questions
mechanical equipment
8.2: Passive and Active Thermography
10.6: Thermal Loading and Operating Condition Errors
mechanical friction
2.7: Heat Generation Sources
mechanical inspection
8: Inspection Techniques
9.14: Job Hazard Analysis (JHA) Templates
mechanical inspections
3.3: Infrared Wavelength Bands
5.8: Handheld vs. Drone-Mounted Infrared Cameras
12.5: Comparative Inspection Techniques
12.8: Safety Considerations Specific to Mechanical Thermography
mechanical safety
9: Safety in Thermographic Inspections
mechanical systems
1.3: Infrared Thermography as an NDT Method
12.1: Introduction
12.13: Summary
12.14: Review Questions
mechanical thermography
12.3: Common Mechanical Components Inspected
12.6: Inspection Conditions and Timing
12.10: Environmental Influences
metadata
7: Image Types and Data Handling
7.5: Metadata and Embedded Information
7.8: Data Transfer and Handoff
7.12: Summary
7.14: Inspection Log Template
18: Aerial Thermal Image Acquisition
18.4: Test Image Capture (Before Full Mission)
19.5: Preservation of Original Data
19.8: Metadata Verification
metadata accuracy
7.11: Quality Control Checks
metadata importance
7.13: Review Questions
metadata loss
10.11: Data Handling Errors
metadata preservation
18.13: Data Handling and Handoff
metadata traceability
19.15: Summary
metadata verification
19: Post-Flight Data Handling and Preparation
microbolometer
5.3: Infrared Detector Types
microbolometers
5.10: Summary
microwaves
3.2: The Electromagnetic Spectrum
minimize errors
11.12: Common Errors in Electrical Thermography
minimum detectable target size
15.3: Lens Field of View (FOV) and Resolution
misrepresentation
1.6: Ethics and Professional Responsibility
7.9: Data Integrity and Ethics
missing metadata
19.14: Common Post-Flight Data Handling Errors
mission
18.6: Viewing Angle and Sensor Orientation
18.16: Quality Control (QC) Checklists for Aerial Thermography
mission execution
17.17: Review Questions
mission objectives
16.5: Operational Planning and Briefings
17.12: Pre-Flight Briefing Participation (Level I Role)
mission plan
19.11: Documentation of Limitations and Anomalies

mission planning
14: Introduction to Drone-Based Thermography
14.9: Mission Planning Fundamentals (Level I Awareness)
14.16: Summary
17.1: Introduction
17.3: Target Characteristics and Resolution Requirements
17.4: Altitude Selection and Ground Sample Distance (GSD)
17.7: Focus, Range, and Distance (FoRD) Verification
17.8: Environmental Assessment
17.10: Safety Planning and Risk Mitigation
17.14: Post-Flight Review and Documentation
17.16: Summary
17.17: Review Questions
18.3: Focus, Range, and Distance (FoRD) Verification
mission planning errors
17: Mission Planning for Aerial Thermography
mission plans
19.10: Flight Logs and Supporting Data
mission review
21.5: SECTION 4- Aerial Thermography
mission safety
18.7: Environmental Monitoring During Flight
mission success
17.15: Common Mission Planning Errors
model
6.13: Documentation of Camera Settings
modes of heat transfer
2.11: Review Questions
moisture
2.8: Environmental Influences on Heat Transfer
8.7: Environmental and Operating Condition Considerations
10.5: Atmospheric and Environmental Errors
13.4: Building Envelope Thermography
17.2: Defining the Inspection Objective
moisture detection
8.10: Building and Infrastructure Inspection Techniques
moisture presence
13.9: Infrastructure Thermography
moisture protection
5.9: Care, Handling, and Maintenance
monitoring
17.13: In-Flight Data Collection Considerations
monitoring changes
7.3: Still Images vs. Video
motion
10.7: Motion and Stability Errors
12.9: FoRD Considerations in Mechanical Inspections
12.14: Review Questions
motion blur
15.8: FoRD Considerations for UAS Payloads
18.5: In-Flight Image Acquisition Techniques
19.3: Initial Image Quality Review (QC Confirmation)
21.7: SECTION 6- Quality Control (QC)
motion control
18.5: In-Flight Image Acquisition Techniques
motion errors
10: Common Sources of Error
motors
8.9: Mechanical Inspection Techniques (Level I Scope)
multidisciplinary
20.8: Communication and Teamwork
multiple sensors
7.10: Drone-Specific Data Handling Considerations
multirotor
14.5: Drone Platforms Used for Thermography
multirotor platforms
14.16: Summary
MWIR
15: UAS Platforms and Thermal Payloads
15.6: Radiometric vs. Non-Radiometric Thermal Payloads
15.10: Documentation and Payload Identification
MWIR sensors
15.11: Summary
15.12: Review Questions

N

naming
19.7: File Naming and Identification
naming conventions
7.6: File Naming and Organization
19.12: Preparing Data for Analysis and Handoff
narrow FOV
15.4: Mid-Wave vs. Long-Wave Infrared (MWIR vs. LWIR)
narrow range
6.4: Temperature Range Selection
NDT
1: Introduction to Nondestructive Testing (NDT) and Infrared Thermography
1.1: What Is Nondestructive Testing (NDT)?
1.3: Infrared Thermography as an NDT Method
1.8: Summary
NDT methods
1: Introduction to Nondestructive Testing (NDT) and Infrared Thermography
1.2: Common NDT Methods
near infrared
3.3: Infrared Wavelength Bands
NETD
5.4: Key Camera Performance Specifications
5.11: Review Questions
noise
12.8: Safety Considerations Specific to Mechanical Thermography
noise equivalent temperature difference
5.4: Key Camera Performance Specifications
nondestructive testing
InfoPage
1: Introduction to Nondestructive Testing (NDT) and Infrared Thermography
1.1: What Is Nondestructive Testing (NDT)?
1.9: Review Questions
Appendix
References and Standards
normal thermal patterns
11.4: Typical Thermal Patterns in Electrical Systems
number
6.13: Documentation of Camera Settings

O

objective
17: Mission Planning for Aerial Thermography
objective language
20.3: Documentation Standards
20.12: Summary
objective writing
21.8: SECTION 7- Documentation Practice
oblique angles
4.6: Viewing Angle and Measurement Error
17.6: Viewing Angle and Sensor Orientation
18.6: Viewing Angle and Sensor Orientation
oblique viewing angles
10.9: Viewing Angle Errors
observation documentation
20.1: Introduction
observation example
21.8: SECTION 7- Documentation Practice
observations
1.6: Ethics and Professional Responsibility
20.8: Communication and Teamwork
observed differences
8.5: Comparative Inspection Techniques
obstacles
17.10: Safety Planning and Risk Mitigation
opaque
4.4: Transmissivity
operating
11.6: Inspection Conditions and Timing
operating condition errors
10: Common Sources of Error
operating conditions
10.13: Summary
11.5: Comparative Inspection Techniques
11.13: Summary
12.6: Inspection Conditions and Timing
12.11: Documentation and Reporting (Level I Role)
12.13: Summary
operating limitations
16.3: Aviation Regulations for Drone-Based Thermography
operating machinery
9.1: Introduction
operating roles
16.12: Common Regulatory and Operational Errors
operational
9.7: Drone-Based Thermography Safety
operational constraints
16.9: Operational Limitations Affecting Thermography
operational limitations
14.10: Regulatory and Compliance Awareness
17.14: Post-Flight Review and Documentation
operational limits
16.14: Review Questions
operational planning
16: Regulatory and Operational Considerations
operational procedures
16.1: Introduction
operations
16.2: Overview of Applicable Regulatory Frameworks
operator certification
16.10: International and Non-U.S. Operations (Awareness)
optical assembly
15.2: Thermal Sensor Resolution and Pixel Count
optical properties
4: Emissivity, Reflectivity, and Transmissivity
optical sharpness
10.8: Focus, Range and Distance (FoRD) Errors
optical system
5.2: Basic Components of an Infrared Camera
optics
5.10: Summary
15.8: FoRD Considerations for UAS Payloads
organization
7.6: File Naming and Organization
organizational procedures
20.10: Regulatory and Standards Awareness
organizations
20.9: Continuous Improvement and Professional Development

original color scales
20.4: Use of Images in Documentation
original data
7.9: Data Integrity and Ethics
original data files
18.13: Data Handling and Handoff
original image files
7.13: Review Questions
originals
19.5: Preservation of Original Data
outdated guidance
20.10: Regulatory and Standards Awareness
outdoor
9.6: Environmental and Outdoor Safety
13.5: Inspection Conditions and Timing for Buildings
outdoor environments
6.9: Distance and Atmospheric Inputs
outdoor inspections
2.11: Review Questions
outdoor locations
1.7: Safety Considerations in Thermographic Inspections
outdoor weather
11.10: Environmental Influences
overconfidence
10.12: Human Factors and Procedural Errors
overlap
17.4: Altitude Selection and Ground Sample Distance (GSD)
overloaded components
11.5: Comparative Inspection Techniques
overwriting files
19.14: Common Post-Flight Data Handling Errors
oxidation
6.7: Emissivity Input
10.3: Emissivity-Related Errors

