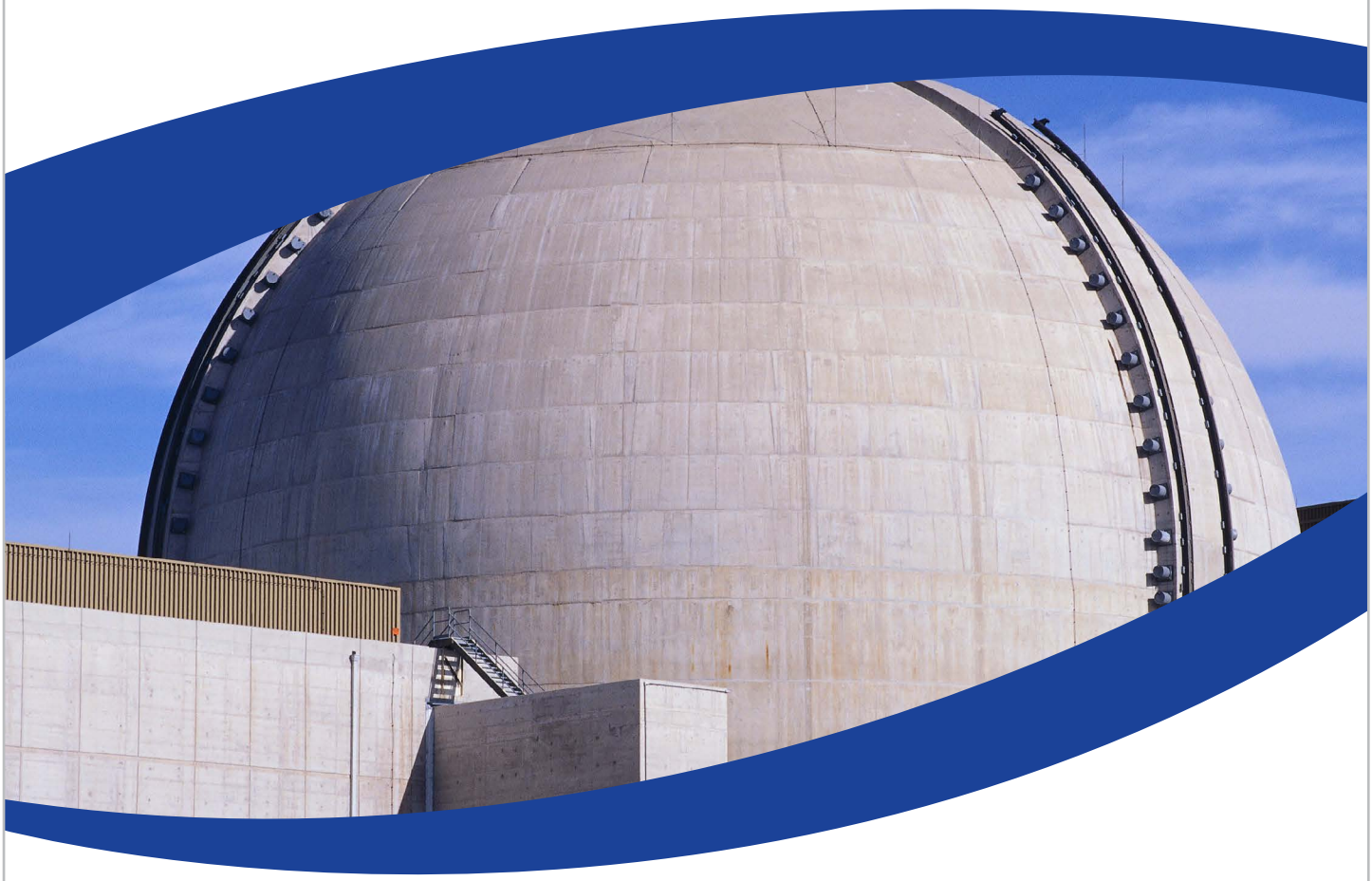
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2015 TECHNICAL REPORT

Flood Protection Systems Guide



Flood Protection Systems Guide

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Final Report, November 2015

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PRODUCT DESCRIPTION

This guide describes flood-protection components at nuclear power plants (NPPs) and the design, testing, inspection, and maintenance of these components. The guide is based on information collected from a consensus of industry peers. Its intent is to provide information for NPP facilities to assist in the development and management of their flood-protection basis requirements in regard to external flooding-related events. In the various sections of this guideline, specific attention is given to flood barrier penetration seals (FBPSs) because of the relative complexity, varying designs, and lack of existing codes and standards for these components. Although the focus of the guide is on external flooding-related events, descriptions of components, design considerations, maintenance activities, and other topics that can apply to both external and internal flood-protection requirements are included. Additional sections within the guide address recent industry events and major considerations for establishing and managing flood-basis requirements at the site level.

Background

Several incidents at various NPPs across the world have highlighted the importance of flood-protection features and the need for reasonable assurance that they will perform as intended should an external flooding event occur. These events have also identified a need for establishing and managing the flood-protection design basis of the site. To date, comprehensive guidance on the design, inspection, testing, and maintenance of flood-protection components has not been assembled. This document includes information related to these topics for a variety of flood-protection components, while focusing specifically on FBPSs.

Objectives

To provide guidance for establishing and assessing plant flood-protection design features by

- Listing common flood-protection components used in NPP applications, along with a description of each.
- Summarizing techniques and methods used for flood-barrier testing and acceptance criteria.
- Developing a comprehensive list of design considerations associated with the testing and installation of various flood-protection components.
- Providing in-service inspection, testing, and maintenance recommendations based on the consensus view of a group of industry experts involved in the development of this guideline.
- Identifying operating experience to provide a current industry performance analysis of flood-related events.
- Identifying good practices associated with establishing and managing flood-basis requirements at the site level.

Approach

Content for this guide was assembled by gathering a Technical Advisory Group (TAG) of industry subject-matter experts with experience in managing or addressing flood-related topics at several NPPs. In addition, other industry subject-matter experts were brought in to assist in developing the various sections of the guide. This guide provides a compendium of some of the processes and practices currently in use for the design, installation, and maintenance of flood-protection components. After providing descriptions of a variety of flood-protection components at the beginning of the guide, specific sections were developed to address other important topics related to these components.

Results

This guide provides information for flood-protection components at NPPs. Key elements include

- Descriptions of flood-protection components used in NPP applications, along with the intended purpose for each.
- Design considerations associated with the testing and installation of these components.
- Current testing parameters and acceptance criteria.
- Inspection, testing, and maintenance recommendations for flood-protection features.
- A summary of identified operating experience impacting flood-protection features, including identification of recurring issues among these events.

Applications, Value, and Use

The information contained in this guide represents a collection of industry processes and practices being used in the design, installation, and maintenance of flood-protection components. It is intended to be foundational to the research EPRI has undertaken with the intent of addressing and improving the understanding of external flooding-related issues. The information contained in this guide will assist in assessing flooding-related issues at the component level as well as in developing both formal and informal flood-protection programs.

Keywords

Flood barrier
Flood barrier penetration seal (FBPS)
Flood components
Flood-protection system
Flooding guidance
Seals and penetrations

ABSTRACT

The Electric Power Research Institute (EPRI) has developed this Flood-Protection Systems Guideline as part of a continuing effort to define, improve, adapt, and apply available technologies to reduce risks associated with flood protection in nuclear power plants (NPPs). It defines and describes common flood-protection components along with the design, testing, inspection, and maintenance of these components.

Preventing water from entering into areas of NPPs that contain significant safety components is the function that various flood-protection components serve across the industry. Several types of flood barriers, both permanent and temporary, are used at NPPs. These barriers include external walls, flood doors, and flood barrier penetration seals (FBPSs) that allow cables, conduits, cable trays, pipes, ducts, and other items to pass between different areas in the plant. As part of a broader flood-mitigation strategy at NPPs, it is important that these flood barriers are installed and maintained in a condition that ensures they will perform their intended function: to prevent excessive amounts of water from entering into areas of the plant that would cause or compound an undesired plant event.

Within the nuclear power industry, several incidents at various plants throughout the world have highlighted the importance of developing and maintaining a flood-protection basis tailored to address the specific risks and hazards applicable to individual sites. Along with fulfilling design-basis requirements, the various types of flood barriers used at each site need to provide plant personnel with a reasonable assurance that they will perform as intended in the event of an emergency. To date, comprehensive guidance on the design, inspection, testing, and maintenance of flood-protection components has not been assembled. This document includes information related to these topics for a variety of flood-protection components, while focusing specifically on FBPSs.

The content developed for this guide was assembled by gathering information from knowledgeable plant personnel, related vendors, and relevant industry organizations. It is intended to serve as a resource to assist engineering and maintenance personnel at NPPs in the development and management of their appropriate external flooding-protection requirements. Despite the focus on external flooding in this guide, there are cases in which the information presented may be applicable to internal flooding-protection requirements as well.

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1
INTRODUCTION

1.1 Purpose and Scope

The purpose of this report is to provide technical information associated with various flood protection components. This includes descriptions, functions, design, testing, inspection, and maintenance information at the component level. In addition to this, a summary of recent and relevant operating experience (OE) is listed along with best practices for developing and managing a flood protection basis. Information in this guide is intended to provide nuclear power plants (NPPs) with technical information to assist in the development or management of their external flooding protection requirements, specifically as they relate to FBPSs and other selected components.

While the primary focus of this report is on flood protection features and components associated with external flood events, many of the components, devices, design considerations and programmatic elements discussed in this document could be applied to components associated with flood protection for internal flooding events.

Information was gathered using knowledgeable industry subject matter experts and vetted through a Technical Advisory Group (TAG) comprised of industry engineers involved in management of the external flooding protection requirements at their site or utility.

1.2 Background

Recent world events and operating experience (OE) provide examples of how internal and external flooding events have led to a focus on and re-evaluation of flood protection and design basis requirements across the industry. These incidents have brought attention to flood protection features and the approach that plants adopt towards installing, testing, and maintaining these components. This guide represents an effort by EPRI to assist the industry in identifying key aspects associated with flood protection component features such as descriptions, applications, design considerations, current testing methods, and relevant industry events.

1.3 Report Structure and Content Overview

Section 1 provides the scope and purpose of this report. It also introduces key definitions and acronyms used throughout the different sections.

Section 2 provides descriptions of various types of flood protection components used in NPP applications and the intended purpose for each.

Section 3 identifies what testing has been done to qualify installed flood barriers to NPPs in terms of their ability to withstand leakage or failure. The main focus is on flood barrier penetration seals (FBPSs) due to the lack of testing codes and standards associated with these

components and their relative testing complexity due to the myriad of applications they are suited for; although, other barriers are addressed.

Section 4 provides information on the design criteria associated with flood barriers. It is targeted towards flood program engineers working with a regulator or potential third party vendors installing or repairing barriers (mainly FBPSs).

Section 5 provides a detailed discussion of inspection, testing, and maintenance recommendations on a variety of permanent and temporary flood protection components.

Section 6 provides an analysis of recent flooding-related events at NPPs across the world and identifies recurring issues as well as corrective actions associated with these events.

Section 7 provides best practices for establishing and managing a flood basis using examples and feedback from the sites and utilities consulted during the creation of this guide.

Within the Appendices, Appendix A provides a listing of key points, Appendix B includes a matrix for flooding components, and Appendix C and D provide information from recent events to support Section 6. Lastly, Appendix E provides a summary of volumetric protection and how it has been applied within a utility.

1.4 Glossary of Terms

1.4.1 Definitions and Nomenclature

Active Flood Protection Components/Mitigation – Components that fulfill a flood protection function by changing their structure or state. These could serve as permanent or temporary items at a plant. Examples referenced in this guide include entrance and egress openings, flood outlet devices, and pumps.

Blockout – A rectangular opening cast in a barrier to allow the passage of multiple penetrating items. Blockout penetrations are typically unlined concrete openings, but in some instances blockout penetrations may have a steel liner.

Bondbreaker Material - A compound applied to the surface of a pipe that passes through a penetration which prevents the penetration seal material from bonding to the pipe. The result is a penetration seal that allows axial pipe movement without damaging the penetration seal material.

Fire Penetration Seal – A fire resistant seal designed to maintain the fire-resistive integrity of the barriers in which it is installed.

Flood Barrier Penetration Seal (FBPS) – A material, combination of materials, or pre-manufactured device installed inside a penetration through a flood barrier to seal the opening and maintain the flood rating of the barrier. Typical penetrations include openings to accommodate the passage of pipe, tubes, conduits, cable trays, cables and ventilation ducts. An Internal Conduit Seal (ICS) may also be classified as a Flood Barrier Penetration Seal (FBPS) if it serves the function of preventing flood water from propagating between areas via the inside of a conduit.

Internal Conduit Seal (ICS) – A material, combination of materials, or pre-manufactured device installed inside of a conduit that creates a seal internal to the conduit. Internal conduit seals are typically installed at the first access point in the conduit from the barrier being

penetrated by the conduit. Typical access points include pull boxes, lateral bend fittings, junction boxes, or an open-end if the conduit terminates in space.

Nationally Recognized Testing Laboratory (NRTL) –A laboratory which is listed and recognized by the United States Dep. Of Labor, Occupational Safety & Health Administration (OSHA), Directorate of Science, Technology, Medicine program. The program recognizes private sector organizations as NRTLs 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 the consensus based standards of safety to provide assurance, required by OSHA, that these products are safe for use as intended.

Passive Flood Protection Mitigation/Components –Components that fulfill a flood protection function without changing their structure or state. These could serve as permanent or temporary items at a plant. Examples referenced in this guide include penetrations, drains, and permanent flood barriers.

Permanent Barrier/Component – Engineered passive or active flood protection barriers or components installed (permanently) in the plant that protect safety related systems, structures and components from inundation and static/dynamic effects of external flooding. Examples include walls, floors, site grading, seals, valves, etc. that are permanently incorporated into a plant structure.

Temporary Barrier/Component – Passive or active flood protection barriers or components within the immediate plant area such as sandbags, removable gates or doors, caps and plugs, etc. that protect safety related systems, structures and components from inundation and static/dynamic effects of external flooding and are temporary in nature, i.e., they must be installed prior to the advent of an external flood.

1.4.2 Acronyms

BAR - Metric unit of atmospheric pressure equal to 14.50 pounds per square inch (lb/in2)

FBPS – Flood Barrier Penetration Seal

FPS - Fire Penetration Seal

FPP – Fire Protection Program

ICS – Internal Conduit Seal

NPP – Nuclear Power Plant

NRTL – Nationally Recognized Testing Laboratory

OE – Operating Experience

PSWR – Penetration Seal Work Release

R/D – Research and Development

RTV – Room Temperature Vulcanization

SSCs – Systems Structures and Components

1.5 Key Points

Appendix A of this report contains a listing of all Key Points in each category. The listing restates each Key Point and provides a reference to its location in the body of the report. By reviewing this listing, users of this report can determine if they have taken advantage of key information that the writers of this report believe would benefit their plants.

Throughout this report, key information is summarized in Key Points. Key Points are bold-lettered boxes that succinctly restate information covered in detail in the surrounding text, making the key point easier to locate.

The primary intent of a Key Point is to emphasize information that will allow individuals to act for the benefit of their plant. Electric Power Research Institute (EPRI) personnel who reviewed this report assisted in the selection of the information included in these Key Points.

The Key Points are organized into four categories: Human Performance, O&M Cost, Technical and Supervisory Observation. Each category has an identifying icon to draw attention to it for the benefit of readers who are quickly reviewing the report. The Key Points are shown in the following way:



Key Human Performance Point

Denotes information that requires personnel action or consideration in order to prevent injury or damage or ease completion of the task.



Key O&M Cost Point

Emphasizes information that will result in reduced purchase, operating, or maintenance costs.



Key Technical Point

Targets information that will lead to improved equipment reliability.



Key Supervisory Observation Point

Identifies tasks or series of tasks that can or should be observed by maintenance first line supervisors to improve the performance of the maintenance staff and improve the reliability of the component.

2
TYPES OF FLOOD BARRIERS USED IN NUCLEAR POWER PLANT APPLICATIONS

2.1 Flood Barriers

Flood barriers are used at Nuclear Power Plants (NPPs) along with drains, pumps and site grading as part of a comprehensive strategy to mitigate the effects of flooding on NPP operations. Flood barriers at NPPs include a variety of both permanent and temporary structures and equipment including walls, doors, berms, and penetration seals.

Permanent flood barriers are typically passive in nature and maintained as part of the design basis for the NPP.

Temporary flood barriers may be staged or deployed to protect or mitigate events, as bridging strategies until permanent engineered features are installed or within a flooding event response plan or procedure.

Flood barriers are often credited to perform multiple functions including fire protection, radiation protection, high energy line break, tornado/wind mitigation, maintaining pressure boundaries and other similar functions. Following the terminology outlined by NEI 12-07, flooding barriers defined within this document are divided into two major areas and then described in this section at the component level [15].

2.2 Passive and Active Flood Protection Components

Table 2-1 and 2-2 divide the different categories of flood protection components into two major areas, passive and active, for easier reference and sub-categorization. Categories appear within each table to group different types of components together in order to provide better structure and allow for cross-referencing in follow-on sections of the guide. The components listed in these tables were narrowed down based on industry member inputs to the guide and descriptions are developed for each in Section 2.3. Along with a definition, these descriptions also explain the description and common application(s) of the component. To improve readability of the guide, the remaining sections are structured - wherever possible and applicable - in a method that attempts to follow the order and layout used within these tables.

Table 2-1
Passive Flood Protection Components

Category	Component
Penetration Seals	FBPSs for pipes, conduits (including ICSs), cable trays, etc. for example: • Boot seals • Grout seals • Silicone Foam seals • Urethane Foam seals • Caulk seals • Silicone Elastomer seals • Epoxy seals • Top Coating Materials • Combination seals • Modular seals (compression seals)
Mechanical System Seals	Dampers (or Closure plates) System seals (Gaskets, O-rings, etc.)
Drains	Blow out panels/hatches Scuppers Floor drains Trenches Yard drains Sewer/drain backflow prevention devices Holding ponds and French drains
Permanent Flood Barriers	Walls Floors/Epoxy Coated Floors Curbs Sloped or raised floors Earthworks, Dikes Upstream holding ponds/ dams Site grading
Temporary Seals	Drain covers Caps and plugs Inflatable or expanding plugs and seals Removable gates or doors
Temporary Flood Barriers	Sandbags Deployable booms, curbs, barriers Obstructions to flow (security barriers, grates, etc.) Diversion excavations

The categories shown in Table 2-2 are listed separately since they represent a type of flood protection component that serves an active role in removing water from areas and mitigating the impact of flooding events.

Table 2-2
Active Flood Protection Components

Category	Component
Entrance or Egress openings	Doors and hatches for example: • Swinging Gate • Horizontal or vertical sliding door • Pressure (submarine) door • Removable closure plates • Hatches
Flood Outlet Devices	Manually operated valves Check valves
Flood Mitigation Equipment	Pumps (portable or permanent)

2.3 Component Descriptions

The following descriptions and applications are provided to give additional information on the components mentioned in the previous tables. This information is intended to serve as a reference for individuals gaining familiarity with the different types of flood protection components that are used at a NPP. Component descriptions and common applications for each are included, along with pictures (as available).

2.3.1 Penetrations Seals

Some of the materials described in this sub-section can be used as both a FBPS as well as an ICS.

2.3.1.1 Boot Seals

Description: Boot seals are comprised of a flexible fabric, typically a silicone-impregnated fiberglass cloth, which is wrapped around a penetrating pipe and the associated penetration sleeve and is secured in place around the pipe (where it meets with the sleeve) using a hose clamp-type device. The penetration cavity beneath the boot material may or may not be filled with a secondary seal material depending on the required functions of the penetration.

Applications: Boot seals are installed in areas where there are considerations for pipe movement associated with penetration being sealed. Boot seals are installed on either one or both sides of a penetration and are attached to both the pipe and the barrier/sleeve itself. Boot seals allow for pipe movement while providing pressure and water resistance from the surrounding area. Figures 2-1 and 2-2 are examples of boot seals.



Figure 2–1
Boot seal

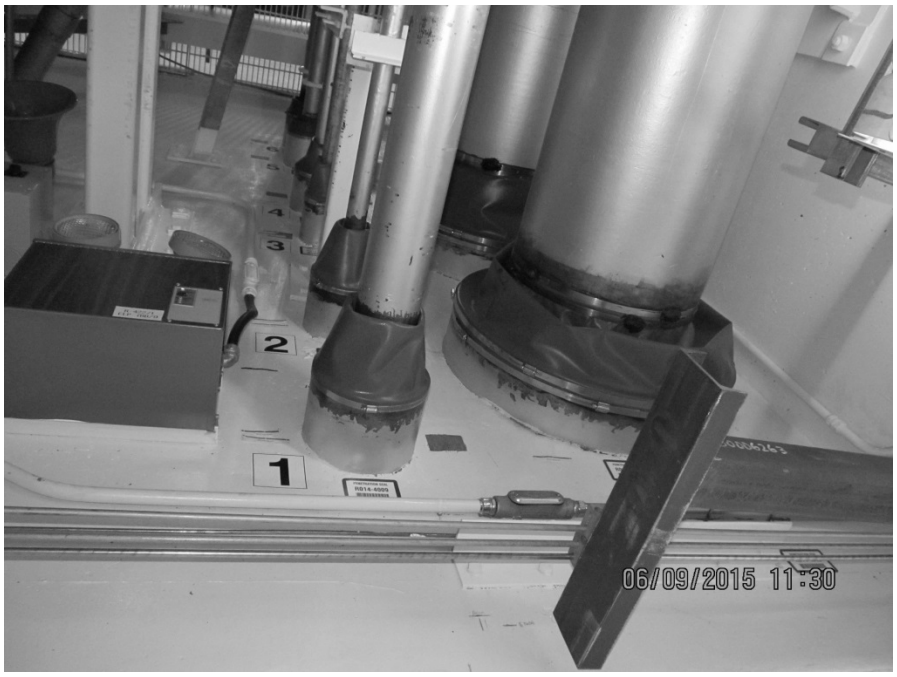


Figure 2–2
Boot Seals Installed Around Pipes

2.3.1.2 Grout Seals

Description: Grout is a construction material used in the repair of masonry, concrete, or pre-cast concrete barriers. It is used to fill voids and sometimes close penetrations. Grout can be either cementitous or epoxy-based, both of which can be utilized for the stated installations above.

Applications: Cementitious grout is usually purchased in premixed bags and combined with water according to manufacturer requirements. Epoxy grout consists of epoxy resin, epoxy hardener, and sand/aggregates. Similar to cementitious grout, epoxy grout is typically purchased in premixed bags and combined with water according to manufacturer requirements. Grout is often used in repairs of concrete or masonry to fill voids in the barrier. It can seal openings, cracks, and gaps to prevent any passage of liquids or gases through the barrier. Proper consideration needs to be given to the potential for minor leakage around grouted commodities, as most all grout materials (including "non-shrink" grout) will exhibit a minor amount of shrinkage during the curing process.

2.3.1.3 Silicone Foam seals

Description: Synthetic polymers made up of repeating units of siloxane. When the constituent components of silicone foam are mixed together and vulcanize, gas bubbles form within the material as it changes from liquid to solid. Several variations of silicone foam have been used in NPPs. In some cases, silicone foam was used in an unaltered form (i.e., as manufactured), while in other instances penetration seal vendors have added proprietary ingredients to the base material resulting in a proprietary blend of silicone foam.

Applications: Proprietary and non-proprietary versions of silicone foam have been used to create formed-in-place penetration seals for a wide range of penetration configurations. Because the silicone foam material expands as it cures, a tight-fitting seal forms in the penetration opening. The continued transition of the seal material from the liquid to the solid state is referred to as "curing" or vulcanization. Both unmodified and modified silicone foam materials generally have a cured density in the range of 15-30 pounds per cubic foot (pcf). The primary application and design of silicone foam is to provide a fire resistant seal for through wall penetrations however, in some cases, silicone foam seals have been used to create pressure resistance penetration seals.

