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American National Standard for Flood Mitigation Equipment

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FOREWORD

NOTE: This foreword is introductory only and is not part of American National Standard FM 2510.

This standard is intended to be used to evaluate the components and performance of flood mitigation equipment.

This American National Standard has been developed by the canvass method of standards development of the American National Standards Institute (ANSI). FM Approvals is an ANSI-accredited standards developing organization (SDO).

Approval of an American National Standard requires verification by ANSI that the principles of openness and due process have been followed and that a consensus of those directly and materially affected by the standard has been achieved. Consensus requires that all views and objections be considered, and that a concerted effort be made toward their resolution. Consensus is established when, in the judgment of the ANSI Board of Standards Review, substantial agreement has been reached.

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1. INTRODUCTION

1.1. PURPOSE

1.1.1. This standard states the examination and test requirements for flood mitigation equipment for use in riverine, tidal, or rainfall related flood conditions.

1.2. SCOPE

1.2.1. This standard encompasses the design and performance requirements for flood mitigation equipment for use in controlling riverine tidal or rainfall related flood conditions. Flood mitigation equipment is categorized for specific flood protection applications which are designated by:

- Function (permanent or contingent)
- Operation (active or passive)
- For flood barriers, the intended application for protection (i.e., opening vs. perimeter)

1.2.2. This standard sets performance requirements for flood abatement equipment in the following product categories:

- Flood Barriers for Opening Barrier Applications
- Flood Barriers for Perimeter Barrier Applications
- Flood Mitigation Valves
- Flood Mitigation Pumps
- Penetration Sealing Devices

1.2.2.1. Flood glazing, as defined in Section 1.9, is considered a type of flood barrier that may be evaluated for opening barrier or perimeter barrier applications. The evaluation of flood glazing shall include the seal made between the glazing panel and the structural frame as well as the seal made between the frame and the structural opening.

1.2.2.2. For the purposes of evaluation to this Standard and applying the appropriate protocol, sluice gates, as defined in Section 1.9, are considered a type of flood barrier for opening barrier applications.

1.2.2.3. Penetration sealing devices include products used to seal the area around a surface penetration or the area within the penetration itself, the later which includes pipe plugs.

1.2.3. Flood barriers for opening barrier applications are evaluated and tested for quasi-static flood conditions.

1.2.4. Flood barriers for perimeter barrier applications are evaluated and tested for quasi-static and riverine flood conditions.

1.2.5. Flood barriers for coastal applications are not included in the scope of this Standard. Protection from tidal-related flood events is included in the scope of the Standard only for applications away from the coast where only quasi-static flood conditions are present.

1.2.6. Wind loading effects on flood barriers are not included in the scope of the evaluation. A full engineering analysis must be conducted by persons acceptable by the Authorities Having Jurisdiction (AHJ) to determine possible wind loading, as well as combined hydrostatic and wind loading, on a barrier structure.

1.2.7. The certification of flood barriers applies only at water levels up to the maximum depth rating, as identified on the product label. Water levels exceeding this amount are outside the scope of this certification.

1.2.8. Flood mitigation pump types included in the scope of this standard consist of submersible and pedestal type sump pumps as well as self-priming pumps.

1.2.9. Flood mitigation pumps are evaluated and Approved as pump packages only, complete with pump, driver, controller, coupling, and other components listed in Appendix C.

1.2.10. Certification to this Standard is limited to the flood mitigation product. Flood waters may produce high hydrostatic or hydrodynamic loading on a protected structure. Appropriate measures must be taken to ensure that an external wall structure (or similar) is able to withstand anticipated flood loading, including any site specific concerns. Some wall construction assemblies often are able to withstand 3 ft (0.9 m) or less of flood loading without needing reinforcement or additional waterproofing. A full engineering analysis must be conducted by persons acceptable by the Authorities Having Jurisdiction (AHJ).

1.2.11. In addition to the general design requirements specified in this Standard, local construction codes and/or agency regulations must also be considered in the design of a flood mitigation product or system.

1.3. BASIS FOR REQUIREMENTS

1.3.1. The requirements of this standard are based on experience, research and testing, and/or the standards of other organizations. The advice of manufacturers, users, trade associations, jurisdictions and/or loss control specialists was also considered.

1.3.2. The requirements of this standard reflect tests and practices used to examine characteristics of flood mitigation equipment. Flood mitigation equipment having characteristics not anticipated by this standard may be tested if demonstrated performance is equal or superior to that required by this standard, or if the intent of the standard is met.

Alternatively, flood mitigation equipment that has met all of the requirements identified in this standard may not be acceptable if other conditions which adversely affect performance exist or if the intent of this standard is not met. It is the sole discretion of the testing laboratory.

1.4. BASIS FOR ANSI SPECIFICATION

1.4.1. Certification is based upon satisfactory evaluation of the product and the manufacturer. Examination and tests on production samples shall be performed to evaluate:

- The suitability of the product
- The performance of the product as specified by the manufacturer
- The durability and reliability of the product

1.4.2. Since each flood mitigation system is unique in its operation and design, component testing shall be performed on a case-by-case basis. If deemed necessary, additional tests which are not included in this standard may be required at the discretion of the test laboratory.

1.4.3. A satisfactory evaluation of the flood abatement equipment's "Design, Installation, Operation and Maintenance Manual" is required. The evaluation shall be performed to ensure that the document is accurate and complete.

1.5. SYSTEM OF UNITS

Units of measurement used in this standard are United States (U.S.) customary units. These are followed by their arithmetic equivalents in International System (SI) units, enclosed in parentheses. The first value stated shall be regarded as the requirement. The converted equivalent value may be approximated. Conversion of U.S. customary units is in accordance with the Institute of Electrical and Electronics Engineers (IEEE)/American Society for Testing and Materials (ASTM) SI 10. Two units of measurement (liter and bar), outside of, but recognized by SI, are commonly used in the international scientific community and are used in this standard.

1.6. NORMATIVE REFERENCES

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the cited edition applies. For undated references, the latest edition of the referenced document (including any amendments) applies:

ASME Publications The American Society of Mechanical Engineers Three Park Avenue New York, NY 10016-5990 **www.asme.org**	ASME *Boiler and Pressure Vessel Code, Section VIII- Rules for Construction of Pressure Vessels, Division 1*

ASTM Publications American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959	ASTM A351 – *Standard Specification for Castings, Austenitic, for Pressure Containing Parts* ASTM B16 - *Standard Specification for Free-Cutting Brass Rod, Bar and Shapes for Use in Screw Machines* ASTM B117 – *Standard Practice for Operating Salt Spray (Fog) Apparatus* ASTM D412 – *Standard Test Methods for Vulcanized Rubber and Thermoplastic Rubbers and Elastomers – Tension* ASTM D395 – *Standard Test Methods for Rubber Property – Compression Set* ASTM D572 - *Standard Test Method for Rubber – Deterioration by Heat and Oxygen* ASTM D573 – *Standard Test Method for Rubber – Deterioration in an Air Oven* ASTM D1056 – Standard Specification for Flexible Cellular Materials – Sponge or Expanded Rubber ASTM D5602 – *Standard Test Method for Static Puncture Resistance of Roofing Membrane Specimens* ASTM G155 – *Standard Practice for Operating Xenon Arc Light Apparatus for Exposure of Non-Metallic Materials*
International Standards Organization 1 rue de Varembé Case Postale 56 CH-1211 Geneve 20 Switzerland	IISO 17025 – *General Requirements for the Competence of Testing and Calibration Laboratories*
United States Department of Transportation (D.O.T.) Washington, DC	*Code of Federal Regulations, Title 49, Transportation*, Parts 171 through 180

1.7. DEFINITIONS

For purposes of this standard, the following terms apply.

Accepted
This term refers to installations acceptable to the authority having jurisdiction and enforcing the applicable installation rules. Acceptance is based upon an overall evaluation of the installation. Acceptance is not a characteristic of a product. It is installation specific. A product accepted for one installation may not be acceptable elsewhere.

Active Flood Barrier or Flood Mitigation Product
A flood barrier or other flood mitigation product which requires human intervention for manual deployment. Active flood barriers or flood mitigation products may either be permanent or contingent.

Automatic Flood Barrier or Flood Mitigation Product
A permanent passive barrier or other flood mitigation product that automatically deploys without need for human intervention when flood conditions are detected. Types of automatic barriers may include, but are not limited to, buoyancy driven (horizontal or vertical) and (pneumatic or hydraulic activated by water sensors).

Backwater Valve
Backwater valves are a type of flood mitigation valve typically installed in drainage or sanitary systems and designed to prevent reverse flow into a protected structure and/or area. Standard flapper or swing type check valves are a common example. Backwater valves may be configured in either a normally open position or normally closed position and may be used for in-line or end of line applications.

Characteristic Curve
Graphic representation of the variation of a pump's outlet pressure (total head), efficiency and/or brake horsepower versus the pump's capacity at a constant speed. Multiple rated speeds may be represented with multiple curves on a single plot.

Contingent Flood Barrier or Flood Mitigation Product	A barrier or flood mitigation product that is not permanently installed and affixed to a structure and which requires some level of transportation and manual deployment. Some elements of the barrier/product may be permanently pre-installed (i.e. frame), but the main components are temporary and require manual deployment. Contingent flood barriers or flood mitigation products may only be classified as active protection
Deflection	The distance a flood barrier has moved from its original location during an applied force event. Deflection may be movement/displacement or distortion of the barrier structure itself. Permanent deflection is the distance the flood barrier has moved from its original location after the applied force is removed.
Deployment Time	The amount of time required for deployment and/or operation of an active flood mitigation product.
Dry-Side (or Land Side)	The side of a flood barrier or flood mitigation product that is protected from flood waters.
Flexible Rubber Type Valves	Flexible rubber type valves, also commonly referred to as duckbill check valves, are a type of flood mitigation valve which uses flexible rubber material to function as the valve mechanism. The position of the flexible rubber flap, or duckbill, is directly manipulated by the water and direction of flow. This provides for automatic open/close function resulting in flow only in the desired direction. Flexible rubber type valves may be constructed entirely of flexible rubber material or may be encased in a solid body.
Flood Doors	Any door, permanent or otherwise, which provides complete coverage of an exterior or interior door opening with the principle function of preventing flood waters into a structure.
Flood Glazing	A permanent, passive flood barrier constructed of reinforced glass material that is set and sealed within a structural frame. The frame is then installed and sealed within the structural opening. Flood glazing barriers may be configured as single panels (i.e. windows) or as multiple panels in a modular series to form a wall structure of the desired length. Flood glazing may also be installed within another permanent barrier structure such as a flood wall. Flood glazing may be used for opening barrier and/or perimeter barrier applications.
Flood Mitigation Pumps	A pump used for the removal of unwanted flood water. Types of flood mitigation pumps include but are not limited to submersible, pedestal, and self-priming pumps. Flood mitigation pumps may be utilized in one or more of the following applications; as part of a flood barrier system to remove water resulting from leakage past the barrier, permanently installed in a building as part of a water removal system (i.e. drainage system with sump), and/or a portable device used for removal of unwanted flood waters from a desired location.
Flood Mitigation Valve	This term refers to any style of valve that is used to mitigate the passage of water into a protected area during flood events. These products may be installed in-line or at the end of line outflow locations. Backwater valves are a type of flood mitigation valve. Other non-standard designs may also be utilized for this intended purpose, such as flexible rubber type valves.
Flood Panel Barrier	A flood barrier consisting of a large rigid panel(s) as the main structural element. During a flood event, the panel is manually affixed to a pre-installed barrier frame, or other pre-installed receiver components, at the location of deployment.
Flood Plank Barrier	A flood barrier consisting of multiple rigid planks which are guided through a vertical frame and stacked on top of each other to form a wall structure.
Leakage Rate	The rate at which water moves past or through a flood barrier or other flood mitigation product from the wet-side to the dry-side of the barrier, expressed as gallons per hour per linear foot (liters per hour per linear meter) length of seal.
Major Repair	A repair made to a flood barrier during the performance testing that requires changes to barrier design by the manufacturer.

Maximum Load	Maximum radial hydraulic load on the impeller of a flood mitigation pump at any point on the performance curve based on a specific gravity of 1.0. This usually occurs at the point of maximum total discharge head.
Maximum Power	The greatest speed-corrected power required to drive a flood mitigation pump at rated speed and at any point along its characteristic curve, and through the pumps total run out condition.
Minor Repair	A small repair made to a flood barrier during the performance test series. A repair will constitute as a “minor repair” only if; (1) the repair can be easily replicated by the end user, and (2) the Design, Installation, Operation, and Maintenance Manual instructs how to conduct the repair. If a minor repair becomes part of the deployment procedure in the Design, Installation, Operation, and Maintenance Manual, it will no longer be considered a repair.
Nationally Recognized Testing Laboratory (NRTL)	A laboratory which is listed and recognized by the United States Department of Labor, Occupational Safety & Health Administration’s (OSHA) Directorate of Science, Technology, and Medicine program. The program recognizes private sector organizations as NRTL’s, and recognition signifies that an organization has met the necessary qualifications specified in the regulations for the Program. The NRTL determines that specific equipment and materials ("products") meet consensus-based standards of safety to provide the assurance, required by OSHA, that these products are safe for use in the U.S. workplace.
Normally Closed Backwater Valve	A backwater valve designed in such a manner that when installed, the backflow prevention element remains closed until flow causes it to open.
Normally Open Backwater Valve	A backwater valve designed in such a manner as not to interfere with the movement of the air through the connected pipework. When installed, the backflow prevention element is in a normally open position.
Opening Barrier Applications	Applications in which a flood barrier is used to protect against water entering through an opening in a structure between two linear points (i.e. doorway, window, receiving bay, etc.). The barrier is supported by the permanent structure on both sides or along the full perimeter of the barrier/opening. Typical products used in opening barrier applications include flood doors, flood panels, and flood planks. Other products may include, but are not limited to, flexible membrane barriers, sluice gates, and flood glazing. Flood barriers certified for opening barrier applications are evaluated/tested to withstand quasi-static flood conditions.
Overtopping	The action of water flowing over the top of a flood barrier.
Passive Barrier or Flood Mitigation Product	A permanent barrier or other flood mitigation product that, after its initial installation, either requires no deployment or requires no human intervention for deployment. Examples of passive protection are engineered flood walls, flood glazing, penetration seals around pipes/cables, and automatic flood barriers. Passive barriers or flood mitigation products may only be classified as permanent.
Pedestal Pump	A pump that is comprised of; a pumping element in a sump, pit, or a low point, and a motor mounted on a column or pedestal extended vertically above the pumping element. The motor is not be exposed to the water in the sump, pit, or low point.
Perimeter Barrier	Applications in which a flood barrier is used to prevent flood water from entering an area surrounding a protected structure. Flood barriers evaluated for perimeter barrier applications may be contingent or permanent. The barrier is installed at some distance away from the protected structure allowing for additional flood mitigation methods (i.e. flood mitigation pumps) to be used to control any seepage before it reaches the protected structure. Perimeter barriers may be configured as a full perimeter wall or a terminating wall which may or may not be supported by a permanent structure. Flood barriers Approved for perimeter barrier applications are evaluated/tested to withstand quasi-static and riverine flood conditions.

