July 31, 2013

National Shipbuilder Research Program, Electric Technologies Panel: Transit Sealant Evaluation

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Contract Number:
2005-339 TO 23

Prepared For
SCRA

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Date: July 31, 2013

Contract: 2005-339 TO 23

Prepared For

SCRA
NSRP ETP

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Change Record

Date	Revision	Reason for Change
July 31, 2013	-	Initial Release

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Executive Summary

Under the National Shipbuilder Research Program Electric Technologies Panel, a project was conducted to evaluate the performance of three types of penetration sealing systems, from three different manufacturers. Four companies participated in the project, reviewing materials and providing input at various stages of progression. Although certain sealant products, both soft sealants and block systems, are approved for use on various applications within the US Navy and Auxiliaries, this project is meant to survey and demonstrate available products on the market, compile information and present that information in a concise manner, and recommend solutions based on project findings.

Product data was researched and three products were selected for performance testing. Data was compiled from data sheets and compared to standards and specifications typically levied on ship programs, thereby creating a basis for the down selection process. The companies whose products were being evaluated supplied product needed to manufacture a demonstration unit that would form the foundation of this evaluation project.

Demonstrator designs were generated and reviewed by project members. Adjustments were made to the designs and test procedures before being released for manufacture. The demonstration units were constructed in a very robust manner in the hopes of being able to utilize them for any future testing that may be warranted.

An independent lab conducted testing in accordance with testing procedures generated by the project team and standards referencing Navy protocols. Although this has not been considered a product qualification process, it is considered a first step in that process and the demonstrators could possibly be used for this purpose for future testing. However, generally this has been part of a first article testing and left to the manufacturer to conduct. The design could be leveraged for this purpose though, once it is determined that the design can support such activities.

Because of some limitations in certain sealant products, not all products performed equally well, but there was close similarity. However, there is an opportunity to consider other products other than what has to date been considered and used for various ship programs. The results of this testing and the observations made are of value in determining whether certain product systems will be suitable for certain applications, whether certain product systems require further refinement and advancement, and whether costs can be avoided during original asset construction as well as life cycle management. It is recommended the Navy and other ship asset managers consider product systems of this sort, initiate and maintain programs that qualify products and product advancements, and seek ways to reduce costs while improving quality and safety in this area.

Recommendations include future work in further validating results of this report, including estimated benefits and savings, developing general requirements specifically addressing sealant system performance and physical attributes, and optimizing existing products to better serve the marine shipbuilding industry.

Symbols, Abbreviations, and Acronyms

ABS American Bureau of Shipping

ANSI American National Standards Institute

ASME American Society of Mechanical Engineers

ASTM American Society for Testing and Materials

AWG American Wire Gauge

BIW Bath Iron Works

BTU British Thermal Unit

°C Centigrade

cm Centimeters

CPI Cost Performance Index

DOD Department of Defense

ECB Executive Control Board

EPISM Electric Plant, Installation Standard Methods

ETP Electrical Technologies Panel

EXCEL Computer Spreadsheet Software Program, supplied by Microsoft

°F Fahrenheit

g Grams

g's G force

GFI Government Furnished Information

HazMat Hazard Materials

Hrs Hours

Hz Hertz

IEEE Institute of Electrical and Electronics Engineers

IMO International Maritime Organization

kV Kilovolts

MBAR milli bar, unit of pressure

MCM Thousands of Circular Mils

MIL Military

Mpa Mega pascals (pressure)

Mil-Dtl-xxx Military Detailed Specification

Mil-Prf-xxx Military Performance Specification

Mil-P-xxx Military Specification

Mil-S-xxx Military Specification

N/A Not Applicable

N Newtons (force)

NAVSEA Naval Sea Systems Command

NEMA National Electrical Manufacturers Association

NPS National Pipe Size

NPT National Pipe Thread

NSRP National Shipbuilding Research Program

NTA Navy Technical Authority

NVR Navy Vessel Rules

Ω Ohms

ROI Return on Investment

ROM Rough Order of Magnitude

PSI Pressure per Square Inch

PU Per Unit

PVC Polyvinal Chloride

RTD Resistance Temperature Detector

Sch Schedule

SPEC Specification (used to denote a specification, such as MIL-SPEC-xxx)

SME Subject Matter Expert

SPI Schedule Performance Index

STD Standard

UL Underwriters Laboratories

UOM Unit of Measure

VFI Vendor Furnished Information

W/m Watts per meter (power density)

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1. Introduction

The National Shipbuilder Research Program (NSRP) Electric Technology Panel (ETP) received funding, as directed by the Executive Control Board (ECB) for a project that focuses on the performance of sealing materials used for penetrations aboard a ship, particularly where water, fumes, fire and other non-desirables may be present, so that neighboring spaces may avoid the ingress of such non-desirables. Primary goals include the demonstration of materials through testing, validating data sheet information, and presenting this information in a concise report with attachments so that future users may be able to reference a report that contains data specific to performance and qualification testing.

Sealants and caulking's have been used for years in the marine industry. Generally they are used for small volume, minimum pressure resistance to water ingress on structurally secured surfaces. In some instances, silicone based sealants are used for water resistance, fire resistance and chemical resistance. Unless integrated with binding devices, such as mesh plates or grids, alone, they have not necessarily been used to withstand mechanical or thermal mechanical forces.

However, sealants available today offer various types of withstand capabilities when coupled to supporting devices. Low pressure water, high temperature fire resistance and withstand to petroleum products are characteristics of sealants, which makes them much more suitable to special applications in the marine industry. For instance, having the ability to withstand a certain head in water pressure, makes sealants capable of protecting spaces containing penetrated boundaries, penetrated by cables and pipes. Standard practices have incorporated transit block systems that are designed to accommodate specific cable or pipe sizes and configurations. Although these systems have high withstand capabilities, they are expensive, lack on site flexibility to change, and may create challenges during life cycle changes. Many specifications are written to accommodate these styles of penetration sealing devices.

Soft sealants that are designed to be used with packing materials, and cure to a specific resilience, hold possibilities in harsh marine environments, such as Navy applications or oil rig platforms. Determining their capabilities, targeted environments, applications and affordability are key aspects of choosing a sealant system. The following sections will describe the nature of the sealants available, the sealants that were chosen and their relative performance results, and recommended practices to continue or change with respect to sealant options. The term "soft sealant" is used throughout to designate sealants that are applied from tubes, bins or cans of material, and required to cure over time to create a hardened mass. It is used to differentiate from other penetration approaches that use blocks and frames, stuffing materials and glands, etc. After the cure is complete, the result is a resilient system that may contain several system components, such as filler, protective tubes (that may expand during fire) and sealant.

This report is organized in several sections, each of which will be briefly described below.

The scope of work is briefly discussed in Sect. 2, which describes the tasking and targeted audience. The type of work will outlay the next section, Goals and Objectives.

Goals and Objectives describes what it is the audience should get from this work done in the course of the study, and after reading the content of the reports generated from the work done throughout the course of the project. Goals are laid out and tied to means and mechanisms to attain those goals through task objectives. Although some evolution does occur, it is the intent of the project to research sealant system products and technologies, investigate current requirements for penetrations shipboard, manufacture demonstration units and test those sealants that are chosen to be of highest interest, and evaluate the products in order to form conclusions about their future in the marine industry.

Section 4 addresses the methods used to conduct the project. These methods are aligned with typical methods outlined in the NSRP (National Shipbuilder Research Program) charter and guidelines, as well as those projects that have been conducted in the past.

Section 5 lays out the entire process for technical assessment. Requirements review, research of existing product offerings, product testing procedure generation, demonstrator design and manufacture, product testing and test report evaluation is described in detail in this section. Costs and benefits are presented in Section 5.9. These values are rough orders of magnitude, but give the audience the appreciation of where some benefits may lie and what areas need to be addressed.

The last section, Section 6, offers the audience some conclusions resulting from the testing that has been conducted, and proposes follow on activities toward the ultimate goal of having more options available than currently exists today. Throughout the course of the project, a general disposition toward any given product is maintained so as to maintain an unbiased position, not to endorse any particular product or company. The products chosen utilize different sealant system approaches and one of the goals is to determine if there is a better approach than another. It is the hope that with various options, flexible product offerings allows the consumer the option to match a specific application to a technology or product capability.

The report is the culmination of several layers of research, testing and validation. From there, it is up to end users to determine whether the product offerings will meet the needs or if variants will need to be assembled and what it will take to diversify the marketplace.

2. Scope of Study

The basic scope of study focuses on testing three product systems for hydrostatic withstand, vibration withstand, Grade A shock withstand and fire resistance. Each material system will be tested in similar circumstances so that comparisons can be made to the material data sheets, as well as the other materials tested. From this, conclusions can be made with respect to performance, needed system improvement, application specifications, and how ship specifications, primarily targeting the US Navy and Auxiliaries ship programs, may need to amend to accommodate the added options of using these types of sealants in various applications. This project is not an official qualification process, but is considered a data gathering process that can be used as reference if and when a qualification official program is instituted. The project white paper, indicating the scope of the project, is shown in Appendix 8.1.

2.1 Target Audience

The primary target audience is the Navy and its agencies. However, due to the nature of the project (introducing and assessing new methods, materials and equipment), other groups will also likely be part of the process of evaluation. The ideas presented herein apply to many applications, not just Navy marine electrical applications.

The direct customer is a contractor administering the National Shipbuilder Research Program Electric Technologies Panel (NSRP ETP) program contract, SCRA. The benefactors of this work will include NSRP ETP members and panel affiliates. It is expected the information could be used in commercial as well as governmental programs. In fact, it may well be that this project segue's into another similar project or is used in some form of reference for extending other similar technologies.

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3. Goals and Objectives

Goals and objectives for this project include the following:

- Find a suitable replacement option, as warranted, for traditional transit block systems that will save time and labor hours
- Evaluate
  - The reliability of sealants (not susceptible to loosening during vibration or shock events or changes in environmental conditions)
  - The ease of installing cables in the future and re-packing the frame
  - The relevance with respect to the passage of cables (evaluate the challenges with designing geometric configurations compared to using transit block systems)
  - Cable component susceptibility to externally initiated compression and crush forces
  - Increase cable passage density
  - Any constraints on cable deratings due to passage density, heat transfer properties of the sealant, and cable passage geometry
- Through a testing and down select process, make recommendations that point to the most suitable candidates for further testing and possible qualification

The primary objectives for this project are twofold: provide a history and an evaluation based on this history on how certain transit systems are used, in what applications they are used and briefly explain the justification for their development and use. Secondly, after evaluating products on paper, determine through a down select which products might be considered for further review due to their apparent flexibility, ease of use and overall applicability across several applications among other considerations. Once down selected, the products will be demonstrated. The following will be used as high level critiquing guidelines for the down-select and the demonstrator:

- Portability and handling characteristics (i.e., how easy is it to take from application to application, the number of tools needed, clean up, preparation requirements, contamination susceptibility, etc.)
- General insulating or conductive characteristics (i.e., electrical, fire, water)
- Engagement properties to 2 different types of metal: Al and steel
- Engagement properties to PVC cable jackets
- Applicable HazMat requirements and response plans needed
- Ability to meet water tight, fire tight/retardant, toxicity requirements

Utilizing this information, one can then assemble and assess the information and recommend changes in practices and materials to better suit the environment or shipboard processes.

These are the goals and objectives as determined in the original white paper submitted to the Executive Control Board (ECB) for funding consideration. Some deviation exists between the compiled data and that which is represented in this list of items. These deviations will be discussed in the report. However, the goals and objectives were primarily attained, and set up a means for future work based on results achieved.

Because, as with many system determinations, this practice involves several variations, the user is cautioned to keep the future work (whether related to qualification testing or not) controlled and reasonably simple. This can be done by phase stepping the process and building documentation as one progresses. An example of this is to target steel flat ovals in one phase sequence (as this project did), then based on results obtained and observations made, target other interfacing materials performance, such as Al (which this project did not target at this time; the scope would have been greater than the funding level could support). Therefore, there are different opportunities for future work, which will be outlined in the Conclusions and Recommendations section, Sect. 6.

4. Approaches and Methods

The approach used for this project is broken down into five primary areas.

- Identify what is currently done on ships today and understand how practices and materials have evolved over time.
- Determine what guidelines and requirements are most often used for cable penetration hardware and testing
- Introduce a technology that has been approved for use in limited applications, but offers a wider or broader option
- Demonstrate what products exist that can be used in the applications targeted through performance testing
- Analyze, compile and correlate data and results to offer recommendations

In order to address these areas, the following methods and tasks were employed. These will be described in more detail in Sect. 5, Technical Assessment.

1. <u>Research Products</u>. Compile a listing of transit sealant products to consider for evaluation.
   Participants – BIW, Bollinger, Newport News.
2. <u>Evaluate Requirements</u>. Generate a list of primary requirements used to decide which products meet expectations. The requirements might be a combination of those levied on each program with which the participants are accustomed; if this is not appropriate, the team will choose a program and use this as the baseline going forward.
   Participants – BIW, Bollinger, Newport News
3. <u>Generate Evaluation Guide</u>. Develop an evaluation guideline for the purpose of down-selecting from the product list generated in Task 1 those products that are deemed suitable for testing. The Evaluation Guide will formalize the requirements collected in Task 2.
   Participants – BIW, Bollinger, Newport News
4. <u>Evaluate Products</u>. Evaluate the list of products developed in Task 1 with the guideline developed in Task 3.
   Participants – BIW, Bollinger, Newport News
5. <u>Develop Test Procedure</u>. Generate a test procedure that will address the requirements and concerns with using a new product that may differ substantially from the current list of products used on Navy programs. The test procedure will target those tests that may tend to make or break a product's chances of being used in a Navy application. The test procedure should be as rigorous as possible within budget constraints which will tend to transition to qualification programs in a smoother way.
   Participants – BIW, Bollinger, Newport News

6. Demonstrator. Design and build a demonstrator for each product that is capable of being tested for the following: tensile strength, crush strength, pressure test, fire test, shock test. Some of these tests are addressed through hydrostatic testing and not considered to be destructive tests.
   Participants – BIW (others to review results)
7. Conduct Testing. Conduct testing on the down-selected products. Results will be thoroughly documented so they can be reviewed by all participants. (Testing may be conducted in-house, at a lab or at a Navy facility.) It was deemed feasible to contract with an outside laboratory to conduct certain tests, since they have the resources to be able to conduct the testing in a more efficient manner.
   Participants – BIW and Laboratory
8. Evaluate Results. Evaluate the test results using the requirements levied on current transit sealant systems as a guide.
   Participants – BIW, Bollinger, Newport News
9. Generate and Review Final Report. Prepare and deliver a Final Report that includes the project methodology, test results and recommendations.
   Participants – BIW (generate), Bollinger, Newport News (review)
10. Project Management. Conduct conference calls, hold review meetings and provide status reports as required.
   Participants – BIW, Bollinger, Newport News

The output of these methods and approaches is shown in the appendices, with rolled up summaries described in the Technical Assessment sections. With each type of assessment, a certain level of freedom was used for the interpretation of the results, and the way in which the information has been portrayed. It is in the reader's best interest to try to assess the data him or herself before accepting the opinions of those who have written and contributed to sections of this report. In all cases, if the reader wishes to explore more on a particular subject matter contained in this report, the reader is directed to contact the customer of the report, SCRA for more information, or to contact the corresponding government program office.

5. Technical Assessment

A primary element of this study is assessing the performance of sealants subjected to a battery of tests, as will be detailed in Sect. 5.4. However, other parts of this study are important as well. Comparisons of the properties of sealants, as advertised by the manufacturer, are often times good indicators of how the material might perform in a test given a particular testing environment. Data sheets and comparison sheets are shown in this section and the assessment is combined with testing results to form a comparative analysis, from which the recommendations are presented.

5.1 Evaluate Requirements

Typical requirements for sealants used on surface ships today include shock and vibration withstand (for Navy surface and subsurface combatants), watertightness under a certain hydrostatic pressure, gas tightness and fire resistance. As well, the material must possess properties that easily accommodate repair and revision, and have the capability of a long life cycle (i.e., the materials do not degrade over time within the environments they are required to serve).

Other requirements that might be considered during a more comprehensive testing process might be the measurement of tensile strength, compression strength, and flexural creep and creep rupture as outlined in ASTM D638, ASTM D695, and ASTM D2990 respectively (or their equivalent in other publications).

Although the study goals do not include qualification, several standards were considered and used as a reference when determining the testing requirements, as shown in the test procedure in Sect. 8.3.2. The standards that were referenced include the following:

- Vibration: MIL-STD-167-1
  - Conduct Type I vibration tests as outlined in Sect. 5.1
- Shock: MIL-S-901D
  - Conduct a Grade A shock test on the heavy machine, conducting the testing for all units at the same time.
- Watertightness: MIL-DTL-24705B
  - 27.5 psi for 10 minutes with no leakage[1]
  - IMO 754 is also referenced for watertightness
- Air Test:
  - 60 psi air nozzle close to the surface, with no bubbles generated on the opposite side[1] (this is a focused test and a different test than the compartment test described below)
  - IMO 754 VI Part 7 Sect. 3d states a test using air pressurized to 30 mbar shall be used (equating to about 12” of H_2O or about 0.43 psi); this references the

[1] Because the demonstrator consists of two layers, unless a leak occurs on both layers, it may not be observed that one side has failed this test unless there is air and/or water leakage out the drain in the bottom of the oval.

compartment gas test, increasing pressure in the entire space to this positive pressure
  - Common pressure values for programs are near 1-2 psi
- Light Test:
  - Shine a 1 million candle power light source on the surface to determine if any pin holes or other compromises exist in the surface[2]
- Fire Test: IMO 754(18)
  - Use the Fire Chart and thermocouple or RTD (Resistance Temperature Detector) placements indicated in Sect. 5.7.5, Appendix 8.3.4, and Figure 5.7.5.1 , or as close to this as possible. The flame shall be directed on the surface of the outer surface and measured on the inner surface. Compromise occurs when the inner surface temperature exceeds the curve at any time during the test.

Other standards were reviewed and considered as general references, such as MIL-STD-3020. It was thought that these requirements resemble closely a qualification program, but may deviate somewhat in certain areas, such as the fire resistance testing, due mainly to cost of the testing program. However, the requirements are close to what would be expected in a marine application and may form the basis for qualification testing in the future, with out the large costs for this study. An excerpt from MIL-STD-3020 characterizes this statement:

> This standard provides the fire resistance test method and acceptance criteria, following shock testing, for approval of N-Class and AN-Class divisions and their penetrations on U.S. Navy surface ships. The fire resistance test method described herein supersedes fire resistance test method requirements of Appendix A in MIL-PRF-32161, and American Bureau of Shipping (ABS) Naval Vessel Rules Part 1, Chapter 2, Section 1. This standard is applicable to fire resistant divisions constructed from steel, aluminum, and polymer composite structures. This standard does not address ignitability, surface flame spread, heat release rates, smoke density, fire gas toxicity or other material fire performance limits or basic system/component design requirements which may be imposed by other documents and the Naval Technical Authority (NTA).

Type I or Type III, Class 3, 4 is likely to be the reference for the material. It is recommended, that once a qualification program is determined, Mil-PRF-32161 be used as a reference for the fire performance testing. Although not comprehensive, this set of requirements represents a set of sound standards that a qualification program can be based. Ship specifications are based on similar standards and requirements (values may be different, but procedures and methods are similar). The list is not included here due to the nature of the distribution of this report.

[2] Similar to the previous note, because the demonstrator consists of two layers, unless a compromise occurs on both layers, it may not be observed that one side has failed this test unless there a light source shown at the bottom of the oval through the drain, indicating a compromise.

Table 5.1.1 is a table that was generated to assess what type of military specifications can be referenced when evaluating products. This is only a partial list, but is a starting point when developing specifications and qualification testing criteria.

Table 5.1.1: Military Specification and Standards Pertaining to Transits

References for Transit Component Usage

Item	Reference	Section	Section Language	Remarks
1	DDG 1000 Engineering Handbook, DESIGN FOR MANUFACTURING HANDBOOK-ELECTRICAL, Document – HNDBKELEC007, Revision B	5.9 ELECTRICAL PRODUCIBILITY "TOP FIFTEEN"	1) Approved multi-cable transit "MCT" system will be used. Rise to be used at manufacturing's discretion where allowed.	
2	MIL-STD-2003-3A DEPARTMENT OF DEFENSE STANDARD PRACTICE ELECTRIC PLANT INSTALLATION STANDARD METHODS FOR SURFACE SHIPS AND SUBMARINES (Penetrations)	4.1.5	4.1.5 Multiple (two or more) penetrations of nonstructural steel bulkheads (other than wire mesh or expanded metal), bends, web frames, transverse girders, and longitudinal girders. Unless otherwise specified, multiple cable metal), bends, web frames, transverse girders, and longitudinal girders. Unless otherwise specified, multiple cable penetrations of nonstructural steel bulkheads, bents, web frames, transverse girders, and longitudinal girders shall employ one of the following: a. Metal stuffing tubes, multiple cable penetrators, nipples (for single cable penetrations) having a minimum length of two inches with a minimum annular area between the cable and the nipple of ¼ inch packed with plastic sealer b. Banding collars (for multiple cable penetrations) having a minimum collar length of three inches with a minimum annular area between the cable and the collar of one inch with the entire void area within the collar (this includes the area between the collar and the cable and the area between the cables) packed with plastic sealer. Cable penetrations of vertical non-tight structures within a compartment nee	Talks about using a plastic sealer in various applications throughout this and similar sections
3		4.1.6	4.1.6 Plastic sealer. After the cables are properly secured, plastic sealer electrical insulation (MIL-I-3064, Type HF) shall be used to seal the space around the cable as follows: a. In cable clamps and bushings entering the top of an electrical enclosure and the side of an enclosure without a drip loop. b. In bushings or nipples used for passing cables through light-tight and fume-tight bulkheads and to seal around cables as they enter stuffing tubes, kickpipes, and swage tubes as shown on the individual figures except that plastic sealer is not required when silicone (red or white) grommets are used. Where compartment air tests are required, it is recommended that plastic sealer be installed after the air test has been satisfactorily performed.	
4		FIGURE 3B51. Community cable tube – watertight decks (poured seal		Shows the use of sealants and multicable transit applications.
5		FIGURE 3B22. Multiple cable penetrator installation notes (type RGS and RGA).		This figure and next talk to using blocks, but may be applicable with sealant materials
6		FIGURE 3B39. Round multi-cable penetrators installation notes		

References for Transit Component Usage

7	MIL-STD-2003-4A DEPARTMENT OF DEFENSE STANDARD PRACTICE ELECTRIC PLANT INSTALLATION STANDARD METHODS FOR SURFACE SHIPS AND SUBMARINES (CABLEWAYS)	4.2 Spare cable space allowance	4.2 Spare cable space allowance. In the organization of principal cableways, spare cable space of approximately 20 percent of that to be occupied by the final cable installation (as known at time of delivery of the ship) shall be reserved on cableways and in cable penetration areas for future cable installations. The additional cable space may consist of unused hangers or combination of unused hangers and space available on used hangers, assuming that for future addition of cable, double banking will be allowed. During the design phase, the contractor shall provide cableway space in excess of the spare 20 percent in order to accommodate cables added as a result of developments occurring during the construction period. Through horizontal cable runs in aircraft carriers' hanger developments occurring during the construction period. Through horizontal cable runs in aircraft carriers' hanger developments occurring during the construction period. Through horizontal cable runs in aircraft carriers' hanger spaces will not be permitted. Through vertical runs such as those from the second deck to the gallery or flight decklevels shall be c	
8		FIGURE 4C40. Cableway through non-watertight bulkheads and beams with firestops. (also addressed in 41-46)	1. Fire stop methods are for non-watertight cable penetrations and also for airtight and flametight spaces where applicable. 2. Stuffing tubes (tubing, collars, and liners) shall be steel for steel structures and aluminum for aluminum structures. 3. The minimum clearance space around cables before packing material is applied shall be ¼" for a single cable and 1" for multiple cables. 4. Pack thoroughly around and between cables with plastic sealer, MIL-I-3064, Type HF. 5. Stuffing unit may be attached by all-around weld, tack weld, or fasteners provided that the attachment conforms to the structural and tightness requirements of the bulkhead or member to which it is attached. 6. All welding shall be in accordance with 5.7.3.7. 7. For existing installations, stuffing units may be split lengthwise for installing over cable.	
9	MIL-I-3064B: MILITARY SPECIFICATION INSULATION, ELECTRICAL, PLASTIC-SEALER	1.1 Scope	This specification covers the electrical and physical requirements of the plastic-sealer compound used for sealing electrical cable penetrations, end sealing cables, and fire stop applications requiring good electrical insulation and heat resistant properties.	
10		1.2 Classification	The plastic-sealer compound shall be of the following types, as specified (see 6.2.1). Type H Type HF - Heat- and flame-resistant for fire stop applications	
11		3.2.2 Toxicity	The material s h a l l have no adverse effects on the health of personnel when used for its intended purpose. At the time of request for tests, the manufacturer shall furnish satisfactory evidence that the compound is non-toxic t o humans during application, provided that the manufacturer's precautions are taken (see 4.1.3). These precautions shall be clearly stated on the label . Failure to furnish satisfactory evidence of nontoxicity of the material will be. cause for non-authorization of tests.	
12		6.1 Intended Uses	The compound will be used for sealing electrical cable penetrations in decks and bulkheads and entrances in electrical enclosures and will also be used for end sealing cables. The compound is also intended for use as a fire stop at cable penetrations in decks and bulkheads. be in direct contact with the exterior surfaces of both armored and unarmored cables and conductor insulation materials.	

References for Transit Component Usage

13	MIL-C-915G: GENERAL SPECIFICATION FOR CABLE, ELECTRICAL, FOR SHIPBOARD USE	4.5.17 Watertightness	This test shall determine the ability of completed cable, which is intended to pass through watertight bulkheads, to prevent the longitudinal flow of low-pressure water.	Included as reference for 25 psi test and use of sealants as watertight bonding agents (6 hr test)
14		4.5.17.1 Specimen	The specimen shall consist of a 60 ± 2 inch length of completed cable. The specimen shall be cut to length using a scissors-action cable cutter. (Saws shall not be used.)	
15		4.5.17.2 Special apparatus	Apparatus shall include the following: (a) A source of pressurized water, which shall be provided at a regulated pressure of 25 ± 1/2 lb/in2 and which shall be for use with the terminal fitting (see (b)) as specified in 4.5.18.3. (b) A metal terminal fitting which applies the source of pressurized water to one end of the specimen, which supports the requirements as specified in 4.5.18.3, and which shall be fabricated as specified in the following. Figure 7 shows one possible arrangement for the terminal fitting. The fitting shall admit the specimen end for the distance specified in 4.5.18.3, and shall have an id, where it fits over the specimen of not greater than the measured overall specimen diameter plus 1/2 inch. The fitting shall have a means for introducing the source of pressurized water to the specimen end, and a means for bleeding off any air, which might be trapped between the specimen end and the source of pressurized water. The fitting shall also have an aperture for introducing a hardening sealant (see (c)), to produce a pressure-tight bond between the fitting and the specimen jacket. A plug (such as a th	
16	ASTM D2990: Standard Test Methods for Tensile, Compressive, and Flexural Creep and Creep-Rupture of Plastics		all	Outlines tensile, compression tests beyond the procedures of ASTM D6xx
17		2.1 Booklet of standard wiring practice	This booklet shall contain standard wiring practices and installation details. They shall include, but not limited to, cable supports and retention, typical radii of cable bends, bulkhead and deck penetrations, cable terminations, cable splicing, grounding details, watertight and certified safe connections, grounding and bonding connections, cable tray and bunch configurations showing clearance and segregation of cables. For cable penetrations through watertight, gastight, and fire-rated bulkheads and decks, evidence of penetration design approval shall be submitted. For watertight and gastight cable penetrations, certificates issued by a competent independent testing laboratory would be acceptable.	
18	MIL-P-24705: GENERAL SPECIFICATION FOR PENETRATORS, MULTIPLE CABLE, FOR ELECTRIC CABLES	3.3.4 Lubricant	Lubricant (see 3.1 and 6.5.2.11), when specified (see 6.2), shall be in accordance with C-T-91.	Note: not all tests are recorded here, only those that may have direct relevance on this project.
19		3.3.5 Toxicity	The material shall have no adverse effect on the health of personnel when correctly used for its intended purpose. Questions pertinent to this effect shall be referred by the contracting activity to the Naval Medical Command (NAVMEDCOM) who will act as an advisor to the contracting agency.	
20		33.6 Hazardous material	Materials and parts containing asbestos, cadmium, lithium, mercury, polychlorinated biphenyl, radioactive materials, chromates, or materials giving off toxic fumes under operation or casualty conditions, shall not be used. Mercury and its compounds shall not be used during processing, handling, and packaging of material and parts.	
21		4.3 Inspection conditions	Unless otherwise specified herein, all measurements shall be made within the following ambient conditions: a. Temperature: 15 to 35 degrees Celsius (“C) b. Atmospheric pressure: 550 to 800 mm of mercury (Hg) c. Relative humidity (RH): 20 to 80 percent.	

References for Transit Component Usage

22		4.4.1.1.1 Test specimen configuration	The test specimen shall consist of a multiple cable penetrator frame, the appropriate insert material items and accessories, loaded with cables conforming to MIL-C-24643 as specified in the applicable specification sheet (see 3.1). The specified cables shall be approximately 1 meter length. Using the test stand specified in 4.7.1 or an approved equivalent, the cables shall be routed through the penetrator frame so that approximately .75 meter of cable shall extend from the side of the frame that will not be directly exposed to the fire or water during testing.	
23		4.73 Vibration	The multiple cable penetrator test specimen shall be subjected to the type I vibration test in accordance with MIL-STD-167-1. Following the test, the multiple cable penetrator test specimen shall meet the acceptability requirements of MIL-STD-167-1, and shall pass the HI shock test specified in 4.7.4 and the watertightness test specified in 4.7.5.	
24		4.7.4 Shock	The multiple cable penetrator test specimen shall be subjected to group A, class I, type A shock test in accordance with MIL-S-901. The mounting fixture shall be type 4A for the lightweight shock machine or standard deck and bulkhead mounting on the medium weight shock machine. Following the test, the multiple cable penetrator shall meet the acceptability requirements of MIL-S-901 and shall pass the watertightness test specified in 4.7.5.	
25		4.7.5 Watertightness	The multiple cable penetrator test specimen mounted on the test plate shall be bolted to the hydro chamber (see figure 1) so that one side of the test specimen is exposed to water, and the opposite side of the test specimen is exposed to air (see figure 1). The hydro chamber shall then be filled with water and pressurized to 25.0 pounds per square inch (lb/in2). This pressure shall be maintained for a minimum of 10 minutes unless specimen failure occurs sooner. The test specimen shall be considered as having failed the watertightness test if, after 10 minutes, the water pressure has decreased to less than 25.0 lb/in2.	
26		4.7.9 Fire stop test	The multiple cable penetrator test specimen shall be as specified in 4.4.1.1, except the frame shall be steel only. The test specimen shall be subjected to the fire stop test specified in 4.7.9.1 and 4.7.9.2.	
27		4.7.9.1 Test equipment	The fire stop test equipment shall consist of a test stand with a fire chamber, an exhaust and vacuum chamber, eight thermocouples, and a 500,000 British thermal unit (Btu) propane burner. The propane burner shall be mounted in the fire chamber so that it will be 12 inches from the face of the test specimen.	
28		4.7.9.2 Test procedure	The multiple cable penetrator test specimen shall be mounted on the test plate bolted to the test stand. Thermocouples shall be placed on both sides of the test specimen at the following locations: two on the fire side; one 8 inches from the penetrator face and one in the center of the penetrator face; six on the nonfire side; three on the vertical centerline at the top, center, and bottom of the insert material; two opposing corners on the insert material; and one on the metal bulkhead 1 inch above the penetrator. The flame shall be applied to the test specimen for not less than 1 hour at a temperature of 1093 "C (see figure 2) measured at the thermocouple located at the center of the cable bundle.	
29		4.7.10 Durometer	A sample of each sealing item shall be subjected to a type A durometer test in accordance with ASTh4 D 2240.	
30		4.7.11 .Compression	A sample of each sealing item shall be tested in accordance with ASTM D 395.	
31		4.7.13 Fluid immersion	A sample insert material shall be placed face down in a container containing approximately ln inch of fluid for not less than 2 hours. The fluids and emperatures shall be as specified in table IV. The samples shall then be removed, blotted to remove excess fluid, and suspended in air at room temperature for not less than 3-1/2, nor more than 4-1/2 hours. Each sample shall then be tested again as specified in 4.7.10. Failure to meet the requirements of this test shall be basis for rejection. Test shall be repeated for each specified fluid.	

5.2 Generate Evaluation Guide

An evaluation guide was created to capture data that would later be used for comparison purposes across products. Table 5.2.1 is a spreadsheet that was used to capture data from Vendor Furnished Information (VFI), information from product representatives or product labels, and results of laboratory testing. If more testing were to be done, this method would be a chosen option. The data is then brought into a common form and performance characteristics compared for preferencing. Primary constraints and requirements are also compared to determine which product will be capable of meeting the most demanding specifications or applications. As will be seen, not all information may be immediately available, but is included in this template in the event that the information becomes available or is needed for a specific determination. Some information may be considered proprietary or a sensitive characteristic of a company's product.

Table 5.2.1: Product Evaluation Guide Template

Evaluation Criteria

The following are criteria that will be used to evaluate the performance of the tested transit sealant products. Some criteria are based on established standards and requirements, which are referenced for convenience.

Product: ______________________ Tested by: ______________________
Date: ______________________ Submitted by: ______________________

Item	Description	Min/Max Requirement	UOM	Value	Meets Requirement? (Y/N)	Testing Date	Comments/Remarks
1	Cure Time		hrs				
2	Operating Temperature - nominal		°F				
3	Max. Operating Temperature		°F				
4	Flame Resistance		°F/hr or °C/hr				
5	Water/Air Pressure Withstand		psi				
6	Packaging Size		in^3				
7	Packaging		n/a				how is the product packaged?
8	Delivery		n/a				how is the product applied (caulking gun, knife, etc.)
9	Shelf Life		months				
10	Installation Temperature		°F				
11	Cure Temperature		°F				
12	Tensile Strength		Mpa				
13	Elongation		%				
14	Hardness		Shore A				
15	Tshear Strength		N/mm				
16	Peel Strength		N/mm				
17	Dielectric Strength		kV/mm				
18	Dielectric Constant						
19	Volume Resistivity		Ω/cm				

Evaluation Criteria

The following are criteria that will be used to evaluate the performance of the tested transit sealant products. Some criteria are based on established standards and requirements, which are referenced for convenience.

Product: ______________________ Tested by: ____________________
Date: ______________________ Submitted by: ____________________

Item	Description	Min/Max Requirement	UOM	Value	Meets Requirement? (Y/N)	Testing Date	Comments/Remarks
20	Consistency						
21	Viscosity		mPa*s				
22	Density		g/cm^3				
23	Tack Free Time		min				
24	Linear Shrinkage		%				
25	Thermal Conductivity		W/m*K				
26	Coefficient of Expansion		1/°K				
27	Vibration Testing - low	4	Hz				
28	Vibration Testing - moderate	60	Hz				
29	Vibration Testing - high	400	Hz				
30	Shock Testing, Grade A	60	g's				
31							
32							
33							
34							
35							
36							

5.3 Evaluate Products

Data sheets were compiled and used to populate the tables similar to that shown in Table 5.2.1, which are shown in Appendix 8.2 in Table 8.2.1, Table 8.2.2, and Table 8.2.3. As can be seen, broad testing performance data has also been included here, but this section focuses on the data sheets. A more detailed analysis of the laboratory testing results will be discussed in Section 5.7.

Each product uses a different component for structural support and barrier for water, fire and gases. Although each sealant flows quite loosely, it is capable of being installed in a horizontal deck, either from the top or from the bottom. This is the result of product adherence both to itself and to the interfacing surfaces. Minimal droop is experienced, unless an exorbitant amount of material is used. Generally, for the purposes of the applications investigated, this is not an issue with any of the products. However, the adherence characteristics does tend to make the materials a bit messy to use, and when in contact with and article unintentionally, it is difficult to get the material to let loose or clean it up.

5.4 Develop Test Procedure

The development of the test procedure was driven in part by the following:

- Project budget
- Project timeline, and laboratory availability
- Importance of the test and relevance to ship programs. The test procedure was designed to segue to a qualification program, whether considered rigorous or otherwise. For instance, shock testing was done in accordance with Mil-S-901, which represents the actual Grade A shock testing levied on many Navy programs. The fire test was done as close to the IMO testing standards as possible, but was not considered in any form, a qualification test or one that is considered close to a qualification test. However, this does not mean the testing is suitable to be used as a qualification reference, only that the tests were chosen as close to those used during qualification as possible.
- Tests were chosen on their direct benefit to the program and category of performance testing (material tests were not covered under this program, but would be part of a procedure if the materials were to be considered under a qualification testing program)
- Some detail was left off the testing procedure to expedite the procedure generation process and to leave some of the testing details in the hands of the SMEs

The design was done in conjunction with the testing, since it was determined that certain sized frames and components were needed for shock and vibration testing. Shock testing was done in three axes, but one type of common axis test, straight vertical (representing a deck penetration) was not completed. Other tests represent the preload during ship roll, pitch and yaw movements during a shock event. For future testing, it is recommended the following be done:

- Vertical shock test
- Materials performance testing (include, but not limited to tensile, compression, shear, elongation, absorption, abrasion, corrosion tests)
- Standard IMO tests, utilizing IMO methods for ramp rates and hi burn testing

The test procedure used for this project is included in Appendix 8.3.4.

5.5 Demonstrators

To evaluate the performance of chosen sealants and experience the ease or difficulty in installing the various sealant systems, demonstration units, termed demonstrators, were constructed at BIW. The units were designed and engineered in accordance with typical ASME standards regarding pressure testing. Calculations and design criteria is shown in Appendix 8.3.1. Since a baseline hydrostatic test calls for testing at 27 psi, the units were designed to accommodate this value, and in fact, designed to far exceed this value such that the component likely to show signs of failure would be the sealant. Valves, plugs and instruments were installed so that the operator of the hydrostatic test could control the test easily and precisely. A drain plug was installed on the flange so that one could assess how much leakage there would be on the inside seal (one 1" thick seal located on the inside of the oval and one 1" thick seal located on the outside of the oval when installed on the pressure tank). This allows the operator to determine if there is a failure of the inner seal before a catastrophic failure occurs. The demonstrators were designed and constructed to be able to be used multiple times for multiple tests, including fire tests. The flange holding the oval, sealant system and cables is capable of being removed from the hydrostatic testing tank and mounted in any arrangement and orientation that supports testing such as shock and vibration testing. This can be seen in the testing report attachment.

The cable supports did need to be reinforced for shock testing. However, the cables were considered secure during cure periods and transport, and the supports did not negatively impact the stability of the sealant systems.

Flat ovals were chosen as the preferred penetration mechanism since it is likely this would be the type of penetrator that would be chosen on the ship. Round and arching penetrations that are interfaced with a band of this sort are preferred to square openings or openings with square corners, since 90 degree corners create weak areas along bulkheads and decks that are subject to fatigue and failure during continuous flexing and stress. Square and rectangular transit frames are often fitted within oval structures with rounded corners for this very reason.

As shown in Sect. 4 of Appendix 8.3.1, the penetration was designed to take multiple sized cables and fill to 40% - 60%. However, some penetrators may have been filled to a little different fill rate, but they used the same sized and type cables, primarily 3/C power cables. The fillers used for each demonstrator are designed to be placed between cables and the inside of the oval band. Fill rate, cable size and cable proximity all have influence over the ease of installation, installation repeatability (important for comparing performance results) and product performance.

Appendices 8.3.2.1 through 8.3.2.3 detail the construction of the demonstrators. Each system contains different filler materials, although the sealant itself is similar across all systems, but not exactly the same. The material make up is not compared, but the handling and manner by which the materials is applied is similar. The FireStop and FireSeal products appeared to be a bit more rubbery than the NOFIRNO material during the curing process. The NOFIRNO product cured to a harder surface in a shorter time than the other products. The filler tubes and sleeves used for the cables were easy to work with, as shown in Appendix 8.3.2.3. The putty material used for the Nelson FireStop system, shown in Appendix 8.3.2.1 was the most challenging to get into place and create good interface with cable and oval inner surfaces. The end product is quite strong, but as will be discussed and is shown in Appendix 8.3.3.1, shows considerable bulging during the hydrostatic test. It is also assumed that during cooler temperatures, the blanket material used for the FireSeal 3000 system would be easy to work with. However, as seen in Appendix 8.3.2.2, there is not a lot of structural rigidity offered by the blanket material. The primary benefit of the blanket material is for fire resistance. The sealant, after curing, is the primary agent of structural rigidity. As shown, the sealant tended to be a little more “flowing or soupy” than the other sealants, which may tend to create more challenge for vertical installations.

As shown in Figure 5.5.1, the fill rate is approximately 40-60% for these demonstrators, nearly what is called for in Section 8.3.2. The cables consist of

- 2 – 3/C 5 kV 400 MCM cables (bottom hanger)
- 1 – 3/C 600 V 400 MCM cable (top hanger)
- 1 – 3/C 600 V 200 MCM cable (bottom hanger)
- 1 – 3/C 600 V 100 MCM cable (bottom hanger)
- 5 – 7/C 600 V twisted pair of 12-16 AWG
- 2 – 7/C 600 V twisted pair of 14-18 AWG
- 3 – 2/C 500 V twisted pair of 12-16 AWG

Figure 5.5.2 and Figure 5.5.3 are slight variations of Figure 5.5.1, which was done first and used as a bit of a baseline for other systems, even though the entire sealant systems are not the same. Most cable that was used was leftover from other jobs, so thereby injecting a small amount of variation. However, it was determined that the percent fill and relative configurations of different sized cables, with this small amount of variation, would not negatively impact the performance of the demonstrator testing. The latter two demonstrators probably do not have the amount of fill as the first one, due to the lack of one of the larger cables, but it is still relatively full. Another item to consider is that the lower fill rate also increases the chance that the structural materials providing support for unused space is tested at a higher level of integrity, effectively testing the capability of the system as a whole more so than if the cables were filling the space entirely. One could argue that the cables provide a bit of a structural map of the space where the sealant can cure to rigidity. As long as the cable grid does not move during cure, and the grid of cables is as concentric as possible, filling the spaces as much as possible, as long as there is minimal or no shear strain caused by heavy cables sagging between sealed faces, and there is proper external support, the tighter the grid, the stronger the penetration product. This assumes that there will be a minimum of sealant between cables such that a cured product is formed and the cables are sufficiently interfaced and supported. This also assumes the technician can gain enough access in the tight spaces between cables, and between penetrator and cable, that sufficient sealant can be applied in order to reach the proper amount of sealant interface.

In reality, this is difficult to achieve sometimes and may be the cause of a premature failure as a result of an interface not properly installed. Although the failure was considered pretty minor, the failure nevertheless prevented the sealed unit from withstanding any more than about 5-10 psi during the hydro testing (see Section 8.3.3.3).

Figure 5.5.1: NOFIRNO Demonstrator Cable Fill

It is likely that the cables shown in Figure 5.5.1, Figure 5.5.2 and Figure 5.5.3 would be laid out in a little more of visually ascetic way, but the fundamental installation is sound and what is generally required, with larger cables on the bottom and smaller, lighter cables above this. It is not always possible to install cables in this manner, depending on how much the cable routing is dependent upon certain cable orientation and accessibility. However, this is generally what the technician aims for so that it is easier to install, access is better for newly added cables, and as the curing and materials settle, it is clear if there is separation from any of the materials toward the top of the penetration opening.

Figure 5.5.2: FireStop 3000 Demonstrator Cable Fill

Figure 5.5.3: FireSeal System Demonstrator Cable Fill

Although no testing on block systems was conducted, it is recommended that a direct comparison be done with a laboratory baseline. However, more precise controls would need to be in place to demonstrate relative performance. It is assumed block systems, when installed properly and validated through testing, will not reduce effectiveness over time unless the penetrator is compromised, revised, or operationally tested near its capabilities leading to fatigue stressing. This is a big assumption, and it is recommended that for more comprehensive future testing, the transit block systems be subjected to similar tests as the soft sealants.