2.3.1.4 Urethane Foam seals

Description: A two-part high-expansion urethane foam that is mixed in a 1:1 ratio through a static mixer during application and cures to a rigid closed-cell structure.

Applications: High-expansion urethane foam seals have been used to seal the inside of conduit penetrations (i.e., ICSs) required to function as flood barrier penetration seals (FBPSs). While high-expansion urethane foam forms a rigid, close-cell seal that is chemically resistant and watertight, this type of product is not suitable for use as a fire barrier penetration seal.

2.3.1.5 Caulk Seals

Description: The category of caulk seals includes a number of sealing materials used to seal joints, seams or openings and gaps in various structures. Depending upon the specific type of caulking material used, caulk seals can provide a water, air, or fire resistance application.

Applications: A caulk seal refers to the application of any number of various sealing compounds packaged in tube/cartridge form and applied using a standard caulking gun and typical caulking techniques to close-up gaps in buildings, fill construction joints, or as a component in penetration fire stopping. Common uses of caulk seals include the sealing of seismic or building joints and gaps, wall-to-floor or floor-to-ceiling joints, or small annular spaces around pipe and conduit penetrations.

It is important to note that some caulk materials are silicone-based and can provide both fire and water resistance, while other caulks are latex-based and fire resistant, but not suitable for wet-area applications. Figure 2-3 provides an example of a building joint or seismic gap that has been sealed with caulk.

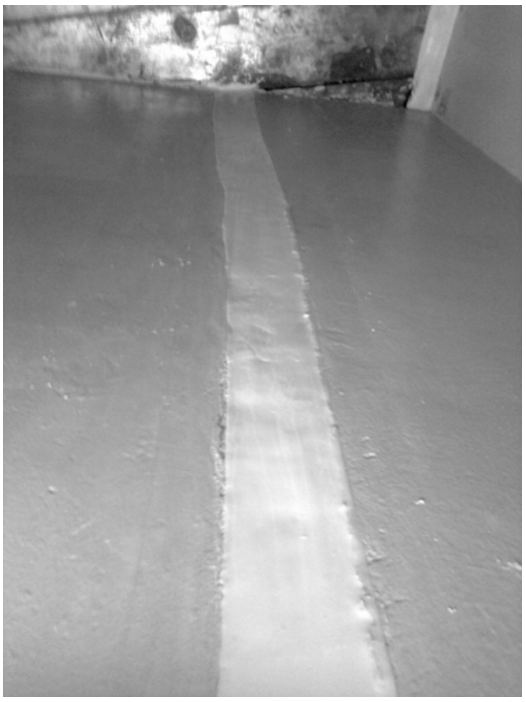


Figure 2–3
Floor Seismic Gap and Flood Seal Caulking

2.3.1.6 Silicone Elastomer Seals

Description: Silicone elastomer seals are comprised of a multi-component non-foaming silicone material which is applied in a liquid form and cures to a solid state. Silicone elastomers come in several blends both with and without additives and fillers. The use of additives and fillers allow the base silicone elastomer material to be modified such that a wide range of cured densities can be achieved. For the purposes of this guide, silicone elastomers will be classified as either Medium Density Silicone Elastomer or High Density Silicone Elastomer. Medium Density Silicone elastomers typically exhibit a cured density in the range of 50-100 pounds per cubic foot (pcf), whereas High Density Silicone Elastomers typically have a cured density between 100-150 pcf.

Applications: Silicone elastomer seals are commonly used to seal inside of sleeve and blockout penetrations containing pipes, conduits, tubes, cable trays and cabling. Medium Density Silicone Elastomers generally provide good fire resistance and may be suitable for some water resistant applications. High Density Silicone Elastomers are also fire resistant, may provide some water resistance, and often serve as radiation shielding seals due to the filler materials used to increase product density.

2.3.1.7 Epoxy Seals

Definition: An adhesive-type product usually composed of thermosetting resins capable of forming tight, cross-linked polymer structures characterized by toughness, strong adhesion, and low shrinkage, used especially in surface coatings and adhesives.

Explanation: Epoxy adhesives are used for bonding or coating in diverse applications. Epoxies are available in a variety of formulations and performance capabilities including general purpose, fast setting, chemical resistance, and water/humidity resistance. Other characteristics to note include their ease of installation, high performance, and excellent strength. Epoxy based seals can be applied to individual components installed in walls or floors and provide a water resistant application. Figure 2-4 is an example of an epoxy surface coating used on a concrete floor (with a notice cautioning people in the room not to damage the coating due to it being credited as a flood barrier).

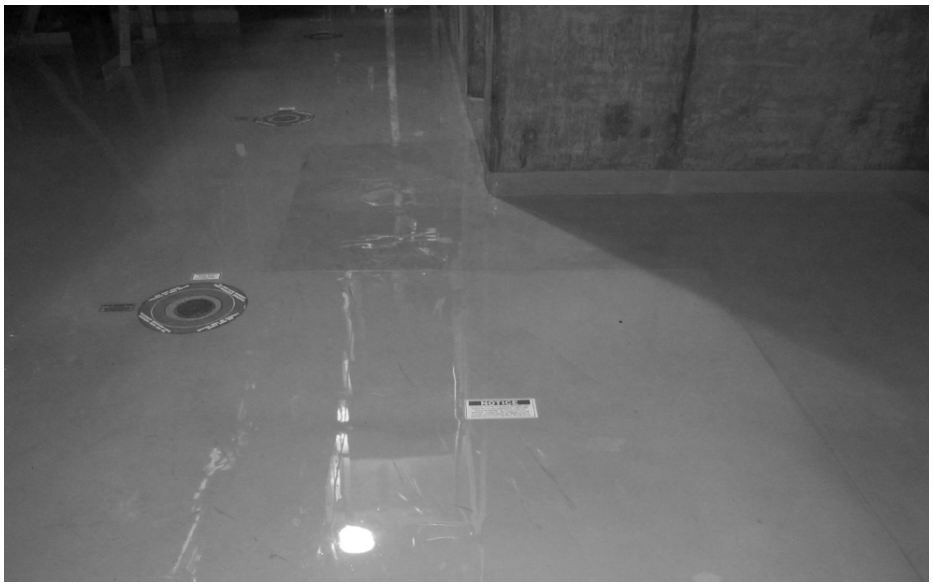


Figure 2–4
Epoxy Coating on a floor

2.3.1.8 Top Coating Materials

Description: A top coat material is a product that is coated over an underlying seal material (i.e., an existing fire penetration seal) as an additional sealant aimed at improving the seals capabilities in flood protection.

Explanation: One common top coating process is to apply a thin layer (1/4”-2” thick) of silicone elastomer over an existing seal in order to make the existing configuration water resistant, while retaining the existing fire resistant properties of the original seal. Top coating materials partially rely on the support of the underlying penetration seal assembly to perform their intended function (i.e., top coating materials generally do not qualify as a stand-alone flood seal). Figure 2-5 is an example of a top coat applied over an existing FPS seal.



Figure 2–5
Top Coat over Existing FPS Seal

2.3.1.9 Combination Seals

Description: Combination seals are essentially two separate seals installed in the same opening or penetration for the purposes of satisfying multiple design functions. Each seal is capable of performing its intended design function, yet neither seal is capable of performing both (or all) required design functions.

Applications: Combination seals likely exist where more than one design function is imposed on a single penetration. One possible example of a combination seal would be a penetration required to serve as both a fire barrier and a flood barrier, where the seal is comprised of a silicone foam seal covered with a boot seal. While the silicone foam seal may be adequate for fire, it may not be sufficient to withstand the flooding requirements. The installation of the boot seal would satisfy the flooding requirement, but the boot seal alone would not function as a fire seal. The combination of the silicone foam fire seal and the boot flood seal together result in a combination seal that satisfies both fire and flood requirements. Depending on how a site defines its typical penetration seal designs, the configuration described above maybe recorded as two separate seals or a single combination seal.

Note: Combination seals are different than combination penetrations which are discussed in Section 4.1.5 of this guide.

2.3.1.10 Modular Seals (compression seals)

Description: A mechanical seal consists of rubber links or blocks shaped to fill the annular space between a conduit, pipe or cables and the opening sleeve. Modular seals work by compression and are tightened in-place to complete the installation process. Figure 2-6.

Applications: Common applications of modular seals include single pipe penetrations (external seal) or as an internal seal for conduit penetrations. These types of penetration systems are designed to deliver a pressure-tight seal for water or air around penetrating items passing through

the barrier. Modular seals are also available in fire rated materials. Figures 2-6 and 2-7 are examples of different types of modular seals installed inside of conduits to seal penetrating cables.



Figure 2–6
Modular Seal (example 1)

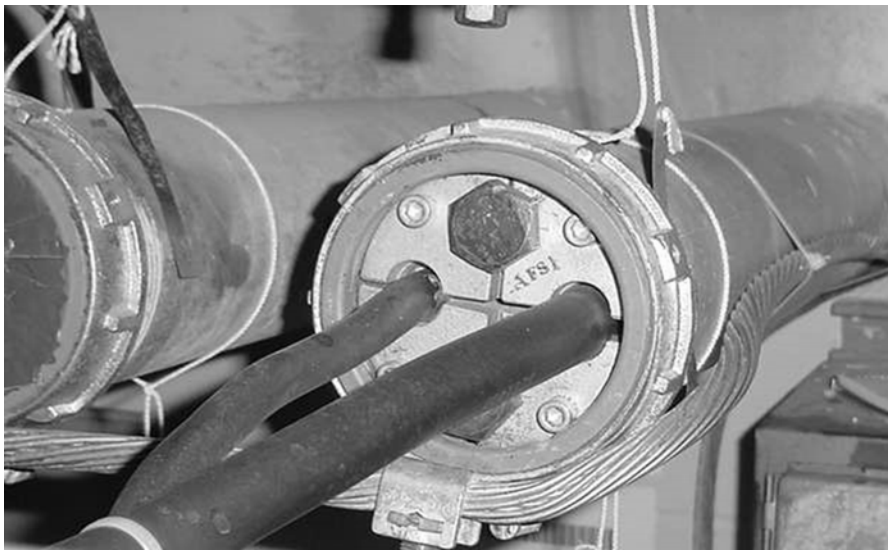


Figure 2–7
Modular Seal (example 2)

2.3.2 Mechanical System Seals

2.3.2.1 Dampers (or closure plates)

Description: A mechanical device, valve, or plate that stops or regulates the flow of a substance (air or water) to a designed rate.

Applications: Dampers are designed to control or regulate flow in various systems. They can be manual, electrical, or remotely operated for controlling the flow of air, smoke or water. Some dampers are designed to close and seal in the event of flooding. Other applications may require the installation of a pre-staged closure plate, designed to seal-off a ventilation opening in preparation for a possible flooding event.

2.3.2.2 System Seals

Description: System seals are associated with mechanical piping or ventilation systems and are relied upon to ensure system leak-tight integrity. These are comprised of various types of flange or gasket materials (firm or flexible).

Applications: System seals include gaskets, O-rings, and similar items that are used to lessen the amount of leakage to the atmosphere or potentially prevent water intrusion. System seals are commonly made of neoprene seal, EPT (Ethylene Propylene Terpolymer), or silicone materials.

2.3.3 Drains

2.3.3.1 Blowout panels/hatches

Definition: Intentionally designed barriers that are incorporated into a structure, enclosure, room, or area where there is a required relief from a sudden over-pressurization that may occur during an unplanned event and result in catastrophic failure of the structure or equipment inside.

Explanation: Blowout panels and hatches provide a relief from over pressurization from a force delivered into a confined area. The typical application is in areas located within NPPs where the potential buildup of energy can result in over pressurization of a structure. These panels and hatches provide the relief of energy if required.

2.3.3.2 Scuppers

Description: An outlet or opening in a wall or barrier designed to remove water from an area in a controlled manner.

Applications: Scuppers are designed configurations that allow for the release of a fluid. They can be round or square in configuration and may have a check valve in the form of a rubber-like door or flap installed to prevent back flow.

2.3.3.3 Floor drains

Description: A floor drain is a plumbing fixture that is installed in the floor of a structure, mainly designed to remove any standing water near it. Their configuration is usually round, but can also be square or rectangular in shape.

Applications: Floor drains are a fixed assembly in a floor that allow unwanted water to drain into a system drain or holding tank for further disposal. Based on the room or floor design and intent, floor drains are incorporated into various plant areas to assist in the removal of water from equipment or rooms.

2.3.3.4 Trenches

Description: Fortifications excavated in the soil or ground to channel or redirect the flow of water from the area where they are installed

Applications: A trench is an engineered excavation feature that allows unwanted water to be redirected away from a structure.

2.3.3.5 Yard drains

Description: A drain that is designed in the pavement or earth utilized to drain away surface water that accumulates in one area.

Applications: A yard drain is a fixed assembly that allows water to drain away from a structure and into a predetermined area for further disposal. Yard drains are located at NPP sites to allow for the control and removal of water from an area due to regular rainfall or flooding events.

2.3.3.6 Sewer/drain backflow prevention devices

Description: A device that prevents water or liquids from backing up from a drain line into the area where it is being removed from or into other connecting lines.

Applications: Sewer and drain backflow prevention devices direct overflow to an area outside of the installation through a manhole or cleanout, rather than inside an area where significant flooding damage may occur. A backflow prevention device is used to protect potable water supplies from contamination or pollution due to backflow.

2.3.3.7 Holding ponds and French drains

Description: A low lying area that is designed to temporarily hold a set amount of water while slowly draining to another location.

Applications: These areas are designed to mitigate flood control when large amounts of rain or other events could cause flash flooding. In particular, French drains are installed at the bottom of a pond or trench and usually backfilled with crushed stone or broken rocks to aid in the slow drainage of water.

2.3.4 Permanent Flood Barriers

2.3.4.1 Walls

Description: An upright structure constructed of building materials such as concrete, masonry block (with or without reinforcement) or comparable building materials. Walls are used to enclose, divide, sub-divide, protect or contain an area for internal and external applications. This can also include sheet piles (precast concrete, steel, or other suitable material).

Applications: Walls are part of a building enclosure that includes the roof, openings, foundation, and above and below-grade ground materials that separate the building from its surrounding environment. In addition, walls act as a thermal barrier, vapor barrier, drainage plane, and air barrier for the installation. Walls are a function for separation of rooms, which aids in protection of Systems, Structures, and Components (SSCs), in the event of flooding or fires. Walls function as a physical barrier, contribute as a containment method, or aid in reducing exposure to flooding which may exist for both internal and external events. Figure 2-8 provides an example.



Figure 2–8
Wall

2.3.4.2 Floors/Epoxy Coated Floors

Description: Continuous, supporting surfaces extending horizontally throughout a building, having a number of rooms, or compartments that constitute one level or stage in a larger structure. In some instances, coatings can be placed over floors and partially up walls to a maximum flood height.

Applications: Floors are constructed of concrete or reinforced concrete and are installed to support the daily operations of installed equipment. Floors are constructed to specific guidelines

to ensure that they meet the general design requirements to support their expected load. In some instances, water has slowly leaked through reinforced concrete floors. Where the barrier must be leak-tight, durable epoxy coatings may be applied that seal concrete surface cracks. An example of a leak-tight floor barrier application may arise when the room below contains safety-related switchgear. Epoxy coated flood barriers, however, would require more frequent inspection.

2.3.4.3 Curbs

Description: An engineered feature designed to check, restrain, or control a spill from occurring in a specific location.

Applications: Curbs are installed to prevent unwanted liquids from reaching or spilling into a designated area or location within the NPP. They are typically constructed of concrete or masonry materials and have a specific height which aids in their use in liquid containment. Curbs are used as a dike or containment to hold and contain a spill of liquid from a piece of equipment or operational action during normal or abnormal operations or events. Examples of permanent and temporary curbs are provided in Figures 2-9 and 2-10.



Figure 2–9
Permanent Concrete Curb



Figure 2–10
Permanent but Removable Flood Curb at a Door Entrance

2.3.4.4 Sloped or raised floors

Description: Floors that are designed to drain water or water buildup away so that water does not buildup or remain in a standing area which can contribute to flooding.

Applications: In some cases, sloped or raised floors are designed engineering features that drain water away from an area or rom within the structure.

2.3.4.5 Earthworks, Dikes

Description: Earthworks are an engineered earth embankment used for the purpose of fortification of a surrounding area. They are designed and placed within a specific area that has been designated to support operations or utilized in for a specific event, (i.e., flooding).

Applications: Any activity that exposes, disturbs, places, or deposits land and soil. Such activities include, but are not limited to: site clearing, cut, and fill operations, and re-contouring of the surrounding area. Earthworks can include a stand-alone application or one that is within a body of water for the purpose of holding back water, providing protection, or separation and isolation.

2.3.4.6 Upstream holding ponds/dams

Description: A permanent pool of water with capacity above the permanent pool designed to capture and then slowly release water over a period of time; also referred to as a retention pond.

Applications: Conventional impoundments are made for the purpose of reclaiming water and aid in water runoff from natural or flooding events. They are constructed of natural or other material linings based on the design, application and location for purpose and use. The upstream holding ponds/dams or retention ponds detain water runoff from natural or flooding-induced events, specifically in designated areas.

2.3.4.7 Site grading

Description: The act of altering the ground surface to a desired grade or contour by cutting, filling, leveling, and/or smoothing a designated area.

Applications: Site grading (in civil engineering) is the work of ensuring a level base, or one with a specified slope for construction work, such as the base course for a road or surface drainage path. When completed, site grading provides a paved or graded dirt or rock-based application (i.e., road or path) which aids in the directional or re-directional flow of water.

2.3.5 Temporary Seals

2.3.5.1 Drain covers

Description: Drain covers are a physical barrier that provide a measure of covering over a drain to prevent unwanted liquids from entering.

Applications: Drain covers are put in place as a cost effective measure to cover and seal a drain to prevent unwanted liquids from entering a system, (usually a storm water type system or access to a body of water (i.e., ocean or bay) that is adjacent to a NPP.

2.3.5.2 Caps and plugs

Description: A structural fitting with either outside or inside threads that has the capability of being installed on to the end of a pipe or conduit to seal the opening.

Applications: Caps and plugs may be used as temporary or permanent means to seal an opening. Caps and plugs are used to seal or close off piping and or conduits to stop the propagation of gases, air, and in some cases water from entering the installation or act as a spare for future use. They are used for sealing piping and or conduits on their open, projected ends. When installed in any of the various applications, they will provide a flush mounted finished installation. Figures 2-11 and 2-12 provide examples of different types of caps and plugs.

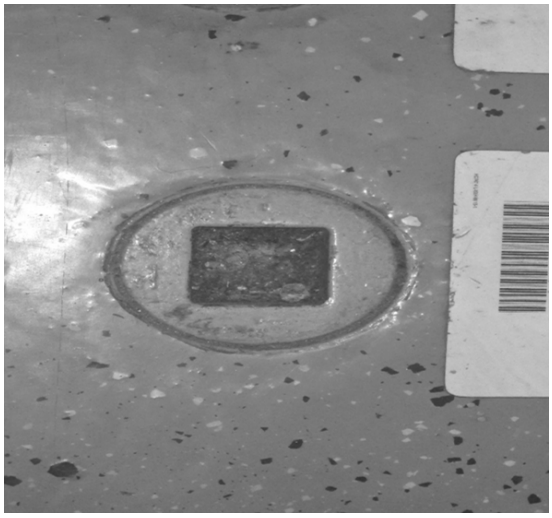


Figure 2–11
Conduit Plug

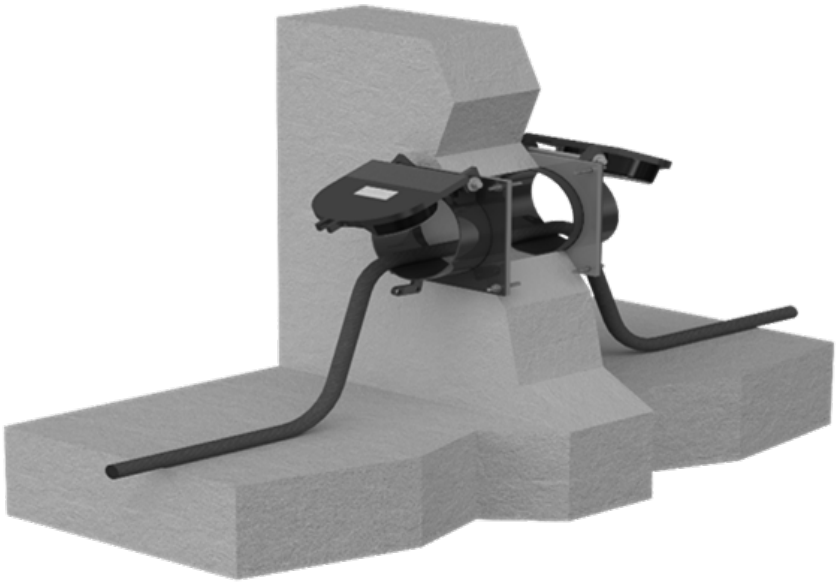


Figure 2–12
Thru Wall Flood Penetration Seal (cap design)

2.3.5.3 Inflatable or expanding plugs and seals

Description: An inflatable object, device or structure especially made of high resistant rubber or other synthetic material filled with air or other fluid to expand and block passage of liquids

Applications: Inflatable or expanding plugs and seals can be internal pipe plugs or external perimeter area barriers surrounding an area. They are manufactured for almost any size, pressure, chemical, and temperature environment for flood protection. Figure 2-13 provides an example.



Figure 2–13
Pipe Plug

2.3.5.4 Removable gates or doors

Description: An engineered feature or structure designed to be a removable barrier to aid in the closing or sealing off of water in preparation for flooding-related events

Applications: A physical barrier that is pre-staged and required to be manually placed in service prior to a flooding condition or event. Removable barriers are designed to block off parts of the NPP's access into areas, compartments or structure to ensure flooding is kept to minimum in specific areas during the event. Once no longer required, these barriers are removed and re-staged back into position.

2.3.6 Temporary or Emergency Flood Barriers

2.3.6.1 Sandbags

Description: A bag, filled with sand, which is used to weigh something down, to build a defensive wall to protect against flooding or rising waters.

Applications: Sand bagging is a versatile flood-fighting tool and is a simple way to prevent or reduce flood water damage. Although sandbags do not guarantee a watertight seal, they can be deployed as a barrier against an anticipated flooding event. Sandbags stacked in a single row can be applied in flood areas where there is no streamflow velocity, danger from floating debris (such as logs and tree stumps), or wave action which could topple the bags.

2.3.6.2 Deployable booms, curbs, barriers

Description: Temporary storm-surge and flood protection barriers that are deployed to prevent and control water as it rises.

Applications: Barriers, curbs and booms act as devices or features that are movable and can be deployed or erected only in times of flooding. The devices can be applied to individual buildings or smaller areas. They can be used at doorways, large truck or rail entrances, and outside entrances to structures that are required to be protected from flooding or rising waters. Figures 2-14 through 2-16 are examples of flood barriers.



Figure 2–14
Non-Deployed Flood Barrier



Figure 2–15
Deployed Flood Barrier



Figure 2–16
Temporary Flood Gate

2.3.6.3 Obstructions to flow (security barriers, grates, etc.)

Description: Obstructions that are placed due to regulatory requirements that may restrict the relief or flow path of natural or flood waters to be removed or assist with a directional flow away from the structure.

Applications: In some cases, within and around NPPs, there are required components to facilitate regulatory requirements for security or other consideration that may affect natural or flooding water removal during events. Common installations of this type are known as a "Jersey Barrier", which is a concrete molded barrier set in place to block passage of a vehicle, while employing a scupper type opening at the bottom to allow some drainage of water when set in location.

2.3.6.4 Diversion excavations

Description: A temporary or permanent ridge or excavated channel or combination of both that is constructed to divert surface water, and possibly subsurface water, from or around designated areas and sites where it can be used or disposed of.

