AUTOMOTIVE SAFETY

The increasing importance of safety performance in all aspects of motor vehicle design, development, manufacturing and marketing, makes it necessary for professionals working in these areas to develop an understanding and awareness of safety considerations to effectively handle future developments in this area.

Automotive Safety: Anatomy, Injury, Testing and Regulation begins with a clear, concise introduction to the terminology and concepts relating to human anatomy and injury. This comprehensive book then focuses on the types of injuries that occur by body region and the mechanisms thought to cause them. Selected anatomical, physiological and clinical concepts are included to support the injury material presented. Injury scaling is also discussed, reviewing techniques such as the Abbreviated Injury Scale (AIS), Glasgow Coma Scale (GCS), and Harm and Impairment. This informative publication concludes with a discussion on the regulatory framework and biomechanical basis of Federal Motor Vehicle Safety Standard (FMVSS) 208 and the New Car Assessment Program (NCAP).

Organized into four information-packed chapters, contents of this valuable publication include: Terminology; Anatomy and Injury; Injury Scaling; Regulation and Testing. Appendices include various safety laws and regulatory-related documents which are referred to in the text. In addition, R-103 includes an extensive reference section and is packed with illustrations and diagrams.

Automotive Safety: Anatomy, Injury, Testing and Regulation is an essential reference for all automotive safety professionals—either technical or managerial, as well as anyone wanting a better understanding of this fascinating area of study.
Automotive Safety
Anatomy, Injury, Testing & Regulation

Jeffrey A. Pike

Published by:
Society of Automotive Engineers, Inc.
400 Commonwealth Drive
Warrendale, PA 15096-0001
To my parents, May and Herbert Pike.
Acknowledgements

Three members of Ford senior management personally supported this effort and I thank them for their encouragement: J.A. Betti, H.O. Petrauskas and R.H. Munson.

Much of the material in this book has been adapted from various lectures I have presented through the SAE Seminar Program, at the Ford Motor Company and at various medical schools. The attendees provided much useful feedback and helped me to identify which information would be most useful to include in this volume. I hope that such "dialogue" will continue and that readers will let me know their reactions and thoughts, especially if something seems unclear, unnecessary or inaccurate, or if additional material should be added. I am particularly interested in whether there is interest in a chapter on clinical imaging (e.g., X-rays, CT, MRI) and/or whether a chapter on burn injuries should be included. Please send written comments to me at Ford Motor Company, Suite 500, 330 Fairlane Plaza South, Dearborn, MI 48126.

Special thanks to Robert H. Munson for providing much-needed encouragement, above and beyond the call of duty, at various points along the way.

One of the most rewarding aspects of writing this book has been interacting with the very talented people indicated below. Although very busy, they were all quite generous with their time and expertise and readily agreed to review parts of the manuscript. They taught me a great deal, not only about the subject matter, but also about graciously helping others. The reviewers were:

Paul Butler; Gary Davidoff, M.D.; Kennerly Digges, Ph.D.; David Doyle, Ph.D.; Frederic Eckhauser, M.D.; Paul Gikas, M.D.; Robert Green, M.D.; Fred Hankin, M.D.; Donald Huelke, Ph.D.; Ellen MacKenzie, Ph.D.; Jeffrey Marcus, Ph.D.; John McGillicuddy, M.D.; Arthur Pancioli, Jr., M.D., I.I.B.; Elaine Petrucelli; Donald Trunkey, M.D.; David Viano, Ph.D. Also, special thanks to Gerald Tanny, Ph.D., for his long-distance "cheerleading."

(In many instances, the reviewers did not get to see final versions of the manuscript, so any errors in the final product should not be associated with them. Rather, to paraphrase a well-known quotation, "The book stops here (with me).")

The research, writing and re-writing of this volume required a great deal of time and energy, and I thank those near and dear who accepted my commitment to this project.

Whenever possible, I have referenced statements in the book to one or more currently available published sources. I hope readers will let me know of any additional citations which should be included.

