

PERFORMANCE OF FLOOD RATED PENETRATION SEALS

W. Mark Cummings, P.E.

Fisher Engineering, Inc.

NRC PROJECT TITLE: Flood Penetration Seal Performance at NPPs

Project Team: Fire Risk Management, Inc. (*now Fisher Eng.*)
Nuvia US

Project Overview:

Project Objective: *To establish Testing Standards and Protocols to evaluate the effectiveness and performance of seals for penetrations in flood rated barriers at NPPs.*

Project Tasks:

Task 1: Development of Testing Standards, Performance Based Criteria, and Protocols

Task 1.1: Identify and describe the various typical seal materials for FPSs used at NPPs

Task 1.2: Develop standard testing procedures, performance based criteria and protocols for testing effectiveness and performance of FPSs.

Task 2: Testing of Selected Flood Penetration Seal Types and Designs

- Designed to “test the test protocol”
- Use observations to determine if mods to Test Protocol are warranted

TASK 1.1 OVERVIEW

- Researched publicly-available information regarding installed Flood-rated Penetration Seals
 - ADAMS database
 - NPP responses to NRC 50.54 Letter (54)
 - NRC Audit Reports
 - LERs, NUREGs, INs. IRs (relevant info noted in 28/-/15/13)
- Wide variety of seal assemblies and materials noted
 - Concrete, Mortar, Grout
 - Mechanical seals (such as boot or link)
 - Silicone foams (high & low densities)
 - Epoxies & Elastomers
 - Urethane
 - Caulking
- Combination of “fill” materials with exterior “damming” materials applied (waterproofing)

TASK 1.1 OVERVIEW (Cont'd)

- Wide range of penetration configurations and types of penetrants
 - Rectangular & Circular
 - Sleeved and Core Bore
 - Single & Multiple Penetrants and “Blanks”
 - Pipes, Cables, Conduit, etc.
 - Varying sizes / diameters
- Both interior and exterior applications
- FPS Assessments
 - “Formed in place” seals (foams, elastomers) appear to exhibit greatest variability in performance
 - Materials / Products (formulations) vary between Manufacturers
- Summary Report Developed: “*Flood Penetration Seal Assemblies at Existing Nuclear Power Plants*” (08/2016)

TASK 1.2 OVERVIEW

- Review of NUVIA Flood Test Apparatus & Procedures
 - NUVIA is only entity currently testing FPSs; using standard procedures/protocols
- Review of UL 1479 – Fire Tests of Through-Penetration Firestops
 - Section 6A – Water Leakage Test (W rating)
- Review of FM Approval Standard for Flood Abatement Equipment
 - Does not address “penetrations” in flood barriers; primarily the barriers themselves, including dikes
 - Does provide some input regarding “impact” resistance
- Review of ASTM E814 – Standard Test Method for Fire Tests of Penetration Firestop Systems
 - Used as a primary “template” for formatting Flood Test Procedure
 - Industry familiarity with formatting

TASK 1.2 OVERVIEW (Cont'd)

- Development of draft Protocol complete – ready for use in Phase II
 - Provided “guidance” and standardized methodology for testing flood-rated penetration seals
 - Test apparatus design; including data acquisition
 - Performance-based approach to metrics (no specific pass/fail criteria)
 - Manufacturers will need to specify limitations of their products
 - Use Task 2 testing to assess Protocol flexibility with the p-based approach
 - NRC Issued Draft for public review/comment 02/2018 – “*Draft Methodology for Testing and Evaluating the Performance of Flood Penetration Seals*”