Permanent Flood Barrier or Flood Mitigation Product	A barrier or flood mitigation product that is pre-installed and permanently affixed to a structure. Permanent barriers or flood mitigation products may or may not require manual deployment. Examples of permanent barriers requiring manual deployment include flood doors, hinged gates, sluice gates, etc.
Rated Capacity	The rate at which a flood mitigation pump delivers water, in gal./min. (L/min), at rated pressure and rated speed.
Rated Pressure	The outlet pressure in pounds per square inch - psi (kilopascals -kPa) developed by a flood mitigation pump when operating at rated capacity.
Riverine Flood Conditions	Flooding of or produced by a river causing water, debris and sediments to be transported onto a flood plain. Riverine flood conditions include various degrees of wave action and water currents, as well as the potential for large debris impact.
Seal	The location on a barrier where the product meets the ground or wall of the structure to prevent water from moving from the wet-side to the dry-side. A seal can also be made between different components or sections within a flood barrier. The linear length of seal, as determined based on the product type, is used for calculation of the leakage rate.
Self-Priming Pump	A flood mitigation pump which, when activated, will evacuate its passages of air and automatically draw in water to the suction side to commence pumping without the need for human intervention.
Shutoff Pressure	The net pressure in psi (kPa) developed by a flood mitigation pump at rated speed with zero flow.
Sluice Gate	A gate installed at the end of a sluice used to control water level and the flow from one area to another.
Structural Opening	Any opening where water can flow through such as doors, windows, air bricks/vent bricks, portals, garage entrance/loading dock entrance, etc.
Submersible Pump	A pump that consists of both the pumping element and the motor in a protective housing which allows the system to run properly when submerged in a liquid.
Sump Pump	A pump powered by an electric motor used for the removal of ground water drainage from a sump, pit or low point in a foundation. Types of sump pumps include, but are not limited to, pedestal and submersible.
Total Discharge Head	The gauge reading in psi (kPa) at the discharge of a flood mitigation pump converted to feet of liquid and corrected to the pump centerline elevation.
Total Dynamic Head	The difference between the total discharge head and the total suction head, or between the total discharge head and the total suction lift, whichever is applicable.
Total Suction Head	The gauge reading in psi (kPa) at the suction of a flood mitigation pump, converted to feet of liquid and corrected to the pump centerline elevation. This condition is present when the liquid supply level is above the pump centerline and the suction pressure is above atmospheric.

Total Suction Lift	The gauge reading in inHg (mmHg) at the suction of a flood mitigation pump, converted to feet of liquid and corrected to the pump centerline elevation. This condition is present when the liquid supply level is below the pump centerline and the suction pressure is below atmospheric.
Wet-Side (or River-Side)	The side of a flood barrier or flood mitigation product that is subjected to flood waters.

2. GENERAL INFORMATION

2.1. PRODUCT INFORMATION

2.1.1. Flood mitigation equipment is designated and categorized by function (permanent vs, contingent) and operation (active vs. passive). This standard defines protection with the following types of flood mitigation equipment.

- Flood barriers for perimeter barrier applications
- Flood barriers for opening barrier applications
- Flood mitigation valves
- Penetration sealing devices
- Flood mitigation pumps

2.1.2. In order to meet the intent of this standard, mitigation equipment shall be examined on a model-by-model, type-by-type, manufacturer-by-manufacturer, and plant-by-plant basis. This is predicated on the basis that identical designs, fabricated in identical materials by different manufacturers have been seen to perform differently in testing. Sample flood mitigation equipment, selected in conformance to this criterion, shall satisfy all of the requirements of this standard.

2.2. APPLICATION REQUIREMENTS

The manufacturer shall provide the following preliminary information that gives a full description of the construction of the flood abatement equipment. All documents shall identify the manufacturer's name, document number or other form of reference, title, date of last revision, and revision level.

Test programs will be scheduled only upon receipt of all material listed herein. All foreign language documents shall be provided with English translation.

2.2.1. Marketing/Ordering Literature - Showing general specifications and functions of the system.

2.2.2. Model Number Breakdown - A specification or drawing showing all system variations and options to be examined.

2.2.3. The Design, Installation, Operation, and Maintenance Manual.

2.2.4. Quality Control Procedures - Document(s) detailing routine testing and final inspection procedures: receiving inspection; in-process inspection; final inspection, and calibration of measuring and testing equipment used. In addition, procedures must detail the system acceptance testing once the flood mitigation equipment system is installed.

2.2.5. Documentation Control Specification - Proposed method of controlling critical documents which may be identified in the Documentation Section of the Test Report. These drawings shall be listed in the report issued at the conclusion of the test program. The testing laboratory shall be notified of changes to these documents.

2.2.6. Production Drawings - The following drawings shall be provided:

- Electrical schematic(s)
- Final assembly drawings and parts lists sufficient to detail primary components (all), operator controls, and their locations
- Complete set of mechanical drawings for all machined parts
- Complete part specifications (including manufacturer’s model numbers, size, ratings, etc.) for all purchased parts
- Specification sheets for all parts/components
- Drawings showing all construction details
- Product label drawing(s) showing all required marking information. The label drawing shall show the proposed label location on the equipment and artwork showing the manufacturer’s name, address, model and serial numbers, equipment ratings, and warning markings.

2.2.7. The number and location of manufacturing facilities.

2.3. REQUIREMENTS FOR SAMPLES FOR EXAMINATION

Sample requirements are to be determined by the testing laboratory following review of the preliminary information. Sample requirements may vary depending on design features and/or the results of any testing. It is the manufacturer's responsibility to submit samples representative of production. Any decision to use data generated utilizing prototype components or prototype systems is at the sole discretion of the testing laboratory.

3. GENERAL REQUIREMENTS

3.1. REVIEW OF DOCUMENTATION

During the initial investigation and prior to testing, the manufacturer's specifications, technical data sheets, and design details shall be reviewed to assess the ease and practicality of installation and use. The system and its components shall be capable of being used within the limits of the investigation.

3.2. PHYSICAL OR STRUCTURAL CONSTRUCTION FEATURES

3.2.1. Flood Barries for Opening Barrier and Perimeter Barrier Applications

3.2.1.1. All materials used in flood barriers shall be suitable for the intended application. Flood barrier components shall be constructed of corrosion resistant materials. When unusual materials are used, additional testing may be necessary to verify their suitability.

3.2.1.2. Flood glazing is considered a type of flood barrier that may be configured for opening barrier or perimeter barrier applications, and shall be evaluated as such.

3.2.1.3. Flood glazing shall be constructed with reinforced glass designed to crack but not shatter, when subjected to debris impact. The glass shall demonstrate the ability to withstand debris impact without compromising structural integrity while maintaining an acceptable amount of leakage.

3.2.1.4. Air / Nitrogen / other gas cylinder(s) for pressurized seal systems shall meet the applicable requirements of either the ASME Boiler and Pressure Vessel Code, Section VIII or Code of Federal Regulations, Title 49, Transportation, Parts 171 through 180; or equivalent national standard of the country of use, reference section 4.9.

3.2.1.5. Manually operated caps, valves, and other mechanisms required for proper functioning of the barrier, must have a securing, locking, and/or supervising component

3.2.1.6. The design of automatic barriers shall be such that major debris that could impact the barrier’s functionality is prevented from entering the system prior to deployment. Other debris shall be able to be flushed from the system during periodic maintenance

3.2.1.7. Automatic barriers shall have a method for manual deployment

3.2.1.8. Automatic barriers shall be evaluated for reliability when any component is exposed to an outside load condition (i.e. vehicular, personnel traffic, etc.) while in the open position. The manufacturer shall provide a complete analysis which illustrates the product’s ability to withstand any anticipated load conditions over the expected life of the barrier. The analysis shall include at a minimum; maximum deflection under load, permanent deflection based on simulated live loads, and a failure analysis of the deployment equipment. The analysis shall be reviewed for accuracy and completeness by the testing laboratory.

3.2.1.9. Flood barriers for opening barrier and perimeter barrier applications shall be constructed so as to be reasonably watertight and shall mitigate seepage to a level within the maximum requirement. Maximum seepage rates of flood barriers for opening barrier applications are provided in Appendix D for various opening widths and design water heights

3.2.2. Flood Mitigation Valves

3.2.2.1. Flood mitigation valves shall be designed and evaluated for in-line and/or end of line applications

3.2.2.2. Backwater valves designed to be normally closed shall be constructed that when the device is installed at the required 1:48 slope (1/4 in. per foot) with respect to the direction of flow, the check member will be in a closed position when no fluid is discharged. The valve shall be designed so that any solids accumulated under low flow conditions are flushed through the valve during full design flow conditions.

3.2.2.3. Backwater valves designed to be normally open shall be constructed that when the device is installed at the required 1:48 slope (1/4 in. per foot) with respect to the direction of flow, the check member will be in an open position but will close when fluid backflow occurs.

3.2.2.4. The internal working parts of a backwater valve, such as valve seat, flap, hinge pins, and stems, shall be copper alloy in accordance with ASTM B16, stainless steel in accordance with ASTM A351, or equally corrosion resisting material.

3.2.2.5. A backwater valve shall be designed and constructed that when installed in its proper operating position, the upper face of the device shall be parallel to the invert of the outlet so that the slope of the device can be readily determined by placing a level on the top of the face.

3.2.2.6. Flood mitigation valves shall be designed to provide access to working components for repair or replacement. The size of the access shall be based upon the requirements necessary to perform the repair or maintenance. The access cover shall be water and air tight once installed. This does not apply to flexible rubber type flood mitigation valves with no mechanical moving parts requiring maintenance and/or replacement.

3.2.2.7. Parts that are used to affect sealing in flood mitigation valves shall be secured in a manner that will maintain proper alignment of mating surfaces. Movement of any stationary parts shall not loosen or detach them during handling or operation of the unit. All seals and parts used to affect sealing shall be replaceable.

3.2.3. Flood Mitigation Pumps

3.2.3.1. Flood Mitigation Pump Packages

A flood mitigation pump manufacturer shall be able to supply the necessary pump accessories (See Appendix C) to provide a complete pump package installation. This responsibility includes control for: design, component sourcing, manufacturing, certification testing, production testing, proper operation and sizing of the pump and the accessories (Appendix C), quality control, and assembly locations.

3.2.3.2. Physical or Design Features

3.2.3.2.1. Connections to suction and discharge piping shall be made with flanged or threaded connections that are compliant to a recognized national or international standard. The use of other styles of connections will be at the sole discretion of the testing laboratory.

3.2.3.2.2. Manufacturers must provide a characteristic curve for each flood mitigation pump. Characteristic curves of discharge pressure (total dynamic head) vs. capacity shall be provided for all rated pump speeds. For submersible pumps, discharge pressure shall be in terms of total dynamic head. For self-priming pumps with suction lift capabilities, multiple performance curves shall be generated for varying degrees of suction lift, up to the maximum rated suction lift.

3.2.3.2.3. A flood mitigation pump shall have solids handling capability to protect against clogging caused by potential floating debris in flood waters. The solids handling capability, expressed as a maximum solid diameter, shall be clearly stated in the manufacturer's technical literature. Pumps shall be fitted with a means of protection from clogging by use of a strainer, or screening, sized to limit the maximum solid size entering the pump to within the stated capability.

3.2.3.2.4. Pump casings shall be designed for easy clean out/flushing in case of clogging, without the use of specialized tools.

3.2.3.2.5. Sealing at the pump shaft may be accomplished with either traditional packing, or mechanical seals.

3.2.3.2.6. Flood mitigation pumps shall be capable of turning on and off manually. In addition, pumps can have the capability of an optional automatic start and stop feature. Automatic operation shall turn on or off by responding to the appropriate water levels in a sump as indicated by the operation of a mechanical float switch, liquid level sensor, or pressure transducer.

3.2.3.2.7. Flood mitigation pumps shall be provided with a manual means for stopping the equipment. This may be located on the control panel on the assembly itself, or via a remote switch.

3.2.3.2.8. Flood mitigation pumps that may be installed in different orientations, shall be tested in each orientation, or it shall be stated which orientation for which the Approval has been granted.

3.2.3.2.9. Electrical devices used as part of a flood mitigation pump package intended for hazardous (classified) locations, requiring explosionproof or submerged service, the examination of electrical components is to include applicable Hazloc evaluations per applicable standards.

3.2.3.2.10. Submersible pumps require a minimum submergence level for continuous operation. Operation under conditions outside of this range may cause significant damage to the pump. Performance ratings for submersible pumps shall be in reference to the pump while at the minimum submergence level and minimum total suction head.

3.2.3.2.11. Self-priming pumps may be designed to utilize various means of drawing water into the pump casing. The manufacturer's literature shall clearly outline the proper operation of the equipment in order to establish prime within the pump. It shall also indicate the amount of lift that each model of pump can produce.

3.2.3.2.12. Skid mounted or frame encased units shall have lifting points clearly marked in order to avoid damage to the unit during transportation.

3.2.3.2.13. Trailer mounted units shall be identified as compliant for over the road travel, or not. All trailer mounted units shall be provided with adjustable supports that may be used to level the unit for operation.

3.2.3.2.14. In order to account for the application, flood mitigation pumps may be driven by electric motors or internal combustion engines.

3.2.3.2.15. Due to the range of pumps considered for flood mitigation applications, the requirements for internal combustion engine drivers have been written around the use of gasoline powered engines up to 15 hp, and diesel engines from 15 hp and larger. Evaluation of engines utilizing other fuels will be on a case-by-case basis at the sole discretion of the testing laboratory.

3.2.3.2.16. Internal combustion engines may be started either by electrical or mechanical means. Where practical, smaller internal combustion engines units with electric start shall also have a manual recoil starting method as a back-up in case of low battery level. Larger engines shall be fitted with an integral starter motor, storage battery, and alternator / generator as a means for cranking the engine.

3.2.3.3. Internal Combustion Engines – Gasoline Engines

3.2.3.3.1. Gasoline engines shall be designed to close-couple to the pump only.

3.2.3.3.2. A manual starting method shall be provided as a means to start the engine. Electric start is permitted, but only with manual recoil as a back-up means for starting the equipment. The addition of electric start shall also be accompanied by a starter motor, solenoid, battery provided to crank the engine, and a means to recharge the battery while the engine is running.

3.2.3.3.3. Gasoline engines may be provided as air cooled or liquid cooled. Any integral fans used to draw cooling air over the engine shall be guarded to provide protection for personnel operating the equipment. Liquid cooled engines shall be provided with a fill port and expansion reservoir in order to reduce the loss of primary coolant due to thermal expansion.

3.2.3.3.4. Gasoline engines may be provided as single speed, or with an adjustable throttle. If provided with an adjustable throttle, markings shall be provided to indicate the direction for increase and decrease of engine speed in proximity to the point of adjustment. Gasoline engines shall not be designed to operate above 3600 rpm.

3.2.3.3.5. Gasoline engines shall be internally lubricated with engine oil that is mechanically circulated throughout the engine. Oil fill and drain ports shall be readily identified either by color, marking, or symbol. The engine oil lubrication path shall pass through a readily replaceable engine oil filter that is readily identifiable, and requires no specialized tools to access or change during maintenance.

3.2.3.3.6. Gasoline engines shall draw their fuel from a fuel tank provided as part of the entire pump assembly. The fuel tank shall be mounted so that fuel is fed to the carburetor via gravity, or with a manual push bulb initial priming assistance. The fuel line between the storage tank and the carburetor shall have a quarter turn valve in it with markings for OPEN and CLOSE clearly marked. The fuel pick-up within the tank shall be located above the lowest point in order to reduce chances for debris making it into the combustion chamber or shall be fitted with a strainer / screen.

