NSRP | National Shipbuilding Research Program

# Navy Standard Bookend Fixtures for Shock Testing In-Line Pipe Components

**NSRP Project: 2024-335-001**

**Report Number: 25-LEIDOS-0224-29029R1**

**Date: 3/15/2025**

**Written By:**

Mike Poslusny

Mike Parnin

Survivability Department

Leidos Gibbs & Cox

Michael.J.Poslusny@leidos.com

Michael.E.Parnin@leidos.com

**TABLE OF CONTENTS**

**TABLE OF FIGURES:**



**LIST OF TABLES:**



**REFERENCES:** (Available upon Request)

1. Fabrication Drawings for the Navy Standard Bookend Fixture Designs, NSRP Project: 2024-335-001, dated 15 March 2025.

2. Navy Standard Bookend Fixtures for Shock Testing In-Line Pipe Components (Limited Version), NSRP Project: 2024-335-001, dated 15 March 2025.

# 1. Project Overview

The Navy Standard Bookend Fixtures for Shock Testing project was a yearlong effort that began in March 2024. These test fixtures are required by MIL-DTL-901E, "Detail Specification, Shock Tests, H.I. (High Impact) Shipboard Machinery, Equipment, and Systems, Requirements For," dated 20 June 2017, for shock testing "in-line pipe" components, however, no Navy Standard drawing existed, unlike other commonly used fixtures This project involved participants from five (5) organizations and sought to streamline the shock qualification process, reduce costs, and avoid schedule delays for shock test bookend test fixtures by developing Navy-approved standardized designs.

Through a process of research, design, testing, and analysis; fabrication drawings for small, medium, and large bookend test fixtures were developed. These drawings, cited as Reference 1, Fabrication Drawings for the Navy Standard Bookend Fixture Designs, are available upon request. The bookend test fixture drawings will be included in the next revision of MIL-DTL-901 and considered "Navy Standard."

This report has been prepared to offer an unlimited distribution overview of the Navy Standard Bookend Fixtures for Shock Testing Project. Details pertaining to the design, modeling, shock testing and analysis activities have been compiled into a limited distribution version of the final report (Reference 2) and is available upon request for all U.S. Shipyards and NSRP members.

## 1.1 Problem Statement

Shock testing of shipboard equipment is conducted in accordance with MIL-DTL-901E. Within this specification, Section 3.1.7.1 states, "Components supported by piping or other flexible connections where simulation of the flexibility is not considered conservative shall be tested by mounting between rigid support structure such as block hangers or bookends."

When shock testing common equipment like valves, educators, and other "in-line pipe" components (e.g., components connected to a pipe installed directly within the flow of the system), bookend test fixtures are often required. Certified shock test facilities currently design and fabricate the needed bookend test fixtures and despite their frequent use, there have been no standardized designs. Each of these bookend test fixtures are considered thus "non-standard" and require submission of associated drawings, models, and analyses to the Shock Delegated Approval Authority (DAA) for review and approval prior to executing the shock test – a process which adds costs and contributes to a lengthier project.

The development of Navy Standard, pre-qualified bookend shock test fixtures will streamline the qualification and installation process, reduce costs, and prevent schedule delays associated with designing and approving bookend test fixtures.

## 1.2 Goals / Objectives

The primary goal of the National Shipbuilding Research Program (NSRP) Navy Standard Bookend Fixtures for Shock Testing project was to design, test, analyze and certify a suite of bookend test fixtures to be included in the next revision of MIL-DTL-901. The fixtures must accommodate a wide variety of "in-line pipe" components and incorporate simple to fabricate designs that ensure commonality across all shipyards and Navy approved shock test facilities. These designs will serve as the basis to create Navy Standard drawings that will optimize shock qualification programs, minimize schedule delays, and reduce costs associated with shock test fixture development for all shock hardened, U.S. Navy ships.

## 1.3 Tasking

The project consisted of four stages:

- Research and Design
  - Review bookend test fixture designs used in previously approved lightweight and medium-weight shock testing.
  - Investigate typical "in-line pipe" components and select a range of sizes / weights for the bookend fixtures to accommodate.
  - Determine common interfaces (ANSI standard flanges, hardware, etc.).
  - Create multiple sizes of preliminary, bookend fixture designs (small, medium and large) and perform a modal analysis on each design to meet MIL-DTL-901E requirements for "non-standard" test fixtures.

- Fabrication and Testing
  - Fabricate a set of bookend fixtures (medium bookend test fixture design).
  - Perform lightweight shock testing on the medium bookend test fixture.
  - Install instrumentation to capture shock acceleration and modal frequency data during testing for comparison to analytical predictions.
  - Determine pros and cons of the medium bookend fixture design regarding fabrication, installation on the lightweight shock machine and shock test performance.