5.6 Conduct Testing

Testing was done at two locations: (1) Initial hydrostatic testing was done at Bath Iron Works to test the quality of the installation, and (2) All other testing outlined in the testing procedure, Appendix 8.3.4, was done at a contracted laboratory, AeroNav Labs. The laboratory results are captured in the attached report, and discussed in further detail in Sect. 5.7. Presented here are general observations. For more information, please see the attached report.

Initial testing at BIW is captured in Appendices 8.3.3.1 through 8.3.3.3. The cure time was approximately 5 days before they were initially hydro tested. During testing, the cables leaked water, increasing as the pressure increased. To reduce the amount of leakage and allow for better visibility as to the performance of the sealants, the cables were capped off. This leaking was due to some cables not having the type of water blocking generally called out in ship programs. This issue did not detract from the focus and intent of the demonstration unit installation or testing. At about 10 psi, the FireSeal and FireStop systems started leaking, although no major catastrophic failures were captured. The NOFIRNO system started some minimal leaking at the maximum test pressure. All leaks were repaired and the units were packaged to be shipped to the laboratory. They were not tested again until they were received by the lab, who then proceeded to hydro test the units to verify they were not damaged during transit. The repairs were validated and all three units were successfully tested to the maximum test pressure.

A key aspect of the process of installation and testing is the curing of the materials. The NOFIRNO product appeared to have the fasted cure time, and due to the nature of the backfill system, appeared to have the most rigidity during hydro testing. However, in the end, they all passed hydro testing after all had about 20 days for cure time (and likely to be nearly 100% cured). It is likely the products would have passed an air and bubble test much sooner, but the focus was to determine what the near term performance was as soon after installation as possible. This will be discussed more in the conclusions section, Sect. 6.

5.7 Testing and Laboratory Results

The demonstrator units were sent to a laboratory for testing, in accordance with the testing procedure, as shown in Appendix 8.3.2. Each of the following sections will briefly describe the primary basis of the test, and high level results. The reader is advised to refer to the attached laboratory report for more details on the tests. Pictures and videos are available for viewing, to gain appreciation for the test response and to view just how the demonstrator units responded.

5.7.1 Hydrostatic Testing

Before the demonstrator units left Bath Iron Works, the units were hydrostatically tested. The cables, although water blocked, were seen leaking water along the conductors so the ends were capped and the test conducted again. Two units were tested up until 10 psi and the 3rd unit tested eventually to 27 psi. Bulging and slight cracking was experienced on all units, but more noticeably on the FireStop unit. Some repair was necessary, so more material was put into the seal and allowed to cure. The units did cure for approximately one week (or more in some cases) before the units were hydro tested again. All units passed, at the pressures indicated, before leaving for the laboratory testing. It was decided, based on the bulging response and signs of interface separation, that the FireSeal and FireStop systems would be tested to the 10 psi limit. Before being shipped to the lab, the seals were inspected and repairs were made and precautions taken to be sure the units did not fail on the first test of the sequence at the lab.

The lab tested the units all at 27 psi, whereby the passed the first hydro test. Upon visual inspection, the seals showed no signs of failure, nor did the inner part of the demonstrator indicate that a failure occurred on the inside seal only, due to the inner drain valve being in the open position.

5.7.2 General Testing and Inspection

The unit was inspected during and after each test. A high pressure bubble test was not completed, but would be recommended during subsequent projects and testing. Replicating the testing that is done on the ship program is important to determine if the test itself may be erroneous or not. It was noted that the demonstration units proved to be adequate to make relative comparisons and offer some flexibility to perform various other configuration tests in the future if necessary.

Once manufactured, the units were visually inspected. Cracks, openings, deformation, were checked throughout the manufacturing process and the units were found to be satisfactory. Even though there was leakage in the units during the first hydrostatic test, it was not clearly apparent due to the size of the compromise (pin hole) and the location of the compromise (under one of the T400 cables near the interface).

5.7.3 Vibration Testing

Each unit was vibration tested in three axes and none of the units failed the test. The structural arrangement and sealant systems tested were considered capable during this test to handle both lower frequencies and higher frequencies of testing. The vibration and shock testing could have been done in a vertical axis, replicating a deck penetration, with the cables in the vertical position, but this could be a focus for future work. This would in essence preload the sealant system due to weight and create acceleration forces that would be directly related to the weight of the sealant system components.

5.7.4 Shock Testing

Each unit was shock tested in three axes and hydro tested to verify proper testing withstand. Only one unit failed to reach the proper hydrostatic pressure indicating a possible compromise during shock testing. It was repaired and the testing continued. The unit probably should have been re-shock tested, but for the sake of schedule and budget, it was determined that the unit will move directly into the fire testing phase after the repair was hydro tested, which did pass.

The mechanism of the failure is not entirely known. Since there were no signs of failure in the vibration test, and the cable support structure was increased in strength and resilience, it is not likely the cable moved considerably during this event. However, since the failure was near a cable surface, it is possible that undue stresses emanated from the cable causing a stress on the sealant and fracturing the cured material enough so water would seep from the failure site.

Since the hydrostatic testing essentially tests the inside surface (unless a total or near total failure occurs on the inside surface, thereby imparting a large pressure on the outside seal), it is not clear was the relative comparison of failures was on the inside surface. However, just the outside seal was repaired to move onto the next phase of testing. The drain in the intermediate area of the oval was leaking a little water, but not at a high rate, so it is likely that there was not a catastrophic failure. When inspected, there was no largely noticeable area showing large gaping holes. One explanation by the sealant company representative was that when the unit was being installed and assembled, there might not have been the best seal or interface between the cable surface and the sealant in this area, causing the sealant to move some during testing and imparting stresses not seen in other areas of the seal surface.

5.7.5 Fire Testing

Fire testing was conducted on all units. A special fire box interface was created and attached to a hot air chamber, the air being heated by a separated furnace. The inside of the air chamber reached the required air temperatures of near 2000 degrees Fahrenheit. The profile of the actual air temperature ramp closely replicated the IMO standard, as shown in Figure 5.7.5.1, as will be shown shortly.

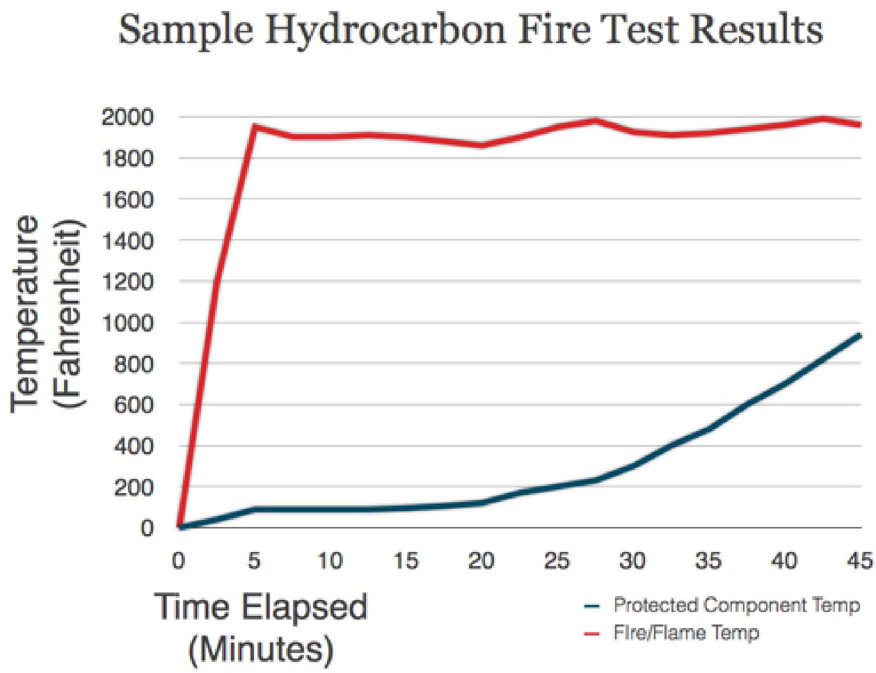

Figure 5.7.5.1: UL 1709 Sample Fire Test Curve

RTD's (Resistance Temperature Detector) were placed on the outside surface of the sealant, as shown in Figure 5.7.5.3. Each unit utilized 8 RTDs around the perimeter of the unit and near the center, held in place by fire resistance materials. The combustion and air chamber temperatures were monitored as well. Figure 5.7.5.2 shows the air chamber and duct work that goes to the combustion chamber. A direct flame was not on the surface of the sealant set up. This would create other scenarios and test for other point combustion situations, which is not the intent of this particular series of tests. The approximately one hour test followed the IMO 754 and UL 1709 testing profiles as close as possible. The ramp rates and nearly constant values of temperature at for the duration were the critical elements. Also, this type of testing is considered a heat and flammability test, detecting how much the materials are dropping thermal BTUs over the interface, and indicating either a thermal insulator or conductor.

Figure 5.7.5.2: General Air Chamber Set Up for Testing

As seen in Figure 5.7.5.3, an interfacing plate was made to interface to the hot air chamber. All surfaces representing unwanted heat intrusion onto sealant surfaces, such as leakage around any suspect points, were insulated. Although a carbon gasket was used to seal the outside from the inside, due to the high temperature requirements, insulating blankets were still used to ensure the heat source was from one side only. No hazardous smoke of quantity was noted during the testing. Figure 5.7.5.4 shows the profile followed to bring the chamber up to temperature. This closely follows the IMO standard and is considered quite accurate. It will be a good reference for future determination on fire resistance for these types of products.

Figure 5.7.5.3: NOFIRNO Pre Fire Test Set Up

Figure 5.7.5.4: NOFIRNO Air Chamber Temperature Profile During Testing

Figure 5.7.5.5: NOFIRNO Test Unit Directly Post Test

As shown in Figure 5.7.5.5, it is quite clear that the materials most vulnerable to the high temperatures are still glowing, but little or no smoke is witnessed. This is partly a result of using military qualified, low smoke, low toxicity cable. This is recommended for future testing when, and if, it is necessary to document this process in more detail or of more official record than what has been done under this task. Although the test apparatus is shown to be quite affected in Figure 5.7.5.6, the unit can be cleaned and reused after all the consumable materials are replaced. This provides an opportunity to continue to do some testing in various configurations to determine best practices and materials to use for a particular application(s). Although it appears the materials used during the testing are a total loss, shown in Figure 5.7.5.6, it is readily seen that such devastation applied to the cables and support structures did not allow for a large conduction of heat across the barrier. This set up, having an air boundary essentially between outer and inner layers of sealant, also helps contribute to the system fire thermal resistance.

Figure 5.7.5.6: NOFIRNO Test Unit Post Test After Cool Down

The surface temperature of all the units tested never exceeded 600 °F, essentially resisting over 67% of the total heat source across the seal, dropping less than 33% of the heat load across this barrier. This type of performance ensures that fire and combustible situations do not (or may not) propagate across bulkheads or decks where such materials and designs are used. Figure 5.7.5.7 through Figure 5.7.5.14 show similar results for the other two sealant materials that were tested

Figure 5.7.5.7: FireSeal 3000 Sealant System Set Up

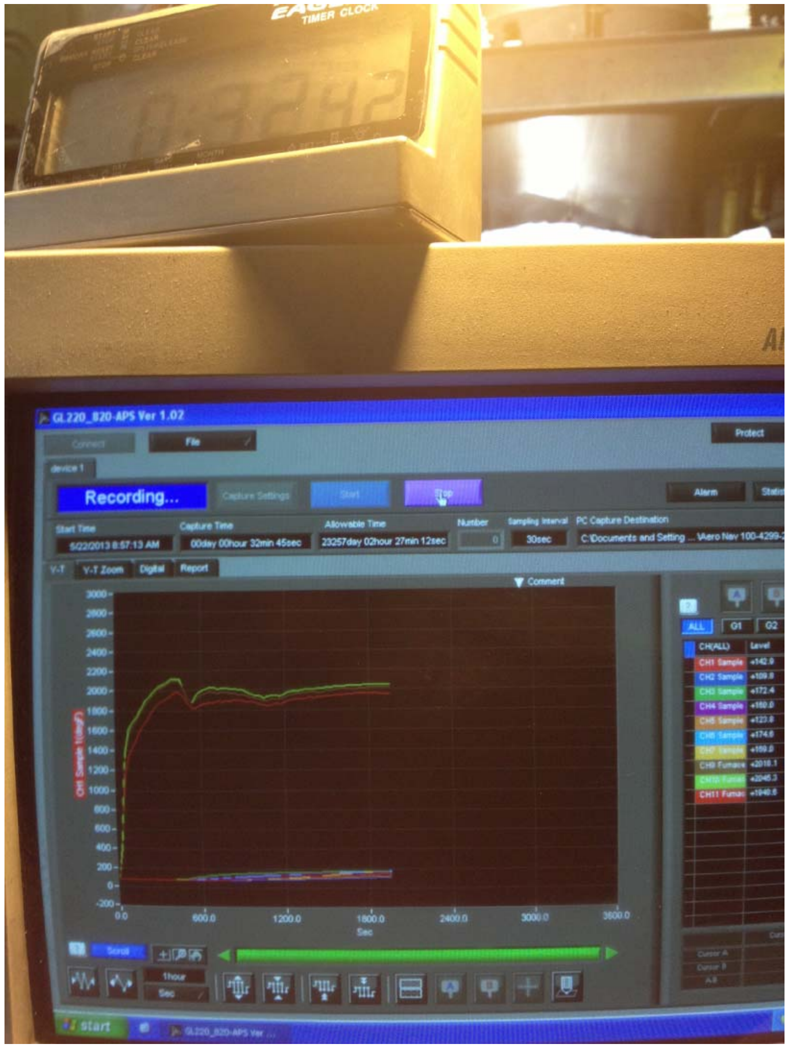

Figure 5.7.5.8: FireSeal 3000 Temperature Profile

Note that the testing temperature profiles are very close for each test, and the results are quite similar for both sides of the testing apparatus. In each case, the temperature stayed fairly low on the non fire side without compromising the surface of the sealant (i.e., fire cracking, sloughing, etc.). Although some discoloration did occur on this surface, it is suspected the structural integrity and stability of the materials has not been compromised. However, this would be a good follow on action in the event the materials are tested again, possibly during a qualification test.

Figure 5.7.5.9: FireSeal 3000 Immediately Post Test


Figure 5.7.5.10: FireSeal 3000 Post Test Non Fire Side

Figure 5.7.5.11: Nelson Firestop Test Set Up

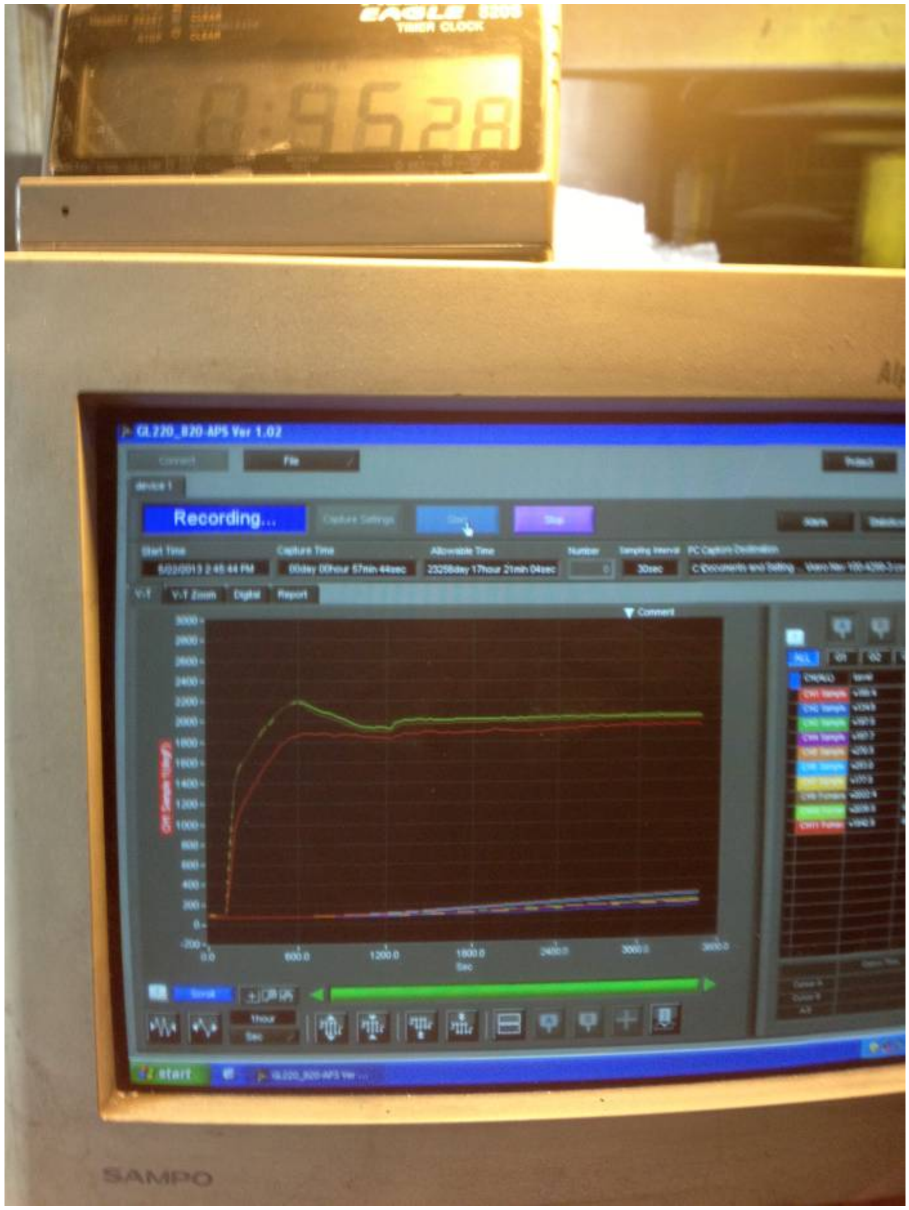

Figure 5.7.5.12: Nelson Fire Stop Temperature Profile

Figure 5.7.5.13: Nelson Fire Stop Post Test

Figure 5.7.5.14: Nelson Fire Stop Non Fire Side Post Test

5.7.6 Demonstrator Inspection

Once the demonstrator units arrived back to BIW, after having been carefully secured, crated and shipped by the laboratory, the units were inspected by the BIW team. All in all the units survived surprisingly well. The following are some observations of each unit, only to compare the individual unit response to all of the testing, including any repair that was done on the units as a result of failures (such as was the case with the NOFIRNO unit during initial testing at the laboratory). The following figures portray the demonstration units after they were shipped back to BIW, at which time, inspections were conducted and the observations shown here. Figure 5.7.6.1 through Figure 5.7.6.7 show the NOFIRNO demonstration unit. Figure 5.7.6.8 through Figure 5.7.6.10 show the FireSeal demonstration unit, and Figure 5.7.6.11 through Figure 5.7.6.16 show the Fire Stop demonstration unit.

As seen in Figure 5.7.6.1 and Figure 5.7.6.2, it appears the sealant separated along a line that is nearly the same point as the end or face of the oval. It is not clear why this has occurred. Speculation as to this occurrence includes this material, to the left of the separation line in Figure 5.7.6.2, may been pushed outward during the initial hydrostatic testing, and before the product was completely cured, thus a bulge occurring and rounding the edge. The separation is fairly large, as seen in Figure 5.7.6.5 and Figure 5.7.6.6, which will be discussed further shortly.

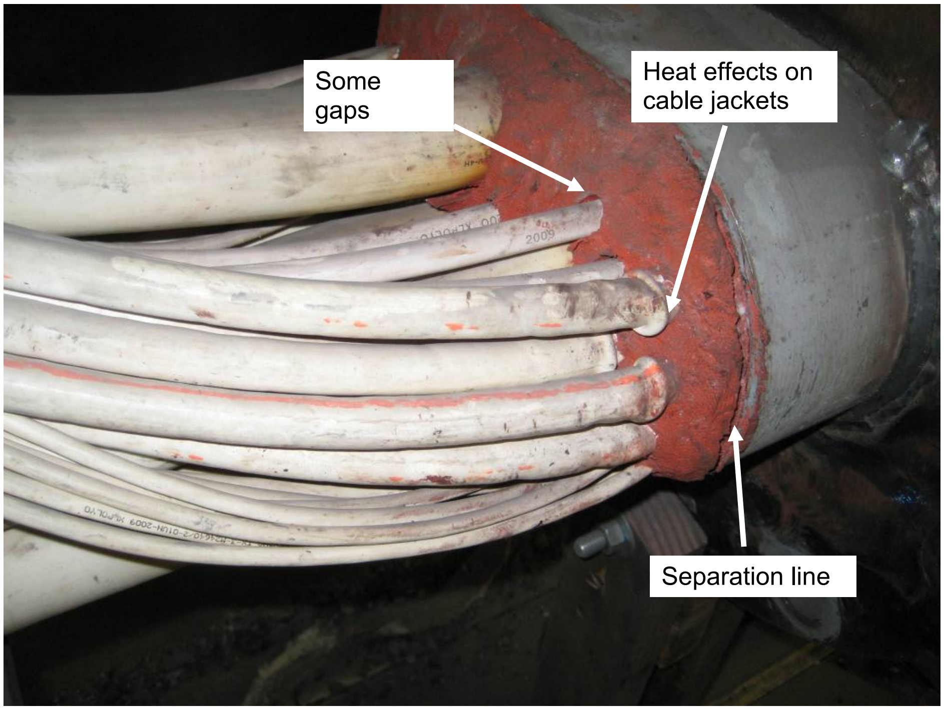

Figure 5.7.6.1: NOFIRNO Demonstrator Inspection, Non-Fire Side

The gap appears to be an anomaly, and does not appear to have affected performance, as this unit passed all tests. As a result, however, the observation may deem further testing, including the manufacture of a new demonstration unit that would be tested under similar conditions, to validate results.

Figure 5.7.6.2: NOFIRNO Demonstrator Inspection, Non-Fire Side, Side View

It was also noted that certain cables got hot enough that the inner components, fillers and water blocking, melted and flowed out the end of the cables. Caps were installed for hydrostatic testing, but when the caps were removed, it was seen that these materials had flowed through the cable out the non-fire side, as shown in Figure 5.7.6.3. This occurred with all demonstrator units, but more for some than others, possibly indicating the degree to which the heat was able to conduct across the transit and across the cable.

Figure 5.7.6.4 shows the tubes exposed, as well as the filler materials. The tubes are relatively unaffected, as well as the filler, to some degree. As with most of the demonstrator units, the sealant exposed to the high temperatures, became quite brittle and was burned to an ash in most areas around the surface. However, the inner components of the demonstrators were mostly fine, as will be shown. The high temperature box did not expose the units to a direct flame, only the high temperature. The next step would be to use flame directly on the demonstrator to determine flammability, toxicity off gassing, etc. This first testing is meant to determine structural integrity and capacity to resist temperature, not necessarily the other factors. Although the tubes are somewhat discolored, they appear to be relatively undamaged, and remain plyable. Therefore, it is safe to say the NOFIRNO product survived the test in pretty decent shape, conducting heat within the IMO standard, without compromising the system as a whole.

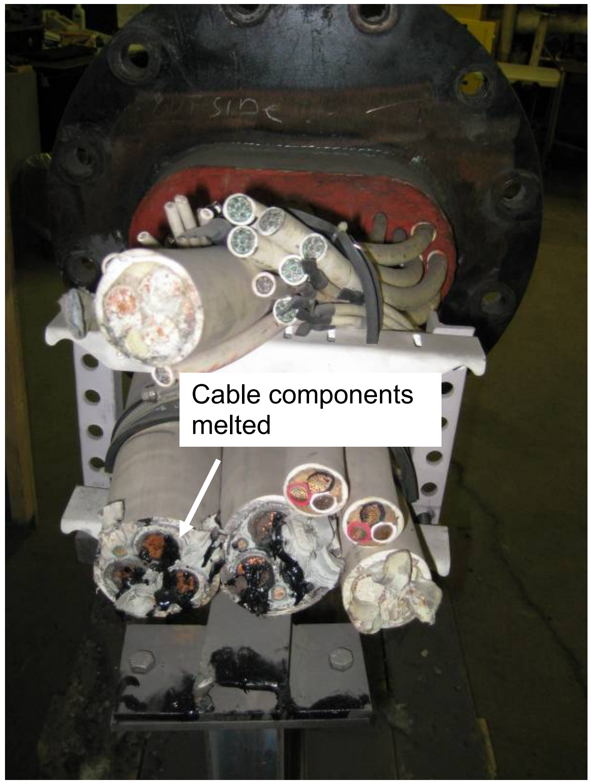

Figure 5.7.6.3: NOFIRNO Demonstrator Inspection, Non-Fire Side, Front View

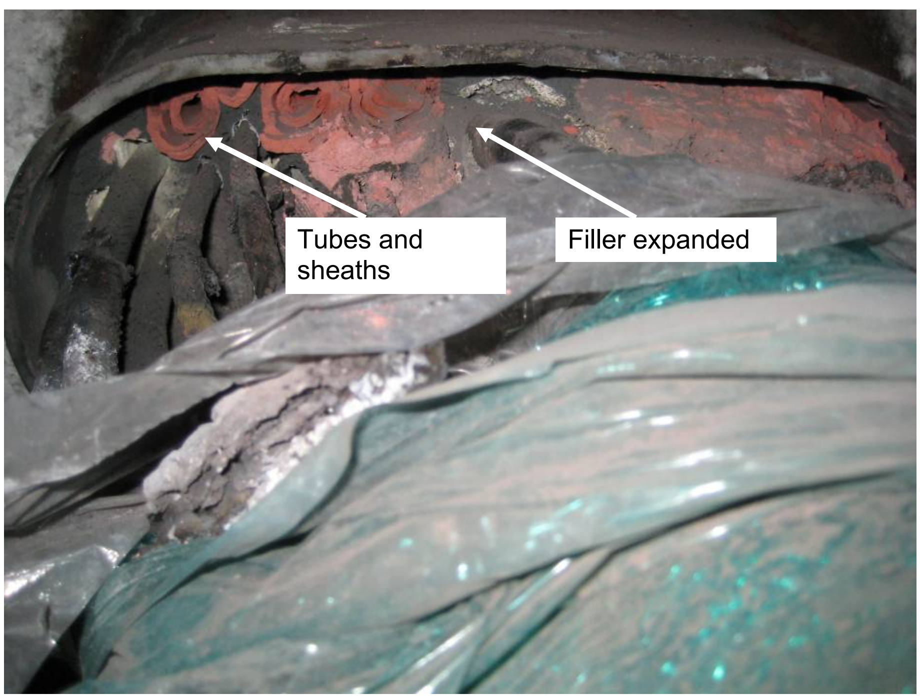

Figure 5.7.6.4: NOFIRNO Demonstrator Inspection, Fire Side, Front View

Figure 5.7.6.5 shows a sample core pulled from the NOFIRNO demonstrator, indicating the separation line that runs the entire top edge, approximately 1.5 inches inward. Further testing is warranted to determine if this would happen again if the product were to be allowed to cure nearly 100% before conducting any tests at all.

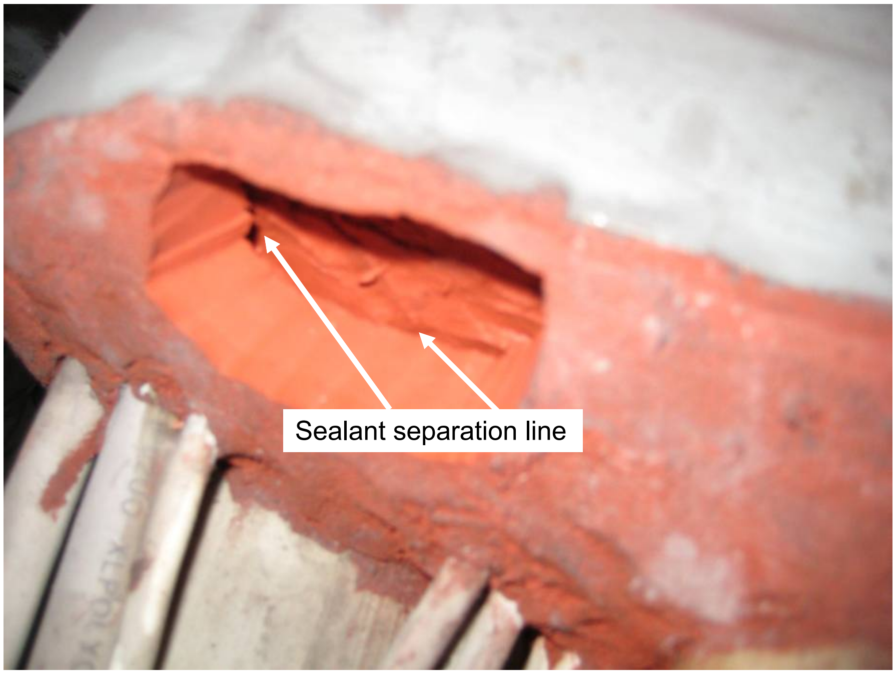

Figure 5.7.6.5: NOFIRNO Demonstrator Inspection, Non-Fire Side Sample Cut Out

Figure 5.7.6.6 and Figure 5.7.6.7 indicate the material and tubes on the non-fire side were basically unaffected by the testing and high temperatures, even with the separation.


Figure 5.7.6.6: NOFIRNO Demonstrator Inspection, Non-Fire Side Cutout Sample Side View

It is not clear, however, if the testing was successful marginally or with great margin. The sample pieces shown in Figure 5.7.6.7 do not reveal a unique stress line or fracture, culminating in a greater separation line. This will probably be further inspected, and if root cause is found to be more definitive than speculative, it will be reported to the panel. Again, it did not affect performance, but if the configuration changes from that used for these tests, such as a thinner sealant layer, performance outcome could be significantly different.

Figure 5.7.6.7: NOFIRNO Demonstrator Inspection, Non-Fire Side Cutout Sample Open View

The FireSeal product, utilizing internal components with what has been considered the least structurally sound characteristics (i.e., blanket material versus heavy putty or linearly strong tubes), performed quite well. The non-fire side surface was practically un phased by the fire testing, as shown in Figure 5.7.6.8, with minor discoloration. Once the sealant material cured for many days, it became quite rigid, offering the inner blanket layers more mechanical support. An interesting observation is the fact that the cable inner components did not flow quite as much as with the NOFIRNO demonstrator. The cables are similar in design, but there may have been more fire resistance across the penetration, with the blanket, than with the tubes. Some separation around the cables did occur, but not as much with the NOFIRNO demonstrator. This occurred, probably due to material movement during hydrostatic and fire testing.

As shown in Figure 5.7.6.9 and with the sample shown in Figure 5.7.6.10, the blanket indicated practically no damage or effect from fire testing. Although it was packed into the space securely, there is enough fiber trapped air to be a good fire resistance layer, protecting the penetrating cables to a large extent. The heat radiating from the surface of the transit is less than others (see test reports).

Figure 5.7.6.8: FireSeal Inspection, Non-Fire Side

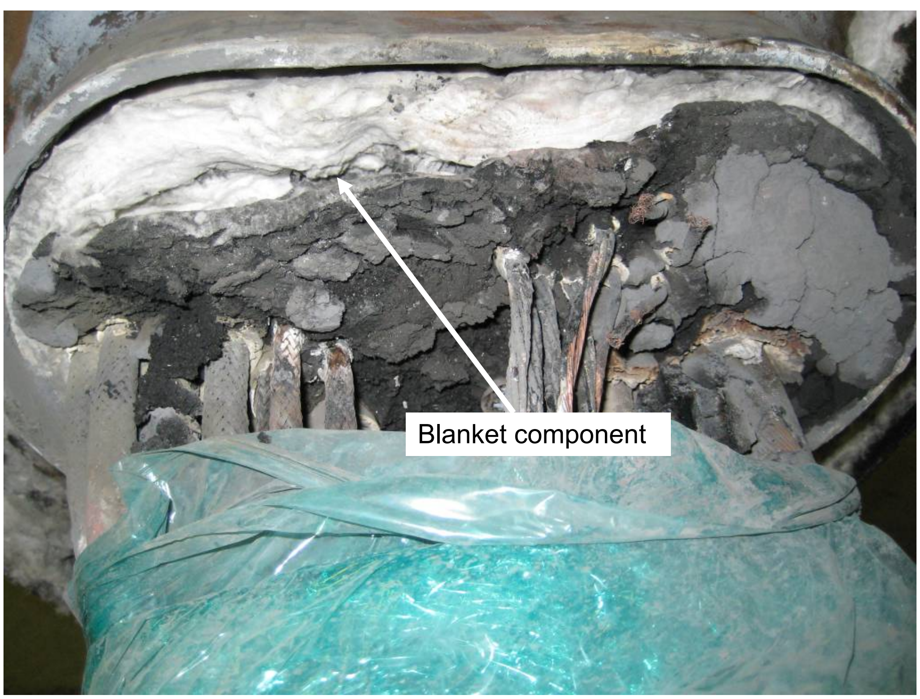

Figure 5.7.6.9: : FireSeal Inspection, Fire Side, Front View

In Figure 5.7.6.10, the sample shows no visible signs of damage, nor does the sample surroundings or hole in the material. The blanket material is unscathed and shows no signs of damage or issue.

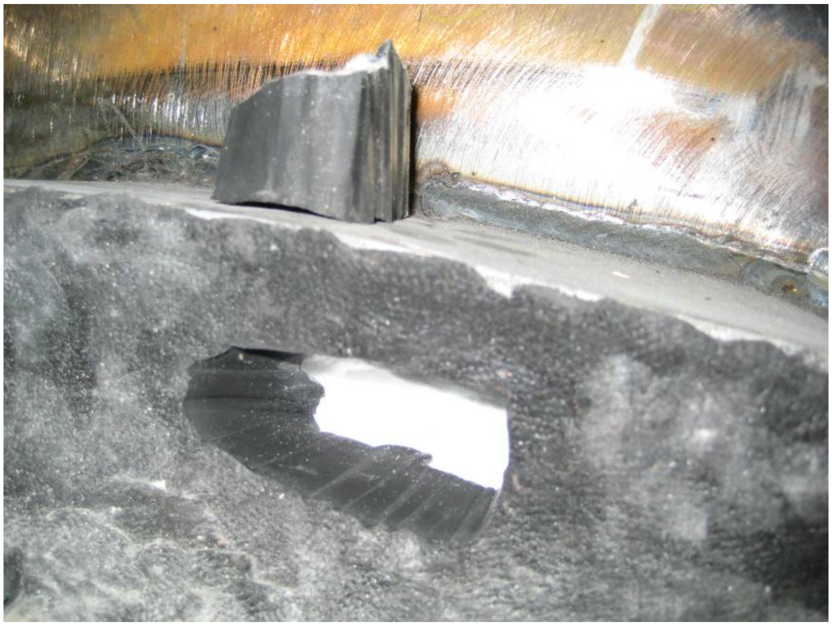

Figure 5.7.6.10: FireSeal Inspection, Non-Fire Side, Sample cut-out

It can be seen in Figure 5.7.6.11 that the Fire Stop system performed the best with respect to separation or movement away from engaging surfaces, such as cables or oval surfaces.

Figure 5.7.6.11: Fire Stop Inspection, Non-Fire Side, Side/Front View

The NOFIRNO system and the Fire Stop system are similar but use different inner structural support components. The separation and migration of sealant is likely due to the sealant itself and not necessarily to other system components. Factors that could contribute to these issues are cure time, testing during the cure cycle, application, and inner components exerting certain stresses on the sealant, tending to push the sealant in a certain way.

Although the sealant was pretty much disintegrated on the fire side of the demonstrator, the putty material held fast and only the very surface came out in small chunks. Otherwise, the putty system stayed stable and static. There is no sign of shifting, expansion or cracking, leading to stress fracturing. Figure 5.7.6.12 shows this to be the case. Figure 5.7.6.13 is a closer view showing some of the unburned areas (indicated by pink) remain steadfast.

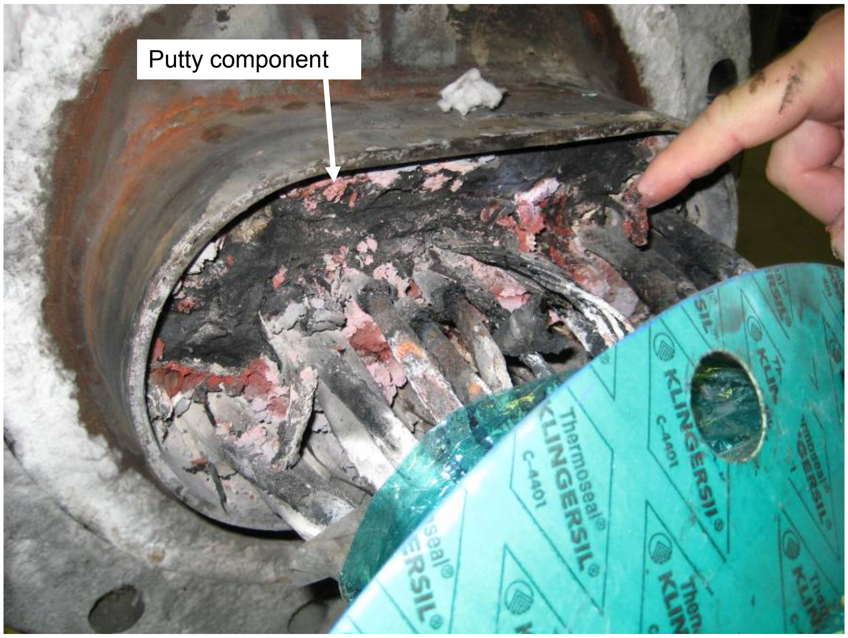

Figure 5.7.6.12: Fire Stop Inspection, Fire Side, Front View


Figure 5.7.6.13: Fire Stop Inspection, Fire Side, Front Close View

Another interesting point with the results is the fact the cable inner components did not necessarily react the same with all three demonstrators. The putty system seemed to be a good compromise between structural integrity and fire resistance. Cable component flow was limited, as shown in Figure 5.7.6.14. Again, this could be result of a variety of reasons, one of which might be small differences between the cables used.

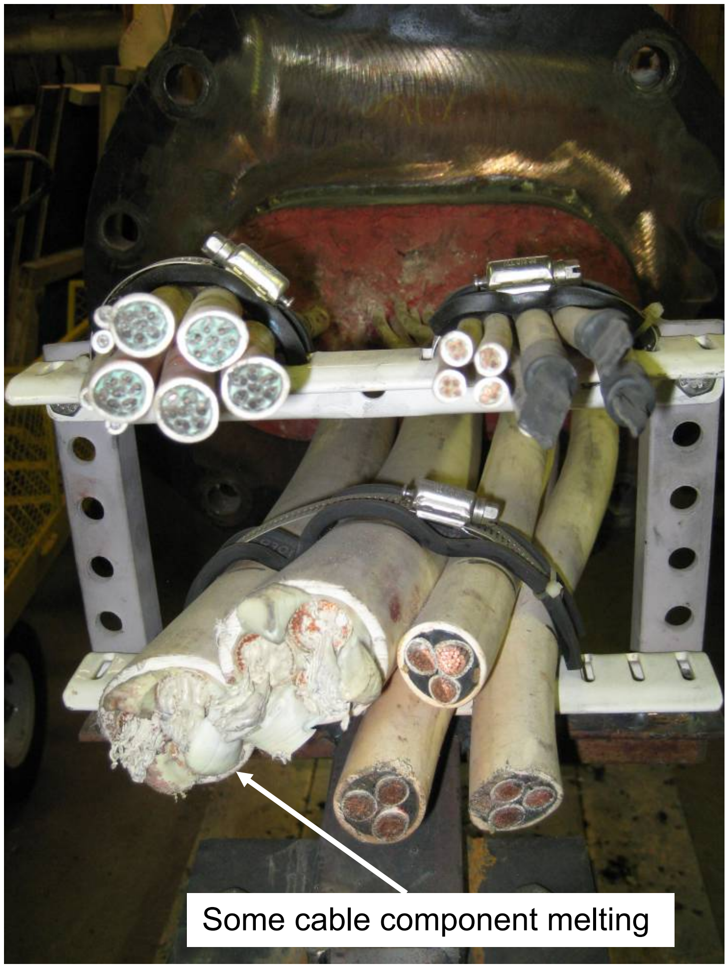

Figure 5.7.6.14: Fire Stop Inspection, Non-Fire Side, Front View

The sample taken from the non-fire side of the demonstrator shows the sealant is well engaged with the putty material. Unlike the other systems, it is likely the putty displaces more air inside the penetration space and thus, is itself not a great conductor of heat. The other systems, by default, use air as a sort of heat resistance block to assist with low heat conduction. The seal having engaged the putty to this degree, shown in Figure 5.7.6.15 and Figure 5.7.6.16, the likelihood of having large air gaps between the two components is reduced, and the stability of the whole system, from a mechanical or structural point of view, is greater. It would take substantially more effort to move the entire system than to move just the sealant layer. Upon examination, the sealant cured quite hard, possibly the hardest of all of the demonstrators. Although porosity and some other material characteristics was not tested specifically, all sealants seem to be similar in nature, dense and shiny on a sliced edge. No pores or dimples were noted with the sample or the prepared surfaces.

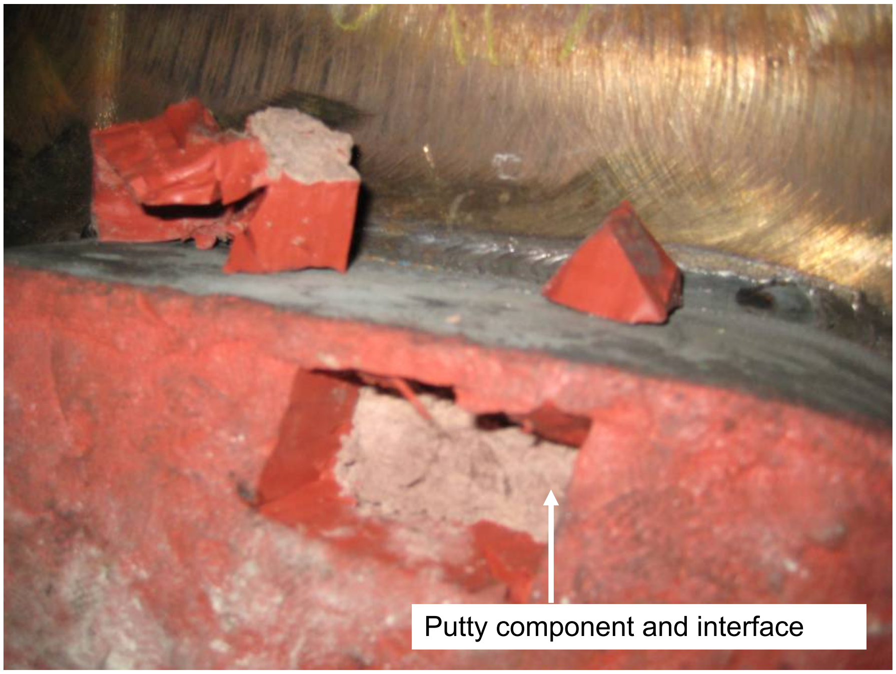

Figure 5.7.6.15: Fire Stop Inspection, Non-Fire Side, Cutout Sample

Figure 5.7.6.16: Fire Stop Inspection, Non-Fire Side, Cutout Sample Detail

As discussed in Section 5.7.7 and elsewhere, the best performing system based on the observed state of materials and system components, installation environment, and testing events is the FireSeal system, due to the strong putty structure and secure seal materials, followed by the other two. This is strictly based on one set of tests and corresponding environmental conditions, installations and demonstrator capabilities. To gain better appreciation for a more nominal results set, one would need to gather more imperial data over a longer time period, and probably over a wider set of operating conditions, to get better averages of performance. However, this is what this team has determined within the boundaries and scope of this project.

5.7.7 Testing Results Summary

Testing results were fairly similar across systems. Each system had issues originally with respect to hydrostatic testing, but this was likely due to cure times that were insufficient for this type of test (rather than a very low pressure compartment air test). Compromises were mainly at interfaces and repairs were easy to make. All other tests, given the context by which they were administered, were successful, with one compromised unit failing after the shock test. However, this was repaired by the distributor and the unit showed no weakness during the fire test.

The products and systems performed quite close to what the expectations were and what the manufacturers state in their materials describing the attributes and performance characteristics of the products. Regarding the types of tests performed, there were no product systems that would be characterized as to completely failing the tests. Although this is not considered a document endorsing any particular sealant system, it is safe to say that the methods employed for use of these types of products in demonstrators of this type is a reasonable approach to utilizing sealed cable penetration mechanisms.

