Designation: F1951 – 21

An American National Standard

Standard Specification for Determination of Accessibility of Surface Systems Under and Around Playground Equipment[1]

This standard is issued under the fixed designation F1951; 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.

INTRODUCTION

The federal accessibility standards require newly constructed and altered public playgrounds by accessible to and usable by people with disabilities. Both the Architectural Barriers Act[2] and the 2010 ADA Standards for Accessible Design[3] require accessible surfaces, including the accessible route within the play area to be firm and stable. At this time, there is no standard specification to measure firmness and stability, which is related to the work for a person with a mobility impairment to traverse a surface, thus highlighting the need for a systematic and consistent means of evaluating the capability of surface systems. The goal of this specification is to establish a uniform means to measure the work for a person with mobility impairment to traverse surface systems in order to provide the potential buyer with performance specifications to select materials and maintain the surface as an accessible surface through the accessible route and at accessible playground equipment.

1. Scope

1.1 This specification establishes minimum characteristics for those factors that determine accessibility. This specification applies to all types of materials that can be used as the accessible route through the play area, under and around playground equipment.

1.2 The material used as the accessible route through the play area, under and around playground equipment that meets this specification must also comply with Specification F1292 or Test Method F3351, or both, if the surface is within the fall zone.

1.3 Surface systems in compliance with this specification will not prevent all types of injuries from occurring when the surface is used.

1.4 The SI unit of work is the joule (J), which is defined as the work expended by a force of one newton through a displacement of one meter. The dimensionally equivalent newton-meter (N*m) shall be used only if it is followed by the term "work" so it is not confused to be a torque value. (1 N*m = 0.73756215 pound-force-feet).

1.5 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard; see IEEE/ASTM SI 10 for further details.

1.6 The following precautionary statement pertains only to the test method portions of this specification: *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.*

1.7 *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:*[4]

IEEE/ASTM SI 10 American National Standard for Use of the International System of Units (SI): The Modern Metric System

[1] This specification is under the jurisdiction of ASTM Committee F08 on Sports Equipment, Playing Surfaces, and Facilities and is the direct responsibility of Subcommittee F08.63 on Playground Surfacing Systems.

Current edition approved Aug. 1, 2021. Published September 2021. Originally approved in 1999. Last previous edition approved in 2014 as F1951 – 14. DOI: 10.1520/F1951-21.

[2] Applicable to facilities owned, operated or leased by the federal government.

[3] Applicable to facilities owned, operated or leased by units of state or local government and public accommodations.

[4] 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.

E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods
E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method
F1292 Specification for Impact Attenuation of Surfacing Materials Within the Use Zone of Playground Equipment
F2075 Specification for Engineered Wood Fiber for Use as a Playground Safety Surface Under and Around Playground Equipment
F3351 Test Method for Playground Surface Impact Testing in Laboratory at Specified Test Height

2.2 *U.S. Department of Justice:*[5]
28 CFR Part 35 Nondiscrimination on the Basis of Disability in State and Local Government Services
28 CFR Part 36 Nondiscrimination on the Basis of Disability by Public Accommodations and in Commercial Facilities
2010 ADA Standards for Accessible Design

2.3 *U.S. Consumer Product Safety Commission Document:*[6]
US CPSC Publication No. 325 Handbook for Public Playground Safety (2015)

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *accessible, adj*—a site, building, facility, or portion thereof that complies with the 2010 ADA Standards for Accessible Design.

3.1.2 *accessible route, n*—the pathway connecting the site arrival point to the accessible features of a site including the entry to the playground, the points of entry to accessible play components and their points of egress.

3.1.2.1 *Discussion*—The accessible route meets the minimum technical provisions for running slope, cross slope, ground walking surface, changes in level, openings, firmness, and stability as defined in Chapter 4 of the 2010 ADA Standards for Accessible Design.

3.1.3 *baseline ramp, n*—a ramp with a hard, smooth surface with grade of 7.1 ± 0.2 % (1:14).

3.1.4 *camber, n*—the angular position in the vertical direction of the individual main wheel axis.

3.1.4.1 *Discussion*—Zero camber occurs when the wheel axis is parallel to the ground surface.

3.1.5 *cross slope, n*—the slope that is perpendicular to the direction of travel.

