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October 15, 2015

Mr. Steve Barnes
APSP-16 Technical Committee Chairman
Association of Pool and Spa Professionals
2111 Eisenhower Ave
Alexandria, VA 22314

Dear Mr. Barnes:

U.S. Consumer Product Safety Commission ("CPSC") staff appreciates the opportunity to comment on the proposed changes to the Association of Pool and Spa Professionals ("APSP") Standard 16, *Standard Suction Fittings for Use in Swimming Pools, Wading Pools, Spas, and Hot Tubs – 2011*, referred to here as APSP-16. The Virginia Graeme Baker Pool and Spa Safety Act ("VGB Act") incorporates by reference the joint American Society of Mechanical Engineers ("ASME") and American National Standards Institute ("ANSI") standard for drain covers ASME/ANSI A112.19.8, *Suction Fittings for Use in Swimming Pools, Wading Pools, Spas, and Hot Tubs.*

Recall that in 2010, the ASME formally approached ANSI requesting to withdraw ASME's sponsorship of the standard because sponsorship of the standard was no longer in the scope of ASME's mission. Subsequently ANSI coordinated transfer of the sponsorship of the standard to APSP from ASME, making APSP-16 the successor standard referenced in section 104 (b) of the VGBA Act. APSP recognized the need to update and revise the standard, which is the subject of this letter, the attached CPSC staff-suggested revisions to APSP-16 2011, the attached CPSC Staff Report on Proposed Changes to Entrapment Ratings, and the attached Suction Outlet Fitting Assembly Full-Scale Study Statistical Analysis Summary.

To develop a thorough understanding of the proposed changes to the standard and their potential effects on safety, CPSC hosted a public meeting of the APSP-16 technical committee at the CPSC laboratory on February 8-9, 2012. Committee members and CPSC staff identified seven significant changes to the standard. The proposed changes included:

1. hair test approach time,
2. hair test targets,
3. hair test approach methods,
4. hair testing at specific ports in channel suction outlet fitting assemblies ("SOFAs"),
5. hair test pull method,
6. body block element size, and
7. body block element removal forces.

Based on input from committee members, CPSC statisticians developed an experiment design that resulted in a method to compare the proposed changes to the APSP-16 2011. The design specified testing the existing and proposed methods on assorted SOFAs; specified the order in which to conduct the tests, the order of which was randomized to reduce bias; and used other statistical techniques to achieve valid results.

The ideal method to compare proposed changes to the standard is to have several different groups perform the same experimentally designed procedure at different facilities. This kind of testing diversity permits the determination of, and the correction of, bias in the results that may be due to variations in the body-blocking element foam, operator technique, or other factors. At the technical committee meeting, four commercial laboratories agreed to participate in such a study. Each laboratory subsequently withdrew their offer to participate because of the cost of participation, leaving CPSC the sole laboratory willing to conduct the tests.

The tests performed by CPSC staff revealed that not all of the proposed changes to the standard maintain the existing level of safety afforded in APSP-16 2011. Therefore, CPSC staff cannot support adopting all of the proposed changes. The complete results of these tests are published separately in the document, *CPSC Staff Report on Proposed Changes to Entrapment Ratings Tests in APSP-16 2011*, a copy of which is attached. Summaries of CPSC staff's findings for each of the seven significant proposed changes are discussed below.

The technical committee continued to revise the standard even as CPSC staff investigated the major proposed changes. The latest draft version of the standard recognized by CPSC staff is *APSP-16 20xx Suction Fittings for Use in Swimming Pools, Wading Pools, Spas, and Hot Tubs revision 7.5a*, referred to here as APSP-16-2011-7.5a. It is to this draft standard that CPSC staff has incorporated the recommended wording for the seven most significant items, as well as made other mostly editorial changes. A copy of the staff-recommended changes to APSP-16-2011 is attached.

Hair Test Approach Time, Hair Test Targets, and Hair Test Approach Methods

The proposed changes to paragraph 4.2.7, which are now covered in section 7.2, include modifications to the hair test approach time, the hair test target areas, and the hair test approach methods.

CPSC staff has determined that the proposed reduction in the hair test approach time from 60 seconds to 30 seconds does not reduce the level of safety established by APSP-16 2011, because the change in the removal force is not significant. Therefore, CPSC staff supports this change to the standard.

CPSC staff has determined that the proposed change to the target area wording does not maintain the current level of safety established by APSP-16 2011. The staff report shows that the proposed addition of language to encourage the targeting of the worst entrapment areas on each SOFA has a mixed effect on release times, depending on the SOFA. Therefore, CPSC staff cannot support this change to the standard.

Hair Testing at Specific Ports in Channel SOFAs

Section 7.2.25 was added to address specifically channel SOFAs, which can have multiple suction outlets located within the sump. The new proposed wording provides direction that the cover/grate area nearest to each suction outlet be subjected to the hair test. CPSC staff has determined that the proposed wording does not reduce the level of safety established by APSP-16 2011, because the proposed wording eliminates an ambiguity in the test procedure when multiple suction outlets are present in one SOFA, and ensures that the intent of the standard is maintained. Therefore, CPSC staff supports this change to the standard. CPSC staff further expanded this interpretation to include all suction outlets in all types of SOFAs, not just channel SOFAs. This revised wording is included in the staff-recommended version of the standard.

Hair Test Pull Method

The working group proposed changes to the hair pull test in Section 4. The existing wording in APSP-16 2011 describes a method where, after being placed against the cover/grate, the hair is pulled away from the SOFA at a constant velocity. The proposed wording describes a method where the hair is placed against the cover/grate, then removed by pulling with a constant force. CPSC staff has determined that the proposed changes to the pull method do not maintain the current level of safety established by APSP-16 2011. The staff report shows that the proposed change to a constant-force method using a falling weight was not as protective as the current constant-speed method. CPSC staff recommends that the working group keep the intent that exists in APSP-16 2011 regarding hair test pull methods. Due to recommended editorial changes, the wording has been revised slightly from what was proposed in 7.5a. The paragraph numbering has also changed. The hair pull test method described in Section 4 is now described in Section 7 of CPSC staff's recommended revision to APSP-16.

Body-Block Element Size

The working group proposed changes to the body-blocking test in Section 5. The proposed wording describes an additional body-blocking element ("BBE") that overlaps the SOFA by 2 inches per side.

CPSC staff conducted tests using the new BBE criteria and have determined that the proposed change to the body-blocking element size results in an indeterminate change in safety as established by APSP-16 2011. CPSC staff recommends that the working group keep the intent that exists in APSP-16 2011 regarding body-blocking element size. Like the hair test method, the exact wording and paragraph numbers have changed.

Body-Block Element Removal Forces

Concurrent with the proposed change in body-blocking element size, the technical committee proposed changes to the removal forces of the new body-blocking element. Because CPSC staff recommends against adopting the new body-blocking element, staff also recommends that the technical committee delete any proposed changes to allowable removal forces. These recommendations have been incorporated into the CPSC staff-recommended revision to the standard.

CPSC staff requests that the technical committee immediately ballot the staff-recommended revisions to APSP-16, *Standard Suction Fittings for Use in Swimming Pools, Wading Pools, Spas, and Hot Tubs – 2011*, and include them in a ballot to the current standard as soon as practicable. If the committee ballots the standard without incorporating all the CPSC staff-proposed changes, the staff will recommend that the Commission not adopt the updated standard. The staff recommendation notwithstanding, the Commission must still vote to determine whether the revision is in the public interest. If the Commission determines that any revision is in the public interest, the Commission shall incorporate the revision into CPSC's mandatory standard after providing public notice. Please contact me if you have any questions. I look forward to continuing to work with the technical committee on swimming pool, spa, and hot tub safety.

Sincerely,

Perry Sharpless

Perry Sharpless

Attachments:

CPSC Staff-Recommended Revision of APSP-16 2011

CPSC Staff Report on Proposed Changes to Entrapment Ratings Tests in APSP-16 2011

CPSC Staff Report on Suction Outlet Fitting Assembly Full-Scale Study Statistical Analysis Summary

CPSC Staff Recommended Revision of

APSP-16 2011, Suction Fittings for Use in Swimming Pools, Wading Pools, Spas, and Hot Tubs

Association of Pool & Spa Professionals

2111 Eisenhower Avenue

Alexandria, VA 22314

APSP.org

1. GENERAL

1.1. This standard establishes materials, testing, and marking requirements for new or replacement bather-accessible Suction Outlet Fitting Assemblies (SOFAs), other than maintenance drains, that are designed to be totally submerged for use in any hot tub, spa, portable spa, or non-portable wading pool intended for swimming or recreational bathing.

1.2. SOFAs that fail any portion of this standard may not be certified as meeting this standard.

1.3. The flow rating for each SOFA is determined by the lowest passing flow rate obtained during the Type 1 hair test, the Type 2 hair test, or the body blocking element test, unless the SOFA manufacturer specifies a lower flow rate, which shall then be the maximum allowable flow rate for that SOFA.

1.4. Any modification made to a SOFA or related component after it has been used to determine the flow rating for this standard voids its certification to this standard.

1.5. Manufacturers must state the installed lifespan of each SOFA component.

1.6. SOFAs shall be replaced at or before the end of their useful life as stated by the manufacturer.

1.7. Skimmers are excluded from evaluation to this standard.

1.8. Vacuum connection covers are excluded from evaluation to this standard. See the International Association of Plumbing and Mechanical Officials (IAPMO) SPS-4, *Special Use suction fittings for Swimming Pools, Spas and Hot tubs for Suction-Side Automatic Swimming Pool Cleaners*.

1.9. When values are stated in U.S. Customary units and in the International System of Units (SI), the values stated in U.S. Customary units shall be considered as the standard.

1.10. Table 1 referenced in the prior edition of the standard has been replaced with Equation 2.

2. RELATED STANDARDS

Since the scope of this standard is directly related to suction fittings, it is important to mention that the fittings themselves represent only one portion of the suction entrapment scenario. Additional standards shall be consulted in order to provide coverage for the various other potential hazards in swimming pools, wading pools, spas, and hot tubs and aquatic recreation facilities. These other standards include, but are not limited to, the following:

ANSI[1]/APSP[2]-1 Standard for Public Swimming Pools
ANSI/APSP-2 Standard for Public Spas

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[1] American National Standards Institute

[2] Association of Pool and Spa Professionals

ANSI/APSP-3 Standard for Permanently Installed Residential Spas
ANSI/APSP-4 Standard for Above-ground/On-Ground Residential Swimming Pools
ANSI/APSP-5 Standard for Residential In-Ground Swimming Pools
ANSI/APSP-6 Standard for Residential Portable Spas
ANSI/APSP-7 Standard for Suction Entrapment Avoidance
ANSI/APSP-8 Model Barrier Code for Residential Swimming Pools, Spas, and Hot Tubs
ANSI/APSP[3]-9 Aquatic Recreation Facilities
ASME[4] A112.19.17 Manufactured Safety Vacuum Release Systems (SVRS) for Residential and Commercial Swimming Pool, Spa, Hot Tub, and Wading Pool Suction Systems
ASTM[5] F 2387-04 Standard Specification for Manufactured Safety Vacuum Release Systems (SVRS) for Swimming Pools, Spas and Hot Tubs
UL 1563 Standard for Electric Spas, Equipment Assemblies, and Associated Equipment

3. References

The following standards are referenced in this document. Unless otherwise specified, the latest edition shall apply.

ANSI/APSP-9 Aquatic Recreation Facilities

ANSI/APSP-1 Standard for Public Swimming Pools

ANSI/APSP-2 Standard for Public Spas

ANSI/APSP-3 Standard for Permanently Installed Residential Spas

ANSI/APSP-4 Standard for Above-ground/On-Ground Residential Swimming Pools

ANSI/APSP-5 Standard for Residential In-Ground Swimming Pools

ANSI/APSP-6 Standard for Residential Portable Spas

ANSI/APSP-7 Standard for Suction Entrapment Avoidance

ANSI/APSP-8 Model Barrier Code for Residential Swimming Pools, Spas, and Hot Tubs

Publisher: Association of Pool and Spa Professionals (APSP), formerly the National Spa and Pool Institute (NSPI), 2111 Eisenhower Avenue, Alexandria, VA 22314

ASME A112.19.17 Manufactured Safety Vacuum Release Systems (SVRS) for Residential and Commercial Swimming Pool, Spa, Hot Tub, and Wading Pool Suction Systems

[3] International Aquatic Foundation (defunct) – Adopted by APSP

[4] American Society of Mechanical Engineers

[5] ASTM International

ASME B1.20.1 Pipe Threads, General Purpose (Inch)

Publisher: The American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016-5990; Order Department: 22 Law Drive, P.O. Box 2300, Fairfield, NJ 07007-2300

ANSI/ASTM D 638 Standard Test Method for Tensile Properties of Plastics

ASTM D 256 Standard Test Methods for Determining the Izod Pendulum Impact Resistance of Plastics

ASTM D 1785-Standard for Poly (Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80, and 120.

ASTM G153-04 Standard Practice for Operating Carbon Arc Light Apparatus for Exposure of Non-Metallic Materials.

ASTM G155-05a Standard Practice for Operating Xenon Arc Light Apparatus for Exposure of Non-metallic Materials.

ASTM D1056-07 Standard Specification for Flexible Cellular Materials—Sponge or Expanded Rubber

ASTM D 2444 Standard Practice for Impact Resistance of Thermoplastic Pipe and Fittings by Means of a Tup (Falling Weight)

ASTM D 2466-02 Standard Specification for Poly (Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 40

ASTM F 1498-2000 Standard Specification for Taper Pipe Threads 60° for Thermoplastic Pipe and Fittings ASTM F 2387-04, Standard Provisional Specification for Manufactured Safety Vacuum Release Systems (SVRS) for Swimming Pools, Spas, and Hot Tubs

ASTM G 154 Standard Practices for Operating Fluorescent Light Apparatus for UV Exposure of Nonmetallic Materials

Publisher: ASTM International (ASTM), 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959

IAPMO PS 33- Flexible PVC Hose for Pools, Hot Tubs, Spas, and Jetted Bathtubs

Publisher: IAPMO Research and Testing, 5001 E. Philadelphia St., Ontario, CA 91761

IAPMO/ANSI Z1033

Publisher: 25 W 43rd Street, 4th Floor, New York, NY, 10036

UL 1439 Standard for Tests of Sharpness on Edges of Equipment

Publisher: UL, 3916 Ranchero Dr., Ann Arbor, MI, USA 48108

4. DEFINITIONS

Accessible A surface that is able to be touched by a bather when all components are installed per the manufacturer's or registered design professional's instructions.

Anticlastic Having opposing curvature in two perpendicular directions, as the surface of a saddle.

Anti-vortex[6] A term that is used to describe suction outlet cover/grates that are designed to prevent an air-entraining vortex from forming.

Aperture, small An opening with two or more dimensions smaller than 1 in. (25 mm).

Aperture, large An opening with only one dimension smaller than 1 in. (25 mm).

Aquatic facility Any hot tub, spa, portable spa, water park, or non-portable wading pool intended for swimming or recreational bathing.

Blockable suction outlet A suction outlet that is able to be shadowed by a body blocking element.

Body blocking element (BBE) A simulated human torso with a width of 18 in. (457 mm), and a length of 23 in. (584 mm).

Branch hose <<<Awaiting input from APSP>>>

Channel drain A SOFA whose perforated area is 3 inches (76 mm) or greater in width and 31 inches (787 mm) or greater in length. <<<Awaiting additional input from APSP>>>

Complete system The materials and equipment needed to collect, filter, and return water to an aquatic facility, generally consisting of a pump, suction outlet(s), vented reservoir(s), inlet(s), filtration equipment, sanitizing equipment, piping, valves, back-up safety devices, vents, and other items that may be necessary for water treatment and circulation.

Collector tank << Awaiting input from APSP >>

Cover A fitting or device placed between the suction piping and the bather. Not used in this document to avoid confusion with a pool cover. See also *cover/grate.*

Cover/grate << Awaiting input from APSP >>

Dual suction-outlets See *multiple suction outlets.*

6 The term anti-vortex has been misused within the industry and is largely misunderstood as somehow relating to entrapment prevention. The term anti-vortex should not be construed to impart any entrapment protection and shall not be referenced in this regard.

Edge The line of intersection between any two surfaces with an intersecting angle greater than 180 degree, measured face to face, and having a transitional radius between the two faces of less than 0.75 in. (19 mm). Refer to Figure 1.

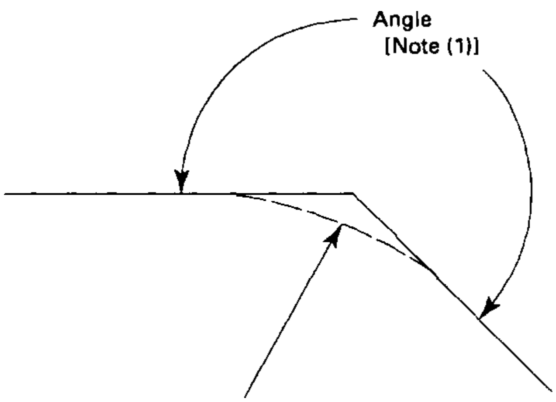

Fig. 1 Finger Probe "Edge"   [[[[APSP will delete the reference to the note in the figure above]]]]

Field-fabricated outlets Suction Outlet Fitting Assemblies that are custom-made for a particular installation at the pool construction site from raw materials, or at a facility not normally engaged in SOFA manufacturing.

Floor The structure of an aquatic facility whose function is to contain the circulation system water, that is sloped between 0 degrees and 45 degrees from horizontal.

Grate An assembly, or panel with multiple openings in its surface. The term is not used in this standard in order to avoid confusion. See also *cover/grate*.

Indirect-suction a method for the transfer of water from an aquatic facility where the low pressure in the SOFA is produced by a difference in water levels by any means that does not include suction directly created by the inlet side of a pump, *e.g.*, gravity flow systems.

Individual suction system A suction system piping arrangement that connects one or more suction outlets to one or more pumps or gravity flow system collector tanks.

Manufactured When applied to fittings, fitting assemblies, cover/grates, or related devices, indicates the routine commercial production of such item(s) for the purpose of providing suction outlet hardware for aquatic facilities.

Maintenance drain An outlet that is only used by maintenance personnel at times when the pool is closed.<< Awaiting input from APSP >>

Maximum system flow rate The highest flow rate that is achievable by the circulation system in accordance with APSP-7.

Multiple-drain use Indicating that the referenced suction outlet may be used only in conjunction with one or more additional suction outlets serving an individual suction system.

Multiple suction outlets shall mean two or more suction outlets connected to an individual suction system.

Open area The area available for water flow through a SOFA cover/grate, as measured parallel to the flow path at each opening. <<<<APSP will be providing Figure 2 >>>>>>

RESERVED FOR FIGURE 2, TO BE PROVIDED BY APSP.

Figure 2. Measurement of Open Area

Pinch point Any location inside an assembled suction fitting where an aperture enlarges upstream and downstream.

Q Volumetric flow rate in cubic feet per second (ft^3/s).

Registered design professional An individual who is registered or licensed to practice their design profession, as defined by the statutory requirements of the professional registration laws of the state or jurisdiction in which the project is to be constructed.

Self-contained factory-manufactured spa A spa hydrotherapy unit consisting of one body of water, in which all control, heating, circulation, and/or filtration equipment is an integral part of the product, which is assembled into the body or the shell of the spa at the time of manufacture.

Self-contained spa fitting Fittings, fitting assemblies, cover/grates, and related components that provide a localized low-pressure area for the transfer of water exclusively from a self-contained factory manufactured spa to the spa's circulation system.

Shadow That portion of a cover/grate which is hidden by the blocking element to a person viewing perpendicularly to the mounting surface of the cover/grate.

Sharp edge An edge that is able to cause a cut-type injury when contacted during normal use or maintenance. Refer to UL 1439 Standard for Tests of Sharpness on Edges of Equipment.

Single-drain use Indicates that the referenced suction outlet may be used as the sole source for water to a pump suction system, provided that for all suction outlets, other than an unblockable suction outlet, they shall be required to be installed with one or more of the additional suction-limiting devices or systems listed in Section 11.

Single or multiple-drain use Indicates that the referenced suction outlet may be used as either the sole source for water to a pump suction system, or may be used in conjunction with additional suction outlets on a pump suction system. In the event the suction outlet is used as the sole source for water to the pump suction system, other than an unblockable suction outlet, it shall be required to be installed with one or more of the additional suction-limiting devices or systems as listed in Section 11.

Skimmer A suction outlet which is designed to permit the removal or filtering of floating debris.

Suction outlet A fitting, fitting assembly, cover/grate, sump, fasteners when used, and related components that provide a localized low pressure area for the transfer of water from a swimming pool, wading pool, spa, or hot tub, to a circulation system.

Suction Port The portion of a suction outlet where a connection to the circulation system is made.

Swim jet combination fitting A manufactured inlet/outlet suction fitting that combines suction and discharge elements into one device.

Unblockable suction outlet A suction outlet that, including the sump, such that its open area cannot be shadowed the body blocking element, and that the rated flow through the remaining open area cannot create a suction force in excess of the values in equation 2.

Vacuum connection cover A cover over a fitting in the wall of a pool intended to provide a point of connection of suction for suction- side cleaners.

Vented reservoir A receptacle or container incorporated as part of a circulation system that is vented to atmosphere and receives water from the pool/spa or water feature by force of gravity, from which the pump draws its water supply.

Venturi outlets manufactured suction outlet fittings that are venturi-activated indirect-suction cover/grates or venturi activated debris collection systems.

Wall The structure of an aquatic facility whose function is to contain the circulation system water, that is sloped more than 45 degrees and less than or equal to 90 degrees from horizontal.

5. FITTING DESIGN, ASSEMBLY, AND MATERIAL REQUIREMENTS

5.1 GENERAL REQUIREMENTS

All threaded fasteners joining components of a suction outlet fitting assembly that are accessible to the bather shall comply with all requirements of this section.

5.1.1. Fasteners shall be removable from the sump and any permanent components, such as frames, rings, support beams, etc., for winterizing or replacement after aging of the component.

5.1.2. When threaded fasteners are used to secure SOFA components, both machine screws with associated metallic inserts or self-tapping screws shall be permitted.

5.1.3. Metal screws shall be passivated stainless steel meeting UNS S31600 or SAE Type 316, or be made from equivalent corrosion resistant material. Metal threaded inserts shall be made from copper alloy C23000, C26800, C27000, C61400, C64700, C65100 or C65500 or equivalent corrosion resistant material.

5.1.4. Accessible fasteners shall not be able to be removed with a United States coin.

5.1.5. Provision for reinstallation or repair of damaged fasteners and corresponding receptacles, insert, tapped, or self-threaded, shall be described in the instruction manual provided by the SOFA manufacturer. Instructions shall include a description of the condition(s) indicating when it is necessary to remove the SOFA from service.

Reinstallation and repair examples:

Remove and replace SOFA component.

Provide additional holes to receive fasteners in a different orientation.

Instructions for drilling new holes, including conditions when and where it is appropriate, and how to confirm proper installation in conformance with the requirements of this standard.

5.1.6. Instructions for replacing threaded inserts, including conditions when and where it is appropriate and how to confirm proper installation in conformance with the requirements of this standard.

5.1.7. Suction fitting assemblies that connect directly to the circulation piping shall attach by a PVC end connection in accordance with ASTM D 2466, or by a threaded end connection in accordance with ASTM F 1498 or ASME B1.20.1.

5.1.8. There shall be no accessible sharp edges, as defined by UL 1439 Standard for Tests of Sharpness on Edges of Equipment, on fully assembled suction fittings.

5.1.9. Suction fittings shall not protrude from the installed surface more than 2 in. (51 mm).

5.1.10. The use of adhesives or other attachment methods that prevent access to SOFA components that require periodic servicing is prohibited.

5.1.11. Manufacturers shall provide installation instructions for fittings marked “Multiple-Drain Use”.

5.1.11.1. Fittings marked “For Multiple-Drain Use” shall only be used in an individual suction system with two or more suction outlets. The arrangement of these fittings shall be such that the two outermost fittings shall be separated by a minimum of three feet center-to-center. If they are located closer than three feet center-to-center, they shall be located on two different planes, *i.e.*, one fitting shall be located on the pool floor, and one fitting shall be located on a vertical wall, or one fitting shall be located on each of two separate vertical walls.

5.1.11.2. Fittings marked for “Multiple-Drain Use” shall be sized and located in a suction system so that if one SOFA is blocked, the remaining suction outlets serving that system shall have a total flow rating capable of permitting the maximum system flow rate.

5.1.12. Sumps shall meet the applicable requirements listed in 5.1.12.1 through 5.1.12.2.

5.1.12.1. Manufactured sumps shall be of a type specified by the cover/grate manufacturer.

5.1.12.2. Field-fabricated sumps shall be constructed to the site-specific design requirements specified by a Registered Design Professional.

5.2 Field-Fabricated Outlets

Field-fabricated outlets are limited to a flow velocity of 1.5 ft/sec (0.46 m/s) through any portion of the open area of the cover/grate, unless rated at a lower flow rate by a registered design professional. Field fabricated outlets are further governed by the stipulations of Figure 3.

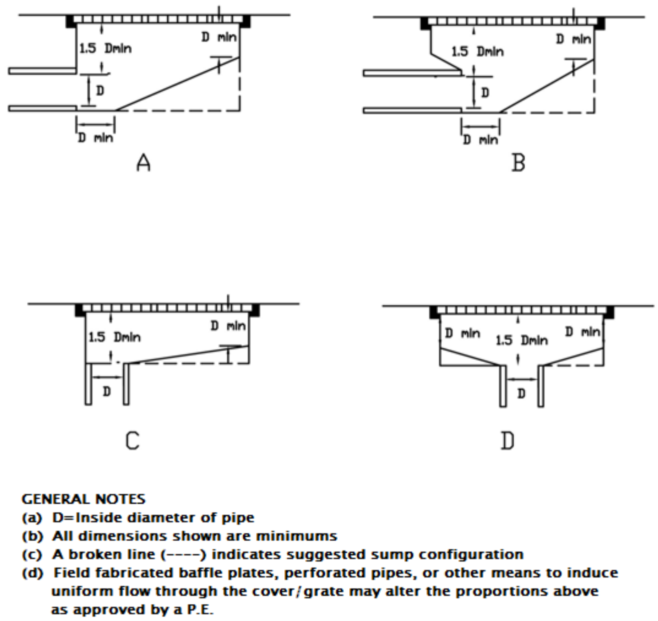

Figure 3. Field-Built Sump Construction Details

5.2.1 Unblockable Suction Outlet Cover/Grates

Suction outlet cover/grates that cannot be completely shadowed by the body blocking element may be rated by the following formulas, which shall yield the maximum allowable flow, *Q*, through the cover/grate. All calculations involve the open area of the cover/grate only.

5.2.2 Entrapping Force Criterion for *Q*

Equation 1:

$$Q = a_R \sqrt{\frac{F}{C \frac{\rho}{2} a_B}}$$

Where:

a_B = largest area of the openings in ft^2, that can be shadowed by the BBE.

a_R = area of the openings, in ft^2, that remains unblocked

C = flow coefficient based on the design of the openings in the cover/grate. It shall be based upon the actual loss coefficient of the cover/grate or representative sample from laboratory test data, unless otherwise demonstrated by calculation or test.

F = 120 lbf (534 N)

Q = limiting flow rate in ft^3/s based on the allowable entrapping force ρ = density of water.

5.2.3 **Maximum Rating, ft^3/s** The maximum flow rating of the cover/grate in cubic feet per second is *Q*.

5.2.4 **Maximum Rating, gal/min** The maximum flow rating of the cover/grate in gallons per minute is Q multiplied by 7.48 gal/ft^3 multiplied by 60 s/min.

5.2.5 **Alternate Test** The body entrapment test of Section 8 may be performed as an alternate method of compliance with the requirements established in paragraph 5.2.

5.2.6 **Sump** Field-fabricated outlets shall have a sump below or behind the cover/grate, of a design provided by a registered design professional in writing to the facility owner, to control flow through the open area of the cover/grate.

5.2.7 **Design** The design of field-fabricated outlets shall be further specified by a registered design professional in writing to the facility owner, so as to fully address the considerations of cover/grate loadings, durability, hair, finger, and limb entrapment issues, possible cover/grate secondary layer of protection, related sump design, as well as features particular to the specific site.

5.3 VENTURI OUTLETS Venturi outlets are outlets that are activated through indirect suction, through a single cover/grate that is generally designed for debris collection. Those that do not connect directly to the circulation piping must have the manufacturer's recommended sump below or behind the outlet cover/grate.

5.4 SWIM JET COMBINATION FITTINGS Swim jet combination fittings are fittings that combine suction and discharge into one housing, and may be used as single inlets/outlets.

5.5 SUBMERGED SUCTION OUTLETS Submerged suction outlets are manufactured cover/grate assemblies that may connect directly to the circulation piping. Those that do not connect directly to the circulation piping shall have either the manufacturer's recommended sump below or behind the outlet cover/grate, or a field-built sump of a design specified by the manufacturer to control flow through the open area of the cover/grate. When the outlet is installed, the manufacturer-recommended sump dimensions for both manufactured and field-built sumps shall be equal to or exceed the dimensions of the sump used during the test as described in paragraphs 7 and 9. Each manufacturer-specified pipe size shall be tested.

5.6 SELF-CONTAINED SPA FITTINGS Self-contained spa fittings shall be used only in self-contained factory-manufactured spas. At least two suction fittings shall be used for each pump.

5.6.1 Self-contained spa fittings shall be installed into the body or shell of the spa at the time that the spa is manufactured. At least two self-contained spa fittings shall be piped so that water is drawn through them simultaneously through a common line to the related pump. The use of valves or fittings capable of isolating one self-contained spa fitting from any other on the common line to the related pump is prohibited. This type of fitting shall be connected to the tee leading to the pump utilizing only the fitting manufacturer's specified size(s) of PVC hose or pipe. The flexible PVC hose specified shall conform to IAPMO/ANSI Z1033. Rigid PVC pipe shall conform to ASTM D 1785-Standard for Poly (Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80, and 120.

5.6.2 The maximum branch hose length difference between any self-contained spa fitting and the tee leading to the pump shall not exceed 13 feet.

5.7 MAINTENANCE DRAIN Maintenance drains are only be used by maintenance personnel at times when the pool is closed to bathers. Maintenance drains are exempt from paragraphs 7 and 8 of this standard.

6. PHYSICAL TESTING

6.1 GENERAL

6.1.1 **Certification and Testing** All testing of products to this standard shall be done by a laboratory accredited to ISO 17025 by the International Laboratory Accreditation Cooperation (ILAC), except for field fabricated suction outlets, which shall be certified in accordance with paragraph 5.2. All certification of products to this standard shall be done by an ANSI-accredited organization.

6.1.2 **Test Conditions** All tests shall be conducted at an air and water temperature of 73.4 °F ± 3 °F (23 °C ± 2 °C).

6.1.3 **Test Procedure** For the tests covered in Section 6, a minimum of six suction fittings shall be tested in each test condition, unless otherwise stated. If the parts are made in different mold cavities, representative samples shall be taken from different mold cavities. Testing shall be performed within <<AWAITING INPUT FROM APSP>>minutes after conditioning, as described in paragraph 6.1.2.

6.1.4 **Test Fixture** The suction outlet, complete with the manufacturer's specified sump, fasteners when used, and related components shall be installed in a rigid fixture that is capable of supporting the fitting(s) in a manner simulating the actual installation.

6.1.5 **Certification** When certifying manufactured suction outlet fittings for use with more than one mounting/sump configuration, each configuration must be adequately replicated in the test fixture.

6.1.6 **Conditioning** All specimens shall be submerged in water at a temperature of 73.4 °F ± 3 °F (23 °C ± 2 °C) for at least 2 hours before testing.

6.1.7 **Crack Detection** After each physical test, the unit shall be washed in the standard liquid detergent solution, rinsed with clear water, and dried prior to application of ink as specified in paragraph 6.1.9.1. After inking, the unit shall be visually inspected in accordance with paragraph 6.1.9.2.

6.1.8 To hasten drying, the surface of the unit shall be permitted to be wiped with a clean absorbent lint-free material for this test only.

6.1.9 Standard liquid detergent shall consist of (by volume):

Monsanto TKPP, 8.0%
Sterox NJ, 7.0%
Stepan SXS, 8.0%
Butyl Cellosolve, 1.5%
Water, 75.5%

6.1.9.1 **Inking Procedure** The entire finished surface of the SOFA shall be rubbed with a sponge and a 50% solution of tap water and water-soluble contrasting color ink after the unit has been washed and dried as described in paragraph 6.1.7. The ink shall be rinsed from the surface with clear water, and the fitting allowed to air dry before inspection.

6.1.9.2 **Method of Inspection** The surfaces shall be inspected for defects with the unaided eye from a distance of between 1 ft and 2 ft (305 mm and 610 mm). The light source shall be equivalent to an illuminance near the surface to be inspected of 150 fc ± 50 fc (1615 lx ± 540 lx).

6.1.10 **Performance Requirement** The fitting shall be free from cracks as determined by inspection in accordance with paragraph 6.1.9. The presence of seams, flow lines, and knit lines shall be permitted and shall not be considered to be cracks.

