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# **American National Standard for Flood Abatement Equipment ANSI/FM Approvals 2510**

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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 abatement equipment.

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## 1. INTRODUCTION

### 1.1 Purpose

1.1.1 This standard states the examination and test requirements for flood abatement equipment.

### 1.2 Scope

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

- Function (permanent, contingent, and emergency)
- Operation (automatic and manual)
- The intended use of protection (i.e., perimeter and opening barriers, flood abatement pumps and backwater valves)

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

- Opening Barriers
- Perimeter Barriers
- Backwater Valves
- Flood Abatement Pumps

1.2.3 Flood waters can produce high hydrostatic or flood dynamic loading on a structure. Appropriate measures must be taken to ensure that an external wall structure (or similar) can withstand anticipated flood loading. 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.

1.2.4 Since each flood abatement system is unique in its operation and design, component testing shall be performed on a case-by-case basis. Upon request for a program, and receipt of appropriate system documentation, the testing laboratory shall prepare a customized evaluation program for the specific flood abatement system. The test program shall verify the manufacturer's design calculations, stated performance requirements, as well as component functionality and reliability.

### 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 abatement equipment. Flood abatement 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 abatement 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 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. Appendix A lists the selected units and conversions to SI units for measures appearing in this standard. 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 10-2010, "American National Standard for Metric Practice." 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 Applicable Documents

This standard is used in conjunction with the following standards, test methods, and practices as referenced in this standard.

### ASME Publications

The American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016-5990 [www.asme.org](http://www.asme.org)

ASME A112.14.1-, *Backwater Valves*

ASME Boiler and Pressure Vessel Code, Section VIII- Rules for Construction of Pressure Vessels, Division I

### ASTM Publications

American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959

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 D471 - *Standard Test Method for Rubber Property-Effect of Liquids*

ASTM D395 - *Standard Test Methods for Rubber Property - Compression Set*

ASTM D573 - *Standard Test Method for Rubber - Deterioration in an Air Oven*

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

ASTM D3273 - *Standard Test Method for Resistance to Growth of Mold on the Surface of Interior Coatings in an Environmental Chamber*

ASTM D5602 - *Standard Test Method for Static Puncture Resistance of Roofing Membrane Specimens*

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 G155 - *Standard Practice for Operating Xenon Arc Light Apparatus for Exposure of Non-Metallic Materials*

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

**FM Global**

FM Global, 75 Remittance Drive Suite #6182, Chicago, IL 60675-6182

FM Global Property Loss Prevention Data Sheet 1-40, Flood

**International Standards Organization**

International Standards Organization, , 1 rue de Varembe, Case Postale 56, CH-1211 Geneve 20, Switzerland

ISO 9001 - *Quality Systems - Model for quality assurance in design, development, production, installation, and servicing*

ISO 9002 - *Quality Systems - Model for quality assurance in production, installation, and servicing*

ISO 17025 - *General Requirements for the Competence of Testing and Calibration Laboratories*

**United States Army Corp of Engineers**

United States Army Corp of Engineers (USACE), Engineering Research and Development Center (ERDC)

*Standardized Testing Protocol for Evaluation of Expedient Floodfight Structures*, June 27, 2010

**United States Department of Transportation (D.O.T.)**

United States Department of Transportation, 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.

***Automatic Flood Barrier***

A permanent barrier that automatically deploys without the use of human interaction when flood conditions are detected. Types of automatic barriers include, but are not limited to, passive barriers (buoyancy driven horizontal or vertical) or active barriers (pneumatic or hydraulic activated by water sensors).

***Backwater Valve***

A device installed in building drainage systems utilizing a check valve to prevent backflow. Backwater valves are designed in either a normally open position or normally closed position.

***Characteristic Curve***

Graphic representation of the variation of the pump's total head, efficiency and brake horsepower versus the pump's capacity at a constant speed.

***Combination Floor Drain and Backwater Valve***

A floor drain incorporating an internal check member to prevent backflow.

***Combination Horizontal Backwater Valve and Manual Gate Valve***

A backwater valve designed to be installed in a horizontal drain line incorporating an internal check member and manual gate valve to prevent backflow.

***Contingent Flood Barrier***

A barrier that is pre-installed but is not permanently affixed to a structure. An example of a contingent barrier is a manual barrier which has pre-installed frame but the barrier itself is stored in a designated area other than the opening it's designed to protect.

***Deflection***

The distance a flood barrier moves from its original location after or during a test.

***Deployment Time***

The amount of time required for setting up and/or operating a flood barrier.

***Door Panels***

Any panel, permanent or otherwise, which provides partial coverage of an exterior or interior door opening with the principle function of preventing flood waters into a structure.

***Dry-Side***

The side of the water basin protected by the flood barrier.

***Emergency Flood Barrier***

Any barrier that can be fitted, installed, or otherwise put in place in a relatively short period of time during a flood event.

***Flood Abatement Pumps***

A pump used for the removal of unwanted water. Types of flood abatement pumps include but are not limited to submersible (ex: a sump pump) and self-priming pumps. Flood abatement pumps shall be utilized in one of the following applications; as part of an open automatic barrier system, installed in a building and used for removal of unwanted water, and/or as a portable emergency device used for removal of unwanted water from a building.

***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.

***Horizontal Backwater Valves***

A backwater valve designed to be installed in a horizontal drain line incorporating an internal check member to prevent backflow.

***Leakage Rate***

The rate at which water moves past or through a flood barrier from the wet-side to the dry-side of the barrier, expressed as gallons per minute per foot length.

***Major Repair***

A repair made to a flood barrier during the performance testing that requires changes to barrier design by the manufacturer.

***Manual Barrier***

A barrier that requires human intervention to operate in the desired manner. Examples of a manual barrier include; an opening barrier which is stored in a designated area other than the opening it's designed to protect or a permanently installed opening barrier with hinges or pivots.