3.1.6 *firm or firm surface, v/n*—a firm surface resists deformation by either indentations or particles moving on its surface.[7]

3.1.7 *firmness – with respect to a surface, adj*—the degree to which a surface material resists deformation, especially by indentation.

3.1.8 *loose fill system, n*—a surface system consisting of individual particles, for example, engineered wood fiber, bark mulch, wood chips, shredded foam, shredded rubber, sand, pea gravel, and so forth.

3.1.9 *maneuverability, n*—the ability of a surfacing material to allow unencumbered traversing or locomotion of a person with or without prosthetic aids or wheelchair.

3.1.10 *pushrim, n*—the outer grip-able tube connected to the wheel of a wheelchair for the purpose of manually propelling a wheelchair. The terms pushrim and handrim shall be used interchangeably.

3.1.11 *qualified personnel, n*—those with current knowledge, training, skill, education and experience who have successfully demonstrated the ability to solve or resolve problems relating to the subject matter and work through the application of professional judgement.

3.1.12 *running slope, n*—the slope that is parallel to the direction of travel.

3.1.13 *stable surface, v/n*—a stable surface resists additional deformation by an indentation that tries to twist or turn on the surface as a result of applied forces.

3.1.14 *stability – with respect to a surface, n*—the degree to which a surface material resists deformation that is twisting or turning on the surface.

3.1.15 *toe, n*—the difference in separation distance between the front of the two main wheels and the rear of the two main wheels of a wheelchair.

3.1.15.1 *Discussion*—Proper toe alignment occurs when the axle is perpendicular to the direction of rolling.

3.1.16 *unitary surface, n*—a top layer of one or more material components bound together to form a continuous surface; for example, urethane and rubber composites, molded foam, molded rubber mats.

3.1.17 *use zone, n*—area beneath and immediately adjacent to a play structure or equipment that is designated for unrestricted circulation around the equipment and on whose surface it is predicted that a user would land when falling from or exiting the equipment.

3.1.17.1 *Discussion*—The surface area within the use zone shall meet the minimum impact attenuation requirements of Specification F1292 from the maximum fall height.

3.1.18 *wheelchair work, n*—a measurement of work, using an instrumented handrim on a manual wheelchair, that calculates the varying torque when propelled for a specified time and distance across a specific surface and slope.

4. General Requirements

4.1 Playground surfaces represented as complying with this specification shall meet all applicable requirements regarding accessibility specified herein. Anyone representing compliance with this specification shall keep such essential records as are necessary to document any claim that the requirements within this specification have been met.

4.2 Surface systems that are within the use zone of the surrounded playground equipment shall be tested in accordance with Specification F1292 or Test Method F3351, or both,

[5] Available from U.S. Government Printing Office, Superintendent of Documents, 732 N. Capitol St., NW, Washington, DC 20401-0001, http://www.access.gpo.gov.
[6] Available from United States Consumer Product Safety Commission, 4330 East West Highway, Bethesda, MD, 20814, http://www.cpsc.gov/.
[7] 2010 ADA Standards for Accessible Design, advisory note 302.1.

and shall comply with the impact performance requirements of Specification F1292. Thus, surface systems shall exhibit a head injury criterion (HIC) not exceeding 1000 and a value of acceleration recorded during an impact (g-max) not exceeding 200 from a height at or greater than the fall height of the play structure.

NOTE 1—This is consistent with the guidance contained in US CPSC Publication No. 325.

4.3 Specification certification compliance for the surface sample shall be conducted by an independent accredited testing laboratory.

5. Performance Requirement

5.1 *Accessible Surface Performance Parameters*—Playground surface materials and surface systems that are used as the accessible route through the playground, under and around accessible play equipment shall be required to comply with technical provisions for the accessible route and clear ground space including running slope, cross slope, openings in the surface, changes in level, pile height, firmness and stability.

5.2 The Accessible Surface Performance Criterion shall apply to the site or play surface sample to be tested, as specified in the 2010 ADA Standards for Accessible Design including the follow provisions. Any deviation from these criteria shall be documented in the resulting report.

