CONTENTS

Foreword xv
Preface xvii
Contributors xix

PART I. Fundamentals of Acoustics and Noise 17
1. Theory of Sound—Predictions and Measurement
   Malcolm J. Crocker 19
2. Sound Sources
   Philip A. Nelson 43
3. Sound Propagation in Rooms
   K. Heinrich Kuttruff 52
4. Sound Propagation in the Atmosphere
   Keith Attenborough 67
5. Sound Radiation from Structures and Their Response to Sound
   Jean-Louis Guyader 79
6. Numerical Acoustical Modeling (Finite Element Modeling)
   R. Jeremy Astley 101
7. Boundary Element Modeling
   D. W. Herrin, T. W. Wu, and A. F. Seybert 116
8. Aerodynamic Noise: Theory and Applications
   Philip J. Morris and Geoffrey M. Lilley 128
9. Nonlinear Acoustics
   Oleg V. Rudenko and Malcolm J. Crocker 159

PART II. Fundamentals of Vibration 169
11. General Introduction to Vibration
    Bjorn A. T. Petersson 171
12. Vibration of Simple Discrete and Continuous Systems
    Yuri I. Bobrovnikskii 180
13. Random Vibration
    David E. Newland 205
14. Response of Systems to Shock
    Charles Robert Welch and Robert M. Ebeling 212
15. Passive Damping  
   Daniel J. Inman  
   225

   Goran Pavić  
   232

17. Statistical Energy Analysis  
   Jerome E. Manning  
   241

18. Nonlinear Vibration  
   Lawrence N. Virgin, Earl H. Dowell, and George Flowers  
   255

PART III.  Human Hearing and Speech  
269

19. General Introduction to Human Hearing and Speech  
   Karl T. Kalveram  
   271

20. The Ear: Its Structure and Function, Related to Hearing  
   Hiroshi Wada  
   277

21. Hearing Thresholds, Loudness of Sound, and Sound Adaptation  
   William A. Yost,  
   286

22. Speech Production and Speech Intelligibility  
   Christine H. Shadle  
   293

PART IV.  Effects of Noise, Blast, Vibration, and Shock on People  
301

23. General Introduction to Noise and Vibration Effects on People and Hearing Conservation  
   Malcolm J. Crocker  
   303

24. Sleep Disturbance due to Transportation Noise Exposure  
   Lawrence S. Finegold, Alain G. Muzet, and Bernard F. Berry  
   308

25. Noise-Induced Annoyance  
   Sandford Fidell  
   316

26. Effects of Infrasound, Low-Frequency Noise, and Ultrasound on People  
   Norm Broner  
   320

27. Auditory Hazards of Impulse and Impact Noise  
   Donald Henderson and Roger P. Hamernik  
   326

28. Effects of Intense Noise on People and Hearing Loss  
   Rickie R. Davis and William J. Murphy  
   337

29. Effects of Vibration on People  
   Michael J. Griffin  
   343

30. Effects of Mechanical Shock on People  
   A. J. Brammer  
   354

31. Hearing Protectors  
   Samir N. Y. Gerges and John G. Casali  
   364

32. Development of Standards and Regulations for Occupational Noise  
   Alice H. Suter  
   377

33. Hearing Conservation Programs  
   John Erdreich  
   383

34. Rating Measures, Descriptors, Criteria, and Procedures for Determining Human Response to Noise  
   Malcolm J. Crocker  
   394
## CONTENTS