***Maximum Load***

Maximum radial hydraulic load on the impeller of a sump 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 abatement 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 testing. 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 swing check 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 in the drainage system. When installed, the swing check hangs in a normally open position.

***Opening Barrier***

Any device capable of preventing flood water from passing through an opening in a structure. Opening barriers are permanent or contingent and operate as automatic or manual.

***Overtopping***

The action of water flowing over the top of a perimeter flood barrier.

***Pedestal Sump Pump***

A sump 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 would not be exposed to the water in the sump, pit, or low point.

***Perimeter Barrier***

A temporary emergency structure which, when deployed, is intended to protect an area surrounding an occupancy from riverine flood conditions.

***Permanent Barrier***

A barrier that is pre-installed and permanently affixed to a structure.

***Rated Capacity***

Rate at which water is delivered, in gal./min. (L/min), at rated pressure and rated speed.

***Rated Pressure***

Pressure in pounds per square inch - psi (kilopascals -kPa) developed by the pump when operating at rated capacity.

***Riverine Flood Conditions***

Flooding of or produced by a river causing both water and sediments to be transported onto a flood plain.

***River-Side***

The side of the basin that imposes the flood water, also referred to as the wet-side.

***Seal***

The location on a barrier where the product meets the ground or wall of the basin to prevent water from moving from the wet-side of the basin to the dry-side. A seal can also be made between different components or sections of the flood barrier.

***Self-Priming Pump***

A pump which will clear its passages of air if it becomes air bound and resume delivery of the pumpage without outside attention.

***Shutoff Pressure***

The net pressure in psi (kPa) developed by a flood abatement pump at rated speed with zero flow.

***Structural Opening***

Any penetration where water can flow such as doors, windows, air bricks/vent bricks, portals, Garage entrance/loading dock entrance, etc.

***Submersible Sump Pump***

A sump pump that consists of both the pumping element and motor submerged in the sump, pit, or low point of a building. Both the pumping element and the motor are exposed to water.

***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.

***Terminal Backwater Valve***

A backwater valve designed to be installed at the discharge end of a horizontal drain line incorporating a check member to prevent backflow.

***Total Discharge Head***

The gauge reading in psi (kPa) at the discharge of a sump pump, referred to the pump centerline, plus the velocity head at the point of gauge attachment.

***Total Suction Head***

The condition when the suction pressure is above atmospheric. The total suction head is the algebraic sum of the gauge reading in psi (kPa) at a flood abatement pump suction nozzle, referred to the pump centerline, plus the velocity head at the point of gauge attachment. Also called “positive suction pressure”.

***Total Head***

The algebraic difference between the total discharge head and the total suction head. Where suction head exists, total head equals total discharge head minus total suction head.

***Vertical or 90-Deg Backwater Valve***

A backwater valve designed to be installed in vertical piping, such as downstream from a P-trap or a holding tank.

## **2. GENERAL INFORMATION**

### **2.1 Product Information**

2.1.1 Flood abatement equipment is designated and categorized by function (permanent, contingent, and emergency) and operation (automatic and manual). This standard defines protection with the following flood abatement equipment.

- Temporary perimeter flood barriers
- Opening flood barriers
- Backwater valves
- Flood abatement pumps

2.1.2 In order to meet the intent of this standard, Flood Abatement 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 Abatement 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 abatement 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 Opening and Temporary Perimeter Barriers

- 3.2.1.1 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.
- 3.2.1.2 All materials used in flood abatement equipment shall be suitable for the intended application. Flood abatement equipment shall be constructed of corrosion resistant materials. When unusual materials are used, additional testing may be necessary to verify their suitability.
- 3.2.1.3 Certain elastomeric materials, particularly those that contain bituminous or asphaltic compounds, are subject to material degradation due to biological attack. This type of degradation is long-term and would not necessarily affect the elastomeric barrier material during a single flood deployment, but could cause substantial degradation over extended storage times. Therefore, these materials shall only be accepted for use at the sole discretion of the testing laboratory.
- 3.2.1.4 Manually operated caps and valves, and mechanisms, must have a securing, locking, and/or supervising component.
- 3.2.1.5 The design of automatic opening barriers shall be such that major debris that could impact the barrier's functionality is prevented from entering the system. Other debris shall be able to be flushed from the system during periodic maintenance.
- 3.2.1.6 Automatic opening barriers shall be capable of manual deployment.
- 3.2.1.7 Automatic opening 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.

#### 3.2.2 Backwater Valves

- 3.2.2.1 A backwater valve shall comply with the minimum dimensional requirements indicated in Tables 1 through 3 and the corresponding figures. Either flange or hub and spigot type ends are acceptable.

Table 1 - Dimensions for Horizontal Backwater Valves  
 Swing Check Type  
 (See Figure 1)

<i>Nominal Size Inches</i>	<i>Dimension A</i>		<i>Dimension B Opening</i>	
	<i>Inches</i>	<i>(mm)</i>	<i>Inches</i>	<i>(mm)</i>
2	2	(50)	3	(75)
3	3	(75)	5	(125)
4	4	(100)	6	(150)
5	5	(125)	7	(180)
6	6	(150)	8	(205)
8	8	(205)	10	(255)