6.2 Ultraviolet Light Exposure Test

Polymeric materials, including fiberglass reinforced plastics, used for the manufacture of suction fitting components that will be exposed to ultraviolet radiation shall meet the requirements of this paragraph.

Either of two test methods may be utilized to test for ultraviolet light degradation. Test Method 1 is suited for products small enough to fit into an ultraviolet (UV) test chamber, while Test Method 2 is suitable for all products.

If Test Method 1 is used, then the ultraviolet test and the structural tests are performed on complete samples that are intended for retail sale.

If Test Method 2 is used, then the ultraviolet test is performed on two sets of “dog bone” samples molded per ASTM D 638 from the same resin as the SOFA. Set A is not exposed to UV light. Set B is exposed to UV light. In addition, all the applicable structural tests described in paragraphs 6.3 through 6.10 are also performed on the as-sold samples. The performance requirements for those tests, however, will be adjusted per paragraph 6.2.2.3 of this standard.

Sumps and other assembly components that are not exposed to UV radiation when fully assembled and installed, according to the manufacturer's instruction, shall not be required to meet the requirements of this section.

6.2.1 **Test Method 1** Twelve new component specimens shall be exposed to ultraviolet light and water spray in accordance with either:

6.2.1.1 720 hr of twin enclosed carbon-arc (ASTM G 153, Table X1.1 Cycle 1 except the Black Panel Temperature should be 50 °C), or;

6.2.1.2 1,000 hr of xenon-arc (ASTM G 155, Table X3.1 Cycle 1 except the Black Panel Temperature should be 50 °C),or;

6.2.1.3 750 hr of fluorescent (ASTM G 154, Table X 2.1 Cycle 1 except the 8-hour UV shall be at a Black Panel Temperature of 50 °C and the 4 hour condensation Black Panel Tempreture shall be 40 °C).

6.2.1.4 Specimens shall be mounted inside the test apparatus, with exposed surfaces of the specimens facing the UV lamps, and positioned so they receive exposure approximating a fully assembled SOFA. After the exposure test, the specimens shall be removed from the test apparatus and rejected if signs of deterioration such as cracking or crazing appear. Discoloration shall not be cause for rejection. The samples shall then be retained under ambient temperature of 72 °F ± 2 °F (22 °C ± 4 °C) for not less than 16 hours, and not more than 96 hours, before being subjected to the following tests:

Deflection Tests

Point Load to Protrusion Test

Shear Load Test

Vacuum

Point Impact Test

Pull Load Test

Note: The intensification factor *K* shall be 1.0 for UV Test Method 1.

6.2.1.5 **Performance Requirement** All the specimens that were subject to the UV Test Method 1 shall comply with all performance requirements of the structural integrity tests in paragraphs 6.3 through 6.10.

6.2.2 **Test Method 2** Specimens of the component polymeric materials shall be exposed to ultraviolet light in accordance with the options specified in paragraphs 6.2.1.1, 6.2.1.2, or 6.2.1.3, and then to the tests specified in paragraphs 6.2.2.1 and 6.2.2.2. For Test Method 2, *K* is derived from paragraph 6.2.2.3.

6.2.2.1 **Tensile Strength** Specimens of non-exposed material (A) and UV-exposed material (B) shall be evaluated for tensile strength as described in the Standard Test Method for Tensile Properties of Plastics, ANSI/ASTM D 638 (ISO 527-2) using Type 1 specimens of 0.125 in. ± 0.02 in. (3.2 mm ± 0.4 mm) thickness and testing speed of 0.2 in./min ± 0.05 in./min (5.1 mm/min ± 1.3mm/min). The tensile strength is to be that value recorded at the yield point, if the material yields, or the value at the break point if the material breaks.

6.2.2.2 **Izod Impact** Specimins of virgin material (A) and UV-exposed material (B) shall be evaluated for impact strength as described in Method A of the Standard Test Methods for Impact Resistance of Plastics and Electrical Insulating Materials, ASTM D 256 or ISO 180, using a 0.125-in. (3.2-mm) thick specimen.

6.2.2.3 **Performance Requirement** Samples of the material shall retain at least 70% of the unconditioned value when the tests indicated in 6.2.2.1 and 6.2.2.2 are performed. An intensification factor *K* shall be defined as the inverse of the lowest retained proportion of the unconditioned virgin value when the tests in paragraphs 6.2.2.1 and 6.2.2.2 are performed. The structural integrity tests described in paragraphs 6.3, 6.4, 6.5, 6.6, 6.7, and 6.8, 6.9 and 6.10 shall be conducted on the complete non-UV exposed samples at loadings equal to the base values multiplied by the intensification factor, *K*. For example, if 80% of the tensile strength is retained in paragraph 6.2.2.1, and 85% of the Izod unit energy measured in paragraph 6.2.2.2 is retained, then $K = 1/0.80 = 1.25$. This will ensure that adequate strength remains after service aging.

6.3 Floor-Mounted Fitting Load and Deformation Test

This test applies only to fittings intended for and marked “Floor Only” or “Wall or Floor”. Six SOFAs shall be tested at four locations. A point load machine readable to, at a minimum, 5 lbf (22 N) increments, and that is equipped with a steel tup of 2 in. (51 mm) minimum diameter, with a 2 in. ± 0.5 in (51 mm ± 13 mm) radius nose. A skin pad consisting of a 0.25 in. (6.35 mm) thick buna-n rubber pad of Shore A durometer 60 ± 5 hardness shall be placed between the tup and the sample being tested.

6.3.1 **Test Method** SOFAs shall be tested as described in 6.3.1.1 to 6.3.1.3.

6.3.1.1 Each fitting shall be mounted on a horizontal plane.

6.3.1.2 The steel tup and pad shall apply a vertical load at a total of four different locations. Two points midway between the center and edge at two points between stiffeners, if any, and at two points furthest from any support element.

6.3.1.3 Using the tup and a 2 in. (51 mm) diameter skin pad on the face of the tup, and a tup speed of 0.20 in./min to 0.25 in./min (5.1 mm/min to 6.4 mm/min), apply a load at each of the above locations until 300 lbf × *K* ± 10 lbf (1334 N × *K* ± 44 N) is reached.

6.3.2 **Performance Requirement**

6.3.2.1 SOFA cover/grates shall not permanently deform, crack, or lose any material from the fitting, exclusive of plating or finish coatings.

6.3.2.2 Minor cracks in polymeric materials on the internal fitting to which the cover/grate is secured do not constitute a failure if they do not affect the function of the unit or allow the assembly to leak water.

6.3.2.3 Metallic covers shall be allowed permanent deformation if they do not adversely affect the function of the unit. Functioning of the unit shall be confirmed through compliance with the Hair Entrapment, paragraph 7, and Body Entrapment, paragraph 8, performance requirements after testing to the requirements of this section.

6.4 Wall-Mounted Fitting Load and Deformation Test

This test applies only to fittings intended for and marked “Wall Only” or “Wall or Floor”. Six SOFAs shall be tested. Fittings to be tested shall be the six units previously tested in paragraph 6.3, if applicable.

6.4.1 **Test Method**

6.4.1.1 The tests described in paragraph 6.3.1 shall be performed with a load of 150 lbf. × *K* ± 5 lbf (667 N × *K* ± 22 N).

6.4.2 **Performance Requirement**

6.4.2.1 The test specimens shall meet the performance requirements of paragraph 6.3.2.

6.5 Point Load to Excess Test

The SOFAs to be tested shall be those six previously tested in paragraphs 6.3 and 6.4, with loads applied as described in paragraph 6.3.

6.5.1 **Test Method** The test equipment set-up and specimen mounting shall be as described in paragraph 6.3. The units shall be subjected to loading at a tup speed of 0.20 in./min to 0.25 in./min (5.1 mm/min to 6.4 mm/min) until the tup protrudes through the cover/grate, or until a value of 600 lbf × *K* ± 10 lbf (2669 N × *K* ± 44 N) is reached.

6.5.2 **Performance requirement** SOFAs shall not sustain loss of any material from the fitting, exclusive of plating or finish. Permanent deformation shall not be considered a failure.

6.6 Shear Load Test

This test shall be applied to all fittings that protrude 0.5 inch (13 mm) or more from the mounting surface when installed per the manufacturer's instructions. Six previously untested SOFAs shall be tested.

6.6.1 Test Method

Each SOFA shall be mounted in a manner simulating an actual installation as closely as possible. The loads transferred from the cover/grate to the rest of the SOFA and thence to the foundation shall represent the load paths of an actual installation.

6.6.1.1 The SOFAs shall be tested by the application of a 150 lbf × *K* ± 5 lbf (667 N × *K* ± 22 N) test load applied 30 degrees from the mounting plane.

6.6.1.2 The test load shall be applied by a steel plate that is 1/2 in. × 2 in. × 2 in. (12 mm × 51 mm × 51 mm), that is covered with a 2 in. × 2 in. (51 mm × 51 mm) skin pad, as defined in paragraph 6.3, on its face.

6.6.1.3 The six SOFAs shall be tested using the point load apparatus described in paragraph 6.3.

6.6.1.4 Three fittings shall be tested with the load placed directly on the fasteners.

6.6.1.5 Three fittings shall be tested with the load midway between fasteners.

6.6.2 **Performance Requirement** The cover/grate shall remain in place. The components shall not permanently deform, crack, or lose any material exclusive of plating and finish.

6.7 Pressure Differential and Point Impact Test

The same six SOFAs used in the paragraph 6.6 Shear Load Test shall be used for the tests described in this paragraph.

6.7.1 Test Method

Each SOFA shall be mounted in a manner simulating an actual installation as closely as possible. The loads transferred from the cover/grate to the rest of the SOFA and thence to the foundation shall represent the load paths of an actual installation. Pressure or vacuum may be used to develop the differential pressure that is required, the magnitude of which is determined by the value of K.

6.7.1.1 The SOFA shall be covered with a 20 mil (0.5 mm) plastic material or other suitable material.

6.7.1.2 The SOFA shall be subjected to an external differential pressure of 28.5 in. Hg × *K* (724 mm Hg × *K*) differential pressure within 60 s ± 5 s.

6.7.1.3 The differential pressure shall be sustained for 5 min ± 10 s.

6.7.1.4 The vacuum or pressure shall be removed from the system, the plastic film shall be removed, and the fitting shall be impacted at 15 ft-lbf × K (20.3 J × *K*) using the test method in ASTM D 2444, with a 5 lbm (2.3 kg) steel tup, 2 in. (51 mm) minimum diameter with a 2 in. ± 1/2 in. (51 mm ± 13 mm) radius nose.

6.7.1.5 The tup shall be dropped onto the center of the fitting from a distance of 3 ft × *K* (914 mm × *K*).

6.7.1.6 The SOFA shall again be subjected to the 28.5 in. Hg × *K* (724 mm Hg × K) differential pressure within 60 s ± 5 s.

6.7.1.7 The differential pressure shall be sustained for an additional 5 min ± 10 s.

6.7.1.8 Remove the sample from the test fixture, and then apply water-soluble contrasting ink in accordance with paragraphs 6.1.9 and 6.1.9.1.

6.7.1.9 The components shall then be inspected for cracks, breaks, or fractures in accordance with paragraph 6.1.9.2.

6.7.2 **Performance Requirement**

6.7.2.1 The cover/grate shall remain in place after the test procedures in paragraphs 6.7.1.1 through 6.7.1.9.

6.7.2.2 The components shall not permanently deform, crack, or lose any material from the fitting, exclusive of plating and finish.

6.8 Pull Load Test

Pull Load Testing shall be required of all SOFAs with openings with at least one dimension of 0.375 in. (9.53 mm) or more affording a finger grip. The pull load test shall be done with the SOFA mounted on the surface used for the hair test as described in paragraph 7.1.5.11. The same six fittings used in the Pressure Differential and Point Impact Test, paragraph 6.7, shall be used for this test.

6.8.1 **Test Method** The cover/grate shall be installed on a SOFA per the manufacturer's instructions. A total force of 200 lbf × *K* ± 5 lbf (889 N × *K* ± 22 N) shall be applied to the underside of the cover/grate assembly, and perpendicular to the mounting surface, in locations that will approximate the load bearing points available to a bather's three fingers. The test shall be conducted once adjacent to fasteners, and conducted once midway between adjacent fasteners. The test apparatus used shall apply an equal load to each bearing location.

6.8.2 **Performance Requirement**

6.8.2.1 The cover/grate shall withstand a 200 lbf × *K* (889 N × *K*) pulling force.

6.8.2.2 Distortion under load shall not compromise the fastener(s), loosen the cover/grate, cause permanent deformation exceeding 0.03 in. (76 mm). Metal cover/grates are exempt from the deformation requirements.

6.8.2.3 When viewed under a light source equivalent to an illuminance near the surface to be inspected of 150 fc ± 50 fc (1615 lx ± 540 lx), no cracks shall be detectable with the unaided eye from a distance of between 1 ft and 2 ft (305 mm and 610 mm).

6.9 Mold Stress Relief Distortion

6.9.1 One sample of the complete, as intended for distribution, non-UV exposed fitting is to be placed in a full draft circulating air oven maintained at a uniform temperature of 140 °F (60 °C). The sample is to remain in the oven for 7 hrs. The sample is then to be removed from the oven, and allowed to return to room temperature before being installed in the test fixture.

6.9.2 This sample shall be used for the hair entrapment tests, paragraph 7, and body entrapment tests, paragraph 8.

6.10 Threaded Fastener Test

Each female thread or thread receptacle shall be successfully tested by driving the fastener to the maximum torque specified by the manufacturer, with a torque-limiting driver.

6.10.1 The test shall be performed three times the lifespan in years identified by the manufacturer in paragraph 1.4, *e.g.*, a SOFA with a 5-year lifespan shall be tested 15 times.

6.10.2 The test shall be performed on a SOFA assembled according to the manufacturer's instructions.

6.10.3 The screws shall be removed manually and started manually each time.

6.10.4 The screws and receptacle shall be at a temperature of 73.4 °F ± 3 °F (23 °C ± 2 °C).

6.10.5 The use of multiple screws shall be permitted to complete this test.

6.10.6 Performance Requirement: The female receptacle shall not strip, and the fastener head shall not cause cracking of the SOFA. Threaded inserts shall not strip, twist, or pull out of the specimen. The specimen used for this test shall subsequently be used for the Pull Load Test in paragraph 6.8.

7 Hair Entrapment

7.1 General

The objective of this section is to measure the removal force of hair that may be drawn into a SOFA.

7.1.1 Hair drawn into or onto suction fittings shall not prevent the escape of a bather.

7.1.2 Two types of hair shall be used in this test. Separate tests shall be run with each type.

7.1.2.1 Type 1; A full head of natural, fine, straight, blond European, human hair with cuticle on hair stems, 16 in. (406 mm) in length, weighing 5.5 oz ± 0.5 oz (155 g ± 15 g), shall be firmly affixed using hook-and-loop fasteners to a Professional Wig Display Mannequin, Model No. FMH-#1SC, or equivalent, in a manner approximating the normal distribution of hair. The completed assembly shall weigh between 1 pound and 2 pounds when submerged at the test depth. An anchoring point shall be provided near the neck of the simulated skull. A fresh sample of hair shall be used for each fitting tested, or when tangles in the hair cannot be removed by combing. Hair shall be trimmed evenly to a length of 16 inches (406 mm) after being attached to the simulated skull.

7.1.2.2 Type 2; Natural, medium-to-fine, light-brown colored human hair weighing 2 oz. ± 0.11 oz. (57 g ± 3 g) and having a length of 16 in. (406 mm) shall be affixed to a 1 in. (25 mm) diameter by 12 in. (305 mm) or longer wooden dowel, as may be required to properly place the hair sample for testing. Consideration shall be given to the buoyancy of the portion of the wooden dowel in excess of 12" (305 mm) in determining the removal force. A method for attaching a scale shall be provided on the opposite end of the dowel. A fresh sample of hair shall be used for each fitting tested or when tangles in the hair cannot be removed by combing. Hair shall be trimmed evenly to a length of 16 inches (406 mm) beyond the end of the dowel.

7.1.3 Only one new suction fitting is required to be tested to the requirements of this section.

7.1.4 Hair entrapment tests are not required for field-fabricated SOFAs.

7.1.5 **Test Equipment**

7.1.5.1 The test apparatus for evaluation of suction fittings for the hair entrapment test shall comply with Figures 4, 5, and 6. The baffle plates shall be constructed as shown in Figure 7.

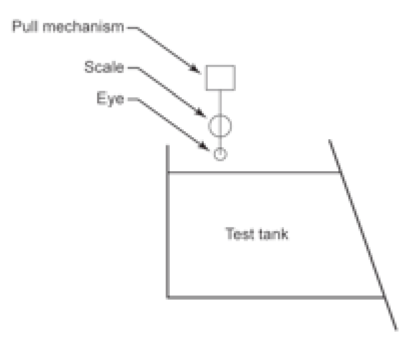

Figure 4. Schematic Diagram of Hair Pull Mechanism

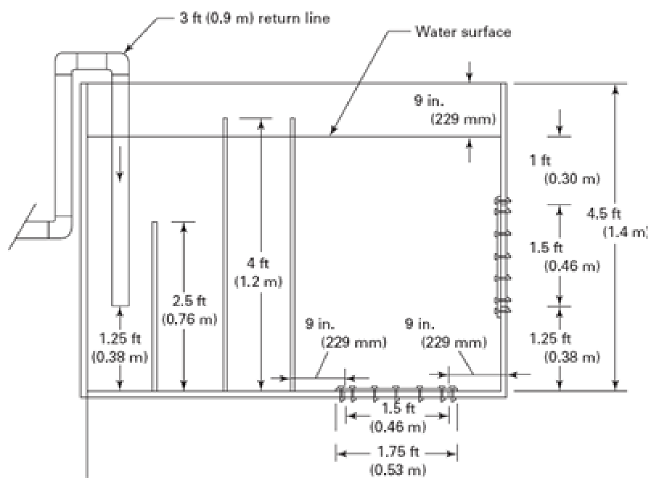

Figure 5. Side View of Test Tank

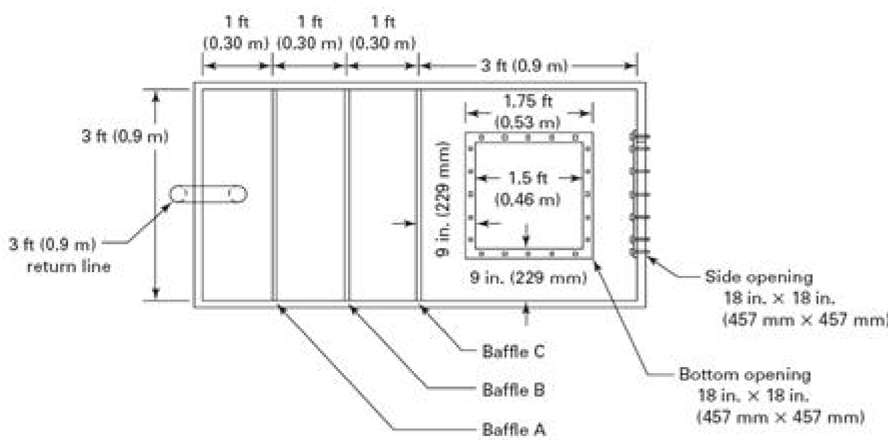

Figure 6. Top View of Test Tank

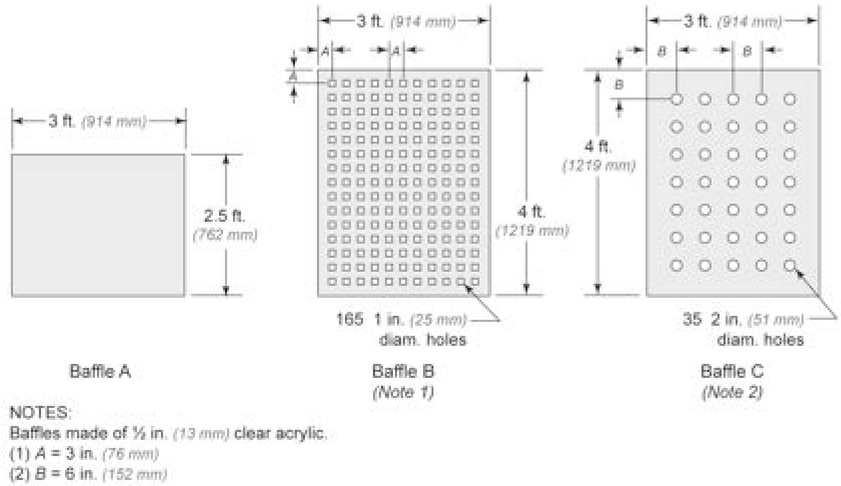

Figure 7. Baffle Construction Details

7.1.5.2 The pump shall be capable of producing a flow rate at least 25% greater than the SOFA manufacturer's anticipated rating of the SOFA.

7.1.5.3 The suction source for the body entrapment tests shall be a pumping system that is capable of producing the required volumetric flow rate, and a suction head of 26.0” Hg measured at the SOFA, when the suction piping is completely blocked after the discharge is throttled to deliver the release flow rate.

7.1.5.4 The vacuum level shall be measured with a vacuum transducer or sensing device with an accuracy of 1%.

7.1.5.5 A flow meter with an accuracy of ±3% at the anticipated rating shall be installed in the piping system.

7.1.5.6 Flow rate shall not be varied by reducing the speed of the pump motor.

7.1.5.7 The pump inlet shall be connected to the 16 in. (406 mm) length of Schedule 40 plastic pipe described in paragraph 7.2.5 using pipe lengths and adapters as necessary.

7.1.5.8 A scale accurate within 0.1 lbf (0.45 N) at a tension of 5 lbf (22 N) shall be used to measure the hair removal force.

7.1.5.9 The hair entrapment test fixture shall be comprised of the test tank and the pull mechanism.

7.1.5.10 For assemblies where all flow passages are provided by the manufactured components, the mounting surface of Figure 8 shall be planar and represent actual field practices, with smooth surfaces immediately adjoining the top edge of the frame or sump, or as specified by the manufacturer.

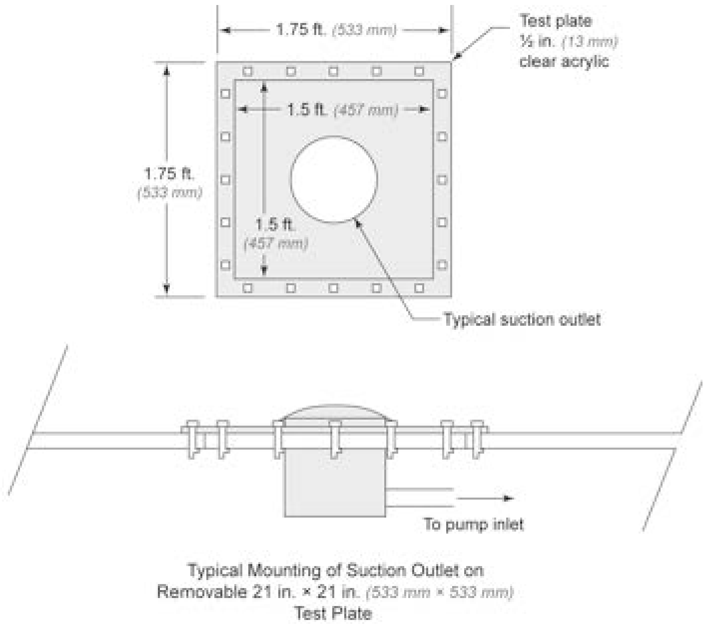

Figure 8. Typical SOFA Mounting Detail

7.1.5.11 For assemblies where a portion of the flow passage is the pool surface and is not controlled by the cover/grate manufacturer, the test mounting surface shall represent field imperfections that may produce a hair entrapment hazard. The nominally square planar mounting surface shall be distorted to an anticlastic surface such that one corner is 2 in. (51 mm) away from a plane defined by the other three corners of a 48 in. × 48 in. (122 mm × 122 mm) square as shown in Figure 9. A convenient means shall support three of the corners in a plane with 1 in. (25 mm) clearance from the nearby surface of the frame, then force the fourth corner 2 in. (51 mm) from the plane of the first three. Supports shall be localized, and 1.5 in. (38 mm) from the edges of the mounting surface. The test specimen shall be firmly attached to the anticlastic surface in a field installation manner as specified by the manufacturer.

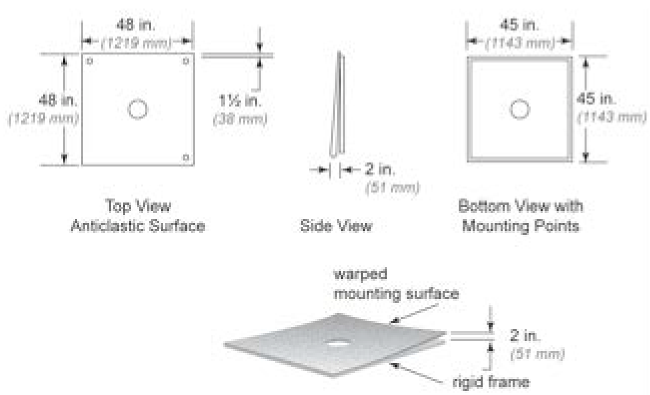

Figure 9. Anticlastic Mounting Surface Detail

7.1.6 **Alternate Test Tank**

7.1.6.1 The same tank as described in paragraph 7.1.5.1, with Baffle C, bottom, sides, and only the one end where the fittings are tested may be used by inserting the tank into a larger body of water so, that the submerged depth of the tank is the same as in paragraph 7.1.5.1.

7.1.6.2 The volume of the water in this larger body of water shall substitute for the return line piping depicted in Figures 5 and 6.

7.1.6.3 Any other body of water may be used if the body of water provides equivalent test results as intended by this standard.

7.1.6.4 Influences of water currents shall be virtually absent in the test pool, as evidenced by the suspension of the hair sample in the tank for 30 seconds and noting its deviation from a vertical plumb line hung at a distance from the non-flowing test specimen of four times the smallest dimension of the test cover/grate. The deviation shall not exceed 1 in. (25 mm) during this time.

7.2 TEST METHOD

7.2.1 The suction fitting, including the sump to be tested, shall be installed in accordance with the manufacturer's installation instructions on the simulated SOFA mounting surface. Refer to Figure 8.

7.2.2 For suction fittings intended for wall installation, the test mounting surface shall be vertical, and for suction fittings intended to be installed only in the floor installation, the test mounting surface shall be horizontal.

7.2.3 Suction fittings intended for installation in either the wall or floor position shall be tested in both positions.

7.2.4 Wall fittings, if the pattern of the cover/grate is not uniform, shall be tested in two positions, representing the essential geometric differences.

7.2.5 The fitting shall be connected to a 90 degree elbow the same size as the fitting outlet and as close to the suction fitting as possible with a minimum of 16 in. (406 mm) of straight Schedule 40 plastic pipe the same size as the fitting socket connected to the 90 degree elbow.

7.2.6 Self-contained spa fittings shall be installed in pairs on the test suction outlet mounting surface using 14 ft. ± 1 ft. (4267 mm ± 305 mm) of flexible PVC hose in accordance with Figure 10.

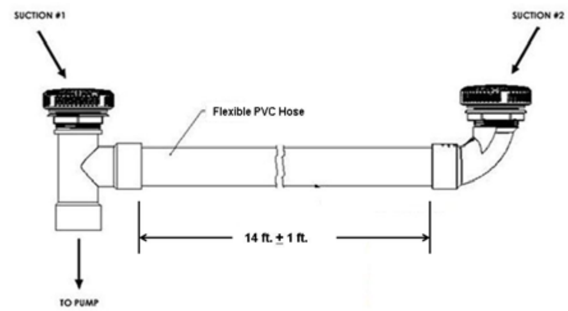

Figure 10. Self-Contained Spa Fitting Hair Test Configuration

7.2.6.1 The size(s) of the flexible PVC hose shall be specified by the self-contained spa fitting manufacturer.

7.2.6.2 When more than one size of hose is specified by the self-contained spa fitting manufacturer, each size of hose shall be tested.

7.2.6.3 Suction #1, shown in Figure 10, shall be tested for hair entrapment in accordance with 7.2.7 through 7.3.

7.2.7 The dimensions of the sump, adequately defining the geometry of sump used during the test shall be documented. As a minimum, documentation shall specify the distance between the underside of the suction cover and the connecting pipe and the pipe size(s).

7.2.8 The manufacturer-specified sump dimensions and connecting pipe size(s) for both manufactured and field fabricated sumps shall be equal to or exceed the dimensions of the sump used during the test.

7.2.9 With water flowing, the tank test chamber shall be at a temperature at 90 °F ± 10 °F (32 °C ± 6 °C) with a minimum depth of 12 inches (305 mm) above the top edge of the cover/grate, or to a depth in accordance with the manufacturer's instructions for swim jet combination fittings.

7.2.10 Prior to energizing the test pump, the pull mechanism shall be verified to ensure consistent speed when pulling weights from 2 lbm to 10 lbm (8.9 N to 44 N). Within that range of test weights, the speed of the pull shall be 5 inches per second ± 0.25 inches per second (127 mm/s ± 6 mm/s).

7.2.11 The test pump shall be running and the flow shall be regulated to 10 gpm (38 L/min) less than the fitting manufacturer's recommended gpm flow rate. If the fitting rating is not known, this test shall be started at 25 gpm (95 L/min). The fitting manufacturer may specify the starting test flow rate for each fitting to be tested.

7.2.12 Prior to use, the hair test sample shall be cleaned in a solution of 10% by volume of sodium alpha olefin sulfonate (AOS), and water. The hair test sample shall be rinsed in potable water after cleaning.

7.2.13 Hair samples shall be cleaned after every ten pulls.

7.2.14 The hair shall be submerged in the test tank water for a minimum of 2 minutes prior to use.

7.2.15 The free end of the hair shall be placed 12 in. (305 mm) in front of wall-mounted cover/grates, and 2 inches (51 mm) above the top of them, as illustrated in Figure 11.

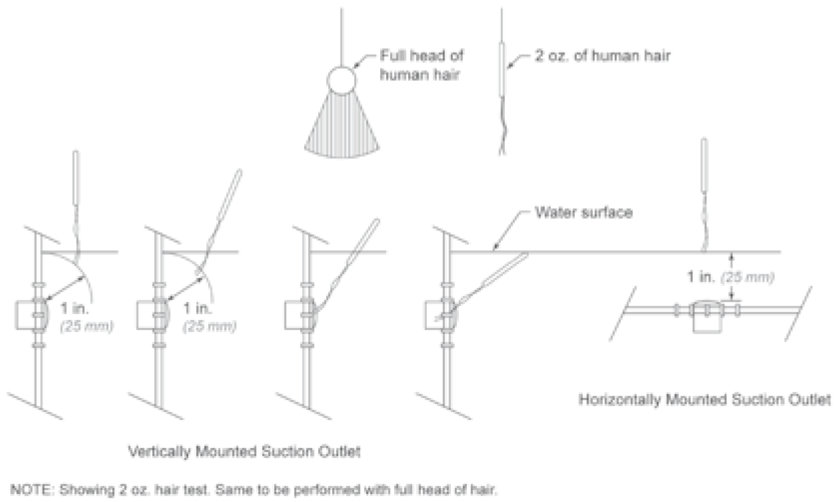

Figure 11. Hair Test Diagrams <<<APSP TO PROVIDE UPDATED DRAWING>>>>

7.2.16 The free end of the hair shall be placed 2 in. (51 mm) above floor-mounted cover/grates, as illustrated in Figure 11.

7.2.17 The hair shall then be uniformly moved closer to the suction portions of the fitting.

7.2.18 The ends of the hair shall be fed into the fitting in the direction of the intake flow, as illustrated in Figure 11.

7.2.19 The hair shall be continuously fed into the fitting while moving the skull or dowel in a sweeping motion.

7.2.20 The magnitude of the sweeping motion shall be reduced with each pass of the skull or dowel.

7.2.21 The hair shall be moved toward the fitting over a period of 30 seconds ±5 seconds.

7.2.22 The skull or dowel end shall be held against the fitting for 30 seconds ± 5 seconds.

7.2.23 The skull or dowel shall then be released and allowed to float or remain free for 30 seconds ± 5 seconds.

7.2.24 In testing any fitting which is not entirely symmetric, or those mounted on an anticlastic surface, testing shall start with the free end of the hair at least 2 in. (51 mm) from any portion of the fitting.

7.2.25 For the hair entrapment tests, each suction port of a SOFA shall be treated as a separate fitting.

7.2.26 The area of the cover/grate adjacent to each suction port shall be challenged with the Type 1 and Type 2 hair specimens.

7.2.27 The flow rate shall be increased in 5 gpm ±0.15 gpm (19 L/min ± 0.57 L/min) increments.

7.2.28 Ten tests shall be performed at each flow rate.

7.2.29 The hair shall be combed before each test until it is free of tangles.

7.2.30 The amount of force necessary to free the hair from the fitting shall be measured with the test pump operating.

7.2.31 The skull or dowel shall be attached to the scale and the scale shall be zeroed and then pulled vertically away from the fitting by activating the hair removal mechanism. The force of the entrapment shall be measured and recorded.

7.2.32 Where a failure is determined with a specific 5 gpm (19 L/min) increase, the SOFA shall be permitted to be retested in 1 gpm (3.8 L/min) increments up to the point of the previous failure.