Applications: Water diversions consist of a system of structures and measures that intercept clear surface water runoff of a site, transport it around an area, and discharge it downstream with minimal water degradation to the site or surrounding area.

2.3.7 Entrance or Egress Openings

2.3.7.1 Doors

Description: A movable, usually solid, barrier for opening and closing an entranceway that is found in a wall or solid barrier.

Applications: Doors are openings in walls or barriers normally relied upon to provide access to and from one area to another. They are designed to meet building and code requirements for life safety and having a designated fire rating and class based upon the requirement. Doors can also provide a water abatement or resistance up to a certain height.

2.3.7.2 Swinging Gates

Description: A movable barrier for controlling the passage of water or flooding-related waters through a channel or designated and designed embankment.

Applications: When closed, swing gates meet at an obtuse angle that points upstream in order to resist the water pressure. Swing gates are designed to assist in the redirection of water during normal and flooding conditions and can be either manually or power-assisted in operation.

2.3.7.3 Horizontal or vertical sliding door

Description: A movable barrier that is controlled manually or electrically to open or close an opening in either the horizontal or vertical direction.

Applications: Where means of access or egress doors are operated or assisted by power, the design is such that in the event of power failure the door is capable of being opened manually to permit means of egress travel, or closed where necessary to safeguard the means of egress. Horizontal or vertical sliding doors have a watertight seal installed around them with gaskets and are capable of being water resistant for a predetermined time frame. Horizontal or vertical doors are installed in various location in NPPs to allow for movement of personnel or equipment during normal and outage operations. Figure 2-17 and 2-18 provide an example of a vertical and a sliding door.



Figure 2–17
Vertical Swing Door

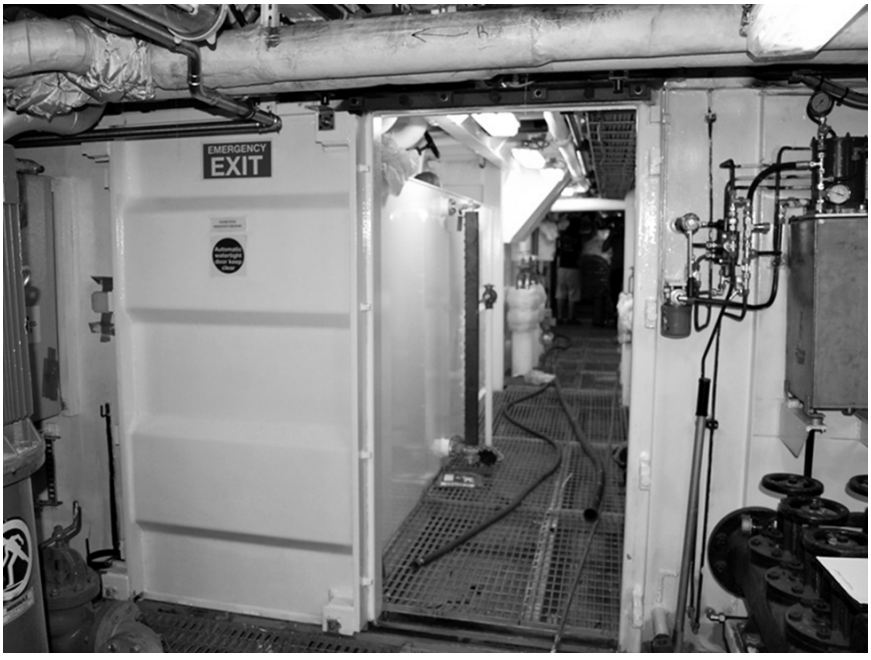


Figure 2–18
Sliding Flood Door

2.3.7.4 Pressure (submarine) Doors

Description: Submarine-type watertight doors are designed to prevent the ingress of water from one compartment to another during flooding-related events. These doors are used in areas where the chances of flooding are high from internal or external events

Applications: Pressure or submarine-type doors are used in areas where chances of flooding are high from internal or external events and the need exists to ensure that each compartment is closed off to a flooding condition. Their function is to seal and make the room or compartment watertight and they can be pneumatic or manually operated. Figure 2-19 provides an example.



Figure 2–19
Watertight Door

2.3.7.5 Removable Closure Plates

Description: An engineered feature that allows access to and from an area, compartment or structure, and is installed until the need for the gate is removed.

Applications: A physical gate or barrier that is installed and required to manually be removed when directed or needed and then manually placed in back into service when the event or need is completed. Removable closure gates provide access and egress internally or externally within the structure or compartments of a NPP.

2.3.7.6 Hatches

Description: Engineered features of various size openings allowing for passage from one area to another in walls or floors used in daily operations.

Applications: Hatches provide closure for an opening that exists to allow the passage from one area to another. Hatch openings are not normally used unless required to perform a specific function or action, (i.e., removing equipment from an area). They can be constructed of concrete (with or without reinforcement) or of heavy metal to protect or sub-divide internal compartments. They can have a designated fire rating since they are considered part of the floor assembly. Hatches can also provide a water resistant application for some duration of time if hatch to barrier interfaces are sealed with a gasket, caulk, or some other form of poured in-place sealant material (e.g., silicone foam or silicone elastomer).

2.3.8 Flood Outlet Devices

2.3.8.1 Manually Operated Valves

Description: A physically operated (intended to be driven by human power) valve that normally allows fluid (liquid or gas) to flow through it in either direction. Manually operated valves are two-port valves, meaning they have two openings in the body, one for fluid to enter and the other for fluid to leave.

Applications: Manually operated valves are components of a piping system that can convey liquid and gases in systems and are manually operated as required. They are mechanical devices to control the flow and pressure within a system or process.

2.3.8.2 Check valve

Description: A valve that normally allows fluid (liquid or gas) to flow through it in only one direction. Check valves are two-port valves, meaning they have two openings in the body, one for fluid to enter and the other for fluid to leave.

Applications: Check valves work automatically, and most are not controlled by a person or any external control; accordingly, most do not have any valve handle or stem. A check valve allows flow in one direction and automatically prevents back flow (reverse flow) when fluid in the line reverses direction.

2.3.9 Flood Mitigation Equipment

2.3.9.1 Portable or Permanent Pumps

Description: Portable pumps are typically small, diesel or gas-driven pumps that can be carried or otherwise transported to a water source to facilitate water removal from surround areas. In comparison, permanent pumps will be installed in or around the NPP as a means of removing water from sumps or places where water will collect.

Applications: Pumps are equipment that can be used to assist in water removal for external and internal flooding events. Mitigation strategies at NPPs will often times credit the role that pumps can play in removing water from an area.

3
CURRENT TESTING METHODS AND ACCEPTANCE CRITERIA

The purpose of this section is to identify testing protocols used to qualify flood barriers at NPPs in terms of pressure resistance. Testing associated with base structures that provide flood protection (i.e., walls and floors) are governed by design criteria for structures, systems and components (SSCs) and typically demonstrated as acceptable by analytical methods. Testing for entrance and egress openings (i.e., doors) are generally covered by door testing standards (e.g., U.S. Navy Standards) or through analytical methods. In addition, testing for valves, drainage piping, and pumps is covered by established industry codes and standards. However, for FBPSs, there are currently no codes or standards that address protocol for qualifying pressure resistant penetration seals. Therefore, this section presents test methods and acceptance criteria that have been used for FBPSs due to their relative complexity and criticality as compared with other types of flood barrier components mentioned in Section 2.

3.1 Penetration Seal Overview

Penetration seals are designed to close openings in barriers (e.g., walls or floors) and restore design integrity. Depending on their intended function and classification, penetration seals may be qualified to provide protection in categories that include: 1) Fire resistance, 2) Radiation shielding, and 3) Pressure resistance (air, water, and steam).

Fire rated penetration seals are generally required to maintain separation between fire areas. Fire rated penetration seals are typically qualified, by comparison, to similar configurations that have been successfully fire tested and/or by analysis. Section 3.2 discusses established test standards applicable to the fire testing of penetration seals.

Radiation shielding penetration seals are generally used to protect plant personnel from radiological hazards in support of ALARA principles. Radiation shielding penetration seals are typically qualified by analysis based on the physical properties (density and thickness) of the sealant material.

Pressure rated penetration seals may be required to resist air pressure in support of ventilation system boundaries (e.g., Control Room Envelope and RCA boundary), steam pressure (e.g., High Energy Line Break (HELB) barrier, EQ barrier, etc.), or water pressure (e.g., flood barriers). Pressure rated penetration seals may be substantiated by functional testing as in the case of Control Room Envelope testing, qualified by pressure testing, or qualified by analysis. Within the United States (US), comprehensive test standards have not been published for the pressure testing of penetration seals, although some test methods have been used by penetration seal vendors working with test facilities and laboratories.

3.2 Existing Test Standards for Penetration Seals (Including FBPSs)

There currently exists a variety of test standards that have been specifically developed to test penetration seals. The primary focus of most of these standards, though, is to test the fire resistance of penetration seals and provide a rating to identify the ability of a seal design to maintain the fire rating of the barrier in which they are installed. Test standards for fire barrier penetration seals include:

- ASTM E814 Standard Test Method for Fire Tests of Penetration Firestop Systems
- IEEE 634 IEEE Standard for Cable-Penetration Fire Stop Qualification Test
- UL 1479 Standard for Fire Tests of Through-Penetration Firestops

In addition to these standards, several other test standards developed for the fire testing of barriers (walls, floors, roofs and partitions) have also been used to test fire barrier penetration seals. These standards include:

- ASTM E119 Standard Test Methods for Fire Tests of Building Construction and Materials
- NFPA 251 Standard Methods of Tests of Fire Endurance of Building Construction and Materials

There are also a few test standards for a specific category of penetration seal (i.e., building joint seals). They include:

- ASTM E1966 Standard Test Method for Fire-Resistive Joint Systems
- UL 2079 Standard for Tests for Fire Resistance of Building Joint Systems

UL 1479 and UL 2079 are the only standards that contain provisions for any type of pressure testing of a penetration seal device. Specifically, both UL 1479 and UL 2079 contains a test method and acceptance criteria for establishing "L" and "W" ratings for penetration seals and joint seals. A UL "L" rating is based on the amount of air leakage through the test penetration. Likewise, a UL "W" rating is based on the water resistance of the test penetration. Water pressure equal to 3 feet of water is applied and maintained for 72 hours. Any leakage observed during the test is reported.

While the body of standards discussed above is sufficient to substantiate the fire rating of penetration seal materials and devices used in NPPs, the lack of standards related to the pressure testing of penetration seals is evident. However, the pressure testing of penetration seals, including FBPSs, remains an important step in the penetration seal design and qualification process. Most materials used in FBPS assemblies are non-permeable, and therefore, are not likely to allow the passage of water through the seal material itself. It is the interfaces between the FBPS material and the opening being sealed - as well as the interfaces between the FBPS material and the penetrating commodities being encapsulated - that provide potential leakage paths. Since the pressure exerted on any given seal and the seal's ability to resist the pressure, will both vary based on the seal size, shape, quantity, and type of penetrating items, actual testing of FBPS assemblies provides the data necessary to substantiate the suitability of various FBPS designs.

3.3 Previous Methods Used to Pressure Test Penetration Seals

Since many of the FBPS designs initially installed for pressure applications in NPPs pre-dated UL 1479 and UL 2079 (the only test standards that contain any criteria related to pressure testing of penetration seals), test methods were established by licensees and vendors to substantiate the pressure resistance capabilities of seal designs used in NPPs. As a result, there have been a range of methods used, variations in parameters considered for acceptance, and variations in acceptance criteria applied to the pressure testing of penetration seals.

As part of the development of this guide, the TAG investigated various sources of test data related to the pressure testing of penetration seal materials and designs commonly used in NPPs. Sources of data included pressure tests conducted by and for utilities and considered both recent test applications as well as some older test results.

Table 3-1 provides a summary of the various test methods used to conduct penetration seal pressure testing and the manner in which leakage (if any) was reported.

Table 3-1
Summary of Historic Penetration Seal Testing Methods

Pressure Medium	Pressure Range	Hold Time(s)	Leakage Reported In	Max. Specimen Size Tested
Air	1/8”-40” water column (WC)	30-240 minutes	liters per minute (lpm) standard cubic feet per hour (SCFH)	48” x 48”
Air	0-30 psi	1-120 minutes	Units of leakage not reported	36” diameter
Steam	0-40 psi	1-30 minutes	Noted but not quantified	14” diameter
Water (Static)	½”-18” WC	½-20 hours	Noted but not quantified	30” x 30”
Water (Dynamic)	0-26 psi	1-10 days	Drops per unit of time Gallons per unit of time ml per unit of time liters per unit of time Noted but not quantified	4” diameter
Water w/ Air	0-30 psi	1 minute – 8 days	Cups per unit of time lbs per unit of time ml per unit of time Noted but not quantified	42” diameter
Water w/ Nitrogen	0-28 psi	2 hours	Units of leakage not reported	10” diameter

It is important to note that the data presented in Table 3-1 is a summary of numerous individual pressure tests that were reviewed during the development of this guide. As such, the various categories of data should not be misconstrued. For example, where a table category lists a range of data, such as Hold Time of 1 to 30 minutes, it is intended to convey that some tests applied a 1 minute hold time at each pressure stage, while other tests applied longer hold times at each pressure stage, with the longest noted hold time being 30 minutes at a given pressure.

Studying Table 3-1, it can be seen that pressure testing of penetration seals has been conducted in a number of different manners. The pressure mediums used have included air, steam, standing water (static), water under pump pressure (dynamic), water with air pressure applied, and water with nitrogen applied. Test pressures have varied from as little as 0.0045 psi (~1/8" W.C.) to as high as 40 psi. Hold times have ranged from as short as 1 minute at a given pressure to as long as 10 days at a constant pressure, leakage has been reported and quantified in a number of different manners. Finally, the largest specimen size that can be tested varies by apparatus and covers a range of specimen sizes from 10" diameter up to a 48" x 48" opening.

In the absence of any consensus codes or standards for conducting pressure testing on penetration seals, the degree of usefulness of any of the existing pressure test data is ultimately the responsibility of the end user. For flood barrier applications, any penetration sealing device that is not completely leak tight at the maximum expected pressure for the longest anticipated inundation period will require additional evaluation. Individual penetration or device suitability will be largely dependent upon its location, expected leakage rate (if any), and other plant features and strategies that are available to mitigate any leakage that does occur.



Key Technical Point

In the absence of any consensus codes or standards for conducting pressure testing on penetration seals, the degree of usefulness of any of the existing pressure test data is ultimately the responsibility of the end user. For flood barrier applications, any penetration sealing device that is not completely leak tight at the maximum expected pressure for the longest anticipated inundation period will require additional evaluation.

3.4 Pressure Test Apparatuses

The sections below provide a detailed description, along with figures, of several pressure test apparatuses that have been used to conduct penetration seal pressure testing. The various test apparatuses are presented by type of pressure test conducted (i.e., air pressure, water pressure or steam pressure) with a reference to the general time period when the specified type of test device was used. This information has been included in the guide to enhance the users understanding of the various types of test apparatuses that have been used to conduct penetration seal pressure testing. No attempt has been made in this guide to determine the suitability of these various test apparatuses.

3.4.1 Air Pressure Testing Apparatus (Circa 2013)

The pressure test apparatus described in this section was developed to test penetration seals for their ability to withstand air pressure at various levels and record any leakage that occurred during the air pressure tests. The penetration seal assemblies that have been tested using this apparatus were designed for use in a nuclear fuel fabrication facility and not a NPP. Discussion of this test apparatus was included in the guide because it represents one of the more recent and sophisticated test apparatuses used to pressure test penetration seal assemblies.

The pressure chamber apparatus consists of two hemispherical 72" diameter steel pressure vessels, calibrated equipment and a data acquisition system. The apparatus accurately maintains

the desired air pressure, using one of two sensitive, manually adjustable pressure regulators with a high (0-15 psi) and a low (0-2 psi) range. The manifold to these regulators can be tied to a compressed air source via a quick disconnect fitting. The sealed collection chamber feeds any air leakage that passes through the test specimen back to the test device, where it is channeled through one of two calibrated flow meters with a high (0-200 L/min) and a low (0-20 L/min) range. A calibrated electronic pressure transducer (0-5 psi) measures the differential pressure between the two chambers and the data acquisition software determines the net pressure drop across the test specimen and the leakage through the seal. The data acquisition software resides on a dedicated computer. The pressure chambers are interchangeable and the direction of pressure can be reversed very quickly, so both chambers can serve as the pressure or the collection chamber.

This apparatus is designed to accommodate a test specimen with a penetration opening size up to 48" x 48" and a test pressure up to 10 psi. Higher test pressures are possible but are limited by the method in which the pressure chambers are secured to the test assembly. Figures 3-1 through 3-3 depict examples of this air pressure testing apparatus (circa 2013).



Figure 3–1
Pressure Chambers Without a Test Specimen Installed



Figure 3–2
Pressure Chambers Installed On Test Specimen



Figure 3–3
Data Acquisition Cart

3.4.2 Steam Pressure Testing Apparatus (Circa 2007)

The pressure test apparatus described in this section was developed to test penetration seals for their ability to withstand steam pressure at a relatively high pressure level. The penetration seal assemblies that have been tested using this apparatus were designed for use in a NPP for a HELB compartmentation application.

The primary pressure bonnet was comprised of a 30” long section of 16” diameter Schedule 40 carbon steel pipe. One end of the bonnet was left open and fitted with a flange (welded in place) such that the bonnet could be bolted directly to the test slab. The opposite end of the bonnet was

closed off by welding a steel plate over the end of the pipe. Two threaded connections were welded in place, one to allow for pressure supply and one for pressure venting. A tee fitting was placed at the pressure supply tap to accommodate a pressure gauge for monitoring bonnet supply pressure. The pressure supply line also contained an in-line ball valve to control the supply. A second tee fitting was placed in the vent line to accommodate a second pressure gauge. The vent line also contained an in-line ball valve to control bonnet venting.

The steam pressure was supplied by a Therma-Kleen® Ultra 250 propane-fired power steam machine equipped with a 200,000 BTU/hr burner. The stream output line was connected to the pressure bonnet supply tap. During the pressure tests, the pressure bonnet was wrapped with a ceramic blanket to reduce heat loss through the bonnet. This apparatus was used to conduct pressure tests where the test assembly was exposed to a steam pressure environment of approximately 40 psi. Figure 3-4 depicts the steam test bonnet installed on a test assembly circa 2007.



Figure 3–4
Steam Test Bonnet Installed on Test Assembly

3.4.3 Air Pressure Testing Apparatus (Circa 2008)

This pressure chamber was comprised of a steel box that measured approximately 4’ wide by 6’ long by 3’ in height. Air was introduced into the chamber by an approximate 3” diameter supply line that was fed by a blower unit. An approximately 1” diameter port was used to route the sensing line/probe into the pressure chamber. Chamber pressure was monitored by either a digital manometer or an incline plane manometer.

Inflatable plastic bags were used on the unpressurized side of the test assemblies to detect any leakage through the penetration seals. Figures 3-5 and 3-6 depict examples of air pressure testing apparatus circa 2008.



Figure 3–5
Air Pressure Test with Test Articles Installed

For slab test assemblies, the pressure chamber was inverted and placed on top of the test slab.



Figure 3–6
Air Pressure Test with Chamber On Top of Slab

3.4.4 Static Water Pressure Testing Apparatuses (Circa 2008)

For blockout penetrations, a holding chamber was created for slab test assemblies by constructing a wooden box that sat on top of the slab. Box joints and interfaces were sealed with silicone caulk. Water was added to the box to achieve the required pressure in inches of water column (WC). Leakage was monitored by visual observation of the unpressurized side of the test assembly. Figure 3-7 shows this test apparatus.



Figure 3–7
Water Pressure Test Box On Top of Test Slab

For testing sleeved penetrations, the holding chamber for conduit sleeve test assemblies was comprised of an approximately 30” in length of a 10” diameter carbon steel pipe. The pipe was placed over the test assembly and the interface between the pipe and the backing plate of the test assembly was sealed using silicone caulk. Water was poured into the chamber until the desired pressure as measured from the top of the seal assembly was achieved. Leakage was monitored by visual observation of the unpressurized side of the test assembly. Refer to figure 3-8 for an image of this assembly.



Figure 3–8
Water Test Chamber for Sleeved Assemblies

3.4.5 Dynamic Water Pressure Testing Apparatus (Circa 2013)

The pressure test apparatus described in this section was developed to test internal conduit seal (ICS) configurations and devices for their ability to withstand water pressure at various pressure levels. The penetration seal assemblies that have been tested using this apparatus were designed for use in a NPP in support of flood protection applications. This test apparatus has been categorized as "Dynamic Water Pressure Testing" because the pressure medium used by this test apparatus was pressurized water supplied from a booster pump.

The pressure test apparatus consisted of a constant pressure booster system equipped with an excessive-flow circuit and associated controls and power supply, a water reservoir, and a manifold system capable of simultaneously testing up to four (4) separate internal conduit seal assemblies. The system was designed for unmanned operation after initial start-up, with the capability to monitor and maintain a constant test pressure at potential aggregate flow rates. The pressure test apparatus was also capable of detecting catastrophic failures (defined as flow rates > 2 GPM) and isolating the pressure feed to any failed assemblies, so that the test could continue on the remaining assemblies.

Each individual test assembly was connected to a dedicated branch line using appropriate fittings. This allowed for test assemblies of various sizes, lengths and configurations to be tested. Refer to Figures 3-9 and 3-10 for images of this test apparatus.



Figure 3–9
Dynamic Water Pressure Testing Apparatus without Test Assemblies



Figure 3–10
Dynamic Water Pressure Testing Apparatus with Four (4) Test Assemblies

3.4.6 Other (Vendor) Pressure Testing Apparatuses (Circa 2015)

The pressure test apparatus described in this section was developed by a penetration seal vendor to test various types of sealant materials installed in a PVC sleeve with pipe, conduit or cable commodities.

This device is capable of performing either hydrostatic or pneumatic testing for specimen sizes up to 6 inches in diameter and pressures ranging from 0-50 psi.

Refer to Figure 3-11 for an image of this test apparatus.



Figure 3–11
Vendor Pressure Testing Apparatus

3.5 Test Considerations for Future Pressure Tests

Until some consensus code or standard is developed to direct the pressure testing of penetration seals, any future pressure testing of penetration seal assemblies for flood protection should consider the following items when establishing a test method:

3.5.1 Test Orientation

The orientation of the test configuration should replicate (or bound) end use applications. Horizontally oriented test specimens should avoid being pressurized from below, as the mass of test assembly will offset the applied pressure to a certain degree.

3.5.2 Test Pressure and Pressure Medium

The test pressure should bound or envelope the end use application. Testing with water as the pressure medium is suitable for similar end use applications that involve water, but may not be suitable to draw conclusions with respect to air pressure applications. Testing with air as the pressure medium is suitable for both air pressure and water pressure end use applications. Steam should be used as the pressure medium to replicate HELB end use conditions where appropriate and these results bound that of water and air pressure.

3.5.3 Pressure Duration

Test hold times should envelope end use applications. Test hold times of minutes or hours should not be used to qualify end use applications where the event duration may last for days.

3.5.4 Leakage Identification and Quantification

The test method should contain provisions for identification of leakage locations and methods to quantify leakage rates/volumes recognizing that test leakage does not necessarily constitute test failure.

3.5.5 Impact Pressure vs Static Pressure Considerations

The test method or methods should account for initial surge impact forces (if applicable – represent an impact load), as well as static pressure conditions. A separate test may be warranted to account for impact pressure forces.

3.5.6 Test Configuration Considerations

The pressure tested configuration should be representative (or bounding) of end use applications. Section 4 of this guide provides a comprehensive list of design parameters that should be considered when designing and qualifying FBPS configurations.