- Analysis of Results
  - Compare shock test data results of the medium bookend fixture to analytical predictions (modal frequency content and stiffness characteristics).
  - Update the Finite Element Model (FEM) to better represent the shock tested configuration and match the test data results.
  - Review data results with the Navy Delegated Approval Authority; Naval Sea Systems Command (NAVSEA 05P) and Naval Surface Warfare Center Carderock Division (NSWCCD) to validate the updated analysis approach and determine the desired frequency response for each fixture design.

  - Optimize the three bookend fixture designs following guidance from NSWCCD to achieve desired frequency responses and finalize each design.
  - Review final analysis results for the small, medium and large bookend fixtures with NAVSEA 05P and NSWCCD and determine the limitations for each fixture to include in the "General Notes" section of the drawings.

- Implementation
  - Create Navy Standard drawings of each bookend test fixture, intended for inclusion in the next revision of MIL-DTL-901.
  - Provide *AutoCAD* files of each drawing to NSWCCD.

- Additional tasking requested by NSWCCD:
  - Investigate how the center of gravity (CG) of a test item affects each fixture's frequency response and determine the maximum allowable CG.
  - Investigate the "Swiss cheese" phenomena to determine when the interface plate of each fixture needs to be replaced.

## 1.4 Project Participants

The project team consists of multiple organizations:

- NSRP
  - Jim House – Senior Program Manager
  - Victoria Dlugokecki – Program Technical Representative

- NAVSEA 05P / NSWCDD
  - Tom Brodrick – Senior Engineering Manager (EM), Shock – Submarines
  - Domenic Urzillo – DAA Submarines

- Leidos Gibbs & Cox
  - Mike Poslusny – Project Manager
  - Mike Parnin – Design/Engineering Lead
  - Nikki Washington – Contracts
  - Dominic Price – Drafting
  - Terrence Nelson – Drafting

- Ingalls Shipbuilding
  - Michael S. Thompson – Mechanical Engineer
  - Jamie Breakfield – Project Manager

- General Dynamics NASSCO (Unfunded Observer)
  - Nour Chihwaro – Electrical Engineer
  - Dr. John Moatsos – Principal Engineer

## 1.5 Project Status and Timeline

Figure 1 shows the status and timeline for the project. The project progressed as planned but required a two month, no cost extension due to contractual struggles at the beginning. The final report and drawings were delivered on 15 March 2025.

<table>
<tr><th>Jan '24</th><th>Mar '24</th><th>Jun '24</th><th>Aug '24</th><th>Sep '24</th><th>Dec '24</th><th>Jan '25</th><th>Mar '25</th></tr>
<tr><td>Project Awarded<br>mid-Jan '24</td><td>Kick Off<br>21 Mar '24</td><td colspan="5">Ingalls joins project</td><td>Final Report and Drawing<br>15 Mar '25</td></tr>
<tr><td></td><td colspan="5">Research & Design</td><td></td><td></td></tr>
<tr><td></td><td colspan="2">Mar - Jun '24<br>*Investigated size, weights of "in-line pipe" components<br>*Determined small, medium & large bookend test fixtures support most items<br>*Designed the medium test fixture and preformed modal analysis</td><td></td><td colspan="2">Sep - Dec '24<br>* Designed small & large test fixtures<br>*Obtained Navy concurrence on the small and large test fixture designs</td><td></td><td></td></tr>
<tr><td></td><td></td><td colspan="2">Fabrication & Testing</td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td colspan="2">Jun - Aug '24<br>* Fabricated the medium test fixture<br>* Performed lightweight shock test on the medium test fixture</td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td colspan="6">Analysis of Results</td></tr>
<tr><td></td><td></td><td colspan="2">Jun '24 - Aug '25<br>* Analyzed results from medium test fixture shock test<br>* Validated fixture performance</td><td colspan="2">Sep - Dec '24<br>* Finalized medium test fixture design</td><td colspan="2">Jan - Mar '25<br>* Finalized large fixture design<br>*Presented modal analysis to the Navy</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="2">Implementation</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="2">Jan - Mar '25<br>* Created drawing for the small, medium, and large fixtures</td></tr>
</table>

**Figure 1: Project Status and Timeline**

# 2. Research and Design

## 2.1 Research Phase

At the start of the project, the team acquired Master Equipment Lists for a variety of Navy ship programs and extrapolated a list of "in-line pipe" components; categorized by size and weight. The majority of the list included different types of valves (stop, check, globe, butterfly, etc.), but also included eductors, strainers and filters. Most components were installed in piping systems with a nominal outer diameter (OD) between ½" and 12", with the largest valve weighing 1,278 lbs. The team decided to target a maximum payload of 1,500 lbs. with a maximum OD of 12."