P

palette selection
6.6: Color Palettes
palettes
5.5: Image Display and Color Palettes
Parameters
18.16: Quality Control (QC) Checklists for Aerial Thermography
Part 107
16.3: Aviation Regulations for Drone-Based Thermography
particulates
3.8: Atmospheric Effects on Infrared Radiation
passive thermography
8.2: Passive and Active Thermography
8.13: Summary
8.14: Review Questions
pattern recognition
11.4: Typical Thermal Patterns in Electrical Systems
11.14: Review Questions
12.4: Typical Thermal Patterns in Mechanical Systems
patterns
13.8: Solar Panel (PV) Thermography
pavements
13.9: Infrastructure Thermography
Payload
18.16: Quality Control (QC) Checklists for Aerial Thermography
payloads
18.9: Managing Multiple Sensors (Thermal + Visual)
peer review
20.11: Common Documentation and Professional Practice Errors
performance
13.8: Solar Panel (PV) Thermography
performance specifications
5.1: Introduction
permissions
16: Regulatory and Operational Considerations
16.12: Common Regulatory and Operational Errors
permit
11.6: Inspection Conditions and Timing
permits
16.6: Site Access and Permissions
personal protective equipment
1.7: Safety Considerations in Thermographic Inspections
9: Safety in Thermographic Inspections
9.2: General Safety Principles
9.8: Personal Protective Equipment (PPE)
personally identifiable information
16.8: Privacy and Data Protection Considerations
personnel
16.6: Site Access and Permissions
personnel notification
21.9: SECTION 8- Safety and Professional Judgment
personnel qualification
References and Standards
personnel understanding
19.11: Documentation of Limitations and Anomalies
photography
5.9: Care, Handling, and Maintenance
15.8: FoRD Considerations for UAS Payloads
physics
3.4: Blackbody Radiation
3.5: Relationship Between Temperature and Infrared Radiation
4.5: Relationship Between Emissivity, Reflectivity, and Transmissivity
PII
16.8: Privacy and Data Protection Considerations
pinch points
12.8: Safety Considerations Specific to Mechanical Thermography
pixel
15.7: Gimbal Stabilization and Image Quality
pixel count
15: UAS Platforms and Thermal Payloads
15.3: Lens Field of View (FOV) and Resolution
15.4: Mid-Wave vs. Long-Wave Infrared (MWIR vs. LWIR)
15.12: Review Questions
pixel coverage
10.14: Review Questions
11.9: FoRD Considerations in Electrical Inspections
13.11: Common Errors in Building and Infrastructure Thermography
17.3: Target Characteristics and Resolution Requirements
pixel data
6.10: Image Capture Settings
pixel representation
3.10: Spatial Resolution and Measurement Accuracy
pixels
15.4: Mid-Wave vs. Long-Wave Infrared (MWIR vs. LWIR)
planned altitude
14.9: Mission Planning Fundamentals (Level I Awareness)
17.7: Focus, Range, and Distance (FoRD) Verification
planned mission
17.9: Time-of-Day Considerations
planning
14.4: Typical Applications of Drone Thermography
17.11: Coordination and Communication
17.17: Review Questions
planning inspections
2.11: Review Questions
platforms
9.5: Working at Heights
14: Introduction to Drone-Based Thermography
policies
9.2: General Safety Principles
19.13: Data Security and Confidentiality
polished components
4.3: Reflectivity
poor file organization
19.14: Common Post-Flight Data Handling Errors
poor focus
12.12: Common Errors in Mechanical Thermography
13.11: Common Errors in Building and Infrastructure Thermography
potential issues
11.13: Summary
power systems
15.2: Thermal Sensor Resolution and Pixel Count
PPE
9.2: General Safety Principles
9.8: Personal Protective Equipment (PPE)
9.11: Common Safety Mistakes
9.14: Job Hazard Analysis (JHA) Templates
11.8: Safety Considerations Specific to Electrical Thermography
12.8: Safety Considerations Specific to Mechanical Thermography
PPE checklists
9.10: Safety Documentation
practice exam
21.1: Purpose and Instructions
precautions
9.13: Review Questions
precipitation
8.7: Environmental and Operating Condition Considerations
preflight
18.14: Summary
preserve files
7.9: Data Integrity and Ethics
preserve original data
20.6: Data Integrity and Chain of Custody
prevent issues
20.11: Common Documentation and Professional Practice Errors
prevent unauthorized access
20.6: Data Integrity and Chain of Custody
preventing errors
14.15: Common Errors in Drone Thermography
prevention
10.6: Thermal Loading and Operating Condition Errors
10.9: Viewing Angle Errors
10.10: Camera Setup and Configuration Errors
10.12: Human Factors and Procedural Errors
16.12: Common Regulatory and Operational Errors
prevention steps
10.14: Review Questions
prevention techniques
10.4: Reflection Errors
privacy considerations
16: Regulatory and Operational Considerations

private
19.13: Data Security and Confidentiality
private property
16.8: Privacy and Data Protection Considerations
procedures
6.7: Emissivity Input
6.9: Distance and Atmospheric Inputs
8.1: Introduction
8.11: Drone-Based Inspection Techniques
10.12: Human Factors and Procedural Errors
11.12: Common Errors in Electrical Thermography
14.4: Typical Applications of Drone Thermography
20.5: Handling Limitations and Uncertainty
professional
20.8: Communication and Teamwork
professional boundaries
21.10: SECTION 9- Final Self-Assessment
professional conduct
20: Review, Documentation, and Professional Practice
professional consequences
1.6: Ethics and Professional Responsibility
professional development
20.9: Continuous Improvement and Professional Development
professional ethics
20.7: Professional Conduct and Ethics
professional inspections
15.7: Gimbal Stabilization and Image Quality
professional language
21.1: Purpose and Instructions
professional practice
20.10: Regulatory and Standards Awareness
professional responsibility
1: Introduction to Nondestructive Testing (NDT) and Infrared Thermography
7.9: Data Integrity and Ethics
7.12: Summary
20.6: Data Integrity and Chain of Custody
professional standards
1.6: Ethics and Professional Responsibility
20.1: Introduction
Programs
16.7: Electrical and Industrial Regulatory Awareness
project name
19.6: File Organization and Folder Structure
project organization
7.6: File Naming and Organization
propellers
14.11: Safety Considerations in Drone Thermography
proper focus
11.9: FoRD Considerations in Electrical Inspections
proper load conditions
11.13: Summary
proprietary formats
7.4: File Formats
protect
19.13: Data Security and Confidentiality
protection
9.5: Working at Heights
protective equipment
5.9: Care, Handling, and Maintenance
protocols
18.8: Communication During Image Acquisition
pumps
12.3: Common Mechanical Components Inspected
PV
13.8: Solar Panel (PV) Thermography
PV thermography
13.13: Review Questions

Q

QC
18.16: Quality Control (QC) Checklists for Aerial Thermography
QC checks
19.15: Summary
qualitative
8: Inspection Techniques
qualitative inspections
8.13: Summary
qualitative thermography
8.3: Qualitative vs. Quantitative Inspections
quality
18.14: Summary
21: Practice Level I Practical Examination
quality assurance
18.8: Communication During Image Acquisition
quality checks
7.11: Quality Control Checks
10.11: Data Handling Errors
quality control
1.1: What Is Nondestructive Testing (NDT)?
1.3: Infrared Thermography as an NDT Method
1.9: Review Questions
7: Image Types and Data Handling
18: Aerial Thermal Image Acquisition
19.12: Preparing Data for Analysis and Handoff
21.1: Purpose and Instructions
21.7: SECTION 6- Quality Control (QC)
quality requirements
18.4: Test Image Capture (Before Full Mission)
quality standards
7.11: Quality Control Checks
quality verification
19.1: Introduction
quantitative
8: Inspection Techniques
quantitative thermography
8.3: Qualitative vs. Quantitative Inspections

R

radiant heat
12.10: Environmental Influences
radiation
2.3: The Three Modes of Heat Transfer
2.10: Summary
3: Infrared Theory and Physics
3.1: Introduction
3.2: The Electromagnetic Spectrum
3.4: Blackbody Radiation
3.5: Relationship Between Temperature and Infrared Radiation
3.8: Atmospheric Effects on Infrared Radiation
3.12: Summary
4.5: Relationship Between Emissivity, Reflectivity, and Transmissivity
6.2: Importance of Proper Camera Setup
10.5: Atmospheric and Environmental Errors
13.2: Heat Transfer in Buildings (Level I Review)
Glossary
radio waves
3.2: The Electromagnetic Spectrum
Radiographic Testing
1.2: Common NDT Methods
radiometric
7.12: Summary
15: UAS Platforms and Thermal Payloads
15.7: Gimbal Stabilization and Image Quality
18.13: Data Handling and Handoff
19.5: Preservation of Original Data
radiometric capability
15.10: Documentation and Payload Identification
radiometric capture
18.2: Pre-Flight Camera and Payload Verification
21.2: SECTION 1- Equipment Setup and Pre-Inspection Verification
radiometric data
6.14: Summary
7.3: Still Images vs. Video
7.11: Quality Control Checks
19.3: Initial Image Quality Review (QC Confirmation)
20.2: Review of Collected Data (Level I Role)
radiometric data preservation
19.15: Summary
radiometric files
19.16: Review Questions
radiometric formats
7.4: File Formats
radiometric image files
7.8: Data Transfer and Handoff
radiometric images
6.10: Image Capture Settings
6.15: Review Questions
7.2: Thermal Image Types
7.13: Review Questions
radiometric thermal images
14.13: Data Collection and Documentation (Level I Role)
Rainbow
5.5: Image Display and Color Palettes
Rainbow palette
6.6: Color Palettes
range
14.6: Thermal Sensors and Payloads
14.8: Focus, Range, and Distance (FoRD) in Drone Thermography
range errors
10.8: Focus, Range and Distance (FoRD) Errors
rapid inspection
1.4: Advantages and Limitations of Thermography
recommended practices
19.9: Data Backup and Redundancy
record
19.5: Preservation of Original Data
records
6.13: Documentation of Camera Settings
recovery
9.7: Drone-Based Thermography Safety
redundancy
7.7: Data Storage and Backup
reflected apparent temperature
4.10: Review Questions
6.8: Reflected Apparent Temperature
6.15: Review Questions
7.5: Metadata and Embedded Information
18.2: Pre-Flight Camera and Payload Verification
reflected radiation
4.3: Reflectivity
reflected temperature
3.7: Apparent Temperature
6: Camera Controls and Setup
6.12: Common Setup Errors
10.4: Reflection Errors
10.10: Camera Setup and Configuration Errors