TASK 2 OVERVIEW

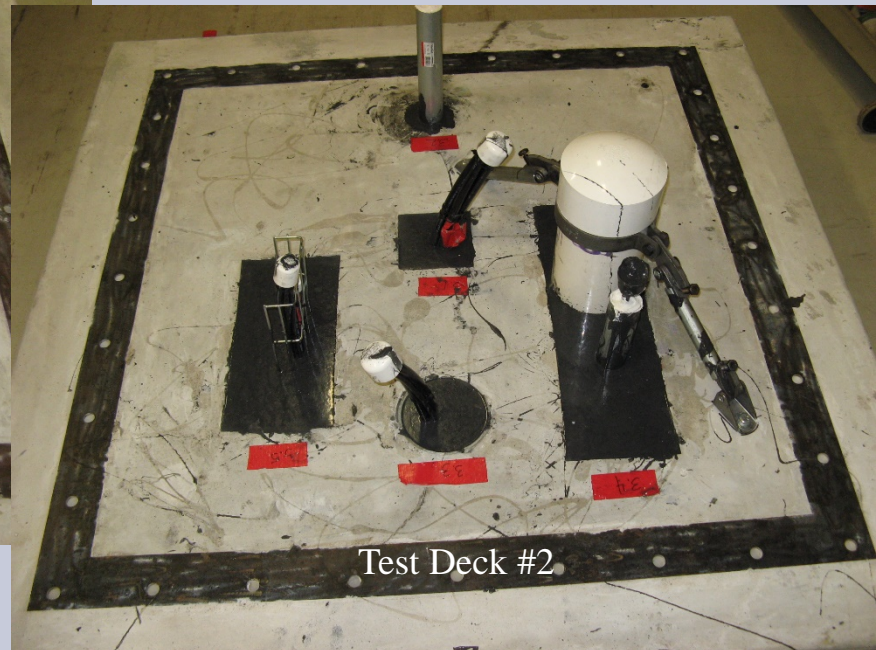
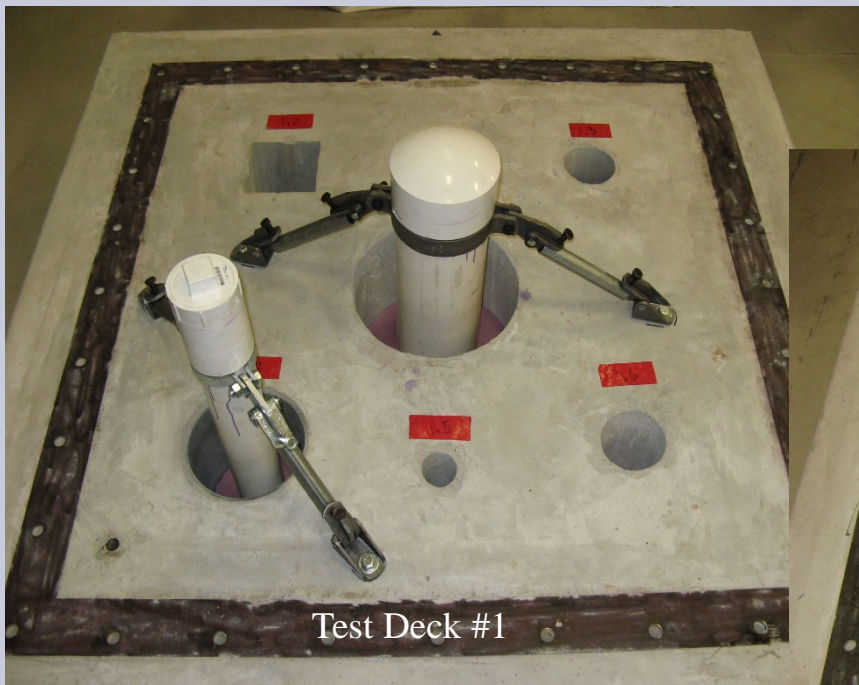
- Updated Draft Test Methodology
 - Updates based on public comment
 - Final draft developed for use during Task 2 testing series; 06/2018
- Development of Test Plan
 - Selection of candidate FPSs; types and numbers to be tested
 - Final design for Test Decks (Installed Penetrations & Seal Assemblies)
 - Location for testing (Framatome Lab in Lynchburg, VA)
 - Inclusive of Test Matrix
 - Range of seal assemblies/materials
 - Greater emphasis on “formed in place” (including configurations noted during Task 1)
 - Specific penetrations assigned to participating Mfgs
 - Final Test Plan submitted to NRC 07/2018; “*Test Plan for Flood-rated Penetration Seal Performance Testing*”
- Test Objective(s)
 - Exercise & evaluate Flood Test Procedure (“test the test”)
 - Research/Evaluation of specific FPS assemblies/materials noted as installed at NPPs

