

Practical Applications of Infrared Thermal Sensing and Imaging Equipment

Third Edition

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Introduction to the Series

Since its conception in 1989, the Tutorial Texts series has grown to more than 70 titles covering many diverse fields of science and engineering. When the series was started, the goal of the series was to provide a way to make the material presented in SPIE short courses available to those who could not attend, and to provide a reference text for those who could. Many of the texts in this series are generated from notes that were presented during these short courses. But as stand-alone documents, short course notes do not generally serve the student or reader well. Short course notes typically are developed on the assumption that supporting material will be presented verbally to complement the notes, which are generally written in summary form to highlight key technical topics and therefore are not intended as stand-alone documents. Additionally, the figures, tables, and other graphically formatted information accompanying the notes require the further explanation given during the instructor's lecture. Thus, by adding the appropriate detail presented during the lecture, the course material can be read and used independently in a tutorial fashion.

What separates the books in this series from other technical monographs and textbooks is the way in which the material is presented. To keep in line with the tutorial nature of the series, many of the topics presented in these texts are followed by detailed examples that further explain the concepts presented. Many pictures and illustrations are included with each text and, where appropriate, tabular reference data are also included.

The topics within the series have grown from the initial areas of geometrical optics, optical detectors, and image processing to include the emerging fields of nanotechnology, biomedical optics, and micromachining. When a proposal for a text is received, each proposal is evaluated to determine the relevance of the proposed topic. This initial reviewing process has been very helpful to authors in identifying, early in the writing process, the need for additional material or other changes in approach that would serve to strengthen the text. Once a manuscript is completed, it is peer reviewed to ensure that chapters communicate accurately the essential ingredients of the processes and technologies under discussion.

It is my goal to maintain the style and quality of books in the series, and to further expand the topic areas to include new emerging fields as they become of interest to our reading audience.

Arthur R. Weeks, Jr.
University of Central Florida

Contents

List of Figures	xiii
List of Tables	xvii
List of Acronyms and Abbreviations	xix
Preface	xxi

Part I: Basics and Instrument Overview

Chapter 1 Introduction	3
1.1 Overview of This Text	3
1.2 Reasons for Using IR Instruments	3
1.3 Advantages of Noncontact Thermal Measurement	4
1.4 Some Historical Background	5
1.5 Evolution of IR Cameras	6
Chapter 2 Basics of Noncontact Thermal Measurements	9
2.1 Heat Transfer and Radiation Exchange Basics	9
2.1.1 Heat and temperature	9
2.1.2 Converting temperature units	9
2.1.3 Three modes of heat transfer	10
2.1.4 Conduction	10
2.1.5 Convection	11
2.1.6 Radiation	12
2.1.7 Radiation exchange at the target surface	13
2.1.8 Specular and diffuse surfaces	14
2.1.9 Transient heat exchange	14
2.2 Infrared Measurement Problem	15
2.2.1 Noncontact thermal measurements	16
2.2.2 Target surface	16
2.2.3 Transmitting medium	20
2.2.4 Measuring instrument	22
2.3 Thermal Scanning and Imaging Instruments	25
2.3.1 Line scanning	25
2.3.2 Two-dimensional opto-mechanical scanning	26