4
DESIGN CONSIDERATIONS ASSOCIATED WITH FLOOD PROTECTION COMPONENTS

This section provides design considerations associated with the various types of flood protection components identified in Section 2. For most components, design considerations are generally straightforward and are presented at a high level in this report, with additional guidance and/or precautionary statements included when warranted.

For FBPSs, Section 4.1 provides a more comprehensive list of design considerations, due to the wide range of materials used for FBPSs and the large number of possible geometric configurations. It should be noted that there are no industry codes or standards that define bounding attributes for the design and qualification of FBPSs. Information contained in Section 4.3 is knowledge-based provided by TAG contributors with extensive experience related to qualification of pressure resistant penetration seals.

4.1 Design Considerations for Penetration Seals

Design considerations for FBPSs vary depending upon the type and complexity of the penetration being sealed. For the purposes of this guide, FBPS types are defined by the following categories:

- Mechanical Penetrations
- Electrical Penetrations
- Ventilation Penetrations
- Combination Penetrations
- Seismic Gaps and Construction Joints

Considerations listed in this section are provided to aid in the design of a FBPS for plant application.

It is important to note that while most of the design considerations discussed are related to a FBPS's ability to resist pressure, some of the design considerations are provided for other reasons, such as to ensure that application of a flood seal does not unknowingly create a secondary concern. For example, polyurethane-based products may be capable of serving as a robust flood seal, however, most polyurethane foams are combustible and their use may create a secondary fire protection concern. Additionally, polyurethane foams are good insulators, and if installed around cables at a significant thickness, could require ampacity de-rating of the electrical circuit. Therefore, proper consideration should be given to each of the design considerations for both the impact on a FBPSs pressure rating and impacts on the systems and components that will come in contact with FBPS material.

Openings in flood barriers designed to accommodate the passage of plant personnel or equipment (e.g., door openings, hatches openings, equipment openings, etc.), including the devices that protect such openings (e.g., watertight doors, personnel hatches, equipment hatches, etc.) are not considered FBPSs and are addressed in other sections of this document.

4.1.1 Generic Considerations for FBPSs

The items in Table 4-1 are design considerations generic to all FBPSs regardless of type. These generic design considerations represent attributes demonstrated to be of importance in the design and qualification of pressure resistance penetration seals. These attributes should be contemplated in conjunction with the appropriate FBPS type-specific design considerations listed in Tables 4-2 through 4-5 (as applicable) to ensure the FBPS design is suitable for the intended end use application.

Table 4-1
Generic Design Considerations for all FBPSs

Design Consideration:	**Orientation**
Definition:	The position of the penetration seal with respect to the horizontal or vertical plane. Penetration seals installed in a wall are referred to as being vertically oriented, whereas penetration seals installed in a floor/ceiling are referred to as being horizontally oriented.
Importance:	For horizontally oriented FBPSs, the corresponding pressure associated with the flood event is added to the existing forces acting on the FBPS during normal operation (gravity, compartment pressures, etc.). The cumulative effect of all forces acting on the seal should be considered during FBPS design and qualification to guard against catastrophic failure of the FPBS during postulated flooding events. For vertically oriented FBPSs, material creep should be considered to ensure isolated leakage paths do not develop over time. Locations susceptible to leakage due to material creep include the interface between the top of the opening and FBPS materials, as well as, the interface between the underside of any rigid penetrating items and the adjacent FBPS materials.
Design Consideration:	**Barrier Type and Thickness**
Definition:	The type and thickness of barrier in which a penetration seal assembly may be installed. Common types of barrier construction include poured concrete, concrete block (both hollow and filled), and gypsum board walls.
Importance:	The barrier type is important in order to address material interface concerns. For unlined penetration openings, the barrier material to FBPS material interaction should be considered. For example, Dow Corning 732 Multi-Purpose Sealant (caulk) contains acetic acid and should not be applied to concrete, mortar or other masonry surfaces where a long term physical bond is required/credited. The barrier thickness should also be sufficient to contain the entire FBPS assembly, unless otherwise allowed by design and supported by testing or engineering analysis.

Table 4-1 (continued)
Generic Design Considerations for all FBPSs

Design Consideration:	**Penetration Opening Size**
Definition:	The largest opening size allowed for a specific seal configuration. For circular openings (i.e., sleeves and core bores or core drills) the maximum opening size is expressed in terms of the opening's diameter. For non-circular openings, the maximum opening size is typically expressed in square inches (in2) with an equivalent rectangular size listed for guidance (e.g., 900 in2, 30" x 30" blockout).
Importance:	Penetration Opening Size should be bounded by testing or engineering analysis. For penetrations where the Penetration Opening Size is smaller than the limit established by testing or engineering analysis, no further consideration of this critical characteristic is required. For penetrations where the Penetration Opening Size is larger than the limit established by testing or engineering analysis, proper consideration of the potential adverse impact on structural integrity of the FBPS is warranted. Industry practice for over-size Fire Seals commonly involved subdividing the opening into smaller sections using a noncombustible damming board material. While this practice was suitable for Fire Seal applications, it is not recommended for FBPSs. Similar but more suitable methods of opening size reduction, such as reduction by adding structural members or welding plates into the opening to subdivide it into smaller openings, should be considered.
Design Consideration:	**Opening Liner**
Definition:	The surface of the penetration opening if something other than the barrier material. A lined penetration opening contains a sleeve or component surrounding the opening that is typically not a part of the barrier construction.
Importance:	For lined (or coated) penetration openings, the material interaction between the liner (or coating) material and the FBPS material should be considered. Epoxy paints and coatings may present a less desirable bonding surface for some FBPS materials. For metal lined penetrations, the interaction between the liner material and FBPS materials should be considered. Additionally, the liner to barrier interface is an additional potential leakage point that should be considered [7].
Design Consideration:	**Penetrating Items**
Definition:	The quantity, types and sizes of items which penetrate a seal assembly. Penetrating items include commodities such as pipes, conduits, cable trays, cabling, instrument lines, etc.
Importance:	The quantity, types, and sizes of penetrating items need to be considered. Quantity and size information is necessary to calculate the Bond Area to Surface Area Ratio discussed below. Type information is critical to identifying material interaction concerns, as certain FBPS products may not provide the same level of leak tightness when in contact with certain materials. Additionally, some seal materials may interact with penetrating items at the interface impacting the long term resistance of the seal (for example; chloride interaction with copper, aluminum or other non-ferrous metals). Type information is also used to invoke additional considerations from other penetration categories (i.e., mechanical, electrical and ventilation penetrations).

Table 4-1 (continued)
Generic Design Considerations for all FBPSs

Design Consideration:	**Bond Area to Surface Area Ratio**
Definition:	The Bond Area to Surface Area Ratio is a numerical ratio calculated as follows: Bond Area = Opening Perimeter + Sum of Penetrating Item Perimeters (except cable) x Seal Material Thickness Surface Area = Surface Area of the Opening – Sum of the Surface Areas of Penetrating Items (except cable)
Importance:	The Bond Area to Surface Area Ratio is a numerical ratio that can be established based on known tested configurations and then compared against the ratio associated with a specific plant penetration to aid in the determination of the plant configuration's ability to withstand flood pressures/conditions in relation to the tested configurations performance. When establishing and applying this ratio, it is essential to ensure that the installed application is at least the same thickness as the tested configuration. This ratio is not intended to suggest that an increase in seal material thickness will result in a linear increase in pressure resistance capability, but rather to aide in determining the impact of changes to geometric shape and the addition, subtraction or change in size for associated penetrating items.
Design Consideration:	**Maximum Free Area**
Definition:	The maximum free area (area of unsupported sealant) is defined one of two ways depending upon the opening shape. For circular openings, such as core drills and sleeves, the maximum free area is expressed in terms of Maximum Annulus (refer to the Maximum Annulus/Spacing design consideration below). For non-circular shaped openings, the maximum free area is defined as the largest rectangular area or span of unsupported seal material. Refer to Figure 4-1 for examples of Maximum Free Area.
Importance:	The Maximum Free Area should be considered to ensure the overall structural integrity of the FBPS. For penetrations where the Maximum Free Area is smaller than the limit established by testing or engineering analysis, no further consideration of this critical characteristic is required. For penetrations where the Maximum Free Area is larger than the limit established by testing or engineering analysis, proper consideration of the potential adverse impact on structural integrity of the FBPS is warranted. A possible solution for FBPS's with a Maximum Free Area larger than allowed by design includes the addition of structural bracing or support in the localized area(s) of concern. By default, larger free areas are void of penetrating items, and therefore, should be accessible for the addition of structural bracing or support. This critical characteristic should be evaluated in conjunction with the Maximum Annulus/Spacing critical characteristic. Note: For penetrations where cables are involved, the design consideration for Percentage of Cable Fill applies in lieu of Maximum Annulus/Spacing for cable penetrants.

Table 4-1 (continued)
Generic Design Considerations for all FBPSs

Design Consideration:	**Maximum Annulus/Spacing**
Definition:	The maximum annulus/spacing is defined as the maximum distance between a penetrating item and the edge of the opening (Maximum Annulus) and the maximum spacing allowed for any two items (Maximum Spacing). Refer to Figure 4-2 for examples of Maximum Annulus/Spacing.
Importance:	The Maximum Annulus/Spacing should be considered to ensure the overall structural integrity of the FBPS. For penetrations where the Maximum Annulus/Spacing is smaller than the limit established by testing or engineering analysis, no further consideration of this critical characteristic is required. For penetrations where the Annulus/Spacing is larger than the limit established by testing or engineering analysis, proper consideration of the potential adverse impact on structural integrity of the FBPS is warranted. A possible solution for FBPS's with a Maximum Annulus/Spacing larger than allowed by design includes the addition of structural bracing or support in the localized area(s) of concern. By default, a larger annular space or large spacing between penetrating items are void of penetrating items, and therefore, should be accessible for the addition of structural bracing or support. This critical characteristic should be evaluated in conjunction with the Maximum Free Area critical characteristic.
Design Consideration:	**Minimum Spacing**
Definition:	The minimum space allowed between penetrating items and/or a penetrating item and the opening edge. Refer to Figure 4-3 for examples of minimum spacing.
Importance:	Minimum Spacing is primarily a constructability concern for FBPSs. There are a variety of materials that can be used in the construction of FBPSs. Some materials, such as silicone foams, urethane foams, and other multi-component cure-in-place materials are poured or injected into an opening and change state during the curing process. Minimum Spacing criteria should be defined by the manufacturer and/or substantiated by testing to ensure that the material will flow in between and around penetrating items prior to curing, such that sufficiently leak-tight FBPSs is created.
Design Consideration:	**Seal Material(s)**
Definition:	The minimum (and occasionally maximum) depth of a specific seal material required to provide the required functional rating. This attribute also considers material density requirements, when applicable.
Importance:	Seal material type, thickness, and density are important attributes to consider. Seal material type(s) should be the same as tested. The installed seal material thickness should be the same (or thicker) than the tested configuration. For multi-component seal materials that are mixed and dispensed at the jobsite, the material density should be checked and confirmed to be within the manufacturers specified acceptable range, or the range established by successful testing.

Table 4-1 (continued)
Generic Design Considerations for all FBPSs

Design Consideration:	**Damming Material(s)**
Definition:	The type, thickness, and density (if applicable) of permanent damming materials required by the seal assembly.
Importance:	For some configurations, damming material type, thickness, and density may need to be considered during FBPS design. These attributes should be considered for FBPS designs where the damming material is relied on (either partially or entirely) to provide pressure retention. Examples where the damming material would be considered to be part of the pressure retaining seal include the following: • Damming material left in place during pressure resistance qualification testing • Boot material in boot and ceramic fiber seals (boot material is the pressure seal) • Elastomer caps installed over other seal materials • Mastics used in conjunction with other sealant materials • Metal plates, caps or plugs used in conjunction with other seal materials Examples where the damming material would not be considered part of the pressure retaining portion of the seal include: • Non-supporting/non-structural ceramic board, blanket and fiber in bulk form used as damming for silicone foam, silicone elastomer, or other primary sealant materials Where permanent damming materials are credited as part of the pressure retaining portion of the seal assembly, the type, thickness, resistance capabilities, and density of the material should be bounded by testing or engineering analysis.
Design Consideration:	**Seal Symmetry**
Definition:	The configuration of required components of a penetration seal design either result in a Symmetrical or Asymmetrical configuration.
Importance:	The symmetry of a penetration seal configuration may impact the performance of the seal assembly. For example, a boot seal configuration that requires a single boot installed on only one side of the barrier is considered asymmetrical and may have different pressure retaining capabilities when pressurized on the installed side versus the uninstalled side. Conversely, a design that requires a boot seal to be installed on both sides of the barrier would be considered symmetrical. Asymmetrical configurations must be tested in both directions or installed symmetrically (both sides of the barrier) to substantiate a specific pressure rating in both directions.

Table 4-1 (continued)
Generic Design Considerations for all FBPSs

Design Consideration:	**Multiple Design Functions**
Definition:	Design functions imposed on a FBPS in addition to the function of providing flood protection. Other design functions may include fire rating, radiation shielding, HVAC confinement, as well as, other functional requirements.
Importance:	If the FBPS is relied upon to provide other design functions in addition to Flood Protection (e.g., Fire, Radiation Shielding, HVAC Confinement) then the additional design function(s) may invoke other design considerations as defined by the other functions. For example, polyurethane foam type FBPSs may not be suitable for Fire Seal applications due to the combustibility of the polyurethane material. Proper attention needs to be given to all design considerations related to FBPSs which serve multiple design functions.

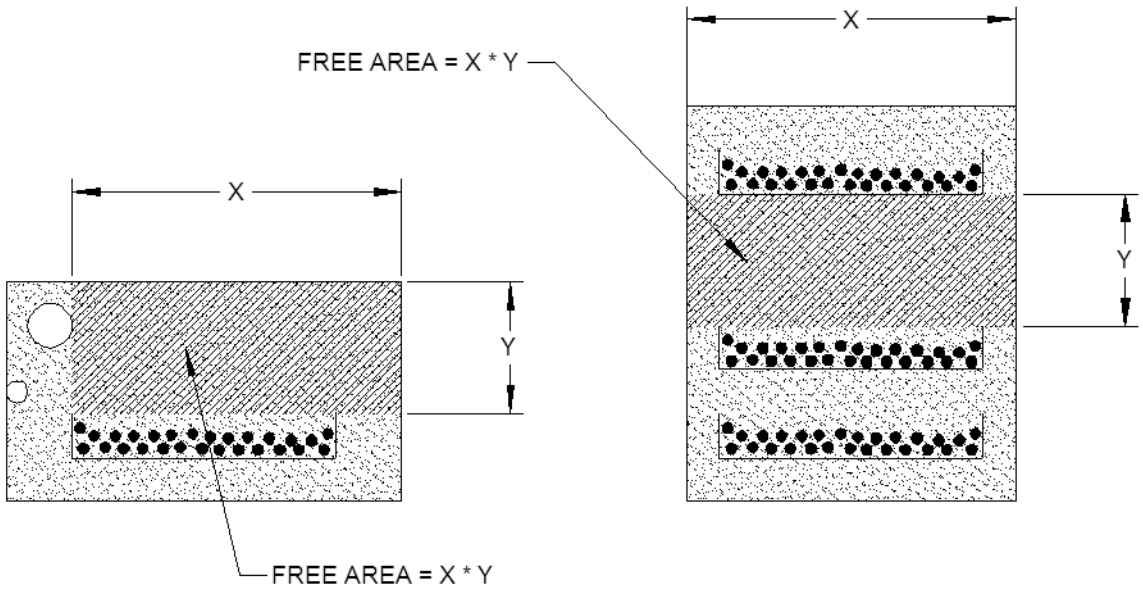


Figure 4–1
Examples of Maximum Free Area

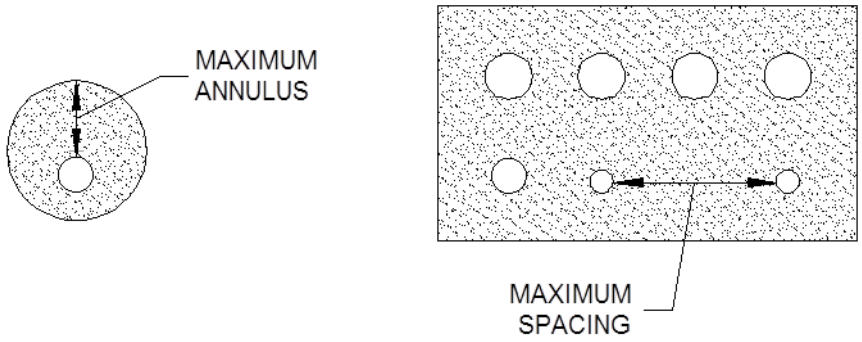


Figure 4–2
Examples of Maximum Annulus/Spacing

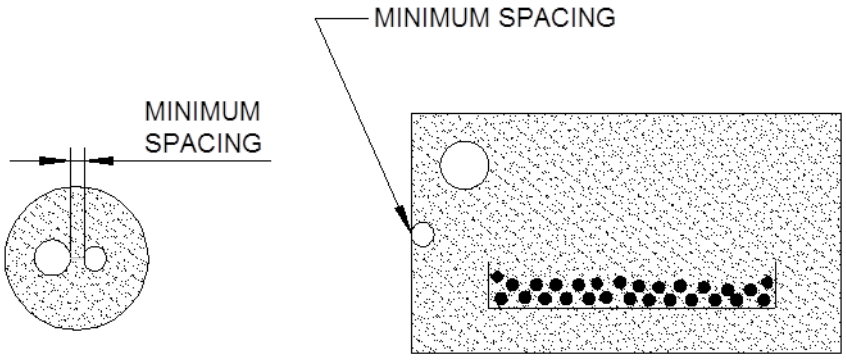


Figure 4–3
Examples of Minimum Spacing

Key Technical Point

Dow Corning 732 Multi-Purpose Sealant (caulk) contains acetic acid and should not be applied to concrete, mortar or other masonry surfaces.

4.1.2 Mechanical Penetration FBPSs

Mechanical penetrations typically contain penetrating items such as, piping, tubing and instrumentation lines.

In addition to the generic considerations for FBPSs, the following additional items in table 4-2 should be contemplated for Mechanical Penetration FBPSs:

Table 4-2
Generic Design Considerations for Mechanical Penetration FBPSs:

Design Consideration:	**Maximum Pipe Movement**
Definition:	The maximum dimension (axial and lateral) that pipes are allowed to move within a penetration seal comprised of a particular material.
Importance:	FBPS materials that come in contact with penetrating pipes should not be adversely affected by the maximum (design basis) pipe movement of the piping system at the penetration. Vendor or material manufacturer recommendations for allowable movements or displacements should be confirmed by testing to validate that FBPS leakage rates do not increase as a result of pipe movement. Limitations on allowable movements should be reasonable considering common logic (e.g., a material's ability to accommodate compression/deflection while maintaining a constant leakage rate is more likely a function of the material thickness and material strain, elongation and adhesion limits, rather than being a fixed value). Typical sources of pipe movement to be considered during penetration seal design include movement due to normal system operation (vibration), thermal impacts, and seismic considerations. Note: In some instances, existing mechanical penetration seals may have been installed with a "bondbreaker" material applied to the pipe to prevent the seal material from adhering to the pipe. This was typically done to accommodate installations where axial pipe movement was required. While application of the bondbreaker material may be acceptable for a fire seal, it may allow leakage under pressure conditions, and therefore, may not be acceptable for pressure resistant applications. The presence of a bondbreaker may not be readily detected by visual observation.
Design Consideration:	**Maximum Pipe Temperature**
Definition:	The maximum operating temperature of a piping system which passes through a penetration seal material.
Importance:	FBPS materials that come in contact with penetrating pipes should not be adversely affected by the maximum operating temperature of the piping system. Many of silicone-based foams, caulks and elastomers commonly used in penetration seal designs are limited to applications with maximum pipe service temperatures below 400°F.

4.1.3 Electrical Penetration FBPSs (including ICSs)

Electrical penetrations typically contain penetrating items such as, conduits, cable trays, wire ways and cabling. Electrical penetrations also include the category of internal conduit seals (ICSs).

In addition to the generic considerations for FBPSs, the following additional items in Table 4-3 should be contemplated for Electrical Penetration FBPSs (including ICSs):

Table 4-3
Generic Design Considerations for Electrical Penetration FBPSs:

Design Consideration:	**Percentage of Cable Fill**
Definition:	The cross-sectional area occupied with cabling described in terms of a percentage of the total cross-sectional area of the opening to be sealed.
Importance:	Acceptable FBPS leakage rates should be confirmed for seal designs based on maximum expected cable fill levels. High concentrations of cable fill present installation challenges to achieving sufficiently leak tight penetration seal assemblies, due to cable congestion which may prevent certain FBPS materials from freely flowing in and around all cables.
Design Consideration:	**Cable Jacket Material Types**
Definition:	The material type that comprises the outermost covering of a cable (i.e., the material that will come in contact with the seal material). Typical cable jackets types include, Polyethylene (PE), Polyvinyl Chloride (PVC), Cross-linked Polyethylene (XLPE), Crosslinked Polyolefin (XLPO), and Chlorosulfonated Polyethylene (CSPE).
Importance:	FBPS materials that come in contact with penetrating cables should not have any material compatibility issues. For example, cure inhibition frequently occurs when 2-part platinum-based cure silicone elastomers are installed around cables with Chlorosulfonated Polyethylene (CSPE) jacket materials. Material compatibility should be confirmed for all cable jacket material types and FBPS products, since cure inhibition at cable interfaces will likely result in seal assembly with significant leakage paths. In addition, material compatibility preventing an adequate bond between cable and seal may result in additional seal leakage at the interface.
Design Consideration:	**Cable Construction**
Definition:	The number, type and configuration of materials (e.g., conductors, cable fillers, inner wraps, jacket thickness, etc.) that make up a cable. Refer to Figure 4-4 for examples of different cable constructions.
Importance:	Cable construction (e.g., number of conductors, cable fillers, inner wraps, jacket thickness, etc.) can impact overall FBPS performance. Many two (2) conductor cables can be susceptible to deformation under pressure, due to the amount of filler used to create a round finished product. This deformation can result in a leakage path. Single conductor cables and cables with more than two (2) conductors are generally less susceptible to deformation under pressure but should be evaluated based on actual cable construction. Although not likely a path for significant leakage, certain cable types or short cable runs associated with electrical penetrations through flood barriers may allow water to leak through the barrier via the inside of the cable itself under certain conditions. Consideration should be given to this scenario (where applicable) and additional actions taken as warranted (i.e., seal the cable at the termination points).

Table 4-3 (continued)
Generic Design Considerations for Electrical Penetration FBPSs:

Design Consideration:	**Cable Ampacity**
Definition:	The maximum amount of current that a wire or cable can safely carry.
Importance:	FBPS materials and configurations should be evaluated to ensure the finished assembly does not create a cable ampacity concern. FBPS materials which are good insulators have the potential to create cable ampacity concerns resulting in degradation or premature aging of the cable if installed at a large enough depth/thickness. For flood seal applications, the thicker a seal material is installed, the better it would be expected to perform as a flood seal. However, if a seal material is installed at too great a thickness, it may cause a cable ampacity concern. Therefore, seal material thickness may need to be limited for electrical penetration applications to prevent cable ampacity concerns.

