Designation: F3523 – 21

Standard Test Method for Exoskeleton Use: Confined Space: Horizontal Movement[1]

This standard is issued under the fixed designation F3523; 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 reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

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 of usage, or both, by the exoskeleton user (see 1.4) in confined spaces with horizontal user movement.

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, military, response, medical, or recreational. Environments in these typical sectors often pose constraints to exoskeleton user movement to various degrees. Being able to pass-through or maneuver, or both, effectively in confined spaces is essential for exoskeleton deployment for a variety of tasks. This test method specifies apparatuses to standardize this confined space task for testing exoskeleton user movement along the horizontal axis.

1.1.3 Exoskeletons shall be able to handle many types of task and terrain complexities. The required movement capabilities include, for example: walking, running, crawling, climbing, traversing gaps, hurdles, stairs, slopes, various types of floor surfaces or terrains, and confined spaces. 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 confined space: horizontal movement test method is a part of the test suite. The apparatuses associated with the test methods challenge specific exoskeleton capabilities in repeatable ways to facilitate comparison of different exoskeleton models or to facilitate application of exoskeleton capabilities to intended tasks.

1.1.5 The test methods quantify elemental exoskeleton use capabilities necessary for sector applications listed in 1.1.2 and perhaps others. As such, users of this test method 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 *Performing Location*—This test method shall be performed in a testing laboratory or the field where the specified apparatus and environmental conditions are implemented.

1.3 *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.

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

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for 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.

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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]

D4276 Practice for Confined Area Entry

F3128 Specification for Poly(Vinyl Chloride) (PVC) Schedule 40 Drain, Waste, and Vent Pipe with a Cellular Core

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

2.2 *Other Standards:*

ISO 13482 Robots and robotic devices — Safety requirements for personal care robots[3]

3. Terminology

3.1 General terminology for ASTM Committee F48 standards are listed in Terminology F3323. Terminology specific to this test method are shown in this section.

3.2 *Definitions:*

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 *artifact, n*—a representative of real structure(s), object(s), or test component(s) and used for a test.

3.2.3 *confined space, n*—limited entry and egress.

3.2.4 *horizontal movement, v*—user moves on the horizontal plane.

3.2.5 *movement, v*—a particular instance or manner of user motion.

3.2.6 *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 moving through a confined space with horizontal movement, is defined as the exoskeleton-user traversing from the START point specified by the test supervisor, and ending at the END point. A test repetition shall be (*1*) when the user passes completely through the confined space or (*2*) when the user passes completely through the confined space and then returns back to the START point after passing completely back through the confined space again, thus enabling continuous repetitions. Either 4.1 (*1*) or (*2*) shall be defined by the test requestor prior to the test. The specified path from the START point to the END point shall be defined by the test requestor prior to the test. The confined space: horizontal movement apparatuses are described in Section 5. See Fig. 1 for an illustration. Artifacts representing real apparatuses are described in Section 6.

4.2 The exoskeleton's capability is defined as the exoskeleton's ability to complete the confined space: horizontal movement task where the user is capable of passing through the set confined space and, if requested by the test requestor, can perform the task at the desired time to complete the test. 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. In such a case, the average time to complete the test shall be used as the exoskeleton user's capability.

4.3 The exoskeleton user is allowed to practice before the test.

4.4 Once the test begins, there shall be no verbal communication between the exoskeleton user and the test supervisor regarding the performance of a test repetition, other than instructions on when to start and notifications of faults and any safety related conditions. The user shall have the full responsibility to determine whether and when they have completed a repetition and notify the test supervisor accordingly. However, it is the test supervisor's authority to judge the completeness of the repetition.

NOTE 2—Practice within the test apparatus could help establish the applicability of the exoskeleton for the given test method. It allows the operator to gain familiarity with the standard apparatus and environmental conditions. It also helps the test supervisor to establish the initial apparatus setting for the test when applicable.

4.5 The test requestor has the authority to select the confined space opening for the traversing task. The test requestor also has the authority to select test methods that constitute the test event, to select one or more test site(s) at which the test methods are implemented, to determine the corresponding statistical reliability and confidence levels of the results for each of the test methods, and to establish the participation rules including the testing schedules and the test environmental conditions.

5. Significance and Use

5.1 Exoskeletons are being used in the industrial, military, response, medical, and recreational sectors to enhance safety and effectiveness of the user to perform tasks. Confined spaces exist in many of these areas, as shown in Fig. 1, requiring people to fit through small spaces and this is potentially even more difficult while wearing an exoskeleton. For example, in the automobile manufacturing industry, workers wearing exoskeletons are required to fit into a confined automobile door opening while carrying tools to attach components to the car body. In emergency response operations, exoskeletons are used to enhance the safety and effectiveness of emergency responders operating in hazardous and confined space environments

[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.