reflected temperature settings
3.11: Practical Implications for Level I Thermographers
reflection
3: Infrared Theory and Physics
3.6: Emission, Reflection, and Transmission
4.5: Relationship Between Emissivity, Reflectivity, and Transmissivity
10.13: Summary
reflection errors
10: Common Sources of Error
18.6: Viewing Angle and Sensor Orientation
reflections
4.8: Common Errors Related to Surface Properties
10.9: Viewing Angle Errors
11.12: Common Errors in Electrical Thermography
reflective surfaces
6.8: Reflected Apparent Temperature
10.4: Reflection Errors
11.9: FoRD Considerations in Electrical Inspections
reflectivity
4: Emissivity, Reflectivity, and Transmissivity
4.1: Introduction
4.3: Reflectivity
4.6: Viewing Angle and Measurement Error
4.9: Summary
4.10: Review Questions
refocus
6.12: Common Setup Errors
regulations
9.7: Drone-Based Thermography Safety
13.7: Drone-Based Roof Thermography
16.2: Overview of Applicable Regulatory Frameworks
16.10: International and Non-U.S. Operations (Awareness)
regulatory
16.2: Overview of Applicable Regulatory Frameworks
regulatory awareness
16.14: Review Questions
regulatory compliance
14.16: Summary
16.10: International and Non-U.S. Operations (Awareness)
16.14: Review Questions
17.4: Altitude Selection and Ground Sample Distance (GSD)
20.3: Documentation Standards
regulatory constraints
14.3: Limitations of Drone-Based Thermography
regulatory frameworks
16: Regulatory and Operational Considerations
16.13: Summary
regulatory requirements
16.1: Introduction
20.10: Regulatory and Standards Awareness
relationship
4.5: Relationship Between Emissivity, Reflectivity, and Transmissivity
relative humidity
6.9: Distance and Atmospheric Inputs
7.14: Inspection Log Template
reliability
1.5: The Role of the Thermography Level I Technician
8.12: Common Inspection Errors
8.13: Summary
Remote Pilot Certificate
16.3: Aviation Regulations for Drone-Based Thermography
Remote Pilot in Command
14.9: Mission Planning Fundamentals (Level I Awareness)
16.1: Introduction
16.4: Roles and Responsibilities in Drone Operations
17.1: Introduction
remote sensing
3.10: Spatial Resolution and Measurement Accuracy
repair recommendations
12.11: Documentation and Reporting (Level I Role)
13.10: Documentation and Reporting (Level I Role)
repeatability
7.12: Summary
20.3: Documentation Standards
report
5.7: Camera Calibration and Accuracy
reporting
6.10: Image Capture Settings
7.3: Still Images vs. Video
9.2: General Safety Principles
18.8: Communication During Image Acquisition
20.8: Communication and Teamwork
requirements
11.8: Safety Considerations Specific to Electrical Thermography
16.7: Electrical and Industrial Regulatory Awareness
resistance
11.2: Basic Electrical Concepts (Level I Overview)
resistance heating
11.2: Basic Electrical Concepts (Level I Overview)
resolution
14.3: Limitations of Drone-Based Thermography
14.6: Thermal Sensors and Payloads
14.14: Ground-Based vs. Drone-Based Thermography
15: UAS Platforms and Thermal Payloads
resolution requirements
17: Mission Planning for Aerial Thermography
17.4: Altitude Selection and Ground Sample Distance (GSD)
response
21.9: SECTION 8- Safety and Professional Judgment
response plan
9.9: Emergency Preparedness
responsibilities
4.8: Common Errors Related to Surface Properties
13.13: Review Questions
14.13: Data Collection and Documentation (Level I Role)
restricted access
16.9: Operational Limitations Affecting Thermography
restricted areas
17.10: Safety Planning and Risk Mitigation
review
13: Building and Infrastructure Thermography
18.10: Post-Flight Image Review (Initial QC)
20: Review, Documentation, and Professional Practice
review questions
4: Emissivity, Reflectivity, and Transmissivity
7: Image Types and Data Handling
19: Post-Flight Data Handling and Preparation
risk assessment
17.18: Mission Planning Worksheets (Aerial Thermography)
risk identification
17.10: Safety Planning and Risk Mitigation
risk level
9.14: Job Hazard Analysis (JHA) Templates
risk management
16.12: Common Regulatory and Operational Errors
risk mitigation
17.10: Safety Planning and Risk Mitigation
risk reduction
19.14: Common Post-Flight Data Handling Errors
roles and responsibilities
17.11: Coordination and Communication
roof
17.2: Defining the Inspection Objective
roof condition
13.6: Roof Thermography (Ground-Based)
roof inspection
8.10: Building and Infrastructure Inspection Techniques
roof inspections
5.8: Handheld vs. Drone-Mounted Infrared Cameras
13.7: Drone-Based Roof Thermography
13.12: Summary
13.13: Review Questions
14.4: Typical Applications of Drone Thermography
roof moisture surveys
17.9: Time-of-Day Considerations
roof systems
13.3: Common Building and Infrastructure Applications
roof thermography
13: Building and Infrastructure Thermography
roofs
8.11: Drone-Based Inspection Techniques
17.9: Time-of-Day Considerations
18.6: Viewing Angle and Sensor Orientation
rooftops
14.2: Why Use Drones for Thermography?
rotating components
12.8: Safety Considerations Specific to Mechanical Thermography
RPIC
16.4: Roles and Responsibilities in Drone Operations
RPIC notification
18.7: Environmental Monitoring During Flight
RPIC role
16.14: Review Questions

S

safe
9.4: Mechanical and Industrial Safety
safe approach distances
8.8: Electrical Inspection Techniques (Level I Scope)
safe operations
9.10: Safety Documentation
16.4: Roles and Responsibilities in Drone Operations
safe work practices
9.1: Introduction

safety
1.1: What Is Nondestructive Testing (NDT)?
1.4: Advantages and Limitations of Thermography
8.6: Distance, Angle, and Access Considerations
9: Safety in Thermographic Inspections
9.1: Introduction
9.2: General Safety Principles
9.5: Working at Heights
9.6: Environmental and Outdoor Safety
9.7: Drone-Based Thermography Safety
9.9: Emergency Preparedness
9.10: Safety Documentation
9.11: Common Safety Mistakes
9.12: Summary
9.13: Review Questions
9.14: Job Hazard Analysis (JHA) Templates
10.12: Human Factors and Procedural Errors
11: Electrical Systems Thermography
11.6: Inspection Conditions and Timing
11.7: Inspection Workflow (Level I)
11.8: Safety Considerations Specific to Electrical Thermography
12.7: Inspection Workflow (Level I)
12.8: Safety Considerations Specific to Mechanical Thermography
12.13: Summary
13.7: Drone-Based Roof Thermography
13.12: Summary
14: Introduction to Drone-Based Thermography
14.2: Why Use Drones for Thermography?
14.11: Safety Considerations in Drone Thermography
14.14: Ground-Based vs. Drone-Based Thermography
16.2: Overview of Applicable Regulatory Frameworks
16.6: Site Access and Permissions
16.7: Electrical and Industrial Regulatory Awareness
17.18: Mission Planning Worksheets (Aerial Thermography)
safety brief
16.11: Documentation and Compliance Records
safety briefings
9.10: Safety Documentation
16.5: Operational Planning and Briefings
safety buffers
14.9: Mission Planning Fundamentals (Level I Awareness)
16.5: Operational Planning and Briefings
safety compliance
16.1: Introduction
17.4: Altitude Selection and Ground Sample Distance (GSD)
safety considerations
1: Introduction to Nondestructive Testing (NDT) and Infrared Thermography
9.13: Review Questions
11.13: Summary
12: Mechanical Systems Thermography
safety constraints
19.11: Documentation of Limitations and Anomalies
safety documentation
9.13: Review Questions
safety glasses
9.8: Personal Protective Equipment (PPE)
safety operations
16.13: Summary
safety practices
9.11: Common Safety Mistakes
safety procedures
9.1: Introduction
11.8: Safety Considerations Specific to Electrical Thermography
21.9: SECTION 8- Safety and Professional Judgment
safety protocols
1.7: Safety Considerations in Thermographic Inspections
17.10: Safety Planning and Risk Mitigation
safety requirements
1.6: Ethics and Professional Responsibility
safety rules
16.13: Summary
sample
18.10: Post-Flight Image Review (Initial QC)
saturation
6.4: Temperature Range Selection
scale bars
20.4: Use of Images in Documentation
scanning building envelopes
8.10: Building and Infrastructure Inspection Techniques
scanning systematically
8.8: Electrical Inspection Techniques (Level I Scope)
secure data
16.8: Privacy and Data Protection Considerations
secure media
19.4: Data Transfer from Aircraft to Storage
security
7.7: Data Storage and Backup
sensitive
19.13: Data Security and Confidentiality
sensitive infrastructure
16.8: Privacy and Data Protection Considerations
sensitivity
6.4: Temperature Range Selection
sensor
14.6: Thermal Sensors and Payloads
15.4: Mid-Wave vs. Long-Wave Infrared (MWIR vs. LWIR)
15.8: FoRD Considerations for UAS Payloads
sensor limitations
17.1: Introduction
Sensor Operator
16.4: Roles and Responsibilities in Drone Operations
sensor orientation
17: Mission Planning for Aerial Thermography
17.6: Viewing Angle and Sensor Orientation
18: Aerial Thermal Image Acquisition
Sensor performance
15.5: Atmospheric Effects on MWIR and LWIR
sensor resolution
5.12: Drone Thermography Specification Tables
14.15: Common Errors in Drone Thermography
14.16: Summary
15.9: Typical Payload Configurations
15.10: Documentation and Payload Identification
17.4: Altitude Selection and Ground Sample Distance (GSD)
17.15: Common Mission Planning Errors
18.11: Documentation and Metadata Recording
18.12: Common Aerial Image Acquisition Errors
19.8: Metadata Verification
21.2: SECTION 1- Equipment Setup and Pre-Inspection Verification
21.5: SECTION 4- Aerial Thermography
sensor stability
14.7: Flat Field Correction (FFC)
sensorcapabilities
15.1: Introduction
sensors
5.4: Key Camera Performance Specifications
6.11: Drone-Specific Camera Setup Considerations
14: Introduction to Drone-Based Thermography
14.5: Drone Platforms Used for Thermography
sequence
19.7: File Naming and Identification
serial
6.13: Documentation of Camera Settings
serial number
19.8: Metadata Verification
serious consequences
7.9: Data Integrity and Ethics
setup
6.2: Importance of Proper Camera Setup
12.7: Inspection Workflow (Level I)
21: Practice Level I Practical Examination
setup checklists
10.10: Camera Setup and Configuration Errors
severity assessment
11.1: Introduction
severity levels
12.11: Documentation and Reporting (Level I Role)
sharing
19.13: Data Security and Confidentiality
sharp image detail
18.3: Focus, Range, and Distance (FoRD) Verification
sharpness
19.3: Initial Image Quality Review (QC Confirmation)
shiny metal surfaces
4.10: Review Questions
shiny metals
4.3: Reflectivity
shutdown inspection
12.6: Inspection Conditions and Timing
signal processing
5.2: Basic Components of an Infrared Camera
site access
16: Regulatory and Operational Considerations
16.13: Summary
site name
19.6: File Organization and Folder Structure
site personnel
16.12: Common Regulatory and Operational Errors
situational awareness
9.2: General Safety Principles
9.11: Common Safety Mistakes
10.12: Human Factors and Procedural Errors
size features
17.3: Target Characteristics and Resolution Requirements
sliding
12.2: Basic Mechanical Concepts (Level I Overview)
small targets
11.9: FoRD Considerations in Electrical Inspections
software controls
21.6: SECTION 5- Thermal Tuning Awareness (Software Review)
solar
13.8: Solar Panel (PV) Thermography
14.2: Why Use Drones for Thermography?
17.2: Defining the Inspection Objective
solar arrays
5.8: Handheld vs. Drone-Mounted Infrared Cameras
8.11: Drone-Based Inspection Techniques
18.6: Viewing Angle and Sensor Orientation
solar heating
13.6: Roof Thermography (Ground-Based)
solar inspections
15.12: Review Questions
solar irradiance
13.13: Review Questions

