

CONTENTS

PART 1. PHYSICAL MEASUREMENTS IN GAS DYNAMICS

EDITOR: R. LADENBURG

A. DENSITY MEASUREMENTS

A,1. Analysis of Optical Methods	3
F. Joachim Weyl, Office of Naval Research, Department of the Navy, Washington, D.C.	
1.1. Introductory Remarks	3
1.2. The Principal Systems	4
1.3. Quantitative Evaluation	8
1.4. Analysis of Shadowgraphs	20
1.5. Conclusions	23
1.6. Cited References	24
A,2. Shadow and Schlieren Methods	26
J. W. Beams, Department of Physics, University of Virginia, Charlottesville, Virginia	
2.1. Introduction	26
2.2. Schlieren Systems	27
2.3. Shadow Methods	38
2.4. Light Sources, Optical Parts, and Photography	40
2.5. Comparison of Schlieren and Shadow Methods	43
2.6. Cited References	44
A,3. Interferometry	47
R. Ladenburg, Department of Physics, Princeton Univer- sity, Princeton, New Jersey	
Daniel Bershader, Department of Aeronautical Engineer- ing, Princeton University, Princeton, New Jersey	
3.1. Introduction	47
3.2. Theory of the Mach-Zehnder Interferometer	49
3.3. Construction of the M-Z Interferometer	56
3.4. Evaluation of Interferograms	61
3.5. Applications	69
3.6. Cited References	75

CONTENTS

A,4. Electrical Discharge and Afterglow Technique	79
Eva M. Winkler, Aeroballistic Division, Naval Ordnance Laboratory, Silver Spring, Maryland	
4.1. Introduction	79
4.2. Nitrogen Afterglow	79
4.3. Air Afterglow	82
4.4. Experimental Aspects of Afterglow Methods	83
4.5. Glow Discharge in Nitrogen and Air	86
4.6. Experimental Aspects of the Discharge Technique	86
4.7. Cited References	87
A,5. Spectral Absorption Method	89
Eva M. Winkler, Aeroballistic Division, Naval Ordnance Laboratory, Silver Spring, Maryland	
5.1. Introduction	89
5.2. Oxygen Absorption Method	90
5.3. Ozone Absorption Method	92
5.4. Mercury Vapor Absorption Method	93
5.5. Concluding Remarks	95
5.6. Cited References	96
A,6. X-Ray Technique	97
Eva M. Winkler, Aeroballistic Division, Naval Ordnance Laboratory, Silver Spring, Maryland	
6.1. Principle and Accuracy of the Method	97
6.2. Apparatus	100
6.3. Application of the X-Ray Technique	103
6.4. Use of Corpuscular Rays	103
6.5. α Particles and Protons	104
6.6. Electrons	105
6.7. Concluding Remarks	106
6.8. Cited References	107
B. PRESSURE MEASUREMENTS	
B,1. The Impact Tube	111
P. L. Chambré, Department of Mathematics, University of California, Berkeley, California S. A. Schaaf, School of Engineering Science, University of California, Berkeley, California	
1.1. Introduction	111
1.2. Viscous Effects	112
1.3. Tolerances in Alignment. Effects of Transverse Velocity Gradient and Free Stream Turbulence	119

CONTENTS

1.4. Impact Tube Theory in Free Molecule Flow	120
1.5. Cited References	122
B,2. Pressure Measuring Manometers and Gauges	124
Walker Bleakney, Department of Physics, Princeton University, Princeton, New Jersey	
Arnold B. Arons, Department of Physics, Stevens Institute of Technology, Hoboken, New Jersey	
2.1. Introduction	124
2.2. Important Characteristics	124
2.3. Low Frequency Gauges	126
2.4. High Frequency Gauges	127
2.5. Mechanical Peak Pressure Gauges	133
2.6. Cited References	134