7.3 Performance Requirement

7.3.1 A pull of 5 lbf (22 N), or greater, on any one of the ten tests, including the equalized weight of the saturated test apparatus, shall be deemed a failure, and the flow rate in gpm at failure shall be recorded. If one failure in ten pulls occurs, repeat the test ten more times. All ten additional tests shall be passed before moving to the next higher flow rate. The maximum allowable certified flow rating shall be the lower of either the highest passing flow rate divided by 1.25, or the flow rating specified by the manufacturer.

7.3.2 The maximum allowable certified flow rating shall be the lower of either the highest passing flow rate for any of a SOFAs suction ports, divided by 1.25, or the flow rating specified by the manufacturer, if it is lower than the value determined by testing to this standard.

8. Body Entrapment

8.1 General

SOFAs shall be designed and installed so as to reduce the potential for body entrapment. The potential for body entrapment is addressed by the proper selection of the size of the cover/grate, the proper installation of more than one suction outlet, by limiting the system flow rate, or by a combination of these or other methods.

8.1.1 The body entrapment test shall apply to all fittings and suction outlets covered under this standard.

8.1.2 For manufactured SOFAs, only one SOFA is required to be tested.

8.1.3 Self-contained spa SOFAs shall be tested for conformance with this paragraph using a single-outlet configuration. The body entrapment test shall not be performed using the configuration of paragraph 7.2.6.

8.1.4 Suction outlet cover/grates that cannot be completely shadowed by the body blocking element may either be rated by the test procedures called for in this section, or by calculation in accordance with paragraph 5.2.2.

8.2 TEST EQUIPMENT Tests shall be performed using the equipment specified in paragraphs 8.2.1 through 8.2.7.

8.2.1 Test tank described in paragraph 7.1.5.

8.2.2 The body blocking element specified in 8.2.6.

8.2.3 An apparatus that can apply 120 lbf (534 N) vertically downward on the body blocking element, immediately release the force, then measure the force required to remove the body blocking element from the SOFA.

8.2.4 The SOFA mounting surface for the body entrapment test shall be in accordance with Section 7.1.5.10 and 7.1.5.11.

8.2.5 The suction source for the body entrapment tests shall be a pumping system that is capable of producing the required volumetric flow rate, at a suction head of 26.0” Hg (880 millibar) measured at the SOFA, when the suction piping is completely blocked after being set to deliver the required flow rate.

8.2.6 The BBE shall be constructed of 2-inch (51 mm) thick closed-cell nitrile butadiene rubber/(poly) vinyl chloride (NBR/PVC) foam with a compression deflection value of 1.5 psi to 3.0 psi (10 kPa to 21 kPa) at 25% deflection, as measured in accordance with ASTM D 1056-00. The foam shall be mounted to a 3⁄4 in. (19 mm) waterproofed plywood backing, with the skin side of the foam facing away from the plywood. The vertical corners of the BBE shall have a radius of 4 inches.

8.2.7 An eyebolt, or equivalent device located at the centroid of the BBE, shall be used to attach the BBE to the test apparatus as shown in Figure 12.

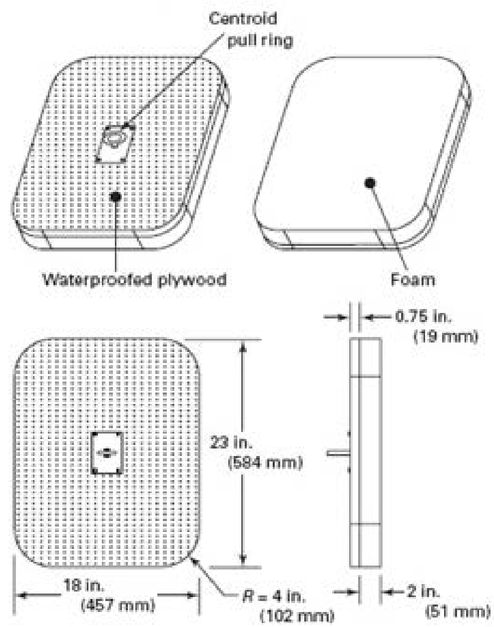

Figure 12. Typical BBE Construction Detail

8.2.7.1 The BBE shall be ballasted to neutral buoyancy, within 0.7 lbf (3.1 N), at the test depth.

8.3 TEST METHOD

8.3.1 With the SOFA flowing the maximum flow specified by the manufacturer, or as determined in paragraph 7.3, whichever is less, the body blocking element shall be centered over the cover/grate or swim jet fitting and oriented so as to cover the largest possible area of the cover/grate.

8.3.2 An applied force of 120 lbf (534 N) shall be applied through the eyebolt, or equivalent, in order to fully seat the BBE on the SOFA.

8.3.3 The applied force shall immediately be removed from the body-blocking element.

8.3.4 Immediately after removal of the applied force, the test apparatus shall lift the body-blocking element from the SOFA.

8.3.5 The maximum force required to remove the body-blocking element from the SOFA shall be recorded as the removal force.

8.4 PERFORMANCE REQUIREMENT Under these test conditions, the removal force shall not exceed the value specified by the equation:

Equation 2: $$F_{max.\ removal} = (W_{derived}/9)^3 \times 15$$

Where:

$F_{max.\ removal}$ is the maximum permissible removal force in pounds

$W_{derived}$ is the minimum width in inches of the rectangular shape whose length is 1.28 times the width, with corners of radius 22% of the width dimension, which completely shadows the SOFA cover/grate, and shall in no case be smaller than 9 inches nor larger than 18 inches.

8.4.1 The maximum permissible removal force shall not be exceeded in three consecutive tests.

8.4.2 Where a failure is determined at the tested flow rate as specified in paragraph 8.3, the SOFA shall be allowed to be tested in 5 gpm (19 L/min) decrements until it passes. The SOFA shall then be permitted to be retested in 1 gpm (3.8 L/min) increments up to the point of failure in order to determine its rating under this section.

9. Finger and Limb Entrapment

9.1 General

9.1.1 SOFAs shall be designed and installed so as to minimize the potential for finger and limb entrapment.

9.1.1.1 When fully assembled, SOFAs shall not have any accessible opening that allows the passage of the 1 in. (25 mm) cylindrical end of the UL articulated probe.

9.1.1.2 Finger entrapment tests shall be conducted on one new SOFA from each mold cavity.

9.1.2 Tests shall be conducted at 72 °F ± 5 °F (22 °C ± 3 °C) using new dry fittings.

9.1.3 Tests shall be conducted with the UL articulated probe in accordance with Figures 13, 14, 15, and 16.

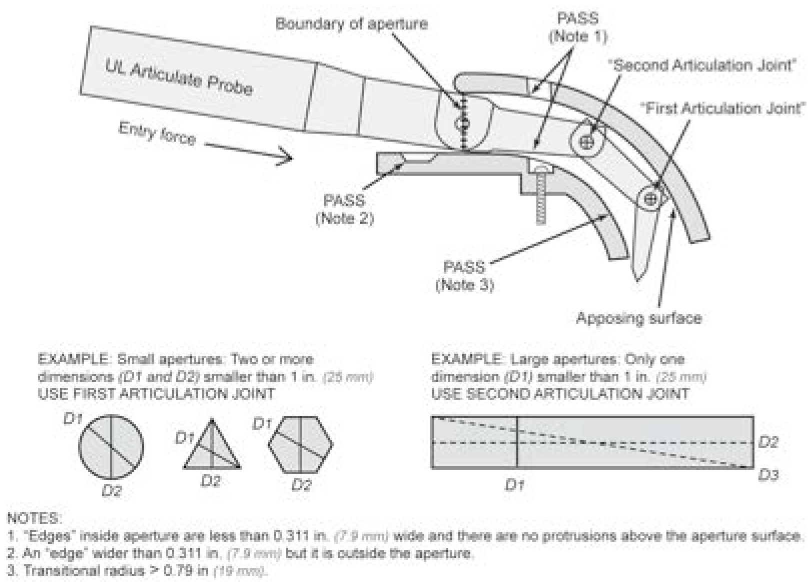

Figure 13. Finger Probe Test

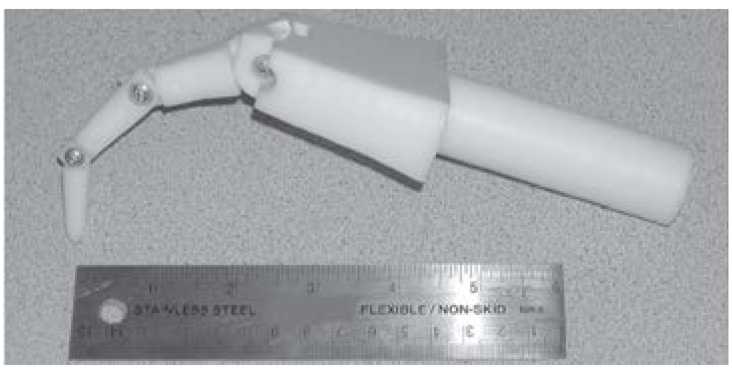

Figure 14. Photograph of UL Articulated Finger Probe

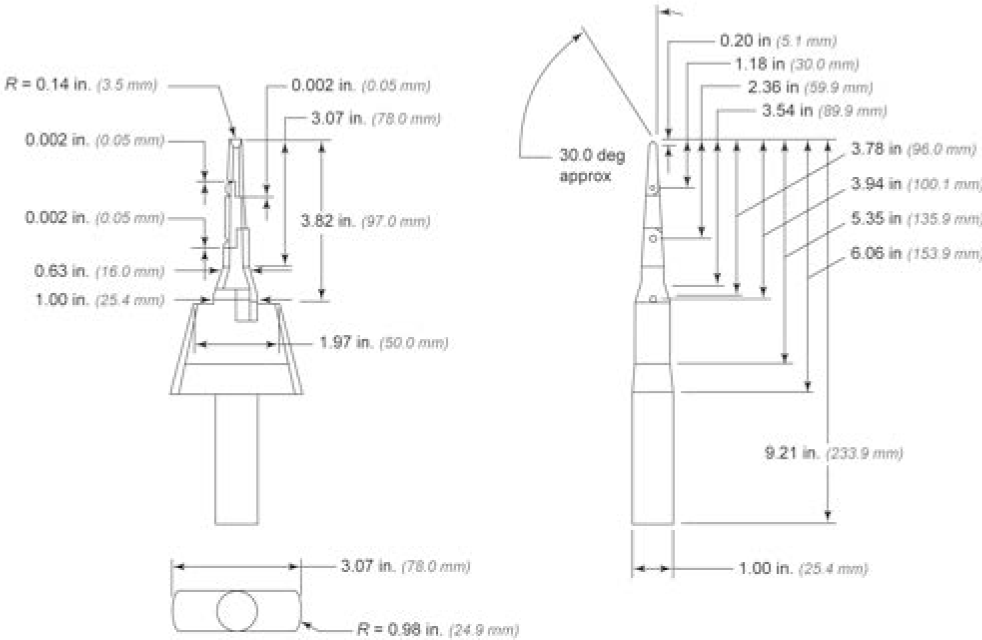

Figure 15. Finger Probe Dimensions

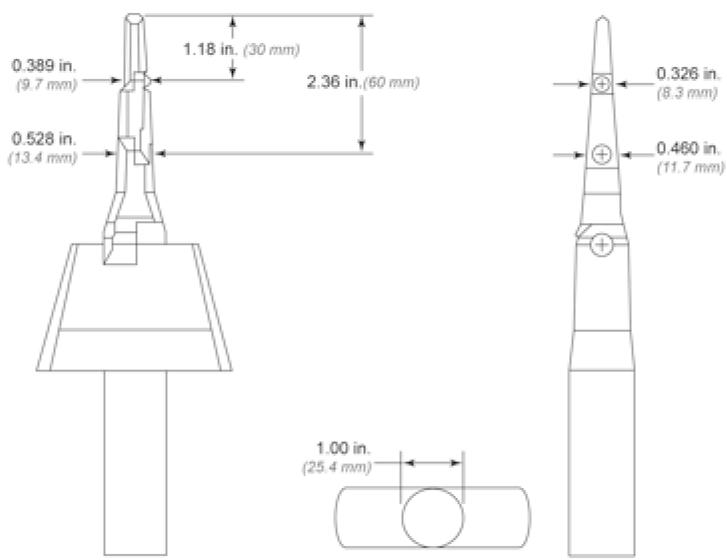

Figure 16. Finger Probe Knuckle Dimensions

9.2 TEST METHOD

9.2.1 Each aperture on the SOFA shall be subjected to the insertion of both ends of a UL articulated probe.

9.2.2 The finger probe shall be inserted with a force of 3 lbf ± 0.15 lbf (12 N ± 0.6 N) into all exposed apertures of the assembled SOFA.

9.3 Performance Requirement

9.3.1 A small or large aperture is permitted when the 1 in. (25 mm) cylindrical end of the UL articulated probe cannot be made to penetrate through to the inside surface of the aperture and as follows:

9.3.2.1 Small apertures shall be permitted when the centerline of the first articulation joint, located 1.18 in. (30 mm) from the point end of the UL articulated probe, cannot be made to pass beyond an edge or pinch point that is located inside the aperture being tested. See Figure 13.

9.3.2.2 Edges and pinch points shall be permitted within the small aperture and within range of the first articulated joint in accordance with Figure 13 if they are less than 0.311 in. (7.9 mm) wide, measured parallel to the aperture opening.

9.3.2.3 Edges and pinch points created by molding lines, engraved text, and symbols shall be permitted within the small aperture provided they do not exceed a height of 0.025 in. (0.64 mm).

9.3.2.4 Large aperture(s) shall be permitted if the centerline of the second articulation joint, located 2.36 in. (59.9 mm) from the point end of the UL articulated probe, cannot be made to pass beyond an apposed edge or pinch point that is located inside the aperture being tested. See Figure 13. Safety Backup Devices or Systems

10. Marking, Packaging, and Installation Instructions

SOFAs shall only be marked for the type of service to which they have been certified by this standard.

10.1. Marking of Factory-Manufactured Cover/Grates

10.1.1. Cover/grates must be permanently marked with the information described in paragraph 10.1.4.

10.1.2. Text font size shall be at least 0.08-in. (2.03 mm) tall.

10.1.3. Markings shall be visible when the SOFA is in the installed position, except as noted in 10.1.4.9.

10.1.4. The positioning or arrangement of the required markings shall be in the following sequence when possible:

10.1.4.1. VGB ####, where #### indicates the year of the standard to which the cover is certified.

10.1.4.2. Certification markings that are required by the responsible jurisdictional authority.

10.1.4.3. The statement “For Single or Multiple-Outlet Use”, “For Single-Outlet Use”, “For Multiple-Outlet Use Only”, or “For Unblockable Use”, as appropriate when SOFAs meet such requirements. Self-contained spa fittings shall be marked “For use in self-contained factory-manufactured spas only”, and “For multiple outlet use only”.

10.1.4.4. The lesser of the maximum flow rate in gpm as determined in accordance with paragraph 5.2.2, 7, or 8. A fitting shall be permitted to be marked with multiple flow rates, *i.e.*, a flow rating for “Floor” installations and another for “Wall” installations.

10.1.4.5. Each SOFA component shall be marked “Replace After X Years” where the manufacturer indicates the appropriate installed life in years. Individual components may be marked with unique life spans.

10.1.4.6. The approved installation position(s): “Wall Only”, or “Floor Only”, or “Wall or Floor” if certified for use in both positions.

10.1.4.7. Manufacturer's name or registered trademark.

10.1.4.8. Model designation.

10.1.4.9. A note to use only fastener hardware and installation methods provided by the SOFA manufacturer. This note is not required to be visible when the cover/grate is in the installed position.

10.1.4.10. Any portion of the SOFA receiving threaded fasteners shall be marked with the appropriate threaded fastener information in a manner similar to the example formats below.

For machine screws:

Use only 10-24 316 SS fasteners

For self-threading screws:

Use only Quantum fastener #123456

10.1.5. The following is an example of a typical marking:

VGB 2015

For Multiple Outlet Use Only

108 GPM

Replace After 7 Years

Wall Only

Quantum 1563-W

Use only Quantum fastener #123456 to fasten this cover.

10.2. Marking of Field-Fabricated Outlets

10.2.1. Field-fabricated outlets may meet the marking requirements by complying with paragraphs 10.1.4.1 through 10.4.1.10, or by complying with paragraphs 10.2.1.1 through 10.2.1.3.

10.2.1.1. The information required by paragraphs 10.1.1 through 10.1.4.10 is provided in writing by the registered design professional to the facility owner where these fittings will be installed.

10.2.1.2. The registered design professional advises the facility owner in writing that the information called for in paragraphs 10.1.1 through 10.1.4.10 shall be maintained in a permanent file by the operating facility.

10.2.1.3. The information required by paragraphs 10.1.1 through 10.1.4.10 is posted on a permanently mounted sign that is adjacent to the pool circulation pump. The minimum text size shall be 0.33 inches tall.

10.3. Packaging of Suction Fittings

10.3.1. The packaging and installation instructions for manufactured fittings shall contain instructions for installation and service including:

10.3.1.1. The statement “Read, then keep these instructions for future reference.”

10.3.1.2. A cautionary note not to exceed the maximum allowable flow rate stated on the suction fitting.

10.3.1.3. A warning not to increase the circulation pump size.

10.3.1.4. SOFA type designation, *e.g.*, field-fabricated, venturi outlet, swim jet combination fitting, submerged suction outlet, or self-contained spa fitting.

10.3.1.5. The requirement for multiple outlets per pump, if such a requirement exists.

10.3.1.6. Instructions not to locate suction outlets on seating areas or on the backrests for seating areas. Large footwells with walls that could be used as backrests shall be considered as well, particularly avoiding configurations that could be used as seat and backrest simultaneously.

10.3.1.7. Instructions stating that when two or more blockable suction fittings are used on a common suction line, two fittings shall be separated by a minimum of 3 ft. (914 mm) center-to-enter. An alternate means of meeting the 3-foot separation requirement is to locate the fittings on two different planes, *i.e.*, one on the floor and one on a wall, or one each on two separate walls. In each case they shall be located so that the body blocking element, when placed in any position, cannot create a suction force in excess of the value calculated in paragraph 8.4.

10.3.1.8. For fittings marked for multiple use, instructions stating that in the event any one of the suction outlets is completely blocked, the remaining suction outlets serving that system shall have a flow rating equal to or higher than the maximum system flow rate.

10.3.1.9. The maximum flow rating of each of the installed SOFAs.

10.3.1.10. A head loss curve provided by the manufacturer or testing laboratory.

10.3.1.11. A statement indicating what size sump and piping were used during the test as described in section 7.2.

10.3.1.12. A statement indicating the manufacturer-recommended sump dimensions and connecting pipe size(s) for both the manufactured and field-fabricated sumps shall be equal to or exceed the dimensions of the sump and pipe size specified in section 10.3.1.11.

10.3.1.13. The mounting position(s) wall/floor, including the allowed placement of the SOFA relative to the pool/spa interior surface.

10.3.1.14. Suction outlet part number(s), and/or model number(s).

10.3.1.15. Detailed field-built sump design specifications, when applicable.

10.3.1.16. Part number/description list, and “Replace within 'YY' installed years” for all parts.

10.3.1.17. A list of tools that are required for servicing or winterizing the SOFA.

10.3.1.18. Service and winterizing instructions.

10.3.1.19. A statement that the suction fitting, including fasteners, shall be observed for damage or tampering before each use of the facility.

10.3.1.20. A statement that missing, broken, or cracked suction fittings shall be replaced before bathers are allowed to use the facility.

10.3.1.21. A statement that loose suction fittings shall be reattached before bathers are allowed to use the pool.

10.3.1.22. A statement indicating that components and fastener receptacles shall be clean and free of debris or obstructions during installation of cover and fasteners.

10.3.1.23. Instructions indicating proper alignment and assembly order of all components.

10.3.1.24. A statement to start initial installation of screws by hand in order to ensure proper thread engagement and to prevent cross threading.

10.3.1.25. A statement indicating that the driver bit appropriate to the fastener shall be used to tighten screws to a snug fit, and to not over-torque screws or damage may occur.

10.3.1.26. A statement indicating the requirement to hand-check cover/grate for snugness to the sump after installation.

10.3.1.27. A statement indicating how to perform corrective actions when required.

10.3.1.28. A statement indicating how to evaluate the integrity of SOFA components, including how to address the following conditions:

10.3.1.28.1. Color change, when applicable, such as from white to off-white in color.

10.3.1.28.2. Brittle components with chunks or pieces broken off.

10.3.1.28.3. Stripped screw holes.

10.3.1.28.4. Cracks.

10.3.1.28.5. If a mud ring is used, cracked or broken pool finish holding the mud ring in place.

10.3.1.29. When any SOFA component is held in place by a surface, that surface shall be free of deterioration and voids.

10.3.1.30. Instructions for reinstallation or repair of damaged fasteners and corresponding receptacles (inserted, tapped, or self-threaded). Instructions shall include when it is necessary to abandon existing receptacles.

10.3.1.31. A “Certificate of Compliance” which shall include the date of manufacture of the cover/grate, or instructions how to secure this information via electronic means.

10.3.1.32. Blockable cover/grates that are marked “For Single Outlet Use” shall specify in the installation instructions the requirement for one or more of the additional backup safety devices or systems listed in Section 8.

10.3.1.33. Installation instructions necessary to ensure compliance with the VGB Act.

11. Safety Backup Devices or Systems

In the event that a suction outlet is used as the sole source for water to the pump suction system, other than an unblockable suction outlet, the suction outlet shall be installed with one or more of the additional safety backup devices or systems as listed below:

a) SAFETY VACUUM RELEASE SYSTEM- A system that ceases operation of the pump, reverses the circulation flow, or otherwise releases the vacuum in a circulation system when a blockage is detected, that has been tested by an independent third party and found to conform to ASME/ANSI standard A112.19.17 or ASTM standard F2387.
b) SUCTION-LIMITING VENT SYSTEM- A circulation system that incorporates a tamper-resistant atmospheric vent that is hydraulically located between the suction outlet and the circulation pump, which allows air to enter the circulation system and release the vacuum within the system when the suction outlet is blocked and the circulation pump is operating.
c) GRAVITY DRAINAGE SYSTEM- A powered circulation system, which utilizes a collector tank hydraulically located between the pump and the suction outlet that is filled by the gravitationally induced flow of water from the suction outlet, and is vented to the atmosphere by a tamper-resistant opening.
d) AUTOMATIC PUMP SHUT-OFF SYSTEM- A system that is designed to sense blockage of the suction fitting and then turn-off the power to the pump, and subsequently release the vacuum in the circulation system when a blockage is detected.
e) DRAIN DISABLEMENT- A device or system that disables the flow of water from a SOFA.
f) OTHER SYSTEMS- Any other system determined by the Consumer Product Safety Commission to be equally effective as, or better than, the systems described in (a) through (e) above, at preventing or eliminating the risk of injury or death associated with pool drainage systems.

CPSC Staff Report on Proposed Changes to Entrapment Ratings Tests in APSP-16 2011

Mark Eilbert. Mechanical Engineer
April 17, 2014
Directorate for Laboratory Sciences
U.S. Consumer Product Safety Commission

TABLE OF CONTENTS

EXECUTIVE SUMMARY

This report describes a study in which CPSC staff in the Directorate for Laboratory Sciences conducted tests comparing the current ANSI/APSP-16 2011 Standard, *Suction Fittings for Use in Swimming Pools, Wading Pools, Spas, and Hot Tubs,* to the proposed ANSI/APSP-16 Rev 7.4 that had been presented by the ANSI/APSP-16 Committee. Staff in the Directorate for Epidemiology developed the experimental design described in the report, *Suction Outlet Fitting Assembly Full-Scale Study Statistical Analysis Summary.*

The study tested the effect of proposed changes to the hair and body entrapment procedures in determining flow ratings. Staff tested four factors in the proposed hair entrapment test procedures and one factor in the proposed body entrapment test procedure for their effect on release forces and the related water flow ratings. A change to a higher release force relates to a lower flow rating. Staff tested four suction outlet fitting assemblies ("SOFA") of various sizes and shapes. In addition to the designed study, staff made other observations concerning the APSP-16 test procedures.

Hair procedure results indicate that the proposed approach time for test hair to arrive at the SOFA was at least as protective and had at least the same release force or higher than the current standard. Changes to pull method, approach method, and target position did not prove to be as protective in this study. The proposed target position language for the channel SOFAs was at least as protective. Body entrapment results indicate that changing the sizes of the body-blocking test device had mixed results, indicating that the release force was higher for one SOFA and lower for another. Apart from the study, additional hair and body entrapment tests are described concerning hair maintenance and foam qualities, respectively.

Based on experimental results that demonstrate whether a proposed change in requirements is as protective as the current standard requirements:

1. Allow the proposed paragraph 4 (paragraph 7 in the staff-proposed standard) change of approach time to 30 seconds.
2. Do not allow the proposed paragraph 4 (paragraph 7 in the staff-proposed standard) change of language describing targets for hair tests.
3. Do not allow the proposed Section 4 (paragraph 7 in the staff-proposed standard) change of language describing approach methods in hair tests.
4. Allow the proposed paragraph 4.2.7.3 (paragraph 7.2.25 in the staff-proposed standard) addition that describes testing at specific ports in channel SOFAs.
5. Do not allow the proposed paragraph 4 (paragraph 7 in the staff-proposed standard) change of pull method to a constant force using weight.
6. Do not allow the proposed paragraph 5 (paragraph 8 in the staff-proposed standard)change to add an additional body-block element and changes to allowable removal forces.

Other recommendations:

7. Consider the effect of hair conditioners on release times in paragraph 4 (paragraph 7 in the staff-proposed standard) tests.
8. Consider how the properties and sizes of body-block elements represent human torsos in entrapments on suction outlet fittings.

9. Consider requirements that support the identification and verification of target positions and approach methods that produce "worst-case" conditions in testing at the final flow rating for representative SOFAs.

INTRODUCTION

The Virginia Graeme Baker Pool and Spa Safety Act ("VGB Act") requires that suction outlet fitting assemblies ("SOFAs") comply with the Association of Pool and Spa Professionals' APSP-16 2011 Standard, *Suction Fittings for Use in Swimming Pools, Wading Pools, Spas, and Hot Tubs*, or its successor standard. The APSP-16 Committee proposed a revision designated as APSP-16 version 7.4. In that revision, the entrapment rating methods in sections 4 and 5 were modified. Those sections address hair and body entrapments, respectively, and through the included test procedures, form the bases to assign a safe flow rating that is stamped on the cover to the SOFA. CPSC staff is tasked with determining whether the revisions to the entrapment tests in the proposed successor standard maintain the same level of safety as the APSP-16 2011 standard.

Revisions to APSP-16 version 7.4 ("proposed standard") affect the test methods and how test results affect flow ratings. The major revisions can be summarized as: (1) a change in how test hair is pulled and how release force is measured; and (2) the addition of a second body-blocking element test and accompanied changes to the entrapment force criteria. These revisions have substantive effects on the hair and body-block tests and require assessments that include comparison tests with the current standard.

In a planning meeting in February 2012, the APSP-16 task group and CPSC staff decided that the assessment of the proposed standard was to begin with a small pilot study to develop the methods that would subsequently be used in a round-robin type study. Four commercially operated test laboratories,[7] plus the CPSC National Product Testing and Evaluation Center ("NPTEC"), agreed to participate. The task group approved a list of representative SOFAs to be tested. CPSC staff would assist by developing experimental test plans and participating in the testing. During the planning phase, all APSP-16 task group member laboratories withdrew from participation in the studies due to the economic cost. There was no business case for them to participate, since after paying the cost of performing the testing, any lab could subsequently take advantage of the work that they had done and do so without compensation. The APSP-16 task group, set up to assess the proposed APSP-16 standard, was disbanded in June 2012. Staff from the Directorate for Epidemiology and the Directorate for Laboratory Sciences continued preparations for experimental and test system design. In April 2013, testing to compare the APSP-16 2011 standard with the APSP-16 member-approved proposed standard began at NPTEC. Pilot-study testing with one SOFA and the full-study testing with four SOFAs was completed in October 2013. The test results, evaluations, and conclusions presented in this report are based on CPSC staff's study and do not include comparisons to other laboratories' test methods, results, or interpretations. Because only a single laboratory performed the tests, the results are less statistically robust.

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[7] The four test laboratories are: National Sanitation Foundation, Underwriters Laboratory, International Association of Plumbing and Mechanical Officials, QAI Laboratories.

(0) Aquastar CDFL. “Channel-flat”; (1) Hayward 1048E. “Round-8”; (2) Waterway 640-349. “Spa”; (3) Waterway 640-1300V. “Channel-dome”

STANDARDS: ENTRAPMENT TEST PROCEDURES

Design considerations for the water circulation system guide the selection of a suction outlet fitting assembly. The SOFA flow rating is an important consideration for a safe suction source and for compliance with the VGB Act. SOFAs are required to be labelled with a flow rating, which must be certified through testing to the APSP-16 2011 flow rating procedures.

Flow ratings are determined through entrapment testing with two geometries of human hair, and a human torso model, through the procedures in APSP-16 sections 4 and 5, respectively. A flow rating represents the highest flow rate that can pass through the SOFA cover and not exceed the forces that can entrap hair or the body torso, as defined in APSP-16.

Each entrapment test procedure results in a flow rating for that test. The allowable flow rating is the lowest of the two flow ratings determined by the hair and body tests. There are two hair entrapment tests and a single body entrapment test in APSP-16 2011. The proposed standard revised those test methods, including a new hair test method and the addition of a second body block test.

SECTION 4 HAIR ENTRAPMENT TEST METHODS

Hair becomes entrapped after water draws in a sufficient length of hair to become entangled with the cover, entrained in the water flow, or blocked into the exit pipe. CPSC staff believes that a general focus on hair entrapment would be to test the greatest interactions between the hair and a SOFA.

Once entrapped, removal of the hair depends on the bather’s behavior. At extremes, a bather might pull the hair slowly until released, or a bather might pull suddenly. Staff believes that the test procedures should model the most likely behaviors and assume a reasonable limit to the force to free the hair.

Integration of these variables requires flexible test procedures. APSP-16 2011 requires a “sweeping” motion when advancing the hair toward the SOFA. This is somewhat prescriptive language. A sweeping motion may not be what entraps hair in a particular SOFA. The proposed standard has broadened the language describing the hair test method, including the requirement to establish the worst-case hair entrapment. Proposed language encourages experimentation with the hair around all entry points of the SOFA. The proposed standard also shortens the time to advance the hair to the SOFA.

Test procedures to remove the hair include: time held on the SOFA, time spent free on the SOFA, and method of pulling to free the hair. The APSP-16 pull method requires a constant speed of 5 in/sec, but does not describe the acceleration from rest to that speed. Various test methods accelerate the hair differently, and therefore, introduce varying forces. This also can mean different

(0) Aquastar CDFL. “Channel-flat”; (1) Hayward 1048E. “Round-8”; (2) Waterway 640-349. “Spa”; (3) Waterway 640-1300V. “Channel-dome”

interpretations in accounting for all of the removal forces seen in the collected data. For example, a short, sharp peak force might be averaged or might be recognized as the release force.

The proposed standard has changed the removal method, requiring instead, a constant pull from a 5-pound weight. In addressing the impulse force, the proposed pull on the hair is imparted by “carefully releasing” the weight.

A comparison of the (current) APSP-16 2011 and proposed standard hair test requirements is shown in Figure 1 and the accompanying descriptions. The time to move the hair to the SOFA has been shortened from 60 to 30 seconds. Note that this affords less time to position the hair, but also less time for the hair to become entangled with itself. The description of the sweeping motion toward the SOFA was expanded to include the goal of experimenting and finding the worst-case entrapment motion and location, or target. Additionally, the hair pull method was changed from collecting force data during a constant-speed pull to a pass/fail constant force method using a falling weight and pulley system. In the CPSC experimental design study, approach time, approach method, SOFA targeting, and pull method were made factors. For reasons to be discussed, the 5-pound weight requirements were met, but were modified to suit the experimental study and retain the intent of the proposed method.

(0) Aquastar CDFL. “Channel-flat”; (1) Hayward 1048E. “Round-8”; (2) Waterway 640-349. “Spa”; (3) Waterway 640-1300V. “Channel-dome”

Figure 1. Summary of Hair Test Procedures

APSP-16 2011: Constant Velocity

-Shampoo hair-

1. Set a flow rate through the SOFA.
2. Brush hair.
3. Move hair to SOFA in 60 sec.
4. Feed hair in direction of intake flow.
5. Sweep hair side to side.
6. Hold on SOFA for 30 sec.
7. Free hair and remain an additional 30 sec.
8. Engage mechanism and pull hair upwards at a rate of 5 in/s.
9. Measure the force to remove the hair.
10. Conduct the test 10 times.
11. If in the 10 trials, a test force exceeds 5 lbf, repeat with 10 more trials.
12. In all trials, if no more than one test exceeds 5 lbf, flow rate may be increased.
13. Continue until no higher flow rate is achievable.

-Shampoo hair after 10 repeat tests-

Proposed Standard: Constant Force

-Shampoo hair-

1. Set a flow rate through the SOFA.
2. Brush hair.
3. Move hair to SOFA in **30 sec.**
4. Feed hair in direction of intake flow.
5. Sweep hair side to side.
   -Probe and find worst case with various movement magnitudes, motions, and locations on SOFA
   -Probe channel SOFAs at each pipe
6. Hold on SOFA for 30 sec.
7. Free hair and remain an additional 30 sec.
8. **Carefully release the weight to impart a 5 lbf pull on the hair.**
9. **Note whether the hair released.**
10. Conduct the test 10 times.
11. If in the 10 trials, **the hair does not release**, repeat with 10 more trials.
12. In all trials, if in no more than one test **the hair does not release**, flow rate may be increased.
13. Continue until no higher flow rate is achievable.