5.2.1 The ground level accessible route through the play area and the surface sample to be tested shall be maintained with a minimum 60 in. (1525 mm) clear width, a running slope not to exceed 1:16 (6.25 %) maximum and a cross slope not to exceed 1:48 (2.08 %) maximum.[8]

5.2.2 The clear ground space for the approach and use of accessible play components and the surface sample to be tested shall be maintained with a slope not to exceed 1:48 (2.08 %) maximum in all directions.[9]

5.2.3 Openings in the ground surfaces shall not allow passage of a sphere more than 0.5 in. (13 mm) maximum.[10]

5.2.4 Changes in level shall not exceed 0.25 in. (6.4 mm) vertical maximum or 0.5 in. (13 mm) beveled maximum with a slope not steeper than 1:2.[11]

5.2.5 Turf, artificial turf, carpet or carpet tile shall have a level loop, textured loop, level cut pile, or level cut/uncut pile texture. Pile height shall not exceed 0.5 in. (13 mm) maximum or be otherwise documented in the report.[12]

5.2.6 The playground surface and/or the surface sample to be tested shall be stable and firm. The wheelchair work test method described here shall serve as a means to determine if the surface is firm and stable in the absence of a specific test method.

5.3 *Maneuverability*—When tested in accordance with the wheelchair work test method described in this standard, a surface in place shall have combined average work per foot (work per meter) value for straight propulsion and for turning less than the combined average work per foot (work per meter) value for straight propulsion and for turning, respectively, on a hard, smooth surface with a grade of 7.1 ± 0.2 % (1:14).

5.3.1 *Calculation of Work Ratio*—The work ratios for straight propulsion and turning shall be calculated by dividing the average work per foot (work per meter) measured using the wheelchair work measurement test procedure by the average work per foot (work per meter) on a hard, smooth surface with a grade of 7.1 ± 0.2 % (1:14) and shall be less than or equal to 1.0.

5.3.2 The test used to determine accessibility, shall have been conducted on surfacing material samples that are the same regarding their design, materials, components, thickness, and manufacture as the installed playground surface.

5.4 Test material from the same lot number or date of manufacture from the manufacturer shall be used to determine the accessibility of the surface using the Specification F1951 wheelchair work test method and shall also be tested to Specification F1292 or Test Method F3351, or both, to the drop height specified by the manufacturer/supplier. The drop height, g, and HIC results of the test shall be recorded and compared with the results of the same product tested to Specification F1292 or Test Method F3351, or both.

5.5 The test used to determine accessibility of materials specified for use in a playground shall have been conducted no more than five years prior to the date of installation of the playground surface.

5.6 It would be permissible to use the wheelchair work test method at an installed playground at the accessible point of entry into the play surface, along the accessible route, and at the clear ground space for each accessible play component.

5.7 Ground surfaces shall be inspected and maintained regularly and frequently to ensure continued compliance with Specification F1951 and the ADA and ABA accessibility standards.[13]

6. Summary of Test Method

6.1 *Wheelchair Work Test Method – Baseline*—The wheelchair work measurement test methods shall be conducted on a hard, smooth surface with a grade of 7.1 ± 0.2 % (1:14) utilizing the straight propulsion test method and the turning propulsion test method to determine the work required to propel a test wheelchair on a reference surface and specified slope.

6.2 *Wheelchair Work Test Method – Surface Sample*—The wheelchair work measurement test methods for straight and turning propulsion shall then be conducted on a level sample surface. The work values obtained on the level sample surface shall be compared to the baseline work value obtained in 6.1.

[8] 2010 ADA Standards for Accessible Design: 1008.2, 1008.2.4.1, 1008.2.5.1, 1008.4.2.

[9] 2010 ADA Standards for Accessible Design, 305.

[10] 2010 ADA Standards for Accessible Design, 302.3.

[11] 2010 ADA Standards for Accessible Design: 303.2, 303.3.

[12] 2010 ADA Standards for Accessible Design, 302.2.

[13] 2010 ADA Standards for Accessible Design, 1008.2.6.1. The frequency by which a playground surface is tested and maintained is likely to be different for every playground and dependent on both the type of surface and the number of daily users.

7. Significance and Use

7.1 The purpose of this specification is to establish quantitative measurements for wheelchair work that are related to the firmness and stability of a surface material or surface system used as the accessible route and clear ground space at components within a playground.

7.2 The specification provides a uniform means of objectively quantifying the performance of different playground surfacing materials.

8. Equipment Operator Qualifications

8.1 Tests for the wheelchair work method shall be conducted by qualified personnel.

9. Test Apparatus

9.1 An Instrumented Test Wheelchair is used to measure the work per foot (work per meter) for a straight propulsion and turning across a surface.