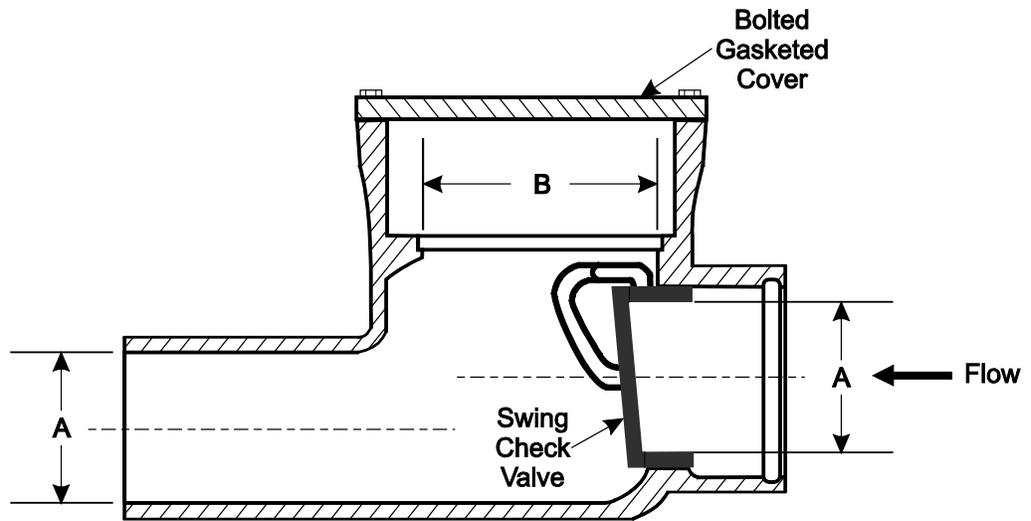


Figure 1 – Swing Check Valve Type

Table 2 - Dimensions for Combination Horizontal Backwater Valves and Manual Gate Valves (See Figure 2)

Nominal Size	Dimension A		Dimension B Opening	
	Inches	(mm)	Inches	(mm)
3	3	(75)	5	(125)
4	4	(100)	6	(150)
5	5	(125)	7	(180)
6	6	(150)	8	(205)

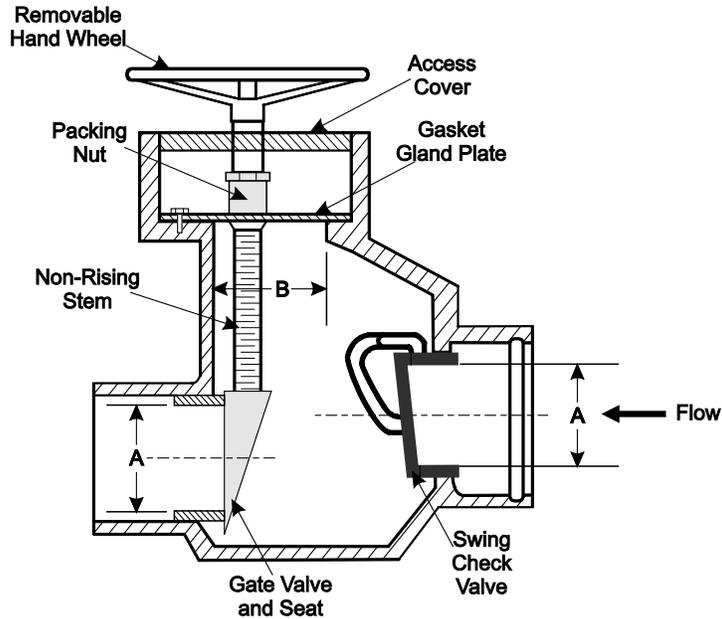


Figure 2 - Combination Horizontal Backwater Valves and Manual Gate Valves

Table 3 - Dimensions for Terminal Backwater Valves  
(See Figure 3)

Nominal Size Inches	Dimension A	
	Inches	(mm)
2	2	(50)
3	3	(75)
4	4	(100)
5	5	(125)
6	6	(150)
8	8	(205)
10	10	(255)
12	12	(305)

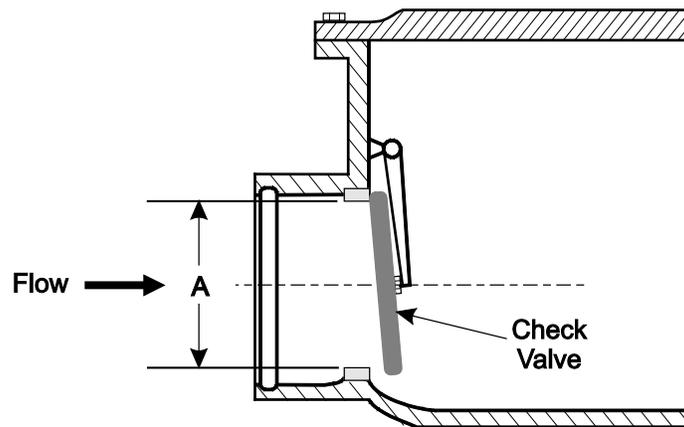


Figure 3 - Terminal Type Valve

- 3.2.2.2 Hub and spigot dimensions of a backwater valve shall comply with the appropriate hub and spigot requirements of the joining material.
- 3.2.2.3 Backwater valves designed to be normally closed shall be constructed that when the valve 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 will remain sufficiently open during periods of low flows to avoid the screening of solids.
- 3.2.2.4 Backwater valves designed to be normally open shall be constructed that when the valve is installed at the required 1:48 slope (1/4 in. per foot) with respect to the direction of flow, check member will be in an open position but will close when fluid backflow occurs. The valve shall not reduce the hydraulic capacity of the connecting pipe.
- 3.2.2.5 Backwater valves shall be designed and constructed that when installed in it's proper operating position in the drainage system, the upper face of the cover shall be parallel to the invert of the outlet so that the slope of the drain can be readily determined by placing a level on the top of the cover.
- 3.2.2.6 Backwater 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 gas tight once installed.
- 3.2.2.7 Parts that are used to affect sealing in backwater valves shall be secured in a manner that will maintain proper alignment of mating surfaces. Moving and stationary parts shall not loosen or become detached during handling or operation of the unit and shall be replaceable.