-Shampoo hair after 10 repeat tests-

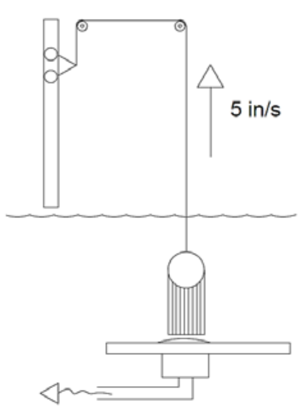

Figure 1a. Constant Velocity Test

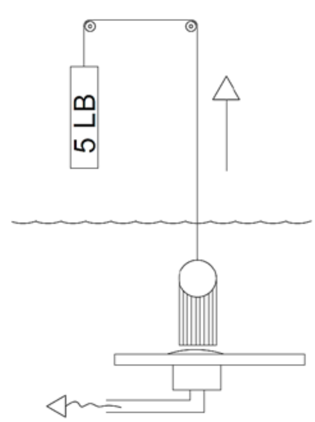

Figure 1b. Constant Force Test

Schematics represent both Full Head and Ponytail Tests

(0) Aquastar CDFL. "Channel-flat"; (1) Hayward 1048E. "Round-8"; (2) Waterway 640-349. "Spa"; (3) Waterway 640-1300V. "Channel-dome"

SECTION 5 BODY ENTRAPMENT TEST METHODS

Human body entrapments occur when the suction pressure from the SOFA creates a force that exceeds the ability of the bather to push away. The pump and water flow induce significant suction pressure over a short distance from the SOFA. Partial blockage creates a force induced by the water flow. Complete blockage of the cover openings stops the moving water mass, creating a maximum entrapment force on the body. The water pump can maintain continued entrapment, whether partial or complete.

SOFA blockage extent varies with human body size. Human body sizes can be roughly correlated with age, and so also with strength. A small SOFA can be blocked by a small child. The entrapment forces should ideally be limited to that typical child's strength or ability. In testing, a model torso can be sized to block, in the worst case, the entire SOFA, up to the largest human body size.

In APSP-16 2011 and the proposed standard, a correlation of SOFA size and human strength appears in Table 1(APSP-16) Applicable Body Block Element – Calculation of Removal Forces. The tabulation of applicable torso sizes is set opposite maximum removal effort.[8] The term "applicable" indicates that dimensions that compare to, or just shadow, the SOFA size are applied in APSP-16 Table 1 to set the upper limit for the removal force. The forces are the test criteria for the body-block element ("BBE") tests. For example, the smallest applicable body-blocking element in comparison to a 9-inch diameter SOFA has 9-inch x 11.5-inch dimensions, and a removal criterion of 15 lbf. The largest torso in APSP-16 Table 1, the 18-inch x 23-inch size, compares to an 18-inch diameter SOFA and has a removal criterion of 120 lbf. The 18-inch x 23-inch size represents the torso of a 95th percentile male.

Separate, although related requirements, determine the dimensions of the physical BBE test foam fixtures. A single 18-inch x 23-inch BBE is used in APSP-16 2011, and removal forces vary from 15 lbf to 120 lbf by SOFA size. The proposed standard retains the original 18-inch x 23-inch BBE, but modifies the removal force upward to 120 lbf for all SOFAs. In addition, the proposed standard introduces a second test using a second BBE. The second BBE has dimensions and removal forces that depend on the SOFA size. Those second BBE dimensions are set to the torso size in APSP-16 Table 1, which is wider than the SOFA by 2 inches. These two proposed formulations for removal forces are both greater than the current removal forces, except for very large SOFA sizes.

In both standards, testing with the BBE is used to determine the highest flow rate through a SOFA that does not exceed the force criterion that applies. The proposed standard uses the lesser flow rate from the two tests of the different BBE sizes.

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[8] The formula used in APSP-16 2011 Table 1 is removal force F= $\left(\frac{width}{9}\right)^3 * 15$, where width is the applicable element dimension.

(0) Aquastar CDFL. "Channel-flat"; (1) Hayward 1048E. "Round-8"; (2) Waterway 640-349. "Spa"; (3) Waterway 640-1300V. "Channel-dome"

Figure 2 summarizes the two standards' procedures and provides an example. The current standard sets a maximum 15 lbf removal force using the 18-inch x 23-inch in BBE on a 9-inch diameter SOFA. The proposed standard allows the lesser of two tests: a 120 lbf removal force using the 18-inch x 23-inch BBE or a 45 lbf removal force of a 13-inch x 16.6-inch BBE for a 9-inch diameter SOFA.

Figure 2. Summary of BBE Test Procedures using Example Size
Schematics Represent Tests for a Generic 9-inch Diameter SOFA

APSP-16 2011

1. Set a flow rate through the SOFA.
2. Align the 18x23 BBE above the SOFA such that the greatest area is blocked.
3. Push the BBE down on the SOFA with 120 lbf.
4. Remove the 120 lbf and measure the force to pull the BBE off the SOFA.
5. Conduct the test 3 times.
6. No test force may exceed the value in Table 1 for the SOFA size. *In this example of a 9-inch diameter SOFA, the force is 15 lbf.*
7. If no test exceeds the force, increase the flow rate and repeat the sequence.
8. Continue until no higher flow rate is achievable.

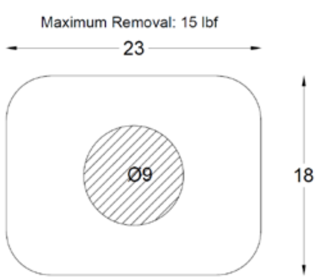


Figure 2a. Current 18 in. x 23 in. BBE Test (Circle represents 9-inch SOFA, while rounded rectangle represents the BBE)

Proposed Standard

1. Set a flow rate through the SOFA.
2. Align the 18x23 BBE above the SOFA such that the greatest area is blocked.
3. Push the BBE down on the SOFA with 120 lbf.
4. Remove the 120 lbf and measure the force to pull the BBE off the SOFA.
5. Conduct the test 3 times.
6. **No measured force may exceed 120 lbf.** *The allowable force is fixed at 120 lbf, regardless of the size of the SOFA.*
7. If no test exceeds the force, increase the flow rate and repeat the sequence.
8. Continue until no higher flow rate is achievable.

****

2nd Test

1. **Repeat the general procedure with the 2-inch overlapping BBE above the SOFA such that the greatest area is blocked.**
2. **Push the BBE down on the SOFA with 120 lbf.**
3. **Remove the 120 lbf and measure the force to pull the BBE off the SOFA.**
4. **Conduct test 3 times.**
5. **No test force may exceed the value in Table 1 for the BBE size.**
   In this example, the force is 45 lbf.

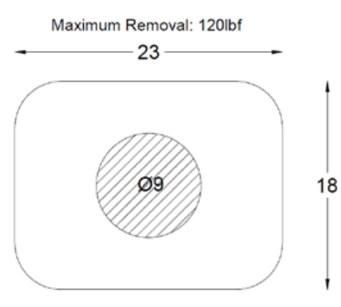


Figure 2b. Proposed 18 in. x 23 in. BBE Test

(0) Aquastar CDFL. "Channel-flat"; (1) Hayward 1048E. "Round-8"; (2) Waterway 640-349. "Spa"; (3) Waterway 640-1300V. "Channel-dome"

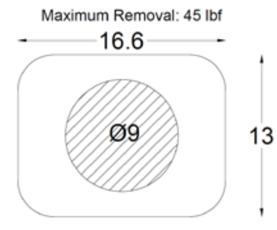


Figure 2c. Proposed 13 in. x 16.6 in. BBE Test

DESIGN OF STUDIES

The goal of these study designs is to inform any CPSC staff recommendations for the proposed APSP-16 standard; specifically, whether the changes to hair and body-block tests provide at least an equivalent level of safety compared to ANSI/APSP-16 2011, the current standard.

A completed pilot study assisted staff in decisions about the test factors and methods applied to the full study. The goal of the full study was to explore whether each change or combination of changes from the current to the proposed standard produced different results. A secondary goal had been to assess inter-laboratory differences, but this was not possible once the other labs withdrew their participation. CPSC staff established a continuously recorded removal force as the response variable for the studies. This differs from the proposed pass/fail criterion for hair tests and was done to provide a common response variable.

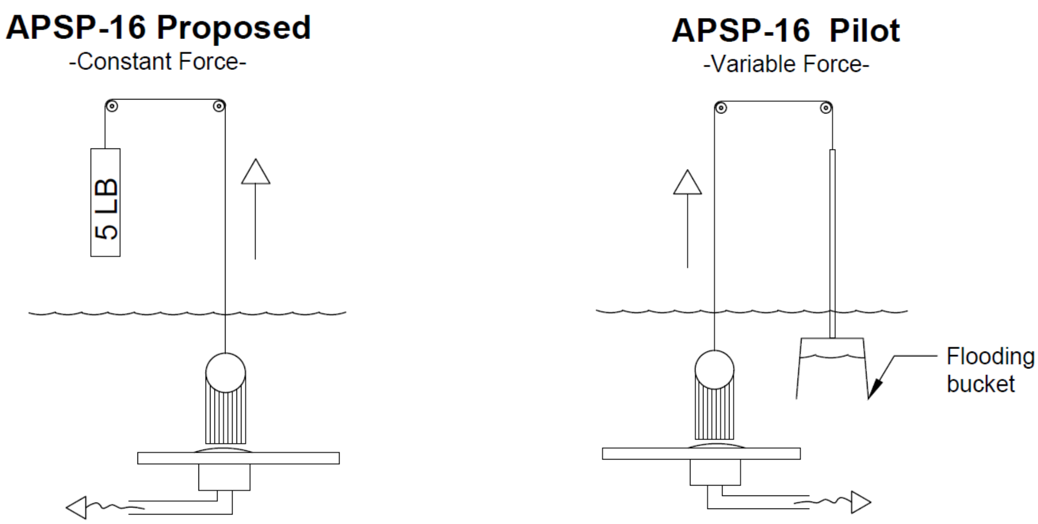
PILOT STUDY

A single 8-inch round SOFA, typical for a backyard pool, was investigated in the pilot study. The goal was to inform the factor selections and designs for the full study and provide experience with the developed test methods and fixtures. Pilot testing followed the CPSC Pilot test plan "Design of Experiments for Suction Outlet Fitting Assembly Pilot Study," developed by staff in the Directorate for Hazard Analysis ("EPHA").

In the hair pilot study, operations technician, hair type fixture, approach time, target position, approach method, and pull method were set as factors. Removal force was the response variable. A total of 350 runs were completed, with 10 trials for each of 35 factor configurations. Since the proposed standard states a 5-pound weight shall be "carefully released," staff developed a "water pull" fixture to approximate a linear mass (weight) increase that imparted the pull force on the hair fixtures. The controlled flow of water into an inverted bucket provided the force increase to the 5 lbf criterion and beyond. CPSC staff developed this method to satisfy both proposed requirements for constant-force and low-impulse release and to provide continuous response data for analysis. Figure 3 shows a schematic of this interim pull method.

(0) Aquastar CDFL. "Channel-flat"; (1) Hayward 1048E. "Round-8"; (2) Waterway 640-349. "Spa"; (3) Waterway 640-1300V. "Channel-dome"

Figure 3. Comparisons of APSP-16 Proposed Hair Test to the CPSC Staff Hair Test for the Pilot Study



Operator and BBE size were chosen as factors in the body block pilot study. The response variable was removal force. A total of 75 runs were completed, with five trials for each of 15 factor configurations.

In brief, data were analyzed to identify the factors and test procedures that have significant effects. A summary of the findings is listed here:

1. Response forces are higher for new hair specimens and differ for the new smaller BBE. Recommend break-in tests: 10 for all new hair specimens; five for new BBE foam.
2. Six trials are sufficient for detecting differences in hair tests. Three trials are sufficient for detecting differences in BBE tests.
3. The water pull method does achieve the gradual application of force up to and beyond the 5 lbf (falling 5-pound weight) requirement - to about 14 lbf, the limitation of the test device. However, test forces above 14 lbf did occur when hair became entangled. That data above 14 lbf would not be collected, making a statistical model from the data incomplete. The pull method developed to satisfy the proposed 5-pound weight method should be improved to allow collection of data at all forces levels.
4. The 5 lbf weight pull method in the proposed APSP-16 standard is not reproduced by a continuous weight accumulation. Staff developed a 5 lbf weight device with additional force, as necessary, to produce force at release for all subsequent runs in the study.
5. The lack of definition for the hair motions creates uncontrolled variation between the operators. CPSC staff recommends that one operator be assigned one type of hair fixture for the study.
6. The vertical drop approach method, introduced to reduce differences between technicians, does not generate a distinct response. CPSC staff recommends eliminating this method.

(0) Aquastar CDFL. "Channel-flat"; (1) Hayward 1048E. "Round-8"; (2) Waterway 640-349. "Spa"; (3) Waterway 640-1300V. "Channel-dome"

(0) Aquastar CDFL. “Channel-flat”; (1) Hayward 1048E. “Round-8”; (2) Waterway 640-349. “Spa”; (3) Waterway 640-1300V. “Channel-dome”

FINAL STUDY DESIGN: SOFA SPECIMENS

The SOFA specimens were chosen to include some varietal shapes, sizes, and types of SOFAs. These four study specimens do not represent a weighted sampling, and are not necessarily representative of market or epidemiological data. These analyses, although valid for the specimens analyzed, may not be applicable to all SOFAs. This specimen limitation underlines the exploratory nature of this first experimental study of APSP-16.

FINAL STUDY DESIGN: HAIR

FACTORS

The requirements that differ between the standards could potentially change the final flow rating for a SOFA. Table 1 shows the factors chosen for the hair studies. The two factor settings are the required values or procedures from each of the two standards. The setting “Other” in Target Position indicates the current standard has non-specific target requirements compared to the proposed “worst case.” “Worst (other)” in Approach Method indicates the proposed standard has an expressed goal to find the worst-case method compared to the current standard’s expressed method to “sweep.” Hair types are treated in the standards as separate tests and are studied independently. Continuous release force is the response variable at the tested flow rate.

Table 1. Experimental Factors - Hair

Hair Type Assembly		***Approach Time, sec***	***Target Position***	***Pull Method***	***Approach Method***	***Force, lbf (Response)***
Full head	C	60	Other	Speed	Sweep	Continuous
	P	30	Worst case	Force	Worst(Other)	
Ponytail	C	60	Other	Speed	Sweep	Continuous
	P	30	Worst case	Force	Worst(Other)	

Current standard (C); Proposed standard (P)

SETTINGS

Not all proposed changes appear to be important factors that impact the release of the hair. Factors that were set not to vary are shown in Table 2. Although an important factor from the pilot study, individual technicians were restricted to a unique hair test to reduce the number of required tests. Staff considered technicians to have too many variables to be adequately described in this study. Buoyancy requirements in the standards were set to the pull method in their respective standards, which had minor differences. Pump and flow differences were set to the proposed requirements for all tests. “Pull impulse” is a CPSC term to describe the rate of change of force on the hair. These forces influence the peak forces that are recorded. Impulse is not defined in the current standard,

(0) Aquastar CDFL. "Channel-flat"; (1) Hayward 1048E. "Round-8"; (2) Waterway 640-349. "Spa"; (3) Waterway 640-1300V. "Channel-dome"

but is tied to laboratory methods. The CPSC laboratory pull method is by chain, driven by an electric gear motor, and impulse varies with load. Impulse is recognized in the proposed standard: the weight is to be "carefully" released. CPSC staff released the weight at a rate of 2.5 in/s using the chain drive, which was chosen arbitrarily because it is half of the current standard's speed.

The current standard compares the continuous release force test data to a criterion force at each flow rate. The proposed standard has observation of release of a weight as the (pass/fail) criterion. The two methods are not compatible in the same study.[9] In these experimental studies, all force data were recorded continuously with a load cell.

Release forces measured in the pilot study indicated that the forces are higher for the initial use of a fresh hair specimen in the fixtures. To reduce the effect of age/usage, 10 break-in tests were performed on each hair specimen. This is not a requirement in either of the standards, but was established to reduce uncontrolled variability and improve statistical analyses.

Table 2. Experimental Settings -Hair

Settings/ Method	***Hair Type Assembly***	***Approach Time***	***Target Position***	***Pull Method***	***Approach Method***
Repetitions	All test configurations had 6 trials				
Technician #1	Full Head				
Technician #2	Ponytail				
Buoyancy(C)				Current	
Buoyancy(P)				Proposed	
Pump Capacity(P)	All tests used proposed pump requirements				
Pump Suction(P)					
Flow Control(P)					
Pull Impulse(C)				n/a	
Pull Impulse (P)				Proposed	
Fresh Hair Specimens	Each SOFA had a Full Head and Ponytail hair fixture. Each hair fixture was tested 10 times prior to study testing.				
Release Measure (C)	All Tests Used the Current Continuous Force Requirement				

Current standard (C); Proposed standard (P).

Pre-test entrapment force test runs were conducted to determine the study water flow rates. Table 3 lists the study flow rates for the hair tests. The differences between the SOFA marked flow rates

[9] Pass/fail studies require significantly more test runs to achieve the same level of statistical confidence as continuous data studies. Continuous data can also be converted into pass/fail data, but not vice versa.

(0) Aquastar CDFL. "Channel-flat"; (1) Hayward 1048E. "Round-8"; (2) Waterway 640-349. "Spa"; (3) Waterway 640-1300V. "Channel-dome"

and these settings reflect the results from pre-test hair entrapments. Pretest goals were to determine flow rates that produce release forces close to the 5 lbf criterion for each hair type and each SOFA. Since SOFA flow ratings tests are independent, different flows are expected.

Table 3. Water Flow Rate Settings in Gallons per Minute (gpm) Used for Hair Studies

SOFA	Marked Rating, gpm	Full Head Flow, gpm	Ponytail Flow, gpm
Spa (2)	120	146	145
8" Round (1)	125	120	85
Domed* Channel (3)	352	458	335
Flat Channel (0)	316	300	226

*The "domed" shaped refers to the rounded top of the channel.

Experiment Design

The technical basis for the experiment design is described in Appendix 1. The CPSC laboratory followed the experimental test matrix of Table 4 in the run order given. This is a notational matrix that indicates the number of factor levels for each factor. Separate full-head and ponytail experiments were conducted using this same design. The design is randomized for the approach time, target position, pull method, and approach method. A "0" represents a level derived from the proposed standard; a "1" from the current standard. SOFA selections were performed in blocks in order to reduce time-consuming change-overs. SOFAs are designated with numerals: (0) flat channel; (1) 8"round; (2) spa; (3) domed channel. Each experimental run was performed with six trials.

(0) Aquastar CDFL. “Channel-flat”; (1) Hayward 1048E. “Round-8”; (2) Waterway 640-349. “Spa”; (3) Waterway 640-1300V. “Channel-dome”

Table 4. Experimental Test Matrix
Proposed: “0”; Current: “1”; SOFAs designated 0-3.

Run	SOFA Specimen	Approach Time	Target Position	Pull Method	Approach Method
1	0	0	1	0	1
2	0	1	0	0	1
3	0	0	0	0	0
4	0	0	0	1	1
5	0	1	1	1	0
6	1	0	0	0	0
7	1	0	0	1	0
8	1	0	0	1	1
9	1	0	1	1	0
10	1	0	1	0	1
11	1	1	1	1	1
12	1	1	0	1	0
13	1	1	1	0	1
14	1	1	1	0	0
15	1	1	0	0	1
16	2	1	1	0	0
17	2	1	0	1	1
18	2	0	0	0	0
19	2	0	1	1	0
20	2	1	1	1	1
21	3	0	0	1	0
22	3	1	0	1	1
23	3	0	0	0	1
24	3	0	1	1	1
25	3	0	1	0	0
26	3	1	1	0	1
27	3	1	1	1	1
28	3	1	1	1	0
29	3	1	0	1	0
30	3	1	0	0	0
31	2	1	1	1	0
32	2	0	0	1	1
33	2	0	1	0	1
34	2	1	0	1	0
35	2	1	0	0	1

(0) Aquastar CDFL. “Channel-flat”; (1) Hayward 1048E. “Round-8”; (2) Waterway 640-349. “Spa”; (3) Waterway 640-1300V. “Channel-dome”

FINAL STUDY: BODY BLOCK

FACTOR

The proposed standard made one substantive change: the addition of a second body block element (“BBE”) test. BBE size was made a factor in the study. BBE1 was designated as the proposed BBE size. BBE2 was designated as the current 18-inch x 23-inch BBE, which is the same in the proposed standard. Release force is the response variable, as release of the body block drives the flow rating calculations. Release force is measured as a continuous variable. BBE sizes and flow rates are shown in Table 5.

Table 5. Experimental Factor – Body Block

SOFA	***Standard***	***BBE Dimensions, in.***	***Test Flow Rate, gpm***
Spa (2)	Current	18 x 23	138
	Proposed	9 x 11	138
Round-8 (1)	Current	18 x 23	165
	Proposed	11.5 x 14.7	165
Flat Channel (0)	Current	18 x 23	242
Dome Channel (3)	Proposed	18 x 23	458

Since proposed BBE sizes increase with SOFA size, each SOFA determines the size of the BBE. However, proposed BBE sizes may not exceed the 18-inch x 23-inch BBE. Therefore, no second BBE was tested with the long channel SOFAs.

SETTINGS

Other than BBE size, the proposed standard made no other substantive changes in requirements or test procedures, other than those described in Table 2. Following the pilot study recommendation, each proposed body block BBE1 (proposed smaller BBE) was pretested five times. BBE2 received no pretests, as no age/usage effect had been recognized. All BBE test had three trials.

EXPERIMENT DESIGN

The technical basis for the experiment design is described in Appendix 1. The CPSC laboratory followed the experimental test matrix of Table 6 in the run order given. The design is randomized for BBE size. SOFA selections were performed in blocks to in order to reduce time-consuming change-overs. SOFAs are designated with numerals: (0) flat channel; (1) 8”round; (2) spa; (3) domed channel.

(0) Aquastar CDFL. "Channel-flat"; (1) Hayward 1048E. "Round-8"; (2) Waterway 640-349. "Spa"; (3) Waterway 640-1300V. "Channel-dome"

Table 6. Experimental Test Matrix—Body Block

Proposed BBE: "0"; Current BBE: "1"; SOFAs designated 0-3.

Run	SOFA Specimen	BBE
1	0	1
2	0	1
3	1	0
4	1	1
5	1	1
6	1	0
7	2	0
8	2	1
9	2	0
10	2	1
11	3	1
12	3	1

SOFA Specimens and Factor Descriptions

SOFA sizes, ratings, areas targeted in hair studies, and BBE sizes are listed in Table 7. Additional details for hair targets and BBE placements are shown in Figure 4. Note that the Spa hair targets are not differentiated due to the small size of the SOFA. The "second SOFA" shown in Figure 8(a) is tested in isolation in the BBE study, and two Spa SOFAs are used for the hair tests, as required by APSP-16 procedures.

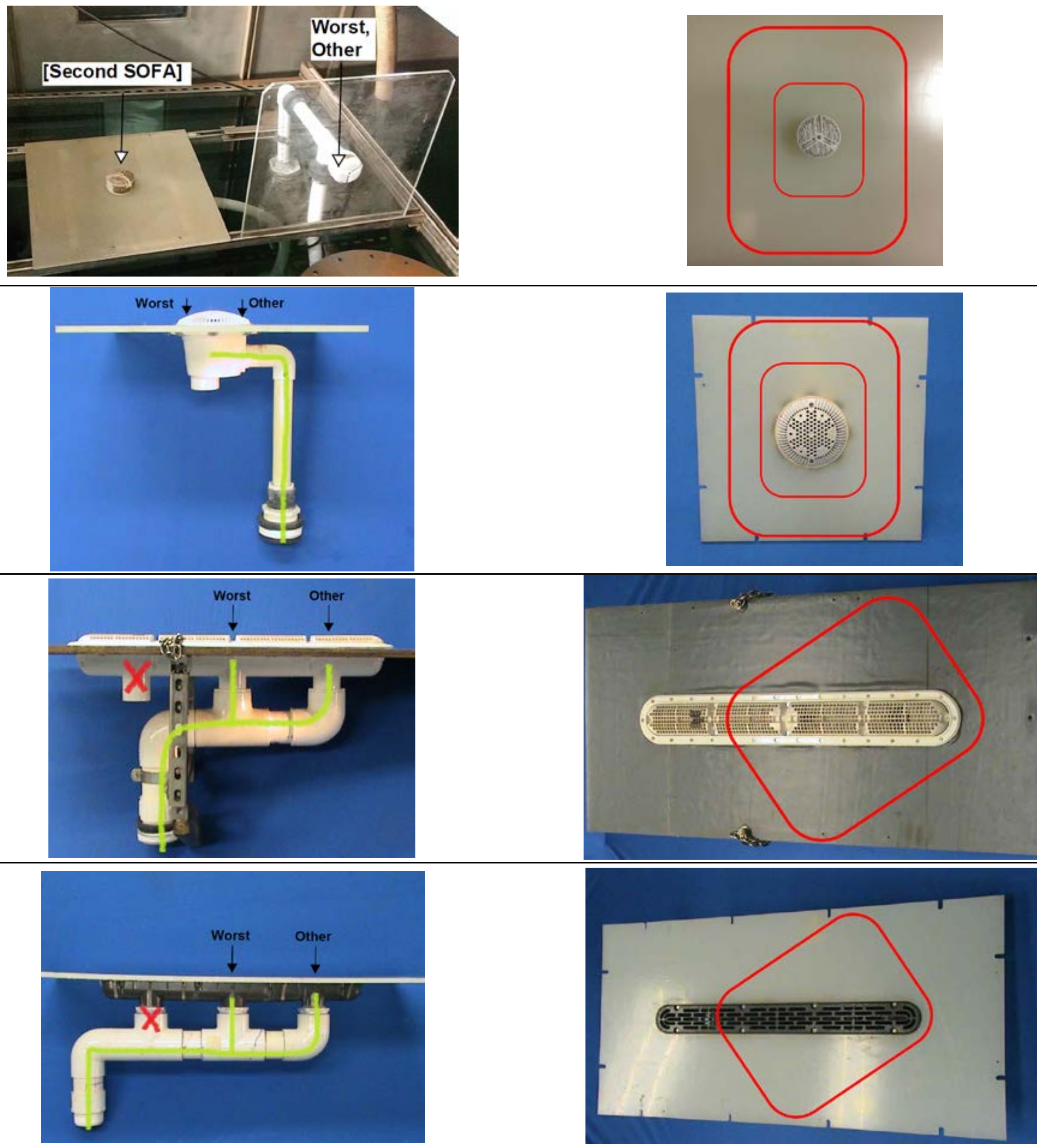
Table 7. SOFA Dimensions, Hair Targets and BBE Sizes

		SOFA			Hair Test Targets		BBE Test Sizes, inches	
SOFA	**Fig. 4**	**Rating, gpm**	**Dimensions (Length x width or diameter Ø), in**	**Height, in**	**Worst**	**Other**	**BBE1**	**BBE2**
Spa (2)	a	120	Ø3.6	2.0	Center	Center	9 x 11.5	18 x 23
8" Round (1)	b	125	Ø7.5	1.38	Opposed Port	Over Port	11.5 x 14.7	18 x 23
Dome Channel (3)	c	352	32 x 4	1.38	Center Port	Far Port	n/a	18 x 23
Flat Channel (0)	d	316	32 x 4	0.0	Center Port	Far Port	n/a	18 x 23

(0) Aquastar CDFL. "Channel-flat"; (1) Hayward 1048E. "Round-8"; (2) Waterway 640-349. "Spa"; (3) Waterway 640-1300V. "Channel-dome"

Figure 4. Hair Targets and BBE Placements on SOFAs

Side View—Hair Targets	Top View—BBE Placements



The 'X' indicates the port is plugged.

The manual approach methods used during the study to feed the hair into the SOFAs are shown schematically in Figure 5. Each technician developed methods to feed hair into each SOFA for his assigned hair type. All hair tests begin with the ends of hair 2 inches above the horizontal SOFA or away from the vertical Spa SOFA. The movements described are of the head form fixture. The hair

(0) Aquastar CDFL. “Channel-flat”; (1) Hayward 1048E. “Round-8”; (2) Waterway 640-349. “Spa”; (3) Waterway 640-1300V. “Channel-dome”

ends move in response to or (generally) opposite these motions, until the SOFA suction predominates and draws in the hair.

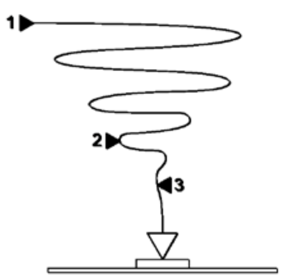
Floor Sweep (Current). This is the current sweep method. Hair is moved from side to side over the SOFA as the hair is dropped down during the approach time period. Each sweep is reduced until the hair is held at rest on the SOFA target position. Both technicians used approximately the same sweep motion as described in the standards.

The proposed standard retains this floor sweep description and adds additional requirements to experiment with other movements, such as “billowing.” CPSC laboratory staff employed alternate approach techniques in keeping with the proposed requirements. The intent was to distribute hair and adjust timing of dispersal to maximize hair entry into SOFA openings.

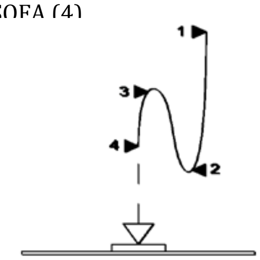
Figure 5. Approach Method Schematics

Key	Full Head	Ponytail
Spa (2)	c	c
8” Round(1)	e	d
Dome Channel(3)	b	e
Flat Channel(0)	b	e

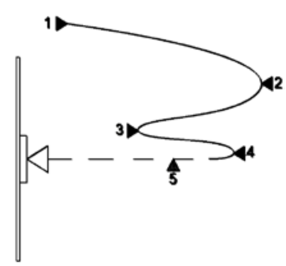
a. Floor Sweep (Current)
Sweep wide (1), diminish each turn (2), feed into SOFA (3) at constant rate



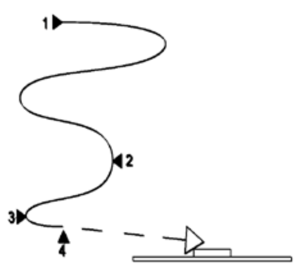
b. Billow and Feed
Drop suddenly (1), reverse (2), allow outward billowing (3), feed into SOFA (4)



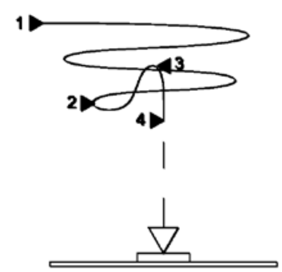
c. Straighten, Feed – Wall
Move away (1), reverse (2) and pull hair towards (3) and away (4), feed into SOFA (5).



d. Straighten, Feed from Side
Sweep (1) to distribute (2), move away (3) and slowly feed into SOFA edge openings (4).



e. Straighten, Feed – Floor
Sweep (1) to distribute (2), move away (3) and slowly feed into SOFA edge openings (4).

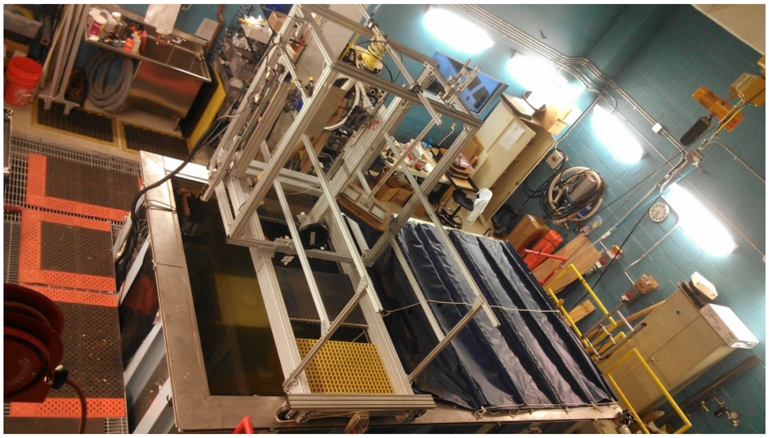


(0) Aquastar CDFL. "Channel-flat"; (1) Hayward 1048E. "Round-8"; (2) Waterway 640-349. "Spa"; (3) Waterway 640-1300V. "Channel-dome"

TEST FACILITY

SOFA testing at NPTEC is performed in a dedicated facility that includes a water tank, test fixtures, data collection systems, and several pumps that cover a wide range of test flows. Figure 6 shows a view of the facility. A carriage that tracks along the top edge of the tank holds the test fixtures for the body block and hair tests. Test SOFAs are installed on a framework inside the tank. The carriage is aligned over the targeted area of the SOFA for each test.