### PART V. Noise and Vibration Transducers, Analysis Equipment, Signal Processing, and Measuring Techniques

<table>
<thead>
<tr>
<th>Section</th>
<th>Pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>35. General Introduction to Noise and Vibration Transducers, Measuring Equipment, Measurements, Signal Acquisition, and Processing</td>
<td>417</td>
</tr>
<tr>
<td>Malcolm J. Crocker</td>
<td></td>
</tr>
<tr>
<td>36. Acoustical Transducer Principles and Types of Microphones</td>
<td>435</td>
</tr>
<tr>
<td>Gunnar Rasmussen and Per Rasmussen</td>
<td></td>
</tr>
<tr>
<td>37. Vibration Transducer Principles and Types of Vibration Transducers</td>
<td>444</td>
</tr>
<tr>
<td>Colin H. Hansen</td>
<td></td>
</tr>
<tr>
<td>38. Sound Level Meters</td>
<td>455</td>
</tr>
<tr>
<td>George S. K. Wong</td>
<td></td>
</tr>
<tr>
<td>39. Noise Dosimeters</td>
<td>465</td>
</tr>
<tr>
<td>Chucri A. Kardous</td>
<td></td>
</tr>
<tr>
<td>40. Analyzers and Signal Generators</td>
<td>470</td>
</tr>
<tr>
<td>Henrik Herlufsen, Svend Gade, and Harry K. Zaveri</td>
<td></td>
</tr>
<tr>
<td>41. Equipment for Data Acquisition</td>
<td>486</td>
</tr>
<tr>
<td>Zhuang Li and Malcolm J. Crocker</td>
<td></td>
</tr>
<tr>
<td>42. Signal Processing</td>
<td>493</td>
</tr>
<tr>
<td>Allan G. Piersol</td>
<td></td>
</tr>
<tr>
<td>43. Noise and Vibration Measurements</td>
<td>501</td>
</tr>
<tr>
<td>Pedro R. Valletta and Malcolm J. Crocker</td>
<td></td>
</tr>
<tr>
<td>44. Determination of Sound Power Level and Emission Sound Pressure Level</td>
<td>526</td>
</tr>
<tr>
<td>Hans G. Jonasson</td>
<td></td>
</tr>
<tr>
<td>45. Sound Intensity Measurements</td>
<td>534</td>
</tr>
<tr>
<td>Finn Jacobsen</td>
<td></td>
</tr>
<tr>
<td>46. Noise and Vibration Data Analysis</td>
<td>549</td>
</tr>
<tr>
<td>Robert B. Randall</td>
<td></td>
</tr>
<tr>
<td>47. Modal Analysis and Modal Testing</td>
<td>565</td>
</tr>
<tr>
<td>David J. Ewins</td>
<td></td>
</tr>
<tr>
<td>48. Machinery Condition Monitoring</td>
<td>575</td>
</tr>
<tr>
<td>Robert B. Randall</td>
<td></td>
</tr>
<tr>
<td>49. Wavelet Analysis of Vibration Signals</td>
<td>585</td>
</tr>
<tr>
<td>David E. Newland</td>
<td></td>
</tr>
<tr>
<td>50. Use of Near-Field Acoustical Holography in Noise and Vibration Measurements</td>
<td>598</td>
</tr>
<tr>
<td>Earl G. Williams</td>
<td></td>
</tr>
<tr>
<td>51. Calibration of Measurement Microphones</td>
<td>612</td>
</tr>
<tr>
<td>Erling Frederiksen</td>
<td></td>
</tr>
<tr>
<td>52. Calibration of Shock and Vibration Transducers</td>
<td>624</td>
</tr>
<tr>
<td>Torben Rask Licht</td>
<td></td>
</tr>
<tr>
<td>53. Metrology and Traceability of Vibration and Shock Measurements</td>
<td>633</td>
</tr>
<tr>
<td>Hans-Jürgen von Martens</td>
<td></td>
</tr>
</tbody>
</table>

### PART VI. Principles of Noise and Vibration Control and Quiet Machinery Design

<table>
<thead>
<tr>
<th>Section</th>
<th>Pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>54. Introduction to Principles of Noise and Vibration Control</td>
<td>649</td>
</tr>
<tr>
<td>Malcolm J. Crocker</td>
<td></td>
</tr>
</tbody>
</table>
55. Noise and Vibration Source Identification
   Malcolm J. Crocker