9.1.1 *Instrumented Test Wheelchair*—A 16-in. (40.64-cm) seat width rehabilitation wheelchair with foot supports and pneumatic front and rear tires shall be used as the test wheelchair. The rear wheels shall be identical to one another with 24 by 1.375-in. (61 by 3.5-cm) pneumatic tires and pushrim diameters of 20 in. (50.8 cm). The front wheels shall be identical to one another with 8 by 1-in. (20.3 by 2.54-cm) pneumatic tires. One instrumented main rear wheel shall be capable of measuring the forces applied to the pushrim that are tangential to the pushrim and parallel to the direction of travel. The wheelchair shall be adjusted such that there is minimal toe in or out and minimal camber. Tire pressures shall be set to the maximum pressure specified by the manufacturer ±2 psi. The total weight of the wheelchair, including any distance measurement or data acquisition equipment residing on the wheelchair shall be 48.4 ± 11 lb (22 ± 5 kg).

9.1.2 *Test Wheelchair Rider*—A 165 +11, –4.4-lb (75 +5, –2 kg) test wheelchair rider shall manually propel the wheelchair using both hand rims during straight propulsion testing. Supplemental weights are permitted to achieve the correct user weight if the rider is less than the required weight. The wheelchair rider shall have the functional ability to step into the wheelchair, without disturbing the test surface that the wheelchair will be propelled over, after the wheelchair is already positioned on the test surface. The wheelchair rider shall be trained to push on both handrims using both hands for the straight propulsion test and push on the outside wheel with only one hand on one handrim for the turning propulsion test. The wheelchair rider shall propel the wheelchair, without touching the wheelrims of the wheelchair such that no work is transmitted to the wheels of the wheelchair except through the handrims. During turn testing, the wheelchair rider shall propel the wheelchair, using only the outside wheel and hand, around the turning guide while using only the wheelchair handrim to push the outside wheel through the turn. The wheelchair rider is trained by repeating the test procedure until the required distance within the required time is achieved.

9.1.3 *Weight Distribution*—The wheelchair rider shall be seated in the wheelchair such that 40± 2 % of the total weight is supported by the front casters and the rear wheels support the remaining 60 ± 2 % when measured in a static position with the wheelchair rider's hands placed on the rear wheel pushrims in the topmost position. When supplemental weights are used to compensate for the rider's weight, these weights shall be positioned to achieve the proper weight distribution. To further adjust the weight distribution, the rear axles of the wheelchair shall be adjusted forward or rearward, and or spacers shall be placed on the back support of the wheelchair behind the wheelchair rider.

9.1.4 *Weight of Total System*—The total weight of the wheelchair-rider system, including any distance measurement or data acquisition equipment residing on the wheelchair, shall be a minimum of 198.0 lb (90 kg) and a maximum of 235.4 lb (107 kg). The same wheelchair, instrumentation and wheelchair rider with the same weight distribution adjustments shall be used for the complete test procedure, pushing the wheelchair on the test surface and on the reference surfaces.

9.1.5 *Distance Measurement*—A method to measure the total distance that the wheelchair has propelled must be present. This distance shall be 6.56 + 0.66 / –0 ft (2.0 +0.20 / –0 m) from its starting, measured to an accuracy of ± 0.79 in. (2 cm).

9.1.6 *Data Acquisition*—A data acquisition system shall be used to record the tangential forces applied to the pushrim from the beginning to the end of the trial at a minimum frequency of 50 Hz.

9.1.7 *Turn Guide Test Fixture*—A test-fixture shall be used to guide the wheelchair through the turning maneuver. The test fixture shall be constructed such that it guides the wheelchair through a 90° turn. The turn guide shall be 4.75 ± 0.4 in. (12 ± 1 cm) in height and have a radius of curvature of 12.00 ± 0.05 in. (30.5 ± 0.13 cm) (see Fig. 1). The outside of the 12.0-in. (30.5-cm) turn guide shall by lined with a 0.25 ± 0.02-in. (0.635 ± 0.05-cm) polyethylene strip to provide an antifriction surface; thus, the turn guide with polyethylene strip shall have an outside radius of 12.25 ± 0.07 in. (31.135 ± 0.18 cm). The rear wheel axle location of the test wheelchair shall be tethered to the center of curvature of the turn guide. The length of the tether shall be set such that when taut the lower portion of the wheelchair pushrim is 0.32 ± 0.08 in. (8 ± 2 mm) from the turn guide.