Figure 6. Overall View of CPSC Pool/Spa Test Facility

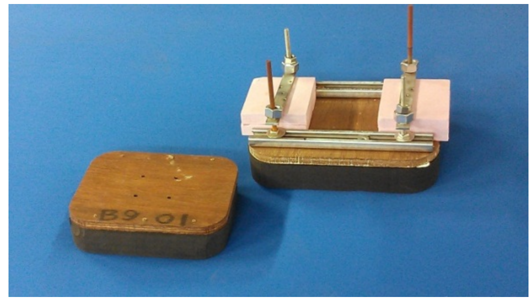


In body-block element entrapment tests, a pole travels vertically through a guide and delivers the BBE to the SOFA. The pole is driven by a pneumatic cylinder capable of delivering a 120 lbf force in both down and up (removal) directions. Removal forces are recorded using a load cell. The BBE is allowed to conform passively on the SOFA using a pivoting mechanism. The test sequence is automated. Each BBE is constructed with closed-cell foam beneath a plywood backing, according to APSP-16 2011 Table 1. APSP-16 2011 and the proposed standard required different BBE sizes. Those used in these studies are shown in Figure 7.

(0) Aquastar CDFL. “Channel-flat”; (1) Hayward 1048E. “Round-8”; (2) Waterway 640-349. “Spa”; (3) Waterway 640-1300V. “Channel-dome”

Figure 7. Body Block Element Sizes Used in Study

a. 18 in x 23 in BBE Mounted and Ballasted. Each SOFA had Similar



b. 9 in x 11.5 in BBE (Spa SOFA) and 11.5 in x 14.7 in BBE (8-in Round)

Hair entrapment tests are conducted using the two hair fixtures shown in Figure 8. The hair fixture is held and lowered by a gripping arm that releases on command. When released, the hair fixture is pulled up by a cable, while an inline load cell measures force. In each hair study, the study factors are either manually applied using a fixture arm, *e.g.* sweep, or are controlled by an automated system, *e.g.* release timing. Approach Method and Target are manually controlled by each test technician. Approach Time and Pull Method are regulated by the data acquisition and control system. When the resistance exceeds the 5 lbm weight in the proposed constant-force pull method, manual release of hair by the technician may be required.

Figure 8. Full Head and Ponytail Fixtures

The sequence shown in Figure 9 describes the movements during a generic hair test. The schematic captures the phases of movement and timing and indicates the relations of the four factors during a

(0) Aquastar CDFL. "Channel-flat"; (1) Hayward 1048E. "Round-8"; (2) Waterway 640-349. "Spa"; (3) Waterway 640-1300V. "Channel-dome"

test. The factors (red) show parenthetically, the current and proposed standard settings, respectively. Each test is started with the 16-inch hair 2 inches above the SOFA. Vertical spa tests have different start offsets to keep the hair free prior to testing.

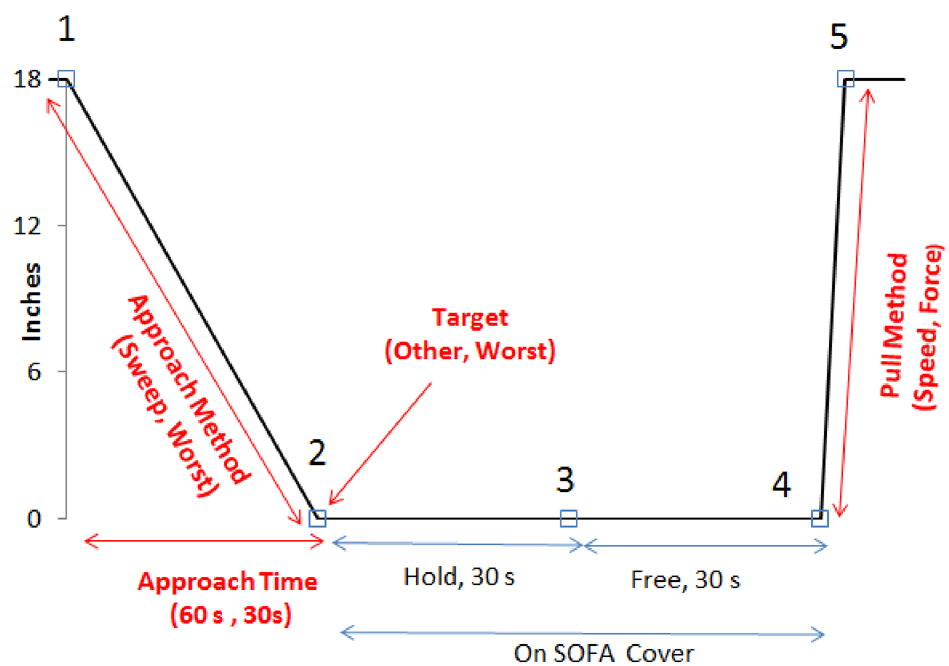
Sequence 1 to 2. Start test, and manually move hair using approach method to the target position on the SOFA as the hair fixture descends over a controlled approach time period.

Sequence 2 to 3. Hair fixture is held and touching SOFA for 30 sec for all tests.

Sequence 3 to 4. Hair fixture is freed from gripper and allowed to float free for 30 sec for all tests.

Sequence 4 to 5. Pull method is engaged and hair fixture is pulled away from SOFA. If hair does not release from SOFA, technician pulls slowly and releases hair fixture. Record force and determine the release force as the maximum value during the pull.

Figure 9. Hair Test Timing Sequence Showing Four Study Factors



STUDY RESULTS

Results from the experimental design studies for full head, ponytail, and body-block tests are presented as the effects on removal force in changing from a current standard parameter or factor to the proposed standard parameter or factor, or selected interactions in factor changes. The SOFA Final Study Analytical Summary ("Final Study") estimates the probability that the changes in removal forces experienced are real, and not due to random error. The metrics in the analyses are the estimated contributions from changing factor settings on the removal force (Least Squares Mean), the calculation of probability, and a statement of confidence based on probability.

The Least Square Means (LS Means) are calculated by isolating each factor or interaction so that the effect of change can be estimated for that factor or interaction. Least Square Means is not a prediction of overall release force. The p-value estimates the probability that a change in force is due to random chance. P-values at or below 0.05 are considered to indicate that a change in force is not due to chance but is an effect caused by the change in the factor between current and proposed values or settings. P-values in the range $0.05 < p \leq 0.10$ are considered to identify "marginal" evidence that the change in the factor is associated with the removal force. A p-value exceeding 0.10 indicates that there is insufficient evidence to conclude that the change in force is due to the change in factor settings and may be due to chance.

The final evaluation of the effects that the current and proposed values in each factor have in the experiment helps to address whether a change to the proposed standard is at least as protective as the current standard. For that purpose, the statistical significance of results from the experimental study, combined with further discussions, will be directed to recommendations on proposed changes to APSP-16 2011, or to further study.

From the SOFA Final Study Analytical Summary, a proposed change that maintains or increases the removal force over the current standard, and is statistically significant, is considered more protective in this SOFA sampling. An increase in removal force tends to reduce the rated water flow, as explained in the Standards section. The statistical evaluations are summarized in the following tables. Where statistically significant evidence is present, the standard the evidence supports will be listed. Where statistically significant evidence is lacking, the change in the factor from one standard to the other will be listed as "not significant." A marginal result will be listed for a marginal p-value as explained previously. A "mixed" result indicates inconsistent results between, for example, factor interactions. Mixed results cannot support a statement that a factor or interaction is more protective.

Although SOFA is used as a factor with four SOFA models, an evaluation of the factor itself is not relevant because the SOFA effect is dominated by the different flows, as well as SOFA characteristics. The study factors and interactions of factors with the SOFAs are of most interest, as well as the other interactions. For brevity, the term "favor" is used in the following discussion to indicate that statistically significant experimental results "point to" one standard, where the effect of the setting is to make one standard more protective.

Ponytail Study Results

Table 8 summarizes data and evaluations from the SOFA Final Study Analytical Summary for the ponytail tests. Each SOFA and each factor are listed as row and column headings. The diagonal boxes are the evaluation for the factor alone, with no interactions. For the SOFAs, the values are LS Mean removal forces. Other boxes show the interactions between two factors. An "(M)" designates marginal.

Approach time (60 sec current, 30 sec proposed) had mixed effect. The time spent maneuvering the hair into position had mixed effect, depending on the SOFA. The interaction between Approach time and the 8" round SOFA, or (Approach time)*(8" round), favored the proposed standard (30 sec). Neither (approach time)*(domed channel) or (approach time)*(spa) had significant effect. (Approach time)*(flat channel) marginally favored the current standard (60 sec). The approach time factor, accounting for all other factors and interactions, favored the proposed standard.

Target position (other, worst case) favored the proposed standard (worst case), but no significant effects were found in interactions with any individual SOFA.

The pull method (speed, force) factor was not significant when considering all the other factors. However, there were mixed effects with individual SOFAs.

The approach method (sweep, worst) factor was not significant when considering all the other factors. There were mixed effects with the individual SOFAs and in the interaction with the pull method factor.

Table 8. Summary of Significance of Factors and Interactions in Ponytail Study
Values are LS Means, lbf

	Flat Channel	8" Round	Dome Channel	Spa	Approach Time	Target Position	Pull Method	Approach Method
Flat Channel (0)	2.89				Current (Marginal)	Not Sig.	Proposed	Current
8" Round (1)		0.8			Proposed	Not Sig.	Not Sig.	Not Sig.
Dome Channel (3)			0.7		Not Sig.	Not Sig.	Current (Marginal)	Proposed (Marginal)
Spa (2)				1.81	Not Sig.	Not Sig.	Proposed	Proposed
Approach Time					Proposed	Not Sig.	Not Sig.	Not Sig.
Target Position						Proposed	Not Sig.	Not Sig.
Pull Method							Not Sig.	Proposed(M) Mixed Current(M)
Approach Method								Not Sig.

Not Sig.= not significant.

FULL HEAD STUDY RESULTS

Table 9 summarizes data and evaluations from the SOFA Final Study Analytical Summary for the full head tests. Each SOFA and each factor are listed as row and column headings. The diagonal boxes are the evaluation for the factor alone, with no interactions. For the SOFAs, the values are LS Mean removal forces. Other boxes show the interactions between two factors.

Approach time (60 sec current, 30 sec proposed). The factor for time spent maneuvering the hair into position favored the proposed standard. Proposed time was also favored in two SOFA interactions: (approach time)*(8" round) and (approach time)*(spa). It was not significant for (approach time)*(dome channel) and (approach time)*(flat channel). Overall, the approach time favors the proposed standard.

Target position (other, worst case) was mixed: favoring the current standard in the (target*flat channel) interaction and favoring the proposed standard for (target*8" round). The target factor itself was not significant.

The pull method (speed, force) factor favored the current standard, favored the current standard in two of the four SOFAs: (pull method*8" round) and (pull method*domed channel), and was not significant in the other SOFA interactions. Results were mixed in the (pull method*target) interaction. Overall, the approach method favors the current standard.

The approach method (sweep, worst) factor favored the proposed standard and favored the proposed standard in three of the four SOFA interactions: (approach method*8" round), (approach method*flat channel), and (approach method*spa). Approach method also favored the proposed standard in the (approach method*pull method) interaction. Overall, the approach method favors the proposed standard.

Table 9. Summary of Significance of Factors and Interactions in Full Head Study
Values are LS Means, lbf

	Aquastar 32CDFL	Hayward 1048E	Waterway 640-1300V	Waterway 640-349	Approach Time	Target Position	Pull Method	Approach Method
Flat Channel (0)	3.38				Not Sig.	Current (Mixed)	Not Sig.	Proposed
8" Round (1)		3.45			Proposed	Proposed (Mixed)	Current	Proposed
Dome Channel (3)			1.81		Not Sig.	Not Sig. (Mixed)	Current	Not Sig.
Spa (2)				3.36	Proposed	Not Sig. (Mixed)	Not Sig.	Proposed
Approach Time					Proposed	Not Sig.	Not Sig.	Not Sig.
Target Position						Not Sig.	Current / Not Sig. (Mixed)	Not Sig.
Pull Method							Current	Proposed
Approach Method								Proposed

Not Sig.= not significant.

BODY-BLOCK ELEMENT STUDY RESULTS

Results from the BBE study are shown in Table 10. Due to the lack of a second BBE for the flat and domed channels, no analysis of the BBE size factor was possible for those SOFAs. The (BBE*8" round) interaction marginally favored the current standard size. The (BBE*spa) interaction favored the proposed standard size. The BBE size factor itself was not significant. Overall, the analysis finds a mixed result with BBE size, the one factor in the experiment.

Table 10. Summary of Significance of Factors and Interactions in BBE Study
Values are LS Means, lbf

	Flat Channel	8" Round	Dome Channel	Spa	BBE
Flat Channel (0)	n/a				n/a
8" Round (1)		7.27			Current (Marginal)
Dome Channel (3)			n/a		n/a
Spa (2)				4.22	Proposed
BBE					Not Sig.

Not Sig.= not significant.

Study Test Examples

Example 1: Constant Pull Force

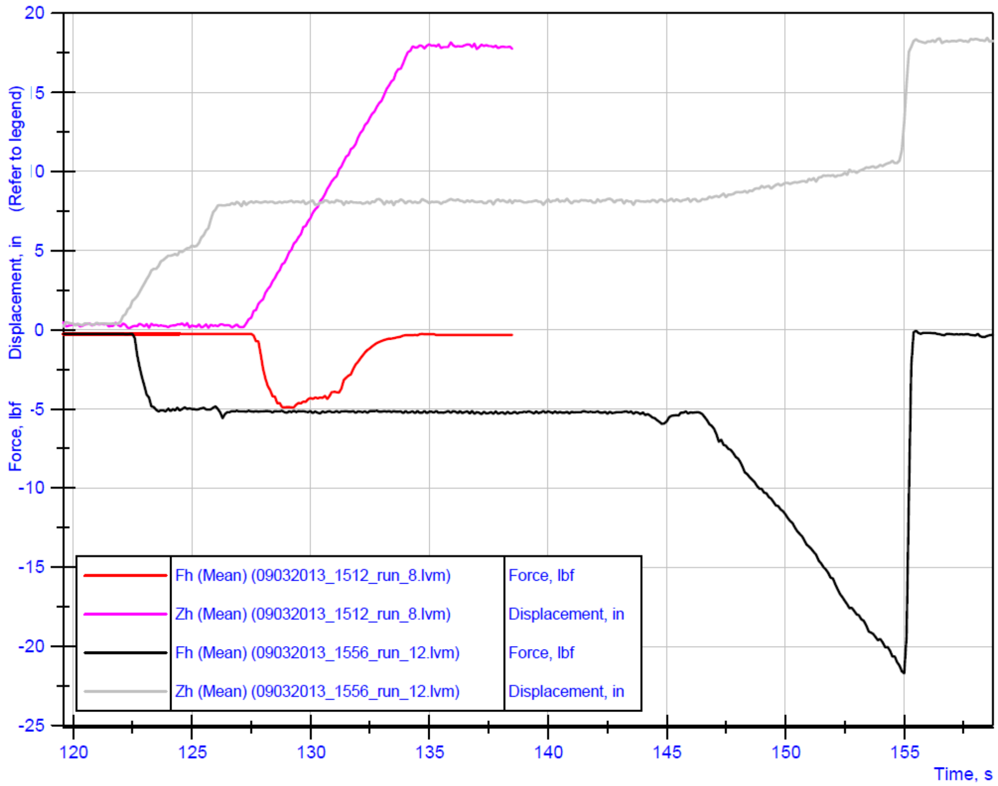
Two trials of the proposed constant-pull method are shown in Figure 10. These trials show the discrepancy between similar trials when release of the falling weight is the criterion. Pink and red are run 8; black and gray run 12. The separation in time of trials in the figure is arbitrary.

In performance of the proposed constant-force method, a net 5 lbm weight is released from a support at 2.5 in/s and pulls the hair fixture up through a pulley system. In trial 8, the falling weight raises the ponytail (pink trace) vertically off the SOFA to 18 inches high, indicating full release of the 16-inch hair. As there was full release, the recorded force (red trace) approached the impressed 5 lbf. In contrast, trial 12 -- same experimental setup -- required manual assistance to release. The trial 12 force (black trace) reached 5 lbf and remained there; only increasing to more than 20 lbf by the technician's pulling the attached cable. Movement during the entrapment (gray trace) indicates hair was entrapped at 8 inches. The technician's pull moved the ponytail from 8 in to 11 in, at which point the remaining 5 inches released suddenly.

This example test demonstrates how separating the 5 lbf and the manual pull in time preserves the proposed pull method while also generating a release force for statistical analysis of all trials.

Nevertheless, note that the 30 sec dwell time is exceeded when a trial is extended. This example also shows that release forces in the same trial series can vary considerably.

Figure 10. Two Trials of Constant Force, Flat Channel SOFA

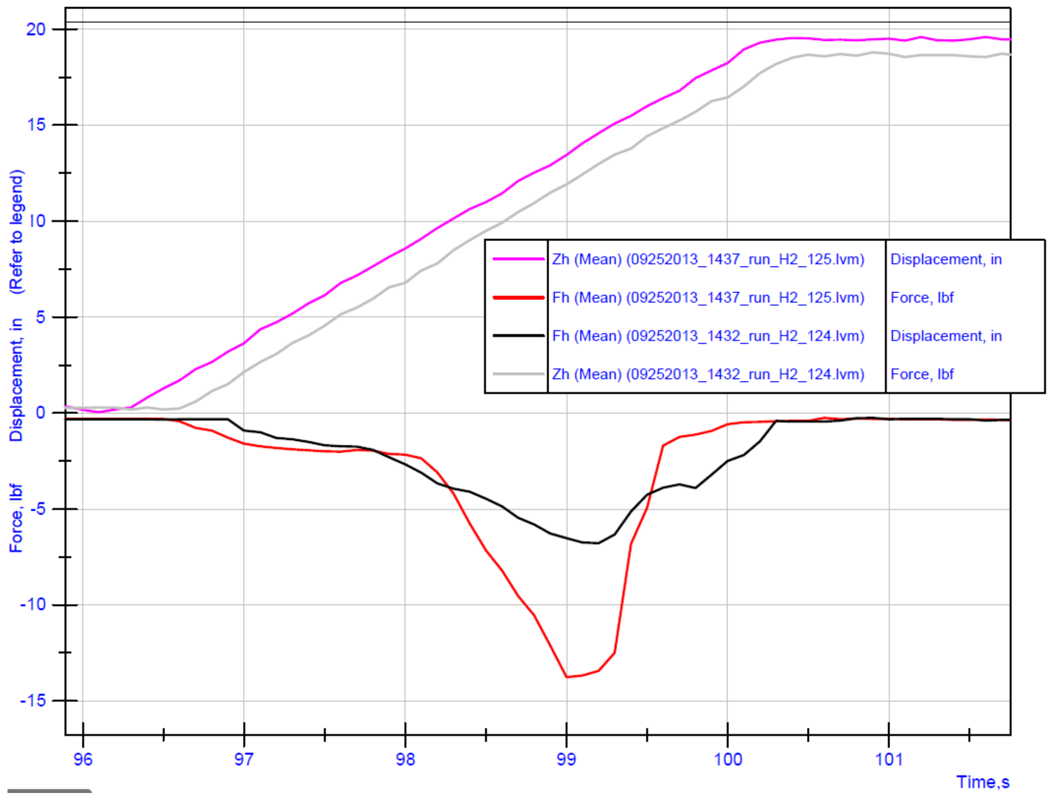


EXAMPLE 2: CONSTANT-PULL SPEED

Two trials of the current constant-speed method are shown in Figure 11. These trials show that constant-speed trials can vary considerably in release force. Pink and red are run 125; black and gray run 124. The separation in time of trials in the figure is arbitrary.

In the APSP-16 2011 hair test method, a constant-pull speed of 5.0 in/sec is required and this speed must be shown to be constant over a range of pull forces (2 lbf to 10 lbf). To achieve this, the NPTEC Pool/Spa Laboratory has a gear motor with sufficient torque to produce the pull forces and achieves necessary pull length by connection to a chain drive. Besides achieving the necessary torque for the requirements, the gear motor has the ultimate capacity to deliver much higher forces compared to the 5 lbf criterion. As a result, all but one trial in both hair studies produced continuous force data through a continuous motion and release of the hair. That one trial produced a result of 52 lbf, which stalled the motor. The hair used for this test had to be manually removed from the SOFA. Figure 11 shows typical APSP-16 2011 constant-speed tests that have the same experimental setup. This comparison demonstrates that the pull speeds (pink and gray traces) remain constant despite the different forces acting (red and black traces). In the constant- pull speed tests, the measured forces can vary significantly, in this example most likely due to hair entanglement.

Figure 11. Two Ponytail Trials at Constant Speed, Domed Channel SOFA



DISCUSSION

CPSC staff conducted these study tests by factor analysis of the current APSP-16 2011 procedures and the proposed procedures in APSP-16 version 7.4. The differences in procedures are the settings for the four factors selected for hair tests and one factor for body block element (BBE) tests in these experimental designs. Experimental design has allowed the specific SOFAs, factors, and two-factor interactions to be isolated for analysis of their effects on the response variable: the entrapment removal force. In APSP-16 procedures, higher flow rates are obtained when the removal forces are below the upper level criteria: 5 lbf for hair tests and 15 lbf to 120 lbf for BBE tests. For a change to be as protective as the current APSP-16 2011, the change should not lower the removal force in the test environment because that change raises the certified water flow rating that may, in turn, increase the entrapment hazard in actual pool installations.

Flow rates were set for each SOFA in each study through preliminary tests to attempt to produce data relevant to the standards' processes in setting flow rates. A separate discussion follows on the low release forces for many BBE tests and includes analysis of additional SOFA tests completed outside the experimental study. In addition, a discussion on hair conditioning addresses wear in the test environment.

The following summaries of study results state whether each proposed change to the water flow rating sections of APSP-16 2011 is as protective as the language in the current standard. Study results that are not significant or that favor a proposed change or factor are considered as protective. Because the BBE rating procedure addresses a different entrapment type, BBE recommendations may stand independent from those from the hair procedures. However, the full head and ponytail hair procedures are from the same section of APSP-16, and recommendations from both studies must favor a proposed change for that change to be considered as protective.

Hair Studies

The results of the two hair studies from Tables 9 and 10 are condensed here in Table 11. Each proposed change, or factor, will be discussed in the context of effects from both hair studies. Effects can be a factor or interactions between factors. In this discussion, the term "partly favors" means an interaction had a different effect, dependent on the level or setting of one of the factors.

Table 11. Significance of Factors in Hair Studies

SOFA	Full Head Study				Ponytail Study			
	Approach Time	Target Position	Pull Method	Approach Method	Approach Time	Target Position	Pull Method	Approach Method
Flat Channel (0)	Not Sig.	Current (Mixed)	Not Sig.	Proposed	Current (Marginal) (Mixed)	Not Sig.	Proposed (Mixed)	Current (Mixed)
8" Round (1)	Proposed	Proposed (Mixed)	Current	Proposed	Proposed (Mixed)	Not Sig.	Not Sig. (Mixed)	Not Sig. (Mixed)
Dome Channel (3)	Not Sig.	Not Sig. (Mixed)	Current	Not Sig.	Not Sig. (Mixed)	Not Sig.	Current (Marginal) (Mixed)	Proposed (Marginal) (Mixed)
Spa (2)	Proposed	Not Sig. (Mixed)	Not Sig.	Proposed	Not Sig. (Mixed)	Not Sig.	Proposed (Mixed)	Proposed (Mixed)
Approach Time	Proposed	Not Sig.	Not Sig.	Not Sig.	Proposed	Not Sig.	Not Sig.	Not Sig.
Target Position		Not Sig.	Current / Not Sig. (Mixed)	Not Sig.		Proposed	Not Sig.	Not Sig.
Pull Method			Current	Proposed			Not Sig.	Proposed(M) / Current(M) (Mixed)
Approach Method				Proposed				Not Sig.

Not Sig.= not significant.

Approach Time favors the current standard (60 sec) in one marginal interaction - approach time* SOFA (0) - in the ponytail Final Study analysis. The remaining results favor the proposed standard (30 sec) or are not significant.

Laboratory staffs' test experiences indicate that most time spent moving hair the full 60 seconds is unnecessary when hair is effectively drawn to target areas within seconds. Too much movement can, in fact, lead to pulling hair out from initial entrapment. By this reasoning and supported by these study results, the proposed change to 30 seconds will be at least as protective as the current standard's 60 seconds.

Target Position favors the current standard (other) in one interaction - target*SOFA (0), and favors the proposed standard (worst) in one interaction –target*SOFA (1), both in the full head Final Study analysis. Target partly favors the current standard in (target position*pull method). All other factors and interaction are not significant. Target Position does not favor the current standard in any ponytail factors or interactions; target factor itself favors the proposed standard. The results are mixed. The results appear to be SOFA-specific. The Final Study analysis does not support a conclusion that one standard is more protective for target position.

Laboratory Sciences ("LS") staff considers that target positioning forms a set of possibilities, of which proposed "worst" is unique, with the current standard's undefined targets, or "other," forming the remaining targets. The descriptive language of "worst" in the proposed standard introduces new target language. To favor the current "other" likely means the "worst" target was not determined by technicians in the break-in or preliminary tests. This may be an issue of uncontrolled variation in how targets were explored.

The proposed standard required experimentation to find the worst targets. These break-ins/preliminaries were always done by LS staff first, coincident with the hair at its freshest state. It may be that the target factor interacted with hair age or usage. That interaction was not part of the study. There is no requirement that this "worst" target be demonstrated, for example: comparing the "worst" target to other candidate targets at the flow rating of the SOFA.

Although the "worst" target is not an ambiguous description, the proposed requirements in finding "worst" for each SOFA range from testing "hydraulically distinct" locations, to testing above specific ports for channel SOFAs. Because ports are always high-velocity regions, these could be more generally described as the starting point.

Because the current standard does not emphasize the target, the proposed language seems to be an improvement. However, finding a maximum condition is not assured and appears to be SOFA-dependent. There are possible test interactions that have not been controlled. The proposed target positioning language lacks assurance that the 'worst' target will have been demonstrated.

Possibly improved target language might identify specific targets for common SOFA shapes, as is done in the proposed Channel Drains section 4.2.7.3. Additionally, a procedure that compares the selected "worst" " target to other targets at the final flow rate may provide a check that the worst target at the final flow has no demonstrated peer.

Approach Method has mixed results in the ponytail study. The current standard (sweep) is favored in one interaction - (approach method* SOFA(0)), and splits between current and proposed in (approach method*pull method). The proposed standard (worst) is favored in one interaction - (approach method* SOFA (2)), and marginally favored in one interaction - (approach method* SOFA (3)). All other factors and interaction are not significant. Approach Method either favors the proposed standard or is not significant in the full head study.

LS staff considers that an approach method is one of a set of possibilities, of which "worst" is unique, with "sweep" being another possibility. Similar to target position, approach method may have uncontrolled interactions with testing staff consistency and hair age or usage. Approach is also determined, through exploratory tests, at a lower flow rate than the final rating. A “worst” approach method can be maximized for each SOFA but, even more so than target position, time constraints and too many variables make establishing a consistent procedure to find the worst case for each SOFA difficult.

Since the current standard does not emphasize the worst case approach, the proposed language is an improvement. However, the Final Study finds mixed results. Any manual procedure to place hair is identified as having many uncontrolled variables. In this study the approach was SOFA-dependent.

LS staff understands the end goal in the approach method is to distribute hair for its final contact with the SOFA cover, and then feeding it in. These operations are distinct and require some practice, including in the transition where continued movement can act in detriment to feeding hair through the cover. The approach method language in 4.2.7 is not required to be, but is known to be done manually by all current laboratories. Even mechanization, although potentially more consistent, would not assure the worst approach was determined and used. A procedure that compares the selected “worst” approach method to other approaches at the final flow rate may provide a check that the worst approach method at the final flow has no demonstrated peer.

Pull Method factor favors the current standard (constant speed) in the full head Final Study analysis, favors the current standard in the interactions (pull method*SOFA (1)) and (pull method*SOFA (3)), and partly favors the current standard in (pull method*target position). Pull Method marginally favors the current standard in the ponytail study interaction (pull method*SOFA (3)), partly favors the current standard in (pull method*approach method), and favors the proposed method in two SOFA interactions. These results indicate that the proposed constant-force procedure cannot be described as more protective than the current constant-speed procedure.

In consideration of the hair entrapment hazard, the current constant-speed pull method has the hair fixture pulling away in one continuous motion, and the resistance due to hair entrapment/entanglement does not generally stop its release. Any recorded force of 5 lbf or greater is defined as stopping the release. In contrast, the proposed constant- force method limits the force applied to 5 lbf. LS staff contends that a difficulty in replacing the current method with the proposed method is in accounting for the dynamic force contribution of the former. The proposed method has much reduced dynamic forces. While this may simplify testing, the pull test is perhaps the most important controllable factor that drives the product rating. Any proposed revision that tends to raise the rating by lowering forces should justify such a significant change by referencing real entrapment scenarios.

The criterion of the proposed pull method is pass/fail, a response that limits comparison studies. These studies required that the proposed method have continuous data to match the current method. Any future studies of a pass/fail criterion will also require altering the method enough to achieve continuous data.

A summary of the analyses of the proposed changes is in Table 12.

Table 12. Analysis That Supports the Proposed Change is as Protective as the Current Standard

	Approach Time	*Target Position*	*Pull Method*	*Approach Method*
SOFA Final Study Analytical Summary	Yes	No, Mixed	No	No, Mixed

OPTIONS FOR TARGET AND APPROACH IN PROPOSED HAIR TESTS

The results from the Final Study indicate the proposed language for target position and approach method do not support a conclusion that the proposed language is as protective as the current language. It is noted that the proposed procedures are not replacing the current language, but are additional clarifications. However, the effect is still to change the test while effectively subordinating the original (current standard) language. "Sweep" is the current approach method, but "worst" trumps "sweep" in the proposed standard.

LS staff is aware that the requirements to find the "worst" cases have the potential to be more protective, as compared to the current standard's non-specified target and specific approach methods. Since this Final Study finds mixed effects with a limited number of SOFAs, assurances that the "worst" conditions are met should be explored. Some options to consider:

1. Require that both the chosen "worst" approach method and the current sweep method be tested and documented. Both methods appear in the proposed language. If hair tests conclude with a flow rating using a presumptive "worst" approach, then confirmation tests at that highest flow using the current sweep approach can at least demonstrate that the "worst" prevails over two choices. Since "sweep" is the current method language, results using that method satisfy APSP-16 2011 requirements and would not conflict with the Final Study findings.

2. Identify target positions for common SOFA shapes and port configurations. As with the high velocity ports in section 4.2.7.3, common areas of high entrapment potential, may already be known. Due to symmetry, most SOFAs have a limited number of targets to explore. A requirement that any significant targets be tested and documented at the "worst" target's final flow rating would at least demonstrate that the "worst" prevails over other choices.

3. Provide requirements that support the identification and verification of target positions and approach methods that produce "worst" case conditions in testing at the final flow rating for representative SOFAs. Representation should be derived from market and epidemiological information.

Hair Aging

As a precondition for the study testing, all hair specimens were broken-in for the expressed purpose to improve study analysis. The break-in tests were conducted according to the APSP-16 2011 protocol using an installed SOFA. Pilot testing results indicated that 10 break-ins would be effective in removing hair age, *i.e.*, new or fresh, as a factor. There are some indications in the study data that this freshness factor was still present. Although this factor cannot be isolated, its effect is perceived to be small. More importantly, the need to break-in the hair specimens has other concerns.

1. Fresh hair is the closest condition to hair maintained on the person. By discarding the fresh hair tests, although with justification for the study, the overall force response lowers and moves away from a real condition.
2. Fresh hair is not likely to be subject to the highest flows during laboratory certification tests. Although APSP-16 2011 requires a "fresh" hair specimen, other requirements require a succession of lower flows (that age the hair) that occur before the final flow rate tests.
3. This fresh or new hair sample quality is fleeting and, apart from combing and shampooing, APSP-16 2011 does not have a complete preservation regime similar to the treatments in common personal hair products. Refer to the section, *Supplemental Testing - Hair Conditioning Tests*, for more discussion.

Body Block Element Study

The results of the BBE study are shown in Table 13. The experimental design had one factor – BBE size – and that was limited to two of the four SOFAs. The results are mixed in the Final Study analysis, with (BBE*SOFA (1)) favoring the current standard with the 18 in x 23 in BBE and (BBE*SOFA (2)) favoring the proposed standard with the smaller BBE. The BBE factor itself was not significant.

For LS staff, a difficulty in the set up for the BBE study was providing a flow rate that produced release forces close to the release criteria for each SOFA so that the data would be most relevant. That was not possible with the spa and 8-in round SOFAs because the flows required to produce the 15 lbf and 31 lbf release criterion, respectively, was beyond the hydraulic system capabilities. APSP-16 requires the piping connected to a SOFA to be sized the same as the outlet port to that SOFA. The small size of the piping connected to the SOFAs "choked" the flow. Choking occurs when the vapor pressure of the water is reached, which severely affects the flow. The hair study flows were better 'tuned' with adequate flow rates. Based on this study, staff cannot determine whether the proposed standard BBE size is at least as protective.

When flow is relatively low, forces don't fully differentiate to the size of the BBE. Although the differences can be studied, a candidate SOFA with better differentiation would yield more meaningful information. Refer to the following section: Supplemental Testing - Body Block Rating Test.