After determining the maximum payload and OD, the team decided that three (3) sizes of bookend fixtures (small, medium, and large) could accommodate the size and weight range of most "in-line pipe" components. The goal was to design a variety of fixtures for use on the lightweight and medium weight shock machines while staying within the weight limitations of each machine.

Prior to the design phase of the project, the team acquired multiple lightweight and medium weight shock test reports for "in-line pipe" components to familiarize themselves with bookend fixture designs from the past 20 years of Navy approved shock testing.

The old bookend fixtures had a lot in common. They consisted of a vertical, interface plate (for test item attachment) that was welded to a horizontal base plate. A set of vertical chocks of various shapes and sizes were located on both sides of the fixtures to provide the appropriate stiffness and allow space for the unit to be easily installed. The bookend fixture configurations were typically welded to an adapter plate or to a Navy Standard Test Fixture to interface with the shock machine. Almost all of them were tailored to custom fit the unit under test.

## 2.2 Design Phase

After reviewing past designs, the team brainstormed ideas and agreed to implement the following characteristics into the new bookend fixture design:

- Simple to fabricate using standard structural shapes, welding practices and bolted joints.
- Made of carbon steel (A36) to reduce cost.
- Assume ANSI Standard flange attachments to determine fixture sizes.
- Create a small, medium and large bookend fixture to accommodate the following range:
    - Up to 3" nominal OD (small).
    - Up to 6" nominal OD (medium).
    - Up to 12" nominal OD (large).
- Allow for pressurization of pipe components using National Pipe Thread (NPT) fittings and clearance holes.
- Easily adaptable to the lightweight and medium weight machine (using bolts).
- Install with standard wrenches and tools.
- Investigate the implementation of a reusable, interface plate for the test item that is bolted to the test fixture in lieu of welding:
    - Allows for custom plates based on component size.
    - May be replaced after multiple uses (instead of the entire fixture).
    - Uses Grade 5 hardware.
    - Meets frequency response guidelines for each shock machine.

## 2.3 Preliminary Medium Bookend Fixture Design

After careful consideration of the desired characteristics, the team designed a medium sized bookend fixture with the intention of being fabricated and shock tested. Ingalls Shipbuilding had a similar bookend fixture onsite that could be cut apart and modified to represent the preliminary medium bookend test fixture design as shown in Figure 2. Preliminary small and large bookend fixtures were also designed to accommodate the range of test item sizes. For clarification purposes, Figure 3 shows the nomenclature and general aspects of a typical bookend test fixture configuration (test article is installed in between two test fixtures).