5.8 Evaluate Results

It is a welcome observation that the materials and apparatus' tested survived the rigorous hydrostatic testing. The materials performed as expected, given manufacturer's installation instructions. What is not necessarily known are the dynamics of the testing. For instance, it is not known whether there was structural compromise from the fact the sealant materials moved considerably during the hydrostatic test. They bulged outward quite a bit, upwards of an inch, and then relinquished as the pressure was released. Did this create an interface engagement issue? It is not known, but something that may be part of a future test to be sure, when these types of events occur, or any event that creates a movement or similar dynamic, it is known with a level of confidence what the capabilities are of the materials, and system components, after the event.

Each product withstood the rigors of the individual tests, nearly as well as the literature would describe. All in all, each offered a different type of system, from cloth/fiber matting, which seemed to be the least effective from a structural standpoint, to rigid tubes, probably providing the most structural integrity. Until the fire testing was completed, it was not known if the FireSeal fire resistance would be better than the other products or not, just because of its physical make up. However, each performed nearly the same as the other.

5.8.1 Sealant Requirements

Section 5.1 discusses what current requirements and standards are used to assess penetrator performance, and details of particular penetrator design. Because so many combinations of size, dimension and cable fill exists for ovals using soft sealant or curable sealant systems, and because the systems themselves may be quite different with regard to system components, one should consider creating and leveraging existing qualification testing procedures and utilize more of a performance requirement than detailed requirement to indicate the type of penetration that can be used for a given application. For instance, the following represent some basic guidelines that could be used to develop requirements:

- The penetration opening cannot be greater than structure supporting bulkheads or decks.
- Penetrator styles and materials must be validated by various calculations and models, indicating the suitability to handle dynamic loads (this could form the basis of a drawing or standard similar to what is used today to fabricate flat ovals for use in structure and bulkheads).
- Penetrators must be welded using standard practices for the type of material used and the stress and strain expected to be seen at the point of juncture.
- Penetrators employing sealants must use sealants of a low smoke, non-combustible, non-toxic, flame resistant nature capable of spanning the life cycle of the ship without repair due to material longevity.
- Sealant systems must have the capability to be modified for future system transition with moderate to low risk in cost and schedule.
- When fully cured, the sealant must be capable of withstanding 27 psi of hydrostatic pressure at ambient conditions of 77 °F and 95% relative humidity.
- Sealants shall be applied at a minimum of ½" on either side of the penetrator with appropriate solid filler between the surfaces.
- Penetrators using sealant systems shall be installed with at least 40% cable fill, and not more than 90% fill in most areas. Actual fill rates will depend on the margins appropriated certain cableways for a particular ship design. The percent of a certain sized cable should be part of the possibilities and part of the boundaries of acceptable design. This deserves more attention.
- The sealant system shall be qualified to be acceptable; to qualify the sealant system, a demonstration unit, designed and built to the smallest and largest intended, with cable installed at the most and least fill rate, whereby several tests shall be performed. These tests would be called out specifically and require more consideration, but the minimum would be those used for this project testing.

This is the start of language that could be considered qualifying information where a sealant product, and the system design that is intended, can be shown to be acceptable for use on a Navy vessel.

5.9 Costs and Benefits of Using Soft Sealant Technology

It is difficult to determine the exact cost savings that are expected in using soft sealants versus block and transit systems. However, the following are relative costs, rough in nature and magnitude, qualified in some fashion, and are considered a starting point to a more detailed cost – benefit analysis or ROI (Return on Investment) evaluation. Some benefits are considered pretty straight forward, such as material costs per unit of material satisfying a particular size and configuration of cables or piping penetrating a bulkhead, while other costs are not so easily predicted, such as determining failure modes and costs to rectify failures such as during a space static pressure test. However, the values used here are considered average based on people's experiences and are meant to be a means to show relative product performance. Some people with a high degree of skill in using certain products will find it more routine and easier than those who use a variety of products and may have less detailed skill with a particular product, but have broad experience with several products. Many factors come into play and this is meant to target only the high level indicators that reveal whether pursuing a particular process and related products makes more sense on a larger scale than not.

5.9.1 Quantitative Assessment

A fairly straight forward cost is the materials costs on a per unit basis. Therefore, a per unit was chosen to be a square foot, and using 3 – 3/C #8 cables. The basis is the fact that there are literally hundreds of thousands of configurations that are possible and every configuration represents a different set of challenges that could impact costs, quality, time requirements, and certain impacts to personnel safety. An average is what has been targeted, so that it can be easily applied to the whole ship. It is assumed that a transit frame that is 2' X 4', carrying 15 cables of various sizes and representing a fill rate of 50%, may be able to be averaged when compared to a larger, 3' X 5' flat oval that is filled 50%, when applied across the entire vessel. Again, this is meant to be a rough estimate, probably on the order of ± 30-40% to lend insight between costs and benefits of the two primary options considered in this project. Therefore, the following primary cost drivers were considered:

- Material cost to do one square foot penetration with blocks and with soft sealant for 4 3/C #8 cables
- Labor costs or hours to install each system
- Typical failure rate and repair time for each system (realigning or replacing blocks versus patching sealants)
- Expected future ease of modification (just a percent savings expected)
- Approximate number of penetrations on the class ship(s) of interest

Table 5.9.1.1: General Cost Comparison Table is a comparison of various costs assessed for installation of both transit block systems and soft sealant systems. These costs are Rough Order of Magnitude (ROM) values that can be used to decide whether to pursue more detailed investigation, pursue qualification processes, and pursue change in design and methods. Sections 5.9.1.1 and 5.9.1.2 describe in more detail the aspects of the costs associated with initial installation and repair and upgrade. Some of the costs, such as that related to failure and repair, depend largely on how stringent requirements are (such as performance and testing specifications) and the skills and capabilities of those performing initial installation and repair. Block and transit systems are more mechanical in nature than sealant systems, but still require the technician to use sound judgment when laying out a penetration map of how the cables will be arranged. Standard practices manuals generally outline how best to arrange cable through a transit block system. As well, when using sealant systems, the technician must be able to not only apply the materials in the most sound method, but be able to identify issues with respect to curing, environmental impacts and any unsuspecting dynamic issues such as cable sagging or axial movement before curing has completed. This will be discussed in more detail below

Table 5.9.1.1: General Cost Comparison Table

NSRP Transit Sealant Project: General Cost Savings Data

Input Data Set	Estimated Cost Difference (pu measures for Transit Systems minus Soft Sealant Systems)					Approx. Number per Ship - Scaled for Materials	Approx. Number per Ship - Scaled for Labor	Estimated Cost Difference (calculated measures for Transit Systems minus Soft Sealant Systems)			
	Initial Installation		Repair		Failure Rate			Initial Installation		Repair	
	Materials	Labor	Materials	Labor				Materials	Labor	Materials	Labor
Averages: All	$380	3	($8)	1	20%	1,413	2,817	$805,482	6,326	($28,228)	565
Averages: Closest	$250	1	$8	1	20%	2,108	4,216	$527,003	4,216	($42,160)	843
Total Cost Savings Using Sealant Systems Over Transit Systems (using 2 closest averages)								**$484,842**	**5,059**		

Notes:

1. Failure rate is defined as not meeting a requirement, such as testing (testing is the basic vehicle referenced here to make that determination)
2. Values are approximations reflecting program experience, experimentation, etc.
3. Programs represents a per unit transit of 2" X 6"
4. Installation includes everything from the time the arrangement drawing is addressed to completion (planning cable routing, does not include testing)
5. The scale is applied to account for the difference with respect to the baseline size of 2" X 6", and the number of this scaled version as a percentage of overall on the ship
6. The above represents a very rough order of magnitude to determine just how much opportunity exists to using one technology over another.
7. Materials are in dollars, labor in hours.
8. Vendor estimates for cost differences is applied to the average scaled values
9. The closest program information is averaged to form one set of data
10. This data assumes the performance characteristics between the two methods is the same
11. It is assumed the soft sealant systems are given adequate time to cure
12. It is assumed the environmental conditions during installation and cure time are compatible with cure time requirements

Cost figures shown in Table 5.9.1.1: General Cost Comparison Table do not necessarily capture all costs in a detailed fashion, but the following primary items were considered and experienced leveraged to generate the table:

- Materials such as transit frames, oval penetrating bands, cost of blocks, cost of tubes of sealant and the corresponding filler materials
- Costs to deploy skilled labor
- Costs to maintain skill labor group
- Time, effort and costs associated with failure rates and cost of mitigation. Planning and scheduling transit and block systems; matrices and maps are generally laid out to orient the routing of the cables through the penetrator to maximize the utility of the penetrator; although guidelines exist to help the technician determine the best possible layout, it does take time and experience to complete this aspect of the tasking.

It is important to note that the figures in the chart are for multiple inputs drawn from various programs and sources. However, the information is considered conservative, and may possibly indicate a higher than expected benefit to using the sealant products, but further study is warranted (see Sect 6 for more detail).

The following are short descriptions of the columns of data. Shown in Table 5.9.1.1: General Cost Comparison Tableis only the average of the multiple data sources considered. Multiple types of ship programs were considered and averaged. Data is generalized and presented as averages. Some data was found to be closer in value on multiple programs. These were averaged and compared to all the data that was ultimately averaged. For the data assessed, these averaged results represent a range or boundary of expectations.

- Input Data Set: Multiple ship programs and vendor feedback was combined to result in averages of information for installation and repair of penetration unit types
- Estimated Cost Difference (pu measures): These are figures indicating the difference in labor and materials to install a 2” X 6” penetration transit and block device and a soft sealant system. This includes all preparation materials and includes all labor from the time the physical job is first planned to the time the work is completed. It does not include testing or cure time. It is already recognized that sealant materials will need certain time to cure and dry, from 30 hours for a soft cure (where a compartment air test can be run) to a hard cure, taking several days. Contained in this information is estimated repair costs and time, and typical failure rates, just for comparison purposes. In this case, the positive failure rate represents the transit and block system costs more than the sealant system, and that the failure rate for the transit block system is higher than the soft sealant system. This also assumes an adequate set and cure time has been allocated to be ready for a particular test. Repair materials for the transit block systems include blocks, possibly a compression plate and possibly a new frame. However, it is likely that the repair needed is only to compress the block arrangement more to close off any leakage that may be noticed. Generally, repair materials for sealants include the sealant materials and possibly a

section of filler if a pressure test damaged the filler materials and the corresponding interfaces.

- Approx. Number per Ship – Scaled for Materials: Data indicating the type and size of each penetration, whether a transit and block unit or sealant system, was gathered. It was then scaled against the baseline penetration unit of 2" X 6" according to area, and again by quantity simply by adding up the various sizes. It is a linear relationship that then uses a multiplier of 50% which effectively creates the scenario that quantifies each scaled value to be 50% more than the baseline (it is not two times the cost just because it is twice the size, but a value that is scaled). As the value in difference in area gets bigger, the larger the actual dollar effect (the percent difference is linear). Therefore, if an actual penetration is twice the size in area than the baseline, after applying the multiplier, the materials cost would be the same and the dollar value would be the same, but small. If the scaled value indicated one that was 10 times the baseline, then the actual value would be 5 times the baseline, and may represent a larger dollar value applied since the scaled value is larger. This is a simple way to keep actual costs from going out of control since it is probably not the case that the materials costs is directly linear with area of the penetrator.
- Approx. Number per Ship – Scaled for Labor: This scale is similar to that for materials except that the multiplier is not applied. This was done to indicate that there could be many more cables through the penetration, and even though the actual materials used is not necessary a linear multiple of the baseline, the labor involved in planning and installing more blocks, or applying more sealant around many more surface areas, could be a linear function. There are many more factors to installation than these multipliers and scaled value represent, but this is a starting point, and really meant to determine level of feasibility or viability.
- Estimated Cost Difference (per program): Initial installation and repair costs are those costs and hours multiplying the calculated scaled materials cost and labor values with the Per Unit values to indicate an estimated cost per program. The positive values represent how much less the soft sealant systems cost or take in time for installation and repair.

Items such as displaced work due to tasking duration and typical cost of quality, of both the installed product and the end product, were not integrated into this cost spreadsheet. However, they may have impact on the overall costs. For instance, the work that a technician could perform had the original assignment, in this case the installation of a penetrator, taken less time, the more time or more work the technician could do elsewhere, increasing overall productivity, from a tasks standpoint, and effectively increasing output. Costs of quality, with respect to the product being installed in and the end product being delivered, may be impacted by the type of system chosen to be installed. If repair is necessary (collected in the quantitative data in Table 5.9.1.1: General Cost Comparison Table), or performance issues cause downtime or lost capability (not captured in the table), there is costs associated with this, in terms of materials costs, direct and indirect labor costs, disruption to mission, and a host of ancillary costs that may or may not be monetary in nature.

The costs shown in Table 5.9.1.1: General Cost Comparison Table is a compilation of various program costs, averaged and rounded, to give the reader a ball park figure of the different costs if all penetrators on a ship were transits versus soft sealant systems. It is unlikely that all penetrator devices would be flat ovals (or variants) using soft sealant materials, but the actual number of devices being targeted can be scaled accordingly. The quantity of a particular type of penetrator used on the ship and the size of penetrator as compared to the baseline penetrator size of 2” X 6” served as linear multipliers to scale the actual values. This allows labor and material costs to be calculated and adjusted for the type and size of ship. The result is a per unit value and an applied and estimated actual value if all the penetrators were of one type or the other, indicating the difference between installing a transit system and a soft sealant system, which can then be applied to the hull type of interest, to gain an appreciation of expected savings or benefits. Although linear approximations may not be entirely accurate, they present a best first look at where opportunities lie and what type of investments will be necessary to receive certain benefits.

5.9.1.1 Material Costs

Material cost differences between transit and block systems and sealants can be summarized by the following table.

Table 5.9.1.1.1: Material Cost Differences Between Transit Systems and Sealant Systems

Item	Transit – Block	Soft Sealant	Tendency	Remark
Penetrating Frame	Precise frame with compression plates	Oval, rectangular frame, circular pipe	Transit frames tend to be more costly due to inherently more construction precision and engaging components	Oval, rectangular and pipe configurations offer more combinations of styles, leading to greater flexibility in the design of penetrating systems and routing of cables; they are also smaller since all the space can be used in the oval, rather than a transit frame mounted in an oval
Cable Engaging Medium – Initial Installation	Blocks, depending on the type of blocks, address a selected range of cable sizes	Inherently, packing and sealant media allows for a high degree of flexibility with respect to different cable sizes and inner packings are small enough or elastic enough to take on various geometries	Blocks typically have less cable usage space across a penetration (not always) than sealant systems with structural inner components, thus requiring more blocks per available cable area and less usable space across the penetration	Soft sealants rely on the cable arrangement and packing that is used for internal structural support. Otherwise, standard kits for bulk quantities of standard components can be used to meet many combinations of demands
Cable Arrangement	A general layout or map must be made to determine how the cable will be routed through the penetration; it is then optimized (more labor intensive, see Sect. 5.9.1.2); use of blocks will depend somewhat on this arrangement	Sealant and inner packing components will depend on general cable routing and arrangement.	The penetrating components cost and usage does not vary here between types of materials used; the larger cost savings come in the form of reduced labor in validating an arrangement	Primary savings is in labor
Repair	A repair may be nothing more than compressing the plate more, or it may require remounting the transit frame;	For small repairs, a patch could be installed easily; however, for large repairs threatening the entire	Making repairs due to not meeting a requirement after initial installation could require similar material changes between the two types of systems; large repairs	Soft sealant systems offer more flexibility, especially is the repair is minimal to moderate in scope; a transit might just need to be tightened up or the frame may be skewed and

Item	Transit – Block	Soft Sealant	Tendency	Remark
	material costs could vary considerably	penetration, this could mean all new materials	favor the block system, since the entire unit may not need repair	require considerable rework
Upgrade	It is likely new blocks will need to be installed to accept the new arrangement; depending on existing arrangements, a new size frame may be required	It is likely a small modification will be required for the arrangement by opening up an area of the existing arranged material, requiring little rework	The tendency is that sealant systems will require less materials to change an existing layout than a transit block system	Although materials may be minimal, labor demands could be similar if the existing arrangement make is difficult to cut in a new cable

Substantial differences in required materials may not be evident between the two types of sealant systems. Each system has caveats, but it is somewhat likely, as evident in Table 5.9.1.1.1: Material Cost Differences Between Transit Systems and Sealant Systems that the soft sealant systems may have more inherent flexibility for repair, upgrade and possibly less initial cost in materials due to the reduced precision products needed to complete the penetrations.

5.9.1.2 Labor Costs

Labor costs are addressed here assuming that sufficient resource skill is available for the installation and repair of both types of sealant systems, and that the training required to develop the skill base is comparable between systems. Each has its own demands. For instance, the technician needs to be able to assess the quality and general arrangement of the cable routing through the penetration to optimize the used space or area, but the transit block system technician generally lays out a map of the arrangement, chooses various block sizes and styles and validates the arrangement before starting the installation. Whereas, the soft sealant technician may lay out the cable routing arrangement to optimize area used, but the installation can start almost immediately since the arrangement can evolve as needed during the course of installation. The arrangement is not as dependent upon which cables are routed in a certain location as in the case of using transit block systems, especially if there are several different sizes of cables that penetrate the bulkhead or deck. The following table is offered as a summary, similar in nature to Table 5.9.1.1.1 except targeting the labor costs.

Table 5.9.1.2.1: Labor Cost Differences Between Transit Systems and Sealant Systems

Item	Transit – Block	Soft Sealant	Tendency	Remark
Penetrating Frame	If the transit frames are purchased, little difference is evident; if they are manufactured by the shipbuilder, because of the high precision and quality	Less precise a product, the penetrator will not take nearly the time needed to construct the transit frame and associated components	Soft sealant systems will tend to require less labor to manufacture the components than those of highly precise transit sealant systems	Oval and pipe penetrators can be mass produced with minimal attention paid to detail; transits need to be quality controlled to tighter tolerances, and may require further processing than sealant based systems

Item	Transit – Block	Soft Sealant	Tendency	Remark
	needed, they can be time consuming to construct			
Cable Engaging Medium – Initial Installation	Installing the blocks requires skill for alignment and determining whether a certain arrangement will work properly under compression	Using the sealant is a messy affair, but installs fairly easily and quickly, except where tight areas of the penetration arrangement are concerned; there my be extra time required to get the material properly installed around tight areas, increasing labor costs	In general, blocks are more labor intensive to install since it requires multiple steps, validating the arrangements and checking to be sure the chosen size blocks will work for the application	As with many skilled crafts, an experienced transit installer might be able to outperform a new soft sealant system installer. In general, there is some time and labor savings in using soft sealant systems, providing the environmental conditions are conducive to installation.
Cable Arrangement	A general layout or map must be made to determine how the cable will be routed through the penetration; it is then optimized (more labor intensive, see Sect. 5.9.1.2); use of blocks will depend somewhat on this arrangement	Sealant and inner packing components will depend on general cable routing and arrangement.	As mentioned in the previous remark, the savings generally comes from not having to validate every arrangement and chosen block size, comparing the information to the originally designed and chosen layout or arrangement.	Primary savings is in labor
Repair	A repair may be nothing more than compressing the plate more, or it may require remounting the transit frame; as with material costs, labor costs could be considerable	For small repairs, a patch could be installed easily; however, for large repairs threatening the entire penetration, much more time might be necessary to install a new cable through the penetration	If a patch is all that is needed, the repair itself might not take much time. However, the cure time might take several hours. In general, cure times is what makes the process so time consuming, not the repair itself.	Soft sealant systems offer more flexibility, especially if the repair is minimal to moderate in scope; a transit might just need to be tightened up or the frame may be skewed and require considerable rework; same comment as for the materials table
Upgrade	Block rearrangement and layout may be required, requiring a re-design,	Unless large changes are necessary, it is likely minimal time would be required to open	The tendency is that sealant systems will require less labor to change an existing layout than a transit block system	Labor demands could be similar if the existing arrangement make is difficult to cut in a new cable, such as a small cable between two larger

Item	Transit – Block	Soft Sealant	Tendency	Remark
	consuming time and labor	up a section to accept a new cable		one near the edge

Some products of blocking materials are more flexible than a traditional Nelson block unit, allowing for a wider range of cable sizes by peeling away precut sections of the inner portion of the block. These types of blocks still require the technician to validate a layout or arrangement, but are also more forgiving in the event the block size and opening is not exactly what is needed. It can also be said that each time a repair is needed to soft sealant systems, another cure schedule is needed. If a pressure test value of 30 mbar is used as a test value for the compartment pressure test, some manufacturers of the soft sealant materials require significantly less time than the 24-48 hour cure time to conduct the test, generally on the order of 2-4 hours. However, they caution that the cure has not completed and moving or straining the materials is not recommended. Although this doesn't add labor time, it does impact schedule, which is another crucial part of the process (typically tracked with metrics such as SPI, or Schedule Performance Index). As discussed in Section 5.3, other factors such as toxicity have an impact on labor costs, since more precautionary materials and clothing needs to be purchased and used, and using the materials may lead to longer periods of installation time due to delay.

5.9.2 Qualitative Assessment

Some qualitative benefits and disadvantages of using either transit block systems or soft sealant systems is shown in Table 5.9.2.1. Although not an exhaustive list of advantages and disadvantages, the table lends some insight into where one method or systems might offer benefits, while the other system may be considered a burden.

Table 5.9.2.1: Qualitative Assessment Table

Qualification Chart: Advantages and Disadvantages between sealant types and systems					
	Block System		Soft Sealant System		
	Advantage	Disadvantage	Advantage	Disadvantage	Remarks
Cure Time	X			X	Before testing can begin, soft sealants must cure at least 24 hours to allow low level compartment testing, 7 days for full cure
Planning Time		X	X		Soft Sealants don't require as much planning to lay out cables across penetration
Repair Time		X	X		Both could take little or a lot of time depending on how the units respond to testing; soft sealant troubleshooting and repair is generally easier
Damage Resilience	X			X	Blocks offer immediate resiliency to damage, while soft sealants are

Qualification Chart: Advantages and Disadvantages between sealant types and systems					
	Block System		**Soft Sealant System**		
	Advantage	**Disadvantage**	**Advantage**	**Disadvantage**	**Remarks**
					susceptible to damage while the material cures
Install Time		X	X		Due to the size of a banded transit frame, it may be a little longer to install in a bulkhead or deck
Size		X	X		Flat ovals and other penetrators that can house cable penetrations will be somewhat smaller for the same number and type of cables since penetration space is used more efficiently.
Future Revision		X	X		It is easy and straight forward to install an added cable in a sealed penetration that utilizes soft sealant. It is nearly as poking a hole in it, stabilize and reseal the area and let it cure.
Sealant MSDS	X			X	Sealant use must be controlled in accordance with all safety and environmental regulations; certain materials may not be allowed depending on their physical properties or how their properties are changed when subject to harsh environmental factors (i.e., flames and toxicity); this is more likely and issue with soft sealants than with block systems, but is not always the case
Installation Messiness	X			X	The soft sealants tend to be messy to work with, especially for unskilled technicians. Solvents are required for clean up. With new peel back block systems, they are easier to use than in the past.

Qualification Chart: Advantages and Disadvantages between sealant types and systems					
	Block System		**Soft Sealant System**		
	Advantage	**Disadvantage**	**Advantage**	**Disadvantage**	**Remarks**
Difficulty of Installation Due to Limited Access		X		X	Both types of systems are difficult to use when access is limited. However, it is a bit more difficult with sealants because it is imperative to get the material in the spaces to engage surfaces, and push it firmly into place, with control of the product. Although it is difficult with blocks, they can be manipulated a little more readily.

Two large aspects of advantage in using soft sealant technologies is the fact that as the work scope for a particular penetration changes (i.e., there is a design change, or the cable is moved from one penetrator to another), the means of accommodating the change with this method is greater than using a more structured penetration system. Literally, a hole needs to be made in the sealant, on both sides, the internal structures removed, and the new cable installed. It could take just a matter of minutes versus hours to do a repair or revision. This depends on several factors such as how much the configuration may change, whether the existing configuration can accommodate the new configuration when the blocks are laid out, and if a new cable (or originally installed cables for that matter) can be installed directly perpendicular to the penetration. This latter point is important to get a good seal when using a transit and block system. The importance of this point is less so with sealant systems, since the technician can compensate by how the material is installed along the cable, creating the interface to the rest of the sealant cross section.

6. Conclusions and Recommendations

Sealant systems are always going to be necessary in the marine industry. What this project focused on is identifying alternatives to hard block transit systems and determine what applications these alternatives might serve. From there, data has been compiled, and presented in the form of comparisons. Testing using prototype demonstration units that tested each product identified was conducted and although not considered a series of qualification tests, the testing was done as close to qualifying testing as possible. It was found that the sealants primary weakness during this series of demonstration installations and testing were the following:

- The materials are messy to use, and in the case of congested cables, difficult to address tight spaces between cables and around interferences
- Some of the systems explored were difficult to use
    - Putty fillers were somewhat difficult to manage in tight spaces around the cables, and had a tendency to push on smaller cables if pressed into position too hard
    - Matting materials did not offer a high level of structural integrity, although during shock testing, no compromise was found to exist during hydrostatic testing
- Some of the system components provided more structural integrity than others; some did not provide much structural support at all until the materials had completely cured, many days after installation
- The materials that showed compromise were repaired quite easily and compromise was difficult to assess (hard to visually determine; the technicians found the compromises during hydrostatic testing, but a bubble test could have revealed the compromise in a similar manner possibly, if both sides were compromised in similar areas)
- Horizontal installation did not seem to create much of an issue, but this may not be the case with vertical installations (I have witnessed vertical installations and the results of vertical installations and it does not seem to be an issue if the appropriate skills are used)
- Cure times are quite long, for a complete cure: many days (up to about 20 days) are needed for a complete cure; only 24-48 hours are needed for a product to cure well enough to conduct a compartment test)

Several advantages were observed during the course of using the sealant systems.

- Repairs were quick once found
- Installing future cables through penetrations is quick and easy
- The cables do not need to be in a particular position or orientation with respect to the penetration opening in order for the cable to be installed; however, the orientation must be able to accommodate the type of fillers that are used (i.e., matting and putty

materials do not require certain alignments, whereas tubes and rigid fillers will require a degree of alignment with the surface plane of the penetrator)
- Material costs appear to be less for sealants, as do labor costs; repair costs could be substantially less if the transit block system is compromised or blocks need to be removed to make a repair (the typical repair is tightening a compression plate which takes a small amount of time and zero materials costs)
- Simple, inexpensive tools are needed to apply the materials
- The end product is quite stiff and resilient, with a degree of elasticity and flexibility that is not brittle and susceptible to bulkhead or deck movement
- In certain instances, the materials may be difficult to apply (congested areas), but in most cases, the materials are fairly straight forward to apply
- Casualty situations are quickly compensated; however, it would be good if manufacturers could develop a material that is compatible with the sealant with a quick curing, engaging compound that allows for casualty repairs without the need to isolate a space and shut systems down

This project has looked at several manufacturer products and tested those against each other, comparing to the experiences with the hard block transit systems. More testing is warranted, but this could be testing in a qualification setting. It is believed the products and their components could be put through the rigors of qualification testing today. The testing procedures used in this project could be leveraged to be used for this qualification testing for a given program, or applied officially across programs. As tested, these products could be used in applications today without (or with minimal) change in system components or the sealant itself. One thing the manufacturers could supply is a cleaning solution that is considered easy to use, non-toxic, and effective in a fast clean environment.

The following recommendations are put forth for future work.

6.1 Future Work: Testing Cost Data Estimates

It is recommended that a series of demonstrators be used (leveraging the existing ones) and manufactured (built to house transit block systems) to test the actual installation of transit blocks versus sealant systems. It would include the same cable layout and types, and the time recorded would be from the time the work order is received, to the time the units are tested and considered complete and useable. This could be done in various configurations (large and small penetrators, utilizing different cable types and fill rates) that would represent a cross section of situations encountered in ship design. The data then could be compared to the estimates presented in this report as a means of verifying the accuracy of the estimate and the validity of the methods and multipliers used. Since this project already tested the products in different ways, only those tests that would be considered different would be part of the testing. Initial acceptance tests would be performed just to find out what products could actually be used (probably using a bubble or compartment test).

Another aspect of this task would be to install a modification of the existing penetration, and collect installation labor and materials costs for this as well. This would further lend validation to the estimates presented here. A part of this test might include conducting a repair and collecting data on this as well.

All the results could be interpolated to form another cost chart, similar to the one used in this report, to estimate costs benefits for a particular ship program according to the assumptions used by and constraints placed on the program.

6.2 Future Work: Qualification Program

A qualification program could be written in the form of test plans to gain acceptance of the use of these products on military vessels. This would be partially based on a set of requirements that may be written specifically for a program or for NAVSEA in general (probably in the form of a military standard). The requirements would need to consider a large sample of configurations, and might have separate qualifications for groups of configurations. Aspects of the sealant system to consider as contributing to a particular configuration are the following:

- Penetration geometry (flat oval versus round penetration)
- Cable Fill rate
- Penetrator medium (mostly for the purposes of this report, cables have been referenced as the penetrator, but this could also apply to piping, tubing, duct, etc.)
- Penetration material would need to be considered since this would effect the surface engagement of the sealant materials, its ductility and energy absorption during shock and vibration events, resistance to corrosion and fire
- Testing for toxicity, flammability, combustibility, smoke release, hazardous chemical release, etc. will need to be part of the official testing
- Actual water tank pressure testing might be conducted, simulating a penetration under water in the most severe conditions (i.e., 30' of head in very warm or cold sea water for a certain period of time); the amount of leakage would be profiled to show when compromise of any sort exists

These tests would need to be written and approved by a testing authority. The tests would need to target all the needs that a particular ship program would require, but be able to serve the greatest number of types of ships, military or otherwise, in the industry, so that costs could be shared across the greatest number of stakeholders. This would tend to keep costs reasonable and allow for more affordable products.

As with the recommendation in Section 6.1, it is likely that ranges of configurations would need to be defined. Since there are so many choices for penetrator configurations, a well defined set of rules is needed to distinguish what is most practical for a given application. For instance, penetrating a bulkhead that may flex a fair amount, with cables that are deemed critical, and a large number of them being small fiber optic cable, it is likely that a guideline to fill the surface area of the penetrator to a high value (such as 80%) to minimize the risk of a large cross section of penetrating sealant materials is the most part, unsupported at the surface (surface sheer is of concern regardless of the amount and type of filler material that is used). Therefore, a well constructed set of configurations, resembling the majority of those encountered on several different types of marine programs, but possibly targeting military programs, should be constructed for reference when moving through a qualification program. This would likely be part of a set of requirements, either universal or specific to a particular program.

6.3 Future Work: Universal Requirements

Performance requirements, and detailed system requirements, need to be generated and applied. Currently, for military programs these requirements are not very detailed and generally are contained in ship specifications or construction contracts. Creating a comprehensive set of requirements that target attributes and product characteristics, such as those found in Table 5.2.1, as well as product performance requirements, such as not passing more than 1 ounce of water across a penetration of a certain size and surface area of interface in a 25 hour period while under 30 psi in a test tank, will help to set a standard whereby sealant products must comply. As indicated by Table 5.1.1, there are many requirements that can be utilized and leveraged to create a standard, requirements set or specification for sealant systems. It could be integrated with existing specifications, or considered a stand alone set of standards, or a subset of what currently exists. Whichever method and approach is used, it is recommended that a set of standards present what is required so that the largest number of options may be available for review. Not all options will probably be available or applicable for a given application or point in time, but generally the more viable options available, the greater the chance to find a solution that is considered optimal or near optimal.

Requirements should include the types of applications the sealant may be suitable for, not just the attributes and characteristics of the materials used or the methods used for installation and repair. For example, these products may be used in small tubes for entry into panels and cabinets, creating other options, not just those employing glands, compression fittings and stuffing tubes.

It is suggested that a team, panel or committee be formed to deal with this set of requirements or standards. It would possibly be administered by a commercial entity, but certainly involve the military, and may even be a military specification. However, if it were developed for commercial use as well, it might just as well come from other certification or testing and licensing agencies who specialize in this type of work, such as NEMA (National Electrical Manufacturers Association), UL (Underwriters Laboratories), or IEEE.(Institute of Electrical and Electronic Engineers).

6.4 Future Work: Product Effectiveness

Certain improvements could be made to the sealant products and components, as well as ancillary products such as cleaning solutions, application kits and repair kits, as mentioned in Section 5.8 and Section 5.9. It is recommended the manufacturers work with the consumers or future consumers of sealant products to form ways to improve the downsides of using these types of products. One item of note and example is the messiness of these products and what it takes to clean the material off other surfaces and themselves. If cleaning solutions could be found that better enable the sealant materials to be cleaned, it is likely the materials will be more readily accepted. This is but one example of many that could be considered catalysts to getting these products on board and determining their longevity and life cycle performance.

Along the lines of installation, a possible future follow on effort would be to test the effectiveness of the products being installed in one layer. It is not known at this time how the sealant system as a whole would have to change to accommodate this type of installation, but it would be an idea worth pursuing, since it could substantially reduce the amount of installation time required to install the units and materials. For instance, the filler materials could be installed as they are currently, one layer of sealant applied, the sealant allowed to cure, and a cosmetic cap placed over each end to create an aesthetic end product. If the sealant, coupled with the filler materials, can withstand all relevant tests, then this might be a viable installation method. The thickness of this layer might be different than is used currently. This is also a possible area of investigation: sealant layer thickness. This would require some empirical testing to determine the minimal amount of material that could be used to perform according to requirements. Reducing the layer thickness would reduce the amount of sealant material used and tend to reduce labor installation time. However, testing would need to be done to determine what this thickness would need to be, to properly engage the surface areas for various configurations. This is outside the scope of this project, but might be something to pursue in follow on work, particularly for manufacturers.

An attribute not explored is the use of a sealant with shielding properties. This type of material would be used where the shield layer stops at a penetration, maybe at an electrical cabinet interface. This could be a product effectiveness assessment to determine the level of EMI attenuation provided by a particular type of sealant material, and then determine the applications suitable for such installations.

Many programs use products of this sort now, so the groups with the experience should definitely be part of this process.

All in all, it is the recommendation of this project team that the Navy, and other stakeholders, pursue these products in an official manner of qualification, survey their application to shipbuilding programs, and consider these products for use on board the ships that require water tight, fire resistance seals. It is likely not all products will be able to serve all applications, but certainly, there may be benefit realized, financial or otherwise, that can be re-invested to further improve the quality of ship products while reducing program cost while improving delivery timelines and flexible products. To this end, the Navy and other marine stakeholders are encouraged to consider the next steps recommended here and to contact the project team with any questions or clarifications needed in order to move in such a direction.

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8. Appendices

The appendices are meant to offer extended information, and the content is placed here so as not to distract during the review of the main document content. In some cases, due to the sensitivity of data, the information has been range valued or estimated, but is close to actual data to indicate the nature of the argument or point. Some information has not been included since distribution would need to be more limited and specific authorizations granted to use the information in this format. However, the appendix is left in the document to indicate to the reader that the topic was explored along the lines described within the appendix.

8.1 Project White Paper

The following is the white paper that was generated for the ETP and Executive Control Board for their review and ultimately, their decision making regarding whether to submit for funding, and whether to allocate funding, respectively.

Transit Sealant Evaluation

Proposer Identification: Lead – GD-BIW
Participants: Bollinger Shipbuilding, Huntington Industries – Newport News

Concept Description: The current practices for many ship designs call for transit block systems to be used when traversing watertight barriers. However, these systems are expensive, challenging to design for multiple and various cable passages, and may not fit every application in the most accommodating way. Sealant products are available that can be packed into and around air spaces created when cables (or other system components) pass through openings. Tubes, pipe sections and ovals can be used as the frames to hold cables and the water tight and fire resistant sealants.

This project would investigate products that are currently available (for military or commercial applications), demonstrate the effectiveness of the top three found, and determine whether the products can be qualified, in general terms, for use on Navy ships. The deliverable would be a report summarizing the findings. An example of products that are available is shown at the following websites.

http://www.cablejoints.co.uk/sub-product-details/duct-seals-duct-sealing-csd-rise-duct-seal
http://www.rise-systems.com/
http://www.stifirestop.com/ezpath/reliable_smoke_sealing.html

Project Goals and Objectives: The goals for the project include the following

- Find a suitable replacement for traditional transit block systems that will save time and labor
- Evaluate
    - The reliability of sealants (not susceptible to loosening during vibration or shock events)
    - The ease of installing cables in the future and re-packing the frame
    - The relevance with respect to the passage of cables (evaluate the challenges with designing geometric configurations compared to using transit block systems)

  - Cable component susceptibility to externally initiated compression and crush forces
  - Increase cable passage density
  - Any constraints on cable deratings due to passage density, heat transfer properties of the sealant, and cable passage geometry

- Through a testing and down select process, make recommendations that point to the most suitable candidates for further testing and possible qualification

Primary objectives for this project are twofold: provide history and evaluation based on this history on how certain transit systems are used, in what applications they are used and briefly explain the justification for their development and use. Secondly, after evaluating products on paper, determine, through a down select which products might be considered for further review due to their apparent flexibility, ease of use, overall applicability across several applications, among other considerations. Once down selected, the products will be demonstrated. The following will be used as high level critiquing guidelines for the down select and the demonstrator:

- Portability and handling characteristics (i.e., how easy is it to take from application to application, the number of tools needed, clean up, preparation requirements, contamination susceptibility, etc.)
- General insulating or conductive characteristics (i.e., electrical, fire, water)
- Engagement properties to 2 different types of metal: Al and steel
- Engagement properties to PVC cable jackets
- Applicable HazMat requirements and response plans needed
- Ability to meet water tight, fire tight/retardant, toxicity requirements

Methods and Procedures Required for Accomplishing Goals and Objectives: Utilize guidance documents, such as Mil-Std-2003-2, as reference when determining what is considered practical approaches and what requirements are typically levied on programs. Team participants will contribute their experiences to the history section of the report. Although this will not be considered a qualification program, the products will be tested and the results evaluated along as many lines as possible. A testing facility will be needed to perform the testing, done by an existing Navy lab, or contracted.

Simple tools will be used, such as Excel or Access to build cost benefit models that indicate what the value added is in using a particular product. Tables of preferences will be used in conjunction with the cost benefit. The report will reflect those preferences and target some high level requirements.

Previous and Current Related Work: No specific studies of this sort are known to have been conducted by the NSRP Electrical technologies Panel (ETP). Certain applications on various ship programs use products of this nature, but generally, these are specific to a particular design.

Deliverables: The deliverable will be a report that compares available products, physical and performance attributes and testing results. The report shall include the following

1) Description and history of transit use, and how it is used with block systems. This will include a cursory look at different styles of block systems.
2) Requirements review, describing how they are referenced for ship programs.
3) Review of sealant materials that are available for commercial sectors. This will include characterization of these products, leading to a down select for physical inspection and cursory testing.

4) Testing of the products and recording relative results.
5) Generate recommendations on the products that are determined to be the greatest asset or add the greatest value.
6) Recommend how requirements will change to accommodate products, or how products will evolve to accommodate updated requirements.

Benefits and ROI: Benefits and ROI will be offered in relative terms. For example, multiple platforms will be addressed to identify the opportunities that exist in the usage of certain sealants, whether levied as a requirement or on a selected basis for specific risk mitigation, the types of savings, and how best practices can be applied. Comparison of application expense and perceived lifecycle value earned will be presented.

Technology Transfer Approach: Upon completion of the final report, it will become available to the shipbuilding community through presentation at an NSRP ETP session or similar forum (such as an industry day). Any demonstrator products will be made available for inspection and evaluation by others, subject to all legal liabilities, obligations and requirements.

Expected Duration: Project duration shall not exceed 12 months from the time of contract or Technical Instruction execution; estimated duration is largely dependent upon contributor availability and depth of study.

Program Funds: Project cost is approximately $100,000

Cost Share: none presented

Weighting Factor: xx%, according to white paper charting

8.2 Product Comparisons

The following are product data sheets that were used to compare products. Each product has certain characteristics that are better than others.

Table 8.2.1: NOFIRNO Product Evaluation

Evaluation Criteria

The following are criteria that will be used to evaluate the performance of the tested transit sealant products. Some criteria are based on established standards and requirements, which are referenced for convenience.

Product: Beele Engineering RISE/NOFIRNO　　Tested by: ____________________

Date: ____________________　　Submitted by: ____________________

Item	Description	Min/Max Requirement	UOM	Value	Meets Requirement? (Y/N)	Testing Date	Comments/Remarks
1	Cure Time		hrs	0.5 - 1.0			Top Layer; humidity and temperature dependent
2	Operating Temperature - nominal		°F or °C	70 degrees C			Max continuous temp
3	Max. Operating Temperature		°F or °C	180 degrees C			
4	Flame Resistance		°F or °C				Low flame according to IMO Resoution A.653(16)
5	Water/Air Pressure Withstand	1.9 bar	psi/bar	2.5 bar			2.5 bar at 40% fill, max 588x288 transit
6	Packaging Size		in^3	310 ml			
7	Packaging		n/a	cartridge			
8	Delivery		n/a	cartridge			
9	Shelf Life		months	6			6 months guaranteed; 12 months if stored

Evaluation Criteria

The following are criteria that will be used to evaluate the performance of the tested transit sealant products. Some criteria are based on established standards and requirements, which are referenced for convenience.

Product: Beele Engineering RISE/NOFIRNO ____________ Tested by: ____________

Date: ____________ Submitted by: ____________

Item	Description	Min/Max Requirement	UOM	Value	Meets Requirement? (Y/N)	Testing Date	Comments/Remarks
							properly
10	Installation Temperature		°F or °C				
11	Cure Temperature		°F or °C				
12	Tensile Strength		Mpa	1.5			
13	Elongation		%	200			
14	Hardness		Shore A	45			
15	Tshear Strength		N/mm				
16	Peel Strength		N/mm				
17	Dielectric Strength		kV/mm				
18	Dielectric Constant						
19	Volume Resistivity		Ω/cm				
20	Consistency						
21	Viscosity		mPa*s				
22	Density		g/cm^3				
23	Tack Free Time		min				
24	Linear Shrinkage		%				
25	Thermal Conductivity		W/m*K				
26	Coefficient of Expansion		1/°K				
27	Vibration Testing - low	4	Hz				
28	Vibration Testing - moderate	60	Hz				
29	Vibration Testing - high	400	Hz				

Evaluation Criteria

The following are criteria that will be used to evaluate the performance of the tested transit sealant products.
Some criteria are based on established standards and requirements, which are referenced for convenience.

Product: Beele Engineering RISE/NOFIRNO

Tested by: ______________________

Date: ______________________

Submitted by: ______________________

Item	Description	Min/Max Requirement	UOM	Value	Meets Requirement? (Y/N)	Testing Date	Comments/Remarks
30	Shock Testing, Grade A	60	g's				
31	Min depth of fill			20mm			Both sides of transit
32							
33	Approvals	ABS Type Approval		2008 Steel Vessle Rules 1-1-4/7.7, 4-8-4/21.13			
34				SOLAS 74/78 (2000 Amendments) II-2/9.3.1			
35				IMO Resolution A. 754(18)			
36							

Table 8.2.2: Nelson FireStop Product

Evaluation Criteria

The following are criteria that will be used to evaluate the performance of the tested transit sealant products. Some criteria are based on established standards and requirements, which are referenced for convenience.

Product: Nelson FireStop CLK Silicone Sealant

Tested by: ______

Date: ______

Submitted by: ______

Item	Description	Min/Max Requirement	UOM	Value	Meets Requirement? (Y/N)	Testing Date	Comments/Remarks
1	Cure Time		hrs	312			Max for 1/2" thickness
2	Operating Temperature - nominal		°F or °C	43 degrees C			Max service temp
3	Max. Operating Temperature		°F or °C				
4	Flame Resistance		°F/hr or °C/hr				IMO A.754(18)
5	Water/Air Pressure Withstand	1.9 bar	psi/bar	9 psi			ABS Type Approval; SK738 round firestop only
6	Packaging Size		in^3/ml	18.5 in^3			Also 2 and 5 gallon pails
7	Packaging		n/a	cartridge			
8	Delivery		n/a	cartridge			
9	Shelf Life		months	18			From date of manufacture
10	Installation Temperature		°F or °C	4 to 32 degrees C			
11	Cure Temperature		°F or °C				
12	Tensile Strength		Mpa				
13	Elongation		%				
14	Hardness		Shore A				
15	Tshear Strength		N/mm				

Evaluation Criteria

The following are criteria that will be used to evaluate the performance of the tested transit sealant products. Some criteria are based on established standards and requirements, which are referenced for convenience.