Table 13. Significance of BBE Factor in BBE Study

	BBE
Flat Channel (0)	n/a
8" Round (1)	Current (Marginal)
Dome Channel (3)	n/a
Spa (2)	Proposed
BBE	Not Sig.

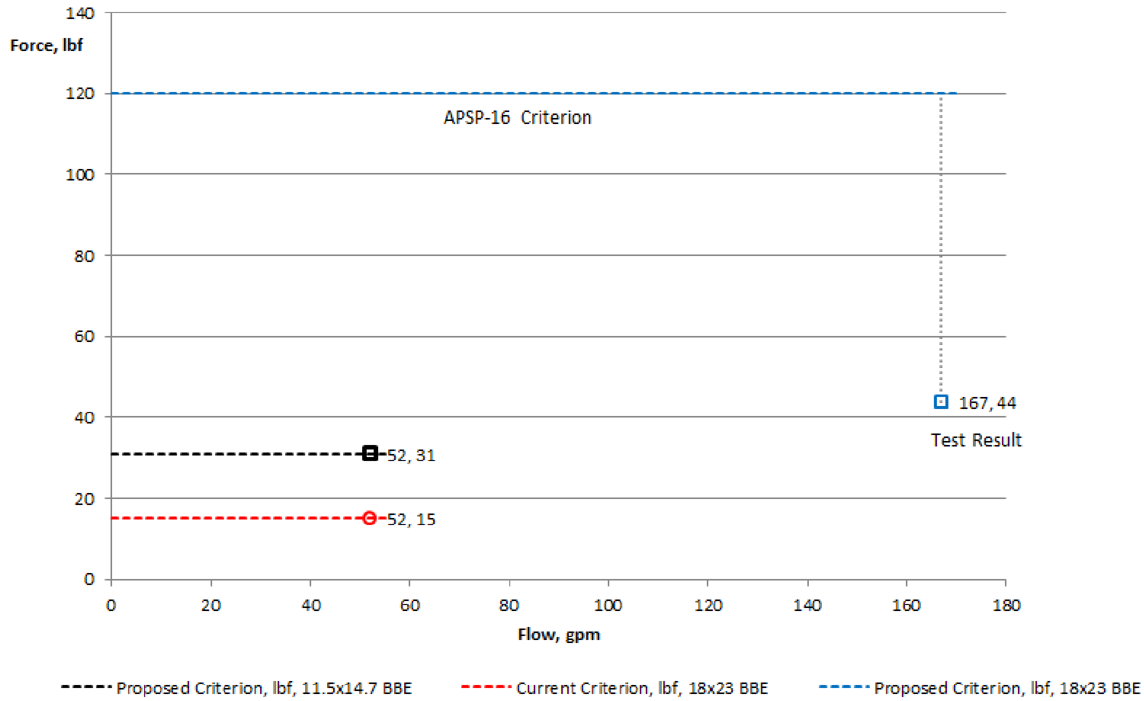
Not Sig.= not significant.

SUPPLEMENTAL TESTING - BODY BLOCK RATING TEST

To contrast the two BBE test methods requires a SOFA with substantial interaction with the key modification: a change in size or area of the BBE. CPSC staff obtained an 8-in round flat SOFA, rated at 96 gpm that had been previously recalled. That SOFA was subjected to the flow ratings methods of the APSP-16 2011 and proposed standards. This work is separate from the formal study.

Staff conducted ratings tests on the flat SOFA and also the SOFA with an accessory ring that raises the height 0.5 in. This discussion pertains to the raised SOFA, as the base SOFA did not produce meaningful ratings. Results are shown in Figure 12.

Figure 12. Body Block Ratings Tests Comparing Current and Proposed Standards
Flat 8-inch SOFA with Raised Ring



The current procedures (red), using the 18 in x 23 in BBE, produced a SOFA rating of 52 gpm at the 15 lbf. criterion. The proposed procedures produced a rating of 52 gpm at the 31 lbf. criterion (black). A rating could not be achieved with the proposed 18 in x 23 in BBE test (blue), since the highest flow of 167 gpm was at 44 lbf, short of the 120 lbf criterion. The flow choked at 167 gpm.

The proposed test with the 11.5 in x 14.7 in BBE indicates the removal forces are, counterintuitively, higher than those forces using the larger 18 in x 23 in BBE at the same flow rates: Compare 31 lbf (11.5 in x 14.7 in) to 15 lbf (18 in x 23 in), both at 52 gpm. Both BBE's had the same 120 lbf initial hold down force applied before the BBE's were removed. However, the smaller BBE was one forth the area of the larger BBE, and subsequently had four times the force per area (pressure) due to the hold down force. For the smaller area BBE to produce higher removal forces indicates the entrapment is due to increased suction of the BBE foam on the pool floor. This increased suction could be due to the noted increased initial pressure creating a better seal on the pool floor, or could be due to other properties of the foam. For example, the foam edges of the smaller BBE are closer to the SOFA than the 18 in x 23 in BBE, and the edges may deflect into and block the cover openings, compared to the larger BBE bridging across, supported by the floor, and forming a potentially larger seal area. A combination of effects may also be present.

This effect of BBE size may not hold for the wide design variations in SOFAs. After all, this was a recalled SOFA. But, since the proposed second SOFA defines the edge of the BBE foam to be 2-inches from suction areas, the edge properties of the specified foam might generally affect ratings. The closed cell foam is understood to be an area model of a human torso, but not of human skin in any aspect.

In this example, the smaller 11.5 in x 14.7 in BBE exhibits new performance effects. The higher removal force at the same flow rate suggests a BBE size or presumptive foam edge effect. There is no evidence, though, that the BBE foam models human flesh, or that the full torso of a small bather is more susceptible to entrapment than a full sized adult on a small SOFA. Whether the BBE construction generally models a human in SOFA entrapments has not been demonstrated.

Differences in BBE Ratings Procedures

Important differences in the procedures to assign maximum removal forces in the current and proposed standards can impact the flow rates and flow ratings. Current procedures allow flow rates that don't exceed the maximum removal force, and those forces increase with ***the SOFA size***. Proposed procedures allow flow rates that don't exceed the maximum removal force, and those forces increase with a ***larger SOFA size*** *(SOFA plus two inches)*. The allowable force is higher with the proposed second BBE procedure for the same SOFA. In addition, the proposed allowable force for the18 in x 23 in BBE test has been raised to the 120 lbf. maximum. This was not discussed in the analysis of BBE study results because the results were mixed and inconclusive.

The higher proposed removal forces could be expected to raise the flow rate and flow rating for a SOFA. In the supplemental tests for the specific 8 inch SOFA, this did not happen: An inverse size/force relationship at the same flow rate raised the measured forces for the small BBE (31 lbf.) above that for the 18 in x 23 in BBE (15 lbf.), countering exactly the increase in allowable force. As discussed previously, test foam properties may be causing the increased blockage.

In the supplemental BBE tests, the proposed smaller BBE method produced higher forces that were offset by a comparable increase in allowable force in the proposed rating procedure. Evidence that the proposed smaller BBE may increase removal forces does not necessarily justify up-rating with higher allowable removal forces. Changes that may maximize entrapment/removal forces, especially those due to test fixture materials, must also consider real human capabilities under those new entrapment physics. The current procedure with the adult-sized 18 in x 23 in BBE and the allowable forces based on SOFA size addresses, or is at least in line with, the known body block hazard. CPSC staff is not convinced the proposed change in rating procedures for the BBE test to be as protective.

Supplemental Testing - Hair Conditioning Tests

Ideally, each hair test should begin with hair in the same untangled condition, as if the bather just entered the water, and with consistency in other important qualities. Hair should behave consistently in water over the course of testing. For SOFA entrapment, the important qualities are those that allow the most hair to enter the SOFA cover. The requirements for hair maintenance in

APSP-16 2011 Section 4 include brushing before each test and cleaning in a mild shampoo[10] after every 10 tests. Brushing helps to maintain test consistency.

Prior to each test, LSM staff combed through the hair with a course and then a fine tooth comb. Each specimen was combed and used up to 70 times, including break-ins. Combing effort was not perceived to be consistent throughout testing with the hair specimens. Hair usage or age (combing, shampooing, testing) was associated with an *increased* combing effort. Also, the supple feel of the new hair specimens and the initially high entrapment forces (study pretests) suggested that fresh hair could be more entrapment prone. To address these suspicions, several additional pull tests were done with conditioned hair following the conclusion of study tests.

Hair conditioner is a common hair care product. LSM staff applied hair conditioner[11] to the ponytail hair specimens after completion of all study SOFA tests. Three SOFA ponytail test studies that had 60 test runs each (including 5 cleanings) were included. Figure 13 suggests that applying conditioner to hair had a notable increase in removal forces with two of the SOFAs.

Figure 13 displays the last six study test runs of each of three SOFA ponytail studies, followed by three tests done after applying hair conditioner. All tests for each SOFA were done under the same test setup. Hair was shampooed and then conditioned following the last study test. The 8" round SOFA (blue trace) indicates that all three tests with conditioner had noticeably higher entrapment forces than the final six study tests. The domed channel SOFA (red trace) indicates a single high entrapment force with conditioner, followed by a return toward expected response values. The forces before and after conditioning for the spa fitting (green trace) are not perceived to be different. Staff found no similar increase in entrapment forces following the normal shampoo regime during the study.

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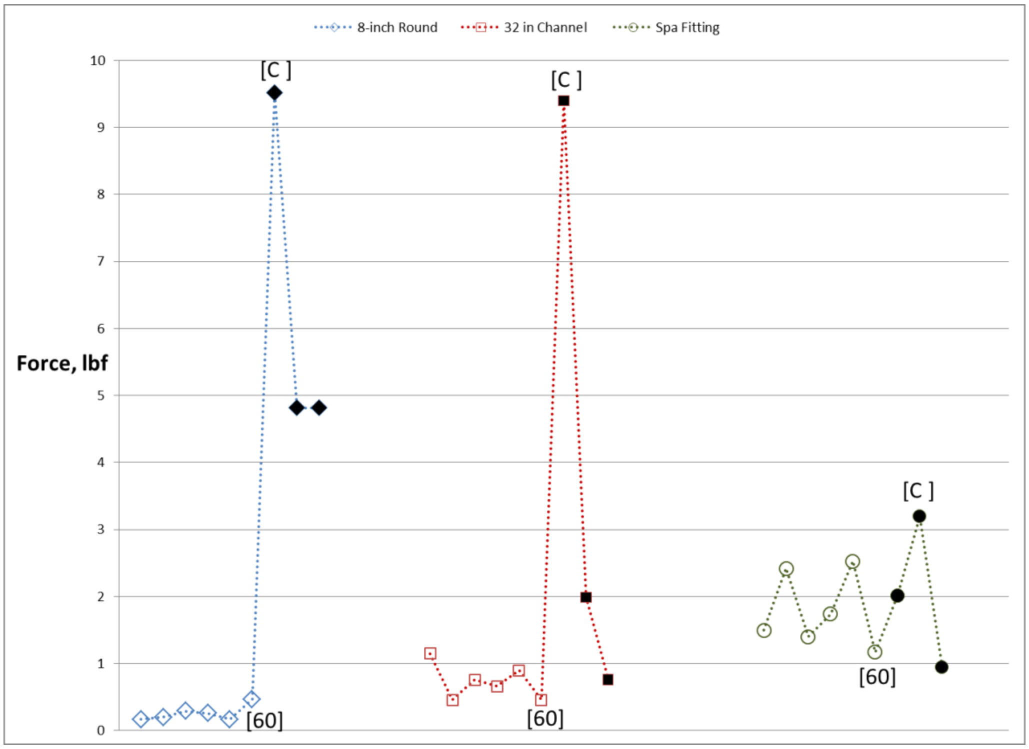
[10] Sodium Alpha Olefin Sulfonate, 10% by volume in water.

[11] Cetyl Alcohol, Pyridinium Chloride, DL Panthenol.

Figure 13. Effects of Hair Conditioner on Removal Force (Ponytail Tests)



The qualitative effect of shampooing is to increase combing effort, perhaps due to increased surface adhesion among the individual hairs. Shampooing removes natural oils that are not replenished in the APSP-16 2011 hair cleaning requirements. The use of hair conditioner can substitute for losses of important hair qualities through testing. The use of shampoo *and* conditioning products can be considered a normal routine in maintaining human hair. A more realistic hair maintenance procedure may provide more consistent test data, extend the useful life of hair specimens, and better represent entrapments of live human hair.

Standard Development

The SOFA Final Study Analytical Summary provides supporting evidence from experimental studies of four typical SOFA specimens to help evaluate the proposed revisions to APSP-16 2011 hair and body block ratings tests. Since the Final Study is the first of its kind with limited SOFA representation, extrapolation to an entire population of SOFAs, *e.g.*, market, or epidemiological, should be done with caution. Although not an exclusive approach, further APSP-16 2011 development that enables experimental studies will allow a comparative analysis that can persuade recommendations.

While CPSC staff appreciates the impetus to simplify the pull method of the hair procedure, recognizes the importance to emphasize the worst case in hair approach and targeting, and can visualize that body size and SOFA size are related in some way in respect to entrapment, the overall effect of these specific modifications in version 7.4 is to expand rather than simplify experimental studies. The "worst" approach method and the "worst" target position still depend on human judgment and choices. The second body block may prove to be important, but this has introduced new foam characteristics that are not known to have a human body counterpart. The weighted hair pull method reduces the impulsive test forces but there's no justification if test results raise flow rates while the victim's release from entrapments is still not understood.

The change in approach time from 60 seconds to 30 seconds was, by comparison to the other changes, simple and easily tested. Fewer factors in an experiment, along with reducing uncontrolled factors, will lead to experiments that can resolve factors and interactions in less time and with fewer test runs. Elimination of manual operations and a better understanding of the physics in the hair/SOFA and BBE material/human skin/SOFA interactions would make experimental study of the APSP-16 2011 standard more easily applied. Outcomes can include reduced testing costs and improved safety.

CONCLUSIONS

Section 4 Hair Entrapment

Approach Time. The Final Study shows that the proposed change to a 30 second approach time is at least as protective as the current 60 second approach time.

Target Position. The Final Study shows that the proposed addition of language to encourage the targeting of the worst entrapment areas on each SOFA has a mixed effect on release times, depending on the SOFA.

Approach Method. The Final Study shows that the proposed addition of language to encourage approach methods that move the hair into the worst entrapment areas on each SOFA has a mixed effect on release times, depending on the SOFA.

Pull Method. The Final Study shows that the proposed change to a constant- pull method using a weight was not as protective as the current constant-speed method.

Section 5 Body Entrapment.

Second Body Block Test. The Final Study was inconclusive on the proposed change to add a smaller body block test and change the ratings criteria.

The following conclusions are based on laboratory tests conducted by CPSC staff test that were not subject to experimental design:

Section 4 Hair Entrapment. Hair that is treated with a hair conditioning product may temporarily increase the entrapment forces compared to hair that is shampooed to the frequency required in Section 4.

Section 5 Body Entrapment. The size and properties of the current foam used in the proposed body block element tests may add new effects to entrapments on certain suction outlet fitting assemblies.

RECOMMENDATIONS

Based on experimental results that demonstrate whether a proposed change in requirements is as protective as the current standard requirements,

1. Allow the proposed Section 4 change of approach time to 30 seconds.
2. Do not allow the proposed Section 4 change of language describing targets for hair tests.
3. Do not allow the proposed Section 4 change of language describing approach methods in hair tests.
4. Allow the proposed Section 4.2.7.3 addition that describes testing at specific ports in channel SOFAs.
5. Do not allow the proposed section 4 change of pull method to a constant force using weight.
6. Do not allow the proposed Section 5 change to add an additional body block element and changes to allowable removal forces.
7. Consider the effect of hair conditioners on release times in Section 4 tests.
8. Consider how the properties and sizes of body block elements represent human torsos in entrapments on suction outlet fittings.
9. Consider requirements that support the identification and verification of target positions and approach methods that produce “worst” case conditions in testing at the final flow rating for representative SOFAs.

Appendix 1: Suction Outlet Fitting Assembly Full-Scale Study Statistical Analysis Summary

Suction Outlet Fitting Assembly Full-Scale Study Statistical Analysis Summary

January 2014

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This analysis was prepared by CPSC staff and has not been reviewed or approved by, and may not necessarily reflect the views of, the Commission.

Executive Summary

This report summarizes statistical modelling results comparing the proposed successor standard, ANSI/APSP-16 Rev 7.4, as presented by the ANSI/APSP-16 Committee, to the current Suction Outlet Fitting Assembly (SOFA) standard, ANSI/APSP-16 2011. There are proposed changes to three testing factors in the hair test: Approach time (proposed: 30 seconds, current standard: 60 seconds), Approach Method (proposed: worst case, current: sweep), and Pull Method (proposed: force, current: speed). Additionally, one factor was created from the proposed standard: Target (proposed: worst case, current: n/a). There is one proposed change to size in the body-block test (proposed: sized according to SOFA size, current: 18 in x23 in). For a proposed change to the standard to be accepted, the pull force required for release from the SOFA should be at least as protective as the current standard. Tests were run using four SOFA samples across two hair and one body block designs. Some of the findings of this report are provided below:

All tests:

- There are statistically significant differences between one or more of the four SOFAs in each test study, indicating that the specific SOFA in use is a significant factor in outcome of the tests.

Full Head Sample:

- The proposed approach time of 30-seconds appears to be at least as protective as the current 60-seconds standard;
- The proposed “force” pull method does not appear to be as protective as the current “speed” standard;
- The proposed “worst case” approach method appears to be at least as protective as the current “sweep method” standard.

Ponytail Sample:

- The proposed approach time yielded inconsistent results, although the proposed 30-second approach time may be reasonable because the only contrary result was a marginally lower interaction result with one SOFA;
- The pull method yielded mixed results and there does not appear to be sufficient evidence that the proposed change in the standard would provide an equal or more protective test;

- The proposed approach method also yielded mixed results and there does not appear to be sufficient evidence that the proposed change in the standard would provide an equal or more protective test.

Body-Block Element Sample:

- The body-block element yielded mixed results, depending upon the SOFA model and no significant difference between body blocks as a main factor. Therefore, there does not appear to be sufficient evidence that the proposed change in the standard would provide an equal or more protective test.

Introduction

The ANSI/APSP-16 Committee met on February 8-9, 2012, to discuss the potential experimental design to test and evaluate the current Suction Outlet Fitting Assembly ("SOFA") standard, ANSI/APSP-16 2011, and the proposed successor standard, ANSI/APSP-16 Rev 7.4. The committee decided to conduct a pilot study first, to help evaluate potential issues before implementing a larger design. Based on findings from the pilot study, the experimental design of the full-scale study was modified. This report summarizes and discusses the results of the full-scale study.

Based on testing requirements set forth in ANSI/APSP-16 2011, the study involved the two hair test designs, one for a full head of hair and another for a ponytail; and one test design for the body block. The tests compared pull force results of the proposed successor standard (ANSI/APSP-16 Rev 7.4) with the current standard (ANSI/APSP-16 2011). There were four SOFAs tested as part of this study. ANSI/APSP-16 Rev 7.4 proposes changes to three test factors for hair tests: Approach time (proposed: 30 seconds, current standard: 60 seconds), Approach Method (proposed: worst case, current: sweep), and Pull Method (proposed: force, current: speed). There is also the new factor: Target (proposed: worst case, current: n/a). The one proposed change to the body-block test is to body-block size (proposed: sized according to SOFA size, current: 18 in x 23 in). For a proposed change to the standard to be accepted, the pull force results should be at least as protective as the current standard. To identify if a proposed change is at least as protective as the current standard, the test results for removal force need be equal or greater than those obtained from the current standard. A greater removal force result would indicate that there would be more test results that exceed the standard requirements, leading to a lower flow rating for the SOFA, thus constituting a more protective methodology.

Goals and Response

The primary goal of the study was to determine whether the proposed SOFA standard provides an equivalent level of safety to the current standard, by identifying whether each change or combination of changes produces different results. The ANSI/APSP-16 removal force has been established as the response variable, which will be measured as a continuous response, measured in pounds of force. For this study, and in the time frame provided, CPSC staff was able to obtain four different SOFAs for testing (described below).

Design Factors

There are three sets of split-plot designs: two hair test designs, one for a full head of hair and another for a ponytail; and one test design for the body block, which are analyzed independently of each other. The two hair test designs, with the exception of the hair type sample used, were identical. For the purpose of running the tests, the three could be run simultaneously as long as the predetermined randomization scheme order of the tests was maintained. The design factors were established for the pilot study based on the ANSI/APSP-16 meeting. Included in the ANSI/APSP-16 Committee's desired outcomes was to study "lab" effects (are the differences observed between labs that could affect outcomes) and "operator" effects (differences between operator or technicians within labs). Before the pilot study, all of the proposed labs, with the exception of the CPSC lab, declined to participate in the study due to the fact that each lab would have had to have borne the cost of testing, which did not make good business sense for them, because other labs who had not paid to perform the testing would be able to benefit from the test results at no cost to them. Therefore, the "lab" effect could not be tested, which resulted in less-robust statistical results. Additionally, due to time and resource constraints, the "operator" factor was also dropped. The full scale round robin study design is based on the results of the pilot study, with the removal of the "lab" and "operator" factors and the use of a continuous response variable of pounds of force for the proposed pull method. In the pilot study, "hair type assembly" ("full head" or "ponytail") was a design element. Because the SOFA standard states that a test failure of either hair type assembly or the Body Block Element ("BBE") constitutes a failure of the SOFA at the specific flow rate, it was decided to run each hair type assembly as a separate test, therefore, "hair type assembly" was removed as a design element. Tables 1 and 2, reiterated from the full-scale study design of experiment, show the factors for the two designs (the two hair designs are identical and are presented once for both). The factors were either categorical or continuous.

Table 1 presents a summary of the four SOFAs in the hair tests and two SOFAs in the BBE tests (channel SOFAs are not tested with smaller BBEs because, due to its design, a suction event cannot occur because the intake cannot be completely covered by the proposed smaller BBE) and the associated estimated flow rates for each test element. This information was provided by CPSC's Laboratory Sciences engineering staff. For channel SOFAs, the BBE tests in the APSP-16 and proposed standards are identical. The proposed standard does not require tests with a reduced-size BBE for SOFAs, *e.g.*, channels that exceed the dimensions of the current 18x23 BBE. A spa SOFA was substituted for the Aquastar LP8AV to give the SOFAs a more representative range. The Waterway 640-349 Spa was mounted horizontally (as the others) for the BBE test and vertically for the hair tests with dual SOFAs, as required in these standards tests.

TABLE 1: SOFA WATER FLOWS (GPM) FOR TESTS

SOFA	Type	Marked Rating	Full Head	Ponytail	BBE2	BBE1* (smaller)
Waterway 640-349	Spa	120	146	145	138	138
Hayward 1048E	Round	125	120	85	165	165
Aquastar 32CDFL	Channel	316	300	226	242	--
Waterway 640-1300V	Channel	352	458	335	458	--

*BBE1 sizes are not tested with SOFAs larger than the 18 inches x 23 inches size - the channel drain SOFAs (Aquastar 32CDFL and Waterway 640-1300V) are approximately 32 inches long. These combinations were restricted in the experimental design, and thus are not represented. As such, the interaction between SOFA and BBE size will not be possible in the model.

Table 2 gives the design factors specific to the hair tests. The flow rate was established by the operator and recorded as a continuous variable.

Table 2: Round Robin Full Study Design Factors for Hair Tests

Factor	Type	Number of Categories or Continuous	Category Description (if applicable)
SOFA	Whole Plot	4	Waterway 640-349
			Hayward 1048E
			Aquastar 32CDFL
			Waterway 640-1300V
Approach time	Split (or sub) plot	2	30 seconds (Proposed) 60 seconds (Old)
Target	Split	2	Other (Old)

position	plot		Worst case (Proposed)
Approach Method	Split plot	2	Sweep (Old) Worst case (Proposed)
Pull Method	Split plot	2	Speed (Old) Force (Proposed)
Flow (gpm)	Split plot	Continuous, Uncontrolled	Measured and recorded at each test

Table 3 has the factors associated with the body block tests. The flow rate was established by the operator and recorded as a continuous variable.

Table 3: Round Robin Study Additional Design Factors for Body Block Tests

Factor	Type*	Number of Category or Continuous	Category Description (if applicable)
SOFA	Whole Plot	4	Waterway 640-349
			Hayward 1048E
			Aquastar 32CDFL*
			Waterway 640-1300V*
Element size	Split (or sub) plot	2	BBE 1
			BBE 2
Flow (gpm)	Split plot	Continuous, Uncontrolled	Measured and recorded at each test

* BBE1 tests will not be run for these SOFAs as the SOFAs are larger than the size of BBE1. This will be established as a restriction to the combinations in the design.

Break-In Period for Samples

Based on results from the pilot test, a break-in period for hair samples of both types and the smaller BBE were necessary. Pilot study results did not suggest that the larger BBE needed a break-in period. Graphs of sequential observations indicated that the initial period of sample usage show a marked higher response (force) level than subsequent levels. Based on the pilot study results, a break-in period of 5 runs was performed with BBE1 prior to initiating testing. For the hair samples, it was decided that a break-in period of 10 runs per whole block (or whenever a new specimen is introduced) be performed before initiating testing. It is believed that more consistent results were likely to be observed after these break-in periods.

Sample Sizes and the Design

The hair test designs that were generated only support estimation of main effects (SOFA, Approach Time, Target Position, Pull Method, and Approach Method) and two-factor interactions for the hair tests due to sample size restrictions. The BBE has 12 runs with 3 replications for each run for a total of 36 trials. The 3 replications were determined to be sufficient for detecting statistically significant differences in release pull force based on the pilot study results. Each hair test (full head and ponytail) has 35 runs with 6 replications for each run for a total of 210 trials. The 6 replications were determined to be sufficient for detecting differences based on the pilot study results, when the proposed pull method was censored at 5 pounds of force. During the course of the study, lab staff made an effort to mitigate censored data to improve the power of the statistical analysis. Staff recorded continuous data results in excess of the proposed 5-pound limit, but in a few trials (approximately 3 percent of the hair tests), augmented force was required to free the hair sample from the SOFA. These results were censored at the highest value recorded before the application of augmented force. A sensitivity analysis concluded that the effects of using the censored value for these few trials would not change the conclusions of the study.

Statistical Analysis

CPSC lab staff completed the testing and provided spreadsheets containing the measurement results. CPSC staff imported the spreadsheets and analyzed the data using SAS JMP 11.0 utilizing a least squares fixed effects and random effects model using the restricted maximum likelihood ("REML") method because of the incomplete block designs. Statistical tests and models were run to determine which of the main effects and two-way interactions are explaining significant amounts of the observed variation of the force variable. The statistical test procedures output a probability value (p-value) of achieving a test result greater than the observed under the hypothesis of no difference indicating the significance level of the effect or interaction. The p-value estimates the probability that the observed differences are due to random chance. In general, a low p-value indicates that it is unlikely that the observed differences are due to chance. For this analysis, p-values at or below 0.05 are considered to indicate that there is sufficient evidence to conclude that the observed difference is not due to chance and is, in fact, an effect caused by the factor being tested. For this analysis, p-values less than or equal to 0.10 but greater than 0.05 are considered to identify “marginal” evidence that the factor being tested is associated with the removal force. A p-value exceeding 0.10 indicates that there is insufficient evidence to conclude that any observed difference is due to the effect or interaction and may be due to chance.

In the graphs accompanying each main effect or interaction analysis, solid bar chart pairs indicate a statistically significant difference (at the 0.05 p-level), heavy hashing indicates marginal significance (0.05 to 0.10 p-level), and light hashing indicate no statistically significant difference (> 0.10 p-level). For a proposed test standard to be deemed to be equally or more protective than the existing standard, the results from the new standard should demonstrate either no significant difference or a significantly higher result. Marginal results are more open to interpretation.

For each model (full head hair, ponytail hair, body block element), each of the main effects and statistically significant interactions will be presented graphically and in tabular form. The comparison of treatments or levels (*e.g.,* which SOFA, which approach time, etc.) will be presented as Least Squares Means (LS Means). LS Means is the output term SAS/JMP uses for marginal means (or EMM - estimated marginal means). In an analysis of covariance model, LS Means are the group means after having controlled for each covariate (*i.e.,* holding it constant at some typical value of the covariates, such as its mean value). The LS Means presented in the tables and figures are model least squares estimates re-transformed back (exponentiated) to the measurement space (pounds of force). The LS Means presented should be considered to represent estimates of the mean values based on the modelled results. The re-transformation back to the measurement space has no effect on the test results and conclusions presented in the analysis and are only presented for clarity. Each p-value given in the tables is the probability that the observed differences are due to chance as described above.

An interaction effect is a relationship among three or more variables in which the simultaneous influence of two variables on a third is not additive. If two variables of interest interact (*e.g.,* SOFA and Approach Time), the relationship between each of the interacting variables and a third dependent variable (Removal Force) depends on the value of the other interacting variable. For example, a significant interaction effect between SOFA and Approach Time would indicate that that the influence of Approach Time on Force would depend on the SOFA being tested. Degree of statistical significance would vary between SOFAs and may even vary in directionality, *i.e.*, for one SOFA the 30-second approach time would yield greater force results, while for another SOFA the 60-second approach time would yield greater force results. The tables in the Interaction sections give the LS Mean for each combination of variable levels along with the associated p-value of the differences observed is an indication of statistical significance and direction of the relationship (in this study, “Greater” indicates that the proposed method yields greater force results and would thus be more conservative than the current standard.)

<u>Hair Tests (Full Head and Ponytail)</u>

CPSC staff ran a non-automated stepwise regression model, where the dependent variable was the resultant pull force, measured in pounds of force, required to free the full head of hair (wig) sample from the SOFA. Analysis of the model residuals indicated that force results were better described by natural lognormal (ln) distribution and, therefore, were ln-transformed prior to model development and analysis to preserve the statistical properties of the test. Tabulated estimates have been transformed back to the measurement space units of pounds of force (lbs.) The independent variables were SOFA (4 types tested), Approach time (2 levels: proposed 30 seconds [proposed], current standard 60 seconds [current]), Target position (2 levels: other, worst case), Approach Method (2 levels: worst case [proposed], sweep [current]), and Pull Method (2 levels: force [proposed], speed [current]). Note that a proposed change was to add a target position method. This variable was included as it was thought to possibly have an effect on test results. Additionally, all two-way interactions involving these factors were included. Interactions were removed from the model if they failed to attain a significant values (p-values greater than 0.10). An interaction occurs when the effect of one variable in the model is dependent upon the level of another variable (or variables) in the model. An example would be if the effect of Approach Time were different depending on which SOFA was being tested. The initial model included all of the main effects and two-way interactions:

- SOFA
- Approach Time
- Target Position
- Pull Method
- Approach Method
- SOFA*Approach Time
- SOFA*Target Position
- SOFA*Pull Method
- SOFA*Approach Method
- Approach Time*Target Position
- Approach Time*Pull Method
- Approach Time*Approach Method
- Target Position*Pull Method
- Target Position*Approach Method, and
- Pull Method*Approach Method

Full Head of Hair Analysis and Results

The regression model with pull force (ln-transformed) as the dependent variable has six statistically significant interactions, four involving the SOFA model factor. Each of the six interactions is presented below. The main effects and the six significant two-way interactions are shown in Table 4.

Table 4. Statistically Significant Main Effects and Interactions in the Full Head of Hair Model

Effect	p-value
SOFA	<0.0001
Approach Time	<0.0001
Target Position	0.6025
Pull Method	0.0020
Approach Method	<0.0001
SOFA*Approach Time	0.0002
SOFA*Target Position	0.0039
SOFA*Pull Method	0.0004
SOFA*Approach Method	0.0218
Target Position*Pull Method	0.0005
Pull Method*Approach Method	0.0143

Note: According to the model, the Target Position main effect is not significant but there were two significant interactions involving the Target Position variable (SOFA*Target Position and Target Position*Pull Method). This indicates that Target Position plays a role in conjunction with other variables in the model.

SOFA Effect

Figure 1 and the accompanying table (Table 5) shows, taking into account the other factors and interactions between factors, that the SOFA model does have a significant effect (p-value = < 0.0001).

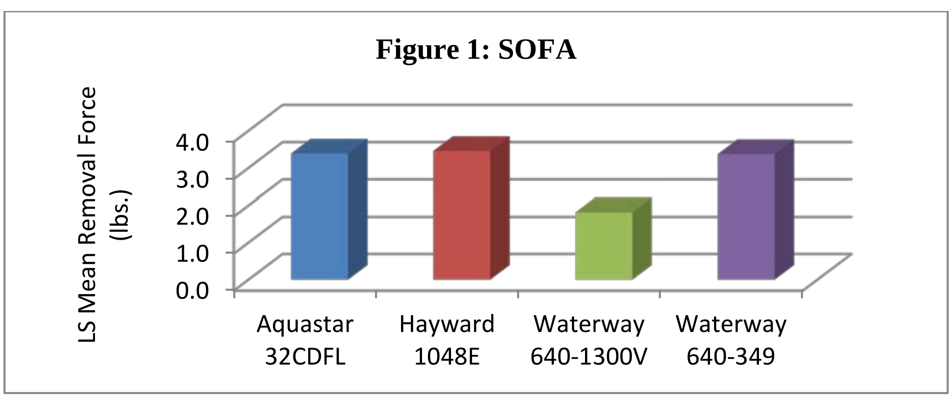


Table 5: Full Head – Model Estimates: SOFA factor

SOFA	LS Mean Removal Force (lbs.)
Aquastar 32CDFL	3.387
Hayward 1048E	3.454
Waterway 640-1300V	1.812
Waterway 640-349	3.367
p-value	< 0.0001

Approach Time Effect

Figure 2 and the accompanying table (Table 6) indicates, taking into account the other factors and interactions between factors, that the Approach Time does have a significant effect (p-value = < 0.0001). The proposed 30-second approach time yields a greater force to free the full-head hair sample from the SOFA. A greater force result for the proposed 30-second approach time indicates that a SOFA would be less likely to pass at the same flow rate. This is consistent with an equal or more protective testing method.

