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Standard Practice for Recording the Exoskeleton Test Configuration[1]

This standard is issued under the fixed designation F3576; 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 This practice describes a means to record the exoskeleton configuration when testing. This practice provides a method for recording exoskeleton hardware and software control parameters.

1.2 This practice: contextualizes the exoskeleton configuration during a test, including the identification and adjustment of main configuration parameters and the addition of other equipment (for example, cameras, markers) used during tests; provides a basis for comparison of the test circumstances across different exoskeletons or tests, or both (for example, varying power or spring settings, prior exoskeleton use, maximum control settings); and allows a test to be recreated.

1.3 The values stated in SI units are to be regarded as the standard. The values given in parentheses are not precise mathematical conversions to imperial units. They are close approximate equivalents for the purpose of specifying exoskeleton characteristics 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 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

F3613 Practice for Recording the Exoskeleton Fit to the User

F3614 Practice for Recording the Exoskeleton User Information

3. Terminology

3.1 Terms used within this standard refer to Terminology F3323.

4. Summary of Practice

4.1 This practice describes a method for recording the exoskeleton configuration when performing tests described in exoskeleton test methods. Without considering the variability of users, exoskeletons have a series of hardware and software parameters that can affect the exoskeleton functionality, for example:

4.1.1 Different exoskeletons, designed to help users perform varying tasks, may perform similarly due to their hardware setups or software capabilities and settings; or

4.1.2 The same exoskeleton models may be expected to perform similarly but instead perform differently due to their hardware setup and software settings.

4.2 The main configuration parameters are, for example:

4.2.1 *Hardware*—Exoskeleton weight, size, age, body part movement/support; and

4.2.2 *Software*—Control and monitor software, firmware versions, and software settings for maximum accelerations and velocities, maximum joint angle limits and torques, and sensor thresholds and impacts of reaching thresholds.

4.3 This practice also provides a standard method to report the exoskeleton configuration of which contextualizes exoskeleton test results. For example, the result of a timed test could

[1] This practice 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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[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.

be dependent upon exoskeleton limitations on walking speed to 0.5 m/s or knee angle rotation limitation from 0° through 120°. As such, comparing two exoskeleton configurations could indicate that to which parameters affect exoskeleton performance.

4.4 This practice does not consider the user or the exoskeleton fit to the user information. These are also two important exoskeleton safety and performance areas that are discussed in Practice F3614 and Practice F3613, respectively.

5. Significance and Use

5.1 The significance of the information to be recorded in a test report allows for exoskeleton safety and performance to be contextualized with the exoskeleton configuration. Exoskeleton tests can also be replicated across similar or different exoskeletons by using this practice to record the exoskeleton test configuration in a standardized way.

5.2 Limitations of the practice are that not all exoskeletons have the same capabilities or configuration parameters. For example, for capabilities, an exoskeleton that moves the legs with electromyography during rehabilitation may behave differently in repeated use over time or within different gait courses (for example, straight or curved). For configuration, an exoskeleton that moves the legs with electromyography during rehabilitation may have varying signal gain/amplification settings.

6. Exoskeleton Information

6.1 *Exoskeleton Photos*—Provide photographs, videos of motion, or computer aided drawings, or combinations thereof, of the exoskeleton front, sides, and back and any other distinguishing features.

6.2 *Main Exoskeleton Hardware Parameters:*

6.2.1 *Make and Model*—Provide the manufacturer and model of the exoskeleton, and mark any and all user's body areas that are intended to be affected by the exoskeleton, including: neck, shoulder, arm, hand, back, leg, ankle, or any other user's body area.

6.2.2 *Part Number(s)*—Provide the part numbers for each of the components, including: neck, shoulder, arm, hand, back, leg, ankle, or other user's body areas.

6.2.3 *Serial Number(s)*—Provide the serial numbers for each of the components, including: neck, shoulder, arm, hand, back, leg, ankle, or other user's body areas.