C. VELOCITY MEASUREMENTS

C,1. Velocity Measurements Using Ions as Tracers	139
Willoughby M. Cady, Physics Division, Naval Ordnance Test Station, Pasadena, California	
C,2. Velocity Measurements by Illuminated or Luminous Particles	142
Willoughby M. Cady, Physics Division, Naval Ordnance Test Station, Pasadena, California	
C,3. Electric Discharge Anemometry	146
Willoughby M. Cady, Physics Division, Naval Ordnance Test Station, Pasadena, California	
C,4. Acoustic Mach Meters	152
Willoughby M. Cady, Physics Division, Naval Ordnance Test Station, Pasadena, California	
Cited References and Bibliography (C,1-C,4)	157
C,5. Velocity of Shock Waves by the Light Screen Technique	159
Walker Bleakney, Department of Physics, Princeton University, Princeton, New Jersey	
Cited References (C,5)	163

D. TEMPERATURE MEASUREMENTS

D,1. Wall Temperature Determination	167
Gerhard R. Eber, Holloman Air Development Center, Holloman Air Force Base, New Mexico	
1.1. Introduction	167
1.2. On the Principle of Wall Temperature Measurements	168
1.3. Thermocouples	169

CONTENTS

1.4. Infrared Radiation	170
1.5. Phosphor Luminescence	173
1.6. Applications	176
1.7. Cited References	184
D,2. Shielded Thermocouples	186
Gerhard R. Eber, Holloman Air Development Center, Holloman Air Force Base, New Mexico	
2.1. Introduction	186
2.2. Theoretical Considerations	187
2.3. The Influence of Conduction and Radiation	188
2.4. Design of Temperature Probes	189
2.5. Miscellaneous Temperature Measuring Devices	195
2.6. Cited References	196
D,3. Temperature Measurement by Sound Velocity Methods	198
Willoughby M. Cady, Physics Division, Naval Ordnance Test Station, Pasadena, California	
Cited References	200
E. SHOCK FRONT MEASUREMENTS	
BY LIGHT REFLECTIVITY	
Donald F. Hornig, Metcalf Research Laboratory, Brown University, Providence, Rhode Island	
E,1. Introduction	203
E,2. Theory of the Method	204
E,3. Experimental Technique	205
E,4. Results. The Thickness of Shock Fronts and Rotational Equilibrium	207
E,5. Cited References	210
F. TURBULENCE MEASUREMENTS	
Leslie S. G. Kováshay, Department of Aeronautical Engineering, The Johns Hopkins University, Baltimore, Maryland	
F,1. Methods to Distinguish between Laminar and Turbulent Flow	213
1.1. Velocity Profile Measurement	215
1.2. Diffusion Methods	215
1.3. Optical Methods	217
1.4. Glow Discharge Anemometer	218
F,2. Hot Wire Method	219
2.1. Introduction	219

CONTENTS

2.2. Hot Wire Probe	223
2.3. Heat Loss in Steady Flow (King's Formula)	228
2.4. Heat Loss of Wire at Supersonic Velocities	233
2.5. Effect of Finite Wire Length on Heat Loss	237
2.6. Angle of Attack	239
2.7. Hot Wire Response to Unsteady Flow	241
2.8. Electronic Equipment (Thermal Lag Compensation, Amplification)	253
2.9. Statistical Processing of the Hot Wire Anemometer Out- put Signal	263
F,3. Optical Techniques	277
3.1. Introduction	277
3.2. Turbulence Measurements from Shadow Pictures	278
3.3. Interferometer Measurement of Density Fluctuations	282
F,4. Cited References (F,1-F,3)	283

G. CONDENSATION STUDY BY ABSORPTION OR SCATTERING OF LIGHT

Eva M. Winkler, Aeroballistic Division, Naval Ordnance
Laboratory, Silver Spring, Maryland

G,1. Introduction	289
G,2. Theoretical Considerations of Light Scattered by Spherical Particles	289
G,3. Measurements	295
G,4. Application to Measurements of Condensation Particles in High Speed Flow	302
G,5. Cited References	304

H. ANALOGUE METHODS

H,1. Free Surface Water Table	309
Ascher H. Shapiro, Department of Mechanical Engineer- ing, Massachusetts Institute of Technology, Cambridge, Massachusetts	
1.1. Introduction	309
1.2. The Basis of the Analogy	309
1.3. Experimental Methods	311
1.4. The Validity of the Analogy	314
1.5. Some Typical Results	319
1.6. Appraisal of Water Channel as Experimental Tool	320
1.7. Cited References	321