3.2.3.3.7. Gasoline engines shall draw their combustion air through a readily replaceable filter media in order to prevent air borne debris from entering the combustion chamber.

3.2.3.3.8. Gasoline engines shall be provided with a muffler to reduce the sound generated. The exhaust and muffler shall be guarded to provide protection from operators of the equipment.

3.2.3.3.9. Gasoline engines shall be designed for use in outdoor environments. Therefore, the electrical connections, air intake, and fuel system shall be designed to operate in dry and rainy environments.

3.2.3.4. Internal Combustion Engines – Diesel Engines

3.2.3.4.1. Diesel engines used with flood mitigation pumps are generally long-coupled to the pump shaft via a power transmission coupling or drive-shaft. Smaller diesel engines (1 or 2 cylinders) however can be supplied as close-coupled to the flood mitigation pump.

3.2.3.4.2. Diesel engines may be supplied as naturally aspirated, turbocharged, or twin turbocharged, and those fitted with after coolers.

3.2.3.4.3. This document does not address the National or Local Codes which require specific emission levels to be met by diesel engines.

3.2.3.4.4. Diesel engines shall be provided with electric starting as the primary means of cranking engines for all engines 3 cylinders and larger. All diesel engines with electric start shall be provided with starter motor, solenoid, storage battery provided to crank the engine, and means to recharge the battery when the engine is running. Single and dual cylinder close-coupled diesel engines may be provided with manual recoil starting as primary means of cranking the engine. Electric start is permitted on single and dual cylinder engines, but only with manual recoil as back-up means for starting the equipment.

3.2.3.4.5. Diesel engines shall be provided as liquid cooled or radiator cooled for all engines 3 cylinders and larger. All liquid cooled and radiator cooled diesel engines shall be provided with a fill port and expansion reservoir in order to reduce the loss of primary coolant due to thermal expansion. Any integral fans used to draw cooling air over the engine, across air heat exchanger, or through a radiator shall be guarded to provide protection for personnel operating the equipment. Single and dual cylinder close-coupled diesel engines may also be provided as air cooled.

3.2.3.4.6. Diesel engines shall be provided with an adjustable throttle for all engines 3 cylinders and larger. Markings shall be provided to indicate the direction for increase and decrease of engine speed in proximity to the point of adjustment. It shall be designed to provide positive locking for any setting. Single and dual cylinder close-coupled diesel engines may be provided as single speed, or with a manually adjustable throttle. Diesel engines shall not be designed to operate above 3600 rpm.

3.2.3.4.7. All diesel engines shall be internally lubricated with engine oil that is mechanically circulated throughout the engine. Oil fill and drain ports shall be readily identified either by color, marking, or symbol. The engine oil lubrication path shall pass through a readily replaceable engine oil filter that is readily identifiable, and requires no specialized tools to access or change during maintenance.

3.2.3.4.8. Diesel engines with 3 cylinders or more shall draw their fuel from a fuel tank provided as part of the entire flood mitigation pump assembly. For assemblies that do not rely on gravity feed of fuel to the engine, a fuel pump shall be provided. The fuel pickup shall not be at the lowest point within the fuel tank in order to reduce the chances of debris from entering into the combustion chamber. As an additional means of protection, fuel will be passed through a minimum of one filter prior to entering the engine. The fuel level shall be indicated either by mechanical fuel gauge or by electrical fuel gauge in the case of pump assemblies fitted with a control panel.

3.2.3.4.9. Diesel engines shall draw their combustion air through a readily replaceable filter media in order to prevent air borne debris from entering the combustion chamber.

3.2.3.4.10. Diesel engines with 3 cylinders or more shall be either provided with a muffler to reduce the sound generated, or shall state the requirements for a silencer if supplied by others. The exhaust and muffler shall be guarded to provide protection from operators of the equipment.

3.2.3.4.11. Diesel engines shall be designed for use in outdoor environments. Therefore, the electrical connections, air intake, and fuel system shall be designed to operate in dry and rainy environments.

3.2.3.4.12. Diesel engines with 3 or more cylinders shall be provided with an engine controller as part of the pump assembly. The engine controller shall provide the operator with the following minimum information and have the following construction features:

• A tachometer shall be provided to indicate the engine speed. The tachometer shall read zero when the engine is not running (or have no reading in the tachometer is digital) and engine battery power is supplied to the controller. If the tachometer is not of the totalizing type, a separate hour meter shall be provided to indicate total time of operation.

• An oil pressure gauge shall be provided to indicate the engine oil pressure.

• A temperature gauge shall be provided to indicate temperature of primary coolant loop for radiator cooled engines. An additional temperature sensor or switch shall be provided to signal an alarm if the primary coolant temperature exceeds manufacturers' predetermined limits.

• All control devices, starting and shutdown switches, and indicator lamps shall be located on the control panel.

• The control panel shall not be allowed to be used as a junction box or conduit for any wiring that is not part of the flood mitigation pump package.

• The control panel shall be located in an area that does not subject the operator to unreasonable hazards from hot surfaces, moving parts, or noise.

• The mounting of the control panel shall be able to withstand the forces associated with equipment transportation, operation, heat, and mechanical damage.

• The control panel shall have, as a minimum, a NEMA Type 2 dripproof enclosure or an enclosure with an ingress protection (IP) rating of IP X1.

• The wiring outside the control panel shall be harnessed, attached, protected and/or enclosed to minimize mechanical, thermal, or engine fluid damage. All electrical connections shall have positive locking mechanisms or screw terminals.

• A speed sensitive switch shall be provided to indicate the engine is running and to terminate the need to crank the engine.

• If the adjustable throttle is electronic, then it shall be either mounted within the engine control panel, or otherwise protected against unauthorized re-adjustment of the speed setting.

• If the engine operation parameters can be changed at the engine control panel, then it shall be either mounted inside the control panel, or be password protected to limit un-authorized changes.

• Engine control panels that contain microprocessors shall be capable of starting manually in the event of failure of any of the microprocessors.

3.2.3.4.13. All diesel driven flood mitigation pump models shall be marked with the allowable fuel specification on /near the fill port. While fuel storage size may vary by assembly design, the anticipated continuous run time for a given full tank of fuel at maximum flow shall be clearly marked on the unit. In addition, fuel level shall be indicated either by mechanical fuel gauge or by electrical fuel gauge in the case of assemblies fitted with control panel.

3.2.3.5. Electric Motors

3.2.3.5.1. Electric motors used in flood mitigation pump packages shall be designed per NEMA MG 1, IEC 60034-1, or equivalent. Functionally equivalent motors designed per other standards will be considered on a case-by-case basis. The manufacturer shall specify which standard is to be referenced, and certify that the motor used is in compliance with said standard, providing any supporting documentation requested to verify compliance.

3.2.3.5.2. The motor shall be sized (in horsepower or kilowatts) such that the maximum motor current in any phase under any anticipated condition of pump load and voltage unbalance does not exceed the motor rated full-load current multiplied by the motor service factor.

3.2.3.5.3. To protect against water ingress, electric motors for flood mitigation pump packages require a minimum rating equivalent to a NEMA open drip proof type or have a minimum IEC rating of IP22.

3.2.3.5.4. If applicable, eyebolts or equivalent lifting points shall be provided on the electric motor to lift the motor safely.

3.2.3.5.5. Electric motors used with flood mitigation pumps shall be provided with a protection device that will prevent damage to the electric motor in case of elevated temperature due to loss of cooling for the enclosure, or temperature rise due to locked rotor current draw. Activation of the device will open the input power circuit directly as a means to prevent damage from continued operation. The electric motor shall be able to be restarted only after the temperature has returned to within pre-determined range and the protection device closes, thus completing the power circuit.

3.2.3.6. Liquid Level Sensors

3.2.3.6.1. Liquid level sensors and switches used to provide ON/OFF signals for automatic operation of flood mitigation pumps may be the float type, mechanical float type, or transducers which react to static water pressure.

3.2.3.6.2. Liquid level sensors and/or switches may be directly assembled, or tethered, to the flood mitigation pump, or located within the water collection area.

3.2.3.6.3. Due to the environments where these devices are intended to operate, the liquid level sensor or switch may also need to be evaluated for ordinary locations, hazardous (classified) locations, or explosionproof as discussed in Section 3.2.3.2.9.

3.2.4. Penetration Sealing Devices

3.2.4.1. Penetration sealing devices shall be rated for a maximum nominal size of penetration (i.e. nominal pipe diameter).

3.2.4.2. Penetration sealing devices designed to seal the area around flexible cable shall have sufficient retention of the cable to prevent significant slippage. The design shall be such that applied forces to the cable do not affect the sealing capabilities.

3.2.4.3. All non-metallic materials used in penetration sealing device construction shall be resistant to deterioration or loss of sealing function under adverse conditions of temperature extremes, long term aging, and, if applicable, UV light exposure.

3.2.4.4. Penetration sealing devices may be permanent or contingent. Permanent or pre-installed metallic components (i.e. frames, structural components) shall be corrosion resistant, having resistance to corrosion equal to or exceeding that of bronze alloy having a minimum copper content of 80 percent, or constructed of Series 300 stainless steel.

3.2.4.5. Penetration sealing devices utilizing inflatable membrane materials shall be provided with a means for measuring fill pressure.

3.2.4.6. Permanently installed penetration sealing devices are susceptible to rodent damage over time, which may impact the product's sealing ability. The manufacturer shall detail periodic maintenance inspections which provide guidelines for assessment of rodent damage and whether the product needs to be replaced.

3.3. POST-INSTALLATION CHECKLIST

3.3.1. As it relates to all flood mitigation products with pre-installed components (permanent or contingent), the manufacturer shall be required to submit a post-installation checklist. This is to ensure proper installation of the product (or pre-installed components) by any installer, whether it be the manufacturer or a 3rd party contractor. Improper installation issues, such as gaps between the barrier and gaskets, gaps between the barrier and the structure, improper installation of frames, and others, may render the flood mitigation product completely ineffective or cause significantly higher leakage than is expected.

3.3.2. The post-installation checklist shall contain all critical aspects of the installation. The installer is to inspect and confirm all items on the checklist have been met after installation is complete in order to ensure proper operation and function of the product. The installer is to complete and sign off on the checklist, leave a copy on site, and send a copy back to the manufacturer to keep on file.

3.3.3. Review and acceptance of the post-installation checklist is to be considered a part of the examination. The test engineer shall review the checklist for accuracy and to ensure that all critical installation aspects are adequately represented.

3.4. COMPONENTS

At a minimum, components required for the flood mitigation equipment shall be designed for proper system functionality, and maximum long term reliability. Flood mitigation equipment designs should take into account the possibility of component failure and the potential for that failure to impair the effectiveness of the system. Such impairments shall be minimized through failsafe, redundant component, over-design, de-rating, or other means demonstrating equivalent reliability.

3.5. MARKINGS

3.5.1. A permanently-marked, legible, corrosion-resistant nameplate shall be securely attached to the equipment where practical and it shall be easily visible. The nameplate shall include the following information, at a minimum:

- Manufacturer's name or trademark
- Model identification

Additional marking requirements for flood barriers include:

- Maximum design water depth
- Approved application (opening or perimeter barrier applications)
- Fill pressure range (as applicable for products with inflatable seals)

Additional marking requirements for flood mitigation valves include;

- Maximum working pressure
- Maximum backpressure
- For plastic valves, the letters "ABS" or "PVC" (as applicable to the material of the valve body)
- Nominal size
- Direction of flow

Additional marking requirements for flood mitigation pump packages, permanently marked on a suitable data plate on the pump, shall include;

- Rated flow
- Rated head
- Speed
- Hertz
- Horsepower
- Voltage
- Amperage
- Phase
- Approximate continuous run time
- Maximum rated suction lift (if applicable)

Note: Pump performance shall be de-rated if it is paired with a driver that is not able to produce the speed and/or power required to operate the pump at full rated capacity.

Additional marking requirements for penetration sealing devices include:

- Maximum design water depth
- Maximum leakage rate
- Fill pressure range (as applicable for products with inflatable seals)

When a penetration sealing device design is such that permanently marking the product is impossible, all information included in the marking requirements shall be represented on a suitable label applied to the product container.

3.5.2. An automatic barrier shall be permanently marked with manual deployment instructions. Alternatively, the barrier's "Design, Installation, Operation, and Maintenance Manual" shall include instructions for manual deployment. The instruction manual must be permanently stored in an easily accessible location within close proximity to the barrier.

3.5.3. The marking for flood mitigation valves shall be located on the cover plate so that it is visible after the valve has been installed.

3.5.4. Any other pertinent marking information required by the referenced standards or other national or international standard to which the system is manufactured shall be permanently marked on a suitable data plate.

3.5.5. The model identification shall correspond with the manufacturer's catalog designation. The manufacturer shall not place this model identification on any other product.

3.6. MANUFACTURER'S DESIGN, INSTALLATION, OPERATION, AND MAINTENANCE MANUAL

The manufacturer shall provide complete instructions required to properly design, install, operate, and maintain a flood mitigation product or system. Such documentation shall be furnished by the manufacturer and submitted to the testing laboratory as a part of the examination.

At a minimum, the manufacturer's Design, Installation, Operation, and Maintenance Manual shall include the following:

- A description of the product and the parts/components needed for installation and/or operation/ deployment
- A procedure for installation of the product (as applicable), including pre-installed components

    The installation manual and operation manual may be separate documents

- A procedure for operation/deployment of the product (as applicable)
- Details regarding periodic maintenance required to ensure product function/performance
- Details regarding trouble shooting/repairs during deployment or flood conditions
- Guidelines for storage of barrier and/or components when not in use (as applicable)
- Reference Sections 4.2.1, 4.3.1, and 4.3.2 for additional details regarding requirements for deployment procedures related to flood barriers.

3.7. CALIBRATION

All examinations and tests performed in evaluation to this standard shall use calibrated measuring instruments traceable and certified to acceptable national standards.

The calibration of recently purchased new equipment is also required. Documentation indicating either the date of purchase or date of shipment, equipment description, model and serial number is required for identification. The period from the time the equipment was put into service to the date of testing must be within an interval that does not require the equipment to be calibrated as determined on the basis of the parameters mentioned above.

3.8. TEST FACILITIES

If review of all required information indicates suitability for testing, representative samples of the flood mitigation equipment for specific application will be scheduled. The range of component, material and performance tests shall be specified by the testing laboratory. If testing cannot be completed at the testing laboratory, the manufacturer shall provide facilities and all properly calibrated instrumentation required to perform these tests. The manufacturer shall also provide personnel to install, operate, and maintain the flood mitigation equipment. For testing not conducted at a testing laboratory, a representative of the testing laboratory shall witness all the tests and shall receive copies of the data and calibration certificates.

3.9. TOLERANCES

Tolerances on units of measure shall be as described in Appendix A, unless otherwise specified.

4. PERFORMANCE REQUIREMENTS

The performance requirements for flood mitigation equipment are composed of two different categories; General Component and Material Testing (Section 4.1) and Performance Testing (Sections 4.2 – 4.6). All flood mitigation equipment, and their applicable components, is subject to the General Component and Material Testing described in Section 4.1. In addition to this component testing, performance testing of the system/assembly is required as described in the performance test section (Sections 4.2 - 4.6) specific to the product category, as shown below in Table 4.