solar loading
2: Fundamentals of Heat Transfer
2.6: Solar Loading
2.8: Environmental Influences on Heat Transfer
8.7: Environmental and Operating Condition Considerations
10.5: Atmospheric and Environmental Errors
14.12: Environmental Influences on Aerial Thermography
17.8: Environmental Assessment
18.7: Environmental Monitoring During Flight
21.10: SECTION 9- Final Self-Assessment
solar loading effects
13.11: Common Errors in Building and Infrastructure Thermography
solar panel inspections
13.13: Review Questions
solar panel thermography
13: Building and Infrastructure Thermography
solar photovoltaic inspections
14.4: Typical Applications of Drone Thermography
solar PV inspections
13.12: Summary
17.9: Time-of-Day Considerations
solar radiation
2.6: Solar Loading
spacing components
17.3: Target Characteristics and Resolution Requirements
span
6.15: Review Questions
span control
6.5: Level and Span Controls
span controls
6: Camera Controls and Setup
spatial detail
15.4: Mid-Wave vs. Long-Wave Infrared (MWIR vs. LWIR)
spatial resolution
3.10: Spatial Resolution and Measurement Accuracy
3.13: Review Questions
5.4: Key Camera Performance Specifications
5.11: Review Questions
6.3: Focus Control
8.6: Distance, Angle, and Access Considerations
10.7: Motion and Stability Errors
10.8: Focus, Range and Distance (FoRD) Errors
15.11: Summary
18.5: In-Flight Image Acquisition Techniques
spectral
14.6: Thermal Sensors and Payloads
spectral band
15.10: Documentation and Payload Identification
spectrum
3: Infrared Theory and Physics
3.12: Summary
spot measurement
21.6: SECTION 5- Thermal Tuning Awareness (Software Review)
stability
14.12: Environmental Influences on Aerial Thermography
stabilization
6.11: Drone-Specific Camera Setup Considerations
15.8: FoRD Considerations for UAS Payloads
18.2: Pre-Flight Camera and Payload Verification
stable
11.6: Inspection Conditions and Timing
stable flight
17.4: Altitude Selection and Ground Sample Distance (GSD)
18.5: In-Flight Image Acquisition Techniques
standard formats
7.4: File Formats
standard glass
4.8: Common Errors Related to Surface Properties
4.10: Review Questions
standardized procedures
12.12: Common Errors in Mechanical Thermography
19.14: Common Post-Flight Data Handling Errors
standards
9.2: General Safety Principles
20.10: Regulatory and Standards Awareness
standoff
14.8: Focus, Range, and Distance (FoRD) in Drone Thermography
standoff distances
16.9: Operational Limitations Affecting Thermography
startup inspection
12.6: Inspection Conditions and Timing
steady_state_inspections
8.4: Steady-State and Transient Inspection Conditions
still images
6.10: Image Capture Settings
7: Image Types and Data Handling
7.3: Still Images vs. Video
storage
7.7: Data Storage and Backup
19.5: Preservation of Original Data
storage media
19.2: Immediate Post-Flight Actions
structural elements
13.3: Common Building and Infrastructure Applications
structures
13.1: Introduction
13.2: Heat Transfer in Buildings (Level I Review)
14.11: Safety Considerations in Drone Thermography
summary
4: Emissivity, Reflectivity, and Transmissivity
sun angle
2.6: Solar Loading
surface
4.5: Relationship Between Emissivity, Reflectivity, and Transmissivity
surface coatings
6.7: Emissivity Input
10.3: Emissivity-Related Errors
surface condition
4.9: Summary
10.3: Emissivity-Related Errors
surface conditions
4.8: Common Errors Related to Surface Properties
6.7: Emissivity Input
surface finish
4.2: Emissivity
surface measurement
4.6: Viewing Angle and Measurement Error
surface properties
3.1: Introduction
3.6: Emission, Reflection, and Transmission
4: Emissivity, Reflectivity, and Transmissivity
surface temperature
1.4: Advantages and Limitations of Thermography
2.2: Heat vs. Temperature
2.3: The Three Modes of Heat Transfer
2.6: Solar Loading
12.1: Introduction
12.13: Summary
surface temperatures
14.12: Environmental Influences on Aerial Thermography
surfaces
12.2: Basic Mechanical Concepts (Level I Overview)
survey
17.2: Defining the Inspection Objective
switchgear
11.3: Common Electrical Components Inspected
symmetrical heating
11.4: Typical Thermal Patterns in Electrical Systems
synchronization
6.11: Drone-Specific Camera Setup Considerations
system_temperatures
8.4: Steady-State and Transient Inspection Conditions
systematic
11.7: Inspection Workflow (Level I)
systems
14.1: Introduction
systems evaluation
1.1: What Is Nondestructive Testing (NDT)?

T

takeoff
14.5: Drone Platforms Used for Thermography
target
8.6: Distance, Angle, and Access Considerations
target characteristics
17: Mission Planning for Aerial Thermography
17.3: Target Characteristics and Resolution Requirements
target distance
5.6: Focus and Image Clarity
target size
17.16: Summary
21.5: SECTION 4- Aerial Thermography
teams
20.8: Communication and Teamwork
teamwork
18.8: Communication During Image Acquisition
20: Review, Documentation, and Professional Practice
technician
10.1: Introduction
technician role
12.1: Introduction
20.1: Introduction
technician skills
21.1: Purpose and Instructions
technician training
6.1: Introduction
8.8: Electrical Inspection Techniques (Level I Scope)
16.1: Introduction
17.12: Pre-Flight Briefing Participation (Level I Role)
technicians
1.6: Ethics and Professional Responsibility
2.9: Practical Implications for Thermography
5.7: Camera Calibration and Accuracy
6.2: Importance of Proper Camera Setup
6.7: Emissivity Input
7.10: Drone-Specific Data Handling Considerations
8.6: Distance, Angle, and Access Considerations
9.4: Mechanical and Industrial Safety
9.9: Emergency Preparedness
10.2: Measurement vs. Indication Errors
19.5: Preservation of Original Data
20.12: Summary
techniques
8.1: Introduction