Product: Nelson FireStop CLK Silicone Sealant

Tested by: ____________________

Date: ____________________

Submitted by: ____________________

Item	Description	Min/Max Requirement	UOM	Value	Meets Requirement? (Y/N)	Testing Date	Comments/Remarks
16	Peel Strength		N/mm				
17	Dielectric Strength		kV/mm				
18	Dielectric Constant						
19	Volume Resistivity		Ω/cm				
20	Consistency						
21	Viscosity		mPa*s				
22	Density		g/cm^3				
23	Tack Free Time		min				
24	Linear Shrinkage		%				
25	Thermal Conductivity		W/m*K				
26	Coefficient of Expansion		1/°K				
27	Vibration Testing - low	4	Hz				
28	Vibration Testing - moderate	60	Hz				
29	Vibration Testing - high	400	Hz				
30	Shock Testing, Grade A	60	g's				
31	Min thickness of layer		mm/in	1/2"			
32	Approvals	ABS Type Approval		2012 Steel Vessels Rules 1-1-4/7.7, Appendix 3, 4-8-4/21.13, 4-6-2/9.7.1, 4-6-2/9.7.2			
33				SOLAS Consolidated Edition 2009, Chapter II-2			

Evaluation Criteria

The following are criteria that will be used to evaluate the performance of the tested transit sealant products. Some criteria are based on established standards and requirements, which are referenced for convenience.

Product: Nelson FireStop CLK Silicone Sealant ____ Tested by: ____

Date: ____ Submitted by: ____

Item	Description	Min/Max Requirement	UOM	Value	Meets Requirement? (Y/N)	Testing Date	Comments/Remarks
				Pt.C/Reg.9.3			
34							
35							
36							

Table 8.2.3: ESSVE FireSeal FireStop Product

Evaluation Criteria

The following are criteria that will be used to evaluate the performance of the tested transit sealant products. Some criteria are based on established standards and requirements, which are referenced for convenience.

Product: ESSVE FireSeal FireStop Sealant 3000 ____ Tested by: ____

Date: ____ Submitted by: ____

Item	Description	Min/Max Requirement	UOM	Value	Meets Requirement? (Y/N)	Testing Date	Comments/Remarks

Evaluation Criteria

The following are criteria that will be used to evaluate the performance of the tested transit sealant products. Some criteria are based on established standards and requirements, which are referenced for convenience.

Product: ESSVE FireSeal FireStop Sealant 3000

Tested by: ____________________

Date: ____________________

Submitted by: ____________________

Item	Description	Min/Max Requirement	UOM	Value	Meets Requirement? (Y/N)	Testing Date	Comments/Remarks
1	Cure Time		hrs	168			20 - 30 min working time
2	Operating Temperature - nominal		°F or °C				
3	Max. Operating Temperature		°F or °C	250 degrees C			
4	Flame Resistance		°F/hr or °C/hr				A0 - A60 per IMO A.754(18)
5	Water/Air Pressure Withstand	1.9 bar	psi/bar	2.5 bar			
6	Packaging Size		in^3/ml	310 ml			
7	Packaging		n/a	cartridge			
8	Delivery		n/a	cartridge			
9	Shelf Life		months	12			
10	Installation Temperature		°F or °C	5 - 35 degrees C			
11	Cure Temperature		°F or °C				
12	Tensile Strength		Mpa	0.7			
13	Elongation		%	1300			
14	Hardness		Shore A	15			
15	Tshear Strength		N/mm				
16	Peel Strength		N/mm				
17	Dielectric Strength		kV/mm				"insulating"
18	Dielectric Constant						

Evaluation Criteria

The following are criteria that will be used to evaluate the performance of the tested transit sealant products. Some criteria are based on established standards and requirements, which are referenced for convenience.

Product: ESSVE FireSeal FireStop Sealant 3000 Tested by: ____________

Date: ____________ Submitted by: ____________

Item	Description	Min/Max Requirement	UOM	Value	Meets Requirement? (Y/N)	Testing Date	Comments/Remarks
19	Volume Resistivity		Ω/cm				
20	Consistency						
21	Viscosity		mPa*s				
22	Density		g/cm^3	1.4			$1400 kg/m^3$
23	Tack Free Time		min				
24	Linear Shrinkage		%				
25	Thermal Conductivity		W/m*K				
26	Coefficient of Expansion		1/°K				
27	Vibration Testing - low	4	Hz				
28	Vibration Testing - moderate	60	Hz				
29	Vibration Testing - high	400	Hz				
30	Shock Testing, Grade A	60	g's				
31	Min layer thickness		mm	15			Each side of penetration
32							
33	Approvals	ABS Type Approval		2010 Steel Vessels Rules 1-1-4/7.7, 4-8-4/21.13, 4-6-2/9.7			
34				SOLAS Chapter II-2 Reg.9.3			
35				IMO Resolution A.754(18)			

Evaluation Criteria

The following are criteria that will be used to evaluate the performance of the tested transit sealant products.
Some criteria are based on established standards and requirements, which are referenced for convenience.

Product: ESSVE FireSeal FireStop Sealant 3000   Tested by: ____________
Date: ____________   Submitted by: ____________

Item	Description	Min/Max Requirement	UOM	Value	Meets Requirement? (Y/N)	Testing Date	Comments/Remarks
36							

Table 8.2.4: RISE Product

Evaluation Criteria

The following are criteria that will be used to evaluate the performance of the tested transit sealant products.
Some criteria are based on established standards and requirements, which are referenced for convenience.

Product: RISE   Tested by: ____________
Date: ____________   Submitted by: ____________

Item	Description	Min/Max Requirement	UOM	Value	Meets Requirement? (Y/N)	Testing Date	Comments/Remarks
1	Cure Time		hrs	0.5 - 1.0			Top Layer; humidity and temperature dependent
2	Operating Temperature - nominal		°F or °C	70 degrees C			Max continuous temp

Evaluation Criteria

The following are criteria that will be used to evaluate the performance of the tested transit sealant products. Some criteria are based on established standards and requirements, which are referenced for convenience.

Product: RISE

Tested by: ______

Date: ______

Submitted by: ______

Item	Description	Min/Max Requirement	UOM	Value	Meets Requirement? (Y/N)	Testing Date	Comments/Remarks
3	Max. Operating Temperature		°F or °C	160 degrees C			
4	Flame Resistance		°F/hr or °C/hr				Low flame according to IMO Resoution A.653(16)
5	Water/Air Pressure Withstand	1.9 bar	psi/bar	2.5 bar			2.5 bar at 40% fill, max 588x288 transit
6	Packaging Size		in^3/ml	310 ml			
7	Packaging		n/a	cartridge			
8	Delivery		n/a	cartridge			
9	Shelf Life		months	6			6 months guaranteed; 12 months if stored properly
10	Installation Temperature		°F or °C				
11	Cure Temperature		°F or °C				
12	Tensile Strength		Mpa	1.15			
13	Elongation		%	125			
14	Hardness		Shore A	35			
15	Tshear Strength		N/mm				
16	Peel Strength		N/mm				
17	Dielectric Strength		kV/mm				
18	Dielectric Constant						
19	Volume Resistivity		Ω/cm				
20	Consistency						

Evaluation Criteria

The following are criteria that will be used to evaluate the performance of the tested transit sealant products.
Some criteria are based on established standards and requirements, which are referenced for convenience.

Product: RISE | Tested by: ____________

Date: ____________ | Submitted by: ____________

Item	Description	Min/Max Requirement	UOM	Value	Meets Requirement? (Y/N)	Testing Date	Comments/Remarks
21	Viscosity		mPa*s				
22	Density		g/cm^3				
23	Tack Free Time		min				
24	Linear Shrinkage		%				
25	Thermal Conductivity		W/m*K				
26	Coefficient of Expansion		1/°K				
27	Vibration Testing - low	4	Hz				
28	Vibration Testing - moderate	60	Hz				
29	Vibration Testing - high	400	Hz				
30	Shock Testing, Grade A	60	g's				
31	Min depth of fill			20mm			Both sides of transit
32							
33	Approvals	ABS Type Approval		2008 Steel Vessle Rules 1-1-4/7.7, 4-8-4/21.13			
34				SOLAS 74/78 (2000 Amendments) II-2/9.3.1; IMO Resolution A. 754(18)			
35							

Evaluation Criteria

The following are criteria that will be used to evaluate the performance of the tested transit sealant products. Some criteria are based on established standards and requirements, which are referenced for convenience.

Product: RISE

Tested by:

Date:

Submitted by:

Item	Description	Min/Max Requirement	UOM	Value	Meets Requirement? (Y/N)	Testing Date	Comments/Remarks
36							

8.3 Demonstrator Unit

8.3.1 Design and Construction

The following are the documents that were used to construct the demonstrator units. Some changes are not fully incorporated in this set of documentation.

National Shipbuilder Research Program, Electric Technologies Panel
Transit Sealant Evaluation Project

Demonstrator Design

Submitted by: Greg Stevens, BIW
5/22/12

1. Summary

This is part of a National Shipbuilding Research Program project aimed to evaluate the operating performance of various sealants available as alternatives to the more traditional transit blocking systems. This document outlines the basics for a demonstration unit that will be used and tested for various operating performance attributes of several sealants, whereby a relative evaluation will be conducted and recommendations made to the greater community on the feasibility of these sealants to be used in various applications.

The following is a depiction of the demonstrator unit design, showing individual components and their interfaces. This is meant to be used as reference during the review, manufacturing and testing processes of the project. As changes are made to the final baseline, revisions will capture the changes accordingly.

The unit has been designed using applicable ASME methods, as shown in the calculations section. The unit has been designed to meet typical pressure vessel standards, but the unit is not formally certified under any particular pressure vessel standard and is considered a testing mechanism for the purposes of sealant performance testing. It is important to note the demonstrator unit is meant to be used as a testing vehicle for sealant testing called out in the testing procedure, and the testing is not to be considered a rigorous set of qualification tests. Rather, this process is a means to evaluate the performance of several types of sealants in order to determine if their performance characteristics offer a possible alternative to traditional penetration sealing systems.

2. Components of the Test Demonstrator Unit

The following are the primary components of the testing demonstrator unit.

- One tank bearing gauges, a valve for pressure relief, a fill and drain valve, and a slip on flange that is welded to the tank
- Testing penetrator housing sealant sample and cables (four units will be manufactured, using the same cable orientations and sizes, to test 4 different sealants, one being considered a baseline for comparison purposes)
- Test support stand that mounts using a yoke mounted plate attached to the front plate housing the transit; this is used to support the cable bundle during shock and vibration testing and is removable

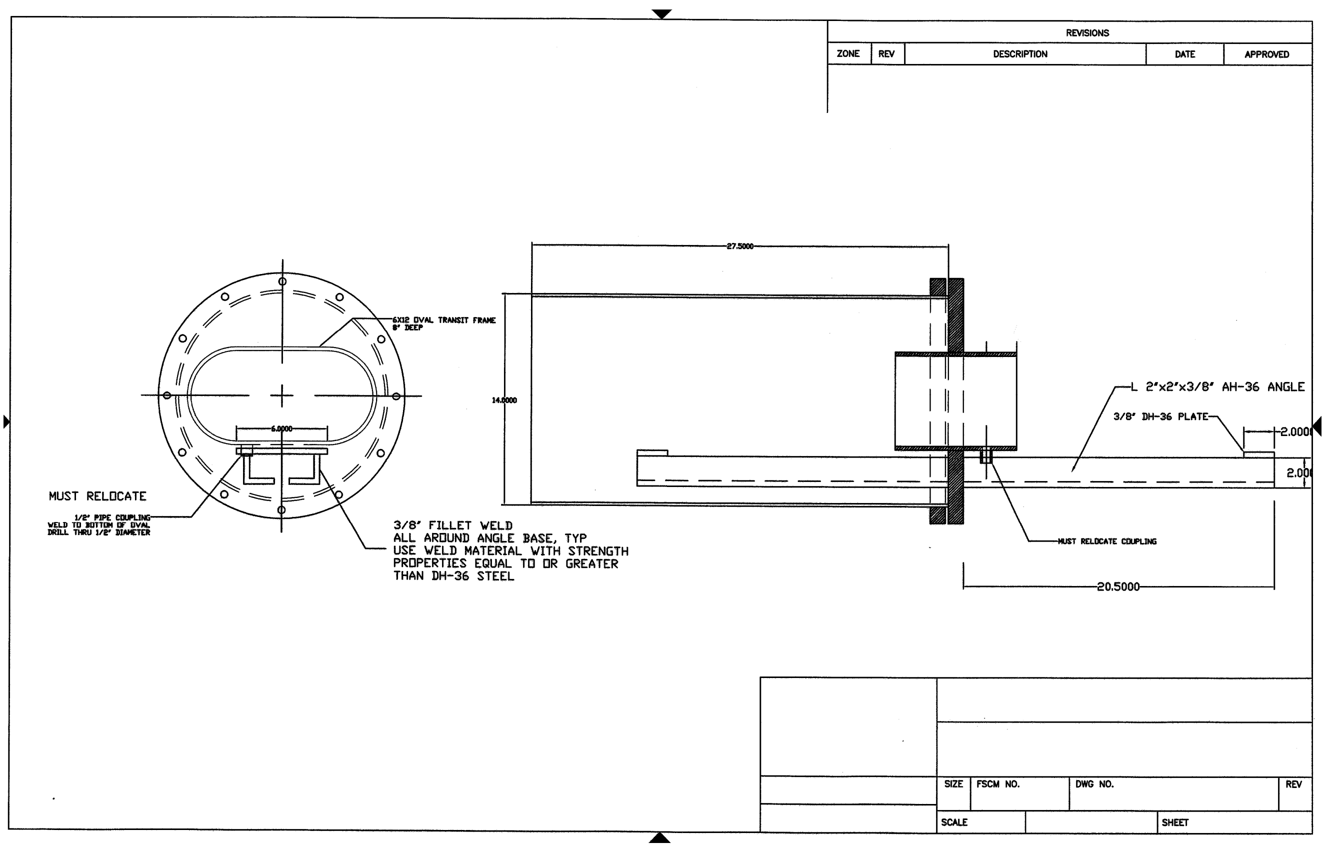
The following is the parts list for the demonstrator components.

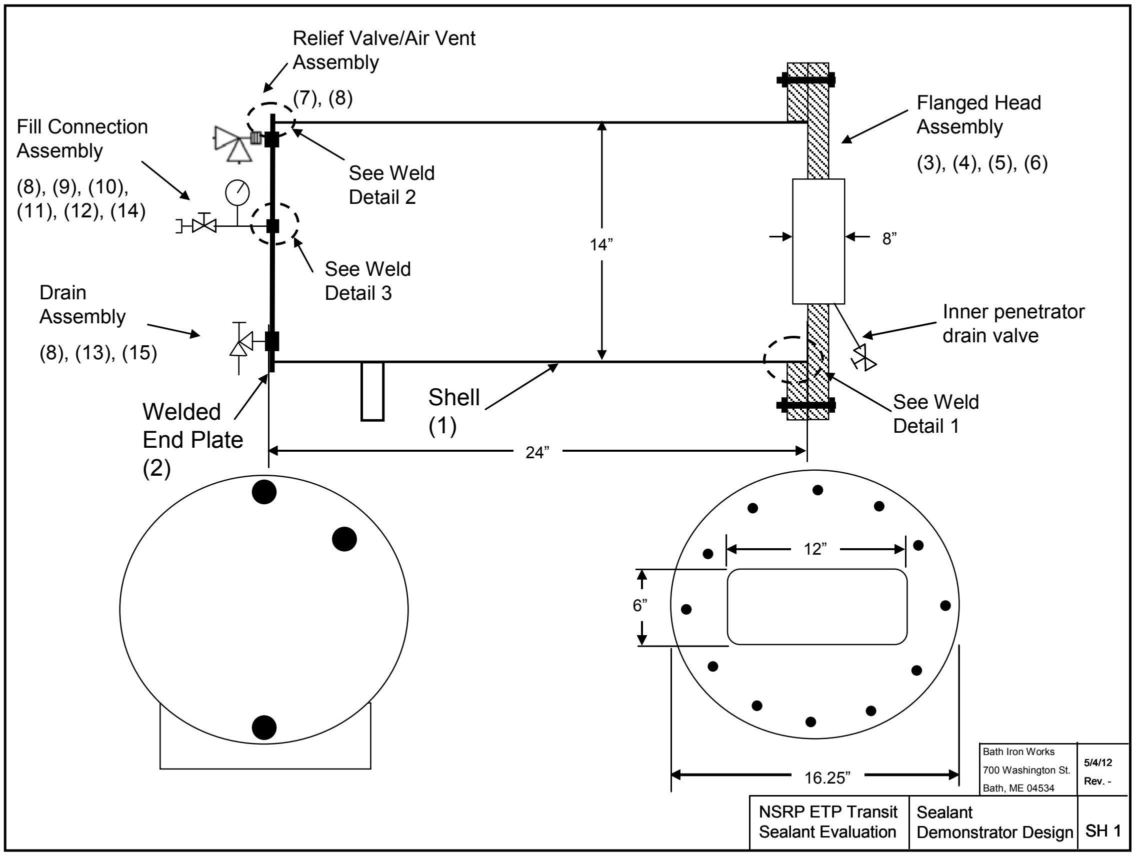
Parts List for NSRP ETP Transit Sealant Demonstrator

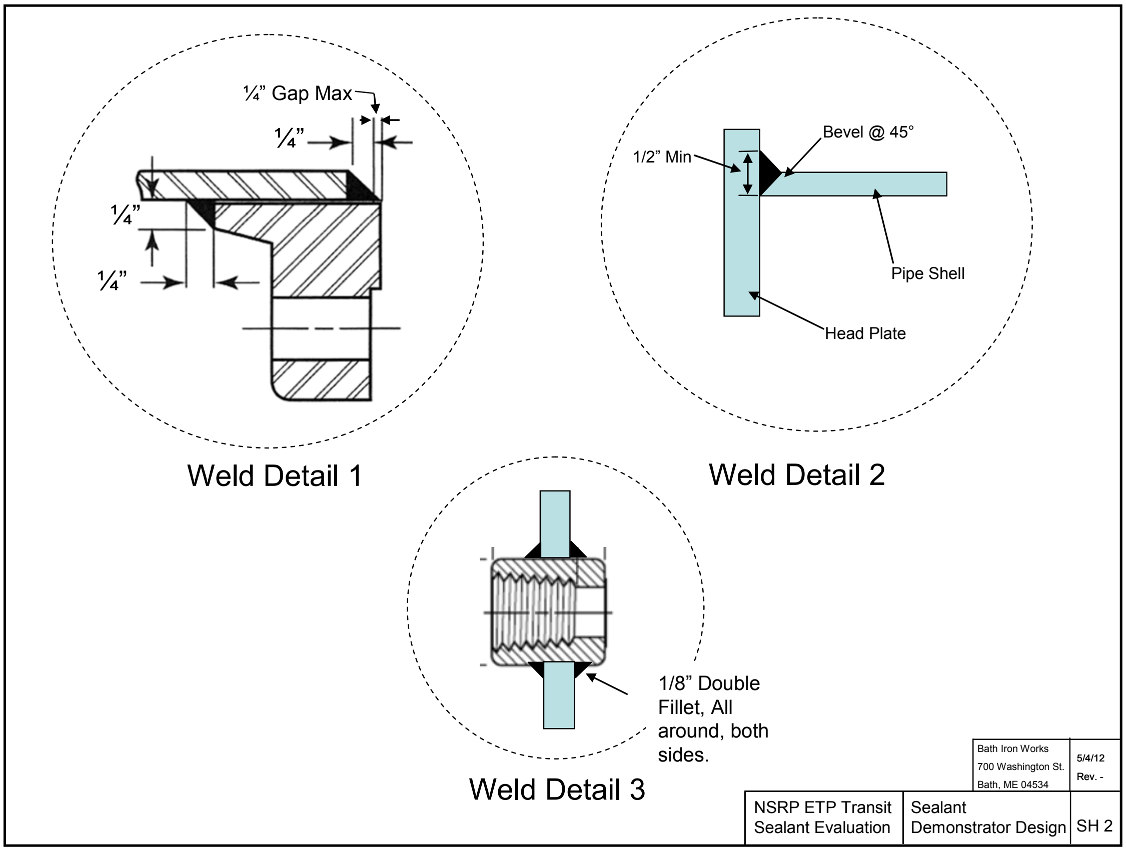
Item#	Desc	Specification	Size	Material	Qty	Measure	McMaster part #	
1	Pipe, Steel		14in NPS, Sch 10	ASTM A53B	2	ft	Special order or another vendor	
2	Plate, Steel		.25" thick, 15in Diameter	ABS DH36	1.6	sq ft	BIW Scrap or Cat #40669xxx	
3	Flange, Slip-On	ASME B16.5	14in NPS	A105	1	ea	Special order or another vendor	
4	Flange, Blind	ASME B16.5	14in NPS	A105	1	ea	Special order or another vendor	
5	Bolt, Hex	ANSI B18.2.2	1in dia x 4.5in long	ASTM A449	12	ea	91247A922	1"-8 thread
6	Nut, Hex	ANSI B18.2.2	1" -8 thread	Grade 5	12	ea	95505A610	3 packs of 5 each
7	Valve, Relief			bronze	1	ea	9889K39	Set pressure = 30 psi
8	Coupling, Half, Threaded	ASME B16.11	1/2" NPT, class 3000	Steel	3	ea	4513K73	
9	Pipe, thread both ends	Sch 40	1/2" NPS, 2" length	Brass	2	ea	4568K173	
10	Tee, Pipe, Reducing		1/2"x1/4"x1/2"	brass	1	ea	4429K226	
11	Valve, Globe, Straight		1/2"	Bronze	1	ea	4600K13	
12	Fill Connection		1/2" MNPT X 3/4" FGHT	Brass	1	ea	70815T45	
13	Valve, Globe, Elbow		1/2"	Bronze	1	ea	4600K43	
14	Gage, Pressure		3.5" face, 1/4" connection		1	ea	4089K64	0-60 psi Scale
15	Pipe, thread both ends	Sch 40	1/2" NPS, 1-1/2"" length	Brass	1	ea	4568K172	
16	1" channel steel		1" box	Steel	10	ft	for test stand	
17	Blind flange	ASME B16.5	14in NPS	A105	1	ea	for test stand	

3. Demonstrator Design

The following are figures showing the design of the demonstrator. These are reference figures and not official drawings. The front plate will be attached to the pressure tank for hydrostatic testing. Otherwise, the front plate and test stand support for the cables will be removed from the tank and placed into various test stands for shock, vibration and flame testing. Failure between tests will be checked using the soap and bubble test method. The flat ovals will be constructed according to BIW drawings SP002002 Rev A., and 8100-3504-0039 Rev N. The ovals shall be 8” deep. A support arm shall be installed on the front and back of the flange plate, as shown on the support diagram, using angle bar, such that the span of cable is sufficiently supported, 18 “ from the face of the flange, in a level fashion with respect to the supporting ground surface. At the end of each support shall be welded a 6” flat bar support spacer to the thickness necessary to align the top of the support with the inside of the transit. Installation of the support spacer shall be ninety degrees to the direction of the support structure. The 400 MCM cables shall be directly banded to the structure, and the other cables laid across the top of the larger cables, then banded as a group. A means of lifting the device shall be provided (this may be a lifting hook at the top of the flange and support unit either welded directly on the flange or a device attached to one of the flange bolt holes).

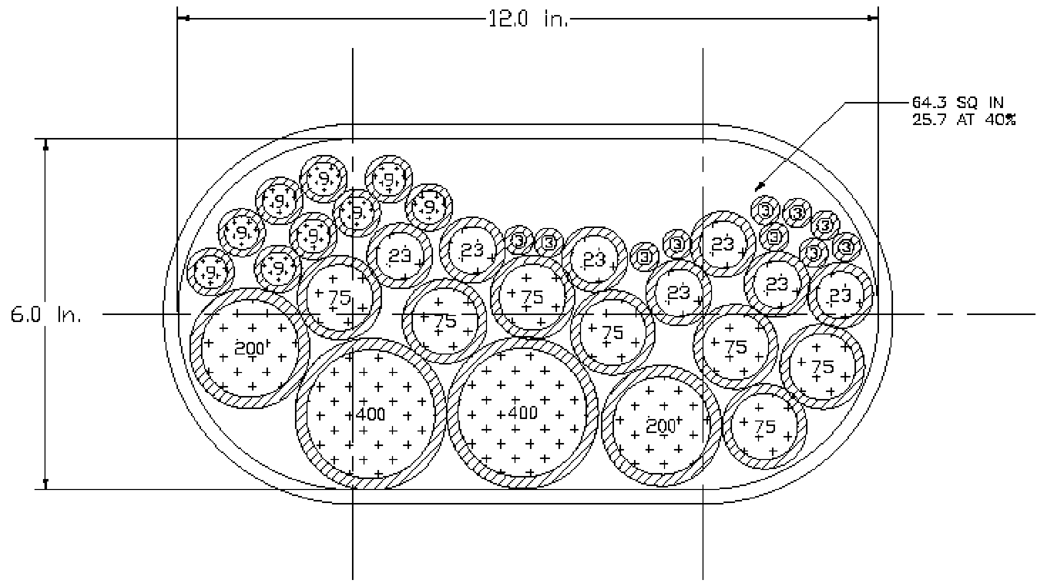



Relief Valve/Air Vent Assembly
(7), (8)
Fill Connection Assembly
(8), (9), (10), (11), (12), (14)
See Weld Detail 2
See Weld Detail 3
Drain Assembly
(8), (13), (15)
Welded End Plate (2)
Shell (1)
14”
24”
Flanged Head Assembly
(3), (4), (5), (6)
8”
Inner penetrator drain valve
See Weld Detail 1
12”
6”
16.25”
Bath Iron Works
700 Washington St.
Bath, ME 04534
5/4/12
Rev. -
NSRP ETP Transit Sealant Evaluation
Sealant Demonstrator Design
SH 1



4. Transit Penetrator Cable Installation

The cables shall be installed according to the following figure. Demonstrator unit cable geometry shall be as consistent as possible. The sealant and filler devices shall be installed per the respective manufacturer's recommendations and guidance. The penetration device shall be 40% filled with cable, and backfilled with the sealant manufacturer's recommendation, and in accordance with their recommendations for installation and inspection.



5. Packaging and Handling

The demonstrators shall be packaged on pallets, strapped down so that all members of the demonstration units are sufficiently supported and do not transfer strain of any kind on the sealant material holding the cable in place through the oval penetrating device. Any type of strain that will compromise the integrity of the seal shall be mitigated by further support mechanisms. Packaging shall be done in a fashion that will support air or ground transport.

5. Calculations

Electrical Transit Test Tank

April 24, 2012

Ken Abbott - Bath Iron Works - 207-442-5410

NOTES:

1. Tank is designed with guidance from the ASME Boiler & Pressure Vessel Code Section VIII Division 1. However, because this tank is for testing and not permanent use, it is not required or intended to be certified by ASME or any other governing board.

1.0 Tank Geometry

1. Body of the tank is 14-inch NPS, Schedule 10 ASTM A53B Steel pipe, about 24 inches long.
2. Welded head material is ABS DH36 High Strength Steel
3. One end is welded flat plate that contains a fill, drain, and vent/relief connections.
4. The opposite end is a bolted cover that uses a 14" NPS B16.5 Slip-on flange and B16.5 blind flange that contains the cable transit to be tested.
5. The tank is designed to sit horizontal.

2.0 Tank Design Data

Design Pressure:	30 psig
Test Pressure:	45 psig
Relief Valve:	30 psig
Design Temperature:	Ambient (72F)
Fluid:	Fresh Water
Material:	ASTM A53B
Corrosion Allowance:	None
Weld Inspection:	VT, PT

3.0 Shell Required Thickness

Calculations done per UG-27 ASME B&PV Code Section VIII, D1.

$S_{max} := 10.2\text{ksi}$ Maximum allowable stress of ASTM A53 Type E Grade A Welded Pipe per ASME B&PV Code Section 2 Part D.

$P := 30\text{psi}$ Design Pressure

$d := 14\text{in}$ Outside Diameter of pipe

$t := .25\text{in}$ Schedule 10

$r := \frac{d}{2} - t = 6.75 \cdot \text{in}$ Inside radius

$E := 1$ Weld Efficiency. The shell is welded pipe, however per UW-12e, it can be considered seamless.

Required Thickness (Circumferential Stress): $t_{reqC} := \frac{P \cdot r}{S_{max} \cdot E - .6 \cdot P} = 0.02 \cdot \text{in}$ 1/4" (.25) Pipe OK

Required Thickness (Longitudinal Stress): $t_{reqL} := \frac{P \cdot r}{S_{max} \cdot E - .4 \cdot P} = 0.02 \cdot in$ 1/4" (.25) Pipe OK

4.0 Bolted Head Design

The bolted head of the tank is made up of an ANSI B16.5 slip-on flange welded to the pipe shell and a ANSI B16.5 blind flange bolted to the flange to form the cover. This blind flange will be cut out to contain the cable transit that will be tested.

These pre-fabricated parts are allowed per UG-44 of the ASME B&PV Code with no supporting calculations.

The flanges will be A105 carbon steel.

4.1 Required Bolt Loads - Appendix 2-5c ASME B&PV Code

$OD_{rf} := 16.25in$ OD of the raised face of the flange (ASME B16.5)

$OD_{gsk} := 16in$ OD of gasket

Use smaller of the ODs.

$ID_g := 14.63in$ ID of the gasket (ASME B16.20)

$N := \frac{OD_{gsk} - ID_g}{2} = 0.685 \cdot in$ Gasket contact surface (width) is the OD of the raised face of the flange minus the ID of the gasket divided by 2.

$b_o := \frac{N}{2} = 0.342 \cdot in$ Gasket seating width per Table 2-5.2.

$b := .5 \cdot \left(\sqrt{\frac{b_o}{in}} \right) = 0.293$ Table 2-5.2

$G := OD_{gsk} - 2 \cdot b \cdot in = 15.415 \cdot in$ Diameter of the center of the gasket

$m := 4.2$

Gasket Properties: Garlock BlueGard 3000, 1/16" thick

$y := 3050psi$

Required Bolt Load, Operating Condition: $W_{m1} := .785 \cdot G^2 \cdot P + 2 \cdot (b \cdot in) \cdot \pi \cdot G \cdot m \cdot P = 9.167 \times 10^3 \, lbf$

Required Bolt Load, Gasket Seating. $W_{m2} := \pi \cdot (b \cdot in) \cdot G \cdot y = 4.322 \times 10^4 \, lbf$

4.2 Required Bolt Area - Appendix 2-5d ASME B&PV Code

$S_a := 23ksi$ ASTM A449 Bolt allowable strength per ASME B&PV Code Section 2 Part D, Table 3 line 11.

$S_b := S_a$ Design temp is the same as atmospheric.

Required Bolt Area, Operating Condition: $A_{m1} := \frac{W_{m1}}{S_b} = 0.399 \cdot in^2$

Required Bolt Area, Gasket Seating: $A_{m2} := \frac{W_{m2}}{S_a} = 1.879 \cdot in^2$

ANSI B16.5 14" Flange uses 12, 1" diameter bolts.

$D_s := 22.307mm = 0.878 \cdot in$ Tensile stress area of a 1" bolt.

$A_b := \frac{\pi \cdot D_s^2}{4} = 0.606 \cdot in^2$ Area of one bolt.

$A_{bTot} := A_b \cdot 12 = 7.269 \cdot in^2$ Total area of 12 bolts.

Total bolt area is greater than required. Bolt area OK. Use 1" Bolts.

4.3 Flange Design Bolt Load - Appendix 2-5e ASME B&PV Code

$W_{op} := W_{m1} = 9.167 \times 10^3 \, lbf$ For Operating Conditions.

$W_{gs} := \frac{(A_{m2} + A_{bTot}) \cdot S_a}{2} = 1.052 \times 10^5 \, lbf$ For Gasket Seating

Available bolt load: $F_b := A_b \cdot S_a = 1.393 \times 10^4 \, lbf$

Bolt load for gasket seating: (The greater load) $\frac{W_{gs}}{12} = 8.767 \times 10^3 \, lbf$

OK - Torque bolts to create this amount of force for gasket seating, or use gasket manufacturer's recommendations.

4.4 Flange Bolt Torque

$T := .2 \cdot D_s \cdot \frac{W_{gs}}{12} = 128.326 \cdot ft \cdot lbf$

dLY

Torque bolts to 130 ft-lbs minimum

Use 1" ASTM ~~A193 B5~~ A449 Bolts.

Can go up to max 450 ft-lbs to get a tight seal.

B16.5 recommends 4.5" bolt length.

5.0 Welded head Design

$P = 30 \, psi$

$D := 2r = 13.5 \cdot in$

$S := 40ksi$ ABS DH36 Max allowable stress per NVR 1-4-3

$E := .5$ Per Table UW-12

$m := \frac{t_{reqC}}{t} = 0.08$ Use weld shown in Figure UG-34g

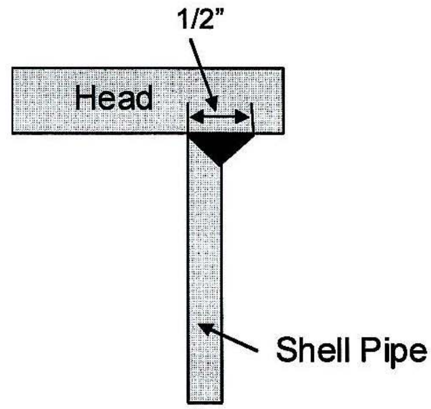
$C := .33m = 0.026$

$C := .2$ Minimum C must be used.

Required thickness: $t_h := d \cdot \sqrt{\frac{C \cdot P}{S \cdot E}}$ $t_h = 0.242 \cdot in$

Use 1/4" plate, overall diameter = 15".

Use joint e-1 of Figure UW-13.2



8.3.2 Demonstrator Construction

The following are snap shots and commentary on the construction, inspection and hydrostatic testing at BIW. The information is also available as a Power Point presentation that may offer more clarity in certain frames.

8.3.2.1 Nelson FireStop EGS

The Nelson FireStop EGS system uses a putty material that is installed as a filler between the cables directly, without installing a sleeve or barrier inside the penetrator. The putty is installed throughout the space to create a thermal barrier of as great a value as possible. We found, in order to get the filler to stand on its own, in the large holes where there were no cables, we needed to make the filling 2 – 3 inches thick, the directions were to place ¾ of an inch. This way it did not fall back in on itself when the outer sealant was applied. Once the holes were all sealed with the filler, the outer sealant was applied.

The sealant appeared to be very wet when applied, and did not stick to the cables as well as expected. It took about 72 hours in order to dry to the touch, and appeared to still be quite wet inside. We could tell this by pressing in one area and watching another area bulge out. The product required touch up as it dried and shrunk away from the cables. This was anticipated.