TASK 2 – Test Series

- Candidate Test Decks
 - General design/configuration predicated on Framatome Test Apparatus
 - 12” concrete “slabs”
 - 5 Sample Decks included in Test Series
 - Variety of circular & rectangular/square penetrations
 - Sleeved & core drilled
 - “blanks” & variety of penetrants: pipe (PVC), cable, cable & cable trays, conduit
 - Low & High density foam & silicone materials
 - Mechanical seals; boot & link types
 - Restrained & unrestrained penetrants
 - Penetrants sealed to prevent leakage “through” penetrating item

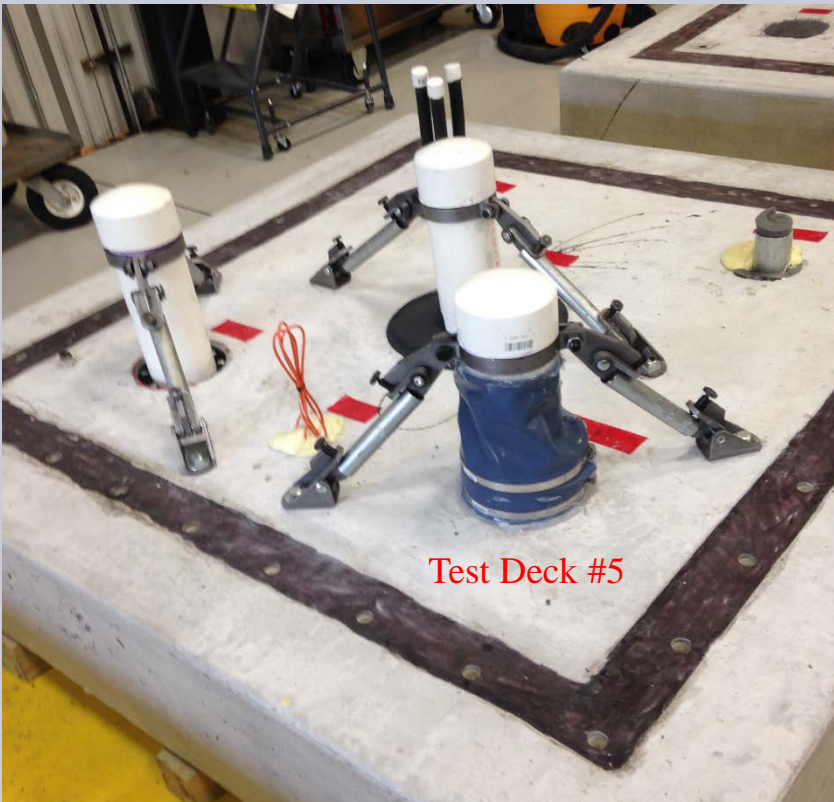
TASK 2 – Test Series

- Candidate Test Decks – Pre-test Preparation



TASK 2 – Test Series

- Candidate Test Decks – Pre-test Preparation