6.2.4 *Hardware Revision/Version*—Provide any revision or version numbers for each of the components, including: neck, shoulder, arm, hand, back, leg, ankle, or other user's body areas.

6.2.5 *Age (Years, Months, Runtime)*—Provide the age of the exoskeleton in years, months, and the amount of runtime (in hours) the exoskeleton has been used.

6.2.6 *Environment(s)*—Provide the environment in which the exoskeleton was used (for example, harsh outdoors, mud, rain, and temperatures between 5 °C and 35 °C).

6.2.7 *Classification*—Provide the main classification for the exoskeleton including, for example, the upper body, lower body, or whole body. If the classification is only by the exoskeleton affected area, select one of the following: neck, shoulder, arm, hand, back, leg, or ankle, or provide any other user's body area(s) affected.

6.2.8 *Weight*—Provide the exoskeleton weight in kilograms, including all components necessary for a fully functional exoskeleton.

6.2.9 *Load Transmission to the Ground*—Provide whether or not the load applied to the exoskeleton (for example, the user's weight) is transmitted to the ground (that is, yes) or not (that is, no).

6.2.10 *Type*—Provide the exoskeleton powered type as: full active (that is, not user-powered), full passive (that is, user-powered), or hybrid (that is, a combination of actively and passively powered).

6.2.11 *Hybrid Joint Power Method*—Provide the exoskeleton hybrid power method for each component (that is, neck, shoulder, arm, hand, back, leg, ankle) as active or passive.

6.2.12 *Spring Selection*—Provide the spring, spring cartridge, or other peak spring force (Nm) settings for the neck, shoulder, arm, hand, back, leg, ankle, or other exoskeleton components (provide the component).

6.3 *Size Settings:*

6.3.1 *Generic Size*—Provide the generic exoskeleton size, if used by the manufacturer (for example, small, medium, or large). In all cases, if known, actual sizes and settings should also be provided (for example, shoulder-to-elbow length equals XX cm, etc.).

6.3.2 *Right/Left Side*—Provide the exoskeleton's size settings by listing or by copy/pasting into the spaces provided (see Fig. 1 for examples).

6.4 *Control and Power:*

6.4.1 *Control Method*—Provide the exoskeleton control method for each component (that is, neck, shoulder, arm, hand, back, leg, ankle) or other exoskeleton components (provide the component) as active (that is, exoskeleton-powered) or passive (that is, user-powered).

6.4.2 *Range of Motion Limit Method*—Provide if the range of motion is limited by hardware or software.

6.4.3 *Range of Motion*—Provide the exoskeleton range of motion for each component: neck, shoulder, arm, hand, back, leg, ankle, or other exoskeleton components (provide the component).

6.4.4 *Power Source*—Provide the exoskeleton power method as onboard battery or tethered.

6.4.5 *Battery Percentage (start/end)*—Provide the exoskeleton battery percentage at the start and end of the test.

6.4.6 *Percentage of Power Settings*—Provide the exoskeleton power settings for each component: neck, shoulder, arm, hand, back, leg, ankle, or other exoskeleton components (provide the component).

6.4.7 *Sensors/Sensor Used for*—Provide the exoskeleton sensor(s) and use of the sensor(s) (for example, angle limit sensor, wall detection sensor, hazard sensor).

6.5 *Main Exoskeleton Software Parameters:*

6.5.1 *All Applicable Software and Firmware Versions (Component/Version)*—Provide the version(s) of any software or firmware used to control exoskeleton components or the full exoskeleton.