Table 4 – Applicable Performance Requirements

Product Category	**Applicable Test Sections**
Flood Barriers for Opening Barrier Applications	4.1, 4.3
Flood Barriers for Perimeter Barrier Applications	4.1, 4.2
Flood Mitigation Valves	4.1, 4.4
Penetration Sealing Devices	4.1, 4.5
Flood Mitigation Pumps	4.1, 4.6

4.1. GENERAL COMPONENTS AND MATERIALS TESTING - FLOOD MITIGATION EQUIPMENT

The components and materials of a flood mitigation product shall be examined and tested in accordance with this standard. However, not all tests within this section of the standard are applicable to every product design. In addition, if the design of a component or assembly cannot be adequately examined with the tests listed in this standard, additional testing may be necessary. Applicable tests will be determined at the sole discretion of the testing laboratory.

Component testing may be conducted on an individual component, component assembly, or as part of an entire flood mitigation system as deemed appropriate.

Material related testing may be waived at the discretion of the testing laboratory if prior testing has been completed by an OSHA Directorate of Science, Technology and Medicine certified NRTL (National Research and Testing Laboratory). Documentation shall be submitted demonstrating compliance to the requirements and confirmation that these tests have been carried out as described in the applicable ASTM Standard and completed with ISO 17025 calibrated equipment.

4.1.1. Examination

4.1.1.1. Requirements

Flood mitigation equipment shall conform to the manufacturer's drawings and specifications, and to the physical and structural requirements described in Section 3, General Requirements.

4.1.1.2. Test/Verification

Flood mitigation equipment and all its individual components shall be examined and compared to the manufacturer's production drawings and engineering specifications. All test samples shall be consistent with the drawings/specifications.

In addition, it shall be verified that the representative test samples conform to the physical and structural requirements described in Section 3, General Requirements.

4.1.2. Hydrostatic Test Strength

4.1.2.1. Requirements

Pressure retaining components or barriers, such as bladders, tubes, or inflatable seals shall withstand 150 percent of the maximum system operating pressure without rupture, cracking or permanent distortion and shall remain fully functional.

4.1.2.2. Test/Verification

Components or barriers shall be subjected to a hydrostatic test pressure of 150 percent of the maximum system operating pressure, for five minutes. Components or barriers subject to external stresses while pressurized (i.e. inflatable seals, inflatable pipe plugs or penetration seals) shall be pressurized while installed as intended. No rupture, cracking, or permanent distortion of the component is allowed. After the pressure test, the components or barrier shall be checked for proper functionality.

4.1.3. System Leakage Test

4.1.3.1. Requirements

Pressure retaining components susceptible to leakage such as caps, fill ports, and valves shall not leak when subjected to a hydrostatic test pressure of 120 percent of the maximum system operating pressure.

4.1.3.2. Test/Verification

Pressure retaining components shall be subjected to a hydrostatic test pressure of 120 percent of the maximum system operating pressure, while installed as intended in the flood mitigation system. Any observation of visible leakage shall be recorded.

4.1.4. Component Durability - Cycling

4.1.4.1. Requirements

Components with moving parts shall not show excessive wear or damage after 500 cycles of operations.

Permanent flood barriers with moving parts (i.e. flood doors and automatic flood barriers) shall be fully deployed and redeployed 500 times through their full range of operation. For automatic flood barriers which operate via subjecting the barrier to flood water, this cycle testing may be conducted by mechanical means.

4.1.4.2. Tests/Verification

The sample component or system shall be cycled 500 times through its full operational range; through its full open to close and close to open positions, or its full range of travel, etc. After cycle testing, the components or system shall be visually inspected for any signs of excessive wear or damage which would impair proper operation or function. If deemed necessary, the component or system shall be subjected to any of the appropriate tests outlined in this standard.

4.1.5. Vibration Resistance

4.1.5.1. Requirements

Components or assemblies containing moving parts susceptible to vibration shall withstand vibration without cracking, loosening, separation, or excessive wear, or other damage that would impair its proper operation or function. This test applies to permanently installed components including those in pre-installation assemblies.

4.1.5.2. Tests/Verification

One of each type of component assembly shall be installed and secured on a vibration table as it would be in its intended installation configuration. The orientation of the sample shall be so that the plane of vibration occurs along the plane that is deemed to be the most susceptible to vibration damage. If no such determination can be made, the sample shall be subjected to the vibration test conditions in all 3 planes.

The test samples shall be subjected to the vibration conditions outlined in Table 4.1.5. The frequency shall be continuously variable with a cycle period of 25±5 seconds. After one (1) hour If one or more resonant point(s) is detected, the component or component assemblies shall be vibrated for the remainder of the duration at such frequency(ies) for a period of time proportionate to the number of resonant frequencies. Otherwise the component or component assemblies shall be subjected to the variable frequency condition for the full 5 hour period.

Table 4.15 Vibration Conditions

Total Displacement/Stroke		***Frequency***	***Time***
Inch	***(mm)***	***Hz***	***Hours***
0.020	(0.51)	18 to 37 (variable)	5

4.1.6. Impact and Wear Resistance

4.1.6.1. Requirement

Plastic securement components which are susceptible to stress, and/ or an outside force during installation, construction, and or during the life span of the flood mitigation product shall not crack or show signs of degradation when subjected to applied stress and/or impact.

4.1.6.2. Test/Verification

A. Each plastic component susceptible to an applied force or torque shall be placed in a refrigeration chamber and exposed to a temperature of 10°F (-12°C) for a 24 hour period. The component(s) shall then be removed from the chamber and the maximum force or torque specified by the manufacturer shall be applied. The sample shall be visually inspected for any damage.

B. Each plastic component shall be placed in a refrigeration chamber and exposed to a temperature of 10°F (-12°C) for a 24 hour period. The component(s) shall then be removed from the chamber and impacted with a spherical steel weight dropped from a height necessary to produce an impact energy of 68 Joules (50 ft-lbf). Impact energy is calculated using the formula W*H, where "W" is the weight of the impact object and "H" is the drop height. The weight shall be dropped three separate times in three different locations and shall be prevented from impacting the test sample more than once for each drop. The sample shall be visually inspected for any damage.

4.1.7. Salt Spray Corrosion – Residue Build-Up

4.1.7.1. Requirements

Components or component assemblies with dissimilar metals shall not deteriorate, crack, fail, or lose functionality due to galvanic corrosion.

4.1.7.2. Test/Verification

Each component or component assembly shall be supported and oriented in its intended installation position. The sample(s) shall be exposed to salt spray (fog) as specified by ASTM B117, Standard Practice for Operating Salt Spray (Fog) Apparatus with the exception of the salt solution. The salt solution shall consist of 20 percent (by weight) of common salt (sodium chloride) dissolved in deionized water with a pH between 6.5 and 7.2 and specific gravity from 1.126 to 1.157.The sample shall be exposed for a period of 240 hours.

Following the exposure, the sample shall be removed from the test chamber and permitted to air dry for a two- to four-day drying period. Subsequently, the component shall be visually inspected to meet the stated requirements and, if deemed necessary, shall be subjected to any of the appropriate tests outlined in this standard.

4.1.8. Tensile Strength, Ultimate Elongation, and Tensile Set Tests

4.1.8.1. Requirements

Elastomeric components which are subjected to tensile type loading shall have a;

- Tensile strength of not less than 1500 psi (103.4 bar)
- Ultimate elongation of not less than 200 percent
- Tensile set of not more than 19 percent

Elastomeric parts constructed of silicone rubber material shall have a tensile strength of not less than 500 psi (34.5 bar) and at least 100 percent ultimate elongation.

Elastomeric parts constructed of open or closed cell expanded foam/cellular rubber materials are not applicable to this test.

4.1.8.2. Tests/Verification

Tensile strength, ultimate elongation, and tensile set shall be determined in accordance with ASTM D 412, Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers - Tension, Method A, with the following exceptions:

For tensile strength and ultimate elongation:

- If a test sample breaks outside the benchmarks or if the measured tensile strength or ultimate elongation is less than the required value; an additional test sample shall be tested and those results shall be considered final.
- It shall be acceptable for a test sample to break in the curved portion just outside the benchmarks if the measured strength and elongation values are within the minimum requirements.

For tensile set:

- The spacing of the benchmark shall be 3 in. (76 mm)
- The elongation shall be maintained for 3 minutes
- The tensile set shall be measured 3 minutes after the release of the specimen

4.1.9. Accelerated Aging Test

4.1.9.1. Requirements

A. Elastomer components other than open or closed cell expanded foam/cellular rubber materials shall not have less than 80 percent of the as-received tensile strength and 50 percent of the as-received ultimate elongation after accelerating the age of the material.

B. Elastomeric components constructed of open or closed cell expanded foam/cellular rubber materials which are subjected to compression type loading shall not have a compression deflection change of greater than ± 20% for open cell sponge type materials and ± 30% for closed cell expanded type materials, when comparing as-received and air-oven aged results.

4.1.9.2. Tests/Verification

A. Elastomeric Components (other than sponge or expanded rubber material):

Test samples shall be prepared in the same manner as for tensile strength and ultimate elongation tests outlined in Section 4.1.8, except that benchmarks spaced 1 in. (25 mm) apart shall be stamped on the specimens after the air oven exposure.

Test samples shall be exposed to 212°F (100°C) for 70 hours in accordance with ASTM D 573, Standard Test Method for Rubber - Deterioration in an Air Oven. After exposure, samples shall be tested in accordance with ASTM D 412, Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers C Tension. The results shall be compared to those obtained on the non-air oven aged samples for comparison and verification of the requirement.

B. Sponge or Expanded Rubber Material Subjected to Compression Type Loading:

Test samples shall be prepared in accordance with ASTM D1056, Standard Specification for Flexible Cellular Materials – Sponge or Expanded Rubber.

Test samples shall be exposed to 212°F (100°C) for 70 hours in accordance with ASTM D573, Standard Test Method for Rubber - Deterioration in an Air Oven. After exposure, samples shall be tested in accordance with ASTM D1056, Standard Specification for Flexible Cellular Materials – Sponge or Expanded Rubber. Compression deflection results shall also be obtained for non-air oven aged samples for comparison

4.1.10. Compression Set Test

4.1.10.1. Requirements

For elastomer components which are subjected to compression type loading, a compression set of the material in the as-received condition shall not be more than 20 percent.

For materials constructed of open or closed cell expanded foam/cellular rubber materials, the compression set shall not be more than 50 percent. Materials of this type exceeding this requirement shall be designated as one-time use only.

4.1.10.2. Tests/Verification

Testing shall be conducted in accordance with ASTM D 395, Standard Test Methods for Rubber Property C Compression Set, Method B. Type I specimens of the material shall be prepared and then exposed for 22 hours at 70°F ± 2°F (21°C ± 1°C).

In the case of open cell sponge type materials, testing shall be conducted in accordance with ASTM D1056, Standard Specification for Flexible Cellular Materials – Sponge or Expanded Rubber. ASTM D1056 makes reference to ASTM D395 but includes minor changes to the test specimen and test procedure.

4.1.11. Ultraviolet Light and Water Test

4.1.11.1. Requirements

Non-metallic components or sealant materials, exposed to outdoor environmental conditions either during standby or during deployment shall be exposed to ultraviolet light and water for 720 hours in accordance with Table X3.1, Condition 1, of ASTM G 155-05a, Standard Practice for Operating Xenon Arc Light Apparatus for Exposure of Non-Metallic Materials. At the conclusion of the test, there shall be no cracking or crazing of the component. Following exposure, all functions such as securement, adjustment, etc., shall operate properly.

4.1.11.2. Tests/Verification

A sample of each non-metallic component shall be exposed to ultraviolet light and water for 720 hours in accordance with Table X3.1, condition 1 of ASTM G155, Standard Practice for Operating Xenon Arc Light Apparatus for Exposure of Non-Metallic Materials. During each operating cycle, each sample shall be exposed to light and water spray for 18 minutes and to only light for 102 minutes (total 120 minutes). The air temperature within the apparatus during operations shall be 109 ± 4.5ºF (43 ± 2.5ºC) and the relative humidity 30 ± 5 percent. The component shall be inspected for cracking and crazing after 360 hours. If no cracking or crazing is apparent, the exposure shall continue for the full 720 hours. After testing, the barrier and/or components shall be visually inspected to meet the stated requirements and, if deemed necessary, shall be subjected to any of the appropriate tests outlined in this standard.

4.1.12. Air-Oven Aging Tests of Nonmetallic Components and Gasket Adhesives

4.1.12.1. Requirements

A. Non-metallic components, other than rubber gaskets, shall not deteriorate, crack or craze following air-oven aging exposure for 180 days 158°F (70°C).

B. All gasket adhesives used in barrier construction shall not deteriorate and lose their adhesive function, following air-oven aging exposure for 180 days at 158°F (70°C). The force required to separate the gasket from a representative sample of barrier material shall not decrease by more than 50%.

4.1.12.2. Test/Verification

A. Samples shall be subjected to an air-oven aging test for 180 days at 158°F (70°C), and then allowed to cool at least 24 hours in air at 74°F (23°C) at 50 percent relative humidity. After the test, the samples shall be inspected to meet the stated requirements and, if deemed necessary, shall be subjected to any of the appropriate tests outlined in this standard.

4.1.13. Environmental Corrosion Resistance (Barriers/Components which are Exposed to Environmental Conditions when Stored or Not in Use)

4.1.13.1. Requirement

Securement components or component assemblies shall be resistant to corrosion resulting from exposures to a moist carbon dioxide-sulfur dioxide-air mixture. Following the exposure period, the samples shall be examined for deterioration or failure to their functionality.

4.1.13.2. Test/Verification

Each component or component assembly shall be supported and oriented in its intended installation position. Each test sample shall be exposed to a moist carbon dioxide-sulfur dioxide-air mixture for a period of 10 days.

Sulfur dioxide and carbon dioxide are to be supplied to the test chamber from commercial cylinders. An amount of sulfur dioxide equivalent to one percent of the volume of the test chamber, and an equal volume of carbon dioxide shall be introduced into the chamber each day after the chamber has been purged. Approximately 0.53 gallons (2.0 liters) of deionized water shall be maintained in the bottom of the chamber.

Following the exposure, the samples shall be removed from the test chamber and permitted to air dry for a two to four-day drying period. Following this drying period, the component or component assembly shall meet the stated requirements and, if deemed, necessary, shall be subjected to any of the appropriate tests outlined in this standard.

4.1.14. Extreme Temperatures Operation (Barriers/Components which are Exposed to Environmental Conditions when Stored or Not in Use)

4.1.14.1. Requirements

A flood barrier or barrier component(s) that requires unfolding, unrolling, etc. to deploy shall operate properly after being exposed to extreme high and low temperatures. In addition, barrier gaskets under tension or compression shall not show signs of cracking or degradation.

4.1.14.2. Test/Verification

The test sample shall be submerged in water for 30 minutes. The sample shall then be conditioned in an environmental chamber set at -40 °F (-40 °C) for a period of 24 hours. Immediately upon removal from the chamber the test sample shall be tested for proper function.

The same test sample shall then be conditioned in an environmental chamber set at 130 °F (54.4 °C) for a period of 24 hours. Immediately upon removal from the conditioning chamber, the barrier and/or components shall be tested for proper function. Subsequently, the barrier and/or components shall be visually inspected to meet the stated requirements and, if deemed necessary, shall be subjected to any of the appropriate tests outlined in this standard.

4.1.15. Abrasion Resistance (Flood Barriers for Perimeter Barrier Applications)

4.1.15.1. Requirement

Membranes, shells, etc. shall be capable of resisting normal wear from anchoring components.

