CHAPTER 19
SHOCK AND VIBRATION STANDARDS

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INTRODUCTION

This chapter is concerned with shock and vibration standards covering (1) terminology; (2) use and calibration of transducers and instrumentation; (3) shock and vibration generators; (4) structures and structural systems; (5) vehicles including land-based, airborne, and ocean-going; (6) machines and machinery including testing, condition monitoring, diagnostics, prognostics, and balancing; (7) human exposure to shock and vibration; and (8) testing. These topics may be covered by international, regional, or national documents that are issued as either standards or recommended practices. The dominant international consensus standards bodies concerned with shock and vibration are the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC). The U.S. members of ISO and IEC are the American National Standards Institute (ANSI) and the United States National Committee of the International Electrotechnical Commission (USNC/IEC), respectively. The USNC/IEC is a committee of ANSI. Examples of regional standards bodies are the European Committee for Standardization (CEN) and the European Committee for Electrotechnical Standardization (CENELEC). Within the U.S.A., ANSI standards are developed by standards committees following the accredited standards procedures of ANSI. These national committees also often furnish the expert members from the U.S.A. to working groups within ISO and IEC. The national standards committees are typically sponsored by professional societies that have an interest in particular areas of standardization work. Within the U.S.A., additional national consensus standards bodies exist, such as the American Society for Testing and Materials (ASTM), that develop standards by consensus of the members of their society.

STANDARDS ORGANIZATIONS AND COMMITTEES

ISO technical committee (TC) 108 (Mechanical Vibration and Shock) and its six subcommittees (SCs) are predominantly responsible for any international standards activity related to shock and vibration. TC 108 and its subcommittees maintain numerous liaisons with other technical committees and subcommittees within ISO and IEC, including ISO TC 20 (Aircraft and Space Vehicles), ISO TC 43 (Acoustics), ISO TC 45 (Rubber and Rubber Products), ISO TC 159 (Ergonomics), IEC TC 2 (Rotating Machinery), IEC TC 5 (Steam Turbines), and IEC TC 87 (Ultrasonics).

The subcommittees of TC 108 also maintain liaisons with other organizations outside of ISO and IEC that are interested in their work. IEC TC 104 is responsible for standards activities related to environmental testing, including testing using shock and vibration. The primary counterpart to ISO TC 108 within the U.S.A. is ANSI-accredited standards committee S2 (Mechanical Vibration and Shock), which holds the U.S. Technical Advisory Group (TAG) for ISO TC 108 and all of its subcommittees except TC 108/SC 4 on human exposure to shock and vibration. The U.S. counterpart to ISO TC 108/SC 4 on human exposure to shock and vibration is ANSI-accredited standards committee S3 (Bioacoustics), which holds the U.S. TAG for ISO TC 108/SC 4. The ANSI-accredited standards committees S2 and S3 and their U.S. TAGs are administered by the Acoustical Society of America Committee on Standards (ASACOS) and the Acoustical Society of America (ASA) Standards Secretariat. The U.S. TAG for IEC TC 104 is administered and managed by the Electronic Industries Alliance (EIA) Corporate Engineering Department. The activities of CEN TC 231 on shock and vibration are reported to ISO TC 108. Much of the standardization work of CEN TC 231 is related to the EU (European Union) Machinery Directive(s).

STANDARDS ACTIVITIES

The various international standards activities related to shock and vibration are summarized in Table 19.1 and discussed in the following sections.

Terminology. Documents on standardized terminology of all aspects of TC 108 and its six subcommittees are coordinated under TC 108. This vocabulary is contained in ISO document *ISO 2041. ISO 2041* has been adopted by ANSI under the Nationally Adopted International Standard (NAIS) *ANSI S2.1.*