2.3.3	Infrared focal plane array (IRFPA) cameras	27
2.3.4	IRFPA detectors	28
2.3.5	Pyroelectric vidicon thermal imagers	29
Chapter 3	Matching the Instrument to the Application	33
3.1	Radiation Thermometers (Point-Sensing Instruments)	33
3.2	Infrared Cameras—Qualitative and Quantitative	37
3.2.1	Performance parameters of quantitative cameras	39
3.2.1.1	Total field of view (TFOV) and instantaneous field of view (IFOV)	40
3.2.1.2	Temperature sensitivity: MRTD or MRT	40
3.2.1.3	Imaging spatial resolution and instantaneous FOV	41
3.2.1.4	Measurement spatial resolution (IFOV _{meas} or MFOV) for opto-mechanically scanned imagers	43
3.2.1.5	Measurement spatial resolution (IFOV _{meas} or MFOV) for FPA imagers	45
3.2.1.6	Speed of response and frame repetition rate	45
3.2.2	Performance parameters of qualitative cameras	46
3.3	Thermal Imaging Software	46
3.4	Thermal Image Fusion Techniques	48
Chapter 4	Instruments Overview	49
4.1	Introduction and Classification of Instruments	49
4.2	Instrument Manufacturers	50
4.3	Discussion of Instruments	50
4.3.1	Point sensors (radiation thermometers)	50
4.3.1.1	Infrared thermocouples and probes	50
4.3.1.2	Portable hand-held instruments	51
4.3.1.3	On-line monitoring and control	52
4.3.1.4	Special instruments	52
4.3.2	Line scanners	53
4.3.3	Infrared cameras (thermal imagers)	54
4.3.3.1	Cameras, nonmeasuring (thermal viewers)	54
4.3.3.2	Cameras, measuring (thermographic imagers)	55
4.3.3.3	Performance comparisons of FPA measuring cameras	56
4.4	Thermal Imaging Diagnostic Software	57
4.4.1	Quantitative thermal measurements of targets	58
4.4.2	Detailed processing and image diagnostics	59
4.4.3	Image recording, storage, and recovery	59
4.4.4	Image comparison	60
4.4.5	Thermal image fusion	60
4.4.6	Report and database preparation	61

Chapter 5	Using IR Sensing and Imaging Instruments	63
5.1	Introduction: The Thermal Behavior of the Target	63
5.1.1	Emissivity difference	64
5.1.2	Reflectance difference	64
5.1.3	Transmittance difference	64
5.1.4	Geometric difference	64
5.1.5	Mass transport difference	65
5.1.6	Phase-change difference	65
5.1.7	Thermal capacitance difference	65
5.1.8	Induced heating difference	65
5.1.9	Energy conversion difference	65
5.1.10	Direct heat transfer difference	65
5.1.11	Learning about the target environment	66
5.2	Preparation of Equipment for Operation	66
5.2.1	Calibration and radiation reference sources	66
5.2.1.1	Checking calibration	67
5.2.1.2	Transfer calibration	67
5.2.2	Equipment checklist	68
5.2.3	Equipment checkout and calibration	68
5.2.4	Batteries	68
5.3	Avoiding Common Mistakes in Instrument Operation	68
5.3.1	Start-up procedure	69
5.3.2	Memorizing the default values	69
5.3.3	Setting the correct emissivity	69
5.3.4	Filling the IFOVmeas for accurate temperature measurements	70
5.3.5	Aiming normal to the target surface	71
5.3.6	Recognizing and avoiding reflections from external sources	71
5.3.7	Avoiding radiant heat damage to the instrument	72
5.3.8	Using IR transmitting windows	72
5.4	The Importance of Operator Training	72
5.4.1	Training programs and certification	72

Part II: Instrument Applications

Chapter 6	Introduction to Applications	77
Chapter 7	Plant Condition Monitoring and Predictive Maintenance	79
7.1	Introduction	79
7.2	Electrical Findings	80
7.2.1	High electrical resistance	80
7.2.2	Short circuits	80

7.2.3	Open circuits	82
7.2.4	Inductive currents	83
7.2.5	Energized grounds	83
7.2.6	Condition guidelines	84
7.3	Mechanical Findings	85
7.3.1	Friction	85
7.3.2	Valve or pipe blockage/leakage	86
7.3.3	Insulation within the plant or facility	87
7.4	Miscellaneous Applications	87
7.4.1	Rebar location	88
7.4.2	Condenser air in-leakage	88
7.4.3	Containment spray ring headers	88
7.4.4	Hydrogen igniters	88
7.4.5	Effluent thermal plumes	89
7.4.6	Gas leak detection	89
7.4.7	Seal failures	89
Chapter 8	Buildings and Infrastructure	91
8.1	Introduction	91
8.2	Measuring Insulating Properties	92
8.3	Considering the Total Structure	92
8.4	Industrial Roof Moisture Detection	93
8.5	Subsurface Leaks and Anomalies	94
8.6	Thermal Image Fusion Benefit	96
8.7	Thermographic Inspection of Our Aging Infrastructure	96
Chapter 9	Materials Testing	97
9.1	Materials Testing—IR Nondestructive Testing	97
9.2	Failure Modes and Establishment of Acceptance Criteria	99
9.3	Selecting the Right IR Imaging System	99
9.4	Pulsed Heat Injection Applications	101
9.4.1	New signal-based technique simplifies image interpretation	103
9.4.2	Case study: Boiler tube corrosion thinning assessment	103
9.5	Infrastructure NDT	106
Chapter 10	Product and Process Monitoring and Control	107
10.1	Evolution of Noncontact Process Control	107
10.2	Full Image Process Monitoring	109
10.3	Product Monitoring of Semiconductors	110
10.4	Steel Wire Drawing Machine Monitoring	110
10.5	Glass Products Monitoring (Spectral Considerations)	112
10.6	Full Image Process Control	112
10.7	Closing the Loop—Examples	114