56. Use of Enclosures
   Jorge P. Arenas and Malcolm J. Crocker

57. Use of Sound-Absorbing Materials
   Malcolm J. Crocker and Jorge P. Arenas

58. Use of Barriers
   Jorge P. Arenas

59. Use of Vibration Isolation
   Eric E. Ungar

60. Damping of Structures and Use of Damping Materials
   Eric E. Ungar

61. Dynamic Vibration Absorbers
   Leif Kari

62. Rotor Balancing and Unbalance-Caused Vibration
   Maurice L. Adams, Jr.

63. Active Noise Control
   Stephen J. Elliott

64. Active Vibration Control
   Christopher Fuller

65. Microelectromechanical Systems (MEMS) Sensors for Noise and Vibration Applications
   James J. Allen

66. Design of Low-Noise Machinery
   Michael Bockhoff

67. Psychoacoustics and Product Sound Quality
   Malcolm J. Crocker

PART VII. Industrial and Machine Element Noise and Vibration Sources—Prediction and Control

68. Machinery Noise and Vibration Sources
   Malcolm J. Crocker

69. Gear Noise and Vibration Prediction and Control Methods
   Donald R. Houser

70. Types of Bearings and Means of Noise and Vibration Prediction and Control
   George Zusman

71. Centrifugal and Axial Fan Noise Prediction and Control
   Gerald C. Lauchle

72. Types of Electric Motors and Noise and Vibration Prediction and Control Methods
   George Zusman

73. Pumps and Pumping System Noise and Vibration Prediction and Control
   Mirko Čudina
74. Noise Control of Compressors
   Malcolm J. Crocker 910

75. Valve-Induced Noise: Its Cause and Abatement
   Hans D. Baumann and Mats Åbom 935

76. Hydraulic System Noise Prediction and Control
   Nigel Johnston 946

77. Furnace and Burner Noise Control
   Robert A. Putnam, Werner Krebs, and Stanley S. Sattinger 956

78. Metal-Cutting Machinery Noise and Vibration Prediction and Control
   Joseph C. S. Lai 966

79. Woodworking Machinery Noise
   Knud Skovgaard Nielsen and John S. Stewart 975

80. Noise Abatement of Industrial Production Equipment
   Evgeny Rivin 987

81. Machine Tool Noise, Vibration, and Chatter Prediction and Control
   Lars Håkansson, Sven Johansson, and Ingvar Claesson 995

82. Sound Power Level Predictions for Industrial Machinery
   Robert D. Bruce, Charles T. Moritz, and Arno S. Bommer 1001

PART VIII. Transportation Noise and Vibration—Sources, Prediction, and Control 1011

83. Introduction to Transportation Noise and Vibration Sources
   Malcolm J. Crocker 1013

84. Internal Combustion Engine Noise Prediction and Control—Diesel and Gasoline Engines
   Thomas E. Reinhart 1024

85. Exhaust and Intake Noise and Acoustical Design of Mufflers and Silencers
   Hans Bodén and Ragnar Glav 1034

86. Tire/Road Noise—Generation, Measurement, and Abatement
   Ulf Sandberg and Jerzy A. Ejsmont 1054

87. Aerodynamic Sound Sources in Vehicles—Prediction and Control
   Syed R. Ahmed 1072

88. Transmission and Gearbox Noise and Vibration Prediction and Control
   Jiri Tuma 1086

89. Jet Engine Noise Generation, Prediction, and Control
   Dennis L. Huff and Edmame Envia 1096

90. Aircraft Propeller Noise—Sources, Prediction, and Control
   F. Bruce Metzger and F. Farassat 1109

91. Helicopter Rotor Noise: Generation, Prediction, and Control
   Hanno H. Heller and Jianping Yin 1120

92. Brake Noise Prediction and Control
   Michael J. Brennan and Kihong Shin 1133
93. Wheel–Rail Interaction Noise Prediction and Its Control  
   David J. Thompson  

PART IX. Interior Transportation Noise and Vibration Sources—Prediction and Control  

94. Introduction to Interior Transportation Noise and Vibration Sources  
   Malcolm J. Crocker  

95. Automobile, Bus, and Truck Interior Noise and Vibration Prediction and Control  
   Robert J. Bernhard, Mark Moeller, and Shaobo Young  

