

Table of Contents

1.	Introduction	1
1.1.	Pressure Sensitive Paint	2
1.2.	Temperature Sensitive Paint	8
1.3.	Historical Remarks	11
2.	Basic Photophysics	15
2.1.	Kinetics of Luminescence.....	15
2.2.	Models for Conventional Pressure Sensitive Paint	18
2.3.	Models for Porous Pressure Sensitive Paint	24
2.3.1.	Collision-Controlled Model	26
2.3.2.	Adsorption-Controlled Model	27
2.4.	Thermal Quenching	31
3.	Physical Properties of Paints	33
3.1.	Calibration	33
3.2.	Typical Pressure Sensitive Paints	34
3.3.	Typical Temperature Sensitive Paints.....	45
3.4.	Cryogenic Paints	50
3.5.	Multi-Luminophore Paints.....	54
3.6.	'Ideal' Pressure Sensitive Paint	56
3.7.	Desirable Properties of Paints.....	58
4.	Radiative Energy Transport and Intensity-Based Methods	61
4.1.	Radiometric Notation.....	61
4.2.	Excitation Light	62
4.3.	Luminescent Emission and Photodetector Response	65
4.4.	Intensity-Based Measurement Systems	69
4.4.1.	CCD Camera System	70
4.4.2.	Laser Scanning System	74
4.5.	Basic Data Processing.....	75
5.	Image and Data Analysis Techniques.....	81
5.1.	Geometric Calibration of Camera.....	82
5.1.1.	Collinearity Equations.....	82
5.1.2.	Direct Linear Transformation	85
5.1.3.	Optimization Method	87
5.2.	Radiometric Calibration of Camera	92
5.3.	Correction for Self-Illumination	95
5.4.	Image Registration	102
5.5.	Conversion to Pressure	105
5.6.	Pressure Correction for Extrapolation to Low-Speed Data.....	107
5.7.	Generation of Deformed Surface Grid.....	112

6.	Lifetime-Based Methods	115
6.1.	Response of Luminescence to Time-Varying Excitation Light	116
6.1.1.	First-Order Model	116
6.1.2.	Higher-Order Model	118
6.2.	Lifetime Measurement Techniques	118
6.2.1.	Pulse Method	118
6.2.2.	Phase Method	119
6.2.3.	Amplitude Demodulation Method	121
6.2.4.	Gated Intensity Ratio Method	123
6.3.	Fluorescence Lifetime Imaging	128
6.3.1.	Intensified CCD Camera	128
6.3.2.	Internally Gated CCD Camera	130
6.4.	Lifetime Experiments	131
7.	Uncertainty	137
7.1.	Pressure Uncertainty of Intensity-Based Methods	137
7.1.1.	System Modeling	137
7.1.2.	Error Propagation, Sensitivity and Total Uncertainty	138
7.1.3.	Photodetector Noise and Limiting Pressure Resolution	141
7.1.4.	Errors Induced by Model Deformation	144
7.1.5.	Temperature Effect	145
7.1.6.	Calibration Errors	145
7.1.7.	Temporal Variations in Luminescence and Illumination	146
7.1.8.	Spectral Variability and Filter Leakage	146
7.1.9.	Pressure Mapping Errors	146
7.1.10.	Paint Intrusiveness	147
7.1.11.	Other Error Sources and Limitations	148
7.1.12.	Allowable Upper Bounds of Elemental Errors	149
7.1.13.	Uncertainties of Integrated Forces and Moments	150
7.2.	Pressure Uncertainty Analysis for Subsonic Airfoil Flows	151
7.3.	In-Situ Calibration Uncertainty	156
7.3.1.	Experiments	156
7.3.2.	Simulation	159
7.4.	Pressure Uncertainty of Lifetime-Based Methods	163
7.4.1.	Phase Method	163
7.4.2.	Amplitude Demodulation Method	164
7.4.3.	Gated Intensity Ratio Method	166
7.5.	Uncertainty of Temperature Sensitive Paint	169
7.5.1.	Error Propagation and Limiting Temperature Resolution	169
7.5.2.	Elemental Error Sources	170
8.	Time Response	175
8.1.	Time Response of Conventional Pressure Sensitive Paint	175
8.1.1.	Solutions of Diffusion Equation	175
8.1.2.	Pressure Response and Optimum Thickness	178
8.2.	Time Response of Porous Pressure Sensitive Paint	182
8.2.1.	Deviation from the Square-Law	182
8.2.2.	Effective Diffusivity	183
8.2.3.	Diffusion Timescale	186

8.3.	Measurements of Pressure Time Response	187
8.4.	Time Response of Temperature Sensitive Paint	194
8.4.1.	Pulse Laser Heating on Thin Metal Film	195
8.4.2.	Step-Like Jet Impingement Cooling	198
9.	Applications of Pressure Sensitive Paint	201
9.1.	Low-Speed Flows	201
9.1.1.	Airfoil Flows	201
9.1.2.	Delta Wings, Swept Wings and Car Models	207
9.1.3.	Impingement Jet	214
9.2.	Subsonic, Transonic and Supersonic Wind Tunnels	215
9.2.1.	Aircraft Model in Transonic Flow	215
9.2.2.	Supercritical Wing at Cruising Speed	221
9.2.3.	Transonic Wing-Body Model	223
9.2.4.	Laser Scanning Pressure Measurement on Transonic Wing	225
9.2.5.	Boundary Layer Control in Supersonic Inlets	226
9.3.	Hypersonic and Shock Wind Tunnels	230
9.3.1.	Expansion and Compression Corners	230
9.3.2.	Moving Shock Impinging to Cylinder Normal to Wall	236
9.4.	Cryogenic Wind Tunnels	237
9.5.	Rotating Machinery	242
9.5.1.	Laser Scanning Measurements	242
9.5.2.	CCD Camera Measurements	247
9.6.	Impinging Jets	249
9.7.	Flight Tests	256
9.8.	Micronozzle	260
10.	Applications of Temperature Sensitive Paint	263
10.1.	Hypersonic Flows	263
10.2.	Boundary-Layer Transition Detection	270
10.3.	Impinging Jet Heat Transfer	275
10.4.	Shock/Boundary-Layer Interaction	280
10.5.	Laser Spot Heating and Heat Transfer Measurements	282
10.6.	Hot-Film Surface Temperature in Shear Flow	289
	References	293
	Appendix A. Calibration Apparatus	313
	Appendix B. Recipes of Typical Pressure and Temperature Sensitive Paints	317
	Appendix C. Vendors	319
	Color Plates	321
	Index	327