Chapter 11 Night Vision, Security, and Surveillance	117
11.1 Introduction	117
11.2 Comparing Thermal Imagers with Image Intensifiers	118
11.3 Homeland Security and other Nonmilitary Applications	118
11.3.1 Aerial-, ground-, and sea-based search and rescue	118
11.3.2 Firefighting and first response	118
11.3.3 Space and airborne reconnaissance	119
11.3.4 Police surveillance and crime detection and security	119
11.3.5 Driver's aid night vision	120
11.3.6 New thermal image fusion applications	121
11.3.7 New military applications	121
Chapter 12 Life Sciences Thermography	123
12.1 Introduction	123
12.2 Thermography as a Diagnostic Aid in the Early Detection of Breast Cancer	123
12.3 Veterinary Medicine	124
12.4 Biological and Threat Assessment Applications	124
Appendix A Commercial Instrument Performance Characteristics	127
Appendix B Manufacturers of IR Sensing and Imaging Instruments	145
Appendix C Table of Generic Normal Emissivities of Materials	149
Appendix D A Glossary of Terms for the Infrared Thermographer	155

List of Figures

Figure	Description	Page
2.1	Conductive heat flow	11
2.2	Convective heat flow	12
2.3	Infrared in the electromagnetic spectrum	13
2.4	Radiative heat flow	13
2.5	Radiation impinging on a surface	14
2.6	Three sets of characteristics in making IR measurements	17
2.7	Blackbody curves at various temperatures	17
2.8	Spectral distributions of a blackbody, graybody, and non-graybody	19
2.9	Components of energy reaching the measuring instrument	19
2.10	Aiming the instrument to avoid point reflections	20
2.11	Infrared atmospheric transmission for a 10-meter path at sea level (50% relative humidity)	21
2.12	Spectral characteristics of glass samples (percent transmission, absorption, and reflectance)	21
2.13	Transmission of IR transmitting materials	22
2.14	Components of an IR radiation thermometer	23
2.15	Typical IR radiation thermometer schematic	24
2.16	Response curves of various IR detectors	25
2.17	(a) The addition of a scanning element to a radiation thermometer for single line scanning. (b) Eliminating the scanning element – the substitution of a linear FPA detector for the single element detector	26
2.18	Infrared line scanner schematic and scanner operation	27
2.19	Infrared opto-mechanical scanning imager	27
2.20	Infrared focal plane array camera schematic	28
2.21	Pyrovidicon camera tube schematic	29
3.1	Instrument speed of response and time constant	34
3.2	Instrument FOV determination	35
3.3	Fields of view of IR radiation thermometers	36
3.4	Measuring temperature of polyethylene	38
3.5	Measuring temperature of polyester	38
3.6	TFOV and IFOV of an IR camera	41