4.1.15.2. Tests/Verification

The test sample shall be orientated and set-up in the same manner as the end-use application. A Norton standard 5 x 2 x 1/2 in. (130 x 50 x 15 mm) nominal size abrasion wheel with the designation 37C36-KVK or equivalent shall be moved to and fro for 3000 cycles along the sample. The wheel shall be prevented from rotating and shall exert its full weight plus the weight of the moving arm, 1/2 lb (0.5 kg), on to the sample. The frequency of cycles shall not exceed 30 per minute. After the 3000 cycles, the sample shall be visually examined for any signs of wear or damage that would cause failure to the flood barrier.

4.1.16. Hail Resistance (Flood Barriers for Perimeter Barrier Applications)

4.1.16.1. Requirement

Membranes, shells, etc., including joints and seams of the membrane, shall show no signs of cracking, crazing, peeling, puncture, rupture or splitting when impacted from potentially damaging hail.

4.1.16.2. Test/Verification

A 2 ft × 4 ft (0.6 m × 1.2 m) test sample is placed on a panel support. The panel support is a 2 ft × 4 ft (0.6 × 1.2 m), outside dimension, box that is open on the top and bottom. The box is comprised of 1- 1/2 in. (38 mm) wide × 3-1/2 in. (89 mm) high wooden panels which are nailed together at its corners. The sample is secured to the box with self-drilling fasteners spaced 12 in. (305 mm) on center along its perimeter. A 1- 3/4 in. (45 mm) diameter steel ball is dropped onto the sample from a height of 17 ft 9- 1/2 in. (5.4 m). A minimum of ten drops of the steel ball is required, five of which shall be conducted on a fabricated seam. Subsequently, the sample shall be visually inspected to meet the stated requirements and, if deemed necessary, shall be subjected to any of the appropriate tests outlined in this standard.

4.1.17. Tear and Puncture Resistance Test (Flood Barriers for Perimeter Barrier Applications)

4.1.17.1. Requirements

An impermeable portion of a barrier (i.e. barrier membrane and any other non-metallic construction material that may come into contact with debris) shall be capable of withstanding the impacts from potentially damaging objects.

4.1.17.2. Tests/Verification

Testing shall be conducted in accordance with ASTM D5602 - Standard Test Method for Static Puncture Resistance of Roofing Membrane Specimens, with the following exceptions;

- The applied weight shall be 35 lbs (16 kg)
- The sample material shall be secured to each side of the test fixture using C-clamps or a similar device

After the test, the sample shall be examined for tears and/or punctures. Any damage that could result in a catastrophic failure of the barrier shall constitute a failure.

4.2. PERFORMANCE TESTING FOR PERIMETER BARRIER APPLICATIONS

The performance testing of flood barriers for perimeter barrier applications has been designed to simulate quasi-static as well as riverine flooding conditions including hydrostatic load, large waves, multiple debris impacts, strong currents, and overtopping conditions.

All tests in this section replicate events that can be anticipated during a single flood occurrence. As a result, all tests listed in Table 4.2 must be completed in sequence with the same barrier assembly.

Performance testing is typically conducted at a facility similar to the US Army Corps of Engineers, Engineering Research and Development Center (ERDC) Coastal and Hydraulics Laboratory, located in Vicksburg, Mississippi.

The design, description, and capabilities of the facility are described in Appendix B. Construction of the barrier must comply with the test set-up and constraints of the facility. Note: A special construction may be required to connect a barrier to the wing walls of the test basin. Leakage from this construction will be included in the test results. However, the construction is not required to be part of the design of the flood barrier. Additionally, special construction may be required for any pre-installed foundation components. Alternative test facilities may be accepted for testing at the sole discretion of the testing laboratory.

Major and minor repairs to the flood barrier during any portion of the performance test series are only allowed at the discretion of the testing laboratory. A major repair may require re-testing of the entire performance test series and/or additional testing. A maximum of three minor repairs shall be allowed, but may require adjustments to the barrier's Design, Installation, Operation, and Maintenance Manual. No repairs shall be allowed that can put facility personnel into harm's way.

Table 4.2 ***Test Series – Flood Barriers for Perimeter Barrier Applications***

Test Description	Water Condition(s)		Duration
	Water Depth*	Other	
Deployment	N/A	N/A	Per Manufacturer's Specification
Hydrostatic Load	1.0 ft (0.30 m)	N/A	22 hr
	2.0 ft (0.61 m)	N/A	22 hr
	100 percent x h	N/A	22 hr
Wave-Induced Hydrodynamic Load	66.7 percent x h	low waves 2-3 in (51-76 mm)	7 hr
	66.7 percent x h	medium waves 6-8 in (152-203 mm)	10 min (3 times)
	66.7 percent x h	high waves 10-12 in (254-305 mm)	10 min
	80 percent x h	low waves 2-3 in (51-76 mm)	1 hr (min) - 7 hr (max)
	80 percent x h	medium waves 6-8 in (152-203 mm)	10 min (3 times)
	80 percent x h	high waves 10-12 in (254-305 mm)	10 min
Overtopping	≥1 in (25 mm) overflow	N/A	1 hr
Debris Impact	66.7 percent x h	12 in (30 cm) diameter log 610 lb (277 kg) weight at 7 ft/s (2.13 m/s)	N/A
	66.7 percent x h	17 in (43 cm) diameter log 790 lb (358 kg) weight 7 ft/s (2.13 m/s)	N/A
Current	66.7 percent x h	7 ft/s (2.13 m/s) current	1 hr
Post Hydrostatic Load	100 percent x h	N/A	1 hr (min) - 22 hr (max)

* The manufacturer's specified maximum design water depth for the barrier is defined as "*h*".

At the discretion of the testing laboratory, the maximum deflection requirement, included as part of each test in the test series, may be waived for certain barrier designs where distortion beyond the requirement is expected and does not affect overall barrier stability or function. Deflection measurements may be taken at the conclusion of the series, after the water has been drained from the basin, to demonstrate no permanent distortion or displacement.

4.2.1. Deployment

4.2.1.1. Requirements

The barrier system shall be deployed within the construction base area as described in Appendix B. The barrier's Design, Installation, Operation, and Maintenance Manual shall be verified for accuracy and completeness of the deployment process. The following items related to the barrier's deployment shall be confirmed:

4.2.1.1.1. Barrier Packaging

No cracks, tears, or other damage that may have occurred during shipping shall be visible. At the discretion of the testing laboratory, minor repairs maybe allowed (i.e. repositioning of a seal). If minor repairs are required, the manual shall include details on how to identify and repair the damage prior to deployment.

4.2.1.1.2. Material, Tools, and Equipment Required

The manual shall include a list of all the materials, tools, and equipment used during the unpacking and deployment of the barrier. In addition, the manual shall indicate if the materials, tools, and/or equipment are supplied or not supplied with the barrier.

4.2.1.1.3. Person-Power Requirements

The manual shall include the number and skill level of the personnel required to deploy the barrier as described below:

- Skilled personnel; a person with specific knowledge of the deployment method of the barrier
- Unskilled personnel: a person that has no knowledge of the barrier design or deployment
- Heavy machine operator

4.2.1.1.4. Deployment Time

The deployment time shall be equal to or less than the time listed in the manual. The deployment time shall be measured in terms of personnel requirements, total man-hours, and length of the barrier.

4.2.1.1.5. Deployment Procedure

The manual shall clearly detail all steps for the deployment of the barrier. The procedure shall be written in such a way so that it can be readily understood by a person with no prior knowledge of the barrier design or deployment.

4.2.1.1.6. Additional Deployment Requirements

The manual shall adequately detail any of the following deployment requirements if identified by the manufacturer and/or preformed during the deployment test process:

- Special construction considerations
- Application limitations
- Foundation requirements
- What to do if damage should occur during deployment

4.2.1.1.7. Barrier Reusability

The manual shall indicate if that barrier is suitable for multiple uses. If multiple use is indicated then the manual shall contain a procedure for how the barrier shall be disassembled and restored to a similar pre-test condition.

4.2.1.2. Tests/Verification

Document the unpacking and deployment of the barrier with a video camera while simultaneously reviewing the Design, Installation, Operations, and Maintenance Manual. At the completion of the deployment, compare the video recording to the manual to assure that all of the requirements listed in Section 4.2.1.1 have been properly documented. The manual must be corrected of any inaccuracies and/or missing information.

If the barrier is reusable, document and verify the disassembling procedure at the completion of the performance testing in the same manner as the deployment, Section 4.2.1.

4.2.2. Hydrostatic Load

4.2.2.1. Requirements

Flood barriers for perimeter barrier applications barrier shall be capable of withstanding the hydrostatic loads created by floodwaters of various heights. The leakage rate shall not exceed 15 gallons per hour per foot length (186 liters per hour per meter length), where the barrier's length is measured along the center point of the barrier's seal to the ground.

In addition, the permanent deflection of the barrier shall be less than or equal to 6 in. (15 cm), as measured from the horizontal and vertical center of each wall.

4.2.2.2. Tests/Verification

Conduct three different hydrostatic load tests at the following water heights;

- 1 ft ± 0.5 in (0.30 m ± 13 mm)
- 2 ft ± 0.5 in (0.61 m ± 13 mm)
- 100 percent x h ± 0.5 in (13 mm)

Where “h” is the manufacturer’s specified maximum design water depth of the barrier. If this water depth is less than or equal to 2.0 ft, the tested water depths may be changed as deemed appropriate by the testing laboratory.

Fill the wet-side of the basin to the desired water level at a maximum rate of 2/3 ft (10.0 cm) per hour. The desired water level shall be held for a minimum of 22 hours at each water depth specified above.

The leakage rate shall be calculated in intervals no greater than 15 minutes at the following times (at a minimum);

- During the filling process
- During the first hour
- During the last two hours

Measure the barrier’s deflection from the horizontal and vertical center of each wall (three locations) at the completion of each test. Additional locations (up to 6 total) shall be required if deemed appropriate for the design of the barrier.

The Hydrostatic Load Test at a water depth of 100 percent x “h” shall be repeated subsequent to the Current Test, as a post test to the Overtopping, Debris Impact, and Current Tests. The test duration for the post test shall be 1 hour, at a minimum. If negative effects (i.e. increased leakage rates or deflection measurements) are observed during the first hour of the post test, then the post test shall be conducted for a maximum of 22 hours.

4.2.3. Wave-Induced Hydrodynamic Load

4.2.3.1. Requirements

Flood barriers for perimeter barrier applications shall be capable of withstanding wave-induced hydrodynamic load conditions from various water depths and wave heights. The permanent deflection of the barrier shall be less than or equal to 6 in. (15 cm), as measured from the horizontal and vertical center of each wall.

In addition, during low wave conditions, the leakage rate shall not exceed 15 gallons per hour per foot length (186 liters per hour per meter length), where the barrier’s length is measured along the center point of the barrier’s seal to the ground.

There is no leakage rate requirement for medium and high wave conditions. However, during these wave conditions the barrier shall not fatigue, experience fill-loss, wall sliding, overturning, or other permanent deflection in excess of the requirement.

4.2.3.2. Tests/Verification

Six tests shall be conducted; consisting of three different size wave heights (low, medium, and high) at each of the following two still water depths:

- 66.7 percent x h
- 80 percent x h

Where “h” is the manufacturer’s specified maximum design water depth of the barrier. If this water depth is less than or equal to 2.0 ft, the tested water depths may be changed as deemed appropriate by the testing laboratory.

Drain the wet-side of the basin to the desired water level, or fill the wet-side of the basin at a maximum rate of 2/3 ft (10.0 cm) per hour, as applicable.

Impact the barrier with waves generated perpendicular to the face of the center wall of the barrier as detailed in Table 4.2.3.2.

At the end of each test condition, allow the waves to dissipate before starting the next test.

Table 4.2.3.2 Wave Spectrums

Wave Description	*Wave Height (Measured from trough to crest)*	*Mean Wave Period*	*Test Duration*
Low Waves	2-3 in (51-76 mm)	2 seconds	7 hr*
Medium Waves	6-8 in (152-203 mm)	2 seconds	10 min (3 times)
High Waves	10-12 in (254-305 mm)	2 seconds	10 min

*For a water depth of 80 percent x h, if no negative effects are observed during the first hour of testing (i.e. increased leakage rates or deflection measurements), the test duration may be reduced to 1 hour.

Measure the leakage rate for the duration of each low wave test at intervals no greater than 15 minutes.

Measure the barrier's deflection at the completion of each test from the horizontal and vertical center of each wall (three locations). Additional locations (up to 6 total) shall be required if deemed appropriate for the design of the barrier.

4.2.4. Overtopping

4.2.4.1. Requirements

Flood barriers for perimeter barrier applications shall not float, overturn, or experience catastrophic failure if the water level of a flood exceeds the height of the barrier.

In addition, the permanent deflection of the barrier shall be less than or equal to 6 in. (15 cm), as measured from the horizontal and vertical center of each wall.

4.2.4.2. Tests/Verification

Fill the river-side of the basin at a maximum rate of 2/3 ft (10.0 cm) per hour until the water level equals 100 percent of structure height plus one inch. Maintain the water level for one hour.

At the completion of the test, measure the barrier's deflection from the horizontal and vertical center of each wall (three locations). Additional locations (up to 6 total) shall be required if deemed appropriate for the design of the barrier.

4.2.5. Debris Impact Test

4.2.5.1. Requirements

Flood barriers for perimeter barrier applications barrier shall be capable of withstanding multiple impacts from floating debris. The leakage rate shall not exceed 15 gallons per hour per foot length (186 liters per hour per meter length), where the barrier's length is measured along the center point of the barrier's seal to the ground.

In addition, the permanent deflection of the barrier shall be less than or equal to 6 in. (15 cm), as measured from the horizontal and vertical center of each wall.

4.2.5.2. Tests/Verification

Drain the wet-side of the barrier until the water level equals 66.7 percent x h ± 0.5 in (13 mm), where *h* is the manufacturer's specified maximum design water depth.

Two tests shall be conducted with two different size logs; 12 in. (30 cm) and 17 in. (43 cm) in diameter, 610 lb (277 kg) and 790 lb (358 kg) in weight respectively. The logs shall be southern pine or similar density and conditioned by submerging in water for a minimum of 2 weeks prior to testing. The cut edges of the logs shall be perpendicular saw-cut with no round edges.

Each floating log shall be pulled into the center wall of the barrier with a velocity of 7.0 ft/s (2.1 m/s) [~5.0 mph (8.0 km/h)] at a trajectory angle of approximately 70 degrees, see Figure 4.2.5.2. The pulling action shall be shut-off immediately prior to the log's impact to the barrier.

Measure the leakage rate during each test at intervals no greater than 15 minutes.

At the completion of each test, measure the barrier's deflection from the horizontal and vertical center of each wall (three locations). Additional locations (up to 6 total) shall be required if deemed appropriate for the design of the barrier.

