Contents

1	Introduction	8
1.1	Introduction and Problem Statement	ç
2	Physical Basics of Thermography	10
2.1	Basic Principle	11
2.1.1	Law for Black-Body Radiation	12
2.1.2	Law for Real Bodies Radiation	16
2.2	Effects of the Environment on Measuring	29
2.2.1	Effects of the Atmosphere	29
2.2.2	Effects of Ambient Radiation and Background Radiation:	
	Evaluation Equation of Thermography	32
2.2.3	Effects of Misjudgment Concerning Emissivity and	
	Ambient Radiation Temperature	38
3	Overview of Thermography Systems	46
3.1	Historical Development	47
3.2	Camera and Sensor Technology	48
3.2.1	Scanner Thermography Systems	49
3.2.2	Focal-Plane-Array Thermography Systems	52
3.3	Criterion for Thermal Resolution	54
3.4	Optical Elements: Lens Systems	55
3.5	Illustration of Thermograms, Storage, and Processing	58
4	Regulations, Guidelines, and Standards	62
5	Accuracy of Temperatures Indicated in Thermograms	64
5.1	Effects of Climate Boundary Conditions and Age of the Building	65
5.1.1	Effects of Transient Influences: "Snap-Through Time" of Temperature Changes	70
5.1.2	Calculation of Daily Fluctuation of Interior Surface Temperatures	71
5.1.3	The Effect of Defective Points in Thermal Insulation	75



5.2	Effects of Wrongly Assumed Emissivity and Background Radiation		
C 0 4	on the Measurement Results	76 76	
5.2.1	Example of Outdoor Thermography	76 78	
5.2.2	Example of Outdoor Thermography	70	
6	Application of Thermography in Civil Engineering	82	
6.1 6.1.1	Basic Principles and Measurement Conditions Measurement Conditions for Outdoor and Indoor Thermography	83 83	
6.2	Localization of Thermal Bridges by Means of Thermography	86	
6.2.1	Systematics of Thermal Bridges	86	
6.2.2	Material-Related Thermal Bridges	86	
6.2.3	Geometric Thermal Bridges	87	
6.2.4	Typical Thermograms of Thermal Bridges without Damage	88	
6.2.5	Computational Approaches for the Examination of Thermal Bridges	94	
7	Practical Examples	100	
7.1	Thermal Bridges	101	
7.1.1	Exterior Wall Corner with Overhanging Concrete Ceiling	101	
7.1.2	Uninsulated Lintel	103	
7.1.3	Steel Beams without Thermal Isolation Traversing the Facade	105	
7.1.4	Solid Round Pillar Traversing the Thermal Insulation Layer	107	
7.1.5	Built-in Roller Blind Box	107	
7.1.6	Mold Formation at an Exterior Wall Corner: Extensive Evaluation	110	
7.2	Use of Thermography in Localizing Air Leaks	117	
7.2.1	Support of Thermography by Means of Pressure Difference Methods		
	(Blower Door Test)	117	
7.2.2	Air Leaks in the Roof and Other Constructions	122	
7.2.3	Air Leaks along Windows and Doors	125	
7.3	Use of Thermography to Detect Permanent Moisture Penetration	126	
7.3.1	Defects Due to Moisture Penetration at a Basement Wall	126	
7.3.2	Defects Caused by Moisture Penetration on Flat Roofs	128	
7.4	Localization of Construction Details by Means of Thermography	133	
7.4.1	Documentation of the Pipe Run of Underfloor Heating	133	
7.4.2	Exterior Walls with Heating Pipes Installed Beneath the Plaster	136	
7.4.3	Load-Bearing Anchors in Three-Layer Elements	137	
7.4.4	Framework Constructions Made of Wood or Concrete	138	
7.4.5	Temperature Distribution of Steel Girders of an		
	Extensively Glazed Open-Sided Floor	140	
7.4.6	Load-Bearing Anchor of a Rear-Ventilated Exterior Wall Construction	140	
7.4.7	Congestion in Pipes	142	

6 Content

7.5	Quality Assurance during Construction Works by	
	Means of Thermography	142
7.5.1	Analysis Before and After an Energy-Focused Building Refurbishment	142
7.5.2	Inspection of a Building with a Thermal Insulation Composite System	145
7.5.3	Acoustic Bridges in Parting Lines of Terraced Houses	147
7.5.4	Missing Thermal Insulation and Air Leaks in Drywall Construction	149
7.5.5	Missing Thermal Insulation in a Window Reveal	151
7.6	Usage of Thermography in Research	153
7.6.1	Studies on the Applicability of the Heat Transition Coefficient (U-Value)	
	as a Parameter for Heat Transfer Processes	153
7.6.2	Concrete Specimen under Cyclic Loading	154
7.6.3	Tensile Test on a Steel Plug	156
8	Thermographic Signatures of Typical Constructions	158
8.1	Wall Constructions, Building Envelope	159
8.1.1	Old Buildings, Partially with Internal Thermal Insulation	159
8.1.2	Old Buildings with Point Heating	160
8.1.3	Rear-Ventilated Exterior Walls	161
8.1.4	Interior Wall Constructions with Interiors Cladding	163
8.1.5	Extensive Glazing	164
8.2	Other Constructions/Materials	166
8.2.1	Thermography of Plastics: Critical Reflection	166
8.2.2	Application of Thermography outside Civil Engineering	168
9	Summary and Short Guide into Thermogram Generation	170
9.1	General Preconditions	171
9.2	Performing the Thermographic Analysis	171
10	Appendix	174
10.1	Nomenclature	175
10.2	Bibliography	177
10.3	Acknowledgments	180
10.4	Index	181
10.5	Authors	183

Content 7