Figure	Description	Page
3.7	Test setup for MRTD measurement and MRTD curve	42
3.8	Test setup for MTF measurement	42
3.9	MRTD and MTF for a system rated at 1 mrad	44
3.10	Test setup for slit response function	44
3.11	Hole response method for determination of IFOV _{meas} (MFOV) for FPA-based cameras	45
3.12	Plot of hole response function for an FPA-based camera where MFOV is measured at 8.2 mrad	46
5.1	Measuring target effective emissivity	70
5.2	Quick calculation for target spot size and IFOV calculation	71
7.1	Excessive heating of a connecting clip due to deterioration	81
7.2	Overheating at a switchyard disconnect due to high contact resistance	81
7.3	Disastrous failure of leaking isolator	82
7.4	Fusion of a visible and thermal image of a complex electrical panel	83
7.5	Overheated pump motor at right caused by lubricant deterioration	86
7.6	Abnormally functioning steam trap shown on the left side	87
7.7	Gas leak in valve appears as a black cloud on the thermogram	89
7.8	Leaking seal in a joint between a gas turbine and a steam boiler	90
8.1	Thermogram of a building showing the effects of air exfiltration	92
8.2	Thermogram of a building showing the effects of insulation deficiencies	93
8.3	Thermogram of a roof with moisture saturation	95
8.4	Roof thermogram with heated interior showing insulation differences and no water saturation	95
8.5	Photo and thermogram of a radiantly heated floor	95
8.6	Insulation void on visibly featureless wall is pinpointed using thermal image fusion	96
9.1	Example of steady-state, active (heat injection) IRNDT for occlusion and void detection	99
9.2	Three-view thermogram of a cable section with electrical current used as the active heat source	100
9.3	Basis for time-resolved IR radiometry (TRIR)	101
9.4	Configuration for pulsed thermography	103
9.5	Examples of IRNDT images using thermal wave injection—see text for descriptions	104
9.6	Results of thermal image reconstruction on a graphite epoxy sample	104

Figure	Description	Page
9.7	In-situ thermogram of a boiler tube section indicating areas of thinning due to corrosion	105
9.8	Thermogram of a new section of boiler tubing not yet put into service—no thinning indicated	105
10.1	Three methods of accomplishing process control	108
10.2	Typical configuration for multisensor process control	108
10.3	Electrolytic tankhouse scan where interelectrode shorts appear as hot spots	109
10.4	Quadrant display of a device under test showing (a) unpowered radiance, (b) powered radiance, (c) emissivity, and (d) “true temperature”	111
10.5	Wire drawing machine capstan thermograms showing (a) proper cooling, and (b) improper cooling	111
10.6	Using the same imager with different filters to measure temperatures of the filaments (top thermogram) and the glass envelope (bottom thermogram)	113
10.7	Thermal image process control using a line scanner and set points	114
10.8	Full image process control using a line scanner and multiple zones: (a) before implementation of full image process control; (b) after implementation of full image process control	115
11.1	Thermogram of a vessel at sea at night in fog (8–12 μm)	119
11.2	Thermogram of an intruder at night (8–12 μm)	120
11.3	Hidden compartment in a vehicle	120
11.4	Driver’s thermal image compared to visible image	121
11.5	Thermogram of freeway traffic at night (8–12 μm)	122
11.6	(a) Visible, (b) thermal, and (c) fused images with smoke	122
11.7	View of a military helicopter from the ground	122
12.1	Sample breast thermograms of three patients: (a) normal, (b) fibrosystic changes, and (c) early stage malignant tumor	124
12.2	Confirmed inflammations at two different locations on a dog’s back	124
12.3	Thermographic results of SARS screening: (a) normal subject, and (b) febrile subject	125
A-1	Target and instrument background	156

List of Tables

Table	Description	Page
2.1	Temperature conversion chart	30
6.1	Industrial applications of thermal sensing and imaging instruments by industry	77
6.2	Industrial applications of thermal sensing and imaging instruments by discipline	78
7.1	Classification of electrical faults	84
7.2	Compensating for wind effects	85

List of Acronyms and Abbreviations

ANSI	American National Standards Institute
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
ASNT	American Society for Nondestructive Testing
ASTM	American Society for Test and Measurement
BCD	binary coded decimal
BST	barium–strontium–titanate
dc emf	direct current electromagnetic force
emf	electromagnetic force
EPRI	Electric Power Research Institute
FLIR	forward-looking infrared
FOV	field of view
FPA	focal plane array
HRSG	heat recovery steam generator
IFOV	instantaneous field of view
IFOV _{meas} or MFOV	measurement IFOV or measurement spatial resolution
IR	infrared
IRFPA	infrared focal plane array
IRNDT	infrared nondestructive testing
IVD	intervertebral disk disease
LWIR	long-wave infrared region
MFOV	<i>see</i> IFOV _{meas}
MRT	minimum resolvable temperature
MRTD	minimum resolvable temperature difference
MTF	modulation transfer function
MWIR	mid-wave infrared region
NDE	nondestructive evaluation
NEI	noise equivalent irradiance
NETD	noise equivalent temperature difference
NIR	near infrared
NIST	National Institute of Standards and Technology (U.S.)
P	proportional