- 3.2.2.8 Hub and spigot connections for backwater valves shall conform to ASTM A 74 for soil pipe and fittings.
- 3.2.2.9 The internal working parts such as valve seat, flap, hinge pins, and stems of a backwater valve shall be copper alloy in accordance with ASTM B 16, stainless steel in accordance with ASTM A 351, or equally corrosion resisting material. The casting or moldings for backwater valves shall be sound, free of blow holes, cold shuts, fins, flashing, and other imperfections affecting casting quality and shall be of uniform thickness.

### 3.2.3 Flood Abatement Pumps

- 3.2.3.1 The flange dimensions, bolt layouts, and threaded openings used in pipe connections for a flood abatement pump shall conform to a recognized national or international standard.
- 3.2.3.2 Manufacturers must provide a characteristic curve for each pump. The maximum power shall be based on the highest power requirement, regardless of where it occurs on the entire characteristic curve.
- 3.2.3.2 A pump shall be cable of turning on and off either manually or automatically. A automatic operation shall turn on or off by responding to the appropriate water levels in a sump.
- 3.2.3.3 A pump must have a means of protection from clogging from floating debris.

## 3.3 Components

- 3.3.1 All components of flood abatement equipment products shall be examined and tested in accordance with this standard. However, not all component tests within this standard are applicable to every product design. In addition, if a component cannot be adequately examined with the tests listed in this standard, additional testing may be necessary. Applicable component tests will be determined at the sole discretion of testing laboratory.

At a minimum, components required for the flood abatement equipment shall be designed for proper system functionality, and maximum long term reliability. Flood abatement 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.

## 3.4 Markings

- 3.4.1 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
  - System ratings (as applicable)
  - Equipment operating ratings (as applicable)
  - Serial number or other traceable code markings
  - Manufacturing location source code (as applicable)

Additional marking for backwater valves include;

- For plastic valves, the letters “ABS” or “PVC” (as applicable to the material of the valve body)
- Nominal size
- Direction of flow

Additional marking for flood abatement pumps include;

- Rated flow
- Rated head
- Speed
- Hertz
- Horsepower
- Voltage
- Amperage
- Phase

- 3.4.3 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.
- 3.4.3 The marking for a backwater valve shall be located on the cover plate so that it is visible after the valve has been installed.
- 3.4.4 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.
- 3.4.5 The model identification shall correspond with the manufacturer's catalog designation. The manufacturer shall not place this model identification on any other product.

### **3.5 Manufacturer's Design, Installation, Operation, and Maintenance Manual**

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

This document must include the following, at a minimum:

- A description of the barrier parts and components needed for installation and deployment
- A description of foundation requirements
- A procedure and/or requirements on how to pre-install the barrier (as applicable)
- A procedure on how to deploy the barrier
- Details regarding maintenance and/or trouble shooting during deployment or flood conditions

**3.6 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.

**3.7 Test Facilities**

If review of all required information indicates suitability for testing, representative samples of the flood abatement 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 abatement 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.

**3.8 Tolerances**

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

## 4. PERFORMANCE REQUIREMENTS

The performance requirements are composed of five different sections; (Section 4.1) general component and material testing for opening and temporary perimeter barriers, (Section 4.2) performance testing for temporary perimeter barriers, (Section 4.3) performance testing for opening barriers, (Section 4.4) testing for backwater valves and, (Section 4.5) testing for flood abatement pumps.

### 4.1 General Components and Materials Testing for Opening and Temporary Perimeter Barriers

The components and materials of a flood barrier 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 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.

Performance testing on components may be conducted for an individual component, component assembly, or as an entire barrier 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

A flood barrier 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

A flood barrier and all its individual components shall be examined and compared to the manufacturer's production drawings and engineering specifications.

In addition, it shall be verified that the representative 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 or tubes, shall withstand 150 percent of the maximum system operating pressure without rupture, cracking or permanent distortion.

##### 4.1.2.2 Test/Verification

Components or barriers of each size shall be subjected to a test pressure of 150 percent of the maximum system operating pressure, for five minutes. The test medium shall be the medium used during operation. No rupture, cracking or permanent distortion of the component body is allowed. After the test the components or barrier shall be fully functional.

4.1.3 System Leakage Test

4.1.3.1 Requirements

Pressure retaining components 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

With the inlet side open to the atmosphere, the upstream side of each component shall be subjected to pressure of 120 percent of the maximum system operating pressure. The test medium shall be the medium used during operation. The test pressure shall be held for five minutes with no leakage allowed.

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.

4.1.4.2 Tests/Verification

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

4.1.5 Vibration Resistance

4.1.5.1 Requirements

Component assemblies shall withstand vibration without cracking, loosening, separation, or excessive wear.

4.1.5.2 Tests/Verification

One of each type of component assembly shall be attached to a vibration machine so that the assemblies are vibrated in their intended installation position.

The test samples shall be subjected to the vibration conditions outlined in Table 4.15. The frequency shall be varied with a cycle period of  $25 \pm 5$  seconds. If one or more resonant point(s) is detected, the component or component assemblies shall be vibrated for the remainder of the five hours 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 vibration condition for a period of 5 hours.

*Table 4.15 Vibration Conditions*

<i>Total Displacement/Stroke Inch (mm)</i>	<i>Frequency Hz</i>	<i>Time Hours</i>
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 barrier shall not craze 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 plastic component(s) shall not show crazing, signs of cracking, or permanent distortion.
- 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 a flat steel weight shall be dropped on each component with an impact of 68 Joules (50 ft-lbf). The weight shall be dropped three separate times and shall be prevented from impacting the test sample more than once for each drop. After the tests, the plastic component(s) shall not show any signs fracture or crazing.

#### 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

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.