technology
13.8: Solar Panel (PV) Thermography
14.3: Limitations of Drone-Based Thermography
15.8: FoRD Considerations for UAS Payloads
telephoto
15.4: Mid-Wave vs. Long-Wave Infrared (MWIR vs. LWIR)
temperature
2: Fundamentals of Heat Transfer
2.2: Heat vs. Temperature
2.11: Review Questions
3: Infrared Theory and Physics
3.1: Introduction
3.4: Blackbody Radiation
3.5: Relationship Between Temperature and Infrared Radiation
5.5: Image Display and Color Palettes
5.6: Focus and Image Clarity
6.7: Emissivity Input
6.13: Documentation of Camera Settings
10.2: Measurement vs. Indication Errors
13.5: Inspection Conditions and Timing for Buildings
temperature accuracy
3.7: Apparent Temperature
temperature anomalies
11.5: Comparative Inspection Techniques
13.4: Building Envelope Thermography
temperature attenuation
10.5: Atmospheric and Environmental Errors
temperature changes
18.7: Environmental Monitoring During Flight
temperature comparison
8.3: Qualitative vs. Quantitative Inspections
temperature data
5.2: Basic Components of an Infrared Camera
6.6: Color Palettes
6.10: Image Capture Settings
7.2: Thermal Image Types
15.7: Gimbal Stabilization and Image Quality
temperature detection
3.3: Infrared Wavelength Bands
temperature differences
2.1: Introduction
2.7: Heat Generation Sources
2.10: Summary
3.9: Infrared Detectors and Image Formation
5.4: Key Camera Performance Specifications
8.2: Passive and Active Thermography
temperature gradients
11.4: Typical Thermal Patterns in Electrical Systems
12.4: Typical Thermal Patterns in Mechanical Systems
temperature information
7.4: File Formats
temperature measurement
2.2: Heat vs. Temperature
3.7: Apparent Temperature
3.13: Review Questions
4.1: Introduction
4.8: Common Errors Related to Surface Properties
5.12: Drone Thermography Specification Tables
6.3: Focus Control
7.2: Thermal Image Types
10.3: Emissivity-Related Errors
10.8: Focus, Range and Distance (FoRD) Errors
14.7: Flat Field Correction (FFC)
temperature measurements
8.3: Qualitative vs. Quantitative Inspections
temperature monitoring
11.10: Environmental Influences
temperature observation
21.8: SECTION 7- Documentation Practice
temperature patterns
13.1: Introduction
temperature range
6: Camera Controls and Setup
6.1: Introduction
6.5: Level and Span Controls
17.7: Focus, Range, and Distance (FoRD) Verification
18.2: Pre-Flight Camera and Payload Verification
18.4: Test Image Capture (Before Full Mission)
19.3: Initial Image Quality Review (QC Confirmation)
20.2: Review of Collected Data (Level I Role)
temperature range verification
18.3: Focus, Range, and Distance (FoRD) Verification
temperature ranges
6.4: Temperature Range Selection
6.12: Common Setup Errors
temperature readings
4.7: Practical Camera Setup Considerations
4.10: Review Questions
10.3: Emissivity-Related Errors
temperature regulation
2.5: Thermal Mass and Heat Storage
temperature stability
2.4: Steady-State and Transient Heat Conditions
terrain
9.6: Environmental and Outdoor Safety
test captures
18.3: Focus, Range, and Distance (FoRD) Verification
test images
18.4: Test Image Capture (Before Full Mission)
testing methods
1.9: Review Questions
textbook
4.5: Relationship Between Emissivity, Reflectivity, and Transmissivity
Thermal
3.12: Summary
8.1: Introduction
12.7: Inspection Workflow (Level I)
13.8: Solar Panel (PV) Thermography
14: Introduction to Drone-Based Thermography
14.1: Introduction
18.14: Summary
21: Practice Level I Practical Examination
Glossary
thermal analysis
1.9: Review Questions
4: Emissivity, Reflectivity, and Transmissivity
8.3: Qualitative vs. Quantitative Inspections
thermal anomalies
1.5: The Role of the Thermography Level I Technician
thermal artifacts
14.7: Flat Field Correction (FFC)
thermal barriers
13.3: Common Building and Infrastructure Applications
thermal bridging
13.4: Building Envelope Thermography
thermal camera
21.2: SECTION 1- Equipment Setup and Pre-Inspection Verification
thermal cameras
6.5: Level and Span Controls
thermal contrast
2.4: Steady-State and Transient Heat Conditions
2.9: Practical Implications for Thermography
6.2: Importance of Proper Camera Setup
7.11: Quality Control Checks
10.5: Atmospheric and Environmental Errors
10.6: Thermal Loading and Operating Condition Errors
10.8: Focus, Range and Distance (FoRD) Errors
14.12: Environmental Influences on Aerial Thermography
17.3: Target Characteristics and Resolution Requirements
17.9: Time-of-Day Considerations
18.4: Test Image Capture (Before Full Mission)
19.3: Initial Image Quality Review (QC Confirmation)
20.2: Review of Collected Data (Level I Role)
21.7: SECTION 6- Quality Control (QC)
thermal data
7.4: File Formats
7.10: Drone-Specific Data Handling Considerations
11.1: Introduction
12.1: Introduction
19.4: Data Transfer from Aircraft to Storage
thermal data collection
17.1: Introduction
thermal data quality
17.6: Viewing Angle and Sensor Orientation
thermal energy
2.1: Introduction
2.2: Heat vs. Temperature
thermal equilibrium
4.2: Emissivity
thermal errors
10.13: Summary
thermal flow
2.3: The Three Modes of Heat Transfer
thermal image
5.2: Basic Components of an Infrared Camera
thermal image quality
5.12: Drone Thermography Specification Tables
18.15: Review Questions
thermal imagery
15.7: Gimbal Stabilization and Image Quality
18.9: Managing Multiple Sensors (Thermal + Visual)
thermal images
1.3: Infrared Thermography as an NDT Method
1.5: The Role of the Thermography Level I Technician
2.2: Heat vs. Temperature
7.2: Thermal Image Types
7.5: Metadata and Embedded Information
10.1: Introduction
19.6: File Organization and Folder Structure
20.4: Use of Images in Documentation

thermal imaging
TitlePage
2.7: Heat Generation Sources
2.8: Environmental Influences on Heat Transfer
3.7: Apparent Temperature
3.9: Infrared Detectors and Image Formation
3.10: Spatial Resolution and Measurement Accuracy
3.13: Review Questions
5.1: Introduction
5.4: Key Camera Performance Specifications
5.6: Focus and Image Clarity
6.15: Review Questions
6.16: Step-by-Step Camera Setup Checklists
7: Image Types and Data Handling
8: Inspection Techniques
8.14: Review Questions
10.4: Reflection Errors
11.10: Environmental Influences
14.7: Flat Field Correction (FFC)
19.16: Review Questions
21.6: SECTION 5- Thermal Tuning Awareness (Software Review)
21.8: SECTION 7- Documentation Practice References and Standards
thermal indications
4.9: Summary
thermal inspection
15.12: Review Questions
19.9: Data Backup and Redundancy
21.2: SECTION 1- Equipment Setup and Pre-Inspection Verification
thermal inspections
8.3: Qualitative vs. Quantitative Inspections
14.16: Summary
thermal loading errors
10: Common Sources of Error
thermal mass
2: Fundamentals of Heat Transfer
2.5: Thermal Mass and Heat Storage
2.11: Review Questions
thermal patterns
2.1: Introduction
2.4: Steady-State and Transient Heat Conditions
2.6: Solar Loading
2.9: Practical Implications for Thermography
2.10: Summary
3.1: Introduction
4.7: Practical Camera Setup Considerations
6.3: Focus Control
8.3: Qualitative vs. Quantitative Inspections
8.8: Electrical Inspection Techniques (Level I Scope)
10.2: Measurement vs. Indication Errors
10.4: Reflection Errors
11: Electrical Systems Thermography
11.11: Documentation and Reporting (Level I Role)
11.13: Summary
12: Mechanical Systems Thermography
12.1: Introduction
12.4: Typical Thermal Patterns in Mechanical Systems
12.11: Documentation and Reporting (Level I Role)
13.2: Heat Transfer in Buildings (Level I Review)
13.9: Infrastructure Thermography
13.10: Documentation and Reporting (Level I Role)
20.3: Documentation Standards
thermal payload
15.2: Thermal Sensor Resolution and Pixel Count
16.4: Roles and Responsibilities in Drone Operations
18.2: Pre-Flight Camera and Payload Verification
19.2: Immediate Post-Flight Actions
thermal payloads
14.16: Summary
thermal performance
2.5: Thermal Mass and Heat Storage
13.1: Introduction
13.12: Summary
thermal radiation
4.2: Emissivity
4.4: Transmissivity
thermal sensitivity
5.4: Key Camera Performance Specifications
6.5: Level and Span Controls
thermal sensor
7.14: Inspection Log Template
15.1: Introduction
15.3: Lens Field of View (FOV) and Resolution
18.2: Pre-Flight Camera and Payload Verification
thermal sensors
5.12: Drone Thermography Specification Tables
15: UAS Platforms and Thermal Payloads
15.5: Atmospheric Effects on MWIR and LWIR
18.1: Introduction
thermal shock
5.9: Care, Handling, and Maintenance
thermal testing
Appendix
thermal tuning
10.13: Summary
10.14: Review Questions
14.15: Common Errors in Drone Thermography
18.12: Common Aerial Image Acquisition Errors
21.6: SECTION 5- Thermal Tuning Awareness (Software Review)
21.10: SECTION 9- Final Self-Assessment
thermal video
7.3: Still Images vs. Video
thermal_contrast
8.4: Steady-State and Transient Inspection Conditions
thermal_patterns
8.4: Steady-State and Transient Inspection Conditions
thermalpayloads
15.1: Introduction
thermodynamics
3.4: Blackbody Radiation
thermogram
3.9: Infrared Detectors and Image Formation
Thermographer
16.4: Roles and Responsibilities in Drone Operations
thermographers
3.1: Introduction
thermographers responsibilities
7.13: Review Questions
thermographic
3.12: Summary
5.6: Focus and Image Clarity
7.7: Data Storage and Backup
8.1: Introduction
8.2: Passive and Active Thermography
9.2: General Safety Principles
9.4: Mechanical and Industrial Safety
9.5: Working at Heights
9.12: Summary
10.2: Measurement vs. Indication Errors
11.4: Typical Thermal Patterns in Electrical Systems
12.4: Typical Thermal Patterns in Mechanical Systems
14.5: Drone Platforms Used for Thermography
14.17: Review Questions
16.2: Overview of Applicable Regulatory Frameworks
16.6: Site Access and Permissions
16.8: Privacy and Data Protection Considerations
19.13: Data Security and Confidentiality
20.8: Communication and Teamwork
thermographic cameras
3.3: Infrared Wavelength Bands
thermographic data
7.1: Introduction
8.14: Review Questions
thermographic error
10.3: Emissivity-Related Errors
thermographic image
5.2: Basic Components of an Infrared Camera
thermographic image quality
12.14: Review Questions
thermographic inspection
21.2: SECTION 1- Equipment Setup and Pre-Inspection Verification
thermographic inspections
2.1: Introduction
2.4: Steady-State and Transient Heat Conditions
2.11: Review Questions
4.10: Review Questions
5.3: Infrared Detector Types
5.11: Review Questions
6.1: Introduction
7.1: Introduction
7.2: Thermal Image Types
7.13: Review Questions
8.7: Environmental and Operating Condition Considerations
9.1: Introduction
9.13: Review Questions
16.1: Introduction
16.14: Review Questions
20.1: Introduction
thermographic measurements
4.1: Introduction
thermographic practice
20.7: Professional Conduct and Ethics
20.13: Comprehensive Review Questions
thermographic signal
3.6: Emission, Reflection, and Transmission
thermographicdata
15.1: Introduction