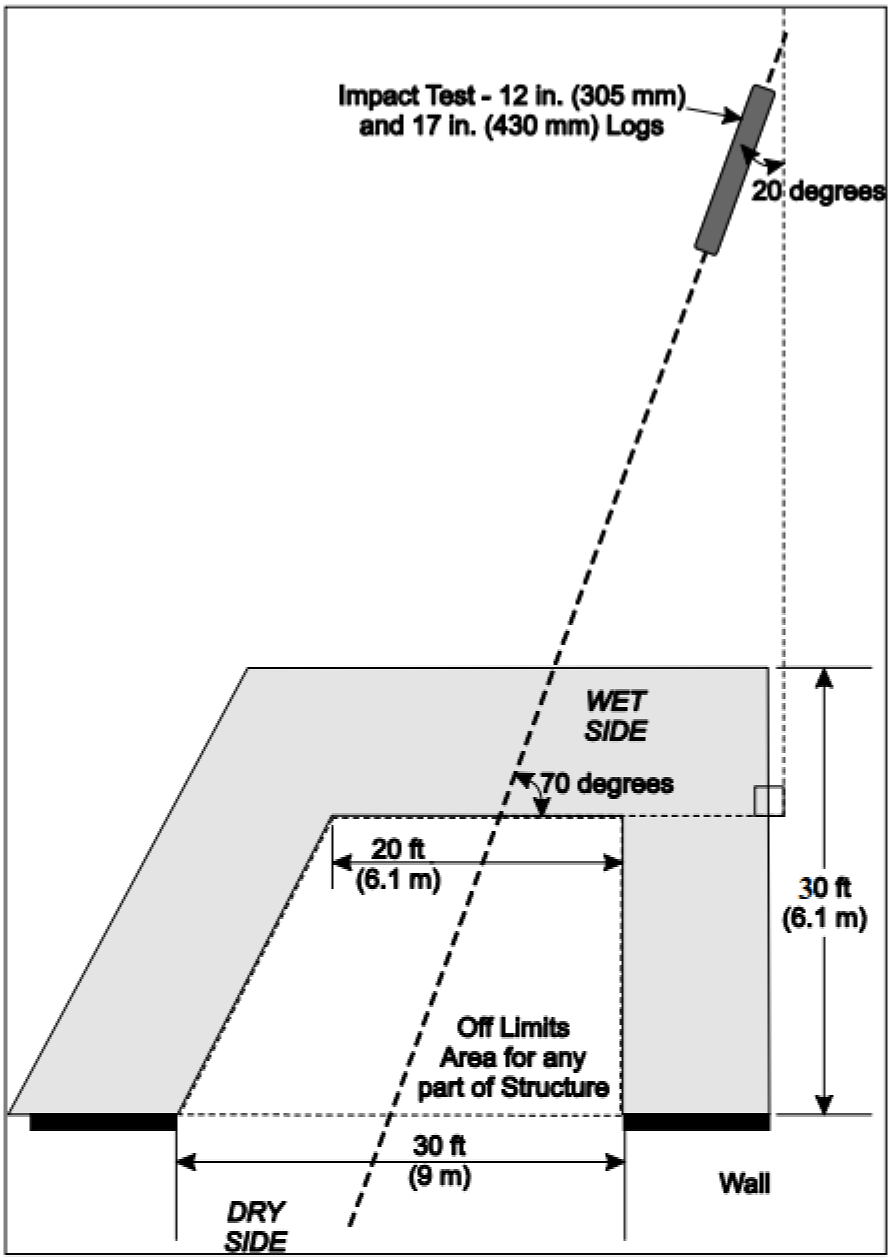

Figure 4.2.5.2 Debris Impact Test Layout

4.2.6. Current Test

4.2.6.1. Requirements

Flood barriers for perimeter barrier applications shall be capable of withstanding forces created by a 7.0 ft/s (2.1 m/s) current. The leakage rate shall not exceed 15 gallons per hour per foot length (186 liters per hour per meter length), where the barrier's length is measured along the center point of the barrier's seal to the ground.

In addition, the permanent deflection of the barrier shall be less than or equal to 6 in. (15 cm), as measured from the horizontal and vertical center of each wall.

4.2.6.2. Tests/Verification

Testing shall be conducted at a water height of 66.7 percent h ± 0.5 in (13 mm), where h is the manufacturer's specified maximum design water depth. A minimum channel width of 6 in. (15 cm) should be created for the water flow. Current shall be applied parallel to the face of the barrier. The water velocity shall be slowly increased to 7.0 ft/s (2.1 m/s) [~5.0 mph (8.0 km/h)] and then maintained steady for a duration of 1 hour.

The water velocity shall be measured at 50 percent of the water depth approximately 6 in. (15 cm) from the front face of the barrier, and the horizontal midpoint of the section of barrier exposed to the current; or 1/2 the distance from the barrier to the wall, which ever is less.

Measure the leakage rate for the duration of the test at intervals no greater than 15 minutes.

At the completion of the test, measure the barrier's deflection from the horizontal and vertical center of each wall (three locations). Additional locations (up to 6 total) shall be required if deemed appropriate for the design of the barrier.

4.3. PERFORMANCE TESTING – FLOOD BARRIERS FOR OPENING APPLICATIONS

The performance testing of flood barriers for opening barrier applications has been designed to simulate quasi-static flood conditions. All tests in this section must be completed in sequence as shown in Table 4.3, with the same flood barrier system.

If the product under evaluation is available in a range of sizes, a worst case system representing the maximum protected opening width shall be tested to the manufacturer's maximum design water depth. Depending on design consistency across size ranges, testing of the worst case may allow for smaller sizes to be considered for certification with little or no further testing.

If a barrier is submitted for modular configurations having intermediate support mullions (or similar) between multiple barrier sections, a minimum of two sections with one intermediate support shall be performance tested. Approval will be restricted to the maximum width measured between each section (between one edge and the intermediate support). Single-span configurations shall also be tested if the maximum width of the single-span configuration exceeds the maximum section width of the modular configuration

Table 4.3 *Performance Test Series – Flood Barriers for Opening Barrier Applications*

Test Description	***Condition****	***Duration***
Deployment	N/A	Per Manufacturer's Specifications
Hydrostatic Load	10 percent x h ± 0.25 in (0.6 cm)**	2 hr
Hydrostatic Load	100 percent x *h* ± 0.25 in (0.6 cm) **	20 hr
Redeploy	Disassemble and redeploy	Per Manufacturer's Specifications
Dynamic Impact Load	Water drained, two 600J impacts (minimum)	N/A
Post Hydrostatic Load	10 percent x h ± 0.25 in (0.6 cm)**	1 hr
Post Hydrostatic Load	100 percent x h ± 0.25 in (0.6 cm)	1 hr

*The manufacturer's specified maximum design water depth for the barrier is defined as "h."

** Hydrostatic load testing may be required at additional water depths, at the discretion of the testing laboratory, if the design of the barrier is such that increased leakage may occur at other depths besides those prescribed above. Additional water depths shall be tested for a minimum duration of 1 hr. Hydrostatic Load testing at 10 percent x h may be waived if the design of the barrier is such that compression forces applied by the water column do not influence the barrier's sealing capabilities.

The tests shall be conducted with a test enclosure that is capable of withstanding the maximum design water depth without significant leakage. A method to maintain the water level at the required depths within the specified degree of accuracy throughout the specified durations shall be established. Some leakage through the test enclosure is permitted provided that the tested water depth is able to be maintained. The test enclosure must be of sufficient size to accommodate the requirements for each test procedure outlined in this performance test series.

Major and minor repairs to the flood barrier during the performance test series are only allowed at the discretion of the testing laboratory. Up to a maximum of three minor repairs are allowed. In addition, each minor repair may require adjustments to the barrier's Design, Installation, Operation, and Maintenance Manual. Any major repair may require retesting of the entire performance test series and/or additional testing. No repairs shall be allowed that can put facility personnel into harm's way.

4.3.1. Pre Deployment Installation Configurations

4.3.1.1. Requirements

The installation of barrier components which are designed to be permanently installed in the protected opening prior to barrier deployment (i.e. frames, tracks, etc.) does not require to be witnessed by FM Approvals. However, the barrier's Design, Installation, Operation, and Maintenance Manual shall include reference to each possible installation configuration and shall be verified for accuracy and completeness (see Section 3.3). These documents shall be furnished prior to the commencing of the test series.

When multiple installation configurations exist, (i.e. externally mounted to a structure, internally mounted to a structure, door jamb mounting, etc.), the performance test series shall be conducted on all configurations desired for certification.

4.3.1.2. Tests/Verification

Verify that the barrier's manual and post-installation checklist accurately details all applicable installations of the barrier components to the test enclosure(s). All installation configuration options shall be represented during testing.

4.3.2. Deployment

4.3.2.1. Requirements

The barrier shall be deployed within the test enclosure as it would be deployed during a flood event to protect the simulated structure opening.

The barrier's Design, Installation, Operation, and Maintenance Manual shall be verified for accuracy and completeness of the deployment process. The manual shall include at a minimum;

4.3.2.1.1. Material, Tools, and Equipment Required

The manual shall include a list of all the materials, tools, and equipment used during the deployment of the barrier. In addition, the manual shall indicate if the materials, tools and/or

4.3.2.1.2. Person-Power Requirements

The manual shall include the number of personal used to deploy the barrier. The same number of personnel shall be used for the deployment process.

4.3.2.1.3. Deployment Time

The measured deployment time shall be equal to or less than the time listed in the manual. The deployment time shall be measured in terms of personnel requirements and total deployment time.

4.3.2.1.4. Deployment Procedure

The manual shall clearly detail the steps for how to deploy the barrier. The procedure shall comply with all of the requirements of Section 4.3.2.1.

4.3.2.1.5. Additional Deployment Requirements

The manual shall adequately detail any of the following deployment requirements if identified by the manufacturer and/or preformed during the deployment test process:

- Foundation requirements

- Special construction considerations
- Application limitations
- What to do if damage should occur during deployment

4.3.2.1.6. Barrier Reusability

For contingent barriers, the manual shall include a procedure for proper disassembly and storage of barrier components to restore the system to a similar pre-test condition.

4.3.2.2. Tests/Verification

Document the deployment of the barrier with a video camera while simultaneously reviewing the Design, Installation, and Operation, and Maintenance Manual. At the completion of the deployment, compare the video recording to the manual to assure that all of the requirements listed in Section 4.3.2.1 have been properly documented. If the disassembly process differs from the inverse of the deployment process, the disassembly process shall also be documented. The manual must be corrected of any inaccuracies and/or missing information.

In addition, the barrier shall be removed or opened (as applicable) and evaluated for wear or damage after each of the Hydrostatic Loads tests, as shown in Table 4.3. The barrier shall then be re-deployed in accordance with Section 4.3.2 before the start of the next test in the sequence. For automatic type barriers, the deployment test shall be conducted at the beginning of the Hydrostatic Load Tests during the filling process of the test apparatus.

4.3.3. Hydrostatic Load Test

4.3.3.1. Requirements

Flood barriers for opening barrier applications shall be capable of withstanding the hydrostatic loads created by quasi-static floodwaters. The leakage rate shall not exceed 0.08 gallons per hour per linear foot (1 L/h/m) of seal over any 15-minute period, where the linear length of seal is the opening width (measured from barrier seal-to-seal) plus two times the water depth. For barriers with a maximum design water height greater than the barrier height (i.e. fully submerged window), the linear length of seal is considered to be the opening width plus two times the water height, or the barrier perimeter, whichever is less. For barriers which are parallel to the ground surface (i.e. subway stair barriers, subway grate barriers, etc.) the linear length of seal is considered to be the perimeter.

4.3.3.2. Tests/Verification

Fill the wet-side of the test apparatus to 10 percent x *h* ± 0.25 in (0.6 cm), where "*h*" is the manufacturer's specified maximum design water depth. Measure the leakage rate over 15 minute intervals until the leakage rate has either stopped or stabilized. Maintain the desired water level for a minimum duration of 2 hrs. Measure the leakage rate during the final 15 minutes. If leakage rate continues to increase, additional time shall be added until stabilization is reached

Increase the water height to 100 percent x h ± 0.25 in (0.6 cm), where h is the maximum design water depth.

Maintain the desired water level for a minimum of 22 hours. Measure the leakage rate over 15 minute intervals until the leakage rate has either stopped or stabilized. Measure the leakage rate during the final 15 minutes. If leakage rate does not stabilize, then measure the leakage rate for 15 minute intervals elapsing at the following time increments, at a minimum:

- 15 min
- 30 min
- 45 min
- 1 hour
- 20 hours

If leakage rate continues to increase, additional time shall be added until stabilization is reached.

The Hydrostatic Load Test shall be repeated as a post test to Dynamic Impact Load testing as shown in Table 4.3. The duration of the post tests shall be a minimum of 1 hour at each water level. If leakage rate is increasing, additional time may be added at the discretion of testing laboratory.

Hydrostatic Load Testing at 10 percent x h water depths may be waived if the design of the flood barrier is such that the compression force applied by the water column does not increase the barrier's sealing capability.

4.3.4. Dynamic Impact Load Tests

4.3.4.1. Requirements

Flood barriers for opening barrier applications shall be capable of withstanding a minimum of two impacts of 600J each from a rigid falling object simulating floating debris. Any damage sustained as a result of the impacts shall not impair functionality/performance of the barrier.

4.3.4.2. Tests/Verification

Drain the wet-side of the test apparatus before conducting the test.

The impact object shall be a piece of saw-cut log with a diameter of 12 in (30.5 cm) and a density similar to wet southern pine [30 lb/ft^3 (48 kg/m^3)]. One end of the log shall have a straight perpendicular cut and the other shall be cut at an angle of 15 degrees off-center with no round edges. The straight cut end of the log shall be attached to a steel block so that the total mass of object is 110 lbs (50 kg). A similar impact object can be substituted at the discretion of the testing laboratory as long as the trajectory of impact and impact energy criteria are met.

The first impact location shall be the predetermined weak point of the barrier structure, or at the horizontal center point of the barrier at 80 percent *x h,* where *h* is the manufacturer's specified maximum water depth of the barrier.

The second location shall be as close to the barrier perimeter as possible, at roughly the same height as the first impact. This location is intended to evaluate the barrier connection to the supporting structure. Additional impact locations on the barrier may be required at the discretion of the testing laboratory (e.g. hinges, plastic parts, etc.).

The impact to the barrier shall be such that the leading edge of the impacting object hits the predetermined location on the barrier. Figure 4.3.4 contains a suggested layout for this test.

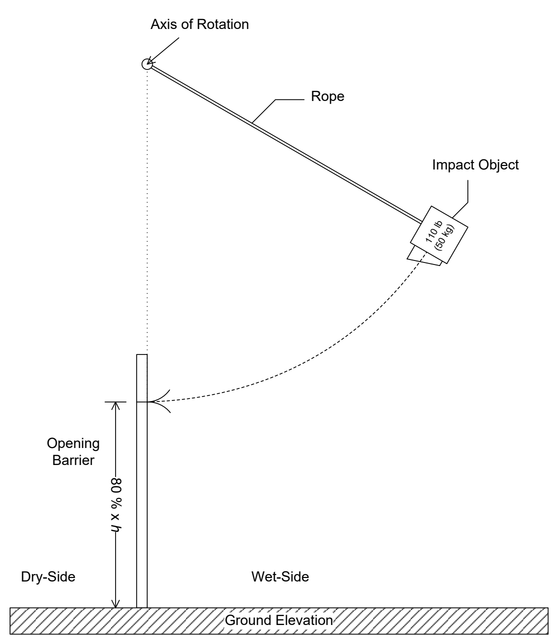

Figure 4.3.4 Impact Test Layout

Impact the barrier by lifting the object to a height of 4 ft (1.22 m) above the point of impact. Then drop the object so that it falls under gravitational acceleration, through a circular trajectory, and impacts the barrier in the horizontal position. The impact force *E* (600J), calculated as potential energy, is determined by the length of trajectory and weight of the impacting object:

$$E = mgh$$

where, *m* is the mass of the impacting object (50 kg), g is gravitational acceleration (9.81 m/s2),
and *h* is the height through which the impacting object falls (1.22 m).