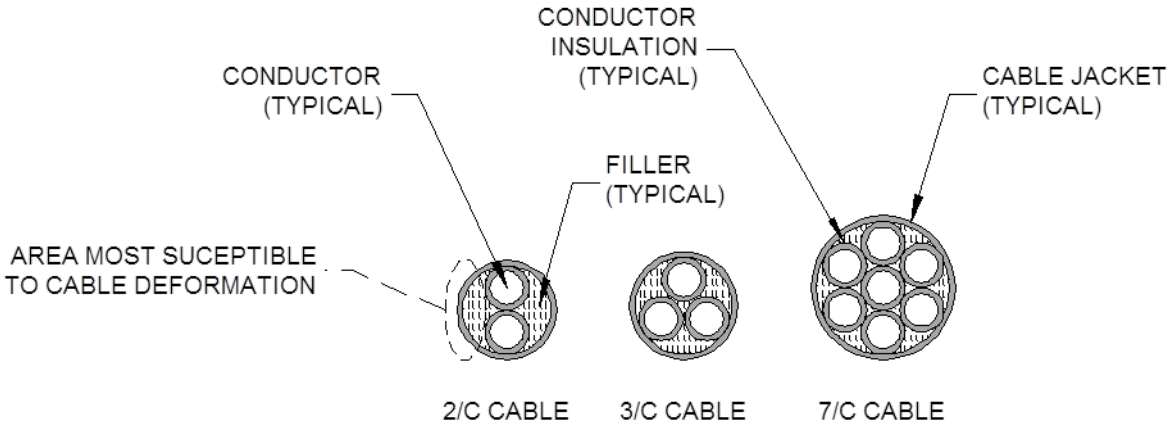


Figure 4–4
Examples of Cable Construction

Key Technical Point

Cure inhibition frequently occurs when 2-part platinum-based cure silicone elastomers are installed around cables with Chlorosulfonated Polyethylene (CSPE) jacket materials. Material compatibility should be confirmed for all cable jacket material types and FBPS products, since cure inhibition at cable interfaces will likely result in a seal assembly with significant leakage paths.

4.1.4 Ventilation Penetration FBPSs

Ventilation penetrations typically contain duct work as penetrating items.

In addition to the generic considerations for FBPSs, the following additional items in table 4-4 should be contemplated for Ventilation Penetration FBPSs:

Table 4-4
Generic Design Considerations for Ventilation Penetration FBPSs:

Design Consideration:	**Internal Damper Devices**
Definition:	A mechanical assembly that changes position when actuated to open up or close off the space inside a ventilation duct. They may also include pre-staged closure plates designed to seal off a ventilation opening in anticipation of a postulated flooding event.
Importance:	Installing FBPS materials external to the duct must not create any operability concerns for any internal damper devices. For example, installing silicone foam, or other FBPS materials that expand while curing, around a duct penetration where there is also a damper inside the duct may result in duct deflection that could adversely impact the internal damper's ability to close or actuate. Installation of pre-staged closure plates designed to seal off a ventilation opening in anticipation of a postulated flooding event need consider operational impacts on the associated ventilation system, including potential impacts on compartment environments and associated SSCs.
Design Consideration:	**Sealing Closure Angles**
Definition:	The materials and methods used to seal interfaces between the duct/perimeter closure angles (retaining angles) and the barrier/perimeter closure angles. Refer to Figure 4-5 for example typical closure angle interfaces that require sealing.
Importance:	The materials and methods used to seal interfaces between the duct/perimeter closure angles and barrier/perimeter closure angles should not affect the overall rating and functionality of any internal damper devices. FBPS material interaction should be considered for any materials used to seal interfaces between the duct/perimeter closure angles and barrier/perimeter closure angles. For example, Dow Corning 732 Multi-Purpose Sealant (caulk) contains acetic acid and should not be applied to concrete, mortar or other masonry surfaces where a long term physical bond is required/credited.

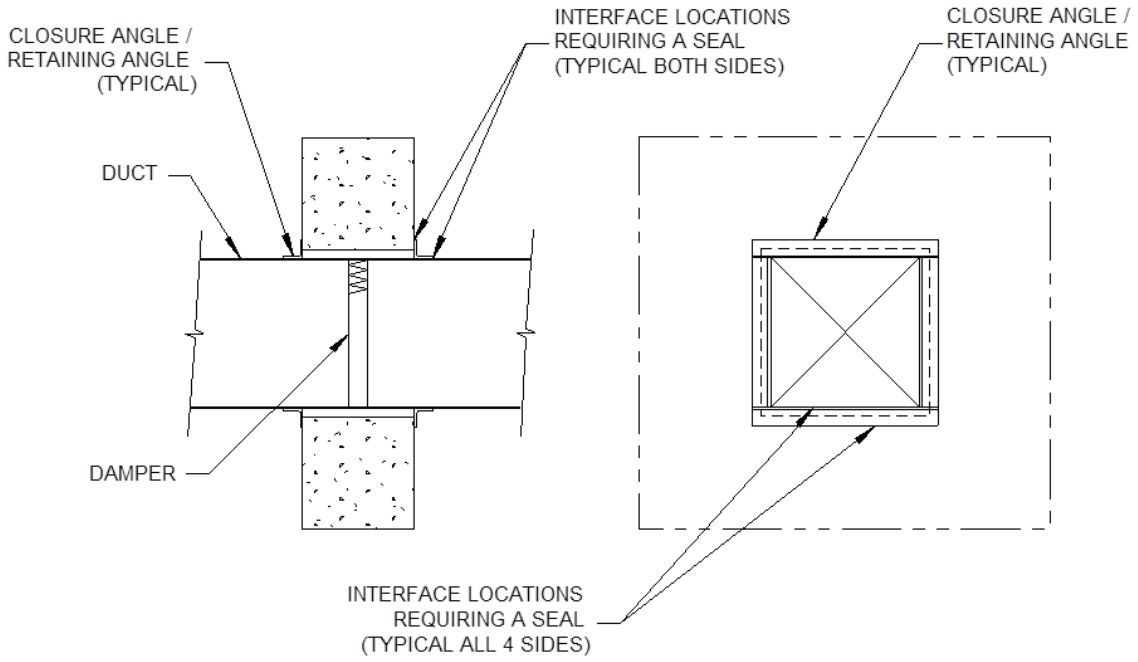


Figure 4–5
Examples of Typical Closure Angle Interfaces

4.1.5 Combination Penetration FBPSs

Combination penetrations contain penetrating items from multiple categories (i.e., mechanical, electrical, and ventilation type penetrating items). In addition to the Generic Considerations for the FBPSs mentioned above, Combination Penetrations should require the appropriate design considerations from other applicable penetration categories.

4.1.6 Seismic Gap and Construction Joint FBPSs

Seismic gap and construction joining FBPSs are used to seal gaps provided between structures to manage seismic interactions.

In addition to the Generic Considerations for FBPSs, the following additional items in table 4-5 should be contemplated for Seismic Gap and Construction Joint FBPSs:

Table 4-5
Generic Design Considerations for Seismic Gap and Construction Joint FBPSs:

Design Consideration:	**Differential Movement Between Structures**
Definition:	Building movement during seismic events may be differential such that the gap between structures will open and close (maximum movement consideration).
Importance:	FBPSs providing protection to a seismic gap or construction joint may need to accommodate anticipated (design basis) compression and expansion. Differential movements vary based on building elevation. FBPS materials installed in seismic gaps and construction joints should be assessed regarding potential impact on seismic considerations including dampening.

4.2 Design Considerations for Mechanical System Seals

General design considerations for mechanical system seals include the following:

- Proper design (i.e., suitable materials and sufficient thickness)
- Adequate installation guidance (i.e., surface or seal preparation, fastener torque requirements, fastener tightening sequence)

4.3 Design Considerations for Drains

General design considerations for drains and drainage systems include the following:

- Properly sized and located to handle the anticipated volume of fluid
- Adequate throughput capacity of system to keep up with anticipated demand

4.4 Design Considerations for Permanent Flood Barriers

Permanent Flood Barriers vary depending upon the type of permanent barrier used. General considerations for permanent flood barriers include the following:

- Proper design (i.e., applicable codes and standards, suitable materials, sufficient thickness, adequate reinforcement, proper height) for walls, floors, and curbs
- Maintenance and upkeep considerations for earthworks, dikes, dams, holding ponds and site grading to guard against erosion and degradation
- Maintenance and upkeep considerations for walls and floors
- Maintenance and upkeep of epoxy coatings where credited for barrier integrity (to address wear or cracking that may occur over time)

4.5 Design Considerations for Temporary Flood Barriers

Design considerations for Temporary Flood Barriers vary depending upon the type of temporary barrier used. General considerations for common temporary flood protection components mentioned in Table 2-1 are further discussed in the following subsections.

4.5.1 Sandbags

Fill materials, fill procedures, required bag quantities, barrier height limitations, bag placement and stacking, required man-power, time and maintenance considerations need to be taken into account to ensure construction of the temporary barrier is both feasible and adequate for the anticipated event. The US Army Corps of Engineers – “Sandbagging Techniques” is a helpful source of information related to use of sandbags for temporary flood protection [16].

4.5.2 Deployable Booms, Curbs, Barriers

Barrier and fill material staging, fill equipment, required manpower and time considerations need to be taken into account to ensure construction of these types of temporary barriers are both feasible and adequate for the anticipated event. Refer to vendor specifications and guidelines for

addition detail. Aquadam®, Hydrodam®, and Hesco Environmental Barriers are examples of deployable barriers for flood protection.

4.5.3 Diversion Excavations or Earthworks

Material staging, earthmoving equipment, required manpower, and time considerations need to be taken into account to ensure construction of these types of temporary barriers are both feasible and adequate for the anticipated event.

4.6 Design Considerations for Temporary Seals

Qualification for pressure resistance of temporary seals is the same as that of a permanent seal. Additional design considerations vary depending upon the type of device used to protect the opening. Additional considerations for Temporary Seals include the following:

- Device and tool staging
- Physical accessibility
- Time and manpower requirements

4.7 Design Considerations for Active Flood Protection Components

Design considerations for Active Flood Protection Components vary depending upon the type of component used. Following the structure established in Section 2, Table 2-2, the following considerations are listed.

Design considerations for entrance or egress openings vary depending upon the type of device used to protect the opening. General considerations for selecting an appropriate device for opening protection include:

- Consideration for the opening's frequency of use (normal access/egress vs. special use)
- Ease of use (hand operated vs. special tools or equipment required)
- Analytical methods required for qualifying structural integrity

Table 4-6 addresses additional considerations for some of the more common devices used to protect entrance and egress openings.

Table 4-6
Considerations for common devices used to protect entrance and egress openings:

Common Devices Used to Protect Entrance and Egress Openings	Considerations
Swinging Gates, Horizontal and Vertical Sliding Doors	Direction of protection vs. direction of closure Self-closing vs. manual closing Automatic latching vs. manual latching Required height plus margin if less than complete opening coverage is provided Gasket materials
Submarine Doors	Time to close and required manpower to close Gasket materials
Removable Closure Plates	Staging of cover plates, tools and hardware required to support installation Time and manpower required for installation and removal Gasket material and/or gap closure methods (e.g., caulking or sealing of gaps) Considerations associated with accessibility actions (i.e., time and actions required to remove closure plates if required by a specific event)
Concrete Floor Hatches	Tools and equipment required for hatch removal and placement Time and manpower considerations Gasket material and/or gap closure methods (e.g., caulking or sealing of gaps)

Table 4-7 provides general considerations for other active flood protection components listed in Section 2, Table 2-2, of this report.

Table 4-7
Considerations for Common Active Flood Protection:

Common Active Flood Protection Components	Considerations
Flood Outlet Devices	Sufficient size and flow capacity Proper backflow prevention Maintenance actions to ensure reliability and functionality
Flood Mitigation Equipment	Availability and staging considerations Time and manpower considerations Power source considerations

4.8 Secondary Design Considerations

Secondary design considerations may apply at the flood barrier (base structure) level or at the individual flood barrier device/component level. Secondary design considerations include, but are not limited to, the following:

- Provisions for addressing potential flow paths that could be created as a result of equipment or components that have been abandoned in place, such as:
  - Cut cables (potential flow path through the cable itself)
  - Pipes (abandoned piping systems should be sealed internally at or near the flood barrier)
  - Conduits (abandoned conduits should be sealed internally at or near the flood barrier)
  - Duct work (abandoned duct work should be closed or sealed internally at or near the flood barrier)

5
INSERVICE INSPECTION, TESTING AND MAINTENANCE RECOMMENDATIONS

Flood protection components at NPPs include a variety of both permanent and temporary equipment, structures and features. Permanent flood barriers are usually comprised of passive civil features such as walls doors and berms. Temporary flood barriers are usually comprised of equipment which can be deployed or installed when needed. These various components typically require regular inspections to ensure they maintain their design function.

Following installation it is not practical to perform in plant verification (full-scale) testing for the majority of these components. Therefore, it is recommended that periodic in-service inspections be performed followed by intrusive inspections as needed. Such periodic in-service inspections may be:

- Regular visual inspections to have confidence that each feature maintains the ability to perform its function when needed.
- Flood protection components which are required to operate, such as watertight doors and gates, should be functionally tested while being inspected. The inspections may be included as part of a comprehensive civil/structural inspection plan, part of a shared inspection process with other programs (such as fire protection), or as a stand-alone effort.

Many NPPs have specific commitments to perform various inspections on a defined periodicity schedule, but there is currently no widely accepted industry standard on inspection criteria or frequencies for flood barrier features. Typical inspection criteria for various flood protection components was assembled and vetted with the TAG associated with development of this guide. Criteria is listed below in Table 5-1 along with example failure criteria to assist in conducting inspections:

Table 5-1
Typical Flood Barrier Inspection Criteria

Type (Category)	Component	Typical Inspection Frequency	Type of inspection	Examples of Failure Criteria
Permanent Flood Barrier	Flood barrier walls, berms and similar features	Walkdown as required by commitment (seasonal readiness, or regulatory requirements)	Visual	Cracks or degradation of wall surface, damage.
Penetrations	Flood Barrier Penetration Seals (FBPSs)	Inspect a 10% sample every fueling cycle such that all seals are inspected approximately every 15 to 20 years (depending on outage schedule)	Visual. Additional intrusive and extent of condition inspections if degradation is found. Samples are increased to include a second population if deficiencies are identified in a population of seals.	Cracks or degradation of filler, damming or caulking, detachment of filler from wall (edge curl, shrinkage), or hardening.
Entrance or Egress openings	Flood doors, gates, hatches and similar features.	Annual or as recommended by the manufacturer	Visual and functional inspections	Feature does not close or fails to seal when operated, degradation or damage to feature, cracks or holes.
Temporary Seals	Temporary or deployable Equipment	Annual or as recommended by the manufacturer	Visual and functional inspection	Feature fails to operate as expected, visible damage or degradation, inadequate staging of equipment.
Drains	Water removal devices(i.e., pumps, floor drains, scuppers)	Annual or as recommended by the manufacturer	Visual and functional inspection	Feature such as scuppers fouled, floor drains plugged and pumps leaking
	Ditches, culverts, canals, conveyances, etc.	Annual or as required based on plant operating experience	Visual	Presence of vegetation, obstructions, silt

5.1 Visual Inspections Recommendations

Visual inspections are conducted by examining the selected components for degradation, gaps and other undesirable conditions in relation to the feature's design criteria.

A reasonable effort should be made to access all sides of each feature during inspections. Scaffolding and ladders are often needed to access flood barriers and seals located above or below the walking surface. Spotting scopes, flashlights, boroscopes, and other tools may be utilized to view hard to access features. Technical justification should be provided for inaccessible areas or other deferments.

One sided inspections should be performed if it is impractical or impossible to access all sides of the flood protection feature. For example, a sub-grade wall with sealed pipe penetrations may only be able to be inspected from one side. Opportunistic inspections should be made anytime normally inaccessible features are made accessible by construction or other activities. Use of a work management system can be employed to flag normally inaccessible features and prompt opportunistic inspections.

If undesired conditions are found, additional inspections are performed to determine if corrective actions are needed and to determine the extent of the condition.

Table 5-2 provides additional guidance related to common FBPS materials and signs of material aging. While these signs do not necessarily constitute material failure, they may serve as indication of decreasing material reliability.

Table 5-2
Indications of Material Aging of FBPSs

Material	Indications of Material Aging
Boot seals	• Boot fabric may become less pliable/flexible. Boot fabric may crack, rip or tear when moved. Boot fabric may exhibit signs of chafing. Fiberglass reinforcing may become exposed. • Bands/clamps at pipe and sleeve interfaces may become loose and require re-tightening. • Caulking at boot seam or at pipe/sleeve interfaces may separate.
Grout seals	• Grout material may exhibit cracking or shrinkage. • Separation may be noticeable at penetrating items or opening edge.
Silicone Foam seal	• Foam material may shrink. Visible signs of shrinkage include edge curl, concaved surfaces, and separation at penetrating items or opening substrate. • Foam may become less pliable/flexible. • Foam may exhibit cracking, tearing or splitting at penetrating item interfaces. • Foam material may harden, crack, tear or darken in color near penetrating items with elevated operating temperatures.

Table 5-2 (continued)
Indications of Material Aging of FBPSs

Material	Indications of Material Aging
Urethane Foam seals	• Foam material may darken in color. • Foam material may become brittle to the touch.
Caulk seals	• Caulk may become less pliable/flexible. • Caulk may separate from bonding surfaces
Silicone Elastomer seals	• Elastomer material may exhibit signs of shrinkage, such as separation from penetrating items or opening substrate. • Elastomer material may harden, crack, tear or darken in color near penetrating items with elevated operating temperatures.
Epoxy seals	• Epoxy may crack and/or separate from bonding surfaces.
Top Coating materials	• Top coating material may crack or become brittle
Combination seals	• Refer to specific seal material type for indications of aging.
Modular seals	• Material may split or tear due to long term compression. • Compression devices may relax or become loose and require re-tightening.



Key Technical Point

Additional guidance related to common FBPS materials and signs of material aging is provided in Table 5-2. While these signs do not necessarily constitute material failure, they may serve as indication of decreasing material reliability.

5.2 Functional Inspections Recommendations

Flood barriers are related to fire barriers in several key areas. Both are passive civil features in nature, share similar environmental and use conditions, and often share the same physical SSCs. Fire Protection Program (FPP) related inspections include both visual inspections of passive features and functional inspections of doors. The need for inspections and the associated frequency of fire protection inspections are usually governed by the NPPs FPP regulatory requirements. Although there may be overlap in flood and fire barrier design and service conditions such that inspections performed to fire barrier standards are suitable to meet flood barrier inspection needs, some penetration seals such as internal conduit seals, may not be inspected by the FPP. Additionally, acceptance criteria for fire protection may differ from acceptance criteria for flood protection. For example, some edge curl may be acceptably tested for a fire barrier seal, but may represent seal degradation that will not allow a seal to perform its intended pressure resistant design function.

Inspection frequencies can vary between NPPs due to specific licensing history, environmental considerations, maintenance history, and by using other performance based methods to

determine the appropriate interval. A suitably designed comprehensive barrier inspection program may be developed to meet both FPP and Flood Barrier inspections requirements on shared barriers with a single inspection procedure.

5.3 Typical Inspection Methods and Frequency

In keeping with the same layout offered in the tables listed in Section 2, the following sub-sections identify the recommended inspection, testing, monitoring and maintenance frequencies for the major categories identified at the beginning of this document.

5.3.1 Flood barrier walls, berms and similar features



Key Human Performance Point

Ensure all openings such as plugs, doors and other features are in place prior to inspections being performed if required.

5.3.1.1 Inspection/Walkdown of Flood Barrier Walls, Berms and Similar Features

Prior to the walkdown/inspection the following should be available/considered:

- Since the inspection is periodic, consider an annual Preventive Maintenance (PM) task where documents can be kept (drawings, calculations etc.) and updates can be made as deficiencies/changes in the task are noted.
- Have plant drawings denoting the structures in hand to ensure all structures are validated on the PM/Work Order.
- Rigging and tools needed to lower or install doors and its inspection frequency and availability in inclement conditions.
- Time and man-hours it takes to activate and install all features of the structural system to ensure available time and resources are available in the event the structural barriers are needed.
- Power Sources and systems required in the event of a Station Loss of Power (SBO event).
- Availability of spare parts and lead times for replacements.

Walkdown/Inspections should include:

- Required documentation in hand and personnel who are required to validate readiness (i.e., Resident Inspector) are on hand or informed
- All barriers are in place
- Inspect all stationary seals for degradation (cuts, tears, age, etc.) and document repairs or degradation
- Validate all features are available and operational

- Door Dogs are functional and properly adjusted
- Required bolting is in place or staged
- Required rigging and tools are in place or staged and properly inspected (i.e., annual rigging inspection); tooling may include ladders or man-lifts to allow installation.
- Any cracks or structural deficiencies are noted and repaired (to the standard of the original) or deficiencies are in the Work Management system and tracked
- Active seals are pressurized and criteria validated (i.e., pressure hold and stabilization)
- Material that ensures seals are preserved is available (i.e., seal covers) and will be re-installed
- Document all deficiencies noted during inspection and place in the Work Management System with appropriate tracking mechanism to ensure timely repairs are completed

Detailed guidance specific to levee inspections is accessible through the US Army Corps of Engineers. Their Levee Inspection Checklist not only includes specific items to inspect (e.g., slope stability, bank protection, and settlement), but provides rating criteria for each item (Acceptable, Minimally Acceptable/Maintenance Required, and Unacceptable ratings) [17]. In addition to this checklist, they also offer a downloadable Levee Inspection Systems Tool that can be used to track levee inspections which comply with US Army Corps of Engineers requirements [18].

An additional reference published by the US Army Corps of Engineers that provides guidance for the inspection and maintenance of levees and other flood protection components is the "Levee Owner's Manual for Non-Federal Flood Control Works" [19]. Despite its name, this manual also provides inspection and maintenance information on floodwalls, concrete structures, storm-water pump stations, channels, different types of closure structures (sandbags, gated structures, etc.), other drainage systems (ditches, culverts/pipes, etc.) and floodways. Several pictures are provided in the manual to identify the rating criteria mentioned in the previous paragraph (Acceptable, Minimally Acceptable/Maintenance Required, and Unacceptable). The manual also provides guidance on flood preparedness and actions to take during high-water events.

5.3.2 Flood Barrier Penetration Seals (FBPSs)

All or a sample of each type of FBPSs should be inspected on a regular basis. If a sampling method is used (i.e., less than 100% of the FBPSs are inspected at each interval), then the sampling method should include provisions for an increase in sample size if degraded FBPSs are identified.

5.3.2.1 Inspection/Walkdown

Boot Seals

- Inspect boot fabric to ensure there are no signs of rips, tears, abrasions or blemishes in the boot material.
- Inspect boot material seam to ensure there are no signs of seam separation.

- Inspect clamps or banding to ensure the boot material is held securely in place at both the boot-to-pipe and boot-to-sleeve interfaces.
- Inspect any flanges or special collars used in conjunction with, or in lieu of, clamps/banding to ensure such devices are secured in place, as required by design.
- If the opening consists of a cast-in-place sleeve or any type of sleeve extension, then inspect sleeve-to-barrier interface for any visible signs of degradation or potential leak paths [7].
- Repair, replace or correct any degraded components of the boot seal assembly via the appropriate mechanism.

Cementitious Grout Filler Seals

- Inspect filler material for surface cracks.
- Inspect filler material interfaces with the opening and at each penetrating item for signs of shrinkage, separation or noticeable gaps.
- If the opening consists of a cast-in-place sleeve or any type of sleeve extension, then inspect sleeve-to-barrier interface for any visible signs of degradation or potential leak paths [7].
- Repair, replace or correct any degraded conditions via the appropriate mechanism.

Silicone Foam Seals

- Inspect silicone foam material to ensure there are no signs of rips, tears or gouges in the surface of the silicone foam seal material.
- Inspect silicone foam seal material interfaces with the opening and at each penetrating item for signs of shrinkage, separation or noticeable gaps.
- If the opening consists of a cast-in-place sleeve or any type of sleeve extension, then inspect sleeve-to-barrier interface for any visible signs of degradation or potential leak paths [7].
- Repair, replace or correct any degraded conditions via the appropriate mechanism.

Caulk Seals

- Inspect caulk material to ensure there are no signs of cuts, tears or gouges in the surface of the caulk material.
- Inspect caulk material interfaces with the opening and at each penetrating item for signs of shrinkage, separation or noticeable gaps.
- If the opening consists of a cast-in-place sleeve or any type of sleeve extension, then inspect sleeve-to-barrier interface for any visible signs of degradation or potential leak paths [7].
- Repair, replace or correct any degraded conditions via the appropriate mechanism.