Figure 2: Approach Time

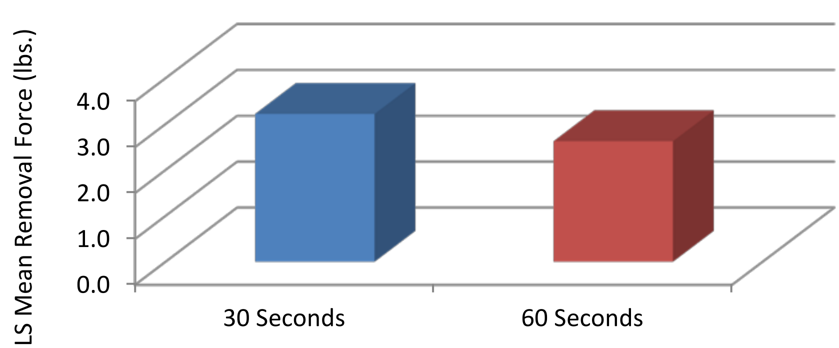


Table 6: Full Head – Model Estimates: Approach Time

Approach Time	LS Mean Removal Force (lbs.)
30 Seconds (Proposed)	3.219
60 Seconds (Current)	2.625
p-value	< 0.0001

<u>Target Position Effect</u>

Figure 3 and the accompanying table (Table 7) indicates that the Target Position does not have a significant effect (p-value = 0.6025). However, as will be seen later, Target Position has a statistically significant interaction effect on removal force so it has been kept in the model.

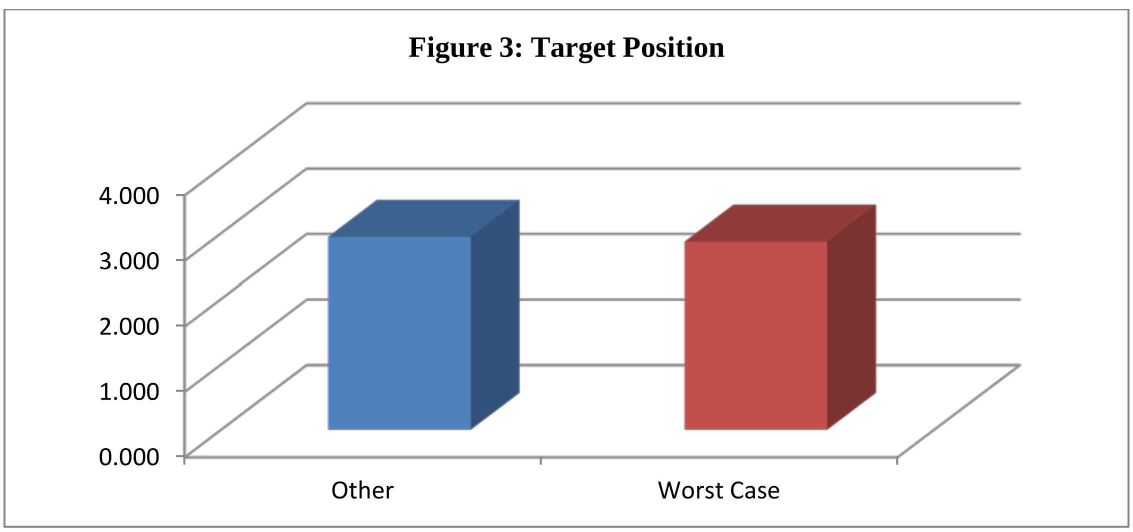


Table 7: Full Head – Model Estimates: Target Position

Target Position	LS Mean Removal Force (lbs.)
Other	2.944
Worst Case	2.870
p-value	0.6025

Pull Method Effect

Figure 4 and the accompanying table (Table 8) indicates, taking into account the other factors and interactions between factors, that the Pull Method does have a statistically significant effect (p-value = 0.0020). The proposed Force method yields a lower force to free the full-head hair sample from the SOFA. A lower force result is not consistent with an equal or more protective testing method. However, as will be shown later, there are contradictory, and significant, interaction effects with the specific SOFA model being tested and also the target position.

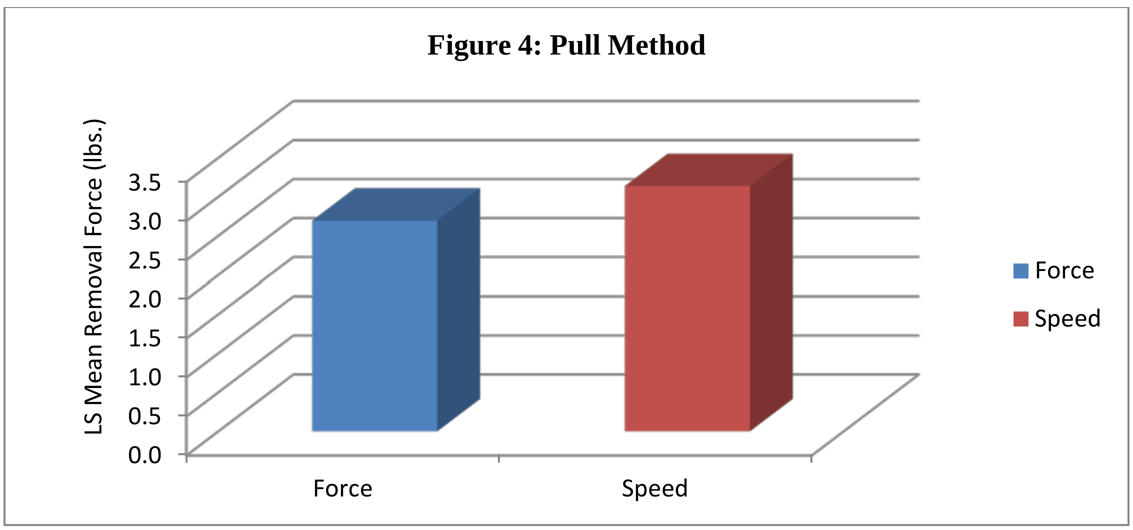


Table 8: Full Head – Model Estimates: Pull Method

Pull Method	LS Mean Removal Force (lbs.)
Force (Proposed)	2.694
Speed (Current)	3.137
p-value	0.0020

Approach Method Effect

Figure 5 and the accompanying table (Table 9) indicates, taking into account the other factors and interactions between factors, that the Approach Method does have a significant effect (p-value = < 0.0001). The proposed worst case approach method yields a greater force to free the full-head hair sample from the SOFA. A greater force result is consistent with an equal or more protective testing method. As will be shown later, this is consistent with interaction effects involving the Approach Method.

Figure 5: Approach Method

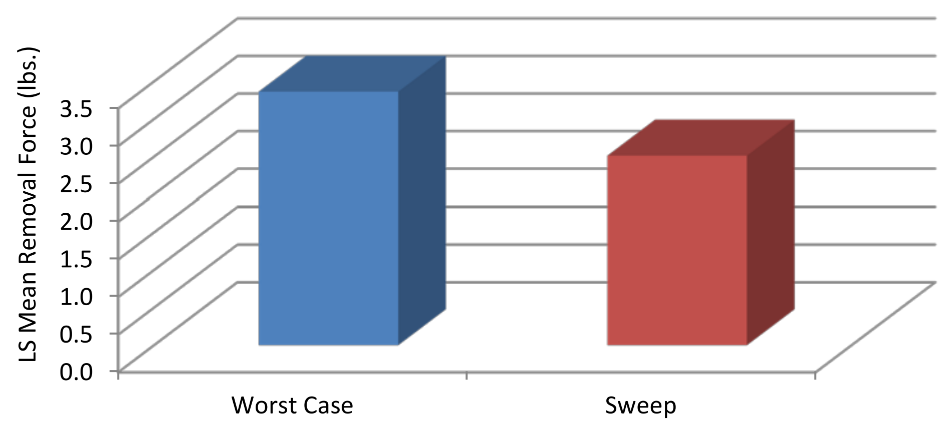


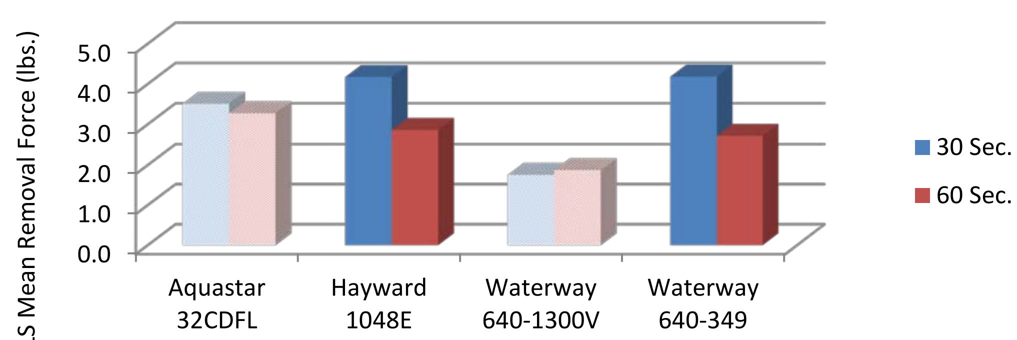
Table 9: Full Head – Model Estimates: Approach

Approach Method	LS Mean Removal Force (lbs.)
Worst Case (Proposed)	3.363
Sweep (Current)	2.512
p-value	< 0.0001

SOFA * Approach Time Interaction

The proposed change to the test standard for approach time is from 60 seconds down to 30 seconds. This analysis identifies statistically significant (and marginally significant) differences between interactions and approach times, given that a specific SOFA is in place. Figure 6 shows a graphical representation of the magnitude of estimates for the SOFA*Approach Time pairs with blue representing the proposed 30 second approach time and red the current standard of 60 seconds. Table 10 below presents the least squares mean estimates for the eight SOFA*Approach Time combinations. For two of the SOFAs tested in the study, the Hayward 1048E and the Waterway 640-349, the 30 second approach time resulted in a greater force estimate (more protective) while for the remaining two SOFAs (Aquastar 32CDFL and the Waterway 640-1300V) no significant difference was discerned as illustrated by the light hatched bars. Based on these results, it would appear for the full-head hair samples that the proposed 30 second approach time, taking SOFA into account would yield as or more protective results because more force is required to pass the proposed test.

Figure 6: SOFA * Approach Time



Note: Solid fill indicates a significant difference has been detected between Approach Times for the given SOFA. Light hashing indicates that no significant difference was detected.

Table 10: Full Head Sample - SOFA * Approach Time Method Interaction LS Means and P-Values

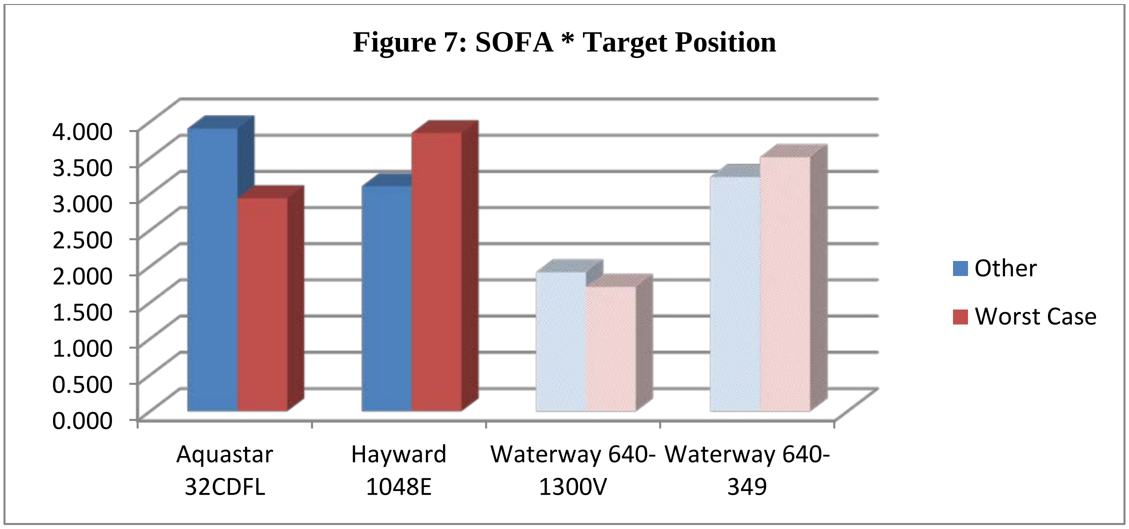
Approach Time (sec)

SOFA	30	60	P-value	Difference*
Aquastar 32CDFL	3.507	3.270	0.5953	Not significant
Hayward 1048E	4.171	2.860	0.0001	Significantly Greater
Waterway 640-1300V	1.754	1.872	0.4559	Not significant
Waterway 640-349	4.183	2.711	< 0.0001	Significantly Greater

* Proposed 30 second versus current 60 second standard.

SOFA * Target Position Interaction

The SOFA and Target interaction demonstrates contradictory results indicating that the relationship between the dependent variable Force and Target Position appears to be SOFA-specific. Figure 7 shows a graphical representation of the magnitude of estimates for the SOFA*Target Position pairs with blue representing the Other position and red the Worst Case position. Table 11 presents the least squares mean estimates for the eight SOFA*Target Position combinations. For two of the SOFAs tested in the study, the Aquastar 32CDFL and the Hayward 1048E, there were significantly different Force results as indicated by the solid bars depending on the target position. For the Aquastar 32CDFL force estimate was greater for the Other positioning (more protective) while for the Hayward 1048E it was the opposite. The remaining two SOFAs (the Waterway 640-349 and the Waterway 640-1300V) no significant difference was discerned as illustrated by the light hatched bars. Based on these results, it would appear that the relationship between the dependent variable Force and Target Position appears to be SOFA-specific.



Note: Solid fill indicates a significant difference has been detected between Target Positions for the given SOFA. Light hashing indicates that no significant difference was detected.

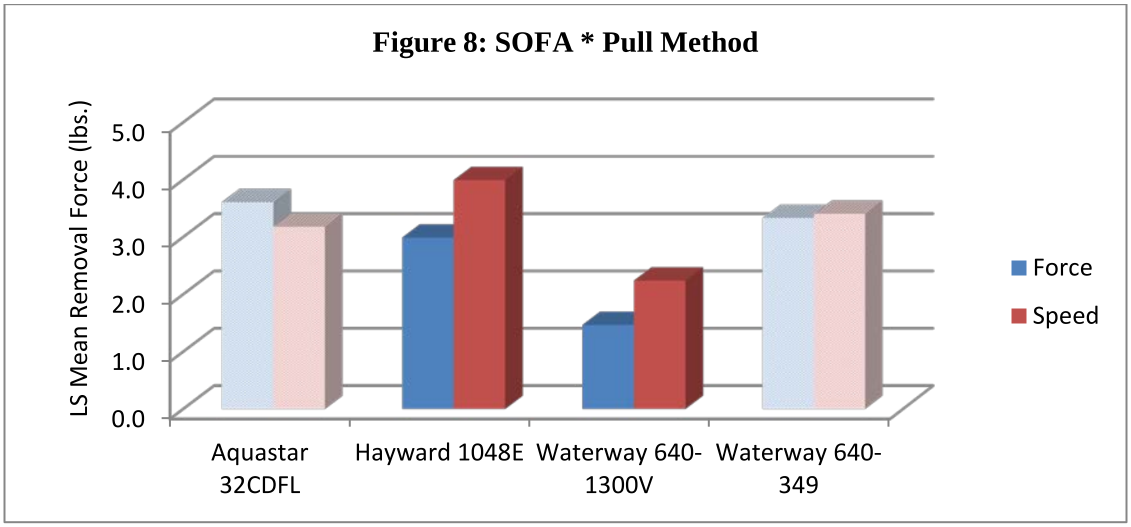
Table 11: Full Head Sample - SOFA * Target Position Interaction LS Means and P-Values

LS Mean	Other	Worst Case	P-value	Difference*
Aquastar 32CDFL	3.903	2.939	0.0278	Significantly Greater
Hayward 1048E	3.106	3.841	0.0147	Significantly Lower
Waterway 640-1300V	1.916	1.714	0.1897	not significant
Waterway 640-349	3.232	3.508	0.3371	not significant

* "Other" versus proposed "Worst Case."

SOFA * Pull Method Interaction

The proposed change to the test standard for pull method is the Force method with the existing standard indicating the Speed method. Figure 8 shows a graphical representation of the magnitude of estimates for the SOFA*Pull Method pairs with blue representing the proposed force method and red the current standard speed method. Table 12 presents the least squares mean estimates for the eight SOFA*Pull Method combinations. For two of the SOFAs tested in the study, the Hayward 1048E and the Waterway 640-1300V, the proposed Force method resulted in a significantly lower force estimate (less protective) as indicated by the solid bars while for the remaining two SOFAs (Aquastar 32CDFL and the Waterway 640-349) no significant difference was discerned as illustrated by the light hatched bars. Based on these results, it would appear for the full-head hair samples that the proposed Force pull method, taking SOFA into account would not yield more protective results. This is consistent with the results of the main effect factor Pull Method.



Note: Solid fill indicates a significant difference has been detected between Pull Methods for the given SOFA. Light hashing indicates that no significant difference was detected.

Table 12: Full Head Sample - SOFA * Pull Method Interaction LS Means and P-Values

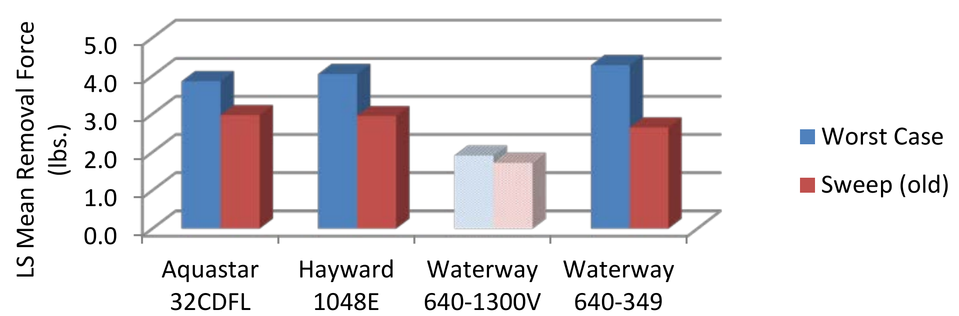
LS Mean	Force	Speed	P-value	Difference*
Aquastar 32CDFL	3.607	3.180	0.3137	not significant
Hayward 1048E	2.989	3.992	0.0010	Significantly Lower
Waterway 640-1300V	1.466	2.241	< 0.0001	Significantly Lower
Waterway 640-349	3.331	3.404	0.8007	not significant

* Proposed “Force” versus “Speed”.

SOFA * Approach Method Interaction

The proposed change to the test standard for approach method is from the sweep method to a worst case method. Figure 9 shows a graphical representation of the magnitude of estimates for the SOFA*Approach Method pairs with blue representing the proposed worst case approach method and red the current standard sweep method. Table 13 presents the least squares mean estimates for the eight SOFA*Approach Method combinations. For three of the SOFAs tested in the study, the Aquastar 32CDFL, the Hayward 1048E and the Waterway 640-349, the worst case approach method resulted in a greater force estimate (more protective) as indicated by the solid bars while for the remaining SOFA (the Waterway 640-1300V) no significant difference was discerned as illustrated by the light hatched bars. Based on these results, it would appear for the full-head hair samples that the proposed worst case approach method, taking SOFA into account would yield as or more protective results. This is consistent with the results of the main effect factor Approach Method.

Figure 9: SOFA * Approach Method



Note: Solid fill indicates a significant difference has been detected between Approach Methods for the given SOFA. Light hashing indicates that no significant difference was detected.

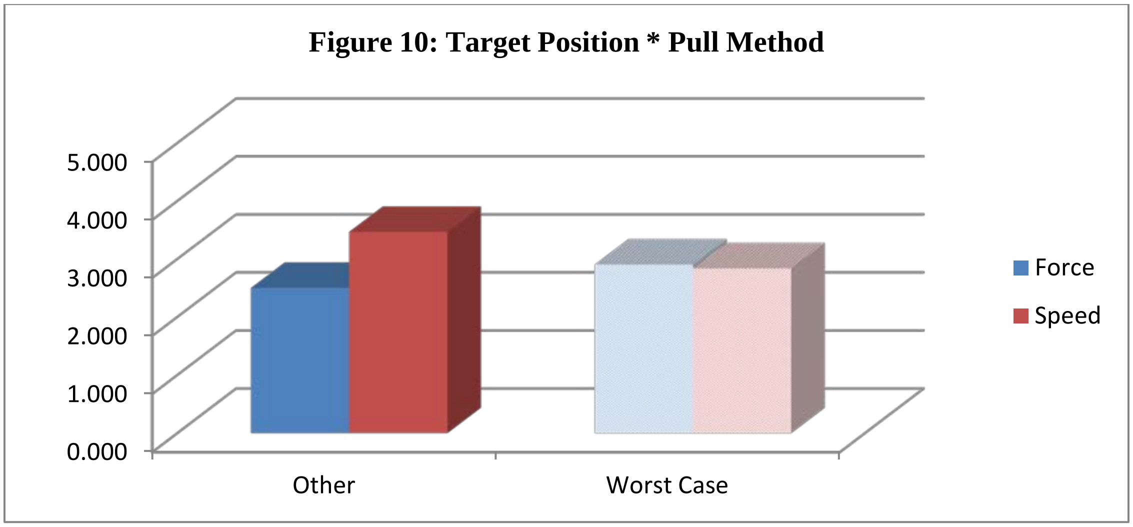
Table 13: Full Head Sample - SOFA * Approach Method Interaction LS Means and P-Values

LS Mean	Worst Case	Sweep	P-value	Difference*
Aquastar 32CDFL	3.859	2.972	0.0426	Significantly Greater
Hayward 1048E	4.048	2.947	0.0003	Significantly Greater
Waterway 640-1300V	1.912	1.718	0.2083	not significant
Waterway 640-349	4.284	2.647	< 0.0001	Significantly Greater

* Proposed “Worst” versus “Sweep”.

Target Position * Pull Method Interaction

Figure 10 shows a graphical representation of the magnitude of estimates for the Target Position*Pull Method pairs with blue representing the proposed force method and red the current standard speed method. Table 14 below presents the least squares mean estimates for the four Target Position*Pull Method combinations. For the Centered target position, the proposed Force pull method resulted in a significantly lower force estimate (less protective) as indicated by the solid bars while for the Worst Case target position no significant difference was discerned as illustrated by the light hatched bars. Based on these results, it would appear for the full-head hair samples that the proposed Force pull method, taking Target Position into account would not yield more protective results. This is consistent with the results of the main effect factor Pull Method. The Target Position main effect was not significant in the model.



Note: Solid fill indicates a significant difference has been detected between Pull Methods for the given Target Position. Light hashing indicates that no significant difference was detected.

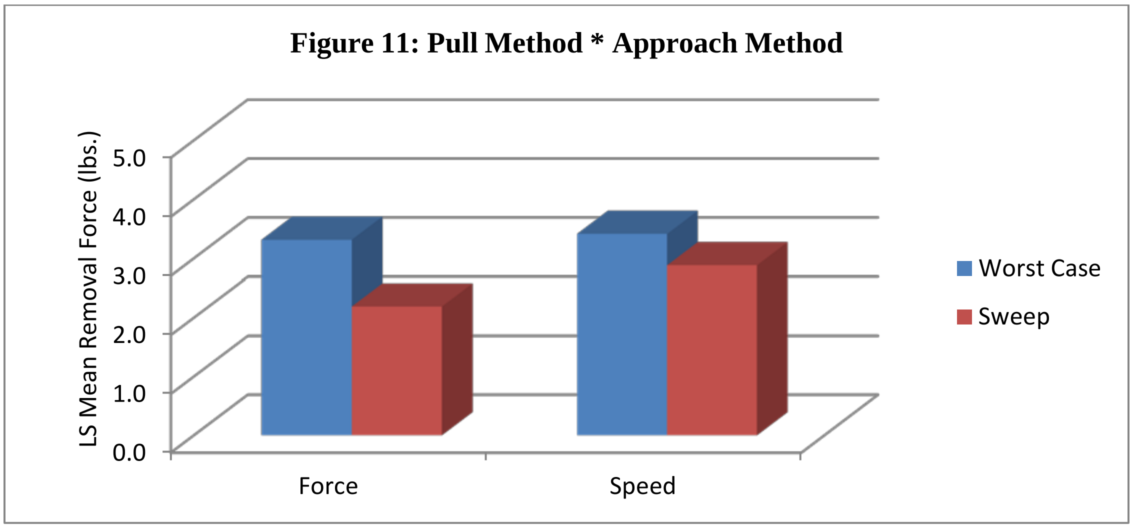
Table 14: Full Head Sample – Target Position * Pull Method Interaction LS Means and P-Values

LS Mean	Force	Speed	P-value	Difference*
Other	2.500	3.467	< 0.0001	Significantly Lower
Worst Case	2.903	2.838	0.7319	not significant

* Proposed "Force" versus "Speed".

<u>Pull Method * Approach Method Interaction</u>

Figure 11 shows a graphical representation of the magnitude of estimates for the Pull Method*Approach Method pairs with blue representing the proposed worst case approach method and red the current standard sweep method. Table 15 below presents the least squares mean estimates for the four Pull Method*Approach Method combinations. For both Pull Methods tested in the study, the worst case approach method resulted in a greater force estimate (more protective) as indicated by the solid bars. This is consistent with the Approach Method main effect but inconsistent with the Pull Method main effect.



Note: Solid fill indicates a significant difference has been detected between Approach Methods for the specific Pull Method.

Table 15: Full Head Sample –Pull Method * Approach Method Interaction LS Means and P-Values

LS Mean	Worst Case	Sweep	P-value	Difference*
Force	3.314	2.189	<.0001	Significantly Greater
Speed	3.413	2.882	0.0151	Significantly Greater

* "Worst Case" versus "Sweep."

Full Head Sample – Model Results Summary

Table 16 summarizes the modeling results for the full head sample tests. Cells along the diagonal are the main effects results (e.g., the cell represented in the "Approach Time" column and the "Approach Time" row is the main factor effect for the Approach Time factor). Cells that contain information other than a dash ("-") is the summary of the interaction effect between the factor labeled in the column heading and the factor labeled in the row heading.

Table 16: Full Head Sample – Summary of Model Results

Factor	SOFA	Approach Time*	Target Position*	Pull Method*	Approach Method*
SOFA	Differences[1]	Proposed	Mixed	Current	Proposed
Approach Time	-	Proposed	n/a	n/a	n/a
Target Position	-	-	Not signif.	Current	n/a
Pull Method	-	-	-	Current	Proposed
Approach Method	-	-	-	-	Proposed

* Identifies which standard is more protective (i.e., which standard resulted in some or all results significantly greater than the alternative. "Mixed" indicates inconsistent results. "Not signif." Indicates that no conclusion could be made.

1 – "Differences" indicates that there were statistically significant results observed between the SOFAs in the test.

n/a – Not applicable. These interaction effects were not modelled as the effect was determined to not be significant (see Table 4).

Based on this summary, for the full-head sample, it could be concluded that:

- There are differences between SOFAs estimates.
- The proposed approach time of 30-seconds appears to be at least as protective as the current 60-seconds standard.
- The proposed "force" pull method does not appear to be as protective as the current "speed" standard.
- The proposed approach method of "worst case method" appears to be at least as protective as the current "sweep method" standard.
- Target position results are mixed.

Hair in Ponytail Analysis and Results

The regression model with pull force (log-transformed) as the dependent variable has four statistically significant interactions, four involving the SOFA model factor. Each of the four interactions is presented in Table 17. In the graphs that follow, solid bar charts pairs indicate a statistically significant difference (at the 0.05 p-value), heavy hashing indicates marginal significance (0.05 to 0.10 p-value), and light hashing indicate no significant difference (> 0.10 p-value). For a proposed test standard to be deemed to be equally or more protective than the existing standard, the results from the proposed standard should demonstrate either no significant difference or a significantly higher result. Marginal results are more open to interpretation. The main effects and the four significant two-way interactions are shown in Table 17.

Table 17: Statistically Significant Main Effects and Interactions in the Ponytail Model

Effect	p-value
SOFA	<0.0001
Approach Time	0.0314
Target Position	0.0474
Pull Method	0.1979
Approach Method	0.9004
SOFA*Approach Time	< 0.0001
SOFA*Pull Method	0.0015
SOFA*Approach Method	0.0010
Target Position*Approach Method	0.0148

Note: According to the model, the Pull Method and Approach Method main effects are not significant but there were significant interactions involving these variables so these were kept in the model.

The magnitude of test effects and the role played by interactions are discussed in detail in the next section of this memo.

SOFA Effect

Figure 12 and the accompanying table (Table 18) shows, taking into account the other factors and interactions between factors, that the SOFA model does have a significant association (p-value = < 0.0001) with the removal force. In the Figure 12, it can be seen that there are observable differences between the effects the specific SOFA has on removal force.

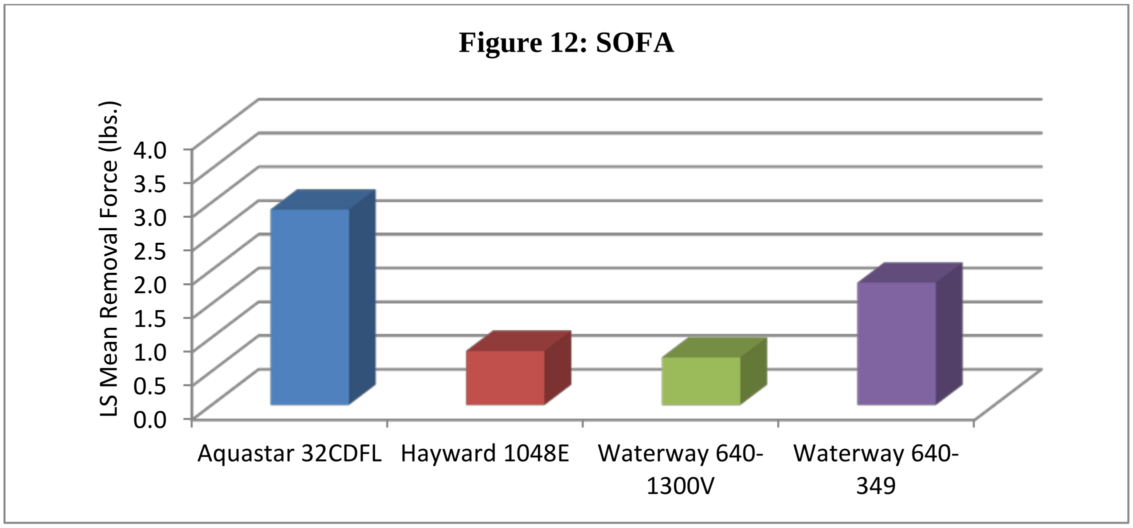


Table 18: Ponytail – Model Estimates: SOFA Factor

SOFA	LS Mean Removal Force (lbs.)
Aquastar 32CDFL	2.892
Hayward 1048E	0.799
Waterway 640-1300V	0.701
Waterway 640-349	1.810
p-value	< 0.0001

<u>Approach Time Effect</u>

Figure 13 and the accompanying table (Table 19) indicates, taking into account the other factors and interactions between factors, that the Approach Time does have a significant effect (p-value = 0.0314). The proposed 30-second approach time yields a greater force to free the ponytail hair sample from the SOFA. An approach time yielding a greater force result is consistent with an equal or more protective method. However, as will be shown later, there are contradictory interaction effects results with the specific SOFA model being tested.

Figure 13: Approach Time

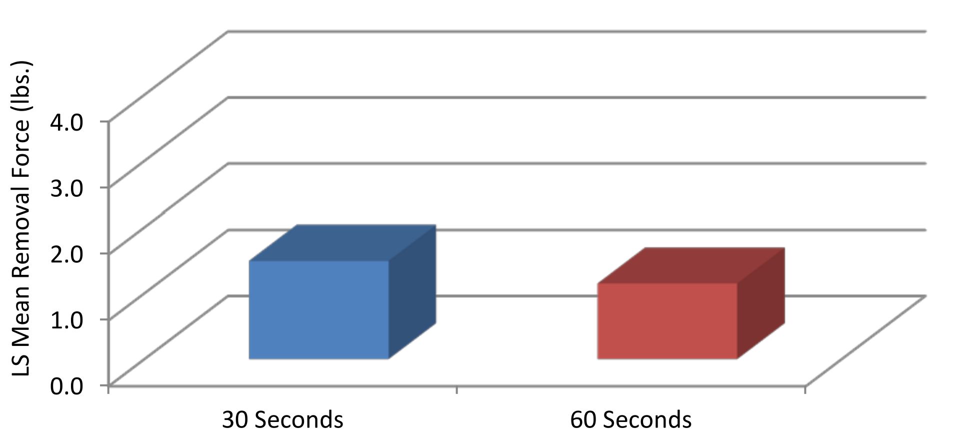


Table 19: Ponytail – Model Estimates: Approach Time Factor

SOFA	LS Mean Removal Force (lbs.)
30 Seconds (Proposed)	1.492
60 Seconds (Current)	1.148
p-value	0.0314

Target Position Effect

Figure 14 and the accompanying table (Table 20) indicates that the Target Position has a significant effect (p-value = 0.0474). The Worst Case target position time yields a greater force to free the ponytail hair sample from the SOFA.