thermography
InfoPage
1.3: Infrared Thermography as an NDT Method
1.5: The Role of the Thermography Level I Technician
1.6: Ethics and Professional Responsibility
1.7: Safety Considerations in Thermographic Inspections
2.2: Heat vs. Temperature
2.3: The Three Modes of Heat Transfer
2.6: Solar Loading
2.7: Heat Generation Sources
2.8: Environmental Influences on Heat Transfer
2.10: Summary
3.1: Introduction
3.6: Emission, Reflection, and Transmission
4.1: Introduction
4.4: Transmissivity
4.6: Viewing Angle and Measurement Error
4.7: Practical Camera Setup Considerations
4.10: Review Questions
5.11: Review Questions
6.1: Introduction
6.3: Focus Control
6.11: Drone-Specific Camera Setup Considerations
6.14: Summary
6.16: Step-by-Step Camera Setup Checklists
7.10: Drone-Specific Data Handling Considerations
7.14: Inspection Log Template
8: Inspection Techniques
8.11: Drone-Based Inspection Techniques
8.14: Review Questions
9.7: Drone-Based Thermography Safety
9.14: Job Hazard Analysis (JHA) Templates
10.4: Reflection Errors
10.6: Thermal Loading and Operating Condition Errors
10.8: Focus, Range and Distance (FoRD) Errors
10.13: Summary
11: Electrical Systems Thermography
11.1: Introduction
11.3: Common Electrical Components Inspected
11.6: Inspection Conditions and Timing
11.7: Inspection Workflow (Level I)
11.8: Safety Considerations Specific to Electrical Thermography
12: Mechanical Systems Thermography
12.1: Introduction
12.7: Inspection Workflow (Level I)
12.13: Summary
12.14: Review Questions
13: Building and Infrastructure Thermography
13.1: Introduction
13.2: Heat Transfer in Buildings (Level I Review)
13.3: Common Building and Infrastructure Applications
13.5: Inspection Conditions and Timing for Buildings
13.7: Drone-Based Roof Thermography
13.8: Solar Panel (PV) Thermography
13.9: Infrastructure Thermography
13.12: Summary
13.13: Review Questions
14: Introduction to Drone-Based Thermography
14.1: Introduction
14.2: Why Use Drones for Thermography?
14.3: Limitations of Drone-Based Thermography
14.6: Thermal Sensors and Payloads
14.7: Flat Field Correction (FFC)
14.11: Safety Considerations in Drone Thermography
15.5: Atmospheric Effects on MWIR and LWIR
15.11: Summary
16.7: Electrical and Industrial Regulatory Awareness
16.13: Summary
17.2: Defining the Inspection Objective
17.13: In-Flight Data Collection Considerations
18.1: Introduction
18.8: Communication During Image Acquisition
18.16: Quality Control (QC) Checklists for Aerial Thermography
19.1: Introduction
20.9: Continuous Improvement and Professional Development
21: Practice Level I Practical Examination
21.1: Purpose and Instructions
21.7: SECTION 6- Quality Control (QC)
Appendix
References and Standards
thermography compliance
16.14: Review Questions
thermography Level I
9.1: Introduction
10.1: Introduction
17.1: Introduction
19.1: Introduction
20.1: Introduction
Thermography Level I technician
1.9: Review Questions
thermography prevention
10.3: Emissivity-Related Errors
thermography technician
1: Introduction to Nondestructive Testing (NDT) and Infrared Thermography
5.1: Introduction
7.1: Introduction
ThermographyLevelI
15.1: Introduction
time
18.11: Documentation and Metadata Recording
19.8: Metadata Verification
time of day
2.6: Solar Loading
17.9: Time-of-Day Considerations
timing
8.10: Building and Infrastructure Inspection Techniques
timing factors
17.16: Summary
tools
9.4: Mechanical and Industrial Safety
towers
14.2: Why Use Drones for Thermography?
traceability
7.5: Metadata and Embedded Information
7.12: Summary
15.10: Documentation and Payload Identification
19.6: File Organization and Folder Structure
19.10: Flight Logs and Supporting Data
20.3: Documentation Standards
20.12: Summary
training
9.9: Emergency Preparedness
9.14: Job Hazard Analysis (JHA) Templates
20.9: Continuous Improvement and Professional Development
21.1: Purpose and Instructions
Appendix
training images
7.2: Thermal Image Types
training methods
8.8: Electrical Inspection Techniques (Level I Scope)
transfer
20.8: Communication and Teamwork
transformers
11.3: Common Electrical Components Inspected
transient
2: Fundamentals of Heat Transfer
transient conditions
2.10: Summary
7.3: Still Images vs. Video
transient heat transfer
2.4: Steady-State and Transient Heat Conditions
transient patterns
12.6: Inspection Conditions and Timing
transient_inspections
8.4: Steady-State and Transient Inspection Conditions
transmission
3: Infrared Theory and Physics
3.6: Emission, Reflection, and Transmission
4.5: Relationship Between Emissivity, Reflectivity, and Transmissivity
transmissivity
4: Emissivity, Reflectivity, and Transmissivity
4.1: Introduction
4.4: Transmissivity
4.9: Summary
transparency
20.5: Handling Limitations and Uncertainty
transparent
4.4: Transmissivity
true surface temperature
3.7: Apparent Temperature
trust
20.12: Summary
trust and safety
20.7: Professional Conduct and Ethics

U

UAS
InfoPage
15.1: Introduction
15.11: Summary
16.1: Introduction
Ultrasonic Testing
1.2: Common NDT Methods
ultraviolet
3.2: The Electromagnetic Spectrum
unauthorized access
19.9: Data Backup and Redundancy
unauthorized modification
7.7: Data Storage and Backup
unbalanced loads
11.5: Comparative Inspection Techniques
uncooled
5.10: Summary
uncooled detectors
5.3: Infrared Detector Types
Uncooled microbolometers
3.9: Infrared Detectors and Image Formation
15.5: Atmospheric Effects on MWIR and LWIR
unethical behavior
7.9: Data Integrity and Ethics
uneven heating
11.4: Typical Thermal Patterns in Electrical Systems
unfavorable conditions
17.8: Environmental Assessment
uniform heating
11.4: Typical Thermal Patterns in Electrical Systems
uninsulated areas
8.5: Comparative Inspection Techniques
unmanned
14.1: Introduction
unmanned aircraft systems
16.1: Introduction
UnmannedAircraftSystems
15.1: Introduction
unsafe condition
21.9: SECTION 8- Safety and Professional Judgment
unusual patterns
12.1: Introduction

usability
19.6: File Organization and Folder Structure
usable altitude
15.11: Summary
utility corridors
13.9: Infrastructure Thermography
14.4: Typical Applications of Drone Thermography

V

valid data
17.3: Target Characteristics and Resolution Requirements
validation
21: Practice Level I Practical Examination
verbal cues
17.11: Coordination and Communication
verification
5.7: Camera Calibration and Accuracy
6.11: Drone-Specific Camera Setup Considerations
6.12: Common Setup Errors
18.14: Summary
verify focus
14.15: Common Errors in Drone Thermography
18.12: Common Aerial Image Acquisition Errors
verify FoRD
17.15: Common Mission Planning Errors
verify payload capability
15.7: Gimbal Stabilization and Image Quality
verify settings
10.10: Camera Setup and Configuration Errors
vertical
14.5: Drone Platforms Used for Thermography
vibration
10.7: Motion and Stability Errors
12.8: Safety Considerations Specific to Mechanical Thermography
video
6.10: Image Capture Settings
7: Image Types and Data Handling
viewing angle
4.10: Review Questions
8.6: Distance, Angle, and Access Considerations
10.4: Reflection Errors
17: Mission Planning for Aerial Thermography
17.6: Viewing Angle and Sensor Orientation
17.16: Summary
21.5: SECTION 4- Aerial Thermography
viewing angles
15.8: FoRD Considerations for UAS Payloads
17.5: Flight Path and Coverage Planning
18.6: Viewing Angle and Sensor Orientation
visible light
3.2: The Electromagnetic Spectrum
visual data
7.10: Drone-Specific Data Handling Considerations
visual documentation
7.4: File Formats
visual imagery
14.13: Data Collection and Documentation (Level I Role)
18.9: Managing Multiple Sensors (Thermal + Visual)
visual images
7.8: Data Transfer and Handoff
19.6: File Organization and Folder Structure
20.4: Use of Images in Documentation
Visual Line of Sight
16.3: Aviation Regulations for Drone-Based Thermography
Visual Observer
16.4: Roles and Responsibilities in Drone Operations
visual patterns
6.6: Color Palettes
visual presentation
21.6: SECTION 5- Thermal Tuning Awareness (Software Review)
Visual Testing
1.2: Common NDT Methods
VLOS
16.3: Aviation Regulations for Drone-Based Thermography
VO
16.4: Roles and Responsibilities in Drone Operations
voltage
11.2: Basic Electrical Concepts (Level I Overview)

W

waiver applications
16.1: Introduction
walls
13.4: Building Envelope Thermography
wavelength
3: Infrared Theory and Physics
3.5: Relationship Between Temperature and Infrared Radiation
15.6: Radiometric vs. Non-Radiometric Thermal Payloads
weather
9.6: Environmental and Outdoor Safety
weather conditions
17.12: Pre-Flight Briefing Participation (Level I Role)
weather events
17.8: Environmental Assessment
wide FOV
15.4: Mid-Wave vs. Long-Wave Infrared (MWIR vs. LWIR)
Wien's Displacement Law
3.5: Relationship Between Temperature and Infrared Radiation
wind
8.7: Environmental and Operating Condition Considerations
10.5: Atmospheric and Environmental Errors
wind effects
14.12: Environmental Influences on Aerial Thermography
wind gusts
10.7: Motion and Stability Errors
wind speed
2.8: Environmental Influences on Heat Transfer
7.14: Inspection Log Template
17.8: Environmental Assessment
18.7: Environmental Monitoring During Flight
Windows
13.3: Common Building and Infrastructure Applications
work
16.6: Site Access and Permissions
workflow
11: Electrical Systems Thermography
11.7: Inspection Workflow (Level I)
12: Mechanical Systems Thermography
12.7: Inspection Workflow (Level I)
working at heights
9: Safety in Thermographic Inspections
9.13: Review Questions
workplace
16.2: Overview of Applicable Regulatory Frameworks
workplace safety
21.9: SECTION 8- Safety and Professional Judgment
Worksheet
17.18: Mission Planning Worksheets (Aerial Thermography)
written procedures
13.6: Roof Thermography (Ground-Based)

Y

yaw minimization
18.5: In-Flight Image Acquisition Techniques

Glossary

Apparent Temperature | The temperature indicated by a thermal camera, influenced by emissivity, reflections, atmospheric effects, and camera settings.
See Chapters 4, 6, 7

ASNT | American Society for Nondestructive Testing

Atmospheric Attenuation | The reduction of infrared radiation reaching the camera due to absorption and scattering by the atmosphere. *See Chapters 3, 15, 17*

Blackbody | An idealized object that absorbs all incident radiation and emits infrared radiation with maximum efficiency for a given temperature.
See Chapter 3

Calibration | Verification of a thermal camera's measurement accuracy against a known reference, typically performed by the manufacturer or authorized service provider.
See Chapters 5, 6