Silicone Elastomer Seals

- Inspect elastomer material to ensure there are no signs of rips, tears or gouges in the surface of the elastomer seal material.

- Inspect elastomer seal material interfaces with the opening and at each penetrating item for signs of shrinkage, separation or noticeable gaps.
- If the opening consists of a cast-in-place sleeve or any type of sleeve extension, then inspect sleeve-to-barrier interface for any visible signs of degradation or potential leak paths [7].
- Repair, replace or correct any degraded conditions via the appropriate mechanism.

Epoxy Seals

- Inspect epoxy seal material to ensure there are no signs of cracks in the surface of the epoxy material.
- Inspect epoxy material interfaces with the opening and at each penetrating item for signs of shrinkage, separation or noticeable gaps.
- If the opening consists of a cast-in-place sleeve or any type of sleeve extension, then inspect sleeve-to-barrier interface for any visible signs of degradation or potential leak paths [7].
- Repair, replace or correct any degraded conditions via the appropriate mechanism.

Caps and Plugs

- Inspect caps and plugs to ensure the device is securely in place (i.e., threaded devices should be at least hand-tight; compressible plugs should remain in place when pressed/pushed with hand; welded devices should be intact with no visible signs of unsealed seams, gaps, or obvious leakage paths.
- If the opening consists of a cast-in-place sleeve or any type of sleeve extension, then inspect sleeve-to-barrier interface for any visible signs of degradation or potential leak paths [7].
- Repair, replace or correct any degraded conditions via the appropriate mechanism.

Top Coating Materials

- Inspect top coat material to ensure there are no signs of rips, tears, gouges, or cracks in the surface of the top coat material.
- Inspect top coat material interfaces with the opening and at each penetrating item for signs of shrinkage, separation or noticeable gaps.
- Inspect the side of the FBPS opposite the top coat material to ensure the seal assembly that has been covered with the top coat is in place and appears undamaged.
- If the opening consists of a cast-in-place sleeve or any type of sleeve extension, then inspect sleeve-to-barrier interface for any visible signs of degradation or potential leak paths [7].
- Repair, replace or correct any degraded conditions via the appropriate mechanism.

Combination Seals

- Inspect the flood seal portion of combination seals using the appropriate inspection criteria based on the seal material(s) used for the flood seal.

Modular Seals (Compression Seals)

- Inspect modular seals to ensure there are no signs of gaps around penetrating items or that penetrating items have been changed without a corresponding change in modular seal blocks.
- Ensure modular seal compression plates, fasteners, etc. are engaged and the seal visually appears under compression.
- Inspect modular seal surfaces for signs of damage or degradation (no rips, tears, gouges, or cracks).

5.3.3 Flood Doors, Gates, Hatches, and Similar Features

Flood doors and similar devices are normally between rooms or are an external door. If the facility has an outer flood wall these doors, gates and hatches will be a part of this outer wall. Flood doors differ from fire doors as they are normally sealed with a continuous gasket (no floor opening) and can be dogged or secured in a manner that ensures the seal is compressed by the door being closed and dogged. These doors often resemble watertight doors on a ship or vessel.

Prior to the walkdown/inspection, the following should be available/considered:

- Validate additional door seals are available in inventory based on the number of doors at the station and the annual condition of the seals (how many are replaced yearly)
- Creation of a breach log to ensure doors and hatches are not obstructed and materials (i.e., hoses, cords) can be easily and rapidly removed
- Maintenance in the area should consider the door may require to be closed and dogged and work such as the erecting of scaffolds does not interfere with function

5.3.1.1 Flood doors, gates, hatches, and similar features inspection/walkdown

- Inspect door seals and ensure they are not degraded (i.e., torn, cracked, hardened, rotted) which will impact their function. If degraded then replace via the appropriate mechanism.
- Ensure doggs function and are not loose or degraded. Function should include inspection to ensure bolting is intact and doggs are free to move.
- Ensure path is not obstructed by hoses, cords, or other devices and, if so, the devices can easily be removed.
- Ensure maintenance in the area does not impact the ability for the door to be closed and secured (i.e., scaffold or materials used in other work in the area but impacting the door path or closure).
- If doors required additional materials to be lowered, installed or closed the required material (jacks, rams, man-lifts, rigging etc.) is available and can be moved to the area rapidly.

5.3.4 Temporary or Deployable Equipment/Materials

Flood protection temporary barriers may include items such as:

- Inflatable berms
- Aggregate and/or material berms
- Temporary structures or opening covers (door and window covers)
- Portable Pumps and hoses (fuel, air or electrically operated)
- Tooling and Equipment (i.e., jacks, rams, man-lifts, cranes, rigging)

Prior to the Walkdown/Inspection the following should be considered:

- A Preventive Maintenance Task that documents all components and contains vendors manuals, drawings and deficiencies noted in components or task and can be updated based on as-found conditions
- Location of all temporary equipment and how it will be moved into the required emergency location; considering roads, bridges, garage doors, forklifts and other equipment/accesses that are required to operate and strategy for operation in the event of a station loss of power or inclement weather
- Personnel hours and tooling required to access and inspect/install equipment to ensure actions are feasible (adequate time and resources available) in an emergency
- Storage Condition (i.e., moisture, rodent and pest access, heat) which may impact the life of the equipment
- Fuel/lubricant availability and requirements for access during an emergency

5.3.4.1 Temporary or deployable equipment inspection/walkdown

- Operate all equipment and validate operability in conditions that will match the required conditions as closely as possible (i.e., Pumps pump water, hoses can be connected, and inflatable berms can be inflated).
- Inspect all areas of the equipment (i.e., all areas of an inflatable boom) for rips, tears or degradation.
- Validate that storage conditions are adequate and storage containers support the ability for the device to be moved and staged rapidly (i.e., rigging points, forklift or other means).

5.3.5 Water Removal Devices (i.e., pumps, floor drains, scuppers)

Water removal equipment can encompass a number of devices. Air driven pumps, fuel driven pumps, sump pumps, scuppers (one way flow drains (check valves), floor drains, area drains and sewer drains and lines are a few of these components. They are normally stored near the area where they will be used and also many must have additional system support to operate (air, DC power, fuel etc.).

Prior to the walkdown/inspection the following should be available/considered:

- Will the power source or fuel be readily available in the case of a Station Blackout (SBO) or in the event of inclement weather?
- Are storage containers in good condition and do they provide adequate protection of the equipment (keep weather and pests from impacting the equipment)?
- Is there a clear path to install the equipment and allow it to perform its function?
- Will additional tooling be required and is it also stored in the area?
- Do the functional tests challenge the equipment to ensure it will perform in the worst case scenario?

5.3.5.1 Water removal devices inspection/walkdown

- Validate the equipment functions and support systems (air, fuel, power etc.) will be available during postulated worst case scenarios. This includes validating floor drains and sewers can support the required flow rate of water. Depending on the size of the sewer line a physical or robotic inspection may be required.
- Ensure equipment can be adequately assessed and installed (access is not obstructed by work in the area).
- Ensure storage containers are in good condition.
- Ensure all tooling required to install equipment stored in area or readily available.

5.3.6 Culverts, conveyances canals, etc.

Prior to the walkdown/inspection the following should be available/considered:

- Pathway is fully understood and can be inspected.
- Materials required to perform the inspection are available (flashlight, mirror, robot etc.).

5.3.6.1 Culverts, conveyances canals inspection/walkdown

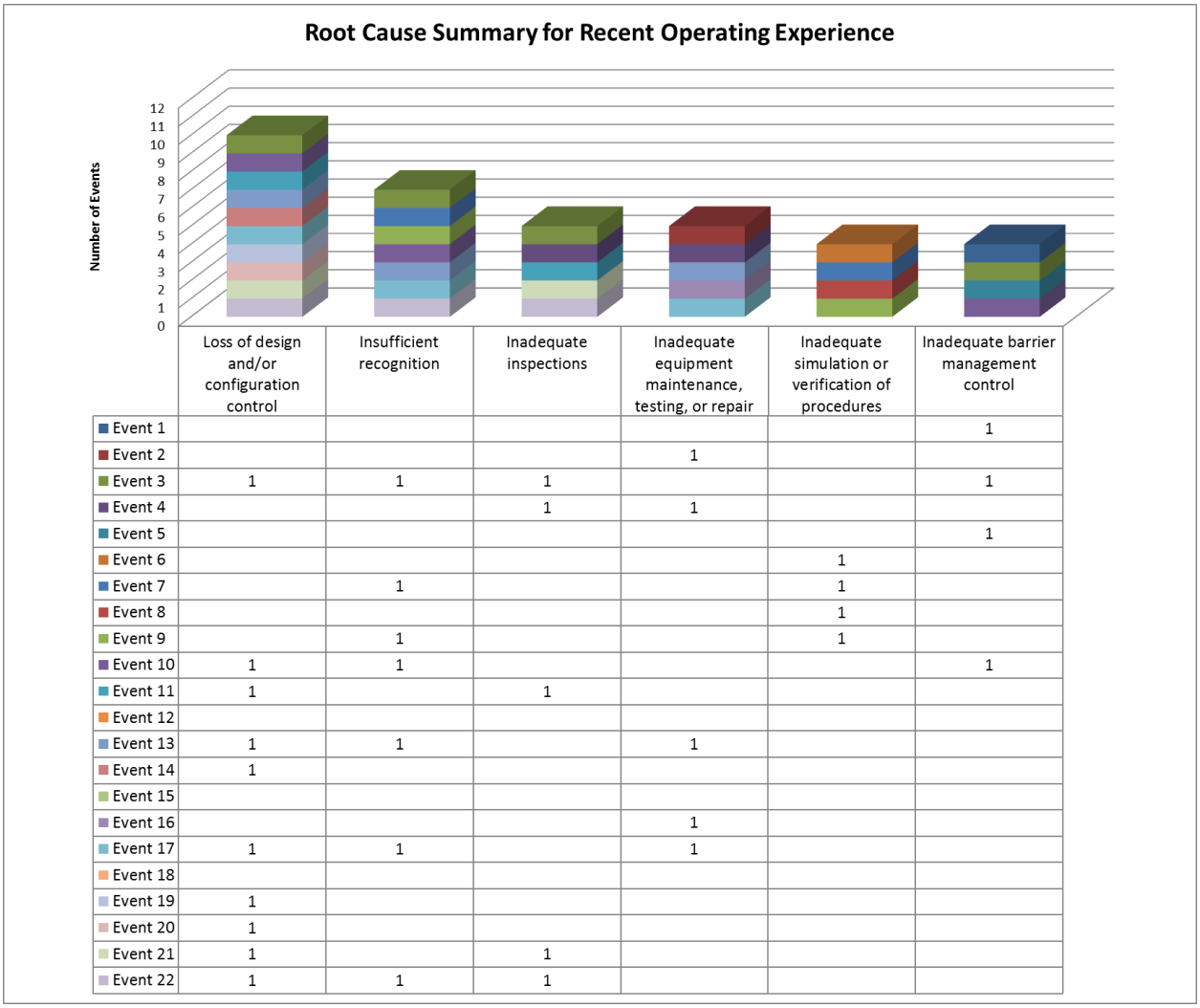
- Validate the feature will perform its function and is clear of debris, vegetation or other items that may block flow or cause flow to be reduced. Depending on the size of the feature a robotic inspection may be required.

6
INDUSTRY PERFORMANCE ANALYSIS

This section is intended to outline recent events that have occurred at NPPs with the goal of providing a summary of recent operating experience to the reader and identifying corrective actions associated with these events. In this way, all stations with access to this report can be knowledgeable of recent OE related to flood protection and also see how these events were addressed and corrected. In addition to this, recurring issues can be presented in hopes of highlighting them and minimizing recurrence as additional utilities and stations examine their flood protection design basis. Information was compiled from the INPO ICES Database along with other industry event reports or notices (both U.S. and international). Information including utility names or site-specific information has been removed.

6.1 Recent Industry Events (2006-2015)

After reviewing a compilation of abstracts from recent flooding-related events or conditions (Refer to Appendix C for a listing of these recent flooding events), the next step is to identify root causes as well as recurring issues in order to focus on key areas that should be examined during establishment or review of a flood basis at the corporate or site level. Figure 6-1 summarizes root causes associated with the events listed in Appendix C and presents them in a method to assist in identifying recurring issues. Realizing that there is some overlap between root causes and multiple root causes (with varying levels of significance) for most of these issues, this chart attributes the most significant root causes to each of the events.



	Loss of design and/or configuration control	Insufficient recognition	Inadequate inspections	Inadequate equipment maintenance, testing, or repair	Inadequate simulation or verification of procedures	Inadequate barrier management control
Event 1						1
Event 2				1		
Event 3	1	1	1			1
Event 4			1	1		
Event 5						1
Event 6					1	
Event 7		1			1	
Event 8					1	
Event 9		1			1	
Event 10	1	1				1
Event 11	1		1			
Event 12						
Event 13	1	1		1		
Event 14	1					
Event 15						
Event 16				1		
Event 17	1	1		1		
Event 18						
Event 19	1					
Event 20	1					
Event 21	1		1			
Event 22	1	1	1			

Figure 6–1
Root Cause Summary for Recent Operating Experience Chart

When viewing this table the reader can see recurring issues that appear towards the left of the table since more 1's appear in the columns below these individual root causes. Based on the categorization used in the table above, the first three root causes have the most ties to these events. In several cases these root causes overlap and appear together in events. These root causes (with examples below them pulled from the events) include:

1) Loss of Design and/or Configuration Control

   – Event 11: Degradation on several conduit couplings in the air intake tunnel was identified and attributed to inadequate configuration management dating back to original station construction.

   – Event 14: Inadequate electrical conduit penetration seals found in an electrical manway were attributed to inadequate flood protection design basis information and the need to develop more detailed inspection basis information.

   – Event 21: Identified flood protection deficiencies outlined in this event were attributed to inadequate design and configuration control of features to protect against flooding.

2) Insufficient recognition of the risk significance of flood protection features or basis requirements
   - Event 7: The station did not ensure proper validation of the external flooding strategy design basis commensurate with safety significance.
   - Event 17: A station mindset existed that assumed the station was safe as is and a questions attitude was not adequately implemented to assure that intake structure penetrations were identified and sealed.
   - Event 22: No effective ownership of Flood Seals as a program which led to the loss of configuration control of conduit seals within an on-site manhole.
3) Procedural Deficiencies
   - Event 3: Site procedures did not contain all needed information required to perform necessary manual actions to effectively respond to external flooding.
   - Event 6: Site plans lacked sufficient detail to ensure station power requirements would be maintained for important safety functions.
   - Event 8: The station failed to establish procedural requirements to implement external wave run-up protection design features.

In addition to the recent events highlighted above, notices from the regulator and other industry organizations identify recurring issues that have been identified from the plant events listed above as well as other related OE. These recurring issues are similar to the ones listed above and include:

- Incorrect flood water inundation times
- Lack of monitoring, inspection, maintenance, design control, and configuration management procedures for flooding barriers (particularly seal penetrations)
- Insufficient flood equipment preventive maintenance
- Inadequate or sufficient mitigating equipment identified and staged for implementing procedures
- Insufficient time requirements for implementation of flood mitigation procedures
- Inadequate simulation of flood emergency procedures during walk downs outlined by reference [15].
- Insufficient training for implementation of flood mitigation procedures
- Process controls to ensure that flood protection program protects critical safety systems
- Drain operability (not being included in any maintenance or test program)
- Unknown or previously unidentified ingress pathways (for external and internal flooding sources)

6.2 Corrective Actions Associated with Listed Events

Appendix D lists the corrective actions associated with the OE presented in Appendix C and referenced above. The same table format, event numbers, and event descriptions used in Appendix C are carried over to Appendix D to allow for easier cross-referencing of events between the two tables. Information including utility names or site-specific information has been removed. Given the increased attention being given to flood protection features and design basis requirements across many stations worldwide, the reader can use this information as a consolidated reference in order to get a better understanding of how other stations addressed flood-related events.

7
ESTABLISHING AND MANAGING FLOOD BASIS REQUIREMENTS

This section is intended to provide information that will assist utilities in establishing and maintaining sustainable flood protection basis requirements at the site level. Recommendations included in this section came from a review of programs (both formal and informal) in place at utilities involved in the Technical Advisory Group (TAG) assembled during development of this guide. The term, basis, is used in this section to encompass the processes, procedures, and practices a site has established in order to ensure that the flood protection features and systems credited in their design basis will function as intended when challenged. In terms of implementation at the site level, the recommendations given in this section may not require that an official program be established or recognized within the organizational structure at the site. A more comprehensive follow-on industry report focused on best practices associated with the implementation and management of the programmatic aspects discussed in this section, is being planned for future publication as a supporting product to the component-level technical information presented in this guide.

Within the different sites represented by this TAG, there were varying levels of maturity and different approaches adopted by sites to manage their flood basis. The sub-sections below represent some of the major components or topics that should be addressed when establishing or maintaining a flood basis commensurate with the risks and flood protection features in place at a given site. Best practices are outlined, where appropriate, for the reader to consider when examining his or her own site-specific flood basis.

7.1 Considerations for Establishing a Flood Basis

For sites establishing a flood basis and associated requirements, this section outlines some of the major considerations and best practices pulled from members providing inputs to this guide. For both new and existing sites, the overall goal for the basis requirements that are implemented is to be able to maintain design basis configuration and license commitments agreed upon with the regulator in a method appropriate to the flood-related risks internal or external to the site.

7.1.1 Recognition of Risk Significance of Flood Protection Features and Documents

Regardless of the nature, formality, and complexity of a site's flood basis, it is apparent from a review of recent flood-related OE that a major contributing factor to several identified events stems from a lack of understanding of the risk significance associated with flood protection features. After reviewing approaches taken by utilities involved in the development of this guide, one common element in the flood procedures was a definition of roles and responsibilities among the various plant groups, regardless of whether the flood basis was defined as an official program. These definitions allow a platform by which an appropriate structure can be developed

to address a sites flood basis. Common processes and procedures developed by TAG members are summarized in the following sub-section for reference.

7.1.2 Common processes and procedures used within site flood basis requirements

While assembling content for this guide, there were certain processes and procedures associated with flood basis requirements that were present among the sites represented within the TAG. Several TAG members had recently (within the last 5 years) developed or re-evaluated their flood basis and provided the associated procedures for consideration.

Procedural guidance and basis documentation is outlined below:

- Basis Documents – This document would outline the scope of the sites flood basis to include responsibilities and relevant documents. Part of this set of documents would typically include a design basis report establishing what the licensing and design basis are for the specific site.
- Flood Components Listing – In order to maintain configuration control, each plant typically has a set of drawings to serve as a reference/log for flood-related penetrations and barriers, including doors, wall and floor penetrations, drains, etc. These drawings indicate where the features are located and depending on the complexity of the drawings or database used to track them, can include a significant amount of additional relevant information. Section 7.4 on Configuration Control includes more information on this topic.
- Inspection Procedures – Captures the inspection responsibilities, methods, periodicities, and actions outlined in Section 5 of this guide. Development of these procedures within some of the utilities interviewed included alignment with the work order process already in use by the Fire Protection Program on-site. In other cases, these procedures called for adoption of Maintenance Rule Program requirements. Practically, these procedures must lead to the development of checklists that can be used by maintenance personnel to perform tasks along with an ability to track results and findings from the tasks.
- Maintenance and Planning Procedures - These would include a combination of maintenance and planning procedures aligned with the chosen work order process. These procedures must ensure configuration control is maintained and flood control features can perform as intended.
- Barrier Control Procedures – Related to Maintenance and Planning Procedures, this would be the process that ensures a flood protection feature maintains operability during and after maintenance or plant modifications that may impact that feature.
- Severe Weather Procedures – These include time-based actions that are triggered as a result of conditions leading up to severe weather events. This would include preventive steps to minimize the impact of such events. Items like inspection or erection of external barriers, communication with other organizations or groups, commencement of special log taking, and responsibilities would be outlined in this document.
- Beyond Design Basis Documentation - If applicable, this would include considerations for flood protection features that are part of mitigation strategies for beyond design basis events.

For sites who establish a formal program to manage their flood basis, there are additional documents that would be expected.

For reference, a site that had recently established a formal program in 2012 provided EPRI with an External Events Protection Program Health Report. This document explains how program health is measured based on three major areas: 1) Compliance, 2) Effectiveness, and 3) Performance. Each of these 3 categories has sub-categories with specific metrics that allow the plant to determine whether the sub-category is green, white, yellow, or red. Depending on the rating or each, this feeds back to an overall score that represents the overall health of the program.

7.1.3 Alignment of Flood Basis with Fire Program

Following the implementation of fire protection requirements across the industry several decades ago, the formality and consistency associated with these requirements has generally become well developed and understood across the industry. This includes responsibilities, inspection, testing, and configuration control from site to site. Realizing how both fire and flooding events have shared protective features, there will be some overlap between both programs, regardless of the creation of separate, official program requirements for flooding. There will also be noticeable differences, as specifically identified within some of the previous sections of this report that deal with testing requirements and design considerations for flood protection seals vs. fire protection seals.

7.2 Training and qualification for Personnel Associated with Flood Basis

This section summarizes the training requirements from utilities that require training and manage qualifications for individuals involved in maintaining their flood basis.

7.2.1 Qualifications for Responsible Individual Overseeing Flood Basis

From the sites involved in the development of this report, it was noted that different roles within different groups at a site can encompass the responsibilities associated with an individual (or individuals) assigned to oversee flood protection basis requirements. The following qualifications come from previously developed site qualifications and are listed for consideration when evaluating the knowledge and experience of an individual assigned to oversee flood protection basis requirements at a site:

- Be able to describe the function of various flood protection components used at the site along with the types of materials used, installation requirements, what constitutes degraded conditions, and methods of component qualification.
- Be knowledgeable on design considerations associated with different types of flood protection components.
- Have a working knowledge of site documents and procedures associated with flood protection basis requirements.
- Have a working knowledge of industry references and recent industry operating experience related to flooding events.

7.2.2 Qualifications for Personnel Inspecting Flood Protection Components

Inspection of flood protection components should be accomplished by individuals who have the ability to recognize signs of failure and degradation in the components they are inspecting. The following general qualifications are offered for consideration in developing site requirements for individuals performing inspections of flood protection components at the site level:

- Be able to recognize various flood protection components and their location at the site.
- Have a working knowledge of how these components function.
- Be knowledgeable on degradation and failure mechanisms associated with these flood protection components (Section 5 of this guide offers some inspection criteria as well as recommendations associated with inspection of various components)
- Have a working knowledge of site documents and procedures associated with conducting inspections on these components.

7.2.3 Qualifications for Personnel Installing Flood Protection Components

In reviewing qualification guides provided by TAG members assisting with the development of this guide, the following items appear consistently within qualification guides for plant personnel and vendors who are installing flood protection components. Depending on the application or type of component, the formality and level of requirements can vary:

- An understanding of applicable industry references and site-specific documentation related to that component.
- Adequate knowledge of material, component characteristics, attributes, degraded conditions, and methods to qualify the component.
- Performance objectives, if applicable, related to selecting the appropriate type of barrier to use for a specific application. In the case of penetration seals, this could mean selecting the appropriate seal design by calculating the maximum free area, area/perimeter ration, cable fill percentage, etc.
- Working knowledge of barrier management and work controls used by the site while before, during, and after maintenance or replacement of the component occurs.
- Understanding of the required identification and documentation (configuration control) associated with a component.

7.4 Configuration Control

Another major aspect that can point to the level of effectiveness of a site at managing its flood basis, no matter how complex, is configuration control. Configuration control represents the processes and practices in place to ensure traceability of specific flood barriers to their design, testing, installation, location, and condition over time. Depending on the number and types of barriers at a site, this could look very different from plant to plant. One TAG member had a single-unit, dry site with approximately 1,200 credited components to protect against external flooding. For another site located inland without a significant risk of flooding, the number of flood-related components could be on the order of a few hundred.