96. Noise Management of Railcar Interior Noise  
   Glenn H. Frommer  

97. Interior Noise in Railway Vehicles—Prediction and Control  
   Henrik W. Thrane  

98. Noise and Vibration in Off-Road Vehicle Interiors—Prediction and Control  
   Nickolay Ivanov and David Copley  

99. Aircraft Cabin Noise and Vibration Prediction and Passive Control  
   John F. Wilby  

100. Aircraft Cabin Noise and Vibration Prediction and Active Control  
     Sven Johansson, Lars Håkansson, and Ingvar Claesson  

101. Noise Prediction and Prevention on Ships  
     Raymond Fischer and Robert D. Collier  

PART X. Noise and Vibration Control in Buildings  

102. Introduction—Prediction and Control of Acoustical Environments in Building Spaces  
     Louis C. Sutherland  

103. Room Acoustics  
     Colin H. Hansen  

104. Sound Absorption in Rooms  
     Colin H. Hansen  

105. Sound Insulation—Airborne and Impact  
     Alfred C. C. Warnock  

106. Ratings and Descriptors for the Built Acoustical Environment  
     Gregory C. Tocci  

107. ISO Ratings and Descriptors for the Built Acoustical Environment  
     Heinrich A. Metzen  

108. Acoustical Design of Office Work Spaces and Open-Plan Offices  
     Carl J. Rosenberg  

109. Acoustical Guidelines for Building Design and Noise Control  
     Chris Field and Fergus Fricke  

110. Noise Sources and Propagation in Ducted Air Distribution Systems  
     Howard F. Kingsbury
CONTENTS

111. Aerodynamic Sound Generation in Low Speed Flow Ducts
   David J. Oldham and David D. Waddington
   1323

112. Noise Control for Mechanical and Ventilation Systems
   Reginald H. Keith
   1328

113. Noise Control in U.S. Building Codes
   Gregory C. Tocci
   1348

114. Sound Insulation of Residential Housing—Building Codes and
   Classification Schemes in Europe
   Birgit Rasmussen
   1354

115. Noise in Commercial and Public Buildings and Offices—Prediction and
   Control
   Chris Field and Fergus Fricke
   1367

116. Vibration Response of Structures to Fluid Flow and Wind
   Malcolm J. Crocker
   1375

117. Protection of Buildings from Earthquake-Induced Vibration
   Andreas J. Kappos and Anastasios G. Sextos
   1393

118. Low-Frequency Sound Transmission between Adjacent Dwellings
   Barry M. Gibbs and Sophie Maluski
   1404

PART XI. Community and Environmental Noise and Vibration
         Prediction and Control

119. Introduction to Community Noise and Vibration Prediction and Control
   Malcolm J. Crocker
   1411

120. Exterior Noise of Vehicles—Traffic Noise Prediction and Control
   Paul R. Donavan and Richard Schumacher
   1427

121. Rail System Environmental Noise Prediction, Assessment, and Control
   Brian Hemsworth
   1438

122. Noise Attenuation Provided by Road and Rail Barriers, Earth Berms,
   Buildings, and Vegetation
   Kirill Horoshenkov, Yiu W. Lam, and Keith Attenborough
   1446

123. Ground-Borne Vibration Transmission from Road and Rail Systems:
   Prediction and Control
   Hugh E. M. Hunt and Mohammed F. M. Hussein
   1458

124. Base Isolation of Buildings for Control of Ground-Borne Vibration
   James P. Talbot
   1470

125. Aircraft and Airport Noise Prediction and Control
   Nicholas P. Miller, Eugene M. Reindel, and Richard D. Horonjeff
   1479

126. Off-Road Vehicle and Construction Equipment Exterior Noise Prediction
    and Control
   Lyudmila Drozdova, Nickolay Ivanov, and Gennadiy H. Kurtsev
   1490

127. Environmental Noise Impact Assessment
   Marion A. Burgess and Lawrence S. Finegold
   1501

128. Industrial and Commercial Noise in the Community
   Dietrich Kuehner
   1509
CONTENTS

129. Building Site Noise 1516
    Uwe Trautmann

130. Community Noise Ordinances 1525
    J. Luis Bento Coelho

Reviewers List 1533
Glossary 1537
Index 1557