#### 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

Elastomer components which are subjected to tensile type loading 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.

##### 4.1.9.2 Tests/Verification

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*.

#### 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 15 percent.

##### 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).

#### 4.1.11 Ultraviolet Light and Water Test

##### 4.1.11.1 Requirements

Non-metallic components 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  $109 \pm 4.5^{\circ}\text{F}$  ( $43 \pm 2.5^{\circ}\text{C}$ ) and the relative humidity  $30 \pm 5$  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

##### 4.1.12.1 Requirements

Non-metallic components, other than rubber gaskets, shall not crack or craze after being subjected to an air-oven aging test at  $158^{\circ}\text{F}$  ( $70^{\circ}\text{C}$ ).

##### 4.1.12.2 Test/Verification

A sample of each non-metallic component shall be subjected to an air-oven aging test for 180 days at  $158^{\circ}\text{F}$  ( $70^{\circ}\text{C}$ ), and then allowed to cool at least 24 hours in air at  $74^{\circ}\text{F}$  ( $23^{\circ}\text{C}$ ) at 50 percent relative humidity. After the test, the 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.

#### 4.1.13 Environmental Corrosion Resistance (Barriers 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 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 (Perimeter Type Barriers)

##### 4.1.15.1 Requirement

Membranes, shell, 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 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 (Perimeter Type Barriers)

##### 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 (Perimeter Type Barriers)

##### 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 Temporary Perimeter Flood Barriers

The performance testing of temporary perimeter barriers has been designed to simulate riverine flood 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 product.

Performance testing is typically conducted at a facility similar to the US Army Corps of Engineers, ERDC Coastal and Hydraulics Laboratory, located in Vicksburg, Mississippi. The design, description, and capabilities of the facility are described in Appendix C. 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 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. Alternative facilities may be accepted for testing at the sole discretion of testing laboratory.

Major and minor repairs to a perimeter 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 harms way.

Table 4.2 Perimeter Flood Barrier Performance Tests

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 water depth for the barrier is defined as "h".

4.2.1 Deployment

4.2.1.1 Requirements

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;

4.2.1.1.1 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 personal required to deploy the barrier as described below:

- Skilled personnel; a person with specific knowledge of the installation method of the barrier
- Unskilled personnel; a person that has no knowledge of the barrier design or installation
- 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 the steps for the deployment of the barrier. The procedure shall comply with all of the requirements of Section 4.2.1.1.

#### 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
- What to do if damage should occur during construction

#### 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

A perimeter barrier shall be capable of withstanding the hydrostatic loads created by floodwaters of various heights. The leakage rate shall not exceed 0.25 gallons per minute per foot length (3.10 liters per minute 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  $\pm$  0.5 in (0.30 m  $\pm$  13 mm)
- 2 ft  $\pm$  0.5 in (0.61 m  $\pm$  13 mm)
- 100 percent  $\times$  h  $\pm$  0.5 in (13 mm)

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

Fill the river-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 for each test.

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 100 percent  $\times$  h water depth shall be repeated after 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

A perimeter barrier 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 0.25 gallons per minute per foot length (3.10 liters per minute 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 deformation.

#### 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 water depth of the barrier. If this water depth is less than or equal to 2.0 ft, the water depths may be changed as deemed appropriate by the testing laboratory.

Drain the river-side of the basin to the desired water level, or fill the river-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 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

<i>Wave Description</i>	<i>Wave Height (Measured from trough to crest)</i>	<i>Mean Wave Period</i>	<i>Test Duration</i>
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

A perimeter barrier 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

A perimeter barrier shall be capable of withstanding multiple impacts from floating debris. The leakage rate shall not exceed 0.25 gallons per minute per foot length (3.10 liters per minute 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 riverside of the barrier until the water level equals  $66.7 \text{ percent} \times h \pm 0.5 \text{ in}$  (13 mm), where  $h$  is the manufacturer's specified maximum water depth of the barrier.

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) [ $\sim 5.0 \text{ mph}$  (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 right before the log impacts 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.