Use and Calibration of Transducers and Instrumentation. The use and calibration of shock and vibration transducers and instrumentation, including standardized calibration methods, measuring instrumentation for human response to vibration, and vibration condition monitoring transducers and instrumentation, is assigned to ISO TC 108/SC 3 (Use and Calibration of Vibration and Shock Measuring Instrumentation). TC 108/SC 3 maintains a liaison with the International Organization of Legal Metrology (OIML). Numerous standards on calibration are contained in the *ISO 5347* series of standards, as well as in the *ISO 16063* series of standards. The ANSI standard on methods of calibration of shock and vibration transducers is *ANSI S2.2.* The ISO standard on measuring instrumentation for human response to vibration is *ISO 8041.* The Instrumentation, Systems, and Automation Society (ISA) administers a number of standards committees, one of which is SP37 on specifications and tests for sensors

TABLE 19.1 Summary of International Standards Activities

Category	Document series	Responsible ISO TC/SC	Related documents
Vocabulary	*ISO 2041*	TC 108	*ANSI S2.1*
Mobility	*ISO 7626*	TC 108	*ANSI S2.31–34*
Isolators	*ISO 2017*	TC 108	*ANSI S2.8*
Balancing	*ISO 1940*	TC 108/SC 1	*ANSI S2.19, S2.42,* and *S2.43*
Balancing machines	*ISO 2953*	TC 108/SC 1	*ANSI S2.38*
Machines/machinery	*ISO 7919* and *10816*	TC 108/SC 2	*ANSI S2.13, S2.40,* and *S2.41*
Vehicles	*ISO 8002*	TC 108/SC 2	
Ships	*ISO 4867, 4868, 6954,* and *10055*	TC 108/SC 2	*ANSI S2.16* and *S2.25; MIL-STD-167*
Buildings	*ISO 4866* and *8569*	TC 108/SC 2	*ANSI S2.47*
Calibration	*ISO 5347* and *16063*	TC 108/SC 3	*ANSI S2.2*
Human response	*ISO 8041*	TC 108/SC 3	
Human exposure	*ISO 2631, 5349, 6897, 8727,* and *13090*	TC 108/SC 4	*ANSI S3.18, S3.29,* and *S3.34*
Generating systems	*ISO 5344, 6070,* and *8626*	TC 108/SC 6	*ANSI S2.5, S2.45, S2.48,* and *S2.58*
Shock machines	*ISO 8568*	TC 108	*ANSI S2.3, S2.14,* and *S2.15*

and transducers used in measurement and control. SP37 has a number of subcommittees that involve transducers used in shock and vibration measurements, e.g., strain gages, accelerometers, servo-accelerometers, and force transducers. SP37.20 is a separate subcommittee of SP37 devoted specifically to vibration transducers.

Shock and Vibration Generators. ISO TC 108/SC 6 (Vibration and Shock Generating Systems) has been assigned standards activities related to systems for the generation of shock and vibration and their terminology. TC 108/SC 6 maintains a liaison with IEC TC 104. IEC TC 104 (Environmental Conditions, Classification, and Methods of Test) is concerned with standardized environmental testing, of which shock and vibration are only two of several variables defining a test environment. ANSI has a number of standards related to the specification of the performance of shock- and vibration-testing machines, as well as standards covering the performance characteristics of these machines.

Structures and Structural Systems. ISO TC 108 (Mechanical Vibration and Shock) and TC 108/SC 2 (Measurement and Evaluation of Mechanical Vibration

and Shock as Applied to Machines, Vehicles, and Structures) both have items in their program of work related to stationary structures or structural systems. Guidelines on building vibration are contained in *ISO 4866* and *ANSI S2.47*. Work on condition monitoring and assessment of structures and structural systems is ongoing in TC 108.