Because of these large differences in the number of components, the systems and databases in place to maintain configuration control could vary anywhere from a simple list of items, to a cross-referenced series of plant drawings and even up to an enterprise-level software system.

Utility Example 1: With respect to the higher level of complexity and large number of flood-related components, the station with 1,200 credited flood protection components mentioned above uses an SAP Database to manage configuration control (used for both fire and flood protection components).

In terms of configuration control, this database was extensive in detail and used for site personnel to track the following information:

- Seal ID
- Type of seal
- Room location
- Opposite room #
- Barrier thickness
- Size of opening
- Whether the liner is painted
- Seal testing requirements
  - Water
  - Air
  - Steam
  - Radiation
  - Fire rating criteria

Also embedded within the SAP Database is the ability to provide the following additional supporting information for flood protection components:

- Links to related plant drawings (with other penetration seals listed on those drawings)
- Links to vendor documents that include related test reports
- Seal material, depth, height, width, and free area of the seal
- Penetrations going through a specific seal (number, type, and diameter of each)
- Cross-references to any engineering design evaluation that may be needed to supplement or support the selected seal design
- Identification of items that pass through the penetration along with the number of each item and physical properties (size and construction)
- Service temperature
- Other features associated with a seal

As a quick reference for penetration seals, this same site manages a Penetration Seal Detail List that indicates the approved seal designs they can use for various applications.

Utility Example 2: A separate site that recently created a formal program to manage their flood bases uses a series of drawings that provide a single-source tabulation of protected features to manage configuration control at their site. They are actually the first site adopting this method of configuration control in what has become fleet-wide effort.

To assist in maintaining design and configuration control of installed penetration seals, a method should exist within the planning and work control process to ensure that flood protection penetrations impacted by maintenance or repair activities are identified, controlled, and that the appropriate mitigating strategies are identified prior to impacting the function or capability of specific flood penetrations. For reference, the site with 1,200 external flood protection components uses a Penetration Seal Work Release (PSWR) form to serve as the method for maintaining their design control process. This form requires personnel doing work to be knowledgeable of the impact of work being done if it impacts a penetration(s). As part of a design change package, there is a question that prompts an individual completing a design change to examine the impact the change has on flood-related components. If maintenance is planned that impacts a FBPS, the design change package is required to have a PSWR to accomplish the maintenance. This then triggers involvement from the responsible flood protection engineer who oversees the site's flooding design basis to examine the impacts and ensure mitigating actions are in place. Restoration requirements for the seal or barrier are also identified within this form as well.

7.5 Maintaining Appropriate Work Controls

Another area of importance that has been singled out for mention within this guide relates to the processes and procedures that exist at the site level to assure that a credited flood protection component will perform its design function during and after maintenance that impacts the component. If the credited design function of this component is impacted during or after maintenance activities, appropriate compensatory measures must be established as part of this process as well.

A utility example of a "Barrier Impairment Form" was submitted through the TAG for inclusion in this sub-section. Details from this form are summarized below and should be considered as an example for sites or utilities either benchmarking their forms or looking to formalize their barrier control processes. Major content included within the form is outlined below:

1) Initiator Section of the Barrier Impairment Form (includes the following information)
    a) Component (include ID and appropriate drawings)
    b) Description of Barrier Impairment
    c) Reason for Barrier Impairment
    d) Support Maintenance Activity (Y/N)
    e) Planned Duration (Days)

2) Compensatory Actions (includes the following information)
   a) Ventilation Barrier
      i) Barrier Type Applicable (Y/N)
      ii) Compensatory Action Required (Y/N)
      iii) Mode Restrictions (describe)
      iv) 90-day time clock applicable (Y/N)
      v) Is a design modification review required (Y/N)
   b) Flood Barrier (similar content as outlined under Ventilation Barrier)
   c) HELB Barrier (similar content as outlined under Ventilation Barrier)
   d) Missile Barrier (similar content as outlined under Ventilation Barrier)
   e) Control Room Envelope and Secondary Containment Barriers (similar content as outlined under Ventilation Barrier)
   f) Post-LOCA Radiation EQ (similar content as outlined under Ventilation Barrier)
3) Approval of Plant Barrier Impairment
   a) This section of the form identifies the appropriate reviews for the different types of barriers listed in Section 2 of the form.

Additional areas of the document that contains the form outlined above provide the appropriate terminology, definitions, review requirements, responsibilities, and references to support the form. In addition to the form, a sample log is provided to outline the summary information required for tracking all of the barrier impairments across the site at any one time. Table 7-1 is a recreation of that tracking log:

Table 7-1
Sample Site Barrier Impairment Log

Log Permit #	Database Tracking #	Description	Work Group	Planned Duration	90-Day Clock (Y/N)	Impaired Date & Time	Impaired Date &Time	Restored Date & Time	Status

7.6 Leakage Definitions

For different types and categories of flood protection components, the amount of allowable leakage may vary depending on the design and application of the component in question. One member of the TAG supplied a definition of the leakage rates that are applied to FBPSs at their utility [25]. These include:

- Leak tight – Seal configuration has no measurable leakage at maximum differential design pressure
- Essentially leak tight – seal configuration has a measurable leak rate that is < 0.1 Standard Cubic Feet per Hour (SCFH) at maximum differential design pressure

- Mitigates leakage – seal configuration mitigates the differential pressure flow with measurable leakage > 0.1 SCFH, but without seal dislodgement: at maximum differential design pressure (dislodgement pressure is defined as the pressure at which there is observable displacement of any portion of the installed seal)

These leakage rates are then assigned to various approved seal designs used at their site so that it is clear what designs can be used for specific applications. These leakage rate definitions are provided more for consideration since definitions may vary from utility to utility.

7.7 Volumetric Protection – An Overall Approach towards External Flooding Protection

Another member of the TAG providing inputs to this guide supplied the team with an approach that his utility had adopted as a result of lessons learned following a major external flooding event in 1999 that impacted a 4-unit site. In simple terms, the volumetric protection approach adopted by this utility identifies a perimeter "made up of external walls of a group of external rooms or buildings containing equipment necessary for attaining or placing the units to a safe state, in case of flooding. The external walls of this group of buildings (walls, floors and ceilings) must be sealed against the risk of external flooding, at a height defined by the flooding hazard studies performed for each site."[28] A Technical Note was released for the purposes of sharing principles behind this approach with readers of this guide and a summary of important items from that note are provided in Appendix E.

8
CONCLUSIONS

This report serves as a technical reference for individuals at NPPs involved in the management of flood protection basis requirements, specifically for ensuring protection against external flooding events. It described common flood protection components at NPPs and the design, testing, inspection, and maintenance of these components (with specific attention given to FBPSs).

Starting with a comprehensive listing of flood protection components in Section 2 of this guide, a component description was provided along with an overview of the function and application of these various components. Following that, available testing methods, acceptance criteria, and design considerations were provided with specific attention given to FBPSs. From the variety of testing methods and results outlined in Section 3, it is apparent that a standard testing protocol has not been developed across the industry to date. Until such a protocol is developed, the design considerations provided within Sections 4 are intended to educate individuals involved in seal or other flood component testing on what design parameters are important in terms of the specific application or need being examined.

In Section 5, specific In-Service Inspection, Testing and Maintenance Recommendations were offered for the broader categories of both active and passive flood components identified within the tables in Section 2. Following this, several recent industry events were captured in Section 6 along with a summary of root causes and recurring issues identified following a review of these events.

Lastly, Section 7 summarized the important aspects and considerations that should be given to individuals at NPPs who are establishing or managing the flood basis requirements at their site. Given the technical focus of this document on flood protection components, Section 7 is not comprehensive, but instead represents some of the more important programmatic considerations identified by utility personnel involved in the creation of this guide. Given the varying degrees of complexity and requirements for external flood protection at utilities worldwide, the examples and recommendations presented in Section 7 are intended to benefit sites who manage either formally defined or informal flood protection programs.

9
REFERENCES

9.1 Regulations and Regulatory Guidance

1. U.S Nuclear Regulatory Commission Regulations (10 CFR) Appendix R to Part 50 – Fire Protection Program for Nuclear Power Facilities Operating Prior to January 1, 1979
2. U.S. Nuclear Regulatory Commission, Information Notice 2015-01, Degraded Ability to Mitigate Flooding Events, 2015
3. U.S. Nuclear Regulatory Commission, Information Notice 2007-01, Recent Operating Experience Concerning Hydrostatic Barriers, 2007
4. U.S. Nuclear Regulatory Commission, Information Notice 03-08, Potential Flooding Through Unsealed Concreate Floor Cracks, 2003
5. U.S. Nuclear Regulatory Commission, Information Notice 94-27, Facility Operating Concerns Resulting from Local Area Flooding, 1994
6. U.S. Nuclear Regulatory Commission, Information Notice 92-69, Water Leakage from Yard Area through Conduits into Buildings, 1992
7. U.S. Nuclear Regulatory Commission, Information Notice 88-60, Inadequate Design and Installation of Watertight Penetration Seals, 1988

9.2 Implementing Standards

8. ASTM E119, Standard Test Methods for Fire Tests of Building Construction and Materials
9. ASTM E814, Standard Test Method for Fire Tests of Penetration Firestop Systems
10. ASTM E1966, Standard Test Method for Fire-Resistive Joint Systems
11. IEEE Standard 634, IEEE Standard for Cable-Penetration Fire Stop Qualification Test
12. NFPA 251, Standard Methods of Tests of Fire Resistance of Building Construction and Materials
13. UL 1479, Standard for Fire Tests of Penetration Firestops
14. UL 2079, Standard for Tests for Fire Resistance of Building Joint Systems

9.3 Industry Guidance

15. Nuclear Energy Institute, Guideline 12-07 (Rev. 0-A), “Guidelines for Performing Verification Walkdowns of Plant Flood Protection Features”, May 2012

16. “Sandbagging Techniques,” US Army Corps of Engineers Northwestern Division, 2004 [Online]. Available: http://www.nws.usace.army.mil/Portals/27/docs/emergency/NWD_Sandbag_Pamphlet.pdf [Sept 6, 2015]

17. “Flood Damage Reduction Segment / System Inspection Report” US Army Corps of Engineers, 2015 [Online]. Available: http://www.usace.army.mil/Portals/2/docs/civilworks/levee/LeveeInspectionChecklist.pdf [Oct 14, 2015]

18. “Levee Inspection System Version 3.2” US Army Corps of Engineers, 2015 [Online]. Available for Download / Installation: http://nld.usace.army.mil/egis/f?p=475:11:13981932700539::NO::: [Oct 14, 2015]

19. “Levee Owner’s Manual for Non-Federal Flood Control Works” Public Law 84-99, US Army Corps of Engineers, 2006 [Online]. Available: http://www.nws.usace.army.mil/Portals/27/docs/emergency/LeveeOwnersManual(final).pdf [Oct 14, 2015]

20. World Association of Nuclear Operators (WANO), Significant Event Report (SER) 2000-3, “Severe Storm Results in Scram of Three Units and Loss of Safety System Functions Due to Partial Plant Flooding”, February 2001.

9.4 Utility Procedures

21. PSEG Nuclear Repair and Installation of Penetration Seals, HC.MD-SP.ZZ-0005(Q), Rev 2, 2012

22. PSEG Nuclear Engineering Training Certification Guide for NECENANPG14BQ Penetration Seals, Rev 1, 2010

23. PSEG Nuclear Plant Barrier Control Program, CC-AA-201 Revision 5

24. Energy Northwest Fire Protection Engineering Evaluation, FPF 1.6 Item 1, Barrier Functions List, Revision 5, 2013

25. Entergy Northwest Fire Protection Engineering Evaluation, FPF 1.1 Item 27, Pressure Test Limiting Design Parameters, Revision 5, 2000

26. TVA WBN Technical Instruction: External Flood Protection Program Bases Document, 0-TI-443 (Bases) Rev.0000, 2013

27. Duke Energy Brunswick Unit 0 Engineering Procedure: External Events Protection Program, 0ENP-66, Rev. 0

28. EDF Technical Note, Management Rules for the Volumetric Protection of Nuclear Installations against External Floods, D4550.31-06/1840, Rev 1, October 2012

A
LISTING OF KEY POINTS

A.1 Key Human Performance Points

Page Number / Section Number	Key Point
5-60 Section 5.3.1	Ensure all openings such as plugs, doors and other features are in place prior to inspections being performed if required.



Key Human Performance Point

Denotes information that requires personnel action or consideration in order to prevent injury or damage or ease completion of the task.

A.2 Key Technical Points

Page Number/Section Number	Key Point
3-32 Section 3.3	In the absence of any consensus codes or standards for conducting pressure testing on penetration seals, the degree of usefulness of any of the existing pressure test data is ultimately the responsibility of the end user. For flood barrier applications, any penetration sealing device that is not completely leak tight at the maximum expected pressure for the longest anticipated inundation period will require additional evaluation.
4-48 Section 4.1.1	Dow Corning 732 Multi-Purpose Sealant (caulk) contains acetic acid and should not be applied to concrete, mortar or other masonry surfaces.
4-51 Section 4.1.3	Cure inhibition frequently occurs when 2-part platinum-based cure silicone elastomers are installed around cables with Chlorosulfonated Polyethylene (CSPE) jacket materials. Material compatibility should be confirmed for all cable jacket material types and FBPS products, since cure inhibition at cable interfaces will likely result in a seal assembly with significant leakage paths.
5-61 Section 5.1	Additional guidance related to common FBPS materials and signs of material aging is provided in Table 5-2. While these signs do not necessarily constitute material failure, they may serve as indication of decreasing material reliability.



Key Technical Point

Targets information that will lead to improved equipment reliability.

B
CROSS REFERENCE MATRIX FOR FLOODING BARRIERS

The table below aligns with the flood protection components outlined in Section 2 and is intended for quick reference in understanding the installation and/or application of the various types of components listed in Tables 2-1 and 2-2 of this guide.

Flood Protection Component Category	Flood Protection Component Type	Recommended Installation / Application
Penetrations	Boot seal	Penetrations where pipe movement cannot be restricted (i.e., pipe must be allowed to move).
	Grout	To fill voids and gaps in concrete and masonry walls. May be used to close penetrations with small annular gaps.
	Silicone foam	Fire/Flood seals with low pressure requirements. May also be used as an internal conduit seal.
	Caulk seals	Gap and joint type penetrations. May also be used to close penetrations with small annular gaps.
	Silicone Elastomer seals	Penetrations of various shapes and sizes with single or multiple penetrating items (pipe, tubes, conduits, cable trays and cable). May also be used as an internal conduit seal.
	Epoxy seals	Typically used as an internal conduit seal or for small penetrations where higher pressures are applied. Also, epoxy may be used as a coating over an existing structure or penetration seal to enhance water-resistance.
	Top Coating Materials	Applied over an existing penetration seal configuration to enhance the water-resistance capability of the overall penetration seal assembly. Not typically qualified as a stand-alone design.
	Combination Seals	Typically used where multiple design functions are required. Separate stand-alone penetration seal designs are applied to satisfy the various required design functions.

Flood Protection Component Category	Flood Protection Component Type	Recommended Installation / Application
	Modular Seals (compression seals)	Commonly used for temporary installations or where re-entry into the penetration is anticipated.
Mechanical Seals	Dampers	Used to prevent/restrict air or fluid movement within a mechanical or ventilation system.
	Systems Seals	Gaskets, O-rings, etc. use to enhance the leak-tightness of a mechanical or ventilation system. May be applied to keep fluid in a system or to prevent fluid from entering a system.
Drains	Blow out panels/hatches	Blowout panels/hatches are intentionally designed barriers that are incorporated into a structure, enclosure, room or area where there is a required relief from a sudden over pressurization.
	Scuppers	An outlet or opening designed to remove water from an area providing a drain off into a different area or location.
	Floor drains	A floor drain is a fixture made of plastic or metal which is placed in an area to allow the drainage of water into a system drain or holding tank.
	Trenches	Used as means to divert water in a desired direction or flow path.
	Yard drains	A drain designed in the pavement or earth utilized to drain off surface water in an area.
	Sewer/drain backflow prevention devices	Drain backflow devices prevent water or liquids from backing up through a drain line.
	Holding ponds and French drains	Holding pond is a low lying area that is designed to temporarily hold a designated set amount of water while slowly draining to another location.
Permanent Flood Barrier	Walls	Poured concrete, reinforced masonry concrete walls. Various thickness installations usually minimum 8”. Used to compartmentalize structures.
	Floors	Poured concrete, reinforced masonry concrete walls. Various thickness installations usually minimum 8”. Used to compartmentalize structures.

Flood Protection Component Category	Flood Protection Component Type	Recommended Installation / Application
	Curbs	Used to prevent fluid migration between areas or as a means of temporary containment. Typically associated with relatively shallow water depths.
	Sloped or raised floors	Sloped floors are used to prevent flood water from collecting in undesired locations. Raised floors are used to keep equipment above postulated flood heights.
	Earthworks, Dikes	Engineered for site-specific applications/events.
	Upstream holding ponds/ dams	Engineered for site-specific applications/events. May have a natural or synthetic lining based on design and location.
	Site Grading	Engineered for site-specific applications/events. Intended to prevent water from accumulating in undesired locations.
Temporary Seals	Drain covers	A cover that allows and draws off gradually water from an area which drains into a retaining tank, pond or area until the water recedes or is permanently removed from the structure or surrounding area
	Caps and plugs	A protective lid that can be screwed or pushed into place to stop the passage of liquids, or objects from entering or escaping the area.
	Inflatable or expanding plugs and seals	Used to temporarily close or seal off an opening.
	Removable gates or doors	Used to temporarily close or seal off openings in response to an anticipated flood event.
Temporary Flood Barriers	Sandbags	Natural or synthetic bag filled with sand, tied off and stacked in placed in front of an area for flooding protection.
	Deployable booms, curbs and barriers	Synthetic barrier made of heavy rubber or plastic, deployable barrier to be placed around or in front of an area for flooding protection.
	Obstructions to flow (security barriers, grates, etc.)	In some locations within the NPP there are required components to facilitate regulatory requirements (mainly security requirements). This encompasses the structures or components placed in a location that may impact the removal or directional flow of water.

Flood Protection Component Category	Flood Protection Component Type	Recommended Installation / Application
	Diversion excavation	Engineered for site-specific applications/events.
Entrance or Egress openings	Swinging Gate	A movable barrier for controlling the passage of water or flooding related waters through a channel or designated and designed embankment.
	Horizontal or vertical sliding door	A movable barrier that is controlled manually or electrically to open or close the door in either a horizontal or vertical direction
	Pressure (submarine) door	Submarine type watertight doors are designed to prevent the ingress of water from one compartment to other during flooding or accidents. These doors are used in areas where chances of flooding are high from internal or external events.
	Removable closure plates	Typically applied to openings that require infrequent or occasional access.
	Hatches	Removable (or have the ability to be opened) to allow for the passage of large items or equipment. Typically require secondary seals or gaskets at the hatch interfaces to serve as flood barriers.
Flood Outlet Devices	Manually operated valves	Valves which require manual intervention to isolate for a given event or postulated scenario.
	Check valves	Typically used to control flow in one direction without the need for manual intervention.
Flood Mitigation Equipment	Pumps (portable or submersible)	Used to support site-specific mitigation strategies. May also be used to supplement permanent plant systems to increase mitigation capabilities.

C
RECENT INDUSTRY EVENTS (2006-2015)

Event #	Brief Description	Abstract	DATE
1	Reactor Auxiliary Building Breached Flood Protection Barrier	The designed caulking used to seal around the roof hatches in the Reactor Auxiliary Building (RAB) had been removed for the lifting of loads and was not immediately restored after the hatches were replaced. As a result, there existed a breached flood protection barrier that was left in an inadequate condition for Barrier Management	03/2014
2	DGB Sump Pumps Failed to provide required capacity during testing	After being classified as flood protection features, the Diesel Generator Building sump pumps were functionally tested. They initially failed to provide the proper amount of flow for external flood protection based on the design basis.	02/2014
3	Inadequate external flood protection barriers, and lack of robust design	Multiple instances of design features may not have provided adequate internal and external flood protection features for safety-related equipment. Most of these deficiencies have existed since initial plant construction. Other conditions related to external flood protection have been identified via the condition reporting process after original construction. During the construction process, the penetration seal material used to seal conduits, pipes and other penetrations changed based on fire protection requirements to include silicone foam. It has been documented through testing and industry operating experience (OE) that silicone foam seals are not completely leak tight. The seal test results were originally evaluated and accepted based on the availability of sumps and sump pumps to mitigate any seal leak-by.	02/2014

Event #	Brief Description	Abstract	DATE
4	Water intrusion into Reactor Auxiliary Building from unsealed conduits	Due to prolonged heavy rainfall, the site storm drain system was challenged and storm water basins started to back up. At ~1610 hours, operators reported that water was backing up through the -0.5 feet elevation floor drains in the reactor auxiliary building (RAB) and into a pump room sumps at the -10.0 feet elevation. The water was observed entering the RAB through an electrical junction box which was below the elevation for which the RAB flood protection was designed. The cause of the RAB flooding was due to legacy installation issues with two non-safety electrical conduits in the ECCS pipe tunnel that lacked the required internal flood barriers. Degradation of the conduits provided a water entry path into the RAB. The extent of condition identified four more conduits with the same legacy installation issue, for a total of six conduits without internal flood seals.	01/2014
5	Failure to Identify and Correct Non-Hydrostatically Sealed Penetration in Battery Room	The regulator identified that this utility failed to identify the need to hypostatically seal two cable penetrations between a manhole and Battery Room after the site's design basis flood height was changed during a 1983 Systematic Evaluation Program (SEP).	02/2014

Event #	Brief Description	Abstract	DATE
6	External flood protection procedure lacked sufficient detail.	The External Flood Protection procedure does not contain sufficient detail and rigor to ensure that activities required to mitigate the design basis probable maximum external flood will be completed in the established response time. The root causes are related to an undefined standard with respect to the level of detail and pre-planning necessary and less than adequate Operating Experience Behaviors. 1. The site plans established to ensure the availability of onsite and offsite power sources lack sufficient detail during various flood elevations to ensure station power requirements are maintained for important safety functions, including the lack of adequate fuel and lubricating oil supplies for the Emergency Diesel Generators. 2. The key mitigating actions to install various bulkheads lack a detailed timing study to demonstrate consistent, timely completion within the required 4 days. Additionally, the details for installation of the back-up power supplies for the required plant sump pumps are not adequate. 3. The required resources and infrastructure necessary to support implementation of the flood strategies is not defined and over relies on future planning during the event. Since the identification of the AB-4 deficiencies, site personnel were in misalignment with the level of detail and preplanning detail needed. There was no definitive standard in which the organization should adhere to.	09/2013
7	Finding for failure to address all the effects of external flooding scenarios	The site failed to maintain the flood Procedure, “Acts of Nature,” such that it could support the timely implementation of flood protection activities within the 12 day timeframe credited in the design basis as stated in the updated safety analysis report (USAR).	08/2013

Event #	Brief Description	Abstract	DATE
8	Failed to establish procedural requirements to implement external wave run-up protection design features	During flood walkdowns inspectors observed that the plant did not have enough jersey barriers to protect the turbine building and pumphouse from flooding. In addition to this discrepancy, it was also observed that there were gaps between the installed barriers with no provisions in the procedure to use sandbags to protect these openings. Lastly, the time required to erect these barriers was not considered within these procedures.	03/2013
9	Potential violation for not having an accurate flood protection plan	The plant did not demonstrate successful performance of the Flooding Abnormal Operating Procedures in the time specified, which resulted in a potential failure to complete the realignment of the plant for flood mode operation.	02/2013
10	New Auxiliary Flood Source from postulated break of non-seismic piping	A pipe trench connects the Auxiliary Building to the Radwaste Facility. Non-seismic piping was recently identified in the Radwaste Facility that could be considered a potential Auxiliary Building flood source during a seismic event. The pipe penetrations through the Auxiliary Building wall into the trench were improved with Silicone Room Temperature Vulcanizing (RTV) foam. During installation of the trench, the implications of draining the trench into the Auxiliary Building and the potential effect on equipment were not considered. This was due to a lack of an overall program for addressing the impacts of changes on the sites ability to respond to flooding events. The station lacked a Design Basis Document, a calculation or other method to capture effects of a flooding event, and a tracking or trending program that adequately addresses margin associated with flooding mitigation.	03/2012