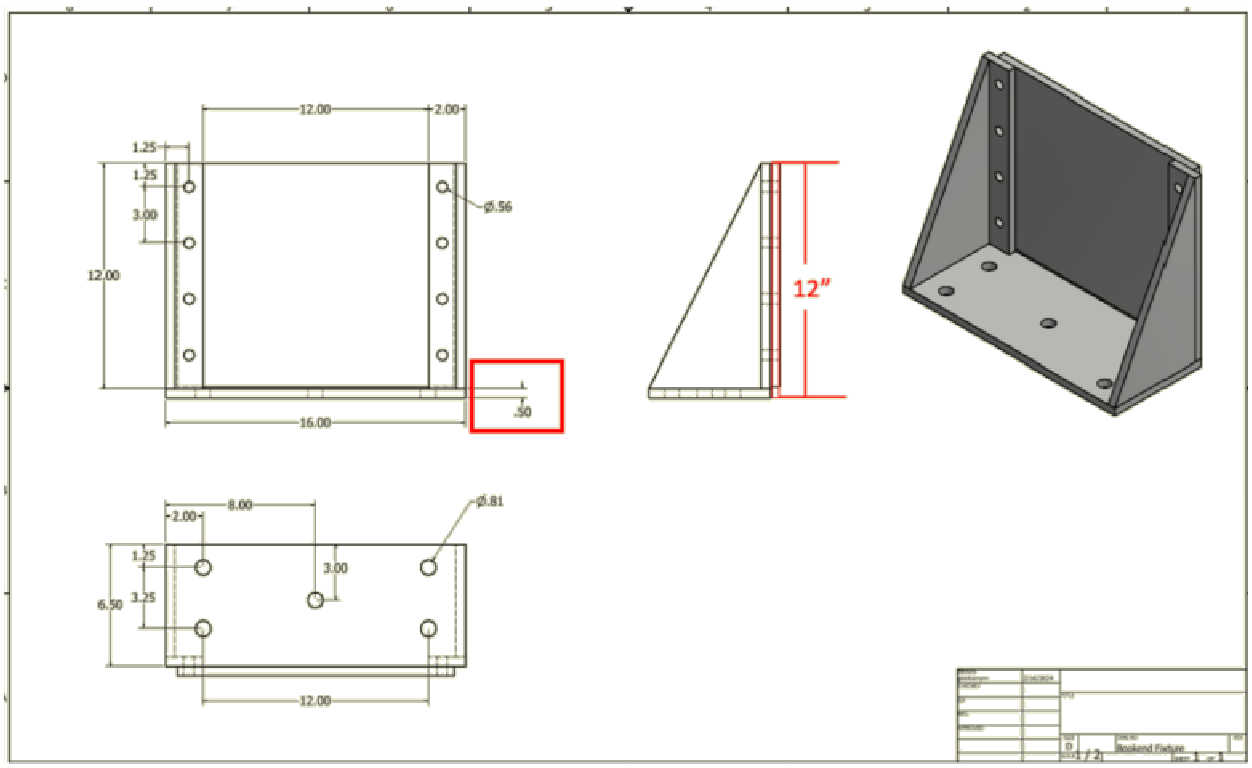


**Figure 2: Preliminary Medium Bookend Fixture Design**

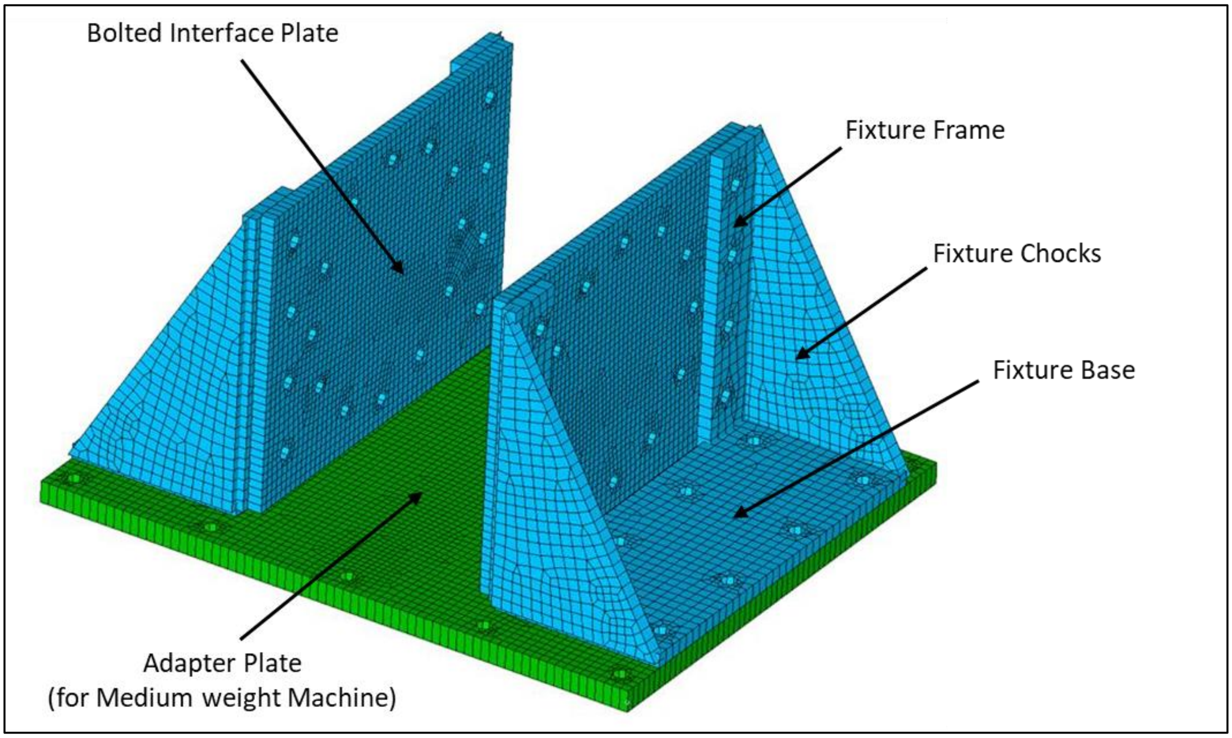


**Figure 3: Bookend Test Fixture Configuration Nomenclature**

## 2.4 Frequency Response

The team hosted regular meetings with NSWCCD to obtain guidance for the desired frequency response of each test fixture design to meet MIL-DTL-901E criteria for “non-standard” test fixtures. The main concern was the natural frequency of the bolted interface plate, since traditional designs incorporated a welded interface plate.

The consensus was to ensure that a bolted interface plate was stiff enough to provide adequate shock loading during shock testing. NSWCCD requested the interface plate resonance to be near 160 Hz for lightweight shock testing applications and above 90 Hz for medium weight shock testing applications.

Leidos / Gibbs & Cox personnel used FEMs and modal analyses to determine the resonant frequency and dominant modes of each bookend fixture / interface plate design to ensure the criteria was met.