Vehicles. This comprises a very broad area of standardization with a small, but important, portion of it directly related to shock and vibration. ISO TC 108/SC 2 (Measurement and Evaluation of Mechanical Vibration and Shock as Applied to Machines, Vehicles, and Structures) is involved with the vibration of ships, and *ISO 4867, 4868,* and *6954* specifically address the measurement and reporting of vibration onboard ships. Much of the U.S. participation in this work is contributed by members of the Society of Naval Architects and Marine Engineers (SNAME). *ANSI S2.16* covers the measurement and acceptance criteria for the vibratory noise of shipboard equipment, and *ANSI S2.25* covers the evaluation and reporting of hull and superstructure vibration in ships. ISO TC 108/SC 2 is also involved with vibration of land-based vehicles, and *ISO 8002, 8608,* and *10326* are specifically related to the evaluation and reporting of the vibration associated with either land-based vehicles or road surface profiles. ISO TC 20 (Aircraft and Space Vehicles) is involved with standards related to aerospace vehicles in general, and a number of ISO technical committees exist that generally cover specific types of land-based vehicles, e.g., construction, agricultural, and off-road vehicles. The U.S. TAG for ISO TC 20 and the U.S. TAGs for many of the ISO technical committees on land-based vehicles in general are administered by the Society of Automotive Engineers (SAE). The CEN document *CEN EN 1032* on testing mobile machinery has been published, and work is ongoing within CEN TC 231 with respect to testing mobile machinery to determine whole-body vibration and vibration emission values. CEN TC 231 maintains liaisons with CEN TC 144 and CEN TC 151 on tractors and agricultural machines, and construction equipment, respectively.

Machines and Machinery. Standardization related to the shock and vibration of machines and machinery including balancing, condition monitoring, diagnostics, prognostics, and testing is within the program of work of ISO TC 108/SC 1 (Balancing, Including Balancing Machines), ISO TC 108/SC 2 (Measurement and Evaluation of Mechanical Vibration and Shock as Applied to Machines, Vehicles, and Structures), and ISO TC 108/SC 5 (Condition Monitoring and Diagnostics of Machines). Numerous ISO and ANSI standards exist on balancing, balancing machines, balancing terminology, balance quality, and the measurement and evaluation of mechanical vibration related to various classes of rotating and reciprocating machinery. The National Electrical Manufacturers Association (NEMA), American Petroleum Institute (API), Compressed Air and Gas Institute, and Hydraulic Institute publish standards on motors, generators, turbines, pumps, and compressors that may contain parts that are related to shock and vibration of these machines. ISO TC 108/SC 1 maintains liaisons with ISO TC 14 (Shafts for Machinery and Accessories) and ISO TC 39 (Machine Tools). TC 108/SC 2 maintains liaisons with more than a dozen different ISO and IEC technical committees and subcommittees including IEC TC 104. TC 108/SC 5 maintains a liaison with IEC TC 2 (Rotating Machinery). ISO TC 118/SC 3 (Pneumatic Tools and Machines) maintains liaisons with ISO TC 108/SC 2 and TC 108/SC 4. CEN TC 231 has a number of published standards related to the vibration of hand-held power tools, as well as guidance on safety standards related to vibration. An additional program of work within CEN TC 231 pertains to the vibration of a variety of hand-held power tools, e.g., grinders, drills and rotary hammers, chipping and riveting hammers, and hammers for construction.

Human Exposure to Shock and Vibration. The program of work on human exposure to shock and vibration is assigned to ISO TC 108/SC 4 (Human Exposure to Mechanical Vibration and Shock). ISO TC 108/SC 4 maintains liaisons with about a dozen ISO technical committees and subcommittees including ISO TC 43 (Acoustics), as well as with other organizations such as the European Committee of Associations of Manufacturers of Agricultural Machinery (CEMA), the International Maritime Organization (IMO), and the International Union of Railways (UIC). There are a number of ISO and ANSI standards on exposure to whole-body and hand-arm vibration including standards covering occupants of fixed-structures, single shocks, guidance on safety aspects of tests and experiments, transmissibility of gloves and resilient materials, and terminology. (See Chap. 42.)

Testing. Numerous standards and handbooks that cover shock and vibration testing have been issued by ISO and IEC, as well as agencies of the U.S. government, in particular the National Aeronautics and Space Administration (NASA) and the Department of Defense (DoD). Although NASA and DoD standards and handbooks are concerned primarily with aerospace vehicles and military hardware, many are sufficiently general to have broad applications to commercial structures, vehicles, and equipment.

