



Designation: F3582 – 22

Standard Test Method for Exoskeleton Use: Gaps¹

This standard is issued under the fixed designation F3582; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reappraisal. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reappraisal.

1. Scope

1.1 Purpose:

1.1.1 The purpose of this test method, as a part of a suite of exoskeleton use test methods, is to quantitatively evaluate an exoskeleton's (see Terminology [F3323](#)) performance or safety, or both, of usage by the exoskeleton user (see [1.4](#)) for gaps.

1.1.2 Exoskeletons shall possess a certain set of allowable exoskeleton user movement capabilities, including user-motion adaptability, to suit operations such as: industrial/occupational, military, response, medical, or recreational. Environments in these typical sectors often pose constraints to exoskeleton user movement to various degrees. Being able to step over gaps, as intended by the user or test requestor, while using an exoskeleton is essential for exoskeleton deployment for a variety of tasks. This test method specifies test setup, procedure, and recording to standardize this gaps task for testing exoskeleton user movement.

1.1.3 Exoskeletons need to function as intended, regardless of types of tasks and terrain complexities (for example, carpet, metal, masonry, rock, wood). Required movement capabilities may include, for example: walking, running, crawling, climbing; traversing gaps, stairs, slopes, various types of floor surfaces or terrains, or confined spaces, or combinations thereof. Standard test methods are required to evaluate whether or not exoskeletons meet these requirements.

1.1.4 ASTM Subcommittee F48.03 develops and maintains international standards for task performance and environmental considerations that include but are not limited to, standards for safety, quality, and efficiency. This subcommittee aims to develop standards for any exoskeleton application as exemplified as in [1.1.2](#). The F48.03 test suite consists of a set of test methods for evaluating exoskeleton capability requirements. This gaps test method is a part of the test suite. The setup, procedure, and apparatuses associated with the test methods challenge specific exoskeleton capabilities in repeatable ways to facilitate comparison of different exoskeleton models or exoskeleton capabilities to tasks. Not all exoskeletons may have the capabilities needed to use this test method.

1.1.5 This test method tests for generic gaps-traversal exoskeleton capability, with straight paths and no test course curves, obstacles, or other complexities not described herein (see [4.6](#)). This test method is considered the basis for exoskeleton gaps capability testing.

1.1.6 The test methods quantify elemental exoskeleton use capabilities necessary for sector applications listed in [1.1.2](#) and perhaps other applications. As such, users of this standard should use either the entire suite or a subset based on their particular requirements. Users are also allowed to weight particular test methods or particular metrics within a test method differently based on their specific requirements. The testing results should collectively represent an exoskeleton's overall safety or performance, or both, as required for the task. These performance data can be used: to guide procurement specifications, for acceptance testing, and for training to use exoskeletons intended for specified applications.

NOTE 1—Additional test methods within the suite are anticipated to be developed to address additional exoskeleton capability requirements, including newly identified requirements and even for new application domains.

1.2 *Exoskeleton*—The exoskeleton shall be used as intended by the manufacturer to perform the test described in this test method. If the exoskeleton is not designed for gaps traversing and the test requestor intends to use the exoskeleton to perform a gaps test (for example, for research, development of gaps-capable use by a manufacturer, gaps training as in military applications), appropriate manufacturer approvals should be sought prior to performing the test method.

1.3 *Performing Location*—This test method shall be performed in a testing laboratory or at a site that represents the place where the exoskeleton will be used.

1.4 *Units*—The values stated in SI units are to be regarded as the standard. The values given in parentheses are not precise mathematical conversions to inch-pound units. They are close approximate equivalents for the purpose of specifying material dimensions or quantities that are readily available to avoid excessive fabrication costs of test apparatuses while maintaining repeatability and reproducibility of the test method results. These values given in parentheses are provided for information only and are not considered standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the*

¹ This test method is under the jurisdiction of ASTM Committee [F48](#) on Exoskeletons and Exosuits and is the direct responsibility of Subcommittee [F48.03](#) on Task Performance and Environmental Considerations.

Current edition approved Nov. 15, 2022. Published February 2023. DOI: 10.1520/F3582-22.

responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.