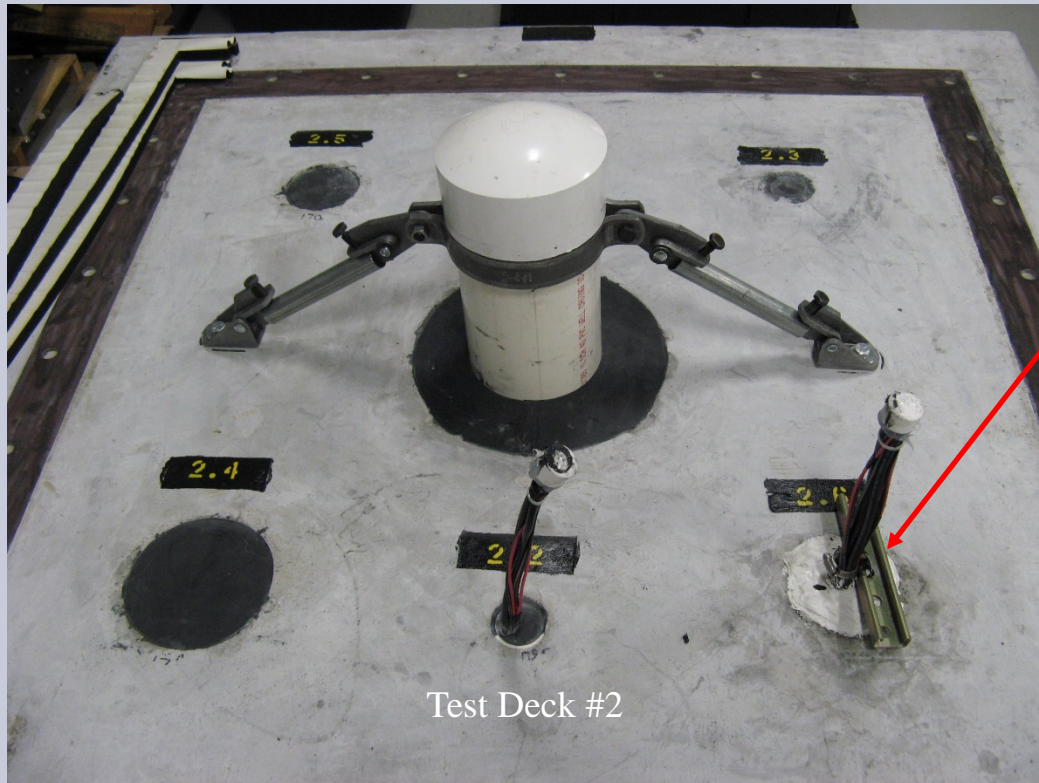
Test Deck #5



Sealed Cable Penetrant

TASK 2 – Test Series

- Candidate Test Decks – Pre-test Preparation



Test Deck #2

TASK 2 – Test Series

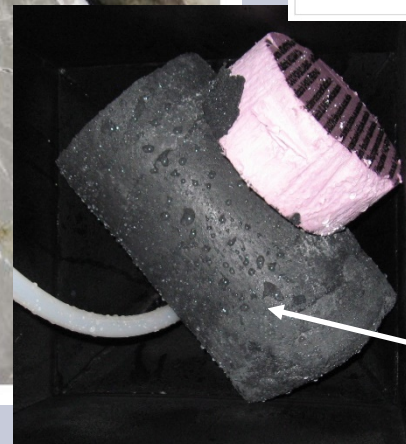
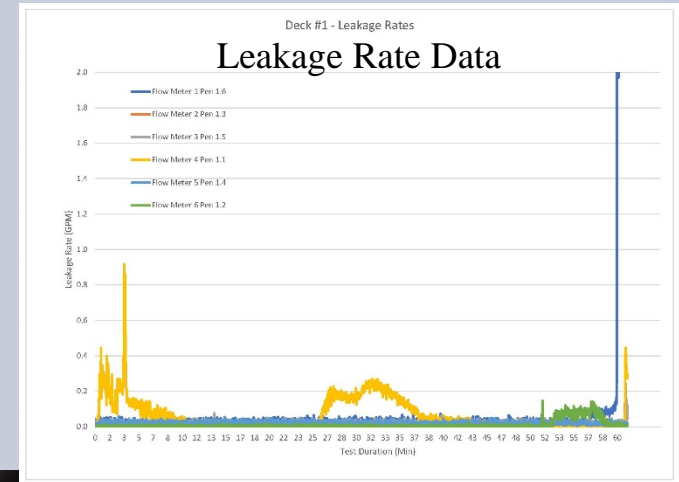
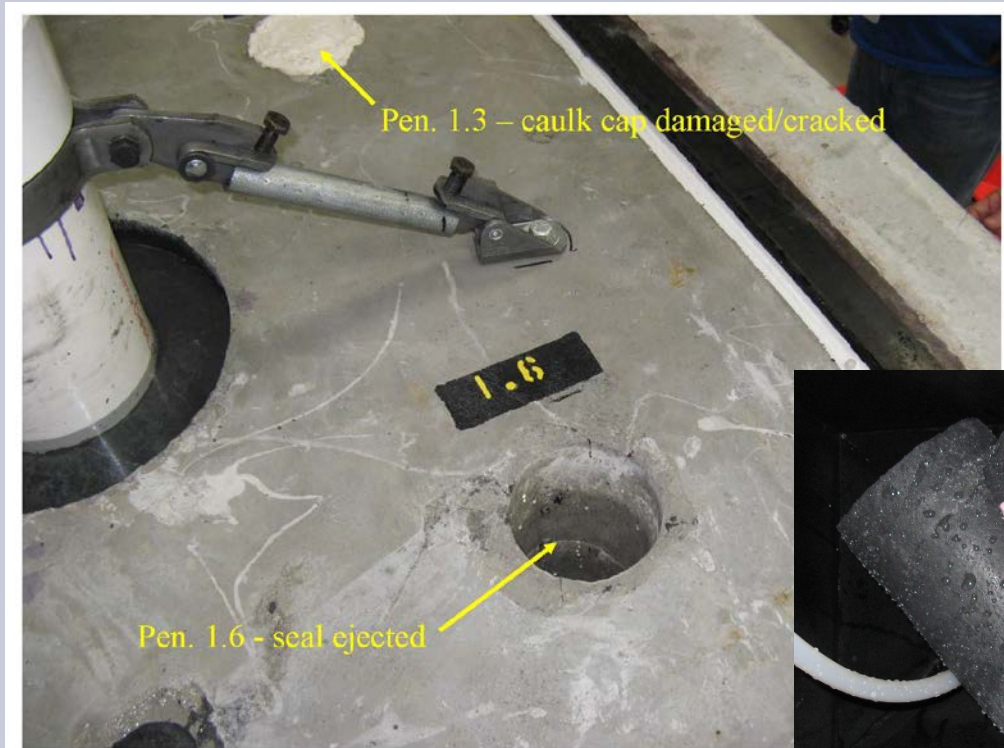
- Candidate Test Decks – Pre-test Preparation