## 2.5 Design Integration with Shock Machines

The team investigated how to interface each bookend fixture with the lightweight and medium weight shock test machines, while staying within the weight limitations required by MIL-DTL-901E. The small and medium bookend fixtures were designed to easily adapt to the lightweight shock machine (LWSM) on MIL-DTL-901E Test Fixtures 4A, 4C, or 11C using a similar bolt pattern used in historical shock testing. Test Fixture 4A is the preferred application, as it can accommodate the largest payload weight and installation surface area. Test Fixture 11C is very heavy (280 lbs.), therefore only the small bookend fixture should be considered for its use It is possible to use the medium bookend on Test Fixture 11C, but due to its weight it can only support a small payload of 50 lbs. to stay withing the weight limitations of the shock machine.

The bookend fixtures (medium and large) can interface with the medium weight shock machine (MWSM) utilizing an adapter plate with a natural frequency above 90 Hz to interface with Figure 13 of MIL-DTL-901E (described in Section 4.6).

The three, preliminary bookend test fixture designs are shown in Figure 4.

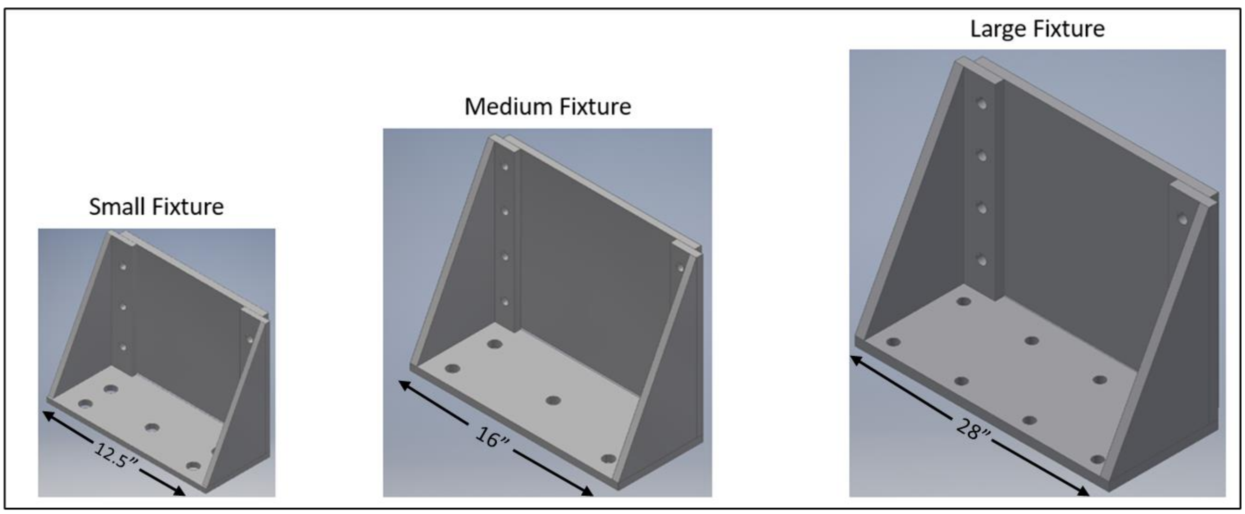


**Figure 4: Preliminary Bookend Fixture Designs**

# 3. <u>Fabrication and Testing</u>

## 3.1 Medium Bookend Fixture Fabrication

The medium bookend test fixtures were fabricated by Ingalls Shipbuilding and used ½" steel plates with ¼" welds and fastened using Grade 5 hardware. A photo of the built fixtures is shown in Figure 5. During this fabrication process, advantages and disadvantages of the design were noted as a means to seek improvement for the final design.

**Figure 5: Fabricated Medium Bookend Test Fixtures**

### 3.2 Lightweight Shock Testing of the Medium Bookend Fixtures

The team conducted a shock test using a Navy certified lightweight shock machine located at Ingalls Shipbuilding in Pascagoula, MS. The shipyard had recently tested a ball valve / actuator combination which was available for use as an ideal representative payload candidate to test out the medium bookend fixture design. Shock testing was performed in late August 2024. Results are documented in Ingalls Shipbuilding Test Report No. TR-SHK-2404 Rev (-), "MIL-DTL-901E Lightweight, High Impact (H.I.) Shock Test Report for Navy Standard Bookend Fixtures," dated 23 September 2024 and is included in the limited version of the final report (Reference 2).

### 3.3 Lightweight Shock Test Configuration

The team decided to utilize MIL-DTL-901E Test Fixture 4A (27″ x 34″ x 1/2″ plate) to interface the medium bookend fixture with the lightweight machine. Shock testing of the medium test fixtures was conducted in several steps. First, an accelerometer was installed in the center of the interface plate on one of the medium test fixtures to measure transient acceleration values and the modal frequency response during testing. A lightweight shock test was performed on a single, medium bookend test fixture to characterize the interface plate. During this test, the fixture was subjected to 1 ft. and 5ft. vertical blows to capture the frequency response and determine the bookend stiffness.