International Standards. While IEC TC 104 (Environmental Conditions, Classification, and Methods of Test) has work programs devoted to a number of environmental variables such as temperature and relative humidity, a portion of the work is directed toward testing using shock and vibration. Specifically, a number of documents in the *IEC 60068-2* series of documents cover sinusoidal vibration, broadband random vibration, shock, drop and topple, free fall, and bump testing. ASTM publishes standards that address using shock and vibration to test unpackaged manufactured products, packaging systems, shipping containers, and materials. *ISO 8568* addresses shock testing machines. ISO TC 108 has a work item on the analysis of the mechanical properties of visco-elastic materials using vibration, and there are a number of ANSI-approved standards published on measuring the mechanical properties of visco-elastic materials using vibration.

NASA Standards and Handbooks. NASA has issued three standards (STD) and two handbooks (HDBK) related to shock and vibration testing that are approved for NASA-wide application to launch vehicles and payloads. Descriptions of the scopes of these publications follow. All of these publications are available via the World Wide Web (www) at *standards.nasa.gov.*

The term *vibroacoustics* is defined as an environment induced by high-intensity acoustic noise associated with various segments of the flight profile (see Chap. 29, Part III of this Handbook). It manifests itself throughout the launch vehicle and payload structure in the form of transmitted acoustic excitation and as structure-borne random vibration. The NASA standard *NASA-STD-7001,* "Payload Vibroacoustic Test Criteria," specifically addresses the acoustic and random vibration environments and test levels associated with vibroacoustics.

Selected environmental exposure tests are contained in *NASA-STD-7002,* "Payload Test Requirements." This standard includes tests that are generally regarded as the most critical and the ones having the highest cost and schedule impact. The standard also includes functional demonstration tests necessary to verify the capability of the hardware to perform its intended function, with and without environmental exposure. Test levels, factors, margins, durations, and other parameters are specified where appropriate. In some cases, these specifications are expressed statistically or are described by reference to other NASA standards.

NASA-STD-7003, "Pyroshock Test Criteria," provides a consistent methodology

for developing pyroshock test criteria for NASA spacecraft, payload, and launch vehicle hardware during all test phases of the verification process. Various aspects of pyroshock testing are discussed, including test environments, methods and facilities, test margins and number of exposures, control tolerances (when applicable), data acquisition and analysis, test tailoring, dynamic analysis, and prediction techniques for pyroshock environments.

The NASA handbook *NASA-HDBK-7004,* "Force Limited Vibration Testing," establishes a methodology for conducting force-limited vibration tests for all NASA flight projects. The methodology in the handbook may be followed by those desiring to use force limiting without having to conduct an extensive literature search or research and development effort before conducting the test. A monograph on force-limited vibration testing is available for reference and is recommended for those needing more detailed technical information (*NASA-RP-1403*).

NASA-HDBK-7005, "Dynamic Environmental Criteria," summarizes procedures for deriving design and test criteria for space vehicles exposed to a wide range of shock and vibration environments. Included in this handbook are detailed discussions of the machines and procedures approved by NASA for the shock and vibration testing of spacecraft and their components. Many of these machines and procedures are equally applicable to the testing of commercial hardware.

DoD Standards. Despite a significant effort to modify or eliminate military (MIL) standards and specifications in favor of commercial standards, a considerable group of MIL standards still remain. In many cases, MIL standards are unique in application and scope and, in some cases, more useful than similar commercial standards. A specific case in point is *MIL-STD-810,* "Environmental Engineering Considerations and Laboratory Tests," now in its "F" revision. This document covers most environments, including shock and vibration. Through its many revisions, the scope of the document has expanded to include new environments and most ground and air platforms. Its principal contribution to product design engineering is its emphasis on *test tailoring,* introduced in the "D" revision and expanded with later revisions. This test concept is not emphasized in any commercial specification and allows *MIL-STD-810* to be used for both defense and commercial applications, and for both U.S. and non-U.S. test programs.