Test Deck #4

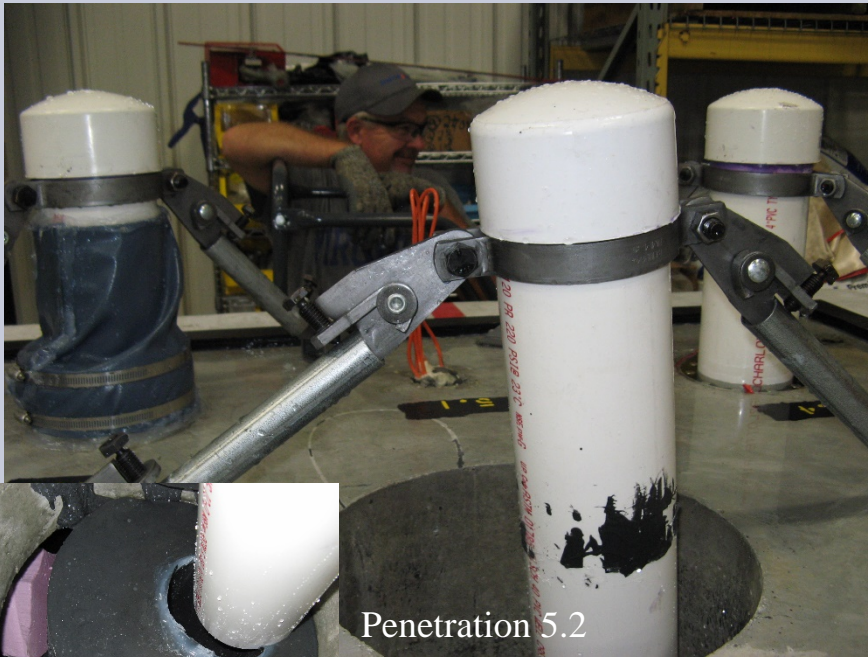
TASK 2 RESULTS

- Candidate Test Decks – Post-test Results



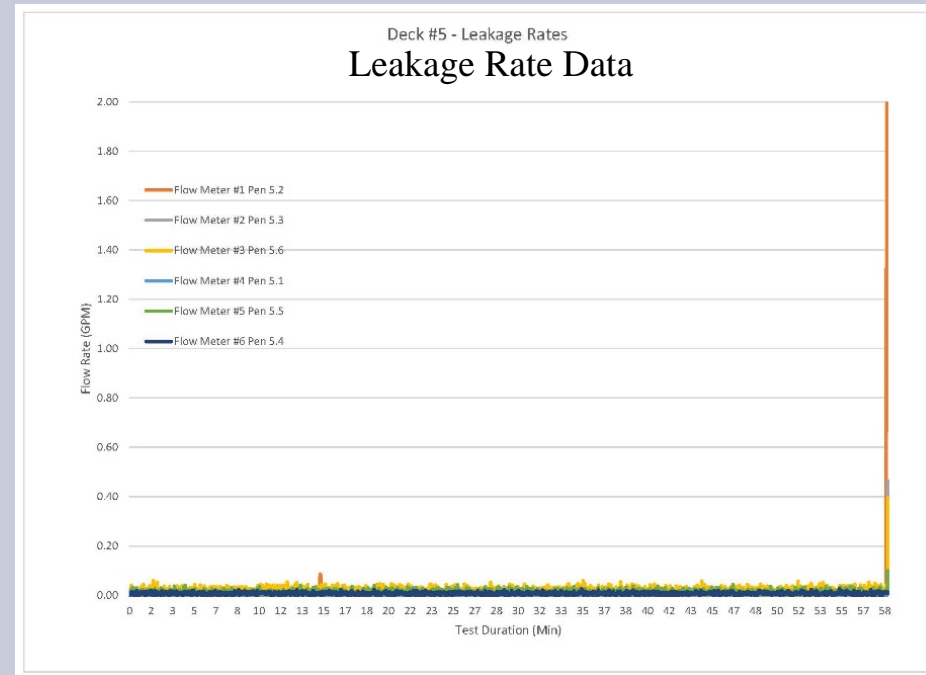
TASK 2 RESULTS

- Candidate Test Decks – Post-test Results



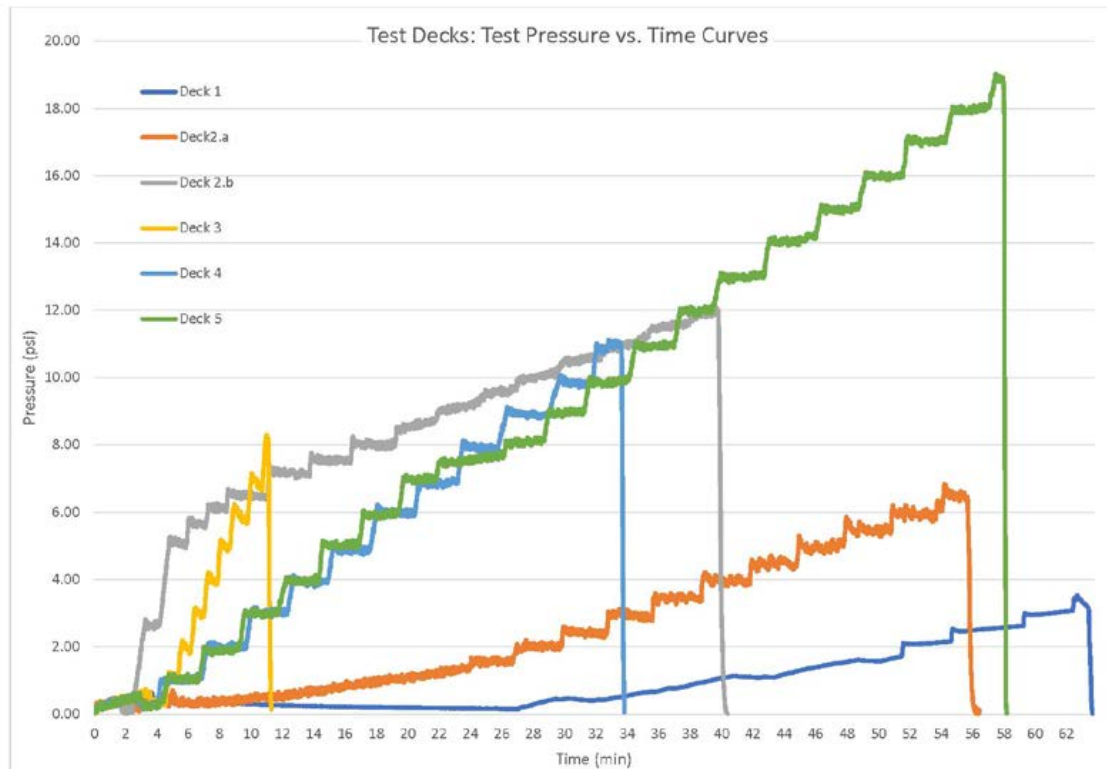
Penetration 5.2

Silicone Elastomer



TASK 2 RESULTS

- Candidate Test Decks – Post-test Results



TASK 2 RESULTS

- Candidate Test Decks – Post-test Results
 - Lessons Learned
 - Mechanical Seals performed well (link & boot seals \geq 19 psig)
 - Performance of low density foam dependant on numerous variables
 - Number/type of penetrant(s)
 - Sleeved vs. unsleeved and sleeve material
 - Small “free area” to circumference ratio (higher density fill ratio)
 - Silicone elastomer did not adhere well to PVC penetrant or sleeve
 - Better performance with restrained penetrant(s) (low density foams/high density elastomers)
 - Test Methodology Appears Adequate and Flexible to Support Seal Performance Data
- Final Task 2 Testing (Summary) Report Submitted
 - “*Flood-Rated Penetration Seal Performance Testing*” (09/2018)

PATH FORWARD

- Promulgation of Test Methodology for Industry Use
 - Issued via NUREG (NRC action)
 - Provide guidance to Industry for standardized process for evaluating/quantifying FPS performance
 - Support NRC oversight requirements
 - FPS pass/fail criteria will be function of Flood PRA requirements; NPP-specific



Flood Penetration Seal Performance Evaluation

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Presenter Info

Mr. W. Mark Cummings, P.E.

FISHER ENGINEERING, INC.

1 Front St., Bath, ME 04530

mark.cummings@feifire.com

207/442-7200

www.feifire.com

NRC Contact Info

Mr. Thomas Aird

U.S. NRC

Office of Nuclear Regulatory Research

Mailstop: TWFN-10A12

1555 Rockville Pike, Rockville, MD 20852-2738

thomas.aird@nrc.gov

301/415-2442