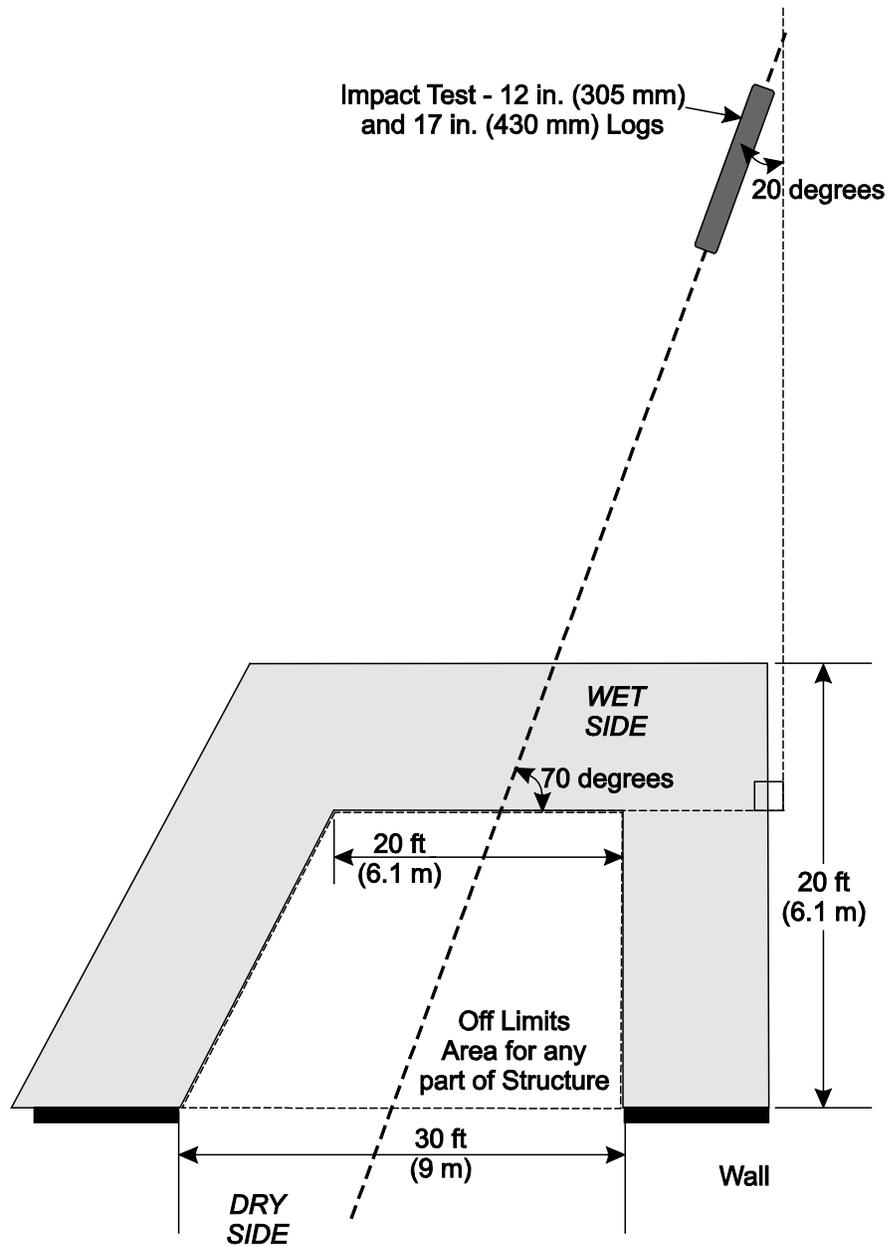


Figure 4.2.5.2 Debris Impact Test Layout

4.2.6 Current Test

4.2.6.1 Requirements

A perimeter barrier shall be capable of withstanding forces created by a 7.0 ft/s (2.1 m/s) current. The leakage rate shall not exceed 0.25 gallons per minute per foot length (3.10 liters per minute 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  $h \pm 0.5$  in (13 mm), where  $h$  is the manufacturer’s specified maximum water depth of the barrier. 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) [ $\sim$ 5.0 mph (8.0 km/h)] and then maintained steady for 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 for Opening Barriers

The performance testing of opening barriers has been designed to simulate quasi-static riverine flood conditions, i.e. slow rising and receding floodwaters with minimal wave exposure and blunt debris impact. All tests in this section must be completed in sequence as shown in Table 4.3, with the same test sample.

Table 4.3 *Opening Flood Barrier Performance Tests*

<i>Test Description</i>	<i>Condition*</i>	<i>Duration</i>
Deployment	N/A	Per Manufacturer’s Specifications
Hydrostatic Load	100 percent x $h \pm 0.25$ in (0.6 cm)	22 hr
Redeploy	Disassemble and redeploy	Per Manufacturer’s Specifications
Dynamic Impact Load	Impact at weakest point of barrier	N/A
Post Hydrostatic Load	100 percent x $h \pm 0.25$ in (0.6 cm)	1 hr
Redeploy	Disassemble and redeploy	Per Manufacturer’s Specifications
Dynamic Impact Load	Impact at the barrier connection to the supporting structure	N/A
Post Hydrostatic Load	100 percent x $h \pm 0.25$ in (0.6 cm)	1 hr

\* The manufacturer’s specified maximum water depth for the barrier is defined as “h.”

The tests shall be conducted with a test enclosure which is capable of retaining water for at least 22 hours at the manufacturer’s specified maximum water depth for the barrier. The length of the test enclosure must accommodate all the requirements for each of the performance tests.

Major and minor repairs to the opening barrier during the performance test series are only allowed at the discretion of the testing laboratory. If minor repairs are conducted then only a maximum of three minor repairs shall be 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 harms way.

#### 4.3.1 Pre-installation

##### 4.3.1.1 Requirements

The barrier's Design, Installation, Operation, and Maintenance Manual shall be verified for accuracy and completeness of the pre-installation procedure and/or requirements.

When the manual indicates multiple pre-installation options, the performance test series shall be conducted on all desired opening barrier pre-installations (i.e. externally mounted to a structure, internally mounted to a structure, door jamb mounting, etc).

##### 4.3.1.2 Tests/Verification

Verify that the barrier's manual accurately details all applicable pre-installations of the barrier to the test enclosure(s).

#### 4.3.2 Deployment

##### 4.3.2.1 Requirements

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 equipment are supplied with the barrier.

###### 4.3.2.1.2 Person-Power Requirements

The manual shall include the number of personal used to deploy the barrier.

###### 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 man-hours.

###### 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

#### 4.3.2.2 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. 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

An opening barrier 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 protected opening over any 15-minute period, where the linear foot of protected opening is the length of the opening width (measured from barrier seal-to-seal) plus two times the water depth.

##### 4.3.3.2 Tests/Verification

Fill the wet-side of the test apparatus to 100 percent  $x h \pm 0.25$  in (0.6 cm), where  $h$  is the manufacturer specified maximum water depth for the barrier.

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. If neither has occurred than measure the leakage rate at the following increments, at a minimum;

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

The Hydrostatic Load Test shall be repeated as a post test to each Dynamic Impact Load Test as shown in Table 4.3. The duration of the post tests shall be 1 hour.