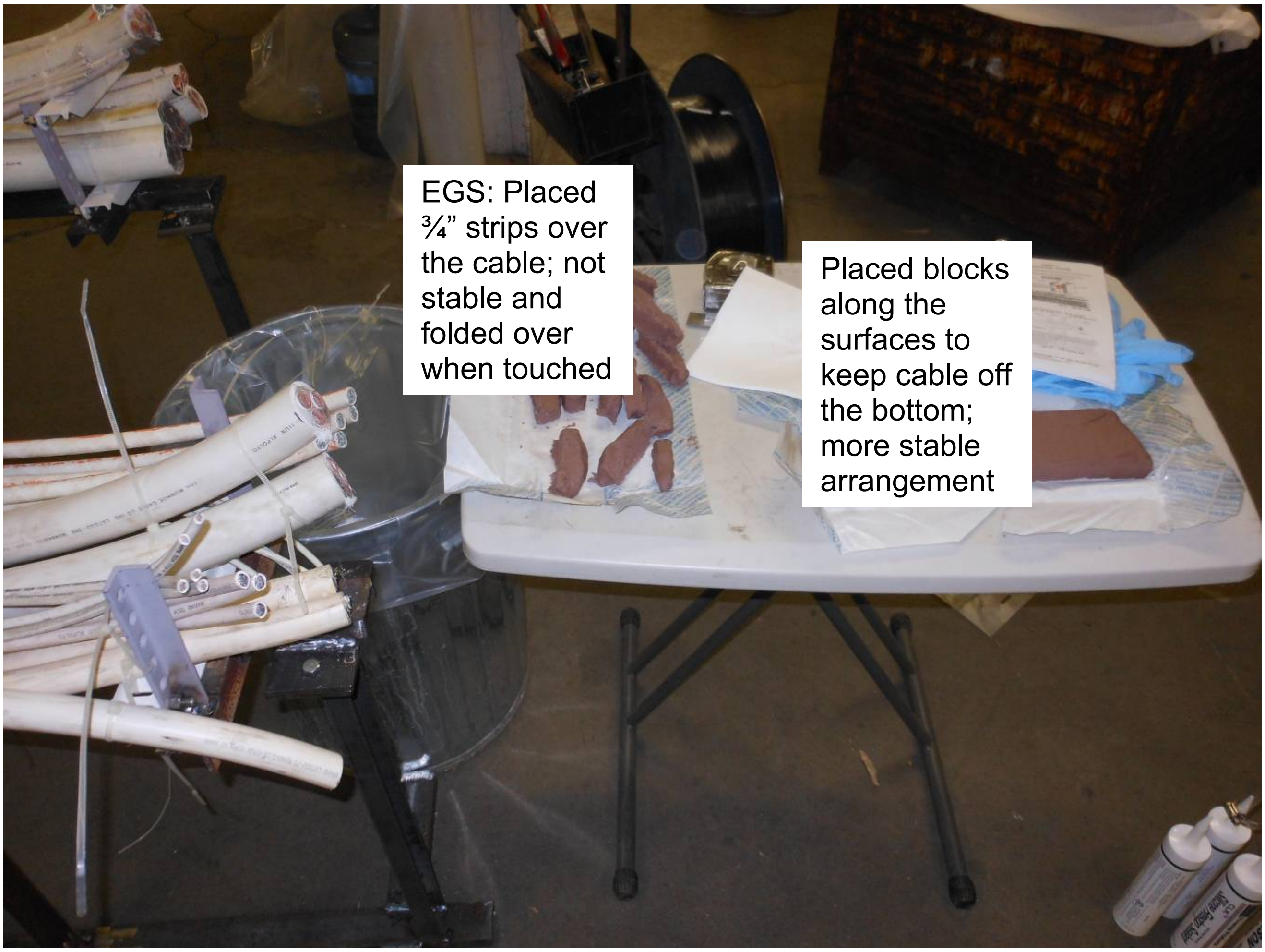


Figure 8.3.2.1.1: FireStop System - EGS Putty Material

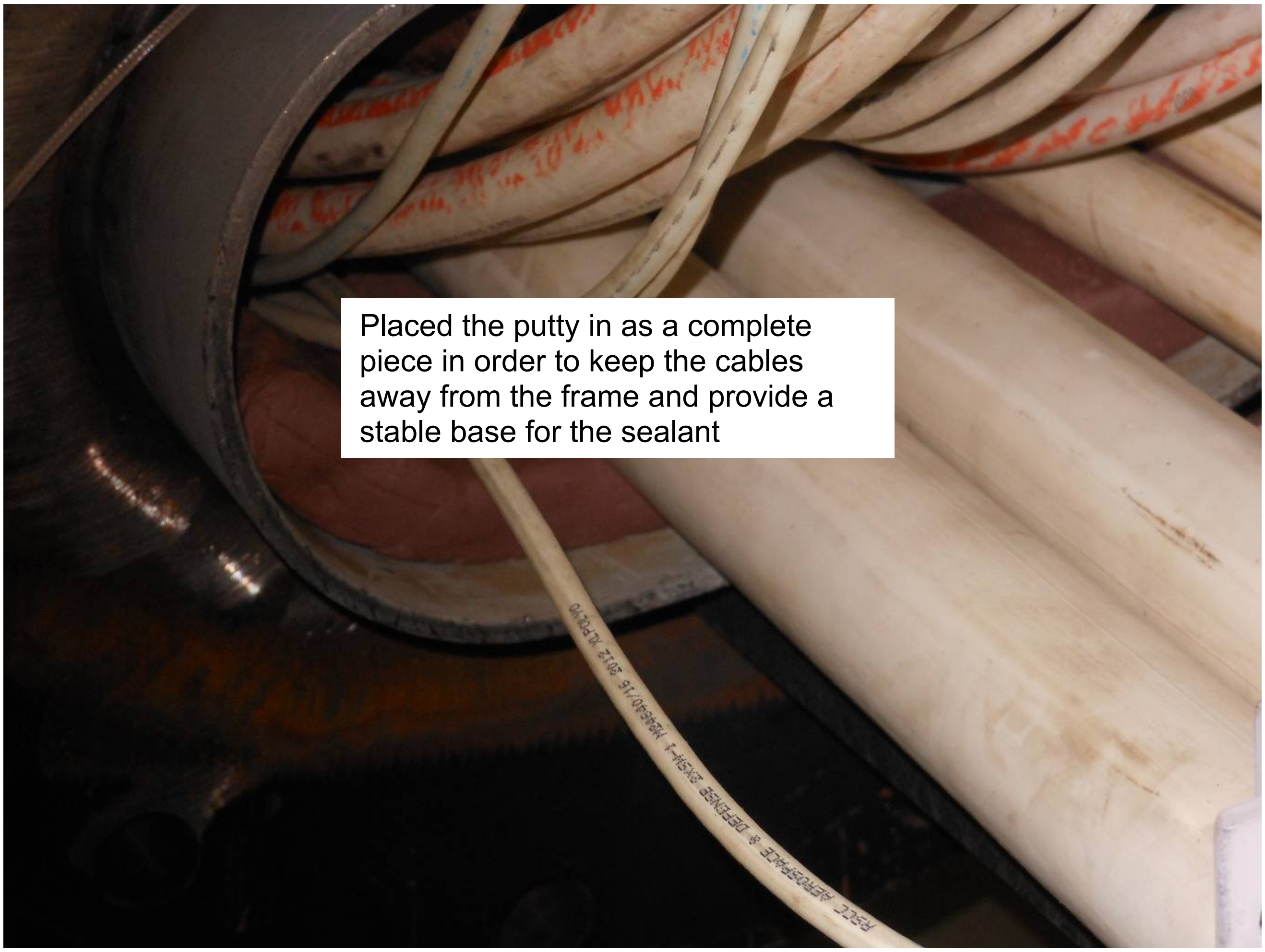


Figure 8.3.2.1.2: FireStop System - Putty Installation

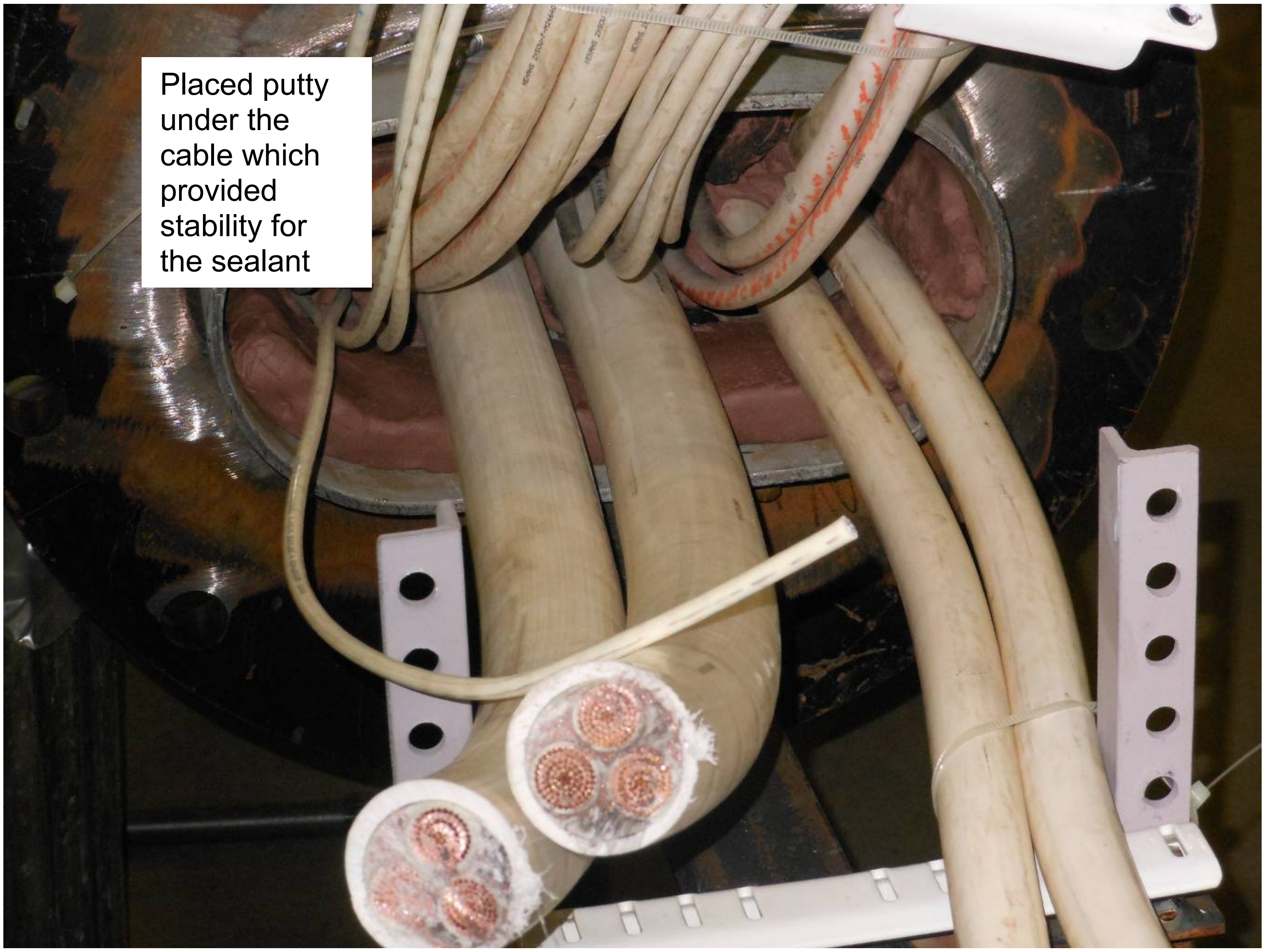


Figure 8.3.2.1.3: FireStop System - Putty Installed Under Cable

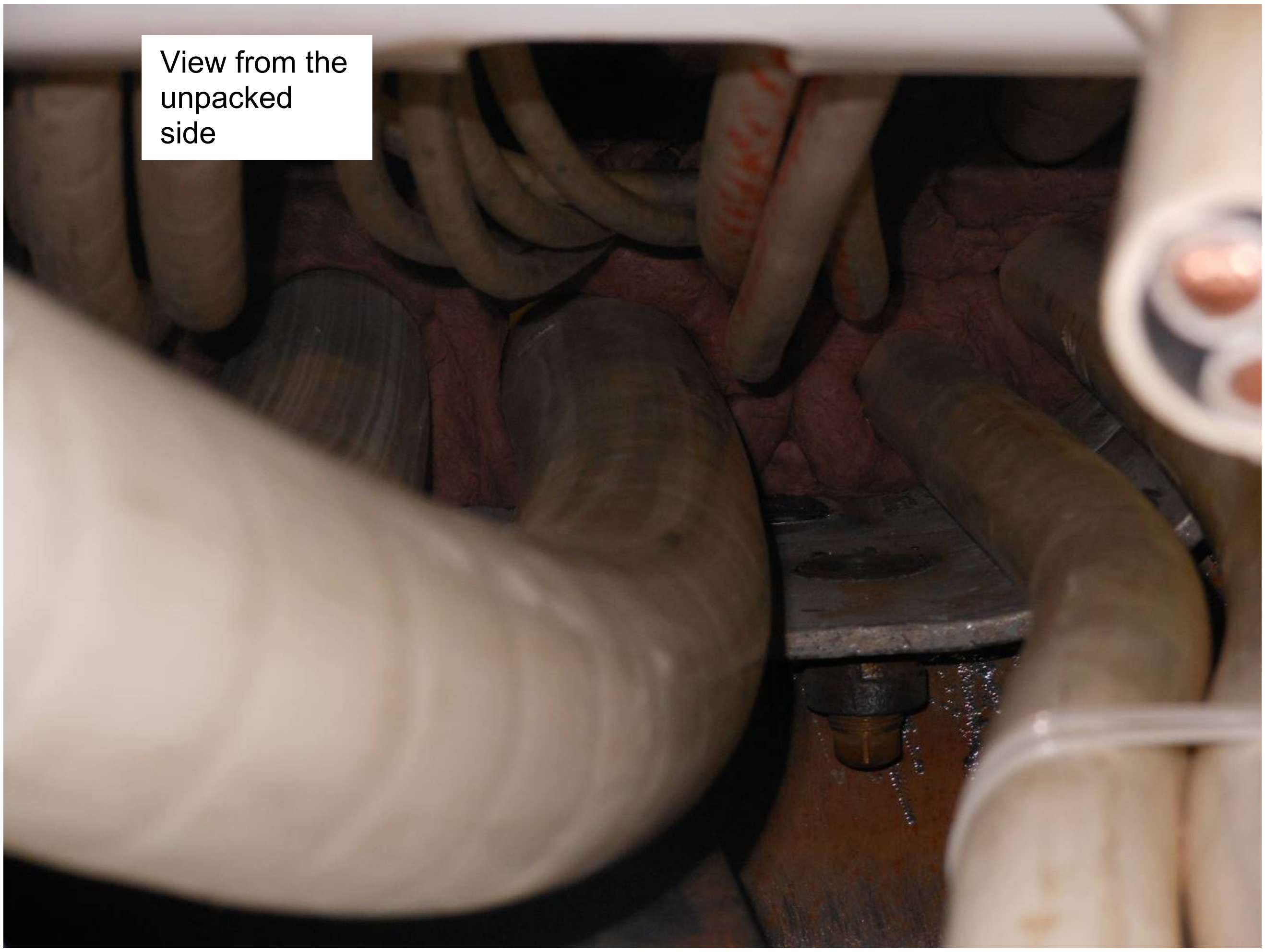


Figure 8.3.2.1.4: FireStop System - View Through Transit

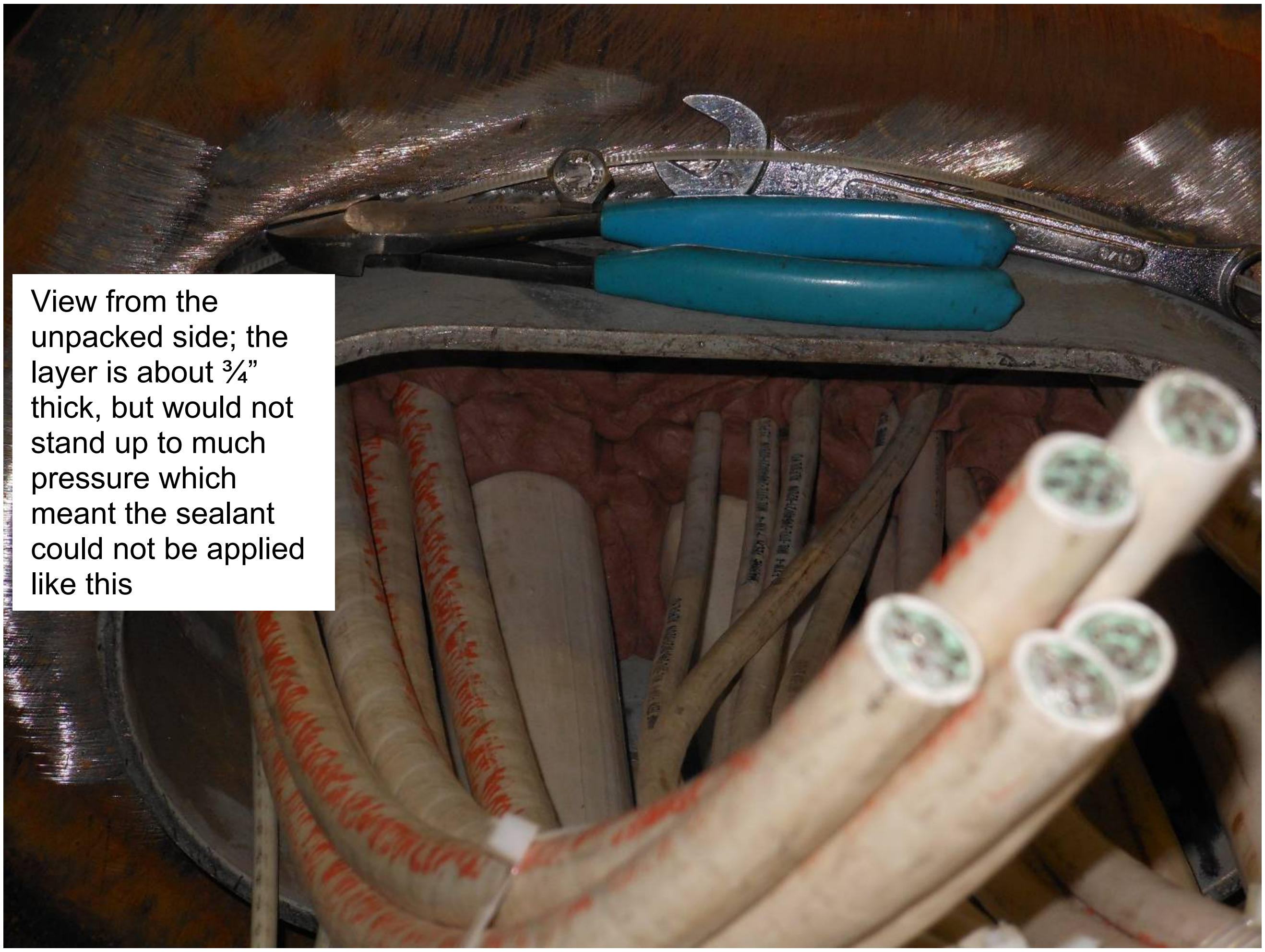


Figure 8.3.2.1.5: FireStop System - View Through0020Transit (cont)

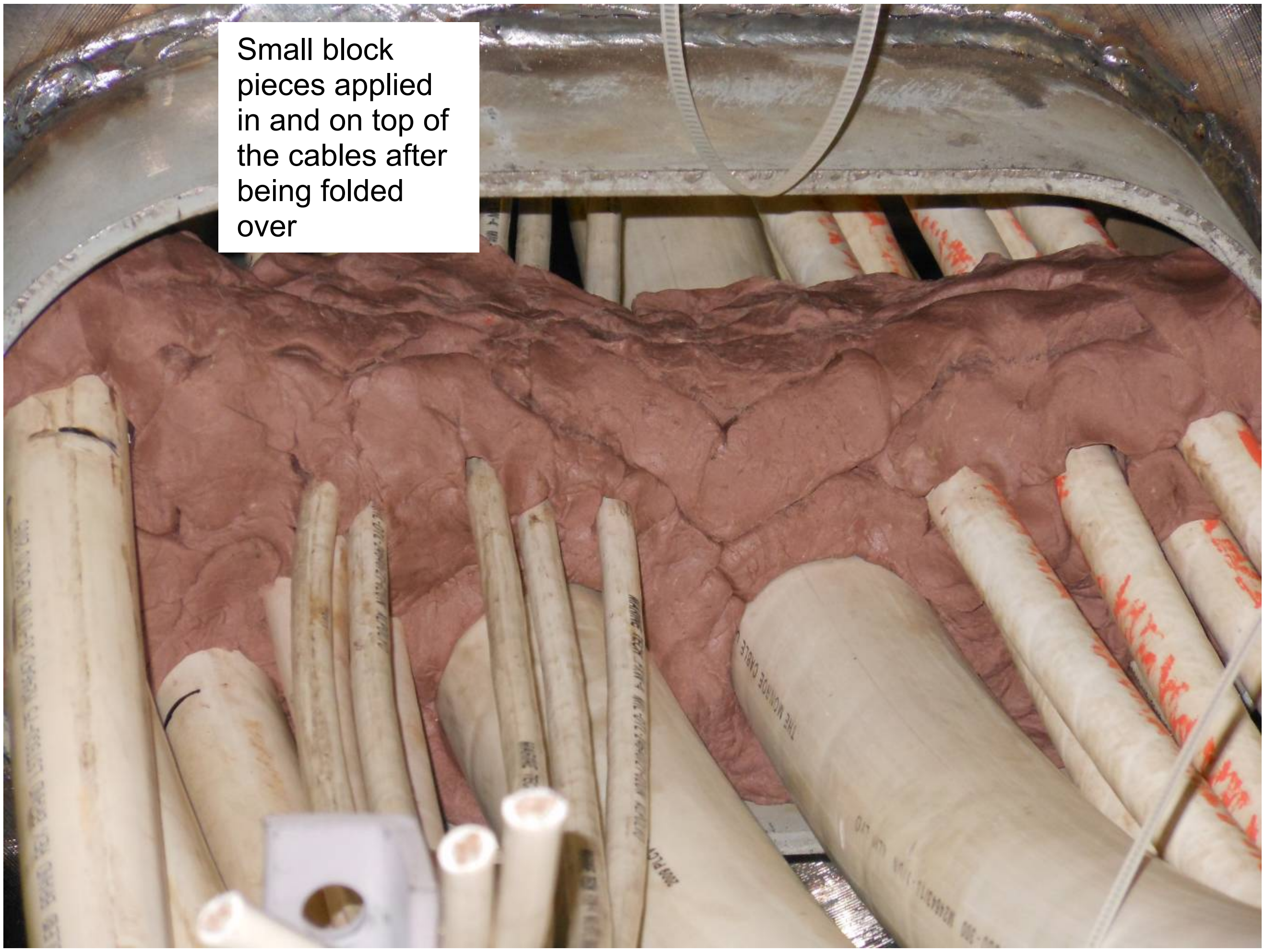


Figure 8.3.2.1.6: FireStop System - Putty Blocks Applied

Figure 8.3.2.1.7: FireStop System - Putty Layering

Figure 8.3.2.1.8: FireStop System - Cables Pushing Down on Putty

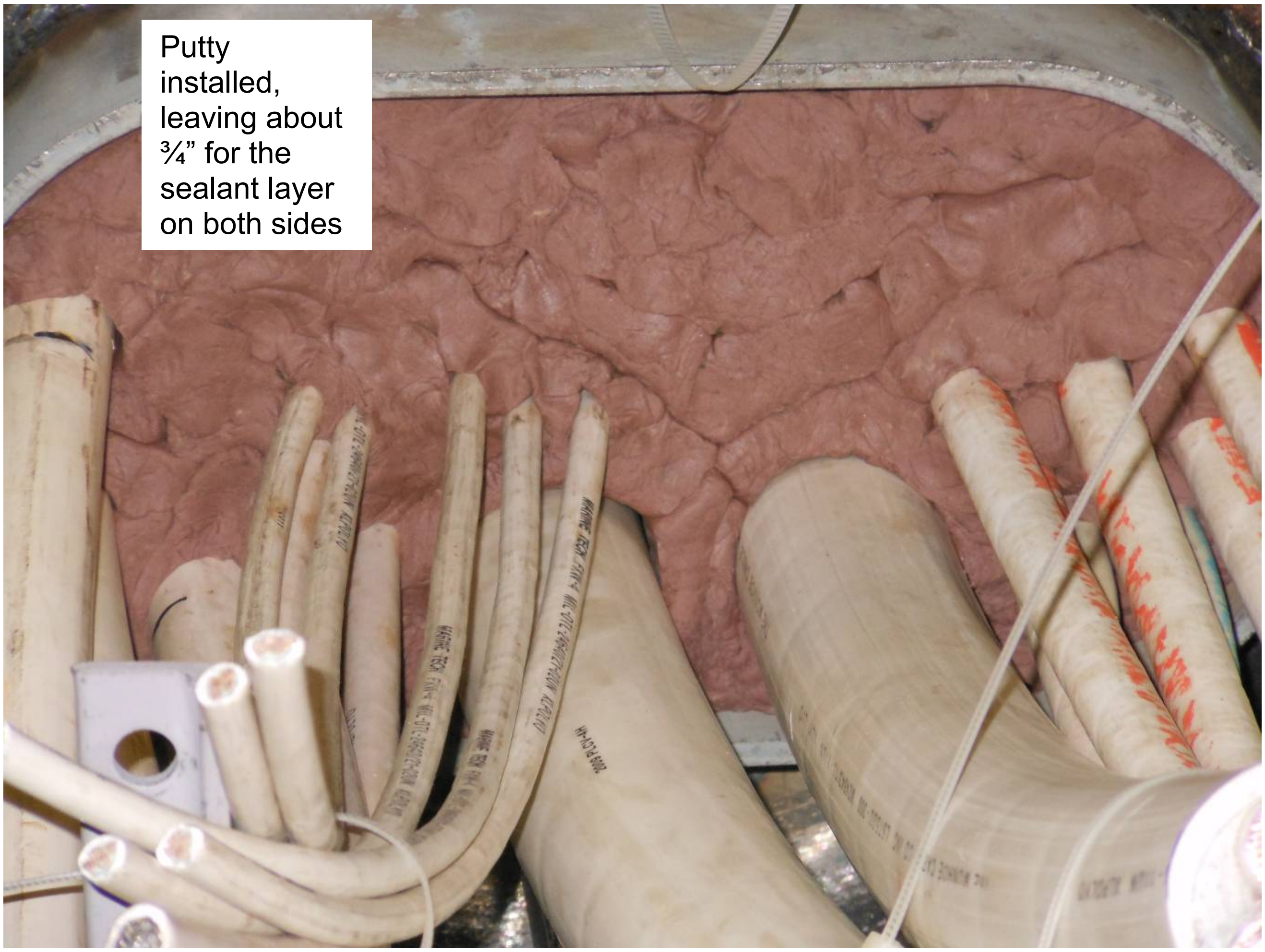


Figure 8.3.2.1.9: FireStop System - Putty Installed

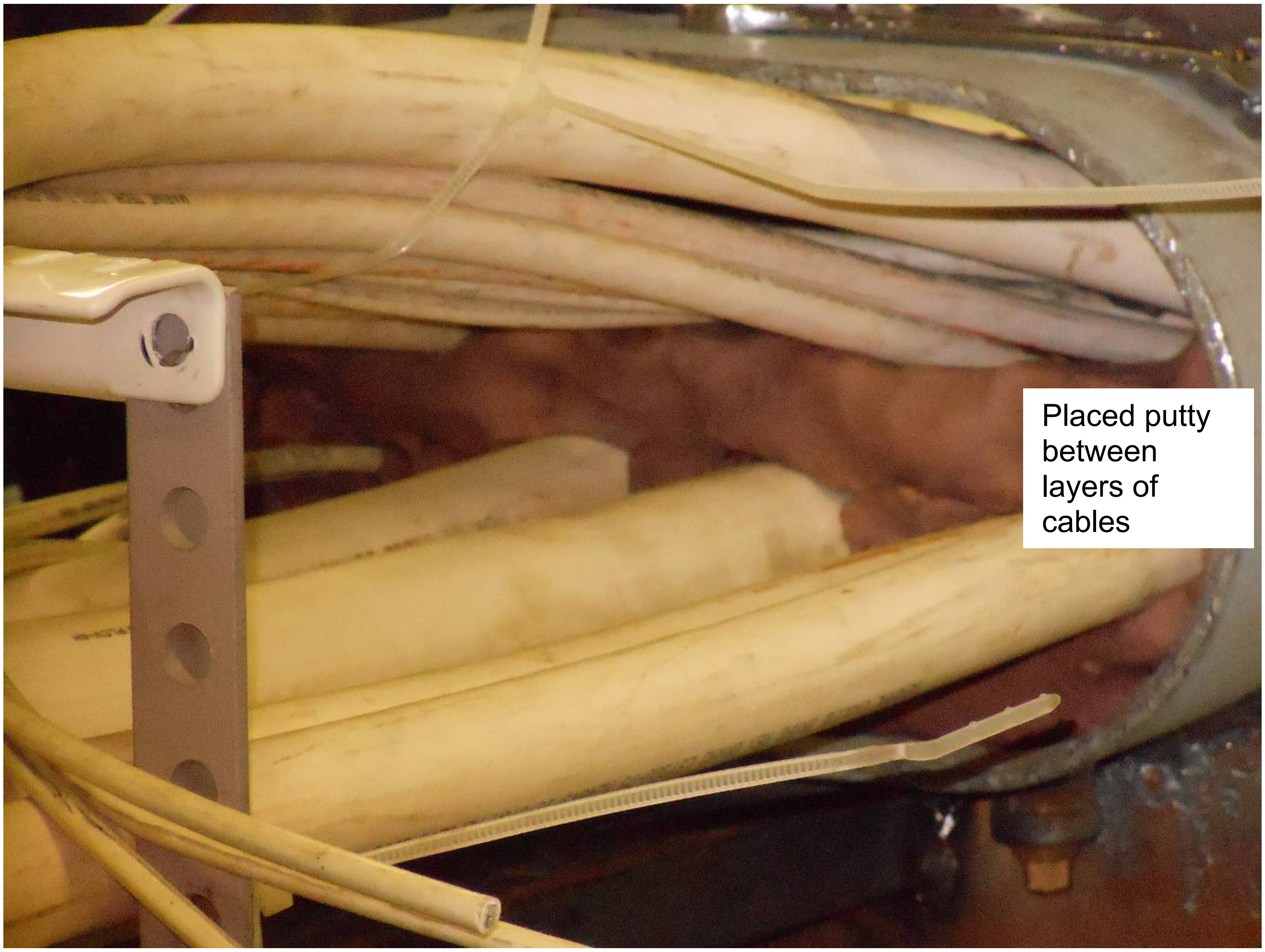


Figure 8.3.2.1.10: FireStop System - Putty Layered Between Cables

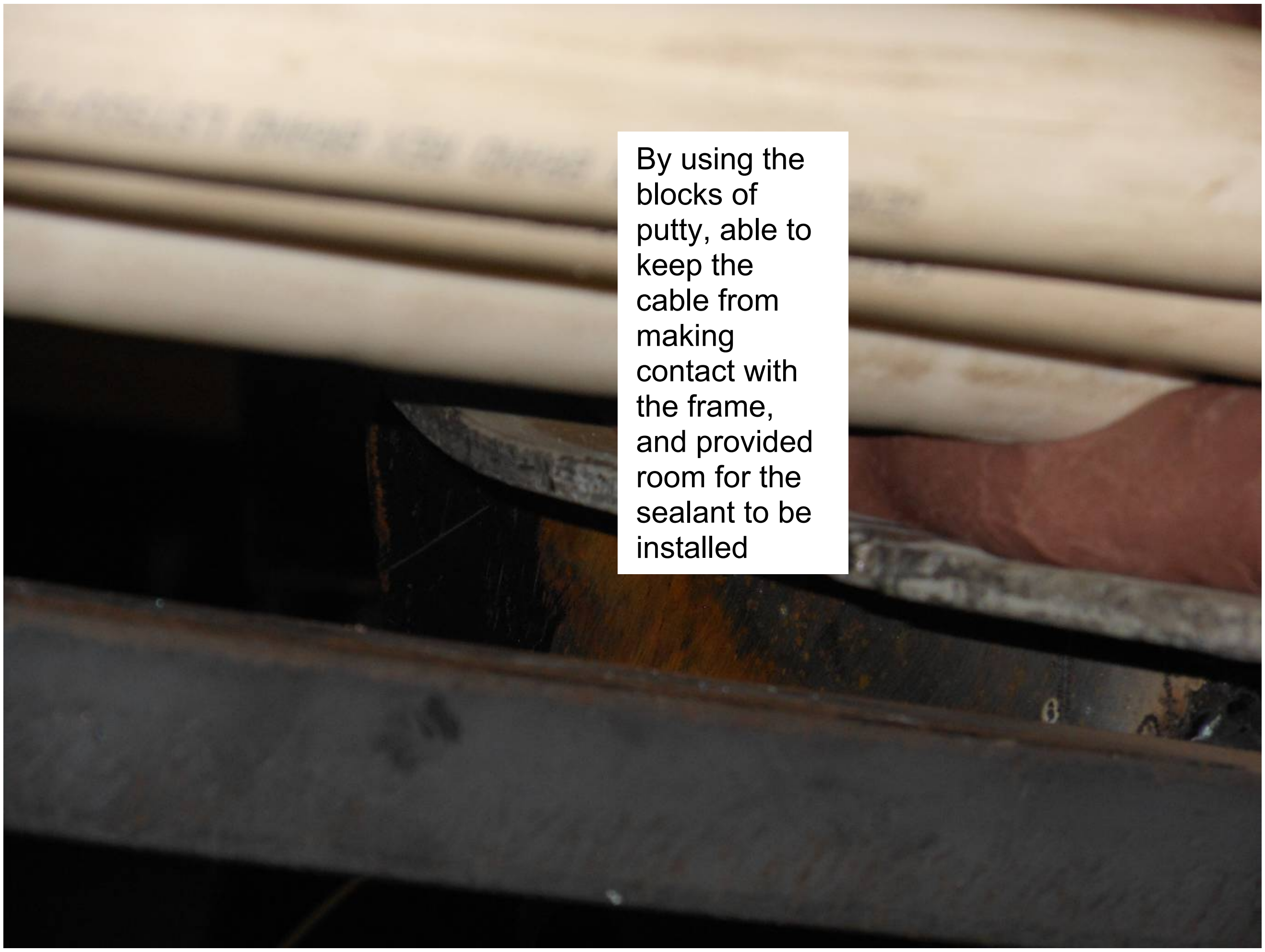


Figure 8.3.2.1.11: FireStop System - Blocking to Protect Cable

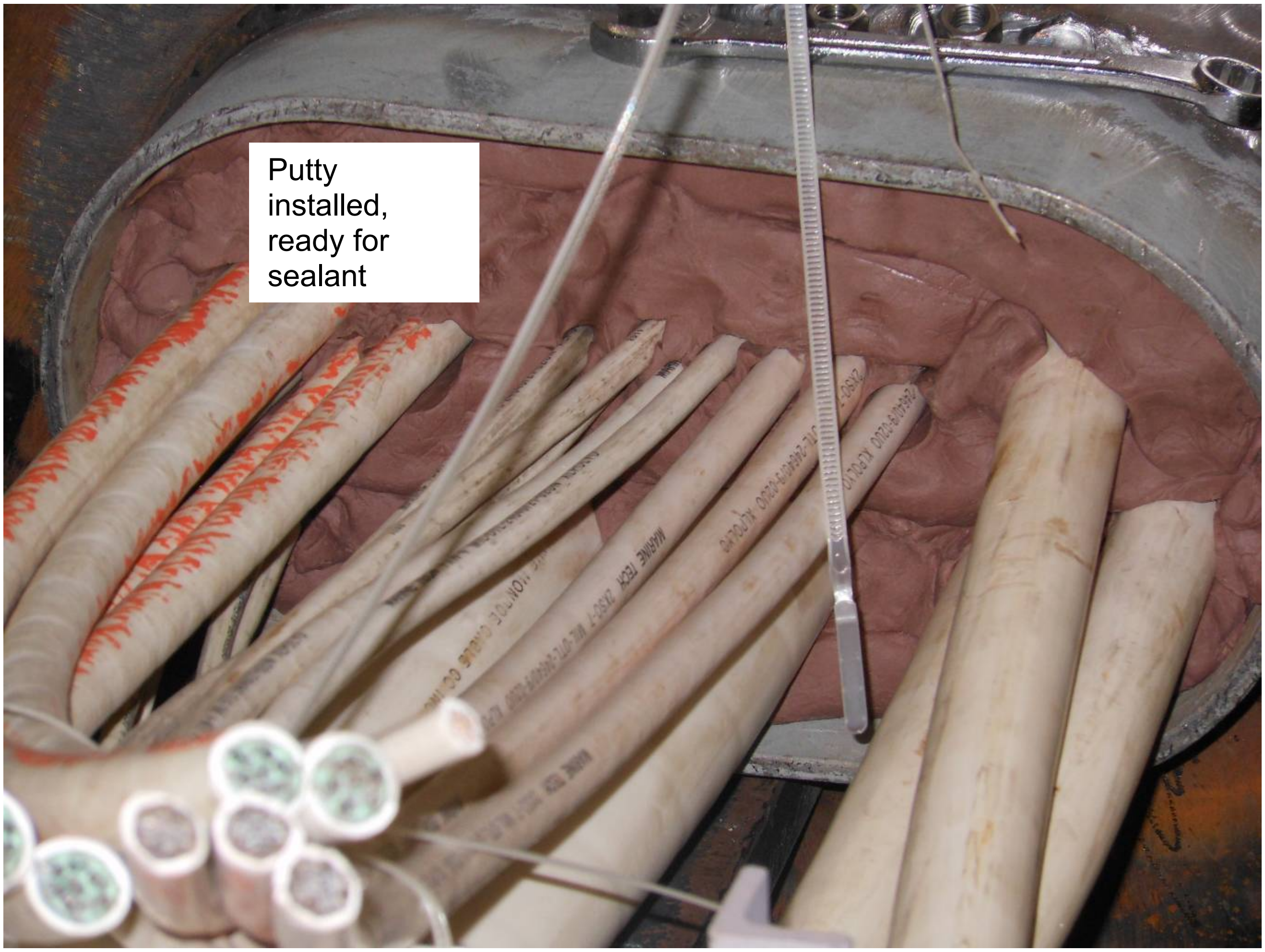


Figure 8.3.2.1.12: FireStop System - Ready for Sealant

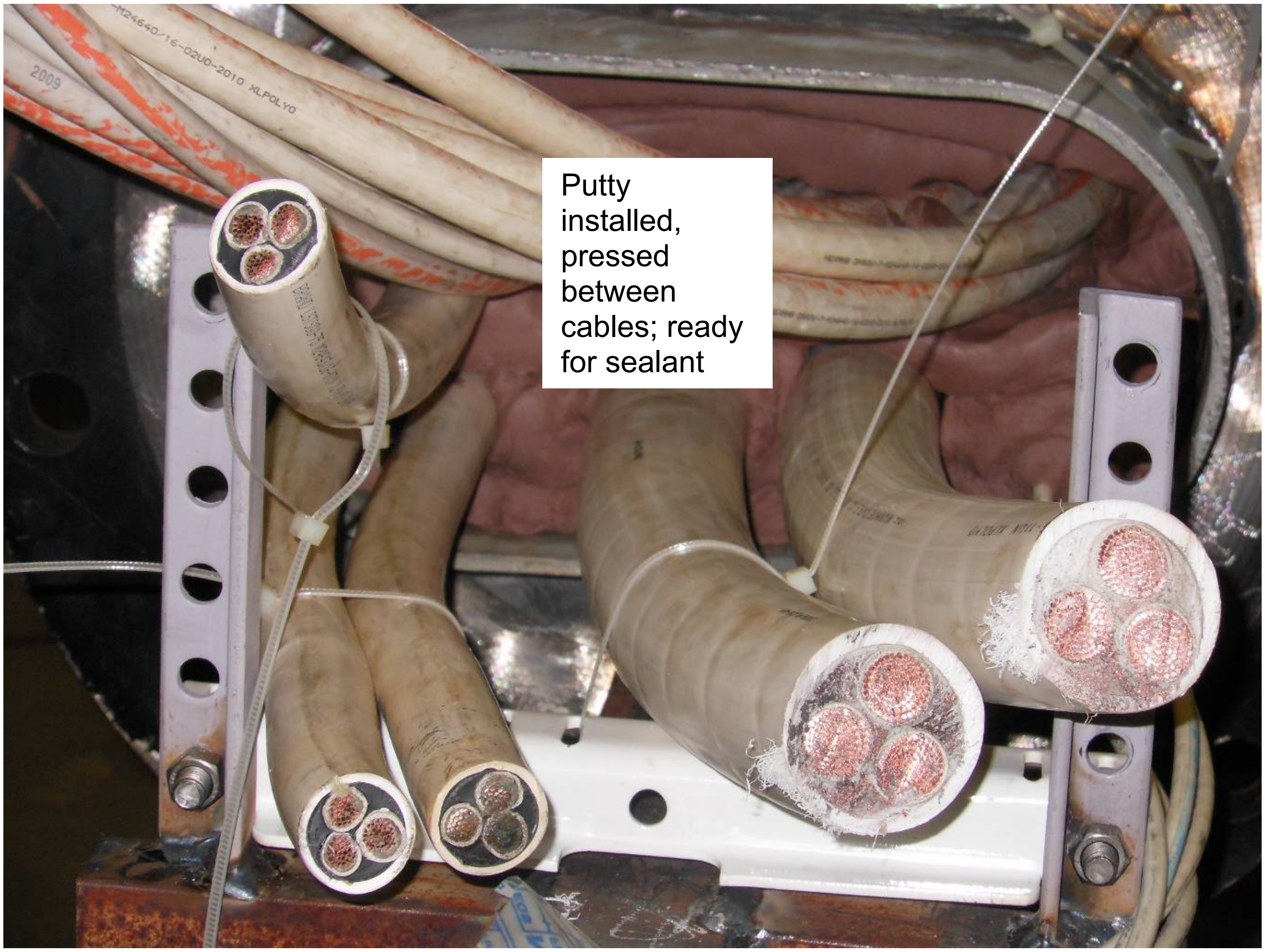


Figure 8.3.2.1.13: FireStop System - Ready For Sealant (cont)

Figure 8.3.2.1.14: FireStop System - Sealant Installed

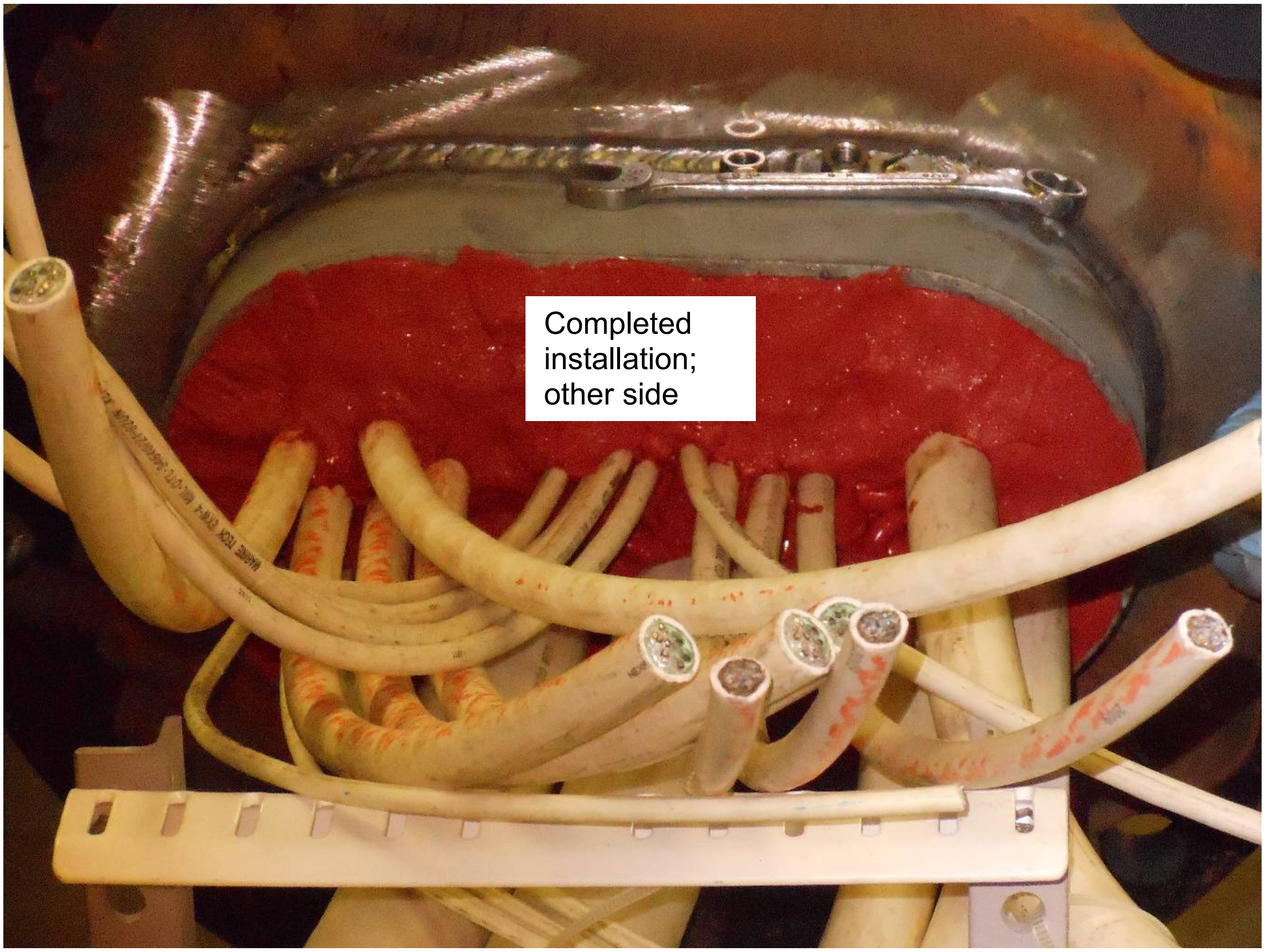


Figure 8.3.2.1.15: FireStop System - Sealant Installed (cont)

Figure 8.3.2.1.16: FireStop System - View Under Cables

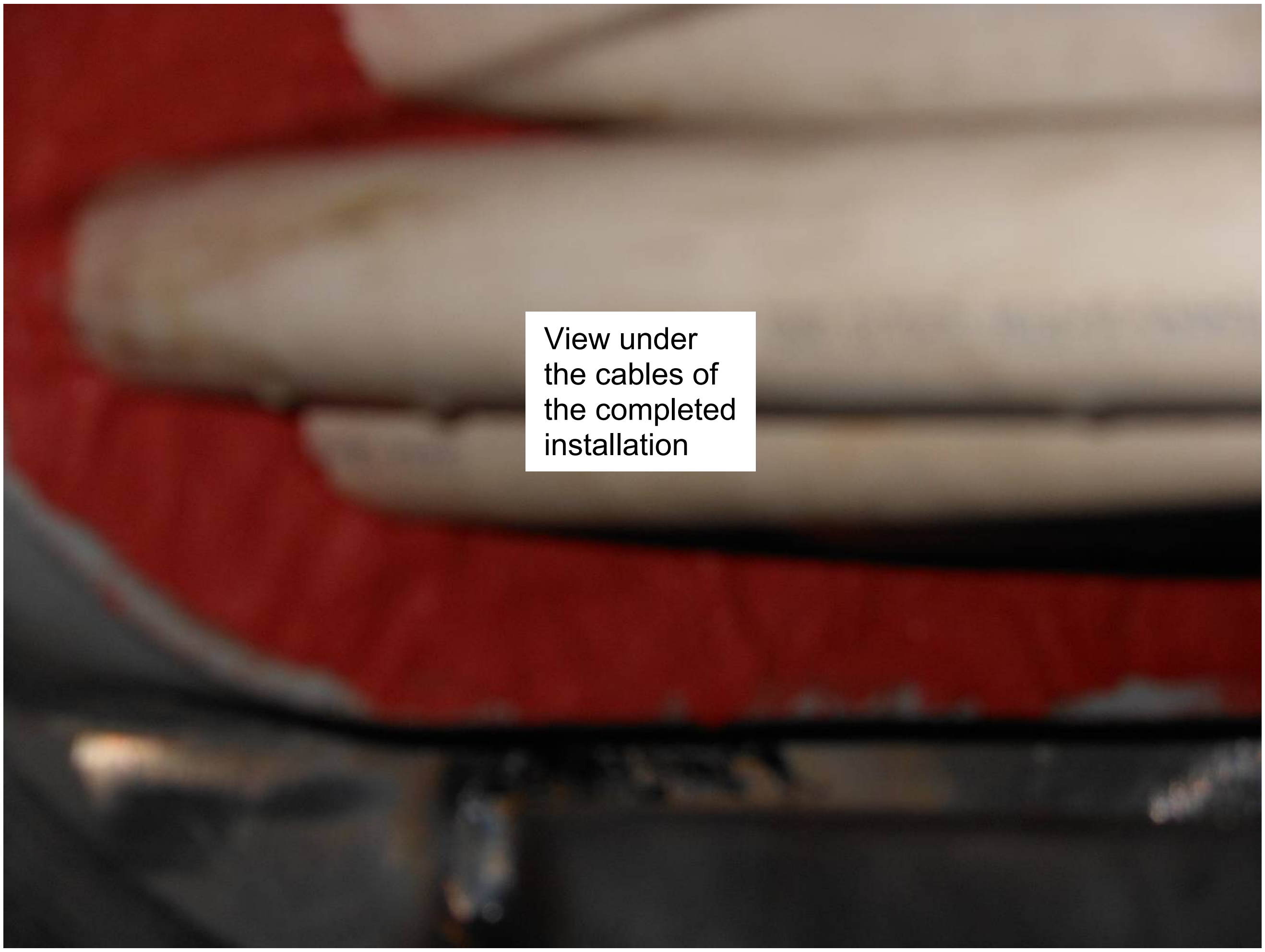


Figure 8.3.2.1.17: FireStop System - View Under Cables (cont)

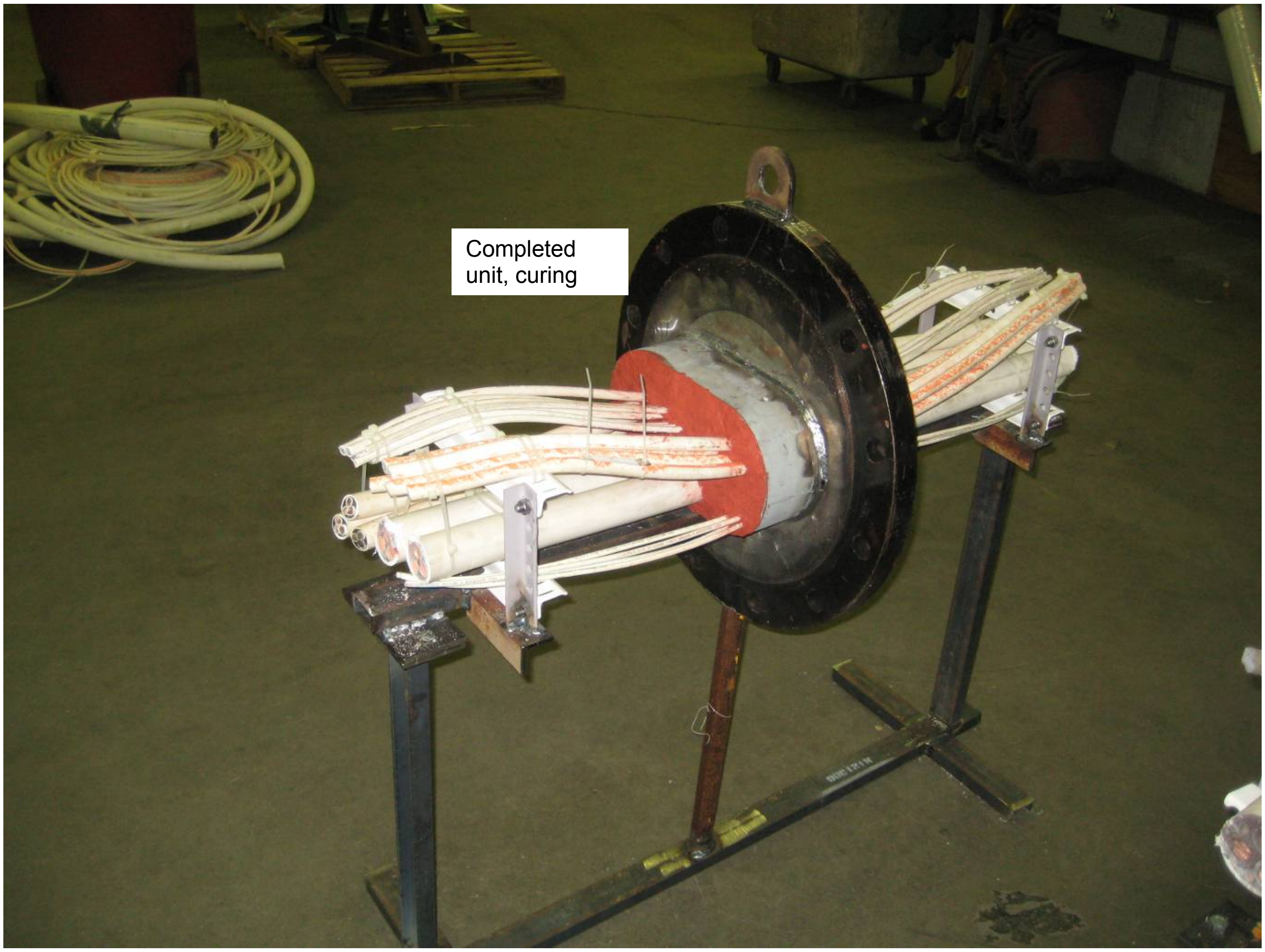


Figure 8.3.2.1.18: FireStop System - Complete Unit During Curing

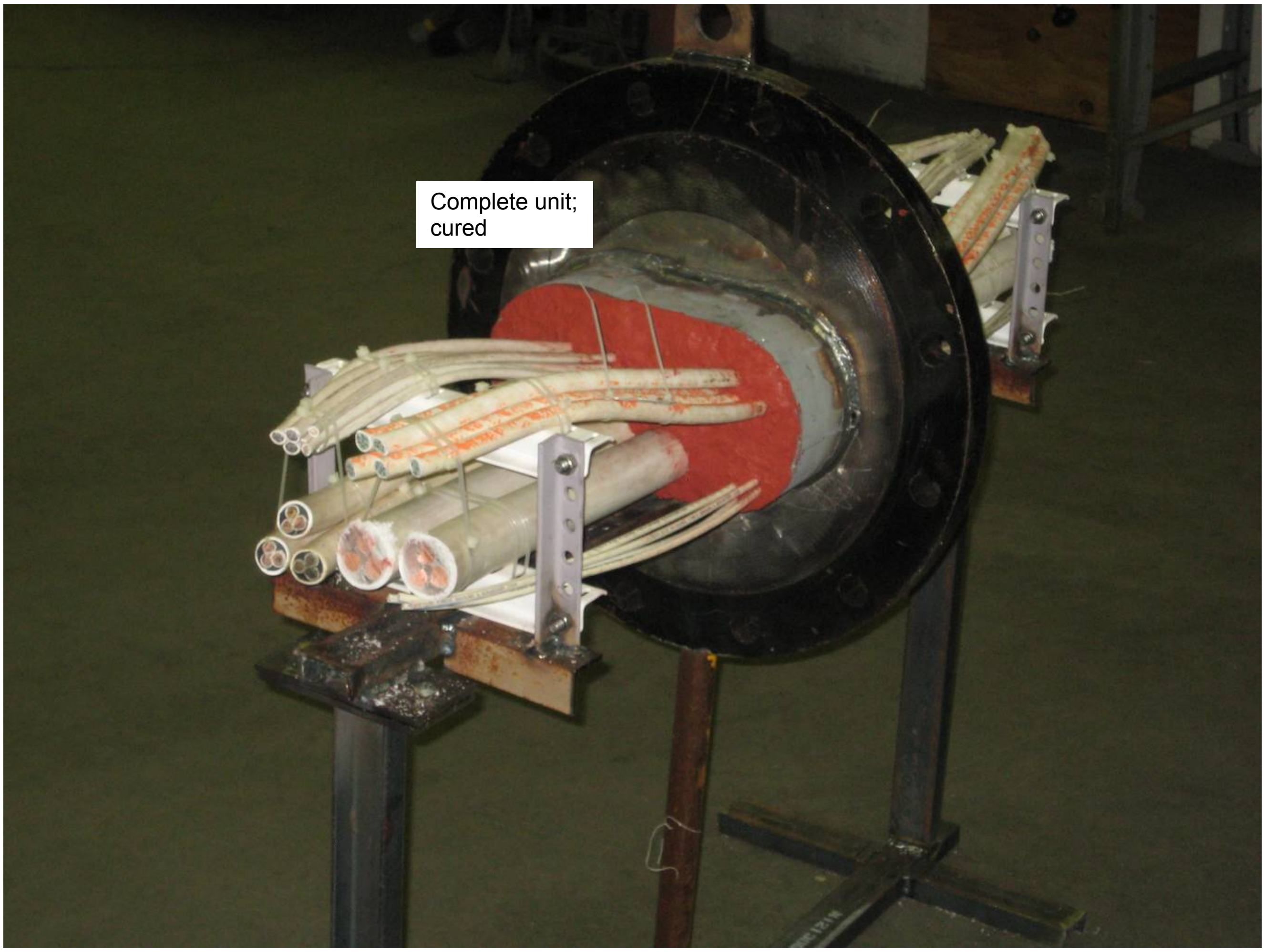


Figure 8.3.2.1.19: FireStop System - Completed Unit After Curing

8.3.2.2 FireSeal 3000 System

The FireSeal 3000 system uses a D-24 silicone based blanket as a filler between the sealant layers. This blanket is 4” in width, and comes in a roll, and we were required to use additional ventilation while handling the blanket. The transit we were using was in actuality, two 4” flat ovals welded together, so, in order to leave a gap of ¾” for the sealant on both sides, we needed to trim the width of the blanket.