Conduction | Heat transfer through direct contact within a material. *See Chapter 2*

Convection | Heat transfer through the movement of fluids (liquids or gases).
See Chapter 2

CP-105 | ASNT Training Outlines for Nondestructive Testing Personnel

Emissivity | A material property describing how effectively a surface emits infrared radiation compared to a blackbody.
See Chapters 4, 6, 10

FFC | Flat Field Correction

Flat Field Correction (FFC) | An internal camera process that compensates for non-uniform detector response to improve image uniformity.
See Chapters 6, 10

Focus | A foundational concept describing three capture-critical factors that determine thermal data validity; FoRD errors cannot be corrected in software.
See Chapters 6, 10, 15, 17, 18

FoRD | Focus, Range, and Distance

FOV | Field of View

Ground Sample Distance (GSD) | The physical ground area represented by a single pixel in an image, commonly used in aerial thermography.
See Chapters 15, 17

GSD | Ground Sample Distance

Infrared Radiation | Electromagnetic radiation emitted by objects as a function of temperature, with wavelengths longer than visible light.
See Chapter 3

IR | Infrared

Isotherm | A visual overlay highlighting pixels within a selected temperature range.
See Chapter 7, Appendix B

Level and Span | Display controls that define how temperature values are mapped to colors in a thermal image.
See Chapters 6, 7, Appendix B

LWIR | Long-Wave Infrared (approximately 8–12 µm)

Motion Blur | Loss of image clarity caused by camera or target movement during image capture.
See Chapters 10, 18

MWIR | Mid-Wave Infrared (approximately 3–5 µm)

NDT | Nondestructive Testing

NETD | Noise Equivalent Temperature Difference

OJT | On-the-Job Training

Radiation | Heat transfer through electromagnetic waves without a physical medium.
See Chapters 2, 3

Radiometric Image | A thermal image containing temperature data for each pixel.
See Chapters 7, 18, 19

Reflected Apparent Temperature | Infrared energy reflected from surrounding objects rather than emitted by the target.
See Chapters 4, 6

RPIC | Remote Pilot in Command

RSI | Related Supplemental Instruction

Solar Loading | Surface heating caused by absorbed solar radiation, which can influence thermographic results.
See Chapters 2, 8, 17

TFR | Temporary Flight Restriction

Thermal Contrast | The temperature difference that allows a target to be distinguished from its surroundings.
See Chapters 2, 8

Thermal Sensitivity (NETD) | The smallest temperature difference a thermal camera can resolve.
See Chapters 5, 8

Thermogram | A visual representation of infrared radiation emitted by a surface.
See Chapters 1, 7

UAS | Unmanned Aircraft System

VO | Visual Observer

Detailed Licensing

Loading...

Appendix A

ASNT CP-105 Alignment – Thermography Level I

Purpose of This Appendix

This appendix explains how *[Textbook Title]* aligns with the American Society for Nondestructive Testing (ASNT) CP-105 training requirements for Thermography Level I. It is provided to help students, instructors, auditors, and industry partners understand how the content of this textbook supports formal Level I training, practical skill development, and certification preparation.

Applicable Standard

- **Standard:** ASNT CP-105 – *Training Outlines for Nondestructive Testing Personnel*
- **Method:** Infrared / Thermal Testing (IR/TT)
- **Certification Level:** Level I
- **Minimum Formal Training Requirement: 32 hours**

ASNT CP-105 defines the minimum training topics and hours required for personnel seeking Thermography Level I certification under employer-based certification programs.

Scope of Alignment

This textbook meets or exceeds ASNT CP-105 Thermography Level I requirements by providing instruction in:

- Infrared and heat transfer fundamentals
- Camera systems and operational controls
- Emissivity and measurement parameters
- Inspection techniques and common applications
- Safety and hazard awareness
- Sources of error and inspection limitations
- Data handling, quality control, and documentation
- Hands-on practical exercises and assessment

Drone-based thermography is included as an inspection platform and application context, consistent with CP-105 guidance, and does not change the scope or certification level.

CP-105 Topic Mapping to Textbook Chapters

CP-105 Required Topic Area (Level I)	Textbook Coverage
Basic Heat Transfer	Chapter 2
Infrared Theory and Physics	Chapter 3
Emissivity, Reflectivity, Transmissivity	Chapter 4
IR Equipment and Instrumentation	Chapters 5–6
Image Types and Data Handling	Chapter 7
Inspection Techniques	Chapter 8
Safety	Chapter 9
Sources of Error and Limitations	Chapter 10
Electrical Applications	Chapter 11
Mechanical Applications	Chapter 12
Building / Infrastructure Applications	Chapter 13
Procedures, Documentation, Ethics	Chapter 20

CP-105 Required Topic Area (Level I)	Textbook Coverage
Practical Training and Demonstration	Labs + Practice & Formal Practical Exams

Training Hour Support

The curriculum supported by this textbook provides a minimum of 32 hours of formal training, consistent with CP-105 Level I requirements.

Typical distribution:

- **Lecture / Theory:** ~18–20 hours
- **Hands-On / Practical:** ~14–18 hours

Expanded labs, drone-based exercises, and software instruction may increase total instructional time beyond the minimum, which is permitted under CP-105.

Level I Role Definition and Boundaries

Consistent with ASNT CP-105, this textbook emphasizes that Thermography Level I personnel are qualified to:

- Set up and verify infrared equipment
- Safely acquire thermal data
- Recognize and document thermal patterns
- Perform quality control and data handling

Thermography Level I personnel are **not** responsible for:

- Data interpretation or diagnosis
- Severity classification
- Root-cause determination
- Repair or corrective action recommendations

These responsibilities belong to Thermography Level II or Level III personnel, as defined by employer certification programs.

Drone-Based Thermography Statement

Drone-based thermography content in this textbook applies the same physics, limitations, safety principles, and documentation requirements as ground-based inspections. All aerial thermography instruction reinforces Level I responsibilities related to data acquisition and quality, not interpretation or flight authorization.

Compliance Statement

This textbook is aligned with ASNT CP-105 training requirements for Thermography Level I and supports the minimum formal training hours, required topic coverage, and practical skill development necessary for Level I certification under an employer-based certification program.

Alignment with ASNT SNT-TC-1A (Employer Certification Programs)

Relationship Between CP-105 and SNT-TC-1A

ASNT **SNT-TC-1A** establishes the framework for **employer-based qualification and certification** of NDT personnel. While CP-105 defines *training content and minimum hours*, SNT-TC-1A defines *how employers certify personnel* using that training.

This textbook is designed to support **both documents** as follows:

· **CP-105** → Defines *what is taught*

· **SNT-TC-1A** → Defines *how personnel are qualified and certified by employers*

SNT-TC-1A Language Alignment

Under SNT-TC-1A, Thermography Level I personnel are described as individuals who:

“Are qualified to perform specific calibrations, tests, and inspections and to record results in accordance with written instructions.”

This textbook aligns with that definition by emphasizing that Level I personnel:

· Follow **written procedures and checklists**

· Perform **equipment setup and verification**

· Conduct **safe and compliant data acquisition**

· Record **objective observations and inspection data**

· Recognize **limitations and sources of error**

· Refer results to **Level II or Level III personnel** for interpretation

At no point does this textbook instruct Level I personnel to:

· Diagnose conditions

· Determine root cause

· Assign severity levels

· Recommend corrective actions

These responsibilities are explicitly reserved for **Level II and Level III** personnel, consistent with SNT-TC-1A.

Training, Experience, and Certification Pathway

This textbook supports the **training portion** of employer certification programs established under SNT-TC-1A by:

· Meeting or exceeding CP-105 **formal training hour requirements**

· Supporting **practical skill demonstration**

· Reinforcing **ethical and professional boundaries**

· Preparing students for **employer-administered written and practical exams**

Final certification decisions, including required experience hours, examinations, and authorization, remain the responsibility of the **employer's Written Practice**, as required by SNT-TC-1A.

Employer Use Statement

This textbook may be used as part of an employer's formal training program for Thermography Level I personnel under SNT-TC-1A, provided that certification decisions are made in accordance with the employer's written practice.

Key Takeaway for Students and Employers

CP-105 ensures you were trained correctly.
SNT-TC-1A ensures you are certified correctly.
This textbook supports both.

Sidebar: What CP-105 Means for You

What CP-105 Means for You as a Level I Student

CP-105 is not a test—it's a roadmap.
It defines *what you must be taught* and *what skills you must practice* before you can be certified as a Thermography Level I technician.

As a student, CP-105 means:

· You are learning **industry-recognized fundamentals,** not informal or ad-hoc material

· Your training hours meet **national minimum standards**

· Your skills focus on **safe equipment setup, data acquisition, and documentation**

· You are **not expected to diagnose problems or recommend repairs**

Completing a CP-105–aligned course helps ensure that when you enter the workforce:

· Your training is recognizable to employers

· Your skills match what Level I thermographers are allowed to do

· You are prepared to advance to Level II with proper experience

Important:
Completing this course does **not automatically certify you.** Certification is granted by your employer under an approved certification program, but CP-105 alignment ensures your training meets the technical requirements needed for that certification.

Appendix B

ISO 9712 Alignment Matrix – Thermographic Testing (Level 1)

Purpose of This Appendix

This appendix documents how *[Textbook Title]* supports preparation for **ISO 9712: Thermographic Testing (TT) Level 1** certification. It provides a clear mapping between **ISO 9712 Level 1 requirements** and the chapters, labs, and assessments contained in this textbook.