Event #	Brief Description	Abstract	DATE
11	Degradation on several conduit couplings in the air intake tunnel identified	Flood barrier seals could not be verified installed. During flood protection walk downs conducted in response to a regulator request for information and performed in accordance with NEI 12-07, the inspection team found internal conduit seal fittings without a seal installed. There are 43 conduits (mostly 4 inch diameter) that lead from areas not protected from an external flood into protected areas. Crouse Hinds Model EYS conduit seal fittings are installed on each conduit. Prior inspections credited the existence of the fitting to conclude that flood protection was adequate.	2012
12	Flooding procedures did not account for reactor coolant system (RCS) inventory losses	During flood protection walk downs performed in accordance with NEI 12-07, inspectors noted that flood procedures did not account for RCS inventory losses. The procedures assumed a flood duration of 4 days, during which time the systems that provide normal and makeup capacity to the RCS would be flooded and unavailable. Plant calculations accounted for a 5 gpm max technical specification allowance for unidentified RCS leakage, but did not account for inventory losses from identified leakage, which could be as high as 20 gpm. This strategy did not provide a method to maintain RCS inventory above the top of the active fuel for RCS leakage rates that were allowable under technical specifications.	2012
13	Site Did Not Respond Effectively to Degraded Conditions Related to Flooding Protective Features	Periodic inspection activities did not identify degraded conditions associated with the Fuel Oil Storage Chamber access structure. This sheet metal enclosure had developed gaps and holes that would allow leakage during design basis flood conditions. Corrective action to repair the condition and evaluate extend of condition was not timely. The structure limits wave run-up leakage into the fuel oil tank chamber. The organization was unaware of the potential plant safety risk presented by external flooding events and tolerated an unclear design basis.	2012

Event #	Brief Description	Abstract	DATE
14	Inspection of electrical manway confirmed inadequate electrical conduit penetration seals	Inspections of an electrical manway confirmed that inadequate electrical conduit penetration seals provided an in-leakage path into a pumping station. The condition had previously been identified and evaluated as a degraded condition based on the fact that flood barriers were not installed to seal the subject electrical conduit penetrations as required by the pertinent design drawings. These non-confirming seals would have allowed flood waters to enter the pumping station at a rate greater than the capacity of the sump pump and could have resulted in the pumping system being unavailable to perform its design function during a flood event below plant grade.	2012
15	Air Inflow through defective Cable Penetrations running from Turbine Building to Main Control Room (MCR)	While operating the Emergency Ventilation Fan during an air inflow measurement of the MCR, two seal defects were found in cable penetrations running between the MCR and the Turbine Building, which is a radiation controlled area. No radioactive materials were detected around the defects, so it was assessed radioactive materials didn't flow into MCR.	2010
16	Discovered computer modeling inconsistencies predicting the performance of dams upstream of plants adversely affected the probably maximum flood (PMF) design-basis analyses	Unanalyzed Condition Affecting Probable Maximum Flood (PMF) Level. The issuance of an updated calculation increased the plant's design basis PMF level from Elevation 719.6 feet to Elevation 722.0 feet. This increase in calculated PMF elevation resulted from several calculation changes including updated dam rating curves using model data and changes in reservoir operating policy.	2009
17	Failed to maintain adequate procedures to protect the intake structure and aux building during external flooding events	During identification and evaluation of flood barriers penetrations in the outside wall of the intake structure were identified below the design flood elevation and not sealed. As a result of the penetrations not being sealed the intake structure is vulnerable to water inflow during an extreme flood event.	2009
18	Sea Water Inflow into Turbine Building	During a condition of high tide level with a typhoon approaching, sea water entered through an unsealed pipe penetration and was found in the first basement floor of the Turbine Building, which was a radiation controlled area.	2009

Event #	Brief Description	Abstract	DATE
19	Auxiliary Feedwater pumps inoperable after discovery of 9 missing flow restrictor plates)	An engineer discovered, contrary to plant drawings, that a total of nine flow restrictor plates were missing in the drains, of the interior steamline and feedline penetration rooms, that route water to the floor drain sumps located in the AFW pump room of each unit. It appeared that this deficiency of the missing flow restrictor plates dated back to initial construction of the plant. Calculations indicated that, with all the flow restrictor plates installed, the flow would be limited so as not to exceed the capacity of the AFW sump pumps following a postulated main feedwater line break in one of two steamline and feedline penetration rooms per unit. The licensee also found that a historical calculation inappropriately assumed the following: (1) a non-conservative flood level and only two drains for each interior steamline and feedline penetration room, and (2) the availability of the floor drain sump pumps in each AFW pump room (which do not receive emergency power) to mitigate an event.	01/2008
20	Flood barrier wall was not constructed to design height credited in PRA analysis	The SSF Flood Barrier at the north entrance is shown on design drawings to have an elevation of 801+0. The PRA analysis for a nearby dam break credits this flood wall to a flood height of 5.00 ft. Based on field survey, the actual elevation was found to vary below EL 801+0 by as much as -7/8".	10/2007
21	Water intrusion into Unit 1 A-Train Emergency Diesel Generator Room (inadequate design and configuration control)	While Unit 1 was shutdown in Mode 3, the Unit 2 Cooling Towers (CT) experienced excessive overflow due to clogged upper level CT screens. This condition created a source of water that followed a flow path through unsealed electrical conduit penetrations to the IA Diesel Generator (DG) Room. The water intrusion condition was discovered and stopped prior to any DG damage. DG 1A was the only DG affected by this condition. However, the presence of this flow path highlighted potential vulnerabilities in barriers to the Probable Maximum Precipitation (PMP) event that could challenge safe shutdown capabilities.	05/2006

Event #	Brief Description	Abstract	DATE
22	Two Conduit in an On-site Manhole were not Flood Sealed	At the completion of the Manhole Conduit Flood Seals Inspection, Electrical Maintenance identified two conduits in one manhole that were not sealed with SYLGARD. One conduit was found sealed with an obsolete expandable plug seal and another conduit was found without a seal. Cause: No effective ownership of Flood Seals as a program which led to the loss of configuration control of the conduit seals that resulted in compromising a flooding barrier.	11/2013

D
CORRECTIVE ACTIONS OPERATING EXPERIENCE

Event #	Description	Corrective Action Summary
1	Reactor Auxiliary Building Breached Flood Protection Barrier	The designed caulking was replaced around the roof hatches of the RAB roof.
2	DGB Sump Pumps Failed to provide required capacity during testing	The likely cause was either a clogged suction strainer or a restriction in the discharge piping. Corrective actions included replacement of the Diesel Generator Building sump pumps valves and discharge piping.
3	Inadequate external flood protection barriers, and lack of robust design	1. Revise the Condition Monitoring of Maintenance Rule Structures procedure for flooding programmatic aspects, including robust program ownership responsibilities. 2. Label flood barriers in the plant to provide in-field awareness of flood protection features. 3. Investigate use of current flood penetration sealants, plan and implement any alterations to improve robustness if necessary. 4. Review and correct current documentation of credible flood paths. 5. Verify the completeness and accuracy of the flooding walk-downs. 6. Provide training to the proper personnel to ensure the risk significance of flood barriers is understood. 7. Issue presentation to Site Lead Team regarding the significant risks associated with external flood barriers and the consequences of insufficient resource allocation. 8. Ensure site procedures contain all needed information required to perform necessary manual actions to effectively respond to external flooding. 9. Develop an approach for notifying Operations personnel of each work order that breaches a flood barrier. 10. Identify and put in place a mechanism for Operations personnel to track compromised flood barriers.

Event #	Description	Corrective Action Summary
4	Water intrusion into Reactor Auxiliary Building from unsealed conduits	Operators with Maintenance support took actions to de-water the station until the severe weather had passed. Additionally the station will establish a preventive maintenance program for the stations subsurface drainage system and storm water system to ensure systems are free of silt, sediment, debris, and vegetation.
5	Failure to Identify and Correct Non-Hydrostatically Sealed Penetration in Battery Room	The penetrations were sealed and added to the Structural Assessment and Monitoring Program. During the corrective action process the need for a comprehensive barrier control program and a method of qualifying penetration seals for flood prevention was identified. As a result, the plant barrier control program was created and engineering documentation was issued, which qualified all credited flooding penetration seals. It was also identified that Engineering and Operations required training focused on emphasizing the need to communicate verified and unverified assumptions. In addition, it was identified that senior leadership required training focused on identifying assumptions or incomplete facts. Training was implemented for the necessary population.
6	External flood protection procedure lacked sufficient detail.	The corrective actions to address the root causes were to establish and communicate a written standard for the level of detail and preplanning expected for External Flooding Mitigation plans/procedures and a combination of management reinforcement and engagement to improve the station's Operating Experience Behaviors. Specifically a marketing campaign of "It can happen here" will be implemented to improve our sensitivity to externally induced events.

Event #	Description	Corrective Action Summary
7	Finding for failure to address all the effects of external flooding scenarios	Actions were completed to reduce the flood mitigation plan timeline to less than 12 days by developing an alternate plan for flood protection features, pre-staging equipment and materials, improving the quality of the procedure, and preplanning work orders necessary to carry out procedural actions. Station Management did not ensure proper validation of the external flooding strategy design basis commensurate with safety significance. To ensure proper validation of the external flooding strategy design basis create a formal engineering program to manage External Flood Mitigation. This program will provide intrusive oversight, governance, systematic review and implementing procedures of external flood mitigation strategies.
8	Failed to establish procedural requirements to implement external wave run-up protection design features	Corrective actions were taken to modify existing jersey barriers to eliminate openings, revise the flooding procedures to direct the installation of jersey barriers in conjunction with sandbags, and pre-staging additional sandbags and jersey barriers.
9	Potential violation for not having a flood protection plan	1. Using information from the walk-down, create a detailed time-line to provide a management tool for implementing the flood mode plan in the required sequence. 2. Revise the "Periodic Assessment of Operations Procedures Related to Natural Disasters" procedure, to include walk-downs of four applicable maintenance instructions during each performance. The Walk-down is to verify procedure is accurate, tools and equipment are staged appropriately, and support documentation such as rigging permits and clearances are pre-staged for use. 3. Revise Conduct of the Engineering Organization procedure, to include a Flood Protection Program within the Corporate Nuclear Engineering Organization with the primary function to ensure that the nuclear plant critical safety systems are protected from all postulated flooding conditions. 4. Develop formal Flood Protection Program Management Implementing Procedure(s).

Event #	Description	Corrective Action Summary
10	New Auxillary Flood Source from postulated break of non-seismic piping	The site will develop a Comprehensive Program for Flooding including a Design Basis Document (DBD) and a calculation or other method to capture effects of a flooding event. · Various solutions are currently being evaluated to address existing flood seal designs that may be inadequate with respect to accommodating seismic motion without damage to the flood seal. Engineering Changes are being scoped to upgrade the design of these Auxiliary Building wall pipe penetrations to maintain a water tight seal following an earthquake.
11	Degradation on several conduit couplings in the air intake tunnel identified	The cause has been attributed to inadequate configuration management during original construction. Plant will the sealing design to provide the required flood protection for the conduits to the Air Intake Tunnel and to other areas identified in the extent-of-condition review.
12	Flooding procedures did not account for reactor coolant system (RCS) inventory losses	Procedures were modified to provide makeup capacity and to isolate the reactor recirculation loops during flood conditions when reactor vessel makeup capabilities are limited so that sources of identified leakage would no longer impact the reactor vessel level.
13	Site Did Not Respond Effectively to Degraded Conditions Related to Flooding Protective Features	Additional resources were allocated for improving flood protection design basis information and the development of more detailed inspection basis information. This ultimately resulted in the creation of an official Program at the station.
14	Inspection of electrical manway confirmed inadequate electrical conduit penetration seals	Corrective actions included installing qualified conduit seals and revising design-basis documents and flood barrier drawings to identify flood boundaries and to include seal details.
15	Air Inflow through defective Cable Penetrations running from Turbine Building to Main Control Room (MCR)	Insufficient filler was identified as the root cause for this incident. To correct this, filler was added into the 2 defective cable penetrations.

Event #	Description	Corrective Action Summary
16	Discovered computer modeling inconsistencies predicting the performance of dams upstream of plants adversely affected the probably maximum flood (PMF) design-basis analyses	The root causes of this event were determined to be the failure to establish a PMF procedure or process that could be used to train personnel to perform, revise, and maintain accurate PMF calculations and inadequate communication between organizations. Contingency measures were put into place to protect the diesel generator sets and spent fuel pool cooling pumps. Applicable plant procedures were revised to incorporate these contingency measures to protect plant equipment during a PMF event.
17	Failed to maintain adequate procedures to protect the intake structure and aux building during external flooding events	The primary cause of the penetrations not being sealed was determined to be a station mindset that the station is safe as is and a questioning attitude was not adequately implemented to assure that the penetrations were identified and sealed. The penetrations have been temporarily sealed and a configuration change has been developed to provide permanent seals in the subject conduits.
18	Sea Water Inflow into Turbine Building	The primary cause of this event was attributed to the rapid rise in sea water level due to the oncoming typhoon and high tide levels. It is believed that the sea water initially leaked into a duct running between the Turbine Building and the sea water discharge area. Water then entered through the pipe penetration and exceeded the capability of the discharge pump. The corrective action involved adding filler into the pipe penetration as well as stoppage plates at the gap in the duct where it meets with the sea water discharge area.
19	Auxiliary Feedwater pumps inoperable after discovery of 9 missing flow restrictor plates)	The root causes associated with this event were described as a lack of design basis knowledge during initial design and the change process in place during initial design contributed to a breakdown in configuration management. The configuration was restored to match the design basis using the design change process. In addition to this creation of a design basis document is planned in order to provide a ready reference for system interdependencies and design basis information.

Event #	Description	Corrective Action Summary
20	Flood barrier wall was not constructed to design height credited in PRA analysis	The apparent cause is settlement of the flood wall after construction. The original as-built wall may have been below EL 801+0, but still within construction allowable tolerances. An engineering change was initiated to add 2" to the top of the wall by installing a 2x2 angle along the full length.
21	Water intrusion into Unit 1 A-Train Emergency Diesel Generator Room (inadequate design and configuration control)	The identified flood protection deficiencies were attributed to inadequate design and configuration control of features to protect against flooding. Also, there were no processes/procedures in place to periodically inspect these flood protection barriers. The flood protection deficiencies were corrected by the installation of new flood protection seal barriers**.**
22	Two Conduits in an On-site Manhole were not Flood Sealed	The cause of this condition was attributed to no effective ownership of Flood Seals as a program which ultimately led to the loss of configuration control of the conduit seals that resulted in compromising a flooding barrier. Corrective actions include: 1) Designate a responsible site engineer for maintaining overall responsibility for flooding seal program. 2) Revise a site procedure to include a table of electrical conduit flood barriers seals that states when they contain cables or contain no cables. This table must maintain configuration of conduits with no cables (spares) and updated if changed by the program engineer for flood seals. 3) Revise Model WO for PM to include a column in each of the existing tables of conduit for each manhole or handhole to include the as-found configuration of each conduit, to document conduit flood seal configuration with each inspection. 4) Revise conduit detail and cable and conduit layout drawings to abandon the use of Spare to identify conduits without cables.

E
VOLUMETRIC PROTECTION APPROACH TO EXTERNAL FLOODING

As mentioned in Section 7, the following information includes a summary of basic principles that define volumetric protection and identify management rules for implementing such an approach at the site level. The volumetric protection was developed and implemented across a fleet of nuclear stations to address the risk of external flooding and as a response to WANO SER 2000-03, “Severe Storm Results in Scram of Three Units and Loss of Safety System Functions Due to Partial Plant Flooding”.

E.1 Definitions Associated with Volumetric Protection

Volumetric Protection (VP) plays a fundamental role in protecting nuclear units against the risk of external flooding. In the section below, the rules to apply in order to guarantee, in real time, the effective leak tightness of the volumetric protection are outlined. Given the fact that the leak tightness can become faulty, the sections below also define the provisions that need to be implemented in the case of a loss of the leak tightness of the volumetric protection.

The volumetric protection perimeter is made up of external walls of a group of external rooms or buildings containing equipment necessary for attaining or placing the units to a safe state, in case of flooding. The external walls of this group of buildings (walls, floors and ceilings) must be sealed against the risk of external flooding, at a height defined by the flooding hazard studies performed for each site. Given the fact that the majority of sites are not floodable (industrial platform is above the maximum flood level), the volumetric protection is limited to an elevation lower than that of the platforms. The volumetric protection will eventually be raised for the superstructure, when post-Fukushima (2011) studies are completed so as to protect the installations against the increased hazards.

The buildings concerned by the volumetric protection outlined in this report are:

- The nuclear island,
- The emergency diesel generator buildings (including buildings with fuel tanks),
- AFW tank buildings,
- IRWST tank buildings,
- Pumping stations, component cooling and raw water filtration pits.

Volumetric protection also integrates the galleries linking the pits in the pumping station to the nuclear island rooms, so as to limit the number of openings that need to be managed. These generic perimeters must be adapted to the specific configurations of each site.

E.2 Determination of the potential waterways in the volumetric protection perimeter

The effective leak tightness of volumetric protection implies:

- An effective sealing of the external walls (absence of openings or of large through-wall cracks, that could lead to water flow that could in turn challenge the dewatering system capabilities)
- The justification of the integrity of water-stop joints, or other similar items, located in the perimeter of the volumetric protection
- The identification and mitigation of potential waterways.

The walls of the buildings making up the volumetric protection can in effect have openings that can threaten the volumetric protection mission if they are not sealed. This may involve, for example:

- Doors at the limit of the volumetric protection
- Vertical or horizontal hoppers, without penetrations (drains, ventilation spaces, unused spaces, etc.)
- Vertical or horizontal hoppers, with penetrations (cable or piping passages)
- Horizontal hatch doors (for employee access, handling of material, etc.)

E.3 Application of Volumetric Protection at Each Site

The implementation of the volumetric protection principle at each site was defined in successive stages. These stages are:

Stage 1: Overall Generic Inventory

This stage consists in defining, for each site, the geographical limit of the volumetric protection and identifying potential waterways (see the sub-section above for the list) as well as the joints located in this volumetric protection. This overall generic inventory is based on studies related to water pathways performed on site (in-situ). The leak tightness deviations located in the volumetric protection are identified and documented. They can involve openings in civil structures (hoppers, coring, casing, tiles, etc.), missing sealed doors to be installed and the possibility of water entry via dewatering circuits

Stage 2: Hazards, water ingress pathways, design requirements and applicable loads

This stage consists of defining the requirements in terms of external flooding (determination of the amount of water to take into account) and in ranking each potential waterway as a “sealed” or “unsealed” waterway (based on the existing sealing technology and the amount of water / loads to be considered). For the waterways ranked as “sealed”, an analysis justifying this “sealed” characteristic must be provided. For the waterways ranked as “unsealed”, the sealing prescriptions and requirements are also defined at stage 2, taking into account all the applicable

requirements (flooding and amount of water, but also complementary requirements, such as fire, internal flooding, environmental protection, the protection of biology, need for ventilation, etc.).

The net water ingress inventory is the result of potential remaining waterways after all the waterways in the walls and through "passive" elements are sealed.

Stage 3: Retrofit and Compliance Work

This stage consists of completing the necessary work to seal the waterways, based on the net water ingress inventory (stage 2) which allowed for the identification of waterways to deal with. This work (not including water-stop joints) was completed in the context of the plant modifications.

Stage 4: Validation Visit

This stage consists of performing a validation visit on site, after the completion of the retrofit and compliance work (stage 3) and based on the different documents prepared in order to ensure the exhaustive treatment of the potential waterways located in the volumetric protection.

Stage 5: Updating of the list of potential waterways

When implementing plant physical modifications, new ingress waterways can be created. They must be treated and accounted for, based on the principles described in stages 1 and 2 above.

If these waterways are ranked as part of the net water ingress inventory, they can be included in the list of all potential waterways in order to ensure their regular and systematic monitoring (stage 2). If not, they are classified and incorporated in the generic inventory list and are part of the management taken care of in stage 1.

The nuclear power stations are responsible for updating the net water ingress inventory list. This action is completed based on information coming from:

- Internal quality control and oversight processes (elements that may have been initially forgotten).
- Impact analysis performed by design engineers (when preparing or reviewing modification work packages).
- The sites ensure the recording of the net water ingress inventory list in their Maintenance Database.

Clarification Point 1:

The volumetric protection elements can be ranked in three categories:

- The nuclear island elements, generic to the entire plant series.
- The nuclear island elements specific to the site or the unit.
- The safety classified and site-specific buildings or structures (pumping stations, etc.).

Clarification Point 2:

The physical tags for identifying elements of the volumetric protection, in the concerned buildings/rooms, were supplied in the context of the compliance work performed to ensure the leak tightness of the volumetric protection

E.4 Barrier Management

Like fire compartments, the management of the volumetric protection requires coordination between the different departments concerned with this activity, notably vis-à-vis the creation and the updating of the database containing all the elements of the volumetric protection and allowing for the feeding of the Work Management Tool.

Clarification Point 3:

The required visual inspections aim essentially at verifying the integrity of the volumetric protection, to ensure that the volumetric protection elements, including those that have not been subjected to work during the refueling outage, have not been degraded in an unplanned way (for example, during interventions completed on other materials located nearby, in the same room).

This control aims at detecting ruptures in the sealing (ex - holes in the hoppers or doors, new coring, doors not closing properly) or for nearby walls, visually detectable degradations. This does not constitute a substitute for the preventive maintenance tasks prescribed in the PM basis. If necessary, a second level control can be completed to confirm or infirm the anomaly identified in the first instance.

As a complement to this exhaustive control during the refueling outage, a visual control in the room will also be completed, after the intervention, on the volumetric protection elements having been subjected to work. Certain volumetric protection elements can be difficult to examine given their location or their visibility. In this case, for the elements subjected to a permanent water load, it is not necessary to proceed with a visual examination, but the absence of a water entry point will serve as the control process. For the other elements, several examples are presented:

- Location in a restricted access zone. When the zone has restricted access for security reasons, it is possible to rely on the maintenance program and/or a risk analysis based on an intervention report tracing the compliance control, where applicable
- Situation where the implementation of particular access devices (ladders, scaffolding) is necessary or physical conditions (crawling, contortions) restrain access. It is possible to rely on the maintenance program and/or a risk analysis based on an intervention report tracing the compliance control, where necessary
- Situation where the elements cannot be inspected on the two surfaces. An inspection on a single surface is considered sufficient in the same way it is considered sufficient for the walls of buildings in the infrastructure.

Clarification Point 4:

A risk analysis must consider all the requirements associated with opening(s): external flooding but also the fire compartment breach, containment, internal flooding, radiological protection, etc.

In the case of interference between different requirements (fire, containment, etc.), the most stringent requirement is applicable (for example, the smallest allowable timeframe for repairs).

When these requirements are not compatible, a temporary device and an adapted procedure must be implemented. For example: the risk analysis, for risks associated with external flooding, must particularly accomplish the following:

- Examine the requirement of implementing palliative measures (complementary mobile pumping, availability of temporary re-capping, etc.)
- Define the type of the final re-sealing to use, based notably on requirements to be met (flooding, fire, confinement, etc.) and examine the requirement to have qualified personnel intervene, in order to identify the constraints in returning to compliance as early and limit as much as possible the time period of the opening.

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