After each impact, make observations of any damage sustained and any possible detriments to the barrier functionality and ability to hold back water. Post-hydrostatic load testing shall be conducted as specified in Section 4.3.3.

4.4. PERFORMANCE TESTING FLOOD MITIGATION VALVES

4.4.1. Examination

4.4.1.1. Requirements

Flood mitigation valves shall conform to the manufacturer's drawings and specifications.

4.4.1.2. Test/Verification

A flood mitigation valve shall be representative of the manufacturer's final production equipment shall be examined and compared to drawings and engineering specifications. It shall be verified that the representative sample conforms to the physical and structural requirements described in Section 3, General Requirements.

4.4.2. Debris Passage

4.4.2.1. Requirements

The opening through a flood mitigation valve shall permit the passage of a cylinder 12 in. (305 mm) long and a diameter as follows:

Nominal Size, Inches	***Diameter of Cylinder, Inches (mm)***
1.5	0.75 (19)
2 2.5	1.00 (25) 1.25 (32)
3	1.50 (38)
4	2.00 (51)
6	3.00 (76)
8 10 12	4.00 (102) 5.00 (127) 6.00 (152)

4.4.2.2. Tests/Verification

The test cylinder as indicated in section 4.4.2.1 shall be passed through the flood mitigation valve in the direction of flow.

4.4.3. Watertightness

4.4.3.1. Requirements

When exposed to a range of backflow pressures, the leakage through a flood mitigation valve shall not exceed the values in the following table.

Nominal Size, Inches	***Maximum Leakage Volume, Fl oz (mL)***
1.5	5.5 (163)
2	9.5 (281)
2.5	15.0 (444)
3	21.5 (636)
4	38.5 (1,139)
6	87.0 (2,573)
8	153.0 (4,525)
10	240.0 (7,098)
12	345.0 (10,202)

4.4.3.2. Tests/Verification

The valve shall be positioned in its normal operating position as prescribed by the manufacturer. A water source capable of maintaining the maximum rated backpressure shall be affixed to the outlet of the flood mitigation valve. The water pressure shall be increased in the following steps:

Water Pressure, psi (kPa)
0.25 (1.7)
0.50 (3.4)
1.0 (6.9)
5.0 (34.5)
Maximum Rated Backpressure

At each step, the pressure shall be maintained for 10 min. ±15 sec. During each test period, any water that is emitted from the entrance side of the fitting shall be collected, measured, and recorded. The total leakage volume over any given 10-minute step period shall be less than the maximum limitation requirement specified above.

4.4.4. Pressure Loss

4.4.4.1. Requirements

For flood mitigation valves designed for in-line applications, the pressure loss through the valve shall be determined throughout the manufacturer's rated flow range and shall be included in the manufacturer's design/maintenance manual. Pressure loss shall be determined at a minimum of four different flow rates to allow for the development of a pressure loss vs. flow curve.

4.4.4.2. Tests/Verification

Each sample shall be installed between two test pipes equipped with a means for attaching a pressure gauge. The test pipes shall be of the same nominal diameters as the sample. Using water as a test medium, the pressure loss between the inlet and outlet shall be measured at a minimum of four flow rates. The test sample shall be removed from the test configuration, and the pressure losses at the same flow rates determined. The pressure loss of the sample is determined by subtracting the loss of the pipe from the loss of the pipe/test sample combination.

4.4.5. Aging

4.4.5.1. Requirements

For resilient seated flood mitigation valves (non-metallic seal), aging of the seat material shall not promote any cracking when tested in accordance with Section 4.4.6.2.

For flood mitigation valve designs constructed of non-metallic material (i.e. flexible rubber type valves), the valve assembly shall be subjected to the 180 day air-oven aging test as described in Section 4.1.12. Following the aging exposure period, the valve shall be subjected to 500 cycles of normal operation, as described in Section 4.1.4, using water as the test medium. The valve shall then undergo the watertightness test described in Section 4.4.3.

4.4.5.2. Tests/Verification

For resilient seated flood mitigation valves (non-metallic seal), a specimen of the valve rubber seat material, approximately 1 x 3 in. (25 x 75 mm) by 1/8 in. thick, supplied by the manufacturer, shall be subjected to an accelerated aging test in accordance with ASTM D572, "Standard Test Method for Rubber – Deterioration by Heat and Oxygen". The test duration shall be 96 hours. After the test, the specimen shall be examined for resilience by being bent double (i.e. bend radius of 180°). Observations of any cracking or deterioration shall be made.

4.5. PERFORMANCE TESTING – PENETRATION SEALING DEVICES

4.5.1. Examination

4.5.1.1. Requirements

Penetration sealing devices shall conform to the manufacturer's drawings and specifications and to the Approval requirements.

4.5.1.2. Test/Verification

A penetration sealing device assembly representative of the manufacturer's final production equipment shall be examined and compared to drawings and engineering specifications. It shall be verified that the representative sample conforms to the physical and structural requirements described in Section 3, General Requirements.

4.5.2. Hydrostatic Pressure Leakage Test

4.5.2.1. Requirements

Penetration sealing devices shall be capable of withstanding the hydrostatic loads created by floodwaters without significant leakage. The leakage rate shall not exceed 0.08 gallons per hour per linear foot (1 L/h/m) of protected opening, where the linear foot of protected opening is the perimeter of the penetration. If the sample being tested accommodates multiple penetrations, the sum of the perimeter of each penetration shall be used. For modular products that include additional sealing surfaces between modular sections, the length of these additional sealing surfaces shall not be included in calculation for linear length of protected opening. For pipe plugs or similar devices used to seal the entire area within a penetration, the perimeter of the maximum protected area shall be represented.

4.5.2.2. Test/Verification

Each sample penetration sealing device shall be installed in the wall of a test enclosure having a penetration of the size specified by the manufacturer. The test enclosure shall be capable of hydrostatically pressurizing the sample to a pressure equivalent to that exerted by a water column at the manufacturer's specified maximum design water depth, plus 10%, and maintaining that pressure throughout the stated duration. A means for collecting leakage through the penetration throughout the duration shall be established.

All pre-installed frame components, if applicable, shall be included in the tested assembly. If the product is designed to seal the area around a penetrating object (i.e. pipe, flexible wire cables), a representative penetrating object of the size specified by the manufacturer shall also be included in the tested assembly. Schedule 40 steel pipe shall be considered representative of piping and standard, round, smooth, PVC cable shall be considered representative of flexible wire cables. Assemblies designed for both pipe and flexible cable type penetrating objects shall be tested with both objects. If Approval for armored type corrugated cables is desired, an additional assembly including armored cable shall be tested.

The test enclosure shall be hydrostatically pressurized to the pressure equivalent to that exerted by a water column at the manufacturer's specified maximum design water depth, plus 10%. The pressure shall be maintained for 72 hours. Leakage through the penetration shall be collected throughout the duration. After each 24 hours, the leakage shall be measured and recorded.

4.5.3. Low Temperature and Impact Resistance

4.5.3.1. Requirements

Penetration sealing devices shall not show any evidence of cracking or deterioration as a result of low temperature conditioning. While at the low temperature, there shall be no damage following impact testing that would impair product function, performance, or installation.

4.5.3.2. Test/Verification

Each sample penetration sealing device shall be immersed in a water bath at 70 ± 10°F (21 ± 5.5°C) for 24 hours. The sample shall then be conditioned to a temperature of 10°F (-12°C) for an additional 24 hours. The sample shall then be removed and inspected for any cracking or other deterioration. While still at that temperature, a 2.2 lb. (1 kg) steel sphere shall be dropped from a height of 3.3 ft. (1 m) onto the sample so that the impact occurs at a predetermined worst case location. Tubing may be used as a guide for the sphere to ensure the impact occurs at the intended location. A minimum of three drops shall be performed at three different locations. Additional drops may be required at the discretion of the testing laboratory.

4.5.4. Aging

4.5.4.1. Requirements

After a penetration sealing device is subjected to the Air-Oven Aging Test for Nonmetallic Components and Gasket Adhesives, as described in Section 4.1.12, the sample shall meet the requirements of the Hydrostatic Pressure Leakage Test, as detailed in Section 4.5.2.

4.5.4.2. Test/Verification

Penetration sealing devices shall be subjected to the Air-Oven Aging Test for Nonmetallic Components and Gasket Adhesives, as described in Section 4.1.12, except the conditioning temperature shall be at the manufacturer's maximum rating. Subsequently, the sample shall be subjected to the Hydrostatic Pressure Leakage Test, as detailed in Section 4.5.2, for verification that leakage remains within the requirement.

4.5.5. Cable Retention Test

4.5.5.1. Requirements

Penetration sealing devices designed to seal around flexible cables shall sufficiently retain the cable during applied forces. When the force is applied along the same axis of the cable, the cable slippage shall be less than .25 in. (6.4 mm). Subsequently, the sample shall meet the requirements of the Hydrostatic Pressure Leakage Test, as detailed in Section 4.5.2.

4.5.5.2. Test/Verification

Each sample penetration sealing device shall be installed as described in Section 4.5.2 - Hydrostatic Pressure Leakage Test. After installation is complete, a marked line shall be made on the cable along the interface between the cable and the penetration sealing device. A static force of 40 lbf (178 N) shall be applied to the cable, along the same axis of the cable, in a direction moving away from the penetration. The force shall be applied for a duration of 5 minutes before being released. Determine the cable slippage by measuring the distance between the inside of the marked line and the penetration sealing device.

Apply a static pull or push force of 40 lbf (178 N) to the cable, at an approximate distance of 6 in. (15cm) from the penetration sealing device, along the axis perpendicular to the cable, in a direction moving vertically upward. The force shall be applied for a duration of 1 minute before being released. Similarly, the same force shall be applied in the vertically downward, right, and left directions.

Subsequently, the sample shall be subjected to the Hydrostatic Pressure Leakage Test, as detailed in Section 4.5.2, for verification that leakage remains within the requirement.

4.6. PERFORMANCE TESTING - FLOOD MITIGATION PUMPS

4.6.1. Examination

4.6.1.1. Requirements

Flood mitigation pumps shall conform to the manufacturer's drawings and specifications.

4.6.1.2. Test/Verification

A pump representative of the manufacturer's final production equipment shall be examined and compared to drawings and engineering specifications. It shall be verified that the representative sample conforms to the physical and structural requirements described in Section 3, General Requirements.

4.6.2. Debris Clearance/ Solid Handling Capability

4.6.2.1. Requirements

A pump shall conform to the manufacturer's maximum rated solids handling capability, expressed as diameter of solid. Compliance shall be verified by the passage of a rigid sphere through the waterway of the pump.

4.6.2.2. Tests/Verification

A sample pump, with no power, shall be capable of passing a rigid sphere from the discharge of the pump to the water inlet. The size of the sphere must be equal to, or greater then, the clearance specifications listed by the manufacturer. The pump shall be rotated from its intended installation position to pass the sphere though the pump but only if the rotation of the pump does not increase the clearance of any opening or passageway.

4.6.3. Pump Performance Testing

4.6.3.1. Requirements

The pump shall develop its rated pressure when delivering its rated capacity as specified by the manufacturer. Pump characteristic curves shall be confirmed for accuracy.

4.6.3.2. Tests/Verification

A sample pump of each rated capacity shall be operated at various flow rates, from shut-off, all the way to full open downstream valve, to verify the manufacturer's characteristic curve. The pump shall be tested at each rated speed (if applicable). A minimum of four flow readings (min, max, and two intermediate points) shall be taken to generate discharge pressure (total dynamic head) vs. capacity curves. At each flow rate, the total discharge head and total suction head, or total suction lift shall be measured. Power measurements may also be measured for the purpose of qualifying additional pump drivers, as described in Section 4.6.5. All test speeds must be within ± 4 percent of the rated speed. Test data shall be corrected to rated speed to develop the characteristic curves.

For self-priming pumps with suction lift capabilities, characteristic curves shall be developed for various degrees of suction lift. Characteristic curves for a minimum of four suction lift values shall be generated, including zero suction lift, maximum suction lift, and two evenly spaced intermediate values.

For submersible pumps, characteristic curves shall be developed at the minimum suction pressure, or the minimum submergence required for operation.

4.6.4. Endurance Test

4.6.4.1. Requirements

A pump assembly shall be capable of continuous operation for 336 hours at its maximum rated capacity without excessive vibration, loosening of parts (fasteners, etc.), visible distortion of the baseplate, excessive generation of heat in the bearings, or rubbing of the rotor.

4.6.4.2. Tests/Verification

A sample pump shall be operated continuously for 336 hours at its maximum rated capacity. No loose parts, distortion, overheating, or degradation of performance shall be allowed. During this test, measurements for flow and discharge pressure shall be recorded at 15 minute intervals. Depending on the construction of the overall pump assembly, additional measurements for rotational speed, fuel consumption rate, lubricant temperature, and power, as applicable, will also be recorded.

Ideally, the pump is to be operated with a driver and coupling that will be included in the submitted pump package(s) (see Appendix C). Each driver and coupling design that is included in the submitted pump package(s) and which is not subjected to this endurance test, shall be subjected to the pump package endurance test described in Section 4.6.5.

Once the test is started, it shall be left to run as near continuous as practical. Stopping for refueling, end of business day, or to make adjustments to the test equipment (not the pump assembly) is allowed. Other than the normal starting / priming procedures, no adjustments are permitted to be made to the pump assembly. Stopping the test for reasons other than indicated above shall be considered a failure. No loose parts, distortion, overheating, or degradation of performance shall be allowed. Following the test, the pump shall be disassembled and examined for signs of rubbing.

4.6.5. Endurance Test – Pump Package

4.6.5.1. Requirements

A minimum of 1 of each pump driver, whether it be a diesel engine or electric motor, shall be endurance tested as part of a flood mitigation pump package. Each coupling design shall also be represented and tested. Drivers and couplings shall be tested with the pump requiring the greatest amount of power for which it is specified to be used. Whenever possible, representative testing may be justified, at the discretion of the testing laboratory, for drivers or couplings having similar designs.

There shall be no excessive vibration, loosening of parts (fasteners, etc.), visible distortion of the baseplate, excessive generation of heat, or loss of pump performance.

Alternative to performing the endurance test on each pump driver, rated power levels obtained as part of the US EPA emission certification or other third party certification process may be considered, at the discretion of the testing laboratory. Power measurements are required to be recorded during the pump performance testing described in Section 4.6.3 to allow for comparison. The rated power shall be greater than the maximum power required by the pump, plus an additional safety factor of 1.1.

4.6.5.2. Tests/Verification

Flood mitigation pump drivers and couplings which were not tested as part of Section 4.6.4 shall be installed in pump packages and run continuously at maximum rated capacity for a duration of 4 hours. During this test, measurements for flow and discharge pressure shall be recorded at 15 minute intervals. Depending on the construction of the overall pump assembly, additional measurements for rotational speed, fuel consumption rate, lubricant temperature, and power, as applicable, will also be recorded.

Throughout the endurance test, observations shall be made for excessive vibration, loosening of parts (fasteners, etc.), distortion of the baseplate, or excessive generation of heat. No loss of pump performance shall also be verified.