9.1.8 *Angle Measurement*—A method to measure the angle that the wheelchair has been turned must be present. This angle shall be 90 +10 / –0° from its starting position, measured to an accuracy of ±2°.

9.1.9 *Baseline Ramp*—A ramp with a hard, smooth, and solid surface with grade of 7.1 ± 0.2 % (1:14). The surface of the 1:14 (7.1 %) ramp shall be a hard, solid surface. The surface of the ramp shall be smooth concrete, metal or plywood covered ramp. The concrete, metal or plywood surface shall have a sufficient coefficient of friction to perform the test as long as the tires on the tires on the wheelchair do not slip on the surface. The slope of the surface shall be within plus or minus 0.2 % of 7.1 % as measured with a digital level measured over a 24 in. span in all locations. The average of all measurements made shall be within 0.1 % of 7.1 %. The ramp must have a planer surface that falls within two imaginary planes 0.25 in.

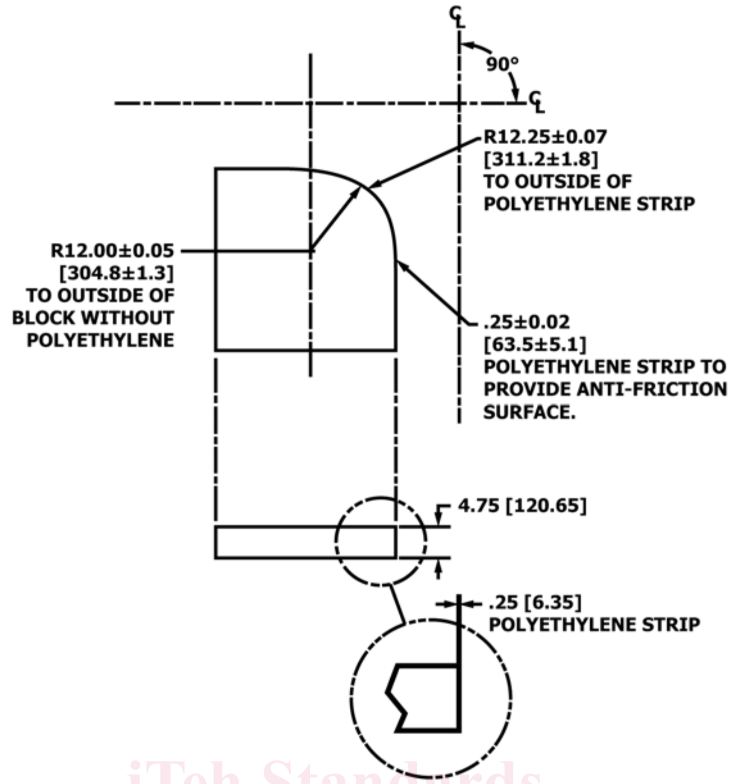

FIG. 1 Turn Guide Test Fixture

apart over a 4 ft. span. The coefficient of friction must be great enough that the tires of the test wheelchair do not slip.

NOTE 2—A standard ramp has a 1:12 slope or 8.33 % allowing a factor of safety in the performance of the surface.

10. Preparation of Surface Sample

10.1 *Test Specimen:*

10.1.1 An installed site or sample test bed of playground surfacing shall be used as the test specimen. The surface material shall be installed according to the manufacturer's installation instructions. The minimum test specimen size shall be 4 ft (1.22 m) wide by 12 ft (3.66 m) in length. The test bed must have a clear space for a wheelchair that is 4.0 ft long with room for the wheelchair rider's feet to extend forward of the foot supports. There must be clearance behind and in front of the wheelchair at the beginning and at the finish of the test.

10.1.2 The depth of the playground surface material shall be consistent with the manufacturer's installation instructions. If the playground surface material is made available to be installed at multiple depths, the testing shall be conducted and reported separately for each depth. It shall not be permissible to combine multiple surface depths into one test procedure or report.

10.1.3 The surface shall be level and free of surface dirt, ice, or contaminants.

10.1.4 Testing shall be conducted when surface temperature, as measured by a temperature probe, is between 40 and 100°F (4 and 38°C).