1.6 This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.

2. Referenced Documents

2.1 ASTM Standards:²

- F3323** Terminology for Exoskeletons and Exosuits
 - F3427** Practice for Documenting Environmental Conditions for Utilization with Exoskeleton Test Methods
 - F3443** Practice for Load Handling When Using an Exoskeleton
 - F3444/F3444M** Practice for Training Exoskeleton Users
 - F3474** Practice for Establishing Exoskeleton Functional Ergonomic Parameters and Test Metrics
 - F3517** Practice for Movement Tests When Using an Exoskeleton
 - F3523** Test Method for Exoskeleton Use: Confined Space: Horizontal Movement
 - F3527** Guide for Assessing Risks Related to Implementation of Exoskeletons in Task-Specific Environments
 - F3528** Test Method for Exoskeleton Use: Gait
 - F3613** Practice for Recording the Exoskeleton Fit to the User
 - F3614** Practice for Recording the Exoskeleton User Information
- ### 2.2 ISO Standards:³
- ISO 13482** Robots and robotic devices — Safety requirements for personal care robots

3. Terminology

3.1 General terminology for ASTM F48 standards is listed in Terminology **F3323**. Terminology specific to this standard are shown in this section.

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *apparatus, n*—a structure, object, test component, or artifact thereof, found or placed in an environment and used for a test.

3.2.2 *gap, n*—break or hole in the ground surface.

3.2.3 *test suite, n*—designed collection of test methods that are used, collectively, to evaluate an exoskeleton's safety and/or performance.

4. Summary of Test Method

4.1 The task for this test method, exoskeleton-user traversing gap(s), is defined as the exoskeleton-user performing

gap(s) traversal test including a number of repetitions as set by the test requestor. A test includes at least 5 repetitions to traverse one or more gaps that have preset, as per the test requestor, horizontal breaks or holes in the ground surface. See **Fig. 1** for an illustration. Further, the test requestor can specify the statistical reliability and confidence levels of such a capability and, thus, dictate the number of successful task performance repetitions that are required. The tests are described as follows:

4.1.1 *Gaps Platform*—A raised, level surface on which the user steps across a set gap between gap platforms and onto another gap platform.

NOTE 2—The gap platform can be, for example, a path where a gap is within the path.

4.2 The test is described as follows:

4.2.1 This test can be used to assess aerobic function, endurance, gap traversal speed, or balance, or combinations thereof.

4.2.2 The test metrics can include, for example, the following:

4.2.2.1 Number of gaps traversed;

4.2.2.2 Distance (see **Fig. 2** for gap axes labeling) of gaps traversed;

4.2.2.3 Change(s) in user (for example, heart rate, fatigue, stability, balance, toe drag, stumbles, near falls/falls) by a specified amount; and

4.2.2.4 Upon traversing the gap(s), the ability to turn around on the floor or gap platform and traverse the gap(s) in the opposite direction.

4.3 For all tests, the specified START point to the END point, and TURN point shall be defined by the test requestor prior to the test. This test method can be combined with other test methods, for example, Test Method **F3528**. The required apparatuses are described in Section 6.

4.4 For any gap test, return from the end marker past the start marker may commence as part of the test or the user may begin each repetition from the start-to-end markers as set by the test requestor.

4.5 The gap test can include one or more gaps, gap-to-gap spacing, and gap distances as requested by the test requestor.

NOTE 3—For the following procedures, the standard gap apparatus is described. The test requestor may instead use the actual gap(s) in situ to the application.

4.6 A full gap test is defined as: the user begins by standing behind a start location, (1) walks across the platform to the opposite side, (2) traverses the gap(s), (3) walks across the platform past the end marker, (4) the user turns around 180°, and (5) repeats steps 1, 2, and 3, and past the start marker.

4.6.1 A phased gap test can include one or more phases of the full gap test as follows, beginning with the user standing behind a start/end location:

4.6.1.1 *Phase 1*—The user stands behind the start line on the platform of the gap apparatus,

4.6.1.2 *Phase 2*—The user traverses the gap,

4.6.1.3 *Phase 2a*—If more platforms and gaps are used, the user traverses multiple gaps,

² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

³ Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, <http://www.ansi.org>.