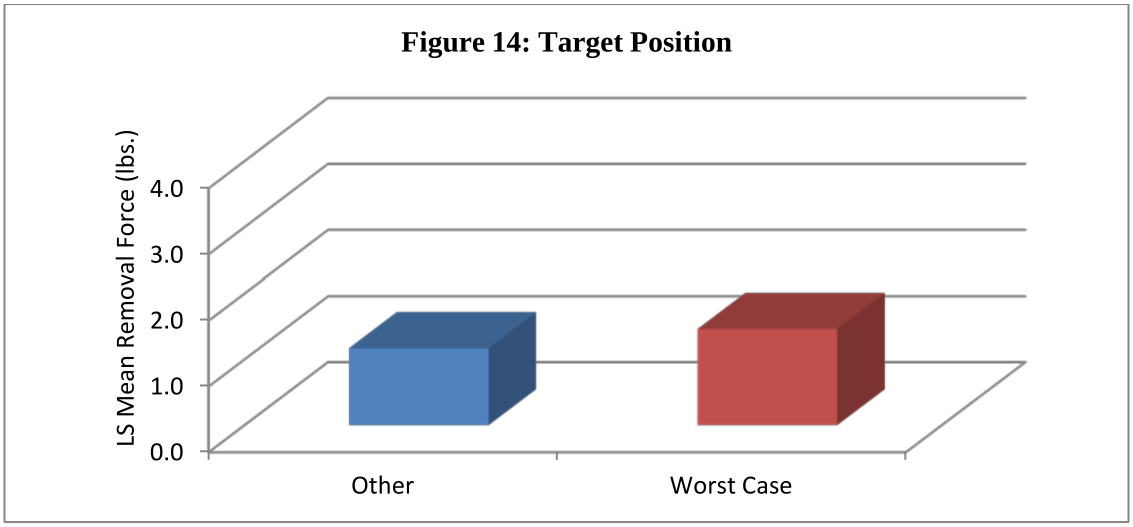


Table 20: Ponytail – Model Estimates: Target Position Factor

SOFA	LS Mean Removal Force (lbs.)
Other	1.171
Worst Case	1.463
p-value	0.0474

Pull Method Effect

Figure 15 and the accompanying table (Table 21) indicates, taking into account the other factors and interactions between factors, that the Pull Method does not have a significant effect (p-value = 0.1979). However, as will be shown later, there are mixed interaction effects with the specific SOFA model being tested and also the target position.

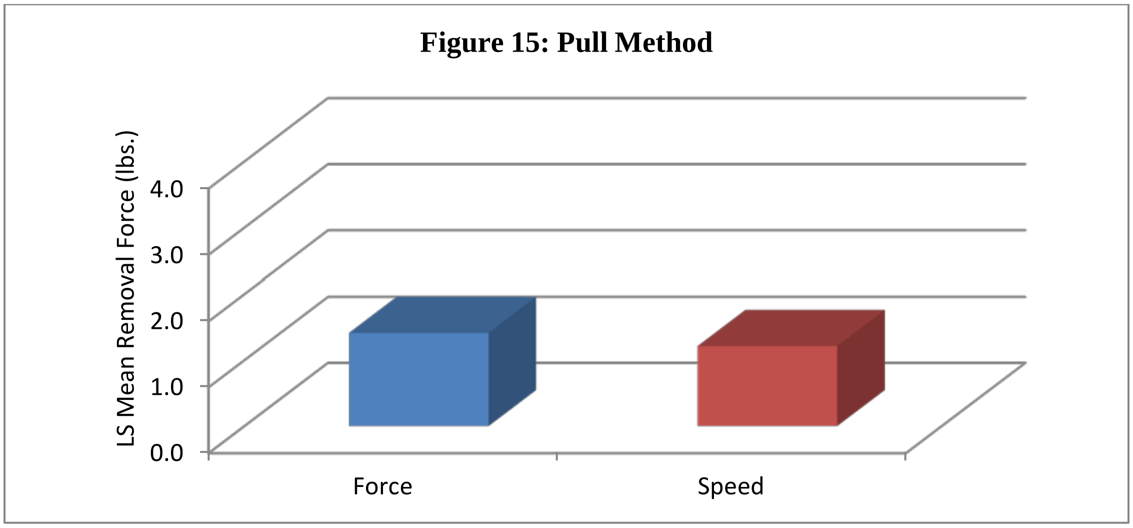


Table 21: Ponytail – Model Estimates: Pull Method Factor

SOFA	LS Mean Removal Force (lbs.)
Force (Proposed)	1.413
Speed (Current)	1.212
p-value	0.1979

<u>Approach Method Effect</u>

Figure 16 and the accompanying table (Table 22) indicates, taking into account the other factors and interactions between factors, that the Approach Method does not have a significant effect (p-value = 0.9004). However, as will be shown later, there are mixed interaction effects with the specific SOFA model being tested and also the target position.

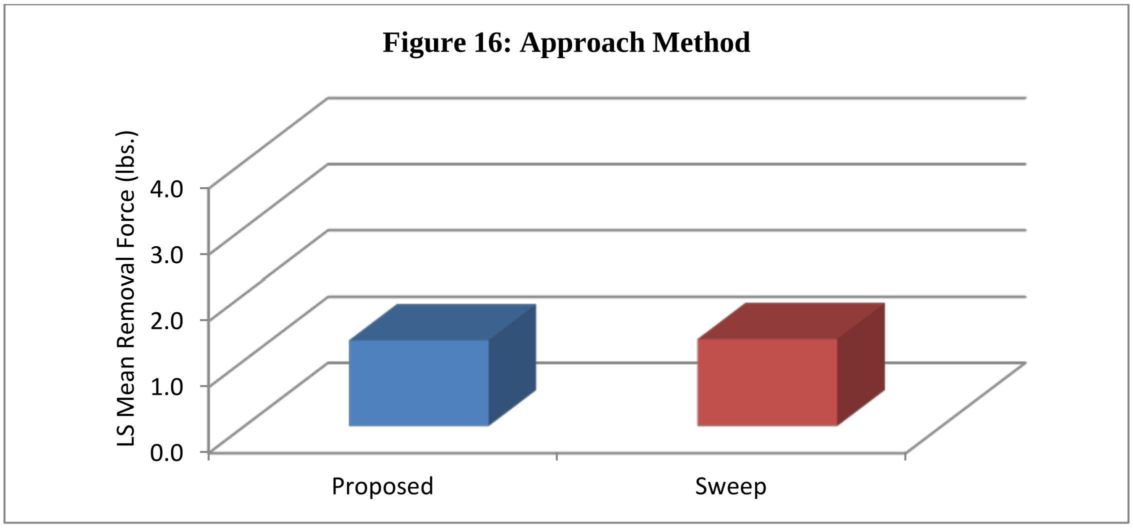


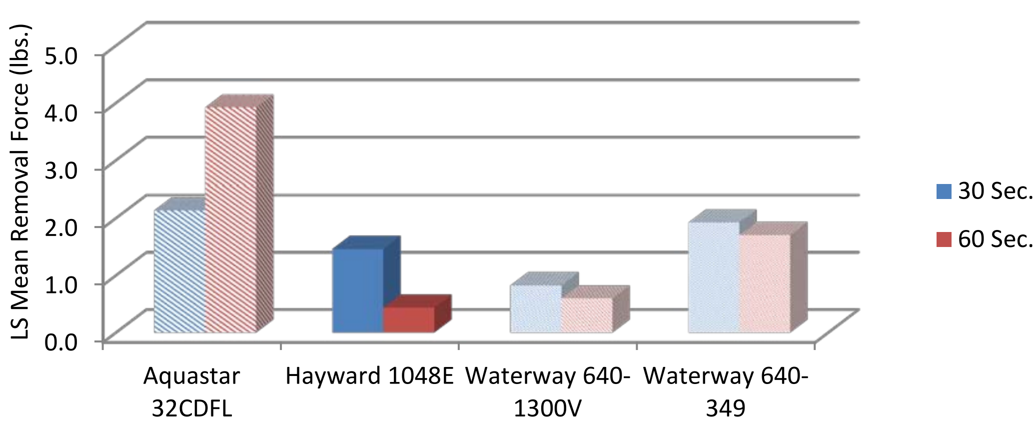
Table 22: Ponytail – Model Estimates: Pull Method Factor

SOFA	LS Mean Removal Force (lbs.)
Proposed	1.299
Sweep (Current)	1.318
p-value	0.9004

<u>SOFA * Approach Time Interaction</u>

The proposed change to the test standard for approach method is from the sweep method to a worst case method. Figure 17 shows a graphical representation of the magnitude of estimates for the SOFA*Approach Time pairs with blue representing the proposed worst case approach method and red the current standard sweep method. The heavy hash marking indicates marginal significance (p-value between 0.05 and 0.10) while light hash marking indicates no significant difference. Table 23 presents the least squares mean estimates for the eight SOFA*Approach Time combinations. For one of the four SOFAs tested in the study, the Hayward 1048E, the proposed 30-second approach time method resulted in a greater force estimate (more protective) as indicated by the solid bars while for another one of the SOFAs, the Aquastar 32CDFL, the proposed 30-second approach time method resulted in a marginally significantly lower force estimate (less protective) as indicated by the heavy hatched bars. The remaining two SOFAs, the Waterway 640-349 and the Waterway 640-1300V, no significant difference was discerned as illustrated by the light hatched bars. Based on these results, it would appear for the ponytail hair samples that the proposed worst case approach method, taking SOFA into account, yields mixed results and could not be said to be consistently more protective.

Figure 17: SOFA * Approach Time



Note: Solid fill indicates a statistically significant difference has been detected between Approach Times for the specific SOFA. Heavy hatching indicates that there is marginal statistical evidence of a difference. Light hashing indicates that no significant difference was detected.

Table 23: Ponytail Sample - SOFA * Approach Time Interaction LS Means and P-Values

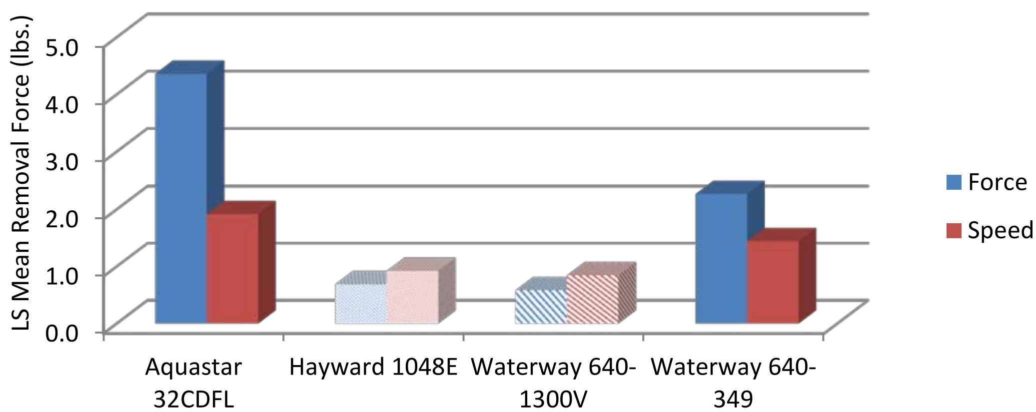
	Approach Time (sec.)			
SOFA	30	60	P-value	Difference*
Aquastar 32CDFL	2.134	3.919	0.0501	Marginally lower
Hayward 1048E	1.461	0.437	< 0.0001	Significantly Greater
Waterway 640-1300V	0.825	0.596	0.1361	Not significant
Waterway 640-349	1.923	1.704	0.5632	Not significant

* Proposed 30 second versus current 60 second standard.

<u>SOFA * Pull Method Interaction</u>

The proposed change to the test standard for pull method is the Force method with the existing standard indicating the Speed method. Figure 18 shows a graphical representation of the magnitude of estimates for the SOFA*Pull Method pairs with blue representing the proposed force method and red the current standard speed method. Table 24 below presents the least squares mean estimates for the eight SOFA*Pull Method combinations. For two of the SOFAs tested in the study, the Aquastar 32CDFL and the Waterway 640-349, the proposed Force method resulted in a significantly greater force estimate (more protective) as indicated by the solid bars while for the Waterway 640-1300V the proposed Force method resulted in a marginally lower force estimate as indicated by the heavy hatched bars. For the remaining SOFA (the Hayward 1048E) no significant difference was discerned as illustrated by the light hatched bars. Based on these results, it would appear for the ponytail hair samples that the proposed Force pull method, taking SOFA into account, yields mixed results and could not be said to be consistently more protective.

Figure 18: SOFA * Pull Method



Note: Solid fill indicates a significant difference has been detected between Pull Methods for the specific SOFA. Heavy hatching indicates that there is marginal statistical evidence of a difference. Light hashing indicates that no significant difference was detected.

Table 24: Ponytail Sample - SOFA * Pull Method Interaction LS Means and P-Values

LS Mean	Force	Speed	P-value	Difference*
Aquastar 32CDFL	4.362	1.917	0.0084	Significantly Greater
Hayward 1048E	0.691	0.924	0.1666	not significant
Waterway 640-1300V	0.583	0.844	0.0792	Marginally Lower
Waterway 640-349	2.270	1.444	0.0322	Significantly Greater

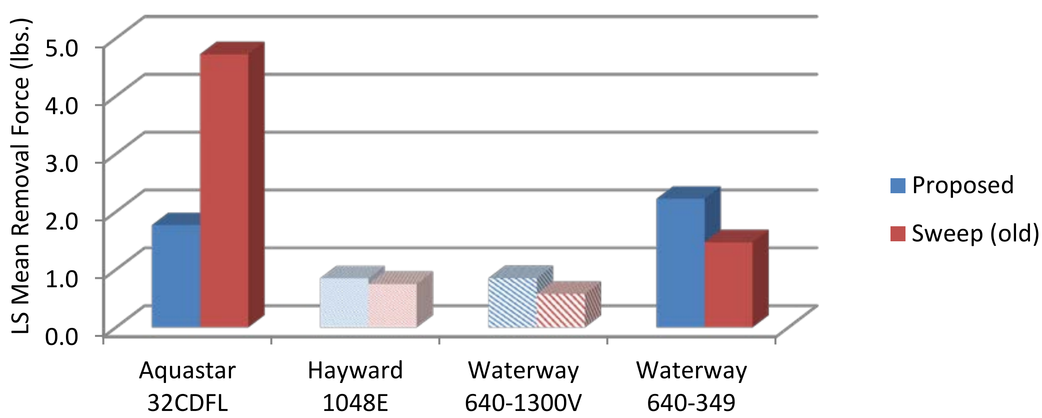
* Proposed "Force" versus "Speed".

<u>SOFA * Approach Method Interaction</u>

The proposed change to the test standard for approach method is from the sweep method to a worst case method. Figure 19 shows a graphical representation of the magnitude of estimates for the SOFA*Approach Method pairs with blue representing the proposed worst case approach method and red the current standard sweep method. Table 25 presents the least squares mean estimates for the eight SOFA*Approach Method combinations. For one of the SOFAs tested in the study, the Waterway 640-349, the worst case approach method resulted in a greater force estimate (more protective) as indicated by the solid bars, while for another SOFA (the Waterway 640-

1300V) a marginally greater force estimate was seen as indicated by the heavy hatched bars. However, the Aquastar 32CDFL yielded a significantly lower force estimate (less protective) as indicated by the solid bars while for the Hayward 1048E no significant difference was discerned as illustrated by the light hatched bars. Based on these results, it would appear for the ponytail hair samples that the proposed worst case approach method, taking SOFA into account, yields mixed results and could not be said to be consistently more protective.

Figure 19: SOFA * Approach Method



Note: Solid fill indicates a significant difference has been detected between Approach Methods for the specific SOFA. Heavy hatching indicates that there is marginal statistical evidence of a difference. Light hashing indicates that no significant difference was detected.

Table 25: Ponytail Sample - SOFA * Approach Method Interaction LS Means and P-Values

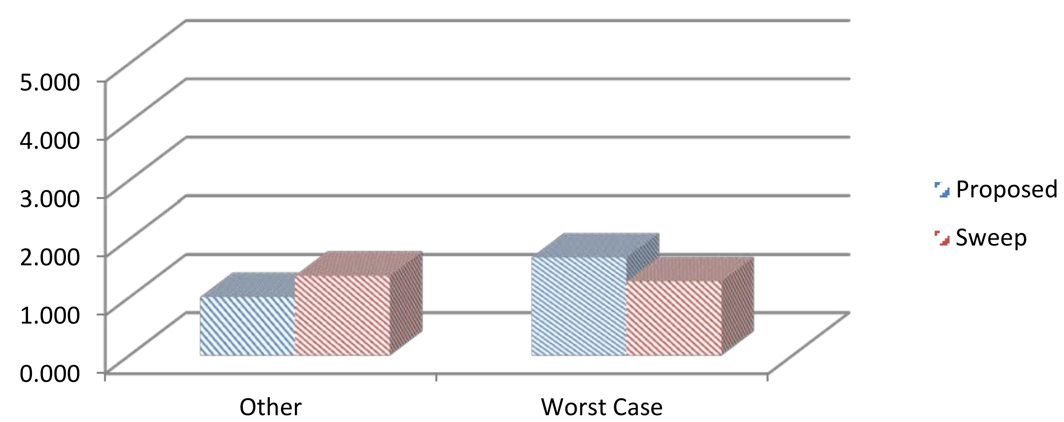
LS Mean	Proposed	Sweep	P-value	Difference*
Aquastar 32CDFL	1.770	4.726	0.0014	Significantly Lower
Hayward 1048E	0.850	0.751	0.5577	not significant
Waterway 640-1300V	0.852	0.577	0.0574	Marginally Greater
Waterway 640-349	2.225	1.473	0.0445	Significantly Greater

* Proposed versus "Sweep".

Target Position * Approach Method Interaction

Figure 20 shows a graphical representation of the magnitude of estimates for the Target Position *Approach Method pairs with blue representing the proposed worst case approach method and red the current standard sweep method. Table 26 below presents the least squares mean estimates for the four Pull Method*Approach Method combinations. The results are mixed, yielding one pairing a marginally greater force estimate, and the other pairing yielding a marginally lower force estimate. Marginally statistically significant differences are shown with heavy hatched bars in Figure 20. Based on these results, it would appear for the ponytail hair samples that the proposed worst case approach method, taking SOFA into account, yields mixed results and could not be said to be consistently more protective.

Figure 20: Target Position* Approach Method



Note: Heavy hatching indicates that there is marginal statistical evidence of a difference between Approach Methods for the given Target Position.

Table 26: Ponytail Sample – Pull Method * Approach Method Interaction LS Means and P-Values

LS Mean	Proposed	Sweep	P-value	Difference*
Other	1.002	1.367	0.0781	Marginally Lower
Worst Case	1.683	1.271	0.0788	Marginally Higher

* "Proposed" versus "Sweep".

Ponytail Sample – Model Results Summary

Table 27 summarizes the modeling results for the ponytail sample tests. Cells along the diagonal are the main effects results (e.g., the cell represented in the "Approach Time" column and the "Approach Time" row is the main factor effect for the Approach Time factor). Cells that contain information other than a dash ("-") is the summary of the interaction effect between the factor labeled in the column heading and the factor labeled in the row heading.

Table 27: Ponytail Sample – Summary of Model Results

Factor	SOFA	Approach Time*	Target Position*	Pull Method*	Approach Method*
SOFA	Differences[1]	Mixed[2]	n/a	Mixed[3]	Mixed[4]
Approach Time	-	Proposed	n/a	n/a	n/a
Target Position	-	-	Worst Case	n/a	Mixed[5]
Pull Method	-	-	-	Not signif.	n/a
Approach Method	-	-	-	-	Not signif.

* Identifies which standard is more protective (i.e., which standard resulted in some or all results significantly greater than the alternative. "Mixed" indicates inconsistent results. "Not signif." Indicates that no conclusion could be made.

1 – "Differences" indicates that there were statistically significant results observed between the SOFAs in the test.

2 – One SOFA*Approach Time combination was significantly greater, one was marginally lower, and the other two were not significant.

3 – Two SOFA* Pull Method combinations were significantly greater, one was marginally lower, and the other one was not significant.

4 – One SOFA* Approach Method combination was significantly greater, one was marginally greater, one was significantly lower and the other one was not significant.

5 – One Pull Method*Approach Method combination was marginally greater, one was marginally lower.

n/a – Not applicable. These interaction effects were not modelled as the effect was determined to not be significant (see Table 4).

Based on this summary, for the ponytail sample, it could be concluded that:

- There are differences between SOFAs estimates.
- The proposed approach time yielded inconsistent results, although the proposed 30-seconds approach time may be reasonable as the only contrary result was a marginally lower interaction result with one SOFA. Note, this differs from the findings for the full head sample.
- The pull method yielded mixed or inconsistent results and there does not appear to be sufficient evidence that the proposed change in the standard would provide an equal or more protective test,

- The proposed approach method also yielded mixed results and there does not appear to be sufficient evidence that the proposed change in the standard would provide an equal or more protective test.
- Target position results indicate that the "worst case" positioning would provide for a more protective test.

Body Block Element Analysis and Results

Body Block

For the body block element (BBE) study, only the body block size was varied. A proposed smaller body block was added to the study. The smaller BBE1 is sized according to the SOFA dimensions, up to the 18x23 BBE size. Because two SOFAs in the study have dimensions larger than 18x23, they were not tested with a smaller BBE, in keeping with the proposed requirements. For the BBE analysis, data from only two SOFAs could be used to test for differences in BBE size. The initial model included the two main effects and the single two-way interaction:

- SOFA
- BBE
- SOFA*BBE

For the body block element (BBE) study, only the body block size was varied. A proposed smaller 18" by 23" BBE (BBE1) was added to the study. But, since the proposed smaller size SOFA could not be tested with two of the SOFAs, only two SOFAs could be tested for differences with both BBE1 (proposed smaller element) and BBE2 (current larger standard). The regression model with pull force (log-transformed) as the dependent variable has two main factors (the SOFA model and the Body Block Element type) and one interaction effect, involving the SOFA model and the Body Block Element factors. Each of the factors and interactions are presented below.

Table 28. Statistically Significant Main Effects and Interactions in the Body Block Model

Effect	p-value
SOFA	<0.0001
BBE	0.3876
SOFA*BBE	0.0027

According to the model, the Body Block Element main effect is not significant but the interaction effect SOFA*BBE was significant which indicates that the Body Block Element plays a role in conjunction with the other variable in the model.

<u>SOFA Effect</u>

Figure 21 and the accompanying table (Table 29) shows, taking into account the other factors and interactions between factors, that the SOFA model does have a significant effect (p-value = < 0.0001). In the figure with the Hayward 1048E and the Waterway 640-1300V performing differently in the tests. Because they are long channel designs, the Aquastar 32CDFL and the Waterway 640-1300V could not be tested with the smaller Body Block Element (BBE1) and were, thus, left out of the analysis.

Figure 21: SOFA

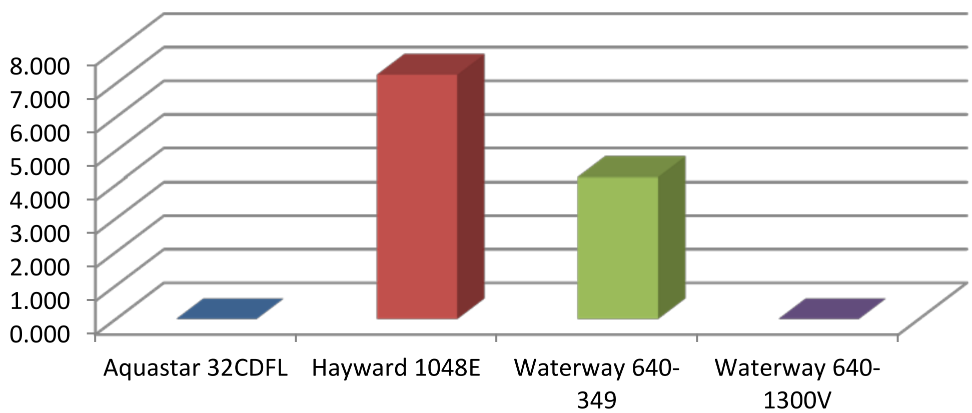


Table 29: BBE – Model Estimates: SOFA factor

SOFA	LS Mean Removal Force (lbs.)
Aquastar 32CDFL	n/a
Hayward 1048E	7.266
Waterway 640-349	4.223
Waterway 640-1300V	n/a
p-value	< 0.0001

Body Block Element Effect

Figure 22 and the accompanying table (Table 30) indicates that the Body Block Element does not have a significant effect (p-value = 0.3876). However, as will be seen later, the Body Block Element has a significant interaction effect on removal force so it has been kept in the model.

Figure 22: Body Block Element

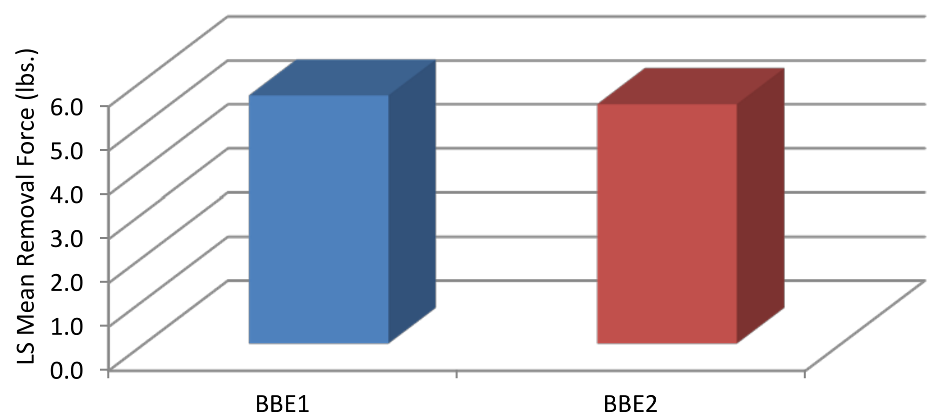


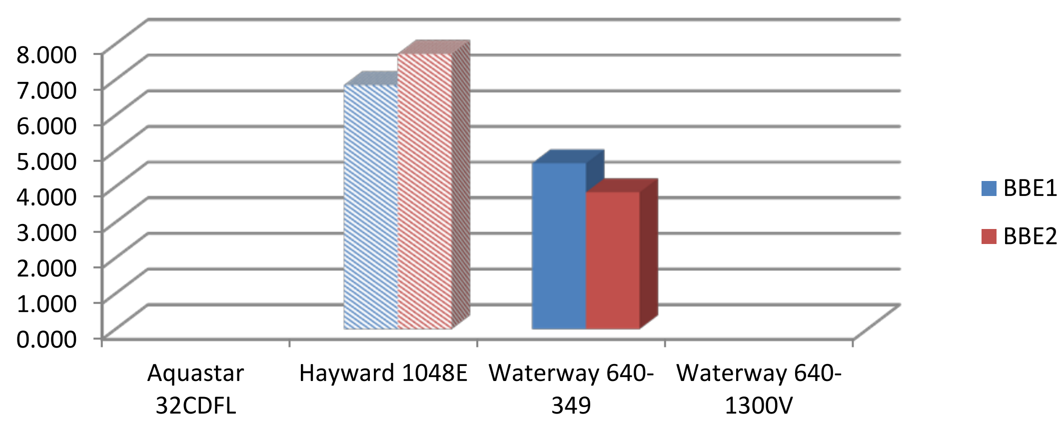
Table 30: Body Block Element – Model Estimates: BBE factor

Body Block Element	LS Mean Removal Force (lbs.)
BBE1	5.639
BBE2	5.442
p-value	0.3876

SOFA * Body Block Element Interaction

The proposed change to the test standard is to employ a smaller, perhaps, child-size body block element (BBE1). Figure 23 shows a graphical representation of the magnitude of estimates for the SOFA*BBE pairs with blue representing the proposed BBE1 and red the current standard larger BBE (BBE2). The solid fill indicates significant differences were observed (p-value < 0.05) while the heavy hash marking indicates marginal significance (p-value between 0.05 and 0.10). Table 31 below presents the least squares mean estimates for the eight SOFA*BBE combinations. For one of the four SOFAs tested in the study, the Waterway 640-349, the proposed BBE1 resulted in a statistically significant greater force estimate (more protective) as indicated by the solid bars while the other SOFA, the Hayward 1048E, resulted in a marginally significant lower force estimate (less protective) for BBE1 as indicated by the heavy hatched bars. Based on these results, it would appear for the body block element samples that the proposed smaller BBE1, taking SOFA into account, yields mixed results and could not be said to be consistently more protective.

Figure 23: SOFA * Body Block Element



Note: Solid fill indicates a significant difference has been detected between BBEs for the specific SOFA. Heavy hatching indicates that there is marginal statistical evidence of a difference.

Table 31: SOFA * Body Block Element Interaction LS Means and P-Values

LS Mean	BBE1	BBE2	P-value	Difference*
Aquastar 32CDFL	n/a	n/a	n/a	n/a
Hayward 1048E	6.840	7.719	0.0559	Marginally Lower
Waterway 640-349	4.649	3.836	0.0063	Significantly Greater
Waterway 640-1300V	n/a	n/a	n/a	n/a

Body Block Element Sample – Model Results Summary

Table 32 summarizes the modeling results for the body block element sample tests. Cells along the diagonal are the main effects results (e.g., the cell represented in the "Body Block Element" column and the "Body Block Element" row is the main factor effect for the Body Block Element factor). Cells that contain information other than a dash ("-") is the summary of the interaction effect between the factor labeled in the column heading and the factor labeled in the row heading.

Table 32: Body Block Element – Summary of Model Results

Factor	SOFA	Body Block Element*
SOFA	Differences[1]	Mixed[2]
Body Block Element	-	Not signif.

* Identifies which standard is more protective (i.e., which standard resulted in some or all results significantly greater than the alternative. "Mixed" indicates inconsistent results. "Not signif." Indicates that no conclusion could be made.

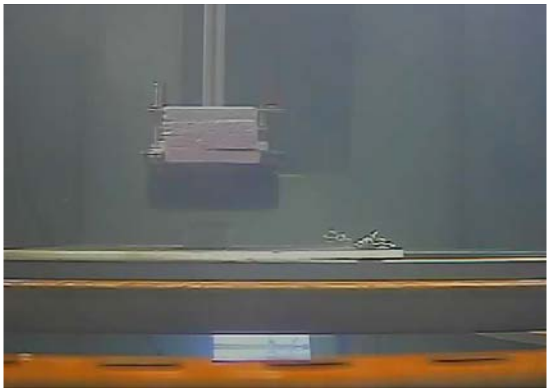
1 – "Differences" indicates that there were statistically significant results observed between the two SOFAs in the test.

2 – One SOFA*BBE combination was significantly greater, one was marginally lower.

Based on this summary, for the body-block element sample, it could be concluded that:

- There are differences between SOFAs estimates,
- The body-block element yielded mixed results in the SOFA interaction and no significant difference between body blocks as a main factor. Therefore, there does not appear to be sufficient evidence that the proposed change in the standard would provide an equal or more protective test.

Appendix 2: Images of Selected Tests



1. BBE1 Test, Centered on Spa SOFA (Run 93, Edge View)

2. Ponytail Test on Spa SOFA (Run 91, Side View)

3. Full Head Test on Spa SOFA (Run 117, Side View)

4. Full Head Test on 8" Round SOFA (Run 41, Side View)

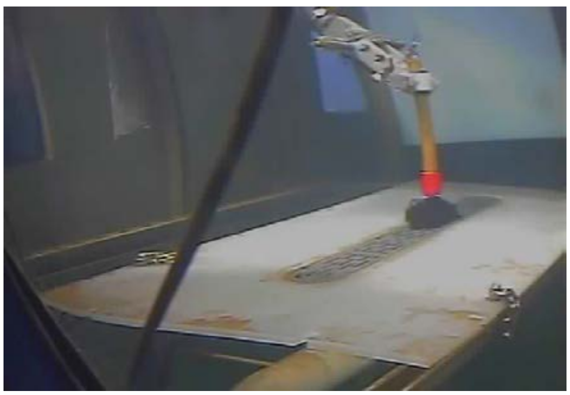
5. Full Head Test on 8" Round SOFA (Run 41, Top View)

6. Full Head Test on 8" Round SOFA (Run 41, Edge View)

Images of Selected Tests(continued)

7. Full Head Test on Domed Channel SOFA
(Run 177, Side View)

8. BBE2 Test, Angled on Domed Channel SOFA
(Run121, Side View)



9. Ponytail Test on Flat Channel SOFA
(Run 22, Side View)

10. BBE2 Test, Angled on Flat Channel
(Run 3, Top View)