Frame Size	Cassette Size	Armrest Size	Spine Notches	Shoulder Notches (inside)	Shoulder Pivots' Width	Armrest Rail Setting	Special Notes (comfort, accessories, mitigations)

Torso Height:	1	2	3	4	5	6	7	8
	Left Side				**Right Side**			
Shoulder Width	1	2	3	4	1	2	3	4
Arm Length	1	2	3	4	5	6	7	
	1	2	3	4	5	6	7	
Support Level	1	2	3	4	5			
	1	2	3	4	5			
Support Angle	60	75	90	105	120			
	60	75	90	105	120			

FIG. 1 Examples of Size Settings (Courtesy SuitX and Levitate)

6.5.2 *Maximum Exoskeleton Velocity*—If applicable, provide the maximum velocity limits for the exoskeleton components or the full exoskeleton.

6.5.3 *Maximum Exoskeleton Acceleration*—If applicable, provide the maximum acceleration limits for the exoskeleton components or the full exoskeleton.

6.5.4 *Maximum Joint Velocity*—If applicable, provide the maximum joint velocity for the exoskeleton components (that is, neck, shoulder, arm, hand, back, leg, ankle) or other exoskeleton components (provide the component).

6.5.5 *Maximum Joint Acceleration*—If applicable, provide the maximum joint acceleration for the exoskeleton components (that is, neck, shoulder, arm, hand, back, leg, ankle) or other exoskeleton components (provide the component).

6.5.6 *Maximum Joint Torque*—If applicable, provide the maximum joint torque for the exoskeleton components (that is, neck, shoulder, arm, hand, back, leg, ankle) or other exoskeleton components (provide the component).

6.5.7 *Sensor Thresholds*—If applicable, provide the threshold settings set for each sensor and the impact of reaching the threshold (for example, audible warning, tactile warning, shutdown).

6.5.8 *Other Key Parameters that are Modified/set for the User*—Provide any other software settings or information not listed in previous sections that may affect the exoskeleton performance.

6.6 *Additional Test Equipment:*

6.6.1 *Added Equipment to the Exoskeleton*—Provide any equipment used for exoskeleton testing that was added to the exoskeleton: for example, optical tracking system (OTS) markers and their locations on the exoskeleton, including their make and model numbers and OTS system model; padding and location.

6.6.2 *Added Equipment to the User*—Provide any equipment used for exoskeleton testing that was added to the user: for example, cameras, including their make and model numbers, and image processing software used for the test; padding and location.

6.6.3 *Added Equipment for Exoskeleton Testing*—Provide any equipment used for exoskeleton testing: for example, cameras, including their make and model numbers, and image processing software used for the test.

6.7 *Additional Parameters and Settings:*

6.7.1 *Event Timing*—Provide the timing of events that are expected to occur when using the exoskeleton (for example, at 100 h of use, the exoskeleton controller will provide notification that lubrication of exoskeleton joints is expected).

6.7.2 *Other Constraints Placed on the Exoskeleton*—Provide constraints that the requestor has placed on the exoskeleton, for example:

6.7.2.1 *Generic Test Environment*—For example, outdoors or indoors, day or night, defined or undefined test areas;

6.7.2.2 Velocity and acceleration that are below the maximum capability; and

6.7.2.3 Spring or other applied force device or setting above the force required to perform the task.

6.7.3 *Context for the Test*—Provide the context for the test (for example, during normal gait operation, the exoskeleton knee torque will be at 25 % or less of maximum, during hill climbing, knee torque will change to 25 % or above depending on torque required).

6.7.4 When are the various software and hardware configurations used during the test? Provide the software and hardware configurations that may change and be used during a test (for example, two software versions may be required as follows: Use configuration A for one activity and configuration B for another activity; leg hardware may be stiffer at body lift versus walking or sitting).

7. Procedure

7.1 When conducting the Committee F48 test methods, the test requestor shall choose the exoskeleton configuration to be recorded as described in Section 5. The test requestor can elect and apply any of the configuration methods and parameters to the exoskeleton-under-test included herein and record the levels as described in Section 7.