11. Test Method for Maneuverability with the Wheelchair Work Measurement Method

11.1 *Wheelchair Work Measurement Test Method – Straight Propulsion:*

11.1.1 The Straight Propulsion Test Method measures the work to roll in a straight line across the test surface. Starting from a stationary position with the wheelchair casters in the trailing position, the test wheelchair rider shall propel the wheelchair across the test surface a distance of 6.56 +0.66 / –0 ft (2.0 +0.20 / –0 m) using four uniform pushes. The distance the wheelchair actually rolls shall be recorded to an accuracy of ± 0.79 in. (± 2 cm). The wheelchair rider shall contact the pushrims only during the trial and shall maintain the same posture assumed during the weight distribution measurement. The wheelchair shall be propelled in a straight path using both hands. All forces pushing on the instrumented wheel must be applied through the instrumented handrim. This means that the wheelchair rider shall only touch the handrim of the instrumented wheel when pushing the wheelchair. Allowing the hand to touch the wheel rim would allow unmeasured energy to propel the wheelchair and would invalidate the results. At least three of the wheelchair wheels shall be in contact with the test surface during the trial. Each trial shall be completed in 7.0 ± 1.0 s.

11.1.2 Record the forces applied to the pushrim to an accuracy of ± 0.15 ft × lbf (± 0.2 N × m), at a minimum frequency of 50 Hz.

11.1.3 The trial is acceptable if it meets the following criteria:

11.1.3.1 Pushrim torque values below –3.69 ft × lbf (–5.0 N × m) (reverse torque) do not occur;

11.1.3.2 One or more wheels do not slip on the surface creating torque values above 7.38 ft × lbf (10 N × m) with no forward movement of the wheelchair;

11.1.3.3 The time to complete the 6.56-ft (2.0-m) distance is 7.0 ± 1.0 s;

11.1.3.4 The torque applied to the wheelchair pushrim is zero or decreasing at the end of the trial;

11.1.3.5 The four propulsion strokes cause the wheelchair to travel a total distance of 6.56 +0.66 / –0 ft (2.0 +0.20 / –0 m).

11.1.4 Repeat 11.1.1 – 11.1.3 until a total of five acceptable trials are recorded. Use a leveled surface for each trial. After each trial the surface shall be leveled and compacted to its original installed condition which shall be in accordance to the manufacturer's installation and maintenance instructions. Failure to level the surface after each trail will create ruts in the surface. It is not permissible to run subsequent trials in the rutted tread. If testing is not able to be completed successfully on the test surface, document the reasons. If the drive wheels of the wheelchair slip in or on the surface while trying to push the wheelchair forward, the surface is not firm enough to conduct the test procedure. Such a surface does not pass the test for straight propulsion.

11.1.5 Repeat 11.1.1 – 11.1.4 with the same test wheelchair rider on a hard, smooth surface with a grade of 7.1 ± 0.2 % (1:14) and a cross slope of 0 ± 0.5 % within 72 h of completing the five measurements of the work to propel in a straight line across the test surface.

11.1.6 The calculation for Wheelchair Work Straight Propulsion shall be measured and expressed in Newtons per meter or Foot-pounds per foot of work.

11.1.6.1 For each trial, calculate the average torque by integrating the area under the torque-time curve and dividing by the time to complete the trial.

11.1.6.2 Calculate the total work required for each trial by multiplying the average torque value by the total wheel angular displacement. If the test wheelchair was instrumented with only one pushrim force measuring wheel, multiply this value by two.

11.1.6.3 For each trial, normalize the total work required to work per foot (work per meter) by dividing by the length of the trial.

11.1.6.4 An alternative method for calculating work per foot (work per meter) for each trial, calculate the average work per foot (work per meter) by integrating the area under the torque-angular displacement curve or the torque-distance curve, and then dividing by the total angular displacement or length of the trial, respectively. If the test wheelchair was instrumented with only one pushrim force measuring wheel, multiply this value by two.

11.1.6.5 Discard the low and high work per foot (work per meter) values and average the remaining three trials to determine the average work per foot (work per meter) required to negotiate the test surface and the hard, smooth surface with a grade of 7.1 ± 0.2 % (1:14).

11.1.6.6 Report work per foot (work per meter) values to the nearest 0.1 ft × lbf (0.1 N × m) and total trial times for all five trials on the test surface and on the hard, smooth surface with a grade of 7.1 ± 0.2 % (1:14).