Several useful MIL standards that include shock and vibration requirements are maintained and available. The most widely used are the latest revisions of *MIL-STD-1540* and *MIL-HDBK-340* on space vehicle shock and vibration, *MIL-STD-901D* on Navy shock, *MIL-STD-781* on reliability, and *MIL-STD-167* on ship vibration (parts of this standard have been, or are in the process of being, converted to ANSI or ISO standards). Nearly all of these standards can be located at the Document Automation and Production Service DoD Single Stock Point (DoDSSP) web site. A complete collection of DoD specifications and standards is indexed in the Acquisition Streamlining and Standardization Information System (ASSIST), which is managed by the DoDSSP. The ASSIST Shopping Wizard web site provides the capability to request DoD standardization documents over the Internet. Users may place orders for documents in paper and CD-ROM formats by establishing a customer account with the DoDSSP. The U.S. Government Printing Office allows the purchase of a variety of DoD and other U.S. Government Agency publications. A catalog of government periodicals and subscription services is available from the Superintendent of Documents, U.S. Government Printing Office. Most DoD standardization documents can also be obtained by contacting the controlling military service. In the case of *MIL-STD-810,* for example, the controlling military service is the U.S. Army.

STANDARDS-DEVELOPING ORGANIZATIONS AND SOURCES

Some societies and organizations involved in the production of standards are given below. Sources for catalogs of standards and for purchasing standards are also given. A significant amount of information concerning standards development, meetings, organizations, catalogs, and procurement is readily available via the World Wide Web (www) at the uniform resource locators (URLs) listed below. This list, while extensive, is not intended to be all inclusive.

Acoustical Society of America (ASA)
Standards Secretariat
35 Pinelawn Road, Suite 114E
Melville, NY 11747 USA
Telephone: +1 631 390 0215
URL: *asa.aip.org*

American National Standards Institute (ANSI)
1819 L Street NW, 6th Floor
Washington, DC 20036 USA
Telephone: +1 202 293 8020
URL: *www.ansi.org*

American Society for Testing and Materials (ASTM)
100 Barr Harbor Drive
West Conshohocken, PA 19428-2959 USA
Telephone: +1 610 832 9585
URL: *www.astm.org*

Document Automation and Production Service
700 Robbins Avenue, Building 4/D
Philadelphia, PA 19111-5094 USA
Telephone: +1 215 697 6257
URL: *www.dodssp.daps.mil*

Electronic Industries Alliance (EIA)
Corporate Engineering Department
2500 Wilson Boulevard
Arlington, VA 22201 USA
Telephone: +1 703 907 7500
URL: *www.eia.org*

European Committee for Standardization (CEN)
Rue de Stassart 36
B 1050 Brussels, Belgium
Telephone: +32 2 550 0876
URL: *www.cenorm.be*

Global Engineering Documents
15 Inverness Way East
Englewood, CO 80112 USA
Telephone: +1 800 854 7179
URL: *global.ihs.com*

International Electrotechnical Commission (IEC)
3, rue de Varembé
Case postale 131
CH-1211 Geneva 20, Switzerland
Telephone: +41 22 734 01 50
URL: *www.iec.ch*

International Organization for Standardization (ISO)
1, rue de Varembé
Case postale 56
CH-1211 Geneva 20, Switzerland
Telephone: +41 22 734 01 50
URL: *www.iso.ch*

Instrumentation, Systems, and Automation Society (ISA)
67 Alexander Drive
Research Triangle Park, NC 27709 USA
Telephone: +1 919 549 8288
URL: *www.isa.org*

NASA/Marshall Space Flight Center
Mail Code: ED41
Marshall Space Flight Center, AL 35812 USA
Attention: Paul Gill
Telephone: +1 256 544 2557
URL: *standards.nasa.gov*

Society of Automotive Engineers (SAE)
World Headquarters
400 Commonwealth Drive
Warrendale, PA 15096-0001 USA
Telephone: +1 724 776 4841
URL: *www.sae.org*

Society of Naval Architects and Marine Engineers (SNAME)
601 Pavonia Avenue
Jersey City, NJ 07306 USA
Telephone: +1 800 798 2188
URL: *www.sname.org*

U.S. Government Printing Office
Washington, DC 20402 USA
Attention: Superintendent of Documents
Telephone: +1 202 512 1704
URL: *bookstore.gpo.gov/subscriptions*

U.S. National Committee of the IEC (USNC/IEC)
11 West 42d Street
New York, NY 10036 USA
Telephone: +1 212 642 4936
URL: *www.ansi.org*