The blanket was very easy to cut using a box cutter, and left no residue. We could then cut the blanket to lengths needed in order to place it under and around the cables going through the oval. We did not roll any of the blanket, as indicated in the instruction, we felt there were too many cables, and we were trying to get some of the blanket between each of them in order to be able to get the sealant applied around each cable.

Once the gaps were filled with the blanket, the 3000 sealant was applied. According to the mechanic performing the job, the sealant was very easy to apply. It spread well, and was easy to smooth out. The side that was filled first was dry to the touch the following day. It seemed to be the quickest to set up and cure. Touch up, as expected, was performed after the product was dry to the touch.

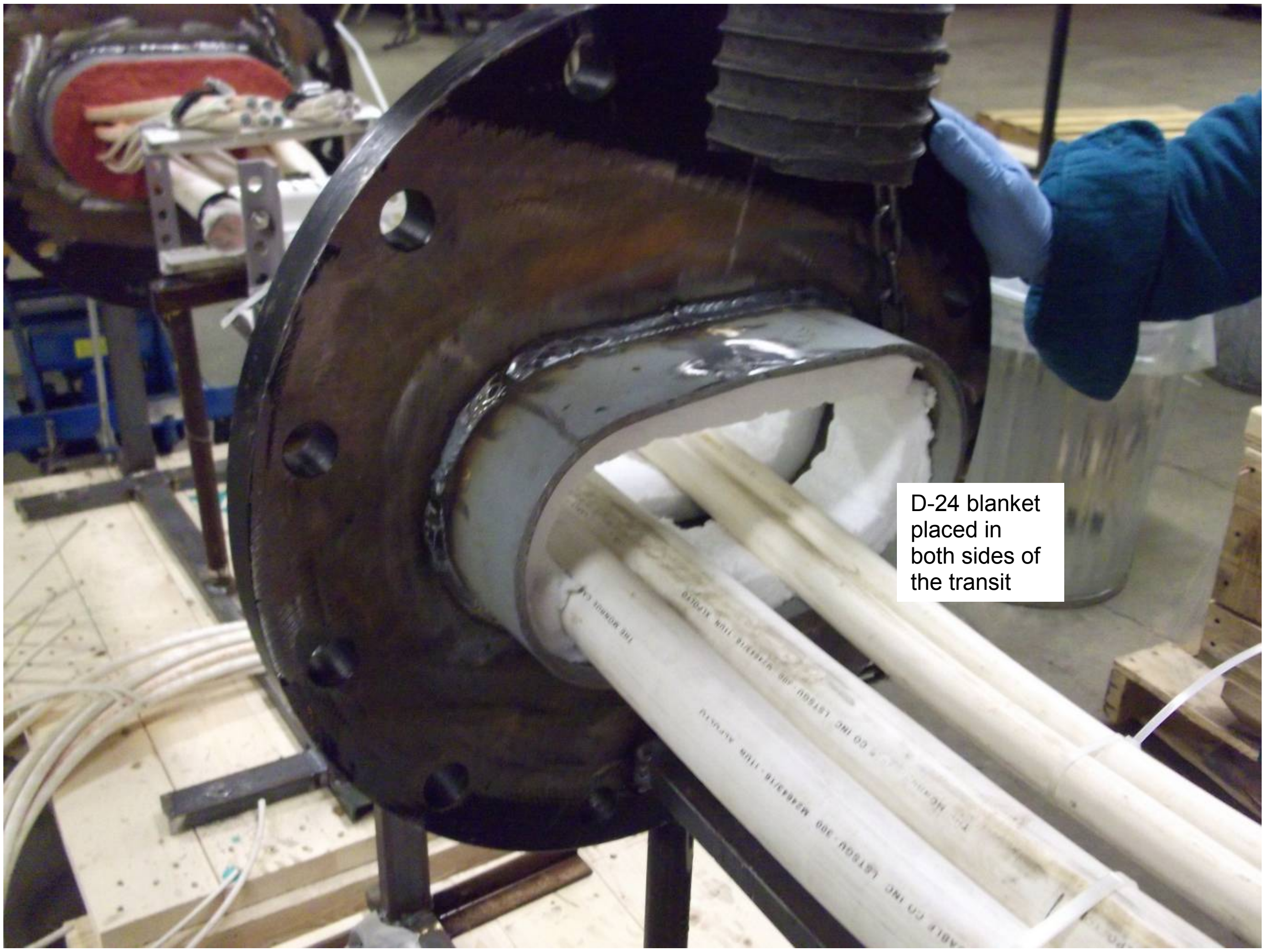


Figure 8.3.2.2.1: FireSeal System - Blanket insert

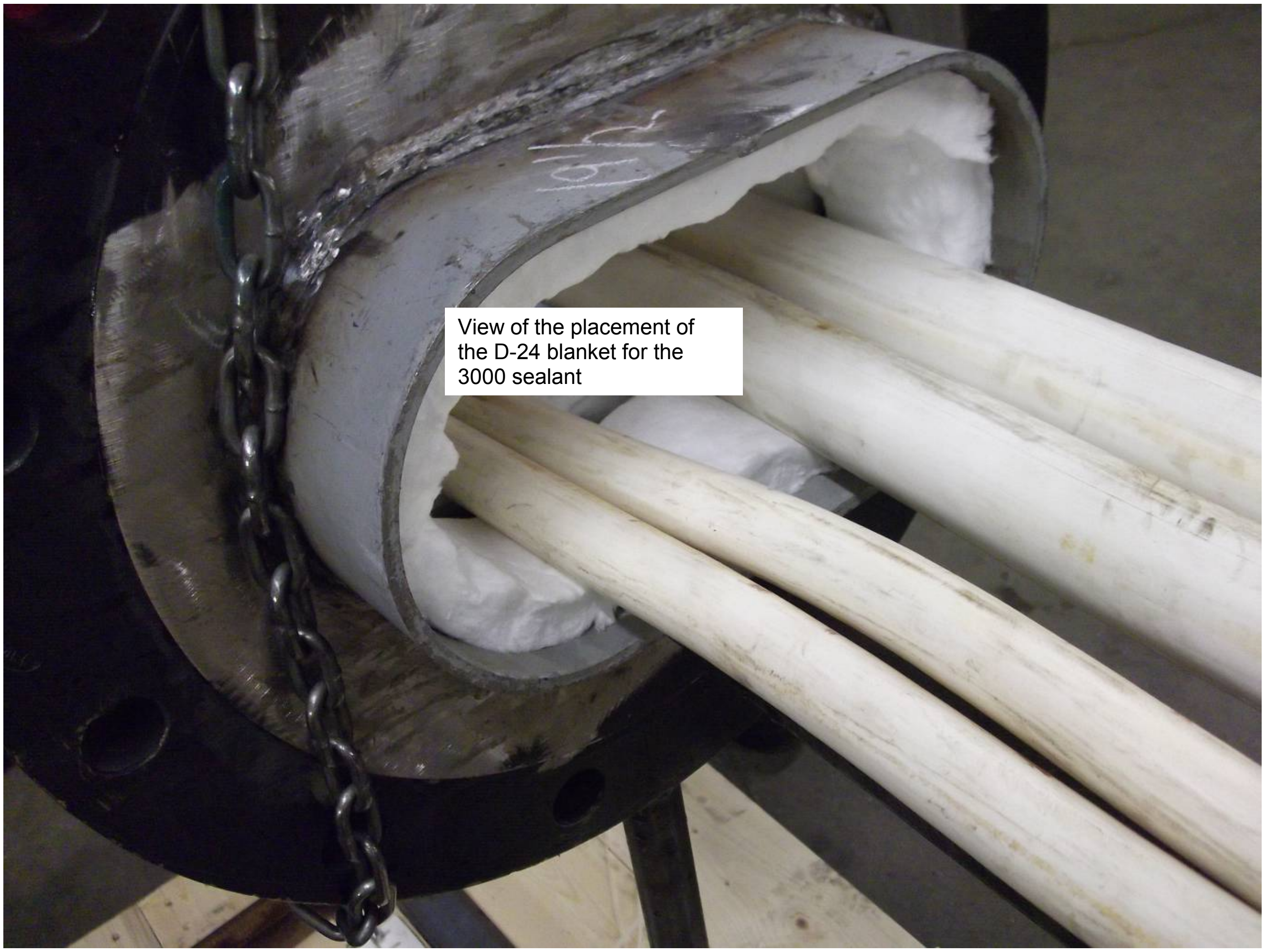


Figure 8.3.2.2.2: FireSeal System - Laying cables in on the blanket

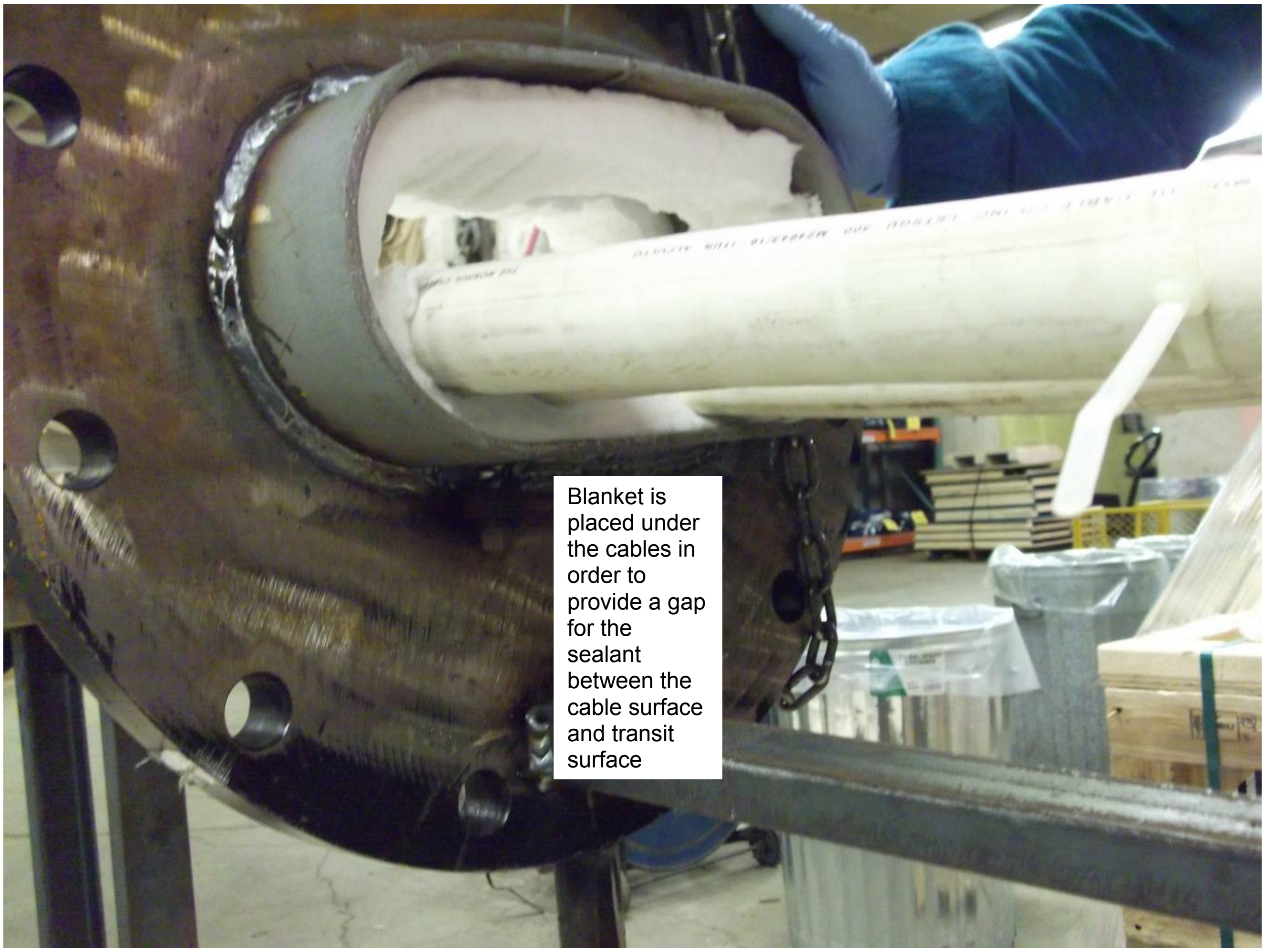


Figure 8.3.2.2.3: FireSeal System - Blanket System (cont)

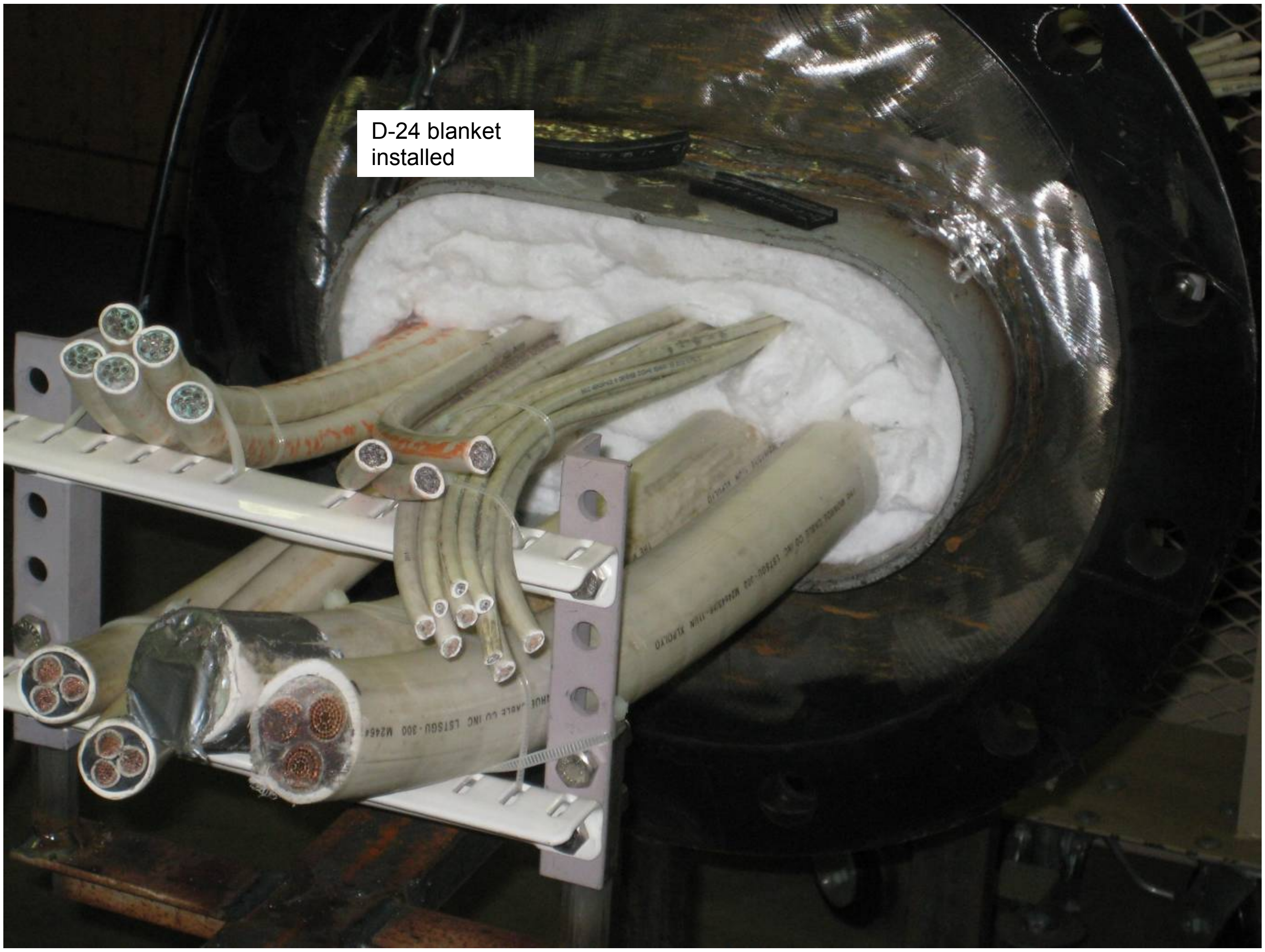


Figure 8.3.2.2.4: FireSeal System - Blanket install complete

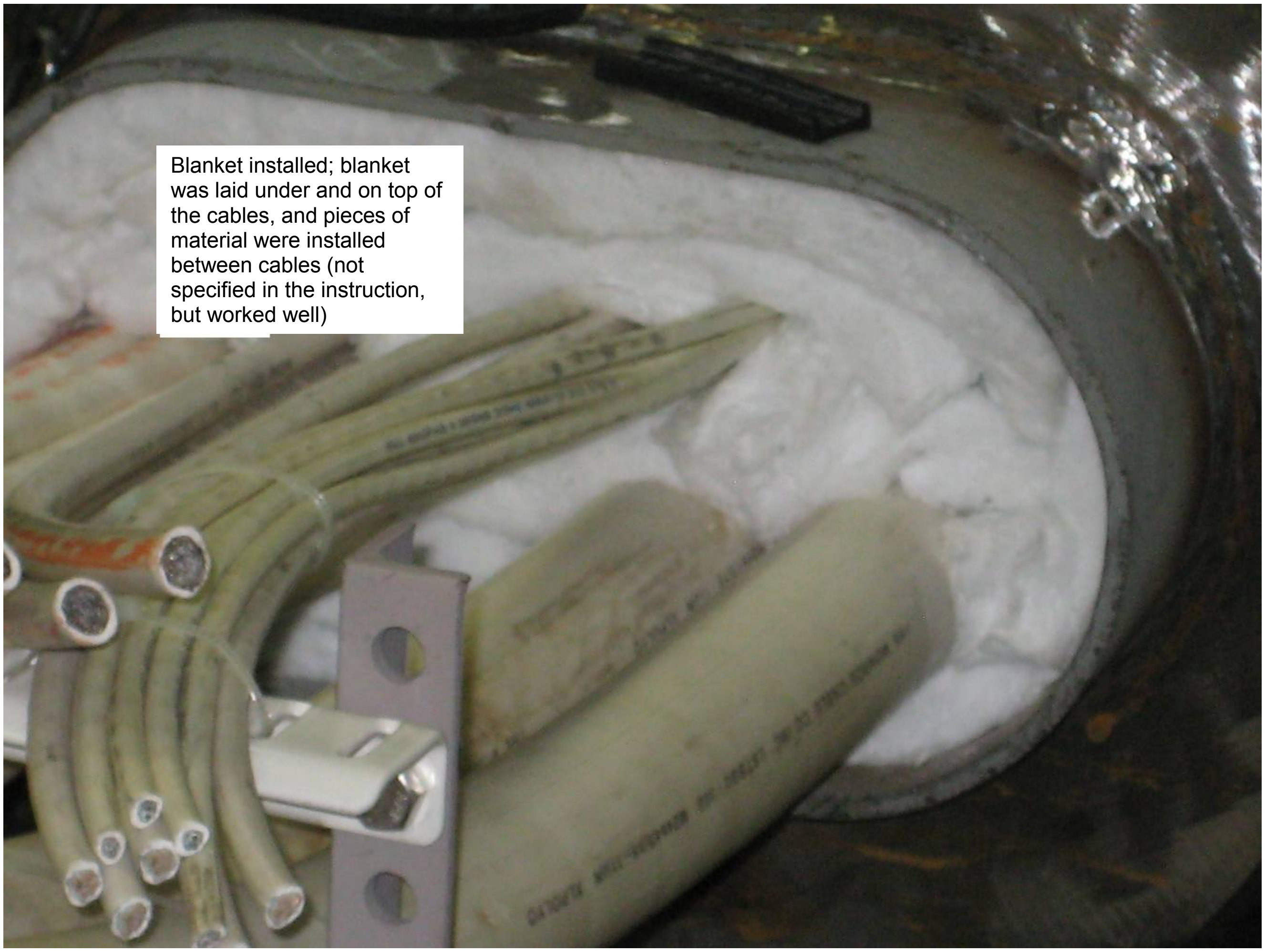


Figure 8.3.2.2.5: FireSeal System - Full packing other side

Figure 8.3.2.2.6: FireSeal System - Blanket intricately placed between cables

Figure 8.3.2.2.7: FireSeal System - Installing FireSeal over blanket

Figure 8.3.2.2.8: FireSeal System - Smoothing the sealant out

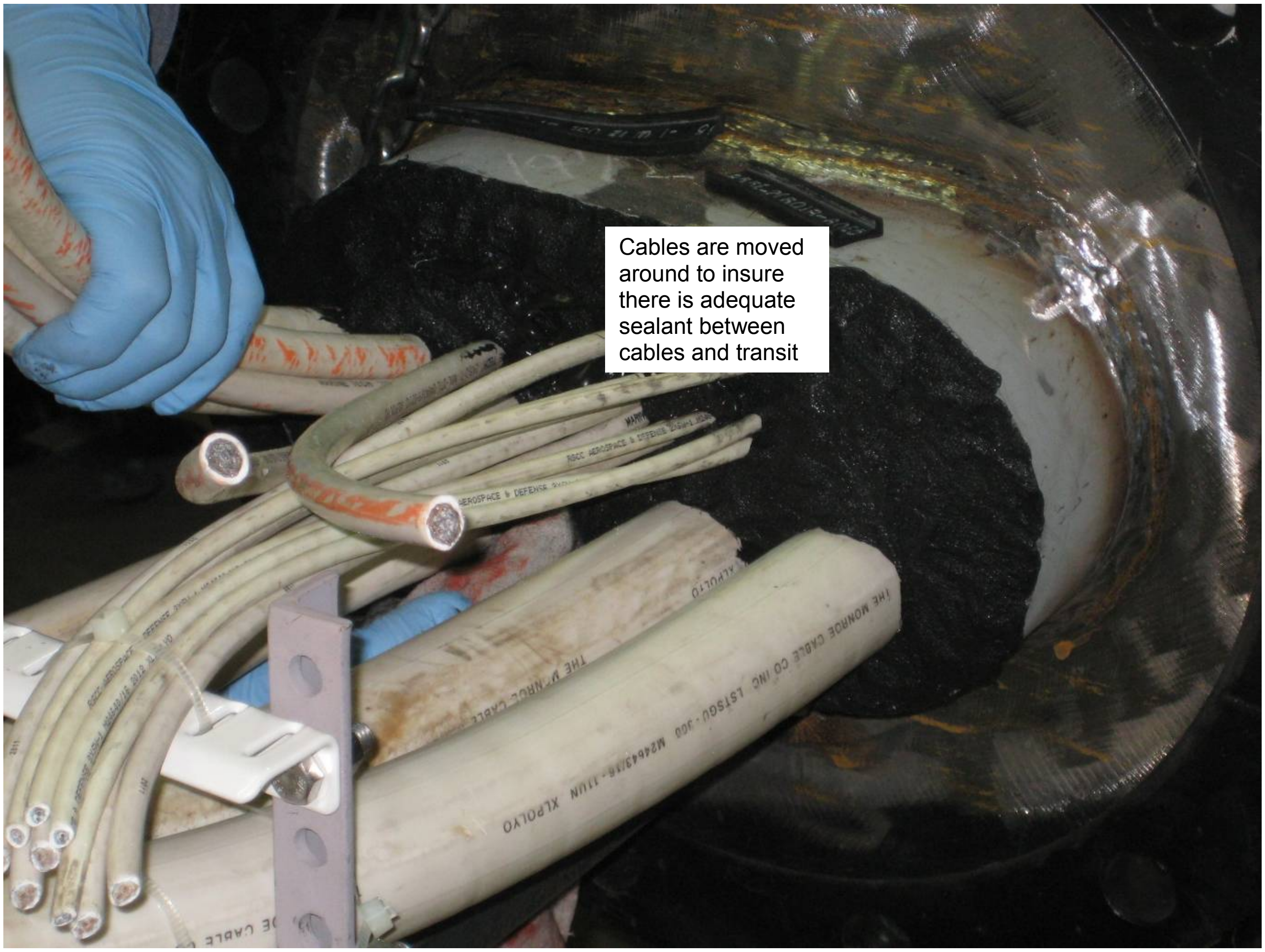


Figure 8.3.2.2.9: FireSeal System - Ensuring adequate sealant coverage

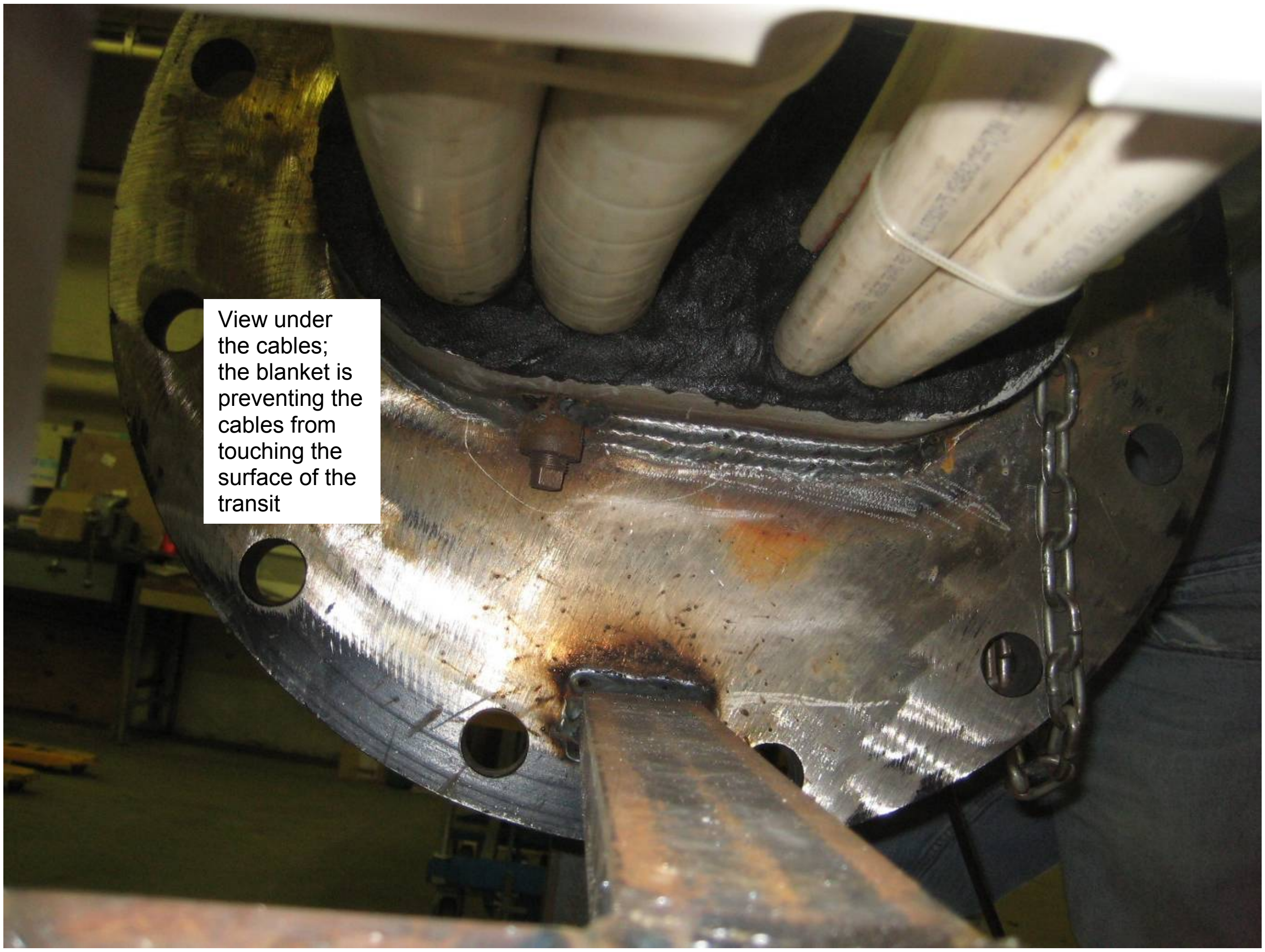


Figure 8.3.2.2.10: FireSeal System - Cables kept off the oval frame

Figure 8.3.2.2.11: FireSeal System - Careful to smooth between cables

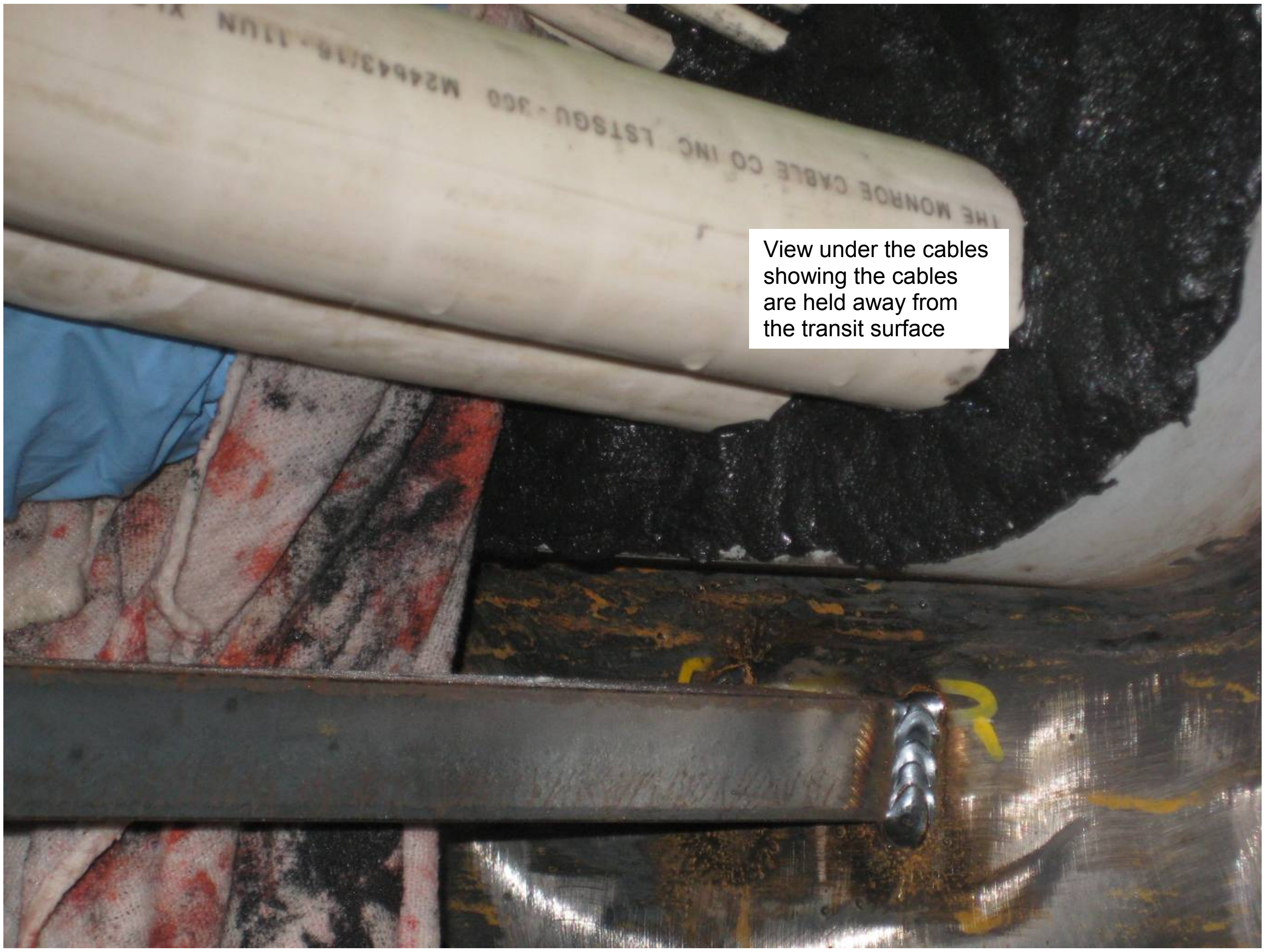


Figure 8.3.2.2.12: FireSeal System - Challenging to get smooth under cables

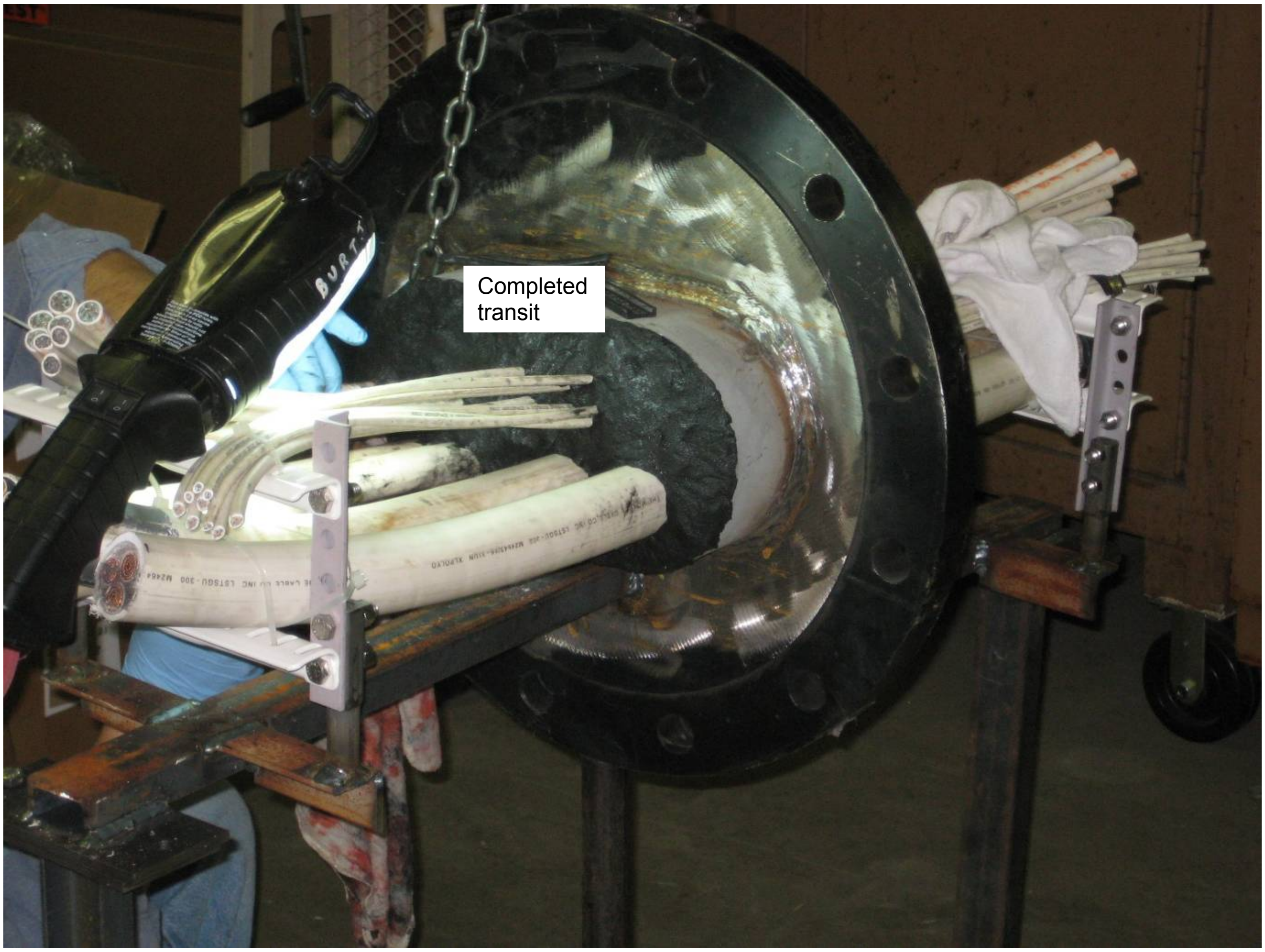


Figure 8.3.2.2.13: FireSeal System - Completed unit

Figure 8.3.2.2.14: FireSeal System - Completed Unit (cont)

Figure 8.3.2.2.15: FireSeal System - Completed unit (cont)

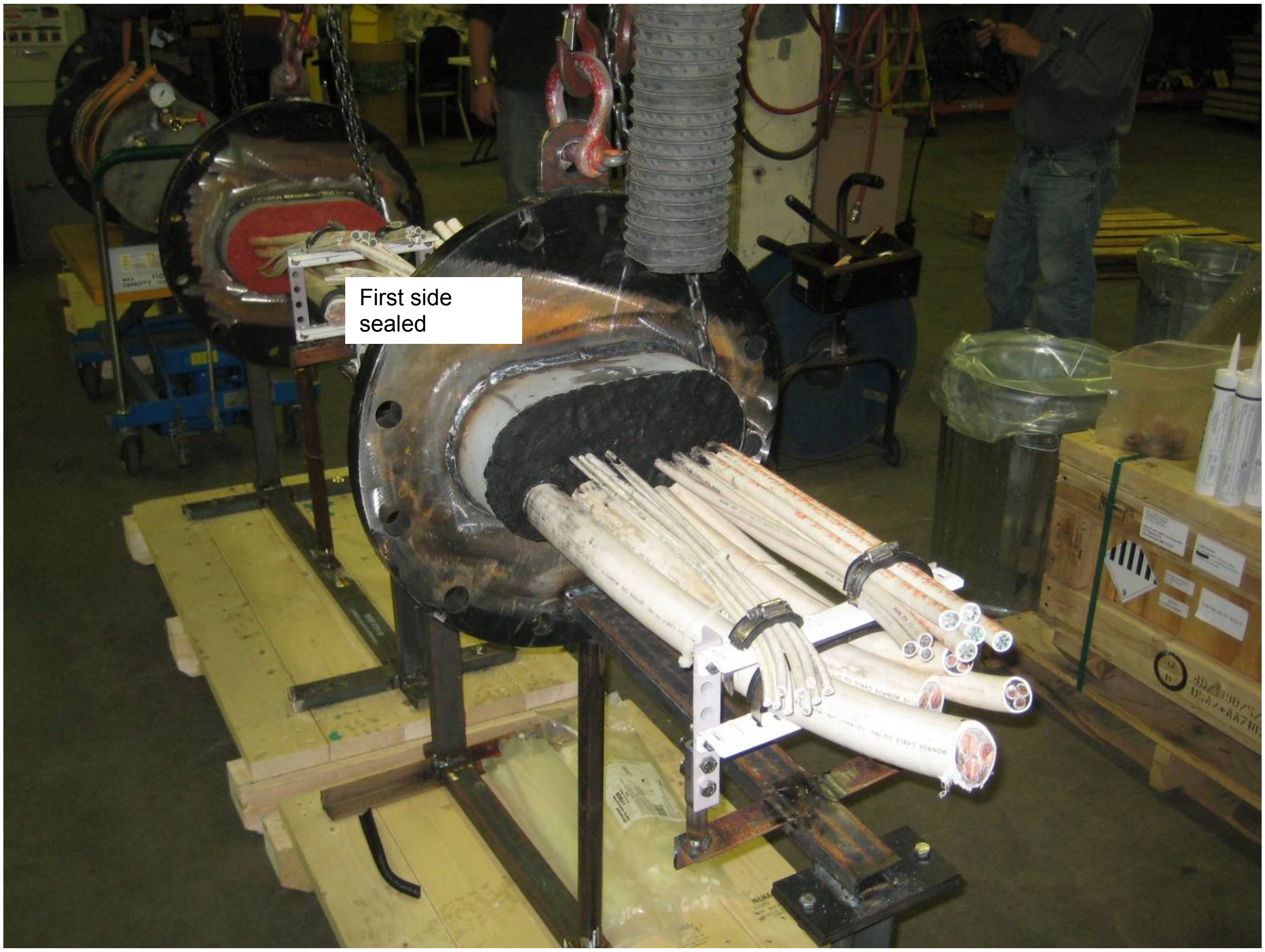


Figure 8.3.2.2.16: FireSeal System - Completed product

8.3.2.3 NOFIRNO

The NOFIRNO system uses a sleeve system. These sleeves are very easy to install as long as you are able to move the cables around so the sleeves can be slid in place. These sleeves made for a good base to lay the sealant onto.