11.1.6.7 Report the average work per foot (work per meter) to the nearest 0.1 ft × lbf (0.1 N × m) for the test surface and for the hard, smooth surface with a grade of 7.1 ± 0.2 % (1:14). If testing could not be successfully completed on the test surface, the report must state this, as well as the reasons why testing could not be performed according to the test procedure. If the wheels of the wheelchair slip or spin on a loose fill surface, the surface fails the test procedure. If the wheelchair continued to roll and could not stop at the specified distance, the work per foot (work per meter) required to negotiate the test surface shall be calculated.

11.2 *Wheelchair Work Measurement Turning:*

11.2.1 The Turning Propulsion Test Method measures the work to propel a wheelchair 90° through a turn across the test surface. The wheelchair shall be positioned with the inside wheel tethered to the Turning Guide Test Fixture as specified in 9.1.7. The wheelchair rider shall be trained as outlined in 9.1.2 on how to propel the wheelchair pushing with only one hand, only on the outside instrumented handrim of the wheelchair without touching the rim of the wheel or tire. Pushing on the inside handrim would allow unmeasured energy to push the wheelchair thru the turn which would invalidate the results. Starting from a stationary position with the wheelchair casters in the trailing position, the test wheelchair rider shall propel only the outside handrim of the wheelchair on the test surface around the turn guide using four uniform pushes until the wheelchair is oriented 90 +10 / –0° from its starting position. The inside hand of the wheelchair rider shall be sitting on the knee or lap of the wheelchair rider. The angle the wheelchair actually turns shall be recorded to an accuracy of ± 2°. The wheelchair rider shall contact only the handrim of the wheel that is on the outside of the turn during the trial and shall maintain the same posture assumed during Weight Distribution Measurement as specified in 9.1.4. The wheelchair rider shall only touch the handrim of the instrumented wheel when pushing the wheelchair. Allowing the hand to touch the wheel rim would allow unmeasured energy to propel the wheelchair which would invalidate the results. All forces pushing on the instrumented wheel must be applied through the instrumented handrim. At least three of the wheelchair wheels shall be in contact with the test surface during the trial. Each trial shall be completed in 7.0 ± 1.0 s.

11.2.2 Record the forces applied to the pushrim to an accuracy of ± 0.15 ft × lbf (± 0.2 N × m), at a minimum frequency of 50 Hz.

11.2.3 The trial is acceptable if it meets the following criteria:

11.2.3.1 Pushrim torque values below –3.69 ft × lbf (–5.0 N × m) (reverse torque) do not occur;

11.2.3.2 The wheel on the outside of the turn does not slip on the surface creating torque values above 7.38 ft × lbf (10 N × m) with no forward movement of the wheelchair;

11.2.3.3 The time to complete the entire turn is 7.0 ± 1.0 s;

11.2.3.4 The torque applied to the wheelchair pushrim is zero or decreasing at the end of the turn;

11.2.3.5 The four propulsion strokes cause the wheelchair to be oriented 90 +10 / –0° from its starting position.

11.2.4 Repeat 11.2.1 – 11.2.3 until a total of five acceptable trials are recorded. Use a leveled surface for each trial. After each test trial, the surface shall be leveled and compacted to its original installed condition in accordance with the manufacturer's installation and maintenance instructions. Failure to level the surface after each trail will create turning ruts in the surface. It is not permissible to run subsequent trials in the rutted tread. If testing cannot be successfully completed on the test surface, document the reasons. If the drive wheels of the wheelchair slip in or on the surface while trying to push the wheelchair forward around the turning guide, the surface fails the test procedure.

11.2.5 Repeat 11.2.1 – 11.2.3 using the same Turning Guide Test Fixture, with the same test wheelchair rider on a hard, smooth surface with a grade of 7.1 ± 0.2 % (1:14) and a cross slope of 0 ± 0.5 % within 72 h of completing the five measurements of the work to push the wheelchair 90° through a turn across the test surface. The wheelchair shall start the turn facing 45° from the uphill direction and be turned toward the uphill direction until it is facing 45° from the uphill direction in the opposite direction that the wheelchair started (see Fig. 2).