Last but not least, my thanks to the crew at SAE, who by their helpfulness and professionalism, helped me to decide that this first book should be a first book. I know there were many people helping "behind the scenes" and I hope they will know this thank you is for them as well.
Introduction

This book is the outgrowth of a number of lectures I have presented during the last five years. As was the case with those lectures, the book discusses "specifics" and also seeks to provide background material and concepts which will be most useful over a long period of time, both in their own right and as a foundation for additional study — especially to help grasp future developments.

The text of this book is divided into four chapters: Terminology, Anatomy and Injury, Injury Scaling, and Regulations and Testing. Chapter 1, Terminology, provides a non-technical introduction to some of the terminology and concepts relating to the body's structure and function, which are used in the other chapters. Chapter 2, Anatomy and Injury, provides a discussion, by body region, of the types of injuries which occur and the mechanisms thought to cause them. Most of the technical terms are defined as they are introduced into the discussion, and so this chapter should be "readable" without a clinical or injury biomechanics background. It does, however, discuss some fairly advanced concepts, and so should be of interest to those with strong clinical and/or biomechanics backgrounds as well. Chapter 3, Injury Scaling, discusses various techniques for assigning a numerical assessment to various injuries. The number may represent a ranking, such as is the case for the Abbreviated Injury Scale (AIS) which was developed specifically for application to vehicular trauma, or may represent a quantitative assessment, e.g., the "Harm" concept which is frequently used in conjunction with Federal regulatory assessments. Chapter 4, Regulation and Testing, discusses the regulatory framework and biomechanical basis of Federal Motor Vehicle Safety Standard (FMVSS) 208 ("Occupant Crash Protection") and the New Car Assessment Program (NCAP). The discussion includes the tests themselves, existing and proposed test criteria, and the test dummies. Finally, the Appendices provide copies of various safety laws and regulatory-related documents which are referred to in the text and which, it was thought, would not be readily accessible to many of the readers.
## Table of Contents

Chapter 1  Terminology ..................................................... 1  
1.1  Introduction ........................................................... 1  
1.2  Anatomy and Injury Terminology ................................. 1

Chapter 2  Anatomy and Injury ........................................ 9  
2.1  Introduction ........................................................... 9  
2.2  The Head .............................................................. 9  
2.3  The Spine ............................................................ 20  
2.4  The Chest ............................................................. 29  
2.5  The Abdomen ....................................................... 34  
2.6  The Pelvis and Lower Extremities ............................... 41

Chapter 3  Injury Scaling .................................................. 47  
3.1  Introduction ........................................................... 47  
3.2  Anatomic Scales (AIS, ISS, POD, OIC) .......................... 47  
3.3  Physiologic Scales (GCS, MISS) ................................. 52  
3.4  Combinations (TRISS) ............................................. 56  
3.5  Impairment, Disability and Societal Loss (Harm, IPR, Disability Scale) ............... 57

Chapter 4  Regulation and Testing ..................................... 61  
4.1  Introduction ........................................................... 61  
4.2  Regulatory Background and NCAP ............................... 61  
4.3  Test Devices .......................................................... 64  
4.4  Test Procedures ...................................................... 65  
4.5  Test Criteria .......................................................... 66  
4.6  Interpretation of Regulatory Testing .............................. 76

REFERENCES .................................................................. 81

APPENDICES  
A. National Traffic and Motor Vehicle Safety Act ......................... 93  
B. Administrative Procedure Act ............................................. 129  
C. Presidential Executive Order 12291 (1981) .............................. 133  
D. Motor Vehicle Information and Cost Savings Act ........................ 139  
E. Code of Federal Regulations Part 571 (FMVSS 208) ..................... 145  
F. Code of Federal Regulations Part 572 (Test Dummy) ............... 149  
G. Docket 74-14; Notices 38, 39, 45, 47 .................................. 153  
H. U.S. Court of Appeals (1972) ............................................. 165  
I. Part 501 (NHTSA Organization) and Part 553 (Rulemaking Procedures) ........... 167