4.3.4 Dynamic Impact Load Test

4.3.4.1 Requirements

An opening barrier shall be capable of withstanding two impacts of 600J each from a rigid falling object simulating floating debris. The maximum amount of permanent deflection from the impacts shall be less than  $L/120$  but not greater than 1 inch (25 mm), where  $L$  is the linear span of the opening measured in inches (millimeters). In addition, permanent dents at the point of impact shall not impair the functionality 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 [ $30 \text{ lb/ft}^3$  ( $48 \text{ kg/m}^3$ )]. 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 panel, 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 panel or frame may be included as deemed necessary by 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.

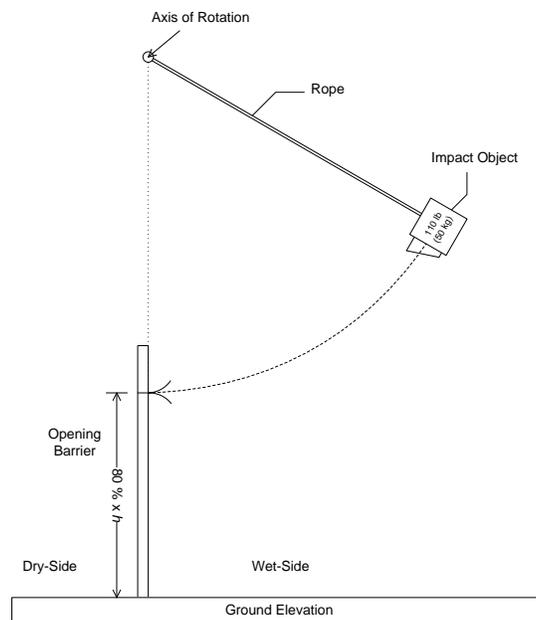


Figure 4.3.4 Impact Test Layout

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 (110 lb or 50 kg),  $g$  is gravitational acceleration (32.2 ft/s<sup>2</sup> or 9.81 m/s<sup>2</sup>), and  $h$  is the height through which the impacting object falls (i.e. 4 ft or 1.22 m).

Measure the permanent deflection after each impact and verify that any permanent dents at the point of impact did not impair the functionality of the barrier. Permanent deflection is measured from the original location of the barrier along its base where it forms the seal, on the riverside of the barrier.

**4.4 Testing for Backwater Valves**

4.4.1 Examination

4.4.1.1 Requirements

Backwater valves shall conform to the manufacturer’s drawings and specifications.

4.4.1.2 Test/Verification

A backwater valve 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 Water Flow

4.4.2.1 Requirements

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

<i>Nominal Size Inches</i>	<i>Diameter of Cylinder Inches (mm)</i>
1.5	0.75 (19)
2	1.00 (25)
3	1.50 (38)
4	2.00 (51)
6	3.00 (76)
8	4.00 (102)

4.4.2.2 Tests/Verification

The test cylinder as indicated in section 4.4.2.1 shall pass through the backwater valve to the point where the valve body has an integral quarter bend on the outlet or assembled in a floor drain.

4.4.3 Watertightness

4.4.3.1 Requirements

A backwater valve shall not exceed the water leakage rate as described in section 4.4.3.2 when exposed to a range of water pressures.

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 a 5 psi (34 kPa) hydrostatic pressure shall be affixed to the outlet of the backwater valve. The water pressure shall be increased to 5 psi (34 kPa) in the following four steps:

<i>Water Pressure Psi (kPa)</i>
0.25 (1.7)
0.50 (3.4)
1.0 (6.9)
5.0 (34.5)

The pressure shall be maintained at each step 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 water leakage shall not exceed the following:

<i>Nominal Size, Inches</i>	<i>Volume of Collected Water, Fl oz (mL)</i>
1.5	5.5 (163)
2	9.5 (281)
3	21.5 (636)
4	38.5 (1,139)
6	87.0 (2,573)
8	153.0 (4,525)

4.5 Testing for Flood Abatement Pumps

4.5.1 Examination

4.5.1.1 Requirements

Flood Abatement Pumps shall conform to the manufacturer’s drawings and specifications.

4.5.1.2 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.

#### 4.5.2 Clearance/ Interference

##### 4.5.2.1 Requirements

A pump shall conform to the manufacturer's clearance and/or interference specifications.

##### 4.5.2.2 Tests/Verification

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

#### 4.5.3 Performance

##### 4.5.3.1 Requirements

The pump shall develop its rated pressure when delivering its rated capacity as specified by the manufacturer.

##### 4.5.3.2 Tests/Verification

A sample pump shall be operated at various flow rates to verify the manufacturer's characteristic curve. A minimum of three flow readings shall be taken; one flow reading should be as close to the rated capacity as possible, while the other two flow readings should be at about 20 percent above and 20 percent below the rated capacity. At each flow rate, the total discharge head, total suction head, and power required shall be measured.

Note: Pumps with a set impeller diameter and operating speed may use a more simplistic test program to confirm that the rated point is met.

#### 4.5.4 Endurance Test

##### 4.5.4.1 Requirements

A pump shall be capable of continuous operation for 336 hours at its 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.

##### 4.5.4.2 Tests/Verification

A sample pump shall be operated continuously for 336 hours at its rated capacity. 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.

#### 4.5.5 Hydrostatic Strength

##### 4.5.5.1 Requirements

A pump shall withstand an exposure to a hydrostatic test. The pump shall not rupture, crack, or exhibit 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.

#### 4.5.5.2 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 ( $2 \times P_{\max}$ ), where  $P_{\max}$  is the maximum shutoff pressure specified by the pump manufacturer. No rupture, cracking or permanent distortion shall be observed.

#### 4.5.6 On/Off Switch Durability - Cycling

##### 4.5.6.1 Requirements

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

##### 4.5.6.2 Tests/Verification

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

#### 4.5.7 Voltage Variation

##### 4.5.7.1 Requirements

Electrically operated motors used in a flood abatement pump shall operate properly at  $\pm 15$  percent of the rated voltage specified by the manufacturer. The pump shall display no hesitation, partial operation, or other failures to operate properly.