11.2.6 Calculation for Wheelchair Work Turning shall be measured and expressed in Newtons per meter or Foot-pounds per foot of work:

11.2.6.1 For each trial, calculate the average torque by integrating the area under the torque-time curve and dividing by the time to complete the trial.

11.2.6.2 Calculate the work per foot (work per meter) required for each trial by multiplying the average torque value by the estimated, total wheel angular displacement over the length of the test, and then dividing by the length of the test to normalize the work required.

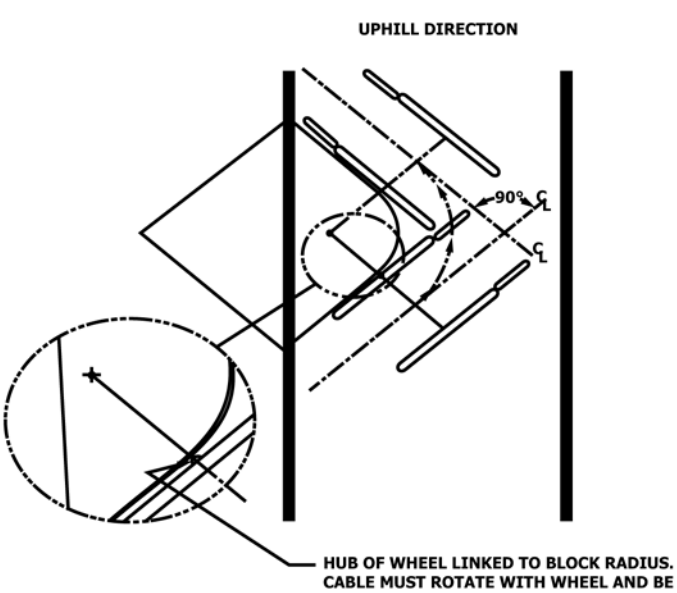

FIG. 2 Turning on Hard, Smooth Surface With Grade of 7.1 ± 0.2 % (1:14)

11.2.6.3 An alternative method for calculating work per foot (work per meter) for each trial, calculate the average work per foot (work per meter) by integrating the area under the torque-angular displacement curve or the torque-distance curve, and then dividing by the total angular displacement or length of the trial, respectively.

11.2.6.4 Discard the low and high work per foot (work per meter) values and average the remaining three trials to determine the average work per foot (work per meter) required to negotiate the test surface and the hard, smooth surface with a grade of 7.1 ± 0.2 % (1:14).

11.2.6.5 Report work per foot (work per meter) values to the nearest 0.1 ft × lbf (0.1 N × m) and total trial times for all five trials on the test surface and using the turning guide on the hard, smooth surface with a grade of 7.1 ± 0.2 % (1:14).

11.2.6.6 Report the average work per foot (work per meter) to the nearest 0.1 ft × lbf (0.1 N × m) for the test surface and using the turning guide on the hard, smooth surface with a grade of 7.1 ± 0.2 % (1:14). If testing could not be successfully completed on the test surface, the report must state this, as well as the reasons why testing could not be performed according to the test procedure. If the wheelchair continued to roll and could not stop at the specified distance, the work per foot (work per meter) required to negotiate the test surface shall be calculated.

12. Report

12.1 All reports resulting from the use of this standard for the testing of surfaces shall include a reference to this specification and shall include the following information:

12.1.1 *Requesting Agency Information*—The name, address, and telephone number of the person or entity requesting the test.

12.1.2 *Testing Agency Information:*

12.1.2.1 The name, address, website, and telephone number of the testing agency.

12.1.2.2 The name and signature of the test operator.

12.1.2.3 Date(s) and time the tests were performed.

12.1.2.4 Date of the report, test conditions, including atmospheric temperatures, surface temperature, taken at a 1.0 in. minimum depth into the surface or at a depth of 50 % of the thickness of the sample, whatever is least, and any other pertinent information including the presence of moisture.

12.1.3 *Description of Each Test Apparatus:*

12.1.3.1 Wheelchair make, model, serial number, weight and photograph.

12.1.3.2 Other test equipment type, model number(s), serial number(s), manufacturer(s) photograph of each piece of equipment used.

12.1.3.3 Weight of test wheelchair rider, total weight and front-to-rear weight distribution of the wheelchair-rider system.

12.2 *Description of Surface Samples:*

12.2.1 A complete description of the surface sample shall include the following information:

12.2.1.1 The quantity or number of samples submitted.