PCMCIA	Personal Computer Memory Card International Association
PI	proportional plus integral
PID	proportional plus integral plus differential
QWIP	quantum well infrared photodetector
SRF	slit response function
SWIR	short-wave infrared region
TE	thermoelectric
TFOV	total field of view
TLV	thermal light valve
TRIR	time-resolved infrared radiometry
TSR	thermographic signal reconstruction
VDC	volts DC

Preface

The mapping of infrared (IR) energy radiated from the surface of natural and manufactured objects makes it possible to detect and recognize objects in the dark and under adverse weather and atmospheric conditions. Quantification of this energy allows users (thermographers) to determine the temperature and thermal behavior of objects.

Infrared thermal sensing and imaging instruments make it possible to measure and map surface temperature and thermal distribution passively and nonintrusively. In addition to the passive measurement of temperature distribution, thermographers have learned to use active or “thermal injection” techniques to study and evaluate the structural integrity of materials and fabricated bonds.

The purposes of this text are:

- To familiarize potential users of commercial IR sensing and imaging instruments with IR measurement and analysis basics;
- To provide the practical information needed for users to select the instrument most appropriate for their application;
- To describe how to perform valid and successful measurements in a variety of applications;
- To serve as a reference to help thermographers examine the validity of new applications.

This text is presented in two parts.

Part I begins with a review of temperature, heat, and heat transfer, with emphasis on radiative heat transfer and its relationship to IR radiation and measurement basics. Physical laws (equations) are presented in terms of their practical importance to the measurement mission.

This is followed by a review and discussion of the characteristics and performance parameters of IR sensing and imaging instruments, including a review of thermal imaging diagnostic software. A discussion of equipment operation follows, including guidelines for making successful measurements.

Part I concludes with a section on training and training programs, highlighting the importance of formal operator training and certification.

What's New?

The second edition of this text was published in 1999, and since that time many improvements have taken place in instrumentation performance and versatility. For example, the almost total replacement of opto-mechanically scanned imagers with focal plane array (FPA)-based “staring” imagers has reduced the size, increased the ruggedness, and improved the spatial resolution of IR cameras, all of which have changed thermographers’ expectations of camera performance.

Thus, this third edition reviews these many changes and how they impact the way thermographers operate, deploy, calibrate, and test the new instruments. In addition, the instruments that have been made essentially obsolete are reviewed as part of the historical evolution of the technology.

Part II introduces typical applications for thermal sensing and imaging instruments. Several chapters present various applications areas and discuss typical solutions to measurement problems.

The applications are grouped into logical categories following the guidelines established by SPIE’s evolving Thermosense series of meetings, held annually since 1978.

In an attempt to classify these applications into logical categories by industry and discipline, the Thermosense symposia usually devote at least one session to each of the following categories:

1. Plant Condition Monitoring and Predictive Maintenance
2. Buildings and Infrastructure
3. Materials Evaluation – Infrared Nondestructive Testing
4. Process Monitoring and Control
5. Night Vision, Security, and Surveillance
6. Life Sciences Thermography
7. Research and Development (R&D)

The first six classifications are self-explanatory; the seventh is a catch-all to include the introduction of new instrumentation or experimental techniques. Papers on subjects classified as “R&D” one year will often be included in one of the other classifications in subsequent years as the instrumentation or techniques mature. Although these classifications have evolved somewhat over the years, they represent reasonable subdivisions. Therefore, the chapters in Part II are organized in general accordance with these classifications.

To assist the user in instrument selection, Appendix A contains a tabulation of currently available instruments by category and manufacturer, including a digest of performance characteristics and features. Appendix B is a current index of manufacturers’ websites, addresses, and phone numbers.

The text also includes quick reference charts and tables to aid the user in on-site measurements (Appendix C) and a glossary of IR/thermography terms (Appendix D).

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