A second test was performed on a representative payload (ball valve with actuator) of 174 lbs. and a CG of 4 – 3/8" above the center of the valve. It was installed between two medium test fixtures to simulate typical equipment under test. The test fixtures were then subjected to 3 ft. and 5 ft. vertical blows. The test arrangement is shown in Figure 6 and Figure 7.

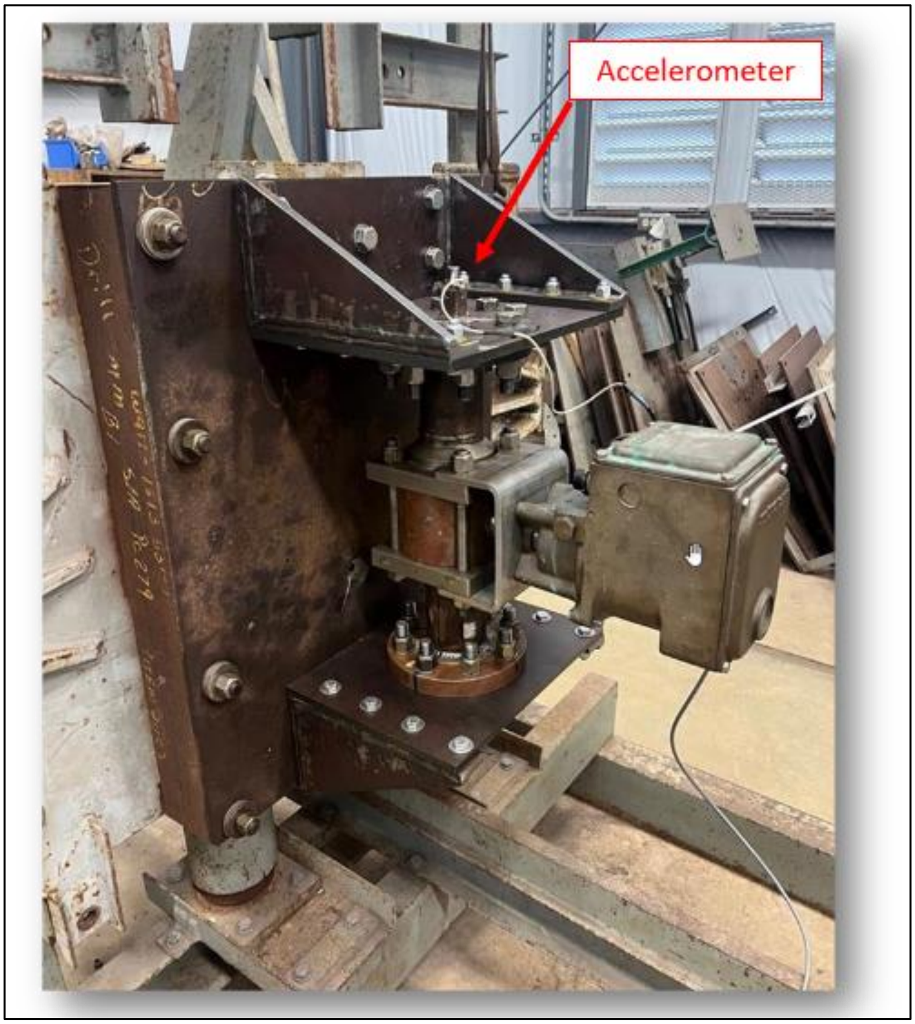


**Figure 6: Test Arrangement Highlighting Accelerometer**

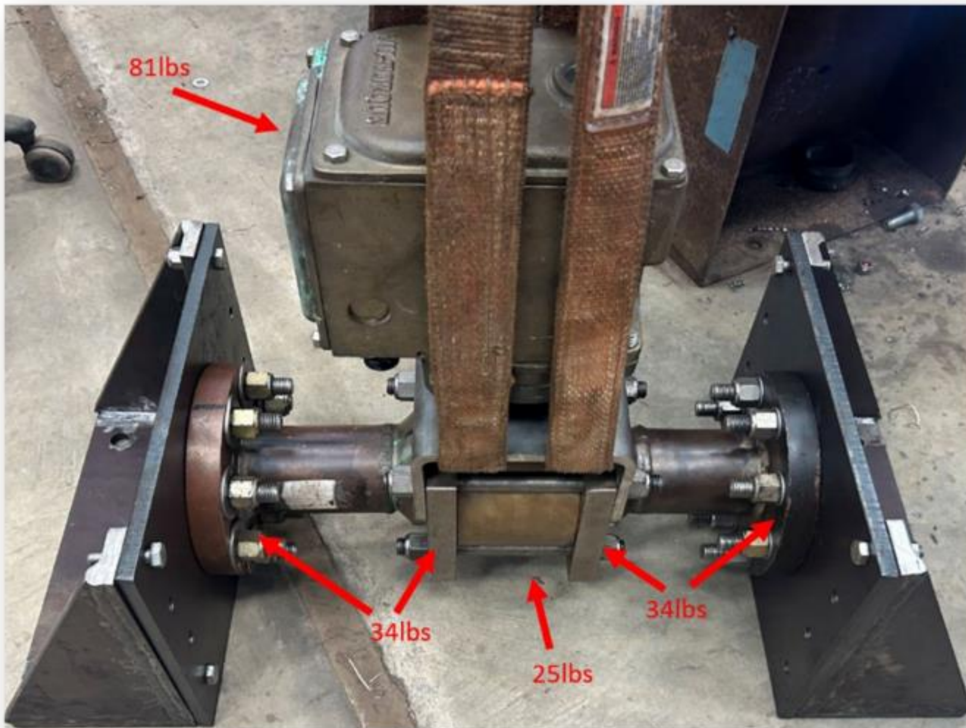


**Figure 7: Test Arrangement Highlighting Dummy Mass**

Throughout testing, acceleration and frequency data was recorded on the top bookend fixture. Shock test data and analysis results are considered "Limited Distribution" and are available upon request. See Reference 2, Navy Standard Bookend Fixtures for Shock Testing In-Line Pipe Components (Limited Version), for data results.

### 3.4 Lessons Learned from Shock Testing

In addition to acquiring data, several lessons were learned during fabrication of the bookend fixture and performance of the shock test series. First, bookend frames need to be wide enough (approximately 1" in depth) to accommodate washers and avoid weld interference. This also allows for installation of the interface plate on either side of the frame to provide additional room for valve installation on the lightweight shock machine (small and medium fixtures only).

Next, the addition of test fixture mounting bolts created extra work after blow 1 due to re-tightening efforts for mate-in surfaces (requirement from MIL-DTL-901E). As a result, the bookend designs were re-evaluated to minimize the number of bolts on the base of each fixture. This effort mainly affected the large bookend design.

Finally, the shock test data showed frequency response results that were not evident in the modal analysis of the stand-alone, medium bookend fixture design. The team set out to determine the reason for the discrepancies.