The sealant was easy to apply, spread relatively easy, and stuck well to the cables. The outer application was dry to the touch in about 24 hours. As the sealant dried, it needed to be touched up where it had pulled away from the cables or developed small cracks. This was considered normal.

Figure 8.3.2.3.1: NOFIRNO - Cable sleeving

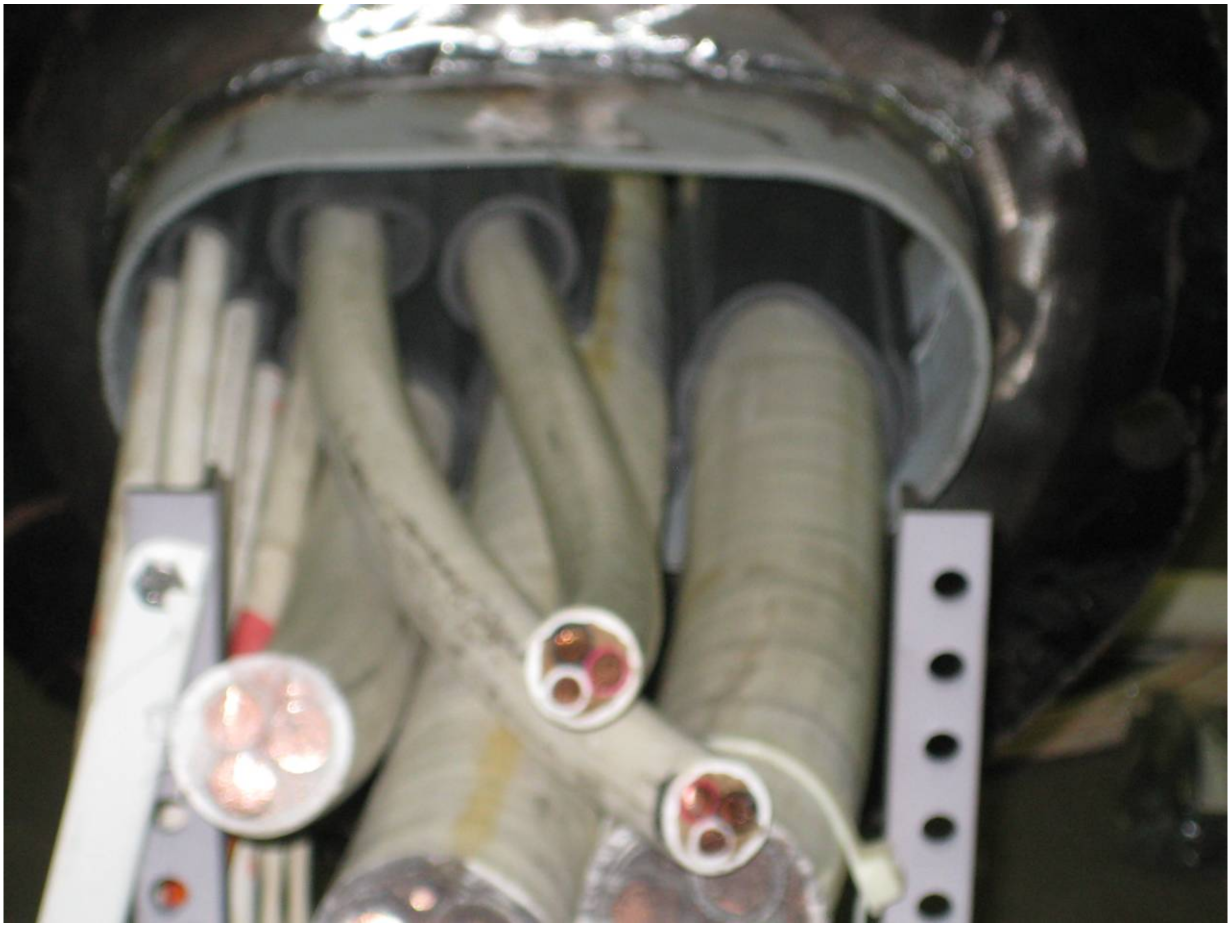


Figure 8.3.2.3.2: NOFIRNO - Sleeving of various sizes

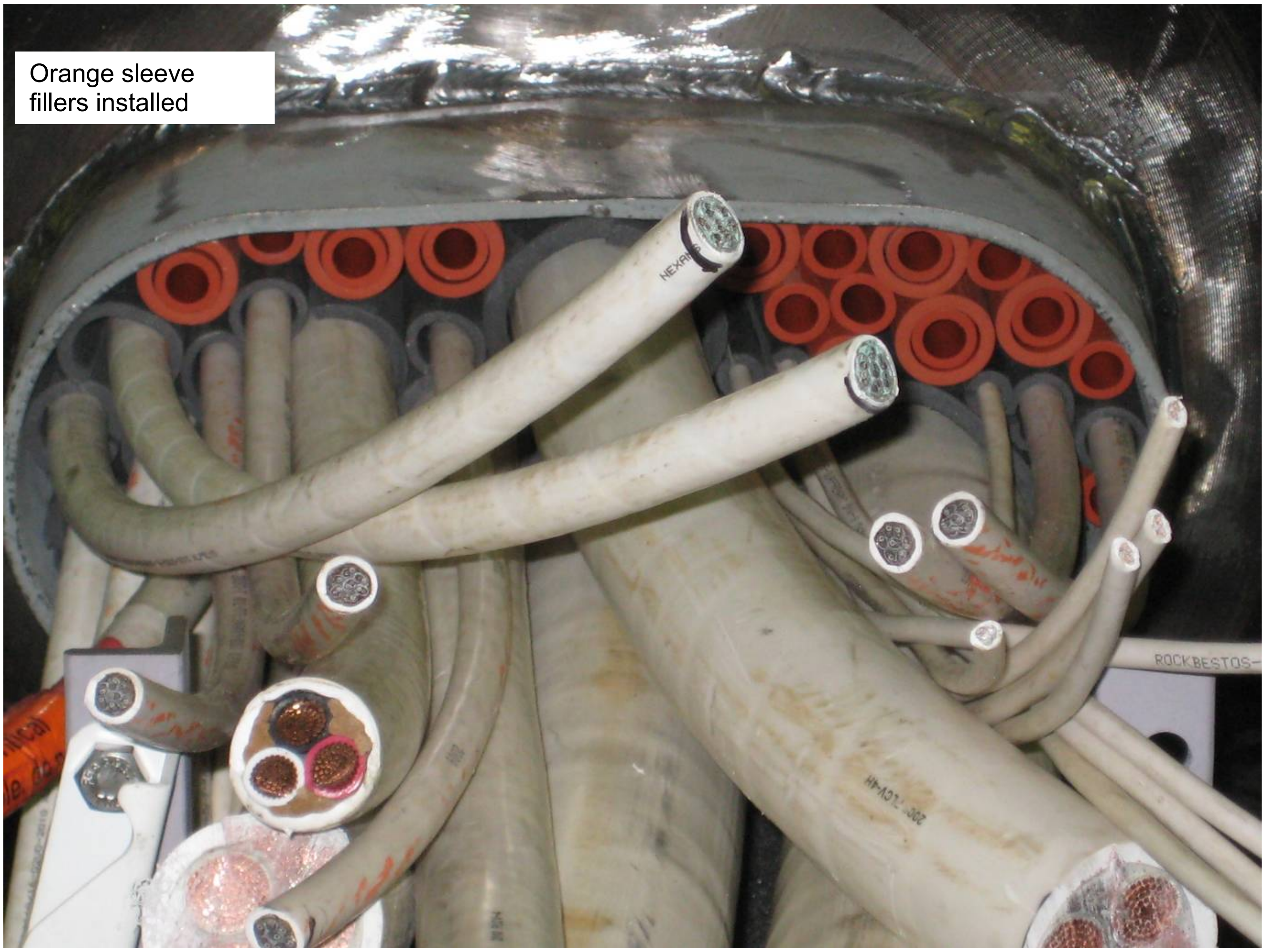


Figure 8.3.2.3.3: NOFIRNO - Orange filler sleeves installed

Figure 8.3.2.3.4: NOFIRNO - Applying sealant

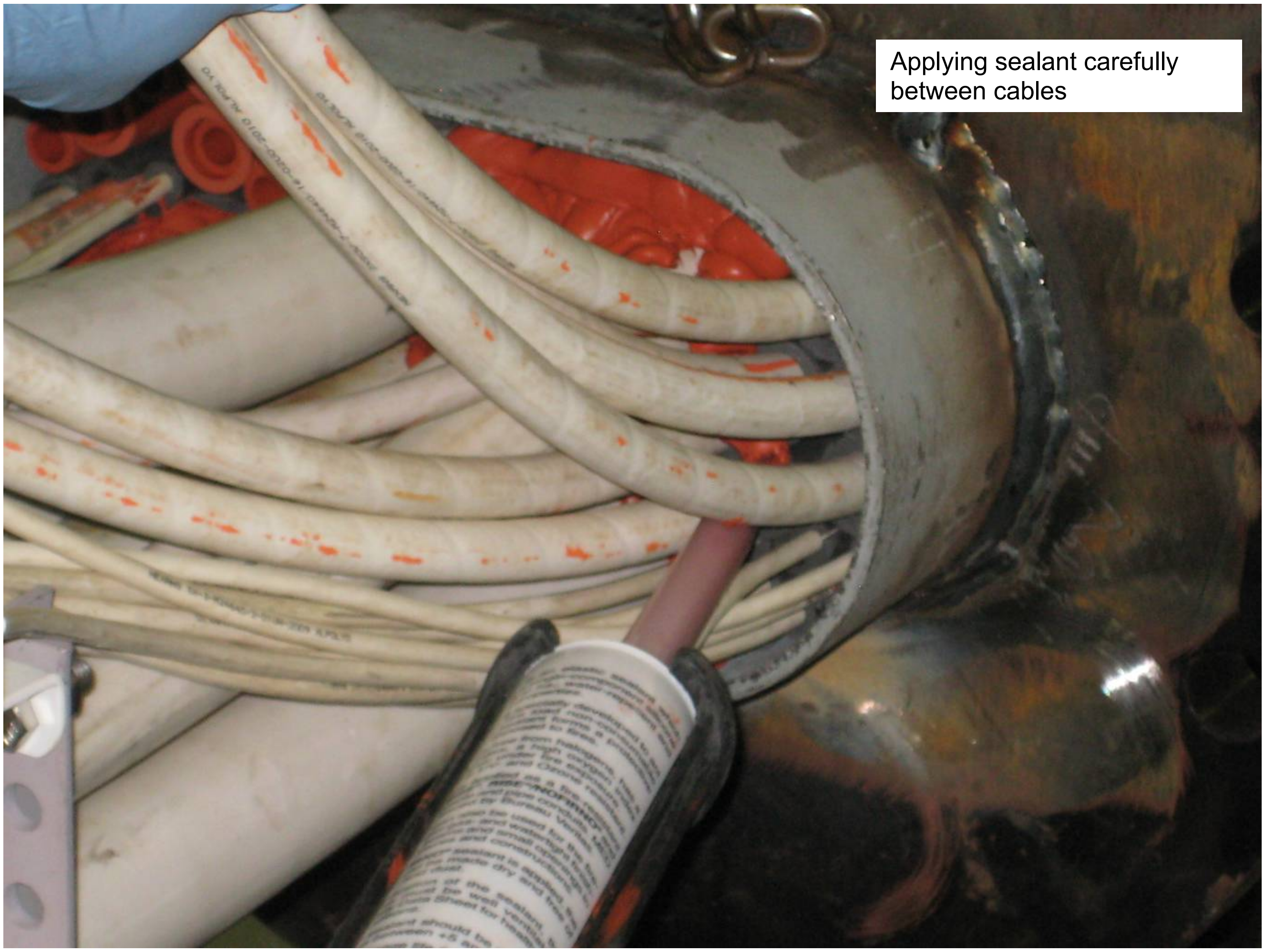


Figure 8.3.2.3.5: NOFIRNO - Applying sealant carefully between cables

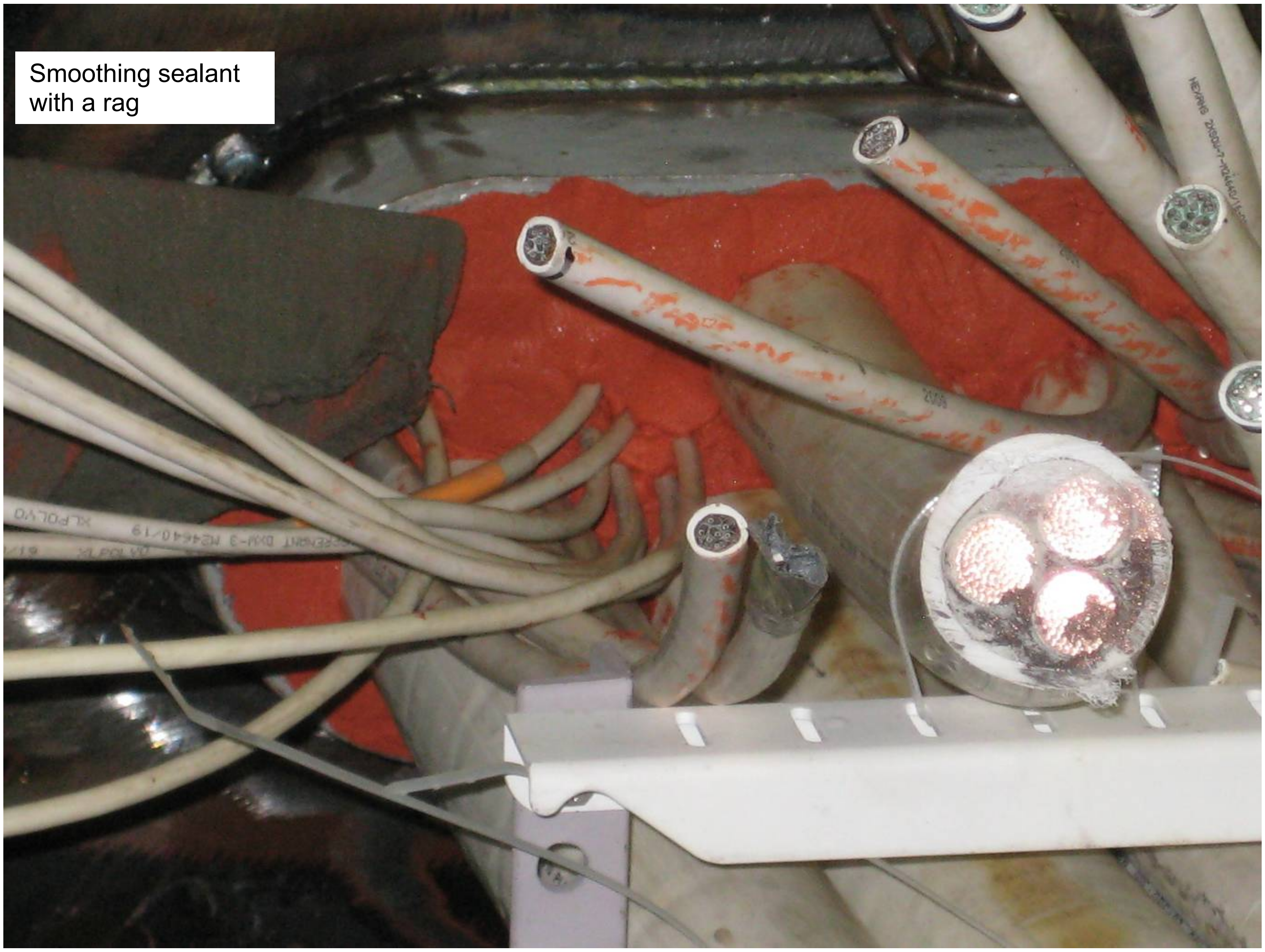


Figure 8.3.2.3.6: NOFIRNO - Smoothing sealant

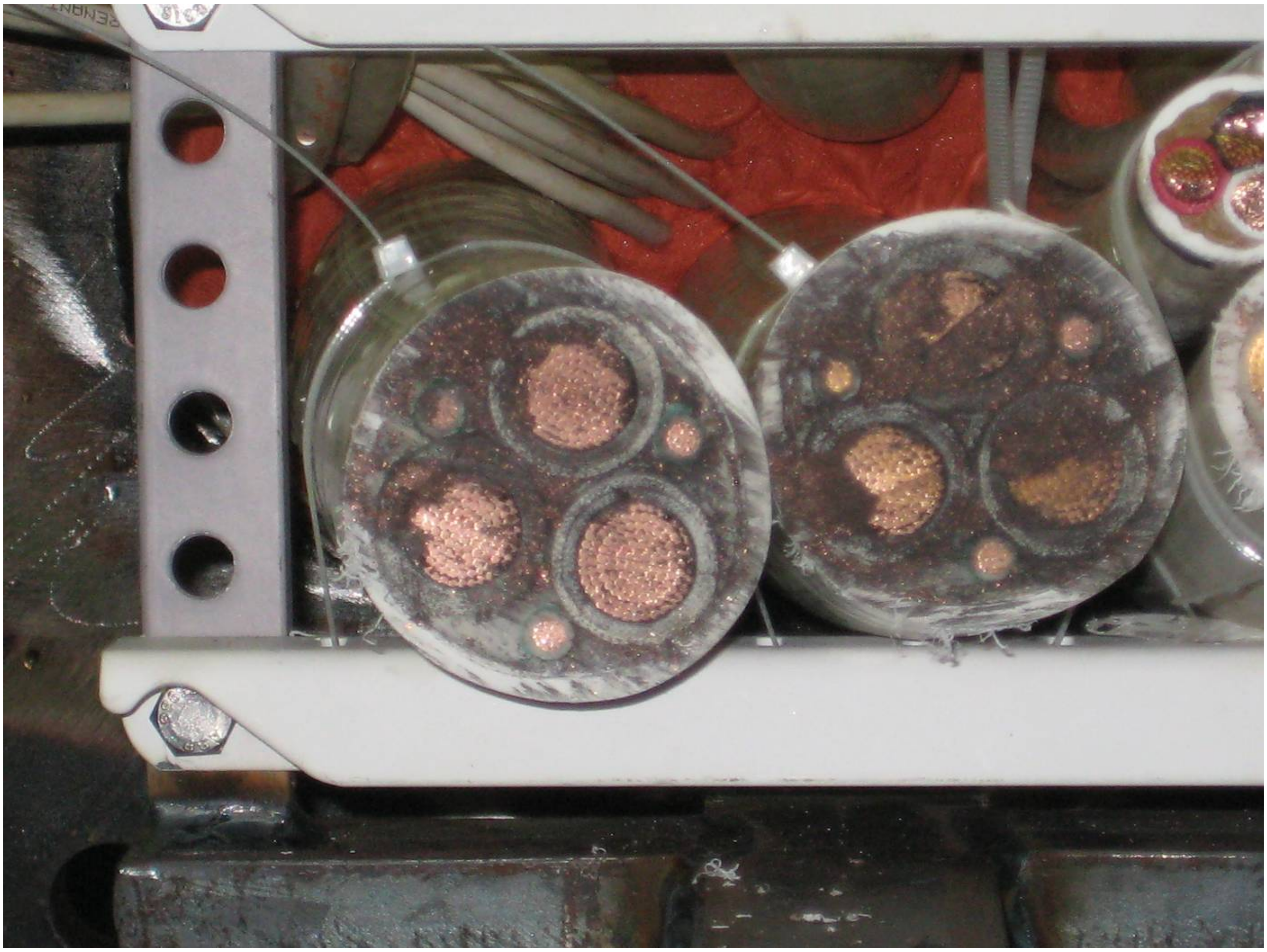


Figure 8.3.2.3.7: NOFIRNO - Close view of cable layout and smoothed sealant

Figure 8.3.2.3.8: NOFIRNO - 3 days of cure time

Figure 8.3.2.3.9: NOFIRNO - Completed unit

Figure 8.3.2.3.10: NOFIRNO - Completed unit (cont)

As shown in Figure 8.3.2.3., the lab requested that they test fixtures be modified to allow for improved interface to their shock and vibration testing equipment and stands. The cables are still supported in a way that mimics a typical cable routing design between the first hanger and the penetration area. The banding has been installed to ensure that no unwanted resonance occurs along the longitudinal axis to the cable, something that would not necessarily be present with a shipboard installation. As well, the stands holding the cable support hangers are increased in size and capacity to reduce the chance of resonance and breakage during the test. Therefore, it is clear that the set up reflects what should be installed in a typical shipboard design, and the test is more apt to be isolating the performance of the sealant from other unwanted effects, thus indicating how well the sealant and the associated interfacing systems perform during the respective test.

Figure 8.3.2.3.11: Increased Structural Support for Shock and Vibration Testing

8.3.2.4 Transit Sealant Construction Observations

The mechanic performing the sealing process with the three products had some comments about the installation of each product.

NELSON FIRESTOP EGS

- The putty is very easy to install. However, it could not be installed as directed. The directions say to place a wall ¾ of an inch thick as a backing for the sealant, but we found the ¾" wall would not hold up. Instead, the sealant was laid across and under the cables, and worked in between them. This worked well to form a base for the sealant. The putty is very pliable and easy to use.
- The sealant appeared to be very wet. It did not stick to the cables as the other products did, and took about 72 hours before it would be dry to the touch. As the outside cured, the inside appeared to still be quit soft. When you placed pressure in one area, another area would bulge out.
- As with the other products, shrinking required touch up of the sealant

FIRESEAL 3000 WITH THE D-24 BLANKET

- The blanket was easy to install, once cut, just wrap and stuff into the gaps. Small strips were used to get in between the cables to separate them from each other.
- The sealant was very easy to install. It flowed easily and spread out without much effort. It also stuck well to the cables, and was dry to the touch in about 24 hours.
- Shrinking is also expected with this product, and will be checked prior to the pressure test.

NOFIRNO

- Application of the sleeves is easy to do as long as you can move the cables around enough to get the sleeves where they are supposed to be. The sealant is easy to apply with an electric caulking gun, stuck well to the cables, and it seams to set up relatively quick, dry to the touch in about 24 hours.
- Return visits are needed. As the product cures, it shrinks, and separates from the cables so some touch up is needed.

General Observations

Of the three products used:

- The putty was the choice for filler material. It was pliable, and easy to press into place, and made a good foundation for the sealant.
- For the sealant, the FIRESEAL 3000 was the choice. It flowed from the caulking gun easily, stuck to the cables well, and spread/smoothed out easily.
- Unfortunately, they do not come together as a system.

Some questions Surface:

1) On the ship, there are places where only one side of the bulkhead is accessible. Previously, we did a double packing from one side, meaning, place sleeves in as far as possible from one side, and apply a thin layer of sealant. After curing, place a second set of sleeves in from the same side leaving about a ¾” gap for the sealant. Will we be able to do the same with these products?
2) The D-24 blanket, our set up was 8” deep. The blanket is 4” wide. We cut the width of the blanket to allow two layers, side by side, and have the ¾” needed on each end for the sealant. Could we have pressed the blanket together instead of cutting it to get the gap needed for the sealant?

8.3.3 Demonstrator Testing at BIW

The following is an account of the testing that was performed at BIW before the demonstrator units were shipped to the lab for further testing. In some instances, as mentioned previously and at various points in the information that follows, the sealants did not meet certain expectations. Various factors contributed to this, such as cure time and expertise in handling the sealant systems. At BIW, skilled craftspeople constructed the units, but their training pertained only to a select list of systems. Other systems have not been employed on the programs the technicians have experience with. Nevertheless, the system instructions were followed, manufacturer representatives consulted and the process documented to account for those factors that influence the performance of a particular sealant system. Much of that information is indicated in Appendices 8.3.1 and 8.3.2.

As the technicians completed more and more tests, just like installation, they became more skilled at the various aspects of testing with these particular demonstrator units. Leaks and anomalies were spotted quickly and the test operation halted to accommodate a repair.

The original testing results file can be viewed from the file, ..\Working Files\Pre lim test 11_27_12\Preliminary test prior to shipping.ppt. The following sections summarize the results for the three products tested.

8.3.3.1 Nelson FireStop

The Nelson FireStop product utilizes a putty material to fill the voids between cables, and act as structural support across the penetration. The following are general notes for this product and testing sequence (the first unit to be tested).

- The drain plug remained in until test was completed to allow the outside seal to be affected by a breach.
- The tank was filed with water, and pressure allowed to bleed off until the tank was full. At that time the vent was closed, and the pressure was taken to 5 lbs to check for leaks before continuing.
- At 15 lbs, water blocked cable started to leak, and the outside seal began to bulge about 1” beyond where it started.
- At the same time, water started to leak out around the large cables.
- Once the pressure was removed, the drain plug was removed, and there was no water.

Figure 8.3.3.1.1: Nelson FireStop - Installation into Test Tank

Figure 8.3.3.1.2: Nelson FireStop - Installation into Test Tank (cont.)

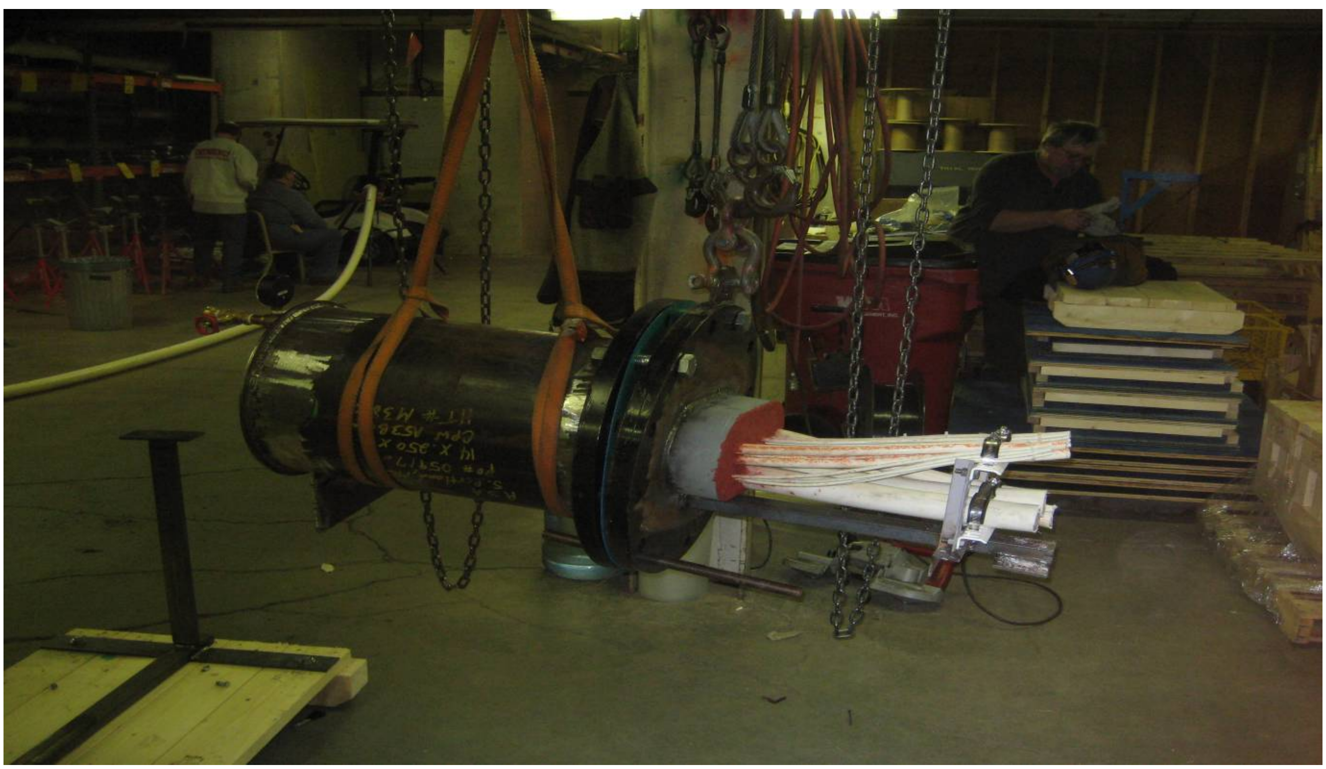


Figure 8.3.3.1.3: Nelson FireStop - Bolting Demonstrator Flange to Tank

Figure 8.3.3.1.4: Nelson FireStop - Preparing to Fill with Water

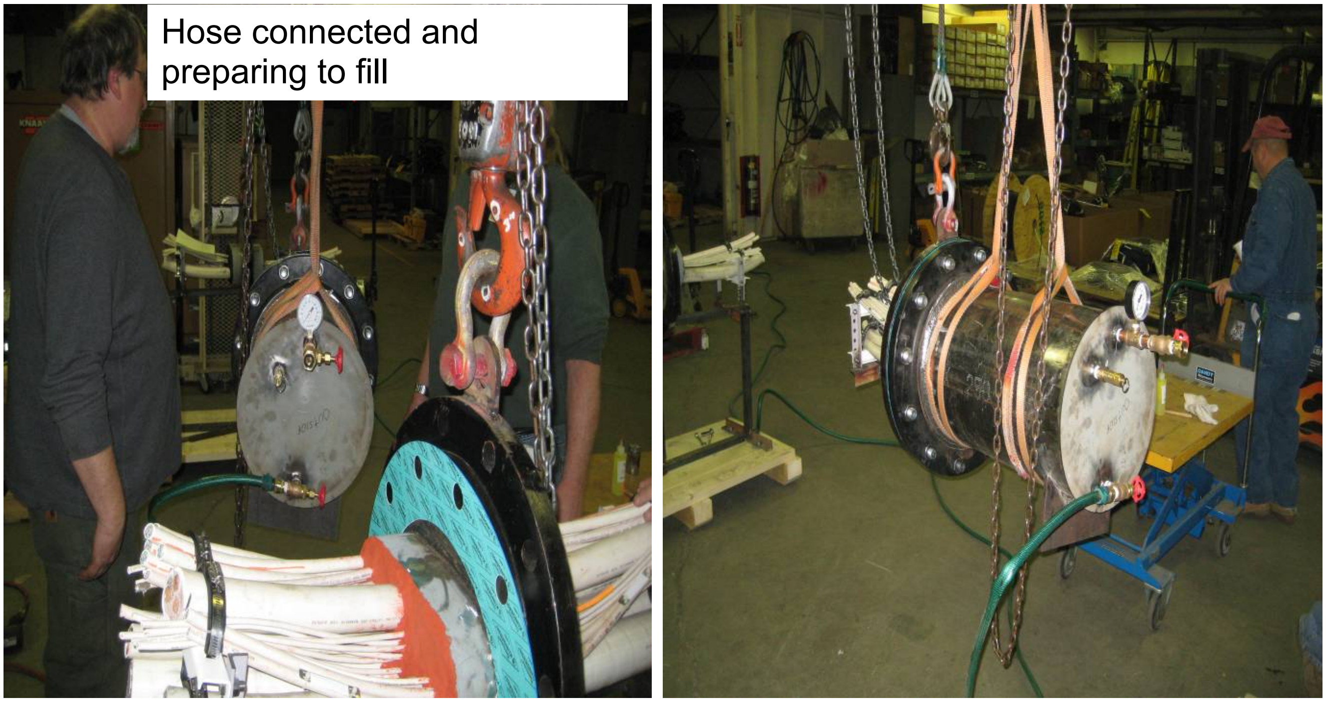


Figure 8.3.3.1.5: Nelson FireStop - Preparing to Fill with Water (cont.)

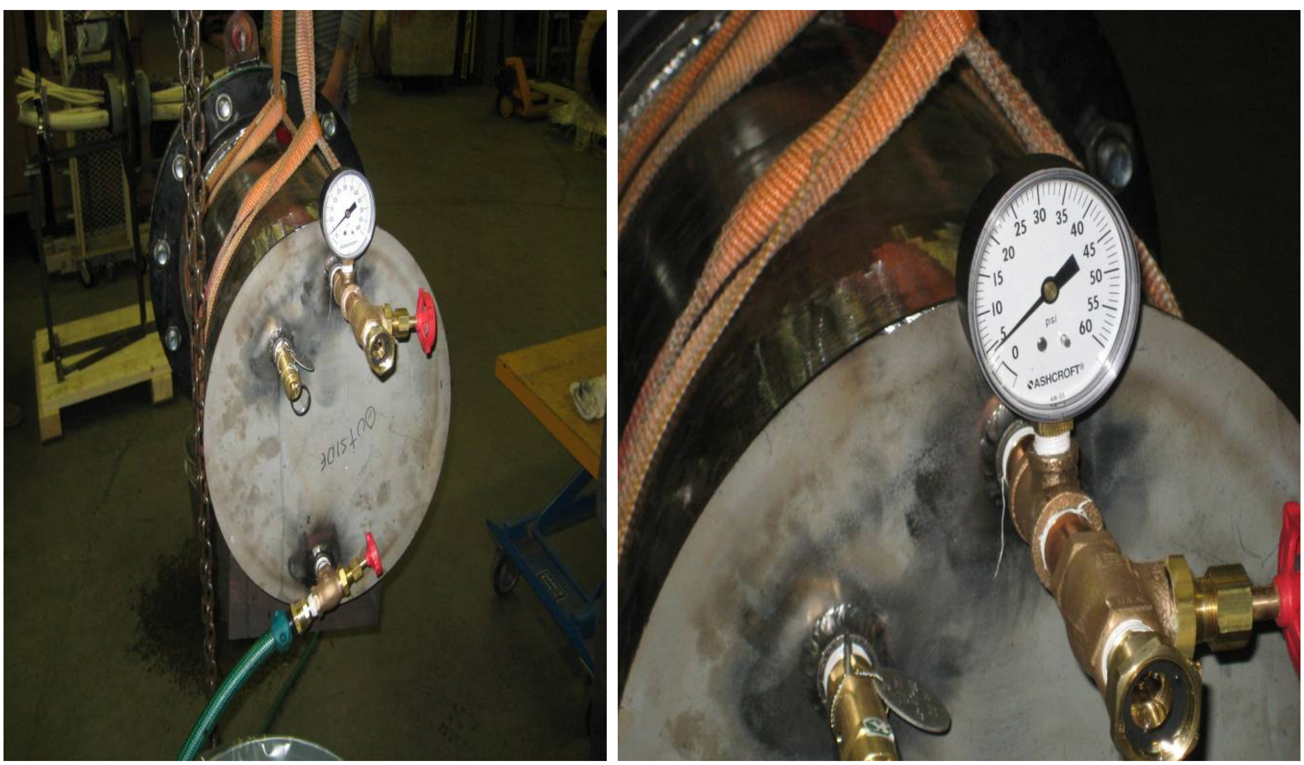


Figure 8.3.3.1.6: Nelson FireStop - Pressure at 4.5 psi

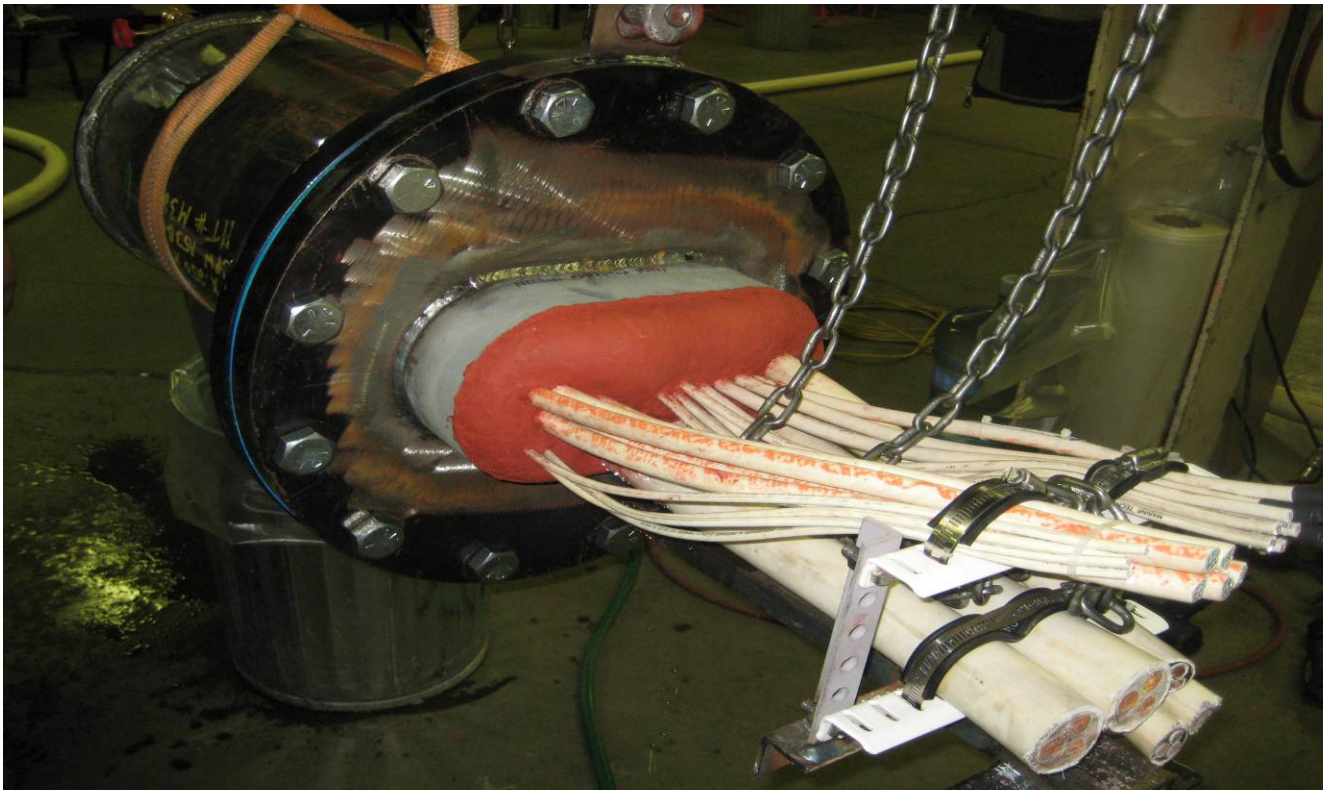


Figure 8.3.3.1.7: Nelson FireStop - 12 psi Bulging

Figure 8.3.3.1.8: Nelson FireStop - 12 psi Bulging (cont)

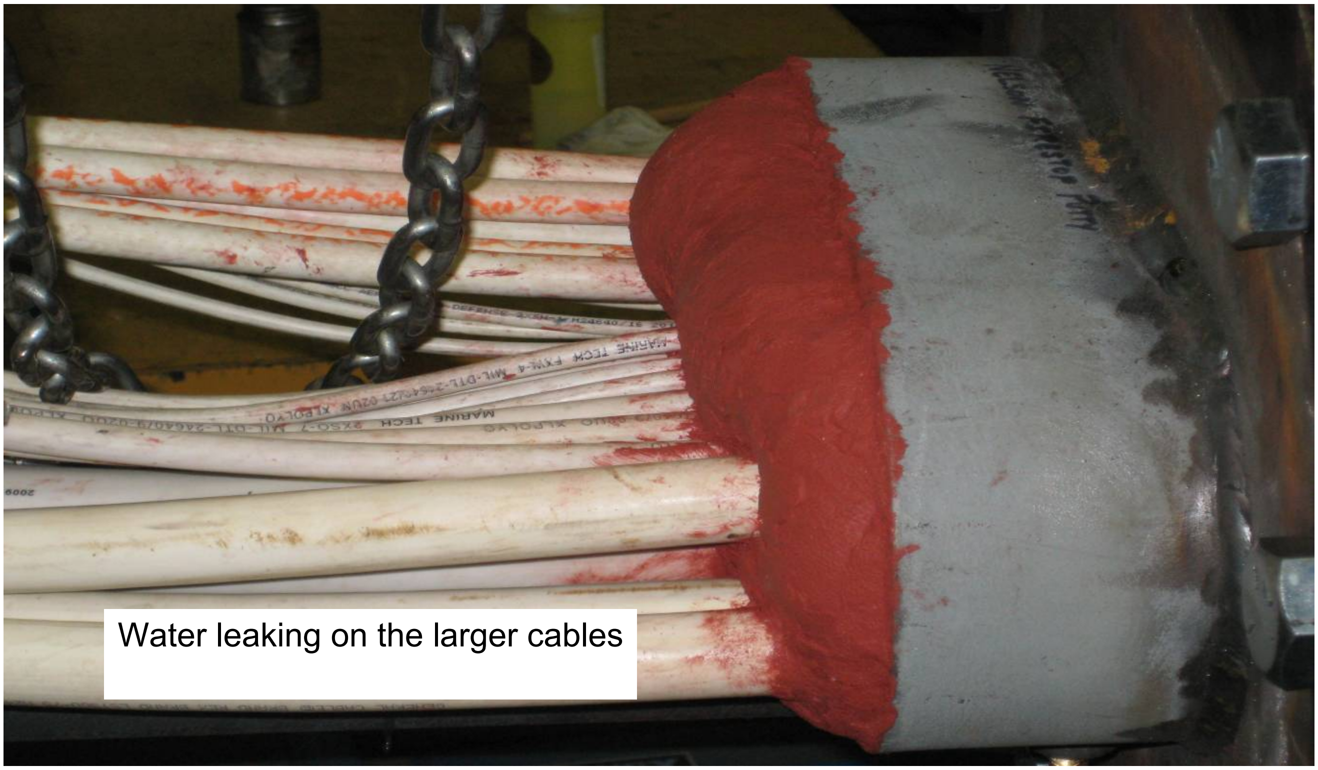


Figure 8.3.3.1.9: Nelson FireStop - Water Leakage at 12 psi

Figure 8.3.3.1.10: Nelson FireStop - Pressure Removed

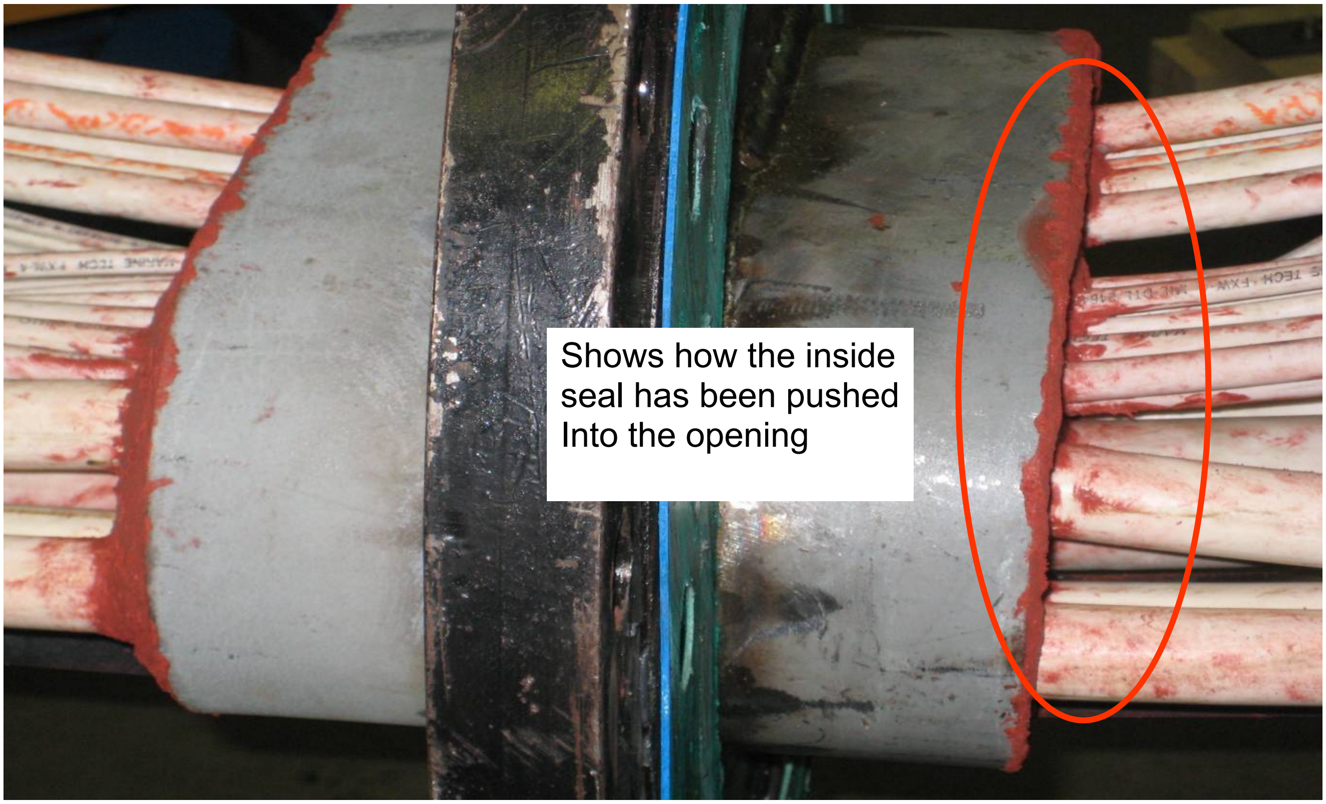


Figure 8.3.3.1.11: Nelson FireStop - Movement of Sealant

8.3.3.2 FIRESTOP 3000 with D-24 BLANKET

A similar sealant system to the previous system was tested, only this time with a blanket instead of a putty filler material, as described in Sect. 5.3. The blanket material offers a high fire and thermal resistance and barrier, but is somewhat more susceptible to installation dynamics, since the blanket moves more during installation than the other filling products; also it is far more compressible than the other materials, since the installation is generally done so that air pockets between the layers and within the fiber layers themselves is what creates the effective thermal barriers. The following is a summary of the testing, with several figures
(

Figure 8.3.3.2.1 to

Figure 8.3.3.2.5).