This appendix is intended for:

· Students exploring a **portable, third-party certification pathway**

· Instructors and curriculum reviewers

· Certification bodies evaluating training suitability

· Employers seeking ISO 9712-ready graduates

Applicable Standard

· **Standard:** ISO 9712: *Non-destructive testing — Qualification and certification of NDT personnel*

· **Method:** Thermographic Testing (TT)

· **Certification Level:** Level 1

· **Certification Model:** Third-party, accredited certification body

ISO 9712 Level 1 Alignment Matrix

ISO 9712 Clause / Requirement	Requirement Summary (Level 1)	Textbook Alignment
Clause 6.1 – Level 1 Definition	Perform thermographic tests in accordance with written instructions; use equipment properly; record and report results within defined criteria	Chapters 8, 11–13, 20; Practice Practical Exam; Documentation Exercises
Clause 7.1 – Eligibility (General)	Eligibility determined by certification body (training, experience, vision, ethics)	Appendix: *ISO 9712 Pathway Overview*
Clause 7.2 – Formal Training	Documented training aligned to TT method and application sectors	Chapters 1–10 (fundamentals & operation); Chapters 11–13 (applications); Chapters 14–19 (aerial TT); Thermal Studio Lab Workbook
Clause 7.3 – Industrial Experience	Logged and verified TT experience hours (scheme-defined)	Appendix: *ISO 9712 Pathway Overview* (experience logs, internship/apprenticeship integration guidance)
Clause 7.4 – Vision Requirements	Near-vision acuity and color vision verification	Chapter 9 (human factors & safety); Appendix: *ISO 9712 Pathway Overview*
Clause 8.1 – Examination Structure	General, Specific, and Practical examinations	Level I Written Exam Study Guide; Practice Written Exam; Practice Practical Examination
Clause 8.1.2 – Examination Elements	Assessment of theory, application, and hands-on performance	Chapters 1–10 (General); Chapters 11–13 & 14–19 (Specific); Practical Exam & Labs
Clause 8.2 – Examination Content & Grading	Defined topic coverage and performance criteria	Chapter-aligned exams; Instructor rubrics; QC checklists

ISO 9712 Clause / Requirement	Requirement Summary (Level 1)	Textbook Alignment
Clause 8.4 – Examination Conduct	Controlled exam administration and impartiality	Instructor Notes; Professional Practice Guidance (Chapter 20)
Clause 9 – Certification	Certification issued by accredited certification body	Appendix: *ISO 9712 Pathway Overview* (roles & responsibilities)
Clause 10 – Renewal	Continued practice and documentation	Chapter 20; Appendix templates (logs & documentation)
Clause 11 – Recertification	Periodic reassessment per scheme	Appendix: *ISO 9712 Pathway Overview*
Clause 12 – Records	Maintenance of training, exam, and certification records	Chapters 7 & 19 (data handling); Appendix documentation templates
Annex B / Annex D (Practical Guidance)	Practical task structure and specimen evaluation	Practice Practical Exam; QC acceptance/rejection exercises

Scope Clarification

This textbook:

· ✔ Supports **training and exam readiness** for ISO 9712 TT Level 1

· ✔ Reinforces **Level 1 role boundaries and professional discipline**

· ✔ Provides **application coverage across electrical, mechanical, building, and aerial thermography**

This textbook does **not**:

· ❌ Issue ISO 9712 certification

· Replace certification body examinations

· ❌ Define scheme-specific experience hour minimums

Certification is issued **only by an accredited ISO 9712 certification body**.

ISO 9712 Readiness Statement

This textbook provides formal training, practical skill development, and examination preparation consistent with the knowledge and performance expectations of ISO 9712 Thermographic Testing Level 1, subject to certification body eligibility and examination requirements.

Appendix C

FLIR Thermal Studio – Level I Lab Workbook

Course: Thermography Level I
Software: FLIR Thermal Studio
Lab Type: Computer Lab / Hands-On
Student Name: _____
Date: _____
Instructor: _____

IMPORTANT LEVEL I STATEMENT (Read Before Beginning)

Thermal tuning affects visualization only.

Thermal tuning **cannot correct**:

- Poor focus
- Excessive distance / low pixel coverage
- Incorrect capture range
- Motion blur

If data quality is compromised at capture, software cannot fix it.

Initials (Required): _____

Lab Objectives

By completing this workbook, you will be able to:

☐ Navigate the FLIR Thermal Studio interface
☐ Open and manage radiometric thermograms
☐ Adjust level and span appropriately
☐ Apply and remove color palettes
☐ Use isotherms to highlight temperature ranges
☐ Use measurement tools responsibly
☐ Explain why thermal tuning does **not** correct FoRD errors
☐ Demonstrate Level I professional boundaries

SECTION 1: Getting Started with FLIR Thermal Studio

Exercise 1.1 – Software Orientation

Open **FLIR Thermal Studio** and identify the following interface elements.

Interface Element	Located? (✔)	Notes
Image Browser / Project Panel		
Main Thermogram Display		
Palette Selector		
Level & Span Controls		
Measurement Tools		
Isotherm Tools		
Metadata Panel		

Instructor Initials: _____

SECTION 2: Opening and Reviewing a Radiometric Image

Exercise 2.1 – Image Import

1. Open a **radiometric thermal image** provided by the instructor.
2. Confirm the file contains temperature data.

☐ Radiometric data present
☐ Temperature scale visible
☐ Metadata accessible

Image Filename: _____

Reflection Question 2.1

Why is radiometric data required for professional thermography?



SECTION 3: Level and Span (Core Thermal Tuning Skill)

Exercise 3.1 – Automatic vs Manual Level & Span

1. Set level and span to automatic.
2. Observe image contrast.
3. Switch to manual control.

4. Narrow the span gradually.
5. Widen the span again.

Setting	Observations
Automatic	
Narrow Span	
Wide Span	

Critical Question 3.1

Did adjusting level and span change the temperature data or only the visual appearance?

☐ Data changed
☐ Visual appearance only

Explain your answer:

SECTION 4: Color Palettes

Exercise 4.1 – Palette Comparison

Apply the following palettes to the same image:

Palette	Pattern Visibility (Good / Fair / Poor)	Notes
Iron		
Rainbow		
Grayscale		
Lava / Arctic		

Reflection Question 4.1

Did any palette reveal new information, or did they only change how patterns were displayed?

SECTION 5: Isotherms

Exercise 5.1 – Applying Isotherms

1. Enable **isotherms**.
2. Set a temperature threshold.
3. Adjust the threshold higher and lower.

Threshold Temp	Area Highlighted	Notes

Critical Thinking Question 5.1

Is an isotherm a **diagnostic conclusion** or a **visual screening tool**?

☐ Diagnostic
☐ Visual screening

Explain why:

SECTION 6: Measurement Tools (Level I Awareness)

Exercise 6.1 – Spot and Area Measurements

1. Place a **spot** on a clear, focused area.
2. Move the spot slightly.
3. Place a measurement on an out-of-focus area.

Location	Temperature Shown	Confidence Level (High / Low)
Focused Area		
Slight Shift		
Out-of-Focus Area		

Reflection Question 6.1

Why should Level I thermographers avoid drawing conclusions from single measurement values?

SECTION 7: Thermal Tuning vs. FoRD (Critical Lab)

Exercise 7.1 – "You Can't Tune Bad Data"

The instructor will provide:

- One **properly captured** image
- One **out-of-focus or distance-limited** image

Apply identical tuning to both.

Image	Result After Tuning
Proper Capture	
Poor Capture	

Mandatory Statement (Check One)

☐ Thermal tuning can fix FoRD errors
☐ Thermal tuning cannot fix FoRD errors

Explain why (required to pass lab):

Instructor Initials: _____

SECTION 8: Professional Practice & Ethics

Exercise 8.1 – Data Integrity Awareness

Answer **YES or NO**:

Action	Allowed at Level I?
Overwriting original images	
Saving tuned copies separately	
Interpreting root cause	
Using objective language	

Acceptable Language Example

Write one **Level I–appropriate** observation:

SECTION 9: FLIR Thermal Studio – Keyboard Shortcuts

(Shortcuts may vary slightly by version; verify with installed build)

Commonly Used Shortcuts

Function	Shortcut
Open File	**Ctrl + O**
Save Project	**Ctrl + S**
Zoom In	**Ctrl + +**
Zoom Out	**Ctrl + –**
Fit Image to Screen	**Ctrl + 0**
Toggle Full Screen	**F11**
Next Image	**Right Arrow**
Previous Image	**Left Arrow**
Add Spot Measurement	**S**
Add Area / Box	**B**
Toggle Isotherms	**I**
Reset Level & Span	**R**
Palette Selector	**P**
Undo	**Ctrl + Z**
Redo	**Ctrl + Y**

Shortcut Practice

Check off each shortcut after testing it:

☐ Zoom controls
☐ Measurement shortcuts
☐ Isotherm toggle
☐ Level/span reset

SECTION 10: Lab Summary & Student Attestation

Student Summary (Required)

In 3–5 sentences, explain:

- What thermal tuning does
- What it does **not** do
- Why FoRD matters more than software

Student Attestation

I understand the limits of thermal tuning and my responsibilities as a **Thermography Level I** technician.

Student Signature: _____
Date: _____

Instructor Evaluation

☐ Student demonstrated correct tuning techniques
☐ Student respected Level I boundaries

☐ Student understands FoRD limitations
☐ Student passed lab requirements

Instructor Signature: _____
Date: _____

Appendix D

Student Quick-Reference Guide (Level I Thermography)

(Recommended for printing on a single sheet or inside back cover)

Level I Role Reminder

✔ Capture valid thermal data
✔ Verify FoRD
✔ Document observations objectively
❌ Interpret causes
Assign severity
❌ Recommend repairs

FoRD Checklist (Before Capture)

☐ Focus verified at inspection distance
☐ Correct temperature range selected
☐ Distance supports sufficient pixel coverage

FoRD Rule:
If FoRD is wrong, the data is invalid — software cannot fix it.

Common Sources of Error

· Poor focus

· Excessive distance

· Incorrect temperature range

· Reflections

· Solar loading

· Motion blur

· Missed Flat Field Correction

Thermal Tuning Reminder

Thermal tuning adjusts:

· Level

· Span

· Palette

· Isotherms

Thermal tuning **does not**:

· Improve resolution

· Fix focus

· Recover missed data

High-Range vs. Low-Range Camera Use

Low-Range:

· Buildings, roofs, solar, mechanical

· High sensitivity, low max temperature

High-Range:

· Electrical, furnaces, industrial

· Handles hot targets, lower low-ΔT sensitivity

Aerial Thermography Essentials

· Verify GSD before flight

· Maintain planned altitude

· Avoid oblique angles

· Monitor environmental changes

· Perform post-flight QC immediately

Professional Language Examples

✔ “Localized elevated temperature observed.”
✘ “Overheating due to loose connection.”

When in Doubt

Stop. Document. Escalate.
Level II or III makes the call.

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