# 4. Analysis of Results

## 4.1 Lightweight Shock Test Data Comparisons

The lightweight shock test data was compared to results from the analysis performed during the medium bookend fixture design phase. Multiple frequency responses were found that did not align with the analysis. The team decided to modify the Finite Element Analysis (FEA) to include Test Fixture 4A to better represent the entire shock test configuration. Following this change, the results started to align. The outlier frequencies were attributed to the rocking of Test Fixture 4A. This was also confirmed by high-speed video taken during shock testing.

Further tailoring of the analysis improved the analysis results even more to match those captured during the shock test. Detailed results are included in Reference 2.

## 4.2 Analysis and Design Changes

By implementing the lessons learned from shock testing, the FEA and Modal Analysis methodology was improved to properly validate the fixture designs. Also, each bookend fixture design was modified to provide additional space for washers and weld avoidance, while allowing the interface plates to be installed on either side of the test fixture frames.

After the changes, the analyses were repeated to ensure the frequency responses were still within NSWCCD's guidelines.

## 4.3 Maximum Payloads Determination

The maximum allowable payload for each test fixture was determined by creating a FEM for a given set of bookend fixtures; and varying the payload weight to see its effect on the modal frequency response of both interface plates and adapter plate attachment to the shock machines. Additionally, the shock test machines have weight limitations dictated by MIL-DTL-901E. The combined weight of the bookend test fixture and maximum payload weight are required to stay within the weight limitations of the corresponding shock test machine (mainly applicable to the medium bookend fixture installed on the lightweight machine). Analysis results for the small, medium and large bookend fixtures are included in Reference 2.

A summary of the maximum allowable payloads for each bookend fixture configuration are included in Table 1.