- The drain plug remained in until test was completed to allow the outside seal to be affected by a breach.
- The tank was filed with water, and pressure allowed to bleed off until the tank was full. At that time the vent was closed, and the pressure was taken to 5 lbs to check for leaks before continuing.
- At 10 lbs, the pressure was held in order to check for bulging in the outer seal, it was beginning to bulge, and the cables began to leak.
- Pressure was removed, and the leaking cable was sealed with shrink.
- When the pressure was resumed, at about 8 lbs, the outer bulge disappeared, and the pressure went to 0 lbs.
- Investigation showed where the water was leaking around the cables.
- When we removed the transit from the tank, we noticed the inner seal had been pushed inward, and had a hole in it
- When the plug was removed, a lot of water was present between the seals

Figure 8.3.3.2.1: FireStop and Blanket – Finished Product Outside Seal Before Hydro Testing

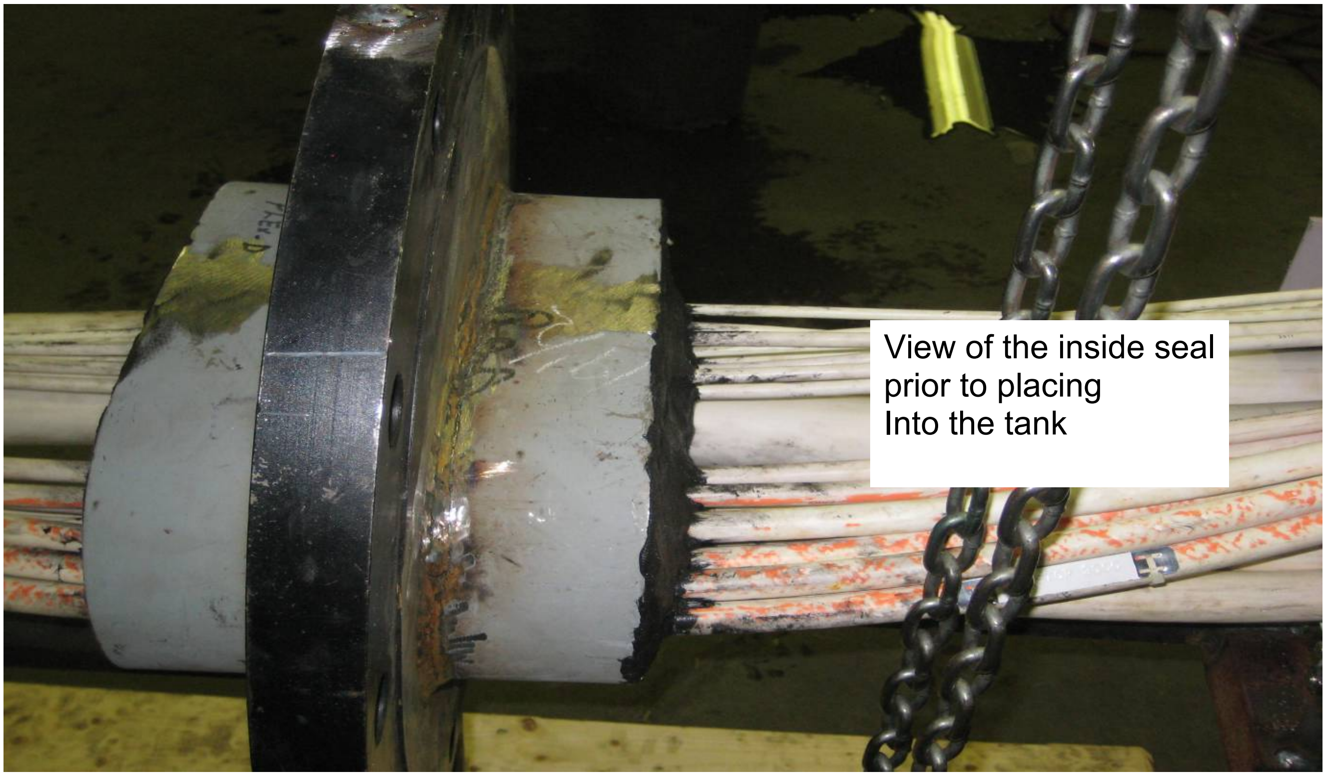


Figure 8.3.3.2.2: FireStop and Blanket – Finished Product Inside Seal Before Hydro Testing

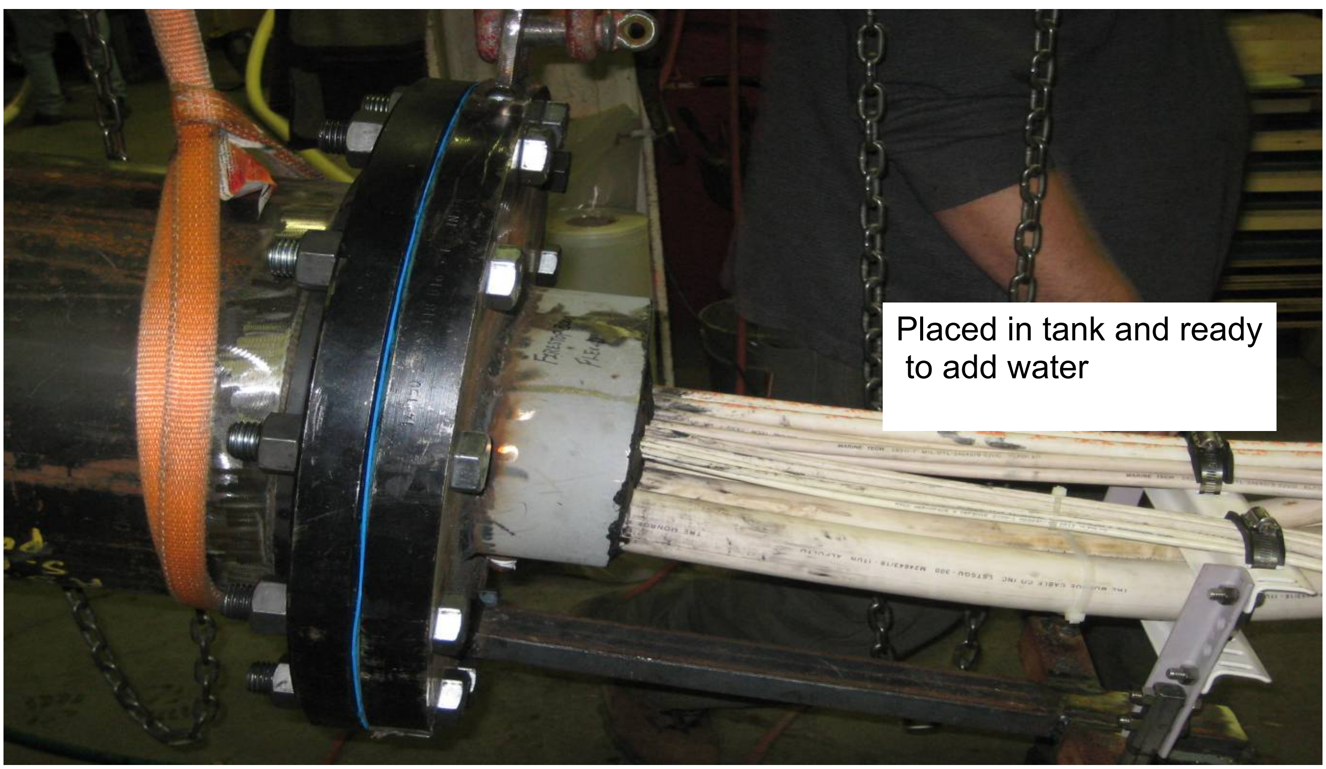


Figure 8.3.3.2.3: FireStop and Blanket - Ready for Water

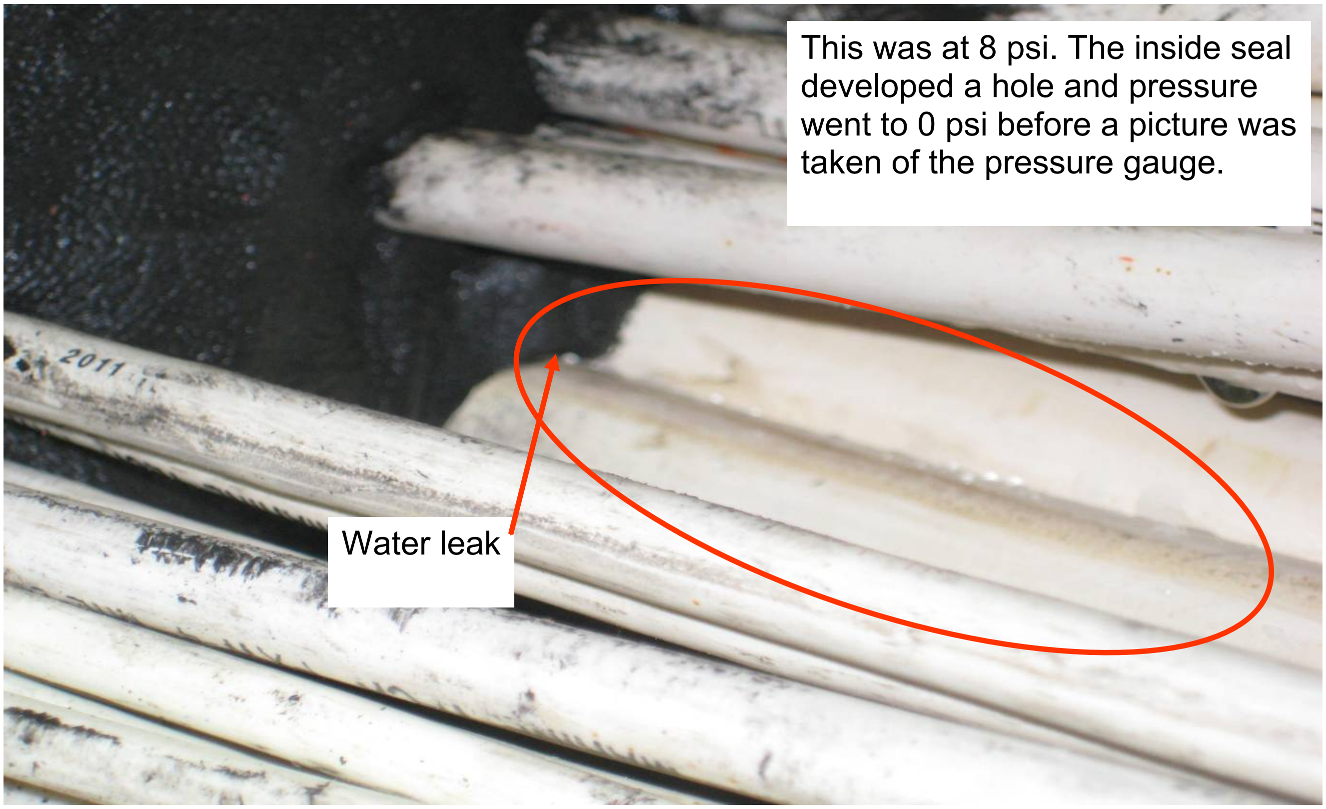


Figure 8.3.3.2.4: FireStop and Blanket - Water Leak at 8 psi

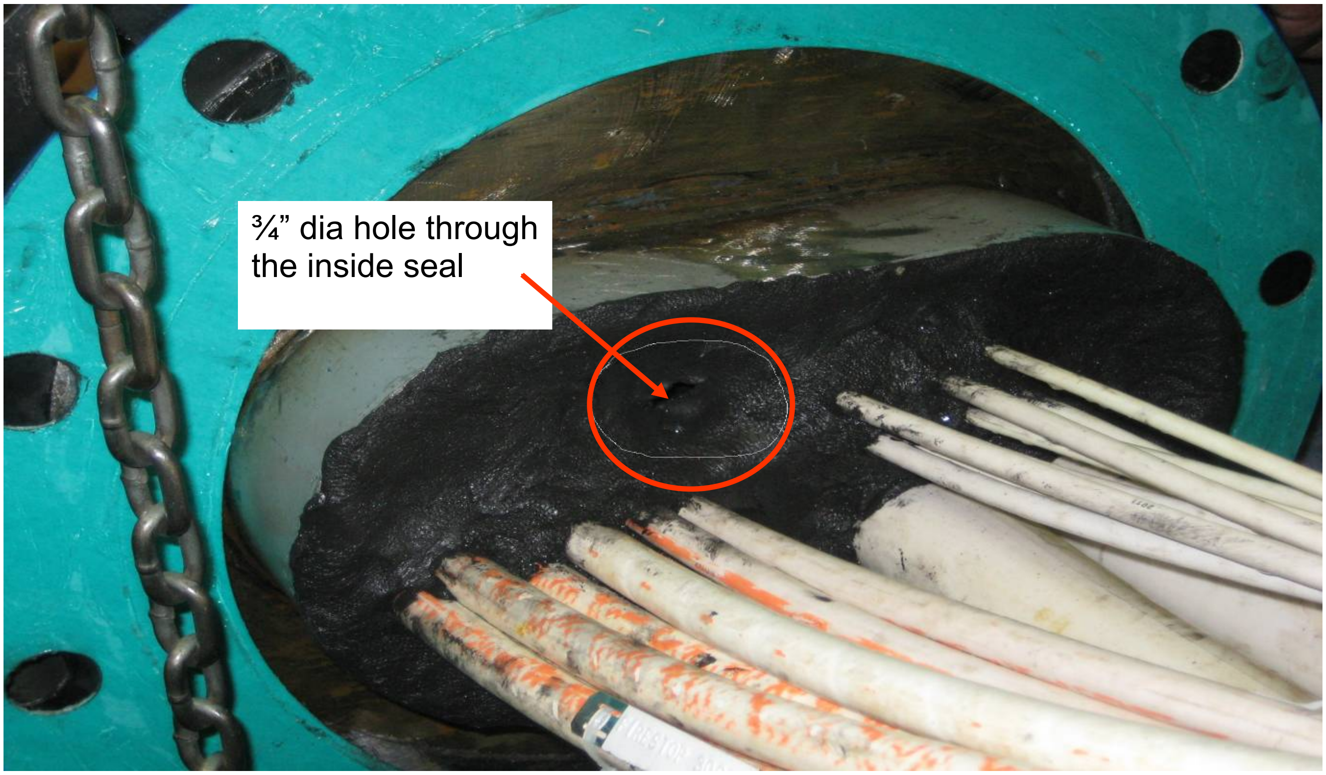


Figure 8.3.3.2.5: FireStop and Blanket - Puncture in Sealant

8.3.3.3 NOFIRNO

The NOFIRNO product uses various sized sleeves that serve to act as protection for the penetrating cables and act as filler in the space between inboard and outboard penetrating surfaces. The sleeves are continuous between surfaces, and serve to interface with greater structural integrity than the blanket, and depending on the way the putty is installed in the FireStop system, creates a better cohesiveness within the space. The following is a summary of the testing and photos depicting the hydro testing results.

- The drain plug remained in until test was completed to allow the outside seal to be affected by a breach.
- The tank was filed with water, and pressure allowed to bleed off until the tank was full. At that time the vent was closed, and the pressure was taken to 5 lbs to check for leaks before continuing.
- Pressure was increased to 22 psi two small leaks were discovered around the cables
- Water blocked cables started to leak water at around 13 lbs.
- Pressure was increased to 28 psi for around 20 seconds, the water blocked cables were spraying too much water to continue.

Figure 8.3.3.3.1: NOFIRNO - Bolted and Ready to be Hydro Tested

Figure 8.3.3.3.2: NOFIRNO - Pressure Testing at 10 psi

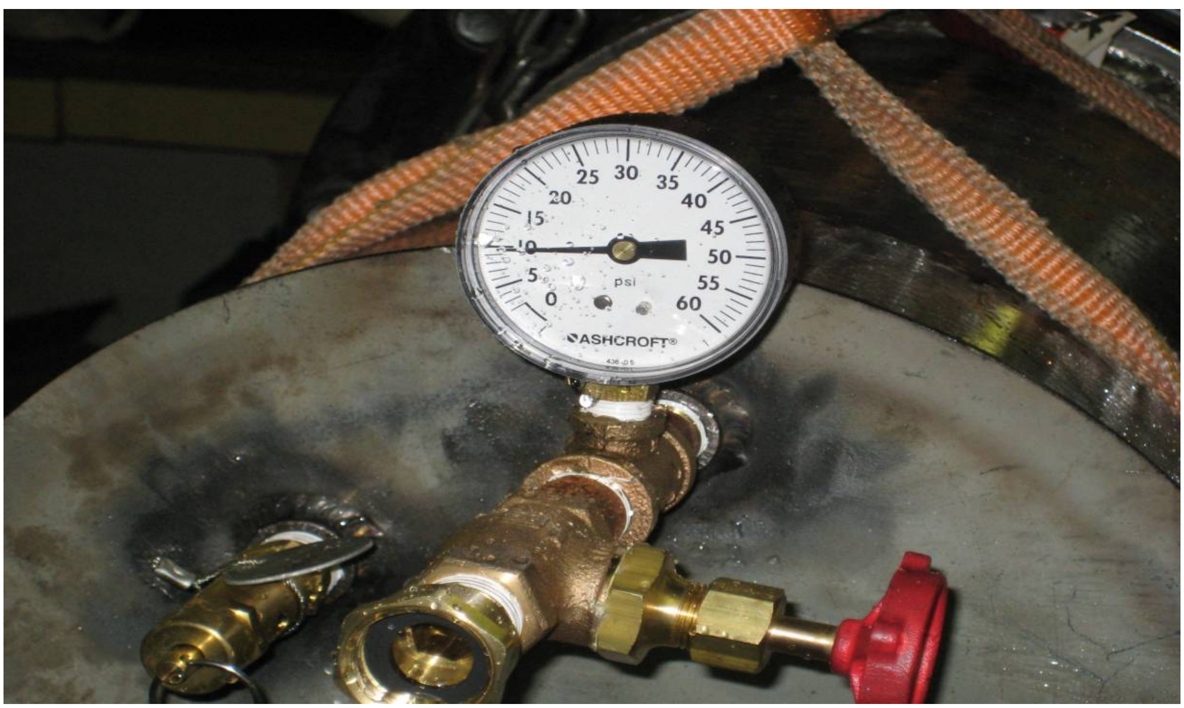


Figure 8.3.3.3.3: NOFIRNO - Pressure Testing at 10 psi (cont)

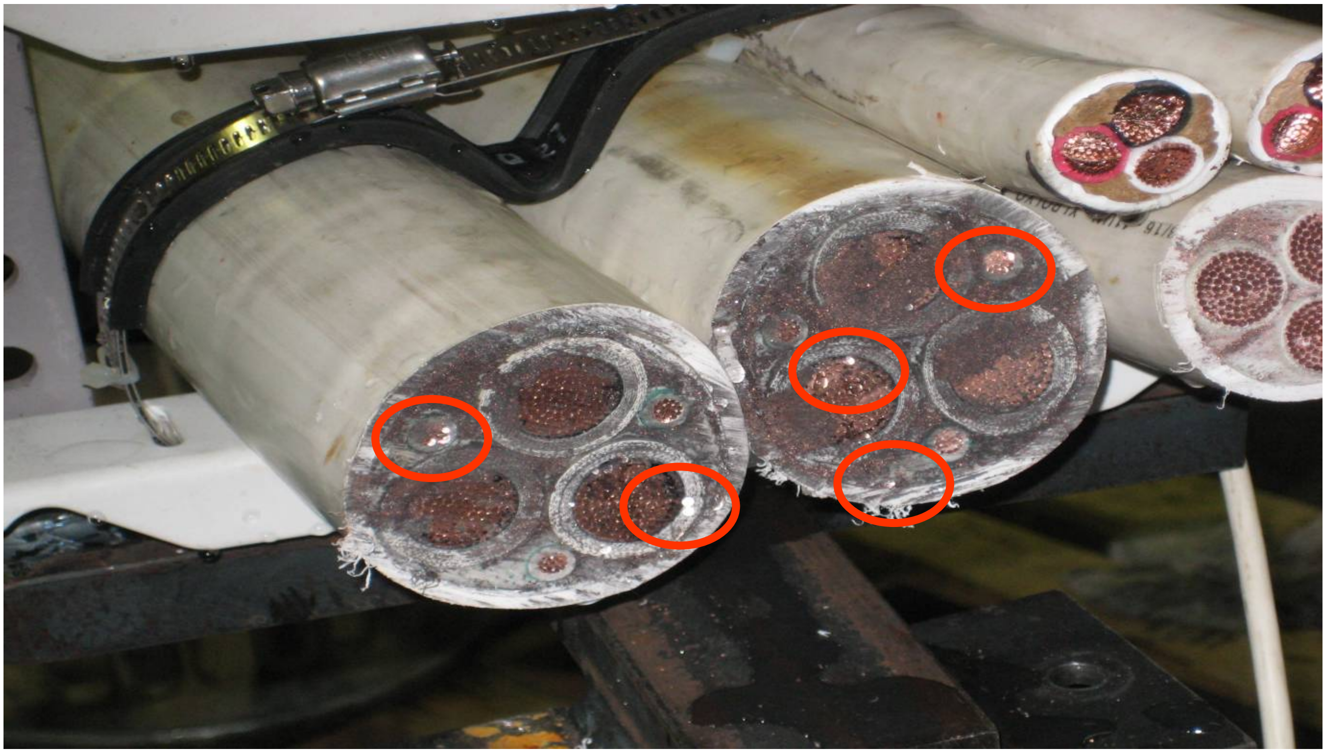


Figure 8.3.3.3.4: NOFIRNO - Water Leaking Through Cables at 13 psi

Figure 8.3.3.3.5: NOFIRNO - Water Leaking Through Cables at 13 psi (cont)

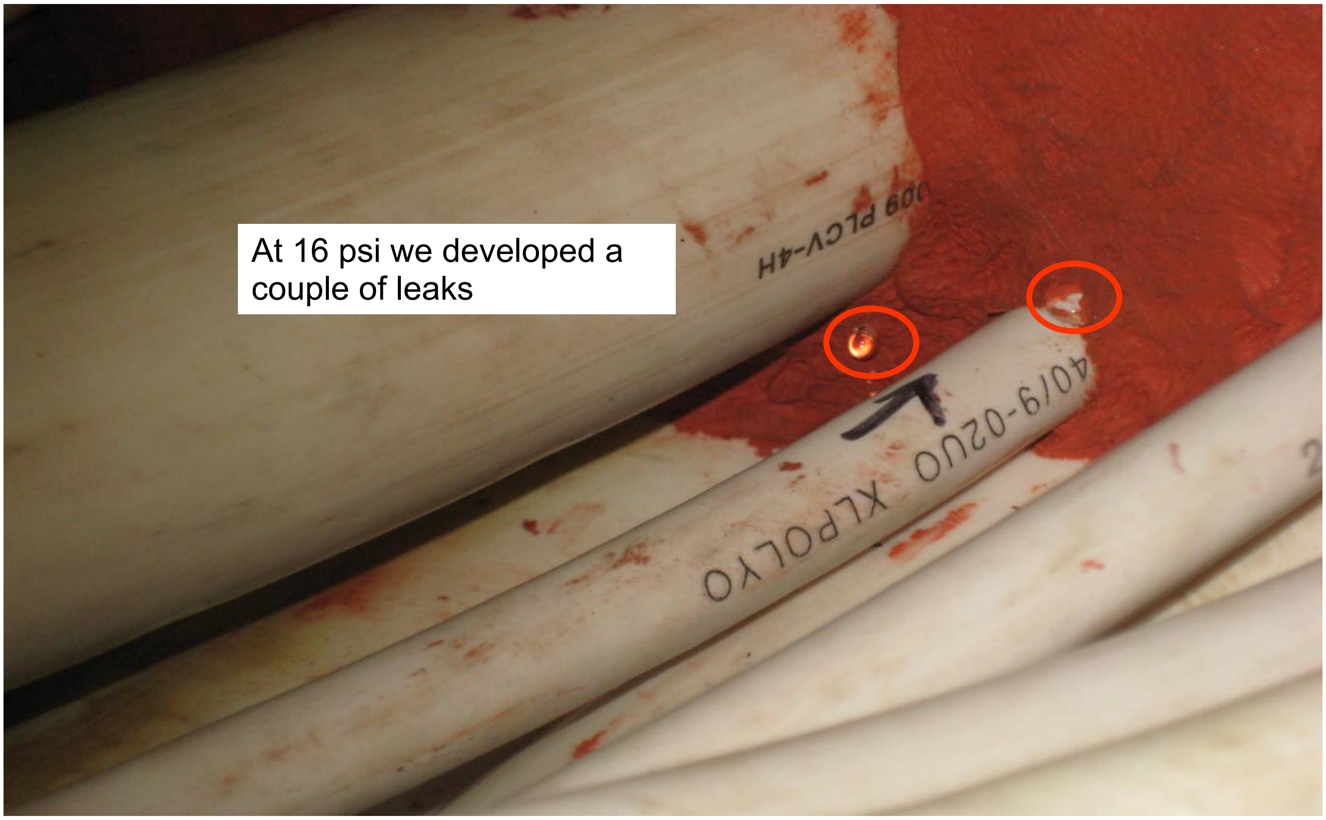


Figure 8.3.3.3.6: NOFIRNO - Water Leaks in Sealant

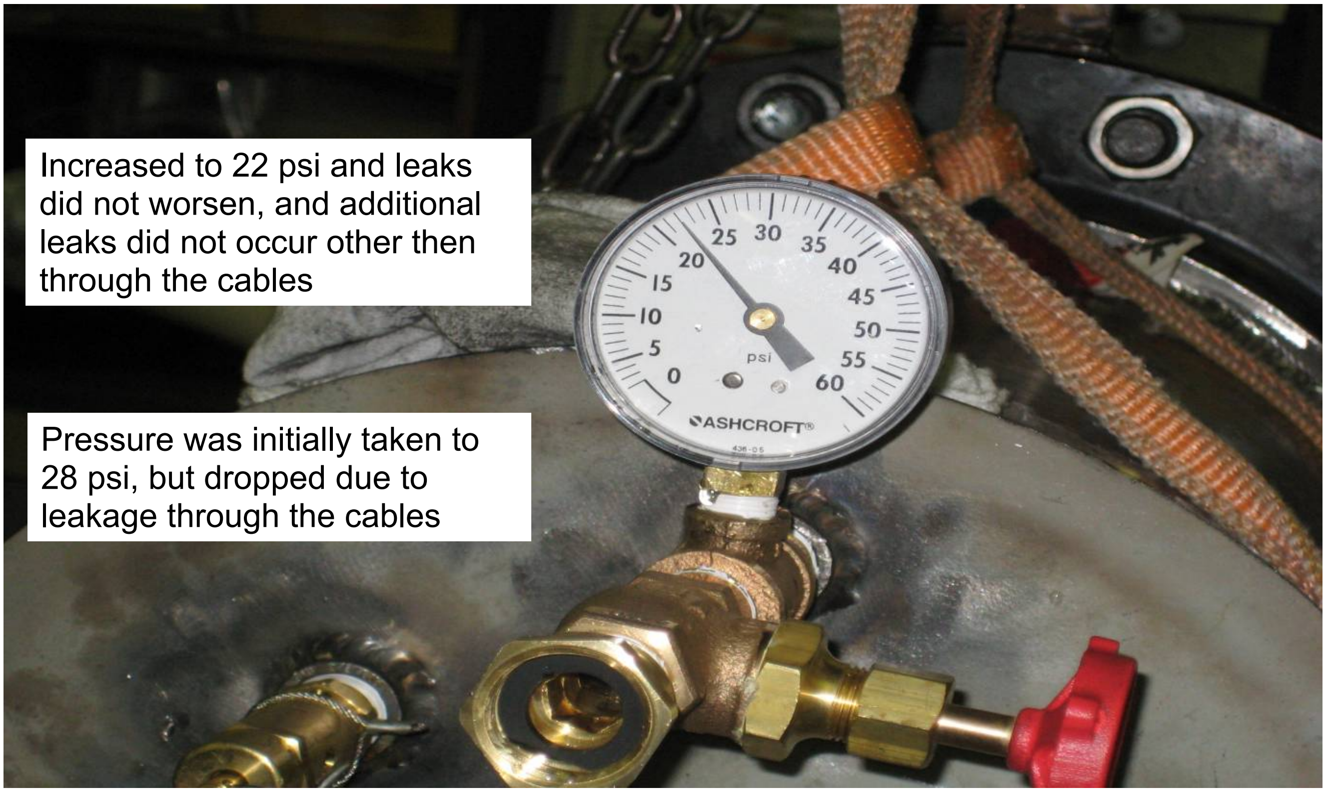


Figure 8.3.3.3.7: NOFIRNO – Test Requirements are Met

Once all the transits were removed from the tank, they were inspected, and sealant was applied in order to reseal the damaged areas. All the cables on the tank side had the ends sealed with heat shrink so no pressure would be lost through the cables. The transits were placed on the stands and packed for shipment to the lab at AERONAV Laboratories. The Scheduled testing at the lab was not estimated to commence before the sealant repairs had adequate time to cure. In fact, the sealants had more than twice the recommended cure time for the entire volume of material, not just the small repair area. As the area applied and volume applied increases, the cure time increases to a maximum across manufacturers of 20 days. The actual cure time that was available do to circumstances exceeded this period of time.

8.3.4 Demonstrator Testing Procedure

The following is the testing procedure that was used to receive estimates and develop scopes of work for the testing of the demonstrator unit. Change information has been included.

National Shipbuilder Research Program, Electric Technologies Panel
Transit Sealant Evaluation Project

Demonstrator Test Procedure

Submitted by: Greg Stevens, BIW
5/22/12
9/7/12, Rev. A

Revision	Date	Description	Pages
-	5/22/12	Initial Release	all
A	9/7/12	Added attachments that describe various clarifications requested by the laboratories bidding on the project	9-22-12

Performance Testing

This is part of a National Shipbuilding Research Program project aimed to evaluate the operating performance of various sealants available as alternatives to the more traditional transit blocking systems. This document outlines the basics for a demonstration unit that will be used and tested for various operating performance attributes of several sealants, whereby a relative evaluation will be conducted and recommendations made to the greater community on the feasibility of these sealants to be used in various applications.

This study investigates how various transit or penetrator sealing products compare in performance and relative cost, particularly as it relates to the marine industry. The products will be demonstrated along basic measures, whereby conclusions can be drawn as to what the most convenient, affordable solution might be for a given set of applications or programs. This is regarded as a performance based sequence of tests, referencing several standards and specifications, both commercial and military in nature. This set of tests and the results obtained thereby do not constitute, in full or part, a qualification program for military use. Rather, it serves as a baseline data point to support evaluation of existing products, approaches and methods used for determination, and a mechanism to build a qualification program based on similar sealant technology. Demonstration of various products is meant to illustrate current technology capability, features, attributes and deficiencies, and this series of tests is not meant to serve as an immediate basis for product selection, discrimination, or dissemination.

Overview

Each sealant sample specimen will be installed in a demonstrator unit which will permit the sample to be performance tested for vibration, shock, watertightness and fire resistance, in that order. The sample specimens will be populated with a representative selection of cables, installed per manufacturer instructions and installed in geometries consistent across all test samples. After each stage of testing, the specimen will be examined for damage or failures.

Testing References

MIL-DTL-24705B(SH); Penetrators, Multiple Cable, Electric Cable, General Specification

Resolution A.754(18); International Maritime Organization (IMO); Recommendation on Fire Resistance Tests for “A,” “B,” and “F” Class

MIL-STD-2003-3A(SH); Department of Defense Standard Practice for Electric Plant Installation Standard Methods for Surface Ships and Submarines (Penetrations)

Demonstrator

1) Sketch

2) Specimen plate with penetrator
3) Cable support

Demonstrator Transit Cable Configuration

An assortment of representative cables conforming to MIL-DTL-24643 shall be used, as outlined below:

CABLE SIZE	LSTSGU-400	LSTSGU-200	LSTSGU-75	LSTSGU-23	LSTSGU-9	DXW-3
DIAMETER	2.203	1.669	1.134	0.812	0.575	0.257
AREA EA	3.81	2.19	1.01	0.52	0.26	0.05
QTY INSTALLED	2.00	2.00	7.00	7.00	9.00	10.00
TOTAL AREA	7.62	4.37	7.07	3.62	2.34	0.52

The total area of the cables listed above is 25.5 in^2. The area of the flat 6" x 12" oval transit is 64.3 in^2, resulting in a fill of 40%, consistent with standard practice. A notional cable arrangement is shown in Figure 1. Refer to the attached design document for more information on the demonstrator design attributes and components.

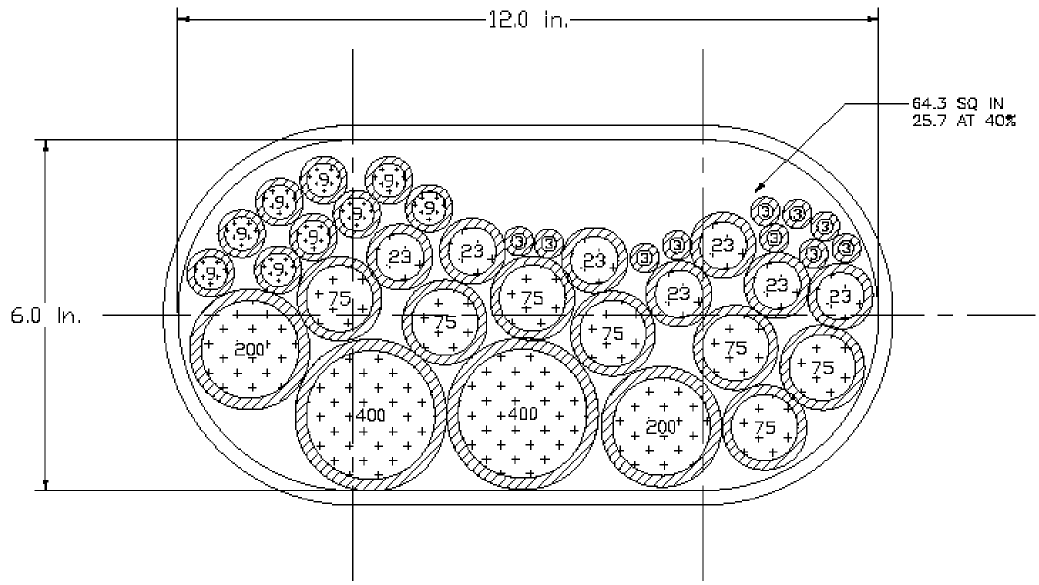


Figure 1: Notional Transit cable fill
NOTE: Filler material not shown.

For conducting the vibration and shock tests prior to the fire resistance test, the specified cables shall project 500mm ± 50mm beyond the transit on each side of the penetration. During vibration/shock tests, adequate support for cables shall be provided using MIL-STD-2003-3A(SH) for guidance.

All installation procedures and techniques shall be done in accordance with the manufacturer's instructions. This includes using the proper back fill devices (i.e., blocks or tubes, plastics, cloths or styrofoam).

The assembly will be allowed to cure per manufacturers recommended minimum period. Testing for proper cure shall consist of the following (somewhat subjective, but considered indicators of proper cure):

- Touch test: check for tackiness and finger printing on the surface to indicate whether the surface has properly cured
- Rub test: rub the surface to check for runny areas, or if the material moves with minimal sheer resistance, indicting the material has not yet cured or has been contaminated
- Visual inspection: inspect for signs of cracking, bumps (indicating air bubbles or contaminants), dimpling (indicating uneven evacuation of material or air during curing), scaring (indicating an incision subject to fracture), disengagement from surfaces (peeling away from a surface leaving a jagged or sheer surface)
- Small movement test: slowly move the apparatus at low frequency, back in forth in 3 planes and check for a gelatin like movement, indicating the material is not entirely cured in the middle, or has disengaged from surfaces; if the cables move in relative fashion, cable engagement is likely satisfactory

Vibration

Upon receiving the demonstrator units, the units shall be carefully inspected for damage. The units will then be hydrostatic tested, in accordance with the test listed below. This will set the baseline for the rest of the testing to be performed on each unit. If failure is noted, immediately contact the procuring group to notify of the failure. It is expected the failure will be repaired by the lab or a representative of the manufacturing company that supplied the testing sample and accompanying components. Another hydrostatic test will be performed if the unit is repaired.

Each sample shall be vibration tested in accordance with Type I vibration requirements of MIL-STD-167-1.

The assembly shall not demonstrate loosening or failure of any component or a detectible change of state of materials that may affect watertightness or fire performance. The penetration integrity after the vibration test shall be verified by painting the penetration assembly with soapy water (both sides) and blowing compressed air at 414 kPa (60 psi) at the sample area. If there are no bubbles on either side emanating in a slow, but steady state from the surface of the sample during and shortly after the air has been removed, the vibration-tested assembly shall then be subjected to the shock test.

Shock

Fire resistant penetrations, with passive fire protection and associated attachment system, shall be subjected to a Lightweight, Grade A shock test in accordance with MIL-S-901-D prior to conducting the fire resistance test.

The assembly shall be inspected after the shock test and shall not demonstrate loosening or failure of any component or a detectible change of state of materials that may affect watertightness or fire performance. If the assembly will not be hydro tested at the shock test facility, the penetration integrity shall be verified by painting the penetration assembly with soapy water (both sides) and blowing compressed air at 414 kPa (60 psi) at the sample area. If there are no bubbles on either side emanating in a slow, but steady state from the surface of the sample during and shortly after the air has been removed, the shock-tested assembly shall then be transported to a separate facility to be subjected to the light test and the hydrostatic pressure test.

Complete functional testing at the shock test site is desired to avoid possibility of damage during shipping and handling.

Light Test

After successfully completing the shock test, the unit will be subject to a light test. In as low light conditions as possible (less than 25 foot candles if possible), one person will shine a light source, comprising at least 1million candle power, on one side of the unit while another person checks for light penetrating the medium. If no light is visible from the light source, continue the test by testing the other side in the same manner. Record the results. If the unit passes the test, proceed to the watertightness test. If it fails, inspect the area more closely and proceed with the hydrostatic test, albeit in a very cautious fashion if the leak appears to be a small pin hole, of no more than one. If there are more holes or the hole is larger than a pin hole, to not conduct the hydrostatic test. The testing is complete to this stage. The unit will then be repaired upon the authorization of the procuring group, in order to complete the testing.

Watertightness

After successfully completing the shock test, specified cable lengths shall be trimmed to meet the cable length requirements of post-shock fire test and watertightness test. Care shall be exercised so as not to compromise the integrity of the penetrator. Be sure, during trimming, the cable is sufficiently supported on each side of the penetration so the cables do not move in relation to the penetrator during trimming, in any direction. If movement is observed, report the direction of movement and the approximate profile of the movement (amount of movement and relationship to the face of the penetrator along 3 axes) for future reference during inspection.

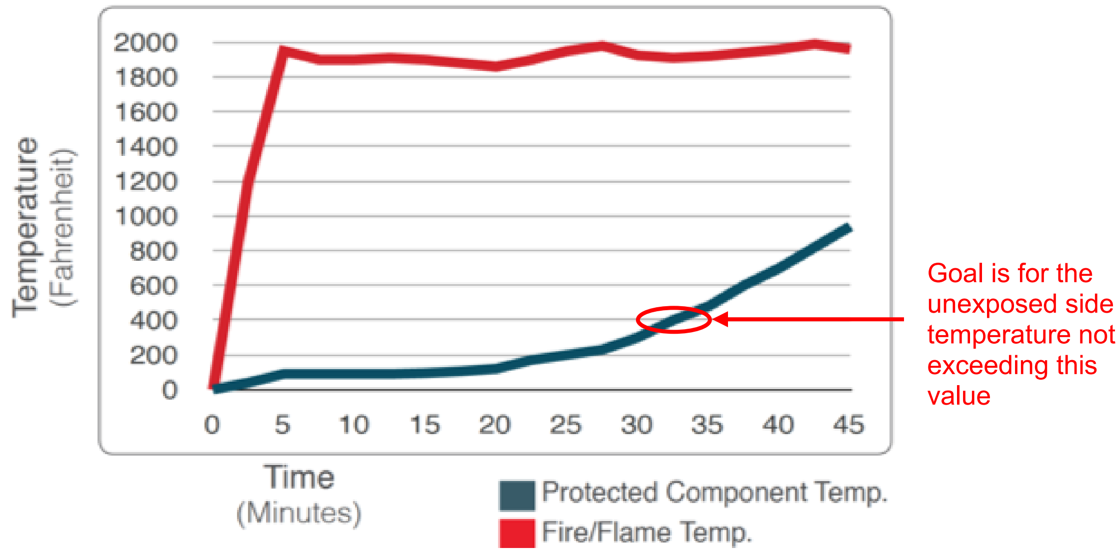
For post-shock fire test and watertightness test, the specified cables shall project 500±50 millimeters (20±2 inches) beyond the transit on the exposed side of the division and 500±50 millimeters (20±2 inches) on the unexposed side.

The multiple cable penetrator test specimen mounted on the test plate shall be bolted to the hydrostatic chamber so that one side of the test specimen is exposed to water, and the opposite side of the test specimen is exposed to air. The hydrostatic chamber shall then be filled with water and pressurized to 1.9 Bars (27.5 pounds per square inch). This pressure shall be maintained for a minimum of 10 minutes unless specimen failure occurs sooner. The test specimen shall be considered as having failed the watertightness test if, after 10 minutes (or before once equalization has occurred), the water pressure, as indicated on the blind flange gauge, has decreased to less than 1.9 Bars. [MIL-DTL-24705B(SH); 4.6.5]. After the test is complete, open the fitting connected through the penetrator to identify any water leakage into the void area of the tubes. Verify that after 5 minutes open to atmosphere, there is no discernable water leakage.

Upon successful hydrostatic testing, a fire resistance test shall be conducted.

Fire Resistance

The fire resistance test is based on the IMO A.754(18) fire test procedure, modified to provide a hydrocarbon pool fire exposure based on the UL 1709 fire curve, for a period of 60 minutes, as shown below.



Courtesy of Unitherm Website (example)

Thermocouples or other temperature measuring devices shall be mounted as indicated in IMO A.754(18) Appendix IV, section 3.1 and Figure A2. The time and temperature measurement at each thermocouple shall be recorded for the duration of the test period, in addition to ambient temperature. A profile shall be generated that clearly shows the performance of the material and installed product.

Test Report and Demonstrator Disposition

A test report shall be generated and submitted to the procuring company, which identifies and describes the following:

- Date of receipt of demonstrator units
- Received condition and any repairs that were needed
- Condition of demonstrator units and samples immediately before and after each test (based on inspections and tests outlined in this procedure)
- Performance of each test, with all applicable data and observations outlined
- Pictures and videos of the demonstrator and samples immediately before and after a particular test, and during the testing if applicable
- Data sheet and description of all testing apparatus used for each test
- Time and date each test was performed
- Environmental conditions 1 hour before, 1 hour after and during each test (i.e., air temperature, air humidity, water temperature for hydrostatic testing)
- Observations on smoke emanating from the sample during the fire test

- Any anomalies encountered during any of the tests

After the testing is completed, the testing company shall package each demonstrator for shipment so the tested samples are stable and at minimal risk for damage (even though it is suspected the units will be in rough shape after the fire testing). The units shall be shipped to the procuring company, whereby further inspection and testing will be performed.