##### 4.5.7.2 Tests/Verification

The motor of a flood abatement pump shall be supplied with minus 15 percent of the rated voltage for a period of 2 minutes. The pump shall display no hesitation, partial operation, or other failures to operate properly. The test shall then be repeated with a supply of plus 15 percent of the rated voltage to the motor.

#### 4.5.8 Dielectric Withstand

##### 4.5.8.1 Requirements

Electrically operated motors used in a flood abatement 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.

##### 4.5.8.2 Tests/Verification

For a motor 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 than 10 seconds, and maintained for a minimum of 60 seconds.

### 4.6 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 abatement 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.

**APPENDIX A: Units of Measurement**

<b>FLOW:</b>	gal/min - “gallon per minute”; (L/min - “liters per minute”) L/min = gal/min x 3.7854
<b>FORCE:</b>	lbf - “pounds-force”; (N - “newtons”) N = lbf x 4.4482
<b>LENGTH:</b>	in. - “in.”; (mm - “millimeters”) mm = in. x 25.4 ft - “feet”; (m - “meters”) m = ft x 0.3048
<b>MASS:</b>	Lb - “pounds”; (kg - “kilograms”) kg = lb x 0.454
<b>PRESSURE:</b>	psi - “pounds per square inch”; (bar - “bars”) bar = psi x 0.06895 psf - “pounds per square foot”; (kPa - “kilopascals”) bar = psf x 0.00479 psi - “pounds per square inch”; (kPa - “kilopascals”) psi = kPa x 6.8948
<b>TEMPERATURE:</b>	°F - “degrees Fahrenheit”; (°C - “degrees Celsius”) °C = (°F - 32) x 0.556
<b>TORQUE/MOMENT:</b>	lbf·ft - “pound-force foot”; (N·m - “newton meters”) N·m = lbf·ft x 1.356
<b>VACUUM:</b>	inHg - “in. of mercury”; psi - “pounds per square inch”; (kPa - “kilopascals”) psi = inHg x 0.4912 kPa = inHg x 3.3864
<b>VOLUME:</b>	gal - “gallons”; (L - “liters”) L = gal x 3.7854 Fl oz - “fluid ounces”; (mL - “milliliters”) FL oz = mL x 29.57
<b>VOLUME PER UNIT AREA:</b>	gal/min/ft <sup>2</sup> - “gallons per minute per square feet” (mm/min - “millimeters per minute”) mm/min = gal/min/ft <sup>2</sup> x 40.75
<b>WORK:</b>	J-“Joules”; (ft·lbf - “foot-pounds force”) J = ft·lbf x 0.7376

**APPENDIX B: Tolerances**

Unless otherwise stated, the following tolerances shall apply:

<b>Angle:</b>	$\pm 2^\circ$
<b>Flow</b>	$\pm 3$ percent of value
<b>Frequency (Hz):</b>	$\pm 5$ percent of value
<b>Length:</b>	$\pm 5$ percent of value
<b>Volume:</b>	$\pm 5$ percent of value
<b>Rotation:</b>	$\pm 1$ RPM
<b>Pressure:</b>	$\pm 5$ percent of value
<b>Temperature:</b>	$\pm 5$ percent of value
<b>Time:</b>	+ 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  $68^\circ\text{F} \pm 18^\circ\text{F}$  ( $20^\circ\text{C} \pm 10^\circ\text{C}$ ).

## APPENDIX C: USACE Coastal and Hydraulics Laboratory Test Facility Description

Performance testing of perimeter barriers is typically conducted at 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.

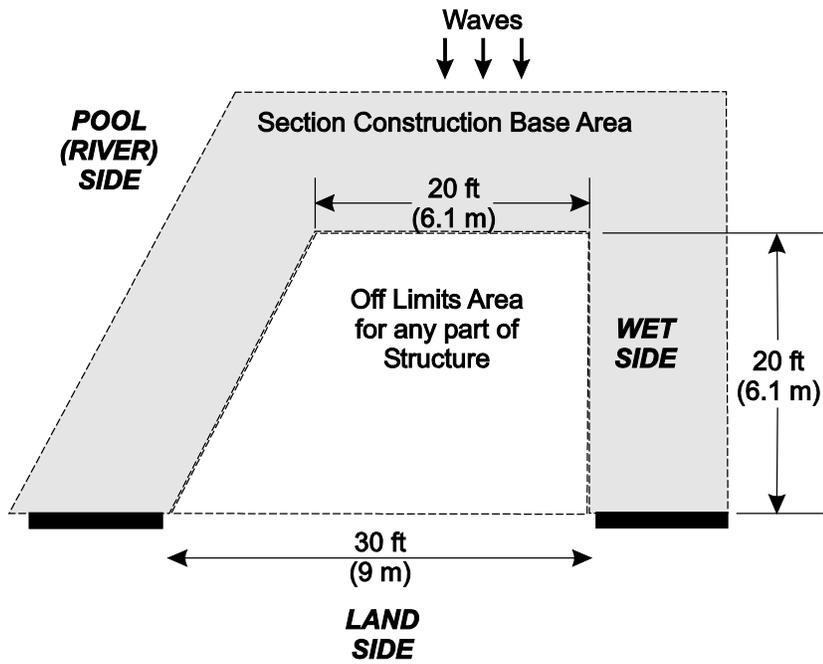
Seepage rates through the test structures are measured by the flow meters in the 4 in. (10.2 cm) diameter pipes and also by a laser pointing at a float in a standpipe in the sump measuring changes in water surface elevation. Several capacitance-type wave gauges measure the changes in water surface elevation 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 temporary perimeter 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.



Pumping capacity needs to be sufficient for current and overflow tests.

Figure C-1. Layout and Barrier Construction