7.2 Exoskeleton configuration may be changed prior to a test. At any time after the start of a test, as instructed by the test supervisor, the exoskeleton configuration shall not be manually changed by any person. In the event that the exoskeleton configuration automatically changes during a test, the test requestor shall inform the test supervisor of such occurrence(s) prior to the test and the occurrence(s) shall be noted on the test report.

8. Report

8.1 A test report is required for recording the exoskeleton configuration. The test report shall include the following features:

8.1.1 A photograph or detailed drawing showing the hardware configuration of the exoskeleton to be tested;

8.1.2 A hardcopy or electronic file of the software configuration of the exoskeleton to be tested; and

8.1.3 Any additional exoskeleton features or important notes, or both, that may cause exoskeleton performance variation.

8.1.4 The test report (see example in Fig. 2) shall be filled out. In the situation where a particular configuration parameter is not known, it shall be noted as such using "unknown."

NOTE 1—The implementation of a test report is not standardized. As such, the resulting test reports can be different while conforming to this specification. Fig. 2 provides an illustration of a blank test report for this practice.

9. Keywords

9.1 configuration; exoskeleton; exosuit; test report

ASTM International Committee F48 on Exoskeletons and Exosuits

Standard Practice for Recording the Exoskeleton Test Configuration

DIMENSIONED AND LABELED DRAWING AND PHOTOGRAPH OF THE EXOSKELETON:

NOTES:

TEST TECHNICIAN: _____

(a)

FIG. 2 Test Report: (a) Drawing

section #			Neck	Shoulder	Arm	Hand	Back	Leg	Ankle
6.2	**Main Exoskeleton Hardware Parameters**								
	Make and Model								
	Part Number(s)								
	Serial Number(s)								
	Hardware Revision/Version								
	Age: Years _____ Months _____ Run Time _____								
	Environment(s)								
	Classification: Upper body _____ Lower body _____ Whole body _____								
	Weight (including all components necessary for a fully functional exoskeleton)								
	Load transmission to Ground?	Yes _____ No _____							
	Type : Full Active _____ Full Passive _____ Hybrid _____								
	Hybrid Joint Control Method (Active or Passive)								
	Spring Selection/Peak Torque								
6.3	**Size Settings**								
	Generic Size (e.g., sm, med, lg)								
	right side								
	left side								
6.4	**Control and Power**								
	Control Method	(e.g., manual, adaptive/automatic)							
	Range of Motion limits set in:	Hardware _____ Software _____							
	Range of Motion Limit Method:								
	Range of Motion:								
	Power source	Onboard Battery _____ Tethered _____							
	Battery percentage	Start _____ End _____							
	Percentage of Power Settings								
	Sensors	Sensor Used for							

(b)

FIG. 2 Test Report: (b) Parameters Table *(continued)*

6.5	Main Exoskeleton Software Parameters								
	All applicable software and firmware versions:								
	Component	Version							
	Maximum Exoskeleton Velocity								
	Maximum Exoskeleton Acceleration								
	Maximum Joint Velocity								
	Maximum Joint Acceleration								
	Maximum Joint Torque								
	Sensor Thresholds	Impact of Reaching Threshold (e.g., Audible warning, tactile warning, shut down)							
	Other key parameters that are modified/set for the user								
6.6	Additional Test Equipment								
	Added equipment to the exoskeleton								
	Added equipment to the user								
	Added equipment for exoskeleton testing								
6.7	Additional Parameters and Settings								
	Event Timing								
	Other constraints placed on the exoskeleton?								
	Context for the test								
	When are the various software and hardware configurations used during the test?								

(c)

FIG. 2 Test Report: (c) Parameters Table *(continued)*

APPENDIX

(Nonmandatory Information)

X1. EXAMPLE EXOSKELETON CONFIGURATION TEST REPORT

X1.1 A fictitious exoskeleton was used to provide the user an example recording of the exoskeleton configuration as described in this practice. Fig. X1.1 shows a completed test report (without a photo) for the fictitious exoskeleton.