4.6.6. Hydrostatic Strength

4.6.6.1. Requirements

A flood mitigation pump shall withstand an exposure to hydrostatic pressure without rupturing, cracking, or exhibiting permanent distortion of any component of the pump. For pumps with mechanical seals, no leakage shall be detected. For pumps with stuffing box packing, no leakage shall be detected with the exception of the stuffing box packaging.

4.6.6.2. Tests/Verification

A sample pump shall be hydrostatically tested for 5 minutes at a pressure equal to, or greater than, twice the maximum shutoff pressure (2 x P_{max}), where P_{max} is the maximum shutoff pressure specified by the pump manufacturer. No rupture, cracking or permanent distortion shall be observed.

4.6.7. On/Off Switch Durability - Cycling

4.6.7.1. Requirements

The on/off switch of a flood mitigation pump, under full electrical load, shall not show excessive wear or damage after 1000 cycles of operations.

4.6.7.2. Tests/Verification

The on/off switch assembly of a flood mitigation pump shall be cycled 1000 times through its full range of travel while under full electrical load. After testing, all parts of the assembly shall be visually inspected. No excessive wear or damage shall be observed.

4.6.8. Voltage Variation and Temperature Extremes

4.6.8.1. Requirements

Electrically operated motors or components used in a flood mitigation pump shall operate at ±85 and 110 percent of the rated voltage specified by the manufacturer, while conditioned to the maximum and minimum rated installation temperatures. The motor/component shall display no hesitation, partial operation, or other failures to operate properly.

4.6.8.2. Tests/Verification

The electrically operated motor or component shall be conditioned at the maximum rated installation temperature for a minimum of 16 hours. Immediately upon removal from the chamber, the motor/component shall be supplied with minus 15 percent of the rated voltage for a period of 2 minutes. The motor/component shall then be supplied with plus 15 percent of the rated voltage for a period of 2 minutes. The motor/component shall display no hesitation, partial operation, or other failures to operate properly. The test shall be repeated with the motor/component conditioned to the minimum rated installation temperature.

4.6.9. Dielectric Withstand

4.6.9.1. Requirements

Electrically operated motors or components used in a flood mitigation pump shall withstand an applied voltage between all terminals provided for external connections and ground, as well as between all combinations of individual connections. There shall be no breakdown of the insulation between the test points. The motor and pump shall continue to function normally subsequent to this test.

4.6.9.2. Tests/Verification

For a motor/component with a rated voltage not exceeding 90 V, the test voltage shall be equal to 500 V. For all other devices, the test voltage shall be calculated as 1000 V plus two times the rated voltage of the circuit. The required voltage shall be applied between each terminal and ground, and between all individual terminals. The voltage shall be increased steadily to the specified value in a period of not less the 10 seconds, and maintained for a minimum of 60 seconds.

4.6.10. Maximum Suction Lift Capability

4.6.10.1. Requirements

Self-priming flood mitigation pumps designed for suction lift applications shall be operated to verify maximum suction lift capability. The priming mechanism shall produce a vacuum pressure equivalent to or exceeding the maximum rated suction lift.

4.6.10.2. Tests/Verification

The pump suction shall be suitably sealed by closing the suction valve or other means used to plug the suction end of the pump and shall be fitted with a vacuum pressure gauge. While the pump suction is sealed, the pump shall be operated, as directed in the manufacturer's priming instructions. The maximum vacuum pressure developed by the priming mechanism shall be recorded. A conversion factor of 2.3 ft. (0.7m) of water per 1.0 psi (2.04 mmHg) vacuum pressure shall be used to determine the equivalent suction lift capability in feet (meters).

4.7. ADDITIONAL TESTS

Additional tests may be required, depending on design features, results of any tests, material application, or to verify the integrity and reliability of the flood mitigation equipment barriers, at the discretion of the testing laboratory.

Unexplainable failures shall not be permitted. A re-test shall only be acceptable at the discretion of the testing laboratory and with adequate technical justification of the conditions and reasons for failure.

5. BIBLIOGRAPHY

ASCE/SEI 24-14, Flood Resistant Design and Construction

ASME A112.14.1, Backwater Valves

ASTM D471, Standard Test Method for Rubber Property Effect of Liquids

ASTM D1242, Standard Test Method for Resistance of Plastic Materials to Abrasion

ASTM D6382, Standard Practice for Dynamic Mechanical Analysis and Thermogravimetry of Roofing and Waterproofing Membrane Material

ASTM E290, Standard Test Methods for Bend Testing of Material For Ductility

ASTM G154, Standard Practice for Operating Fluorescent Light Apparatus for UV Exposure of Nonmetallic Materials

ASTM SI10 - American National Standard for Use of The International System of Units (SI): The Modern Metric System

United States Army Corps of Engineers (USACE), Engineering Research and Development Center (ERDC), Standardized Testing Protocol for Evaluation of Expedient Floodfight Structures

APPENDIX A: Tolerances

Unless otherwise stated, the following tolerances shall apply:

Angle:	± 2°
Flow	± 3 percent of value
Frequency (Hz):	± 5 percent of value
Length:	± 5 percent of value
Volume:	± 5 percent of value
Rotation:	± 1 RPM
Pressure:	± 5 percent of value
Temperature:	± 5 percent of value
Time:	+ 5/- 0 seconds + 0.1/- 0 minutes + 0.1/- 0 hours + 0.25/- 0 days

Unless stated otherwise, all tests shall be carried out at a room (ambient) temperature of 68°F ± 18°F (20°C ± 10°C).

APPENDIX B: USACE Coastal and Hydraulics Laboratory Test Facility Description

Performance testing of flood barrier for perimeter barrier applications is typically conducted at a facility similar to the wave basin at the ERDC Coastal and Hydraulics Laboratory, located in Vicksburg, Mississippi. The research facility consists of a 100 ft. (30.48 m) wide by 150 ft. (45.72 m) long basin. One end of the facility contains three electric-driven piston-type wave generators, each driving a 25 ft. (7.62 m) wide wave paddle. The three wave generators are synchronized so that they all run together as a 75 ft. (22.86 m) wide generator. Guide vanes contain the wave train for the first 50 ft. (15.24 m) in front of the wave generators. The generators are computer controlled and capable of producing monochromatic or spectral wave fields.

Two wing walls, 30 ft. (9.14 m) apart, are centered at the end of the basin away from the wave generators. The wing walls are each 30 ft. (9.14 m) long then turn towards the sides of the basin for 10 ft. (3.05 m) Between the wing walls is an 8 ft. (2.44 m) diameter by 8 ft. (2.44 m) deep sump. The sump is equipped with two 4 in. (10.2 cm) diameter pipes with float-controlled submersible pumps and flow meters, and also two external diesel-powered pumps with 15 in. (0.38 cm) diameter intakes and 12 in. (0.31 m) diameter outfalls.

During testing of a flood-fighting product, seepage through the structure shall be collected in the sump and pumped back into the basin via the sump pumps and 4-in diameter pipes. The diesel pumps are used during the overtopping tests to return the water to the basin and during the current test to provide water flow.

Seepage rates through the test structures are measured by the flow meters in the 4 in. (10.2 cm) diameter pipes and also by a laser pointing at a float in a standpipe in the sump measuring changes in water surface elevation. Several capacitance-type wave gauges measure the changes in water surface elevation within the basin to determine the incident wave fields. Eight lasers record any movement of the structure during testing.

A cable take-up reel has been modified to tow a log into the structure at a calibrated 5 mph (7 ft/s) (for a debris impact test. The log trips a wire set a few in. in front of the test structure which turns off the drive motor on the take-up reel prior to impact. Two web cams with 360-degree pan and telephoto zoom capabilities are used to record construction, testing, and disassembly of each product. The web cams may also be used to broadcast so that the tests may be viewed in real time by anyone with web access.

Due to the restrictive height of the research basin walls, the height of each structure shall be limited to 4 ft (1.2 m). The layout of the base of the barrier construction area is shown in Figure A-1. The ground surface of the wave basin is a smooth, flat, and impervious concrete slab with little elevation changes. The water supply for performance testing shall be the available non-potable (e.g. city water) water supply to the test facility. No purposely contaminated water shall be allowed into the facility.

The wet-side, or river-side, of the wave basin refers to the side of the basin that imposes the flood water. The dry-side of the wave basin refers to the side protected by the flood barrier.

Two web cams with 360-degree pan and telephoto zoom capabilities are used to record construction, testing, and disassembly of each product. The web cams may also be used to broadcast so that the tests may be viewed in real time by anyone with web access.

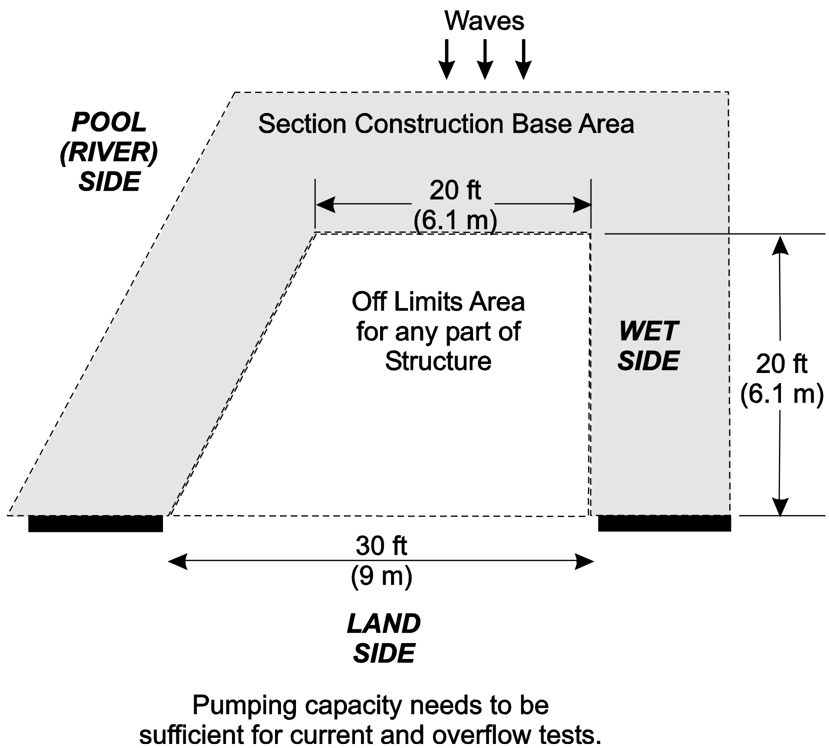

Figure B-1. Layout and Barrier Construction

APPENDIX C: FLOOD MITIGATION PUMP PACKAGE COMPONENTS

The flood mitigation pump package shall consist of the following components which are furnished by the flood mitigation pump manufacturer:

1. Flood mitigation pump
2. Driver – diesel engine or electric motor
3. Pump controller (if applicable)
4. Flexible coupling or drive shaft (if applicable)
5. Suction and discharge pressure gauges (if applicable)
6. Substantial bedplate for pump and driver (if applicable)
7. Diesel engine accessories (if applicable):
    a. starting batteries
    b. rigid cooling water and fuel lines for stationary installations (may have short flexible elements in close proximity to engine to minimize vibration)
    c. exhaust piping and muffler
    d. fuel tank
8. Liquid level sensor (if applicable)
9. Instruction, operation, and maintenance manual in local language

APPENDIX D : MAXIMUM SEEPAGE RATE ALLOWANCE - FLOOD BARRIERS FOR OPENING BARRIER APPLICATIONS

The following table was developed based on the maximum leakage rate criteria and calculation methods described in Section 4.3.3. This table does not apply to flood barriers which have a maximum design water depth greater than the barrier height (i.e. fully submerged windows), if the barrier perimeter is less than the opening width plus two times the water depth. This table also does not apply to flood barriers which are parallel to the ground surface.

Note: To determine maximum seepage flow rate allowances for flood barriers for perimeter barrier applications, simply multiply the barrier length by the maximum leakage rate requirement specified in Section 4.2. Water height is not factored into the calculation.

Maximum Seepage Rate Allowance, (gal/hr)

	Opening Width, (ft.)											
Maximum Design Water Depth, (ft.)	**1**	**2**	**3**	**4**	**5**	**6**	**8**	**10**	**12**	**15**	**20**	**25**
0.5	0.16	0.24	0.32	0.4	0.48	0.56	0.72	0.88	1.04	1.28	1.68	2.08
1	0.24	0.32	0.4	0.48	0.56	0.64	0.8	0.96	1.12	1.36	1.76	2.16
1.5	0.32	0.4	0.48	0.56	0.64	0.72	0.88	1.04	1.2	1.44	1.84	2.24
2	0.4	0.48	0.56	0.64	0.72	0.8	0.96	1.12	1.28	1.52	1.92	2.32
2.5	0.48	0.56	0.64	0.72	0.8	0.88	1.04	1.2	1.36	1.6	2	2.4
3	0.56	0.64	0.72	0.8	0.88	0.96	1.12	1.28	1.44	1.68	2.08	2.48
3.5	0.64	0.72	0.8	0.88	0.96	1.04	1.2	1.36	1.52	1.76	2.16	2.56
4	0.72	0.8	0.88	0.96	1.04	1.12	1.28	1.44	1.6	1.84	2.24	2.64
4.5	0.8	0.88	0.96	1.04	1.12	1.2	1.36	1.52	1.68	1.92	2.32	2.72
5	0.88	0.96	1.04	1.12	1.2	1.28	1.44	1.6	1.76	2	2.4	2.8
5.5	0.96	1.04	1.12	1.2	1.28	1.36	1.52	1.68	1.84	2.08	2.48	2.88
6	1.04	1.12	1.2	1.28	1.36	1.44	1.6	1.76	1.92	2.16	2.56	2.96
7	1.2	1.28	1.36	1.44	1.52	1.6	1.76	1.92	2.08	2.32	2.72	3.12
8	1.36	1.44	1.52	1.6	1.68	1.76	1.92	2.08	2.24	2.48	2.88	3.28
9	1.52	1.6	1.68	1.76	1.84	1.92	2.08	2.24	2.4	2.64	3.04	3.44
10	1.68	1.76	1.84	1.92	2	2.08	2.24	2.4	2.56	2.8	3.2	3.6
11	1.84	1.92	2	2.08	2.16	2.24	2.4	2.56	2.72	2.96	3.36	3.76
12	2	2.08	2.16	2.24	2.32	2.4	2.56	2.72	2.88	3.12	3.52	3.92
13	2.16	2.24	2.32	2.4	2.48	2.56	2.72	2.88	3.04	3.28	3.68	4.08
14	2.32	2.4	2.48	2.56	2.64	2.72	2.88	3.04	3.2	3.44	3.84	4.24
15	2.48	2.56	2.64	2.72	2.8	2.88	3.04	3.2	3.36	3.6	4	4.4
16	2.64	2.72	2.8	2.88	2.96	3.04	3.2	3.36	3.52	3.76	4.16	4.56
17	2.8	2.88	2.96	3.04	3.12	3.2	3.36	3.52	3.68	3.92	4.32	4.72
18	2.96	3.04	3.12	3.2	3.28	3.36	3.52	3.68	3.84	4.08	4.48	4.88
19	3.12	3.2	3.28	3.36	3.44	3.52	3.68	3.84	4	4.24	4.64	5.04
20	3.28	3.36	3.44	3.52	3.6	3.68	3.84	4	4.16	4.4	4.8	5.2