CONTENTS

H.2. Electrolytic Plotting Tank	322
L. Malavard, ONERA, Châtillon-sous-Bagneux (Seine), Paris, France	
2.1. General Principles	322
2.2. The Experimental Method	324
2.3. The Experimental Apparatus	325
2.4. Representation of the Circulation around an Obstacle	327
2.5. Study of a Cascade of Profiles	329
2.6. Representation of Axially Symmetric Flows	329
2.7. Fulfillment of Boundary Condition	330
2.8. Lifting Surfaces	332
2.9. Study of Compressible Flows by the Method of G. I. Taylor	333
2.10. The Hodographic Tank	335
2.11. Conical Flows	337
2.12. Conclusions	339
2.13. Cited References	339

PART 2. PHYSICAL MEASUREMENTS IN COMBUSTION

EDITORS: H. S. TAYLOR, B. LEWIS, AND R. N. PEASE

I. MEASUREMENT OF FLAME TEMPERATURE, PRESSURE, AND VELOCITY

F. P. Bundy and H. M. Strong, General Electric Company,
Schenectady, New York

I.1. Introduction	343
I.2. Spectral Line Reversal Techniques	346
I.3. Absolute Radiation Methods	359
I.4. Spectral Energy Distribution Methods	361
I.5. Thermocouple and Compensated Hot Wire Methods of Flame Temperature Measurement	364
I.6. Gas Temperature from Pneumatic Apparatus	369
I.7. Temperature from Velocity of Sound	372
I.8. Gas Velocity in Supersonic Flames	376
I.9. Gas Pressure in Supersonic Flames	382
I.10. Cited References and Bibliography	385

J. FLAME PHOTOGRAPHY

William T. Reid, Battelle Memorial Institute, Columbus,
Ohio

J.1. Introduction	389
J.2. Direct Photography	389
J.3. Interferometry	396
J.4. Schlieren Photography	398

CONTENTS

J,5. Shadow Photography	401
J,6. Solids in Flames	402
J,7. Comparison of Photographic Methods of Locating Flame Front	404
J,8. Cited References	405

K. MEASUREMENT OF BURNING VELOCITY

Ernest F. Fiock, National Bureau of Standards, Washington, D.C.

K,1. Introduction	409
K,2. Effects of the Structure of the Combustion Wave	410
K,3. Burning Velocities from Stationary Flames	412
K,4. Burning Velocities from Moving Flames	422
K,5. Effects of Operating Parameters on Burning Velocity	428
K,6. Summary of Recent Determinations	430
K,7. Cited References	436

L. MASS SPECTROSCOPY

John A. Hipple, Atomic Physics Section, National Bureau of Standards, Washington, D.C.

Chapter 1. Methods of Mass Analysis

L,1. Introduction	441
L,2. Types of Analyzers of Current Interest to Chemists	442
L,3. The Production and Detection of Ions	446

Chapter 2. Application to Chemical Analysis

L,4. Ionization and Dissociation Processes	447
L,5. Special Requirements for Analysis	453
L,6. Recent Developments	453

Chapter 3. Applications to Flames

L,7. Early Studies of Chemical Reactions	456
L,8. Flame Studies with the Mass Spectrometer at Johns Hopkins Applied Physics Laboratory	458
L,9. Cited References	462

M. SPECTROSCOPY OF COMBUSTION

G. H. Dieke, The Johns Hopkins University, Baltimore, Maryland

M,1. Introduction	467
M,2. Instrumentation	468
M,3. Identification of Flame Constituents	482
M,4. Absorption	486
M,5. Data on Equilibrium Conditions	491
M,6. Departure from Equilibrium Conditions	514
M,7. Cited References and Bibliography	522

CONTENTS

N. ANALYSIS OF THE COMBUSTION WAVE BY PRESSURE EFFECTS AND SPECTROSCOPY

Nigel Thomas, Princeton University, Princeton, New Jersey

N,1. Introduction	527
N,2. Burner Design and Characteristics	528
N,3. Reaction Zone Structure	531
N,4. Spectroscopic Temperature Measurements	534
N,5. Free Radical Concentration Measurements	544
N,6. Pressure Effects and Burning Velocity	553
N,7. Discussion	561
N,8. Cited References	565
Index	567