**Table 1: Bookend Fixture Maximum Allowable Payloads**

| Bookend Fixture Size | Maximum Payload | Test Parameters |
|---|---|---|
| **Small** | 100 lbs. | Lightweight Shock Testing |
| **Medium** | 200 lbs. | Lightweight Shock Testing<br>(Test Fixtures 4A and 4C) |
| | 50 lbs. | Lightweight Shock Testing<br>(Test Fixture 11C) |
| | 400 lbs. | Medium Weight Shock Testing |
| **Large** | 1,500 lbs. | Medium Weight Shock Testing |

## 4.4 Payload CG

The vertical CG for a given test item was also evaluated for lightweight and medium weight shock test configurations. Modal analyses showed that varying the CG of the test item did not negatively affect the interface plates for each bookend configuration. However, the location of the CG influenced the shock machine attachment method (standard test fixture 4A on the lightweight or the adapter plate for medium weight shock testing). Raising the vertical CG can cause rocking modes on the adapter plate, lowering the natural frequency. By forming several modal analyses of each test fixture configuration, it was determined that a CG of 8" above the center of the test item or center of the bookend fixture interface plate was acceptable without causing a detrimental amount of adapter plate flexing for each shock machine configuration. Therefore, each drawing will contain a General Note with a CG limitation of 8" above center of the test item interface to the bookend fixture. CG investigation results are explained and included in Reference 2.

## 4.5 Test Fixture Interface Plate Replacement

Interface plates are often re-used for multiple tests and re-using these plates requires drilling new holes into the plates. This is known as the "Swiss Cheese" phenomena which can cause the natural frequency of the plate to change. To avoid the "Swiss Cheese" phenomena, the team investigated how much material can be removed from an interface plate before its natural frequency falls below the requirements of MIL-DTL-901E, Section 2.4 (natural frequency of 160Hz for LW, 90Hz for MW).

A circular section of plate was removed from the interface plate in each configuration. Removing 50% of the plate resulted in modal frequencies near the requirement. Therefore, the team decided to provide guidance to replace interface plates once 50% of the plate has been removed by drilling multiple holes. This can be easily determined by weighing the interface plate and comparing it to its original weight. A General Note has been added to each bookend fixture drawing to reflect this guidance.

## 4.6 Adapter Plate for Medium Weight Shock Testing

The team designed an adapter plate to interface the large bookend fixture configuration with the MWSM; with a resonance above 90Hz and approved by the Shock Technical Authority. A process recognized by the Navy was used to design the adapter plate. This process includes incorporating Blevin's hand calculations for a clamped-free plate (R. Blevins, Formulas for Natural Frequency and Mode Shape, Krieger, Malabar, Florida, 1979). The frequency response of the plate was also validated analytically with a modal analysis.

A drawing of the adapter plate is included in Reference 1. The adapter plate can vary in length to support different sizes of "in-line" pipe components that weigh between 250 lbs. and 1,500 lbs. The size of the adapter plate should be tailored to achieve the smallest possible footprint of the test article installation on the medium weight machine.

The following General Note was added to the Large Fixture Drawing to provide details for fabricating the approved adapter plate in accordance with MIL-DTL-901:

*When testing on the medium weight shock machine, the bookend test configuration shall adapt to the standard mounting platform (Figure 13) using a suitable adapter plate above 90Hz. The following steel adapter plate may be utilized without approval from the Technical Authority:*

| | |
|---|---|
| ***Configuration:*** | *Case 4 of Figure 13 (between sets of channels)* |
| ***Test Item Weight:*** | *250 lbs. to 1,500 lbs.* |
| ***Thickness:*** | *1.5"* |
| ***Width:*** | *36" (B = 32")* |
| ***Length (TYP):*** | *44" (A = 40")* |
| ***Allowable Length:*** | *36" (A = 32") to 60" (A = 56")* |

- *Length shall be tailored to achieve the smallest possible footprint*
- *Mounting bolts shall be within 2" from the edge of the plate*

## 4.7 Final Bookend Fixture Dimensions

After a thorough analysis by the team, the bookend fixture designs were finalized. Dimensions, limitations and characteristics of the final bookend fixture designs are shown in Table 2.

**Table 2: Final Bookend Test Fixtures Dimensions**

| | Small Fixture | Medium Fixture | Large Fixture |
|---|---|---|---|
| **In-line Pipe Size (OD)** | Up to 3″ nominal OD | Up to 6″ nominal OD | Up to 12″ nominal OD |
| **Size (W x H x D)** | 12.5″ x 9.375″ x 5.375″ | 16″ x 12.5″ x 7″ | 28″ x 21.75″ x 13″ |
| **Weight** | 26 lbs. per fixture | 59.5 lbs. per fixture | 370 lbs. per fixture |
| **Vertical CG** | Up to 8″ above center of valve / interface | Up to 8″ above center of valve / interface | Up to 8″ above center of valve / interface |
| **Interface Plate Weight** | 10.2 lbs. | 26.8 lbs. | 157 lbs. |
| **Payload** | Up to 100 lbs. (LW) | Up to 200 lbs. (LW: 4A, 4C)<br>Up to 50 lbs. (LW: 11C)<br>Up to 400 lbs. (MW) | Up to 1,500 lbs. (MW) |
| **Material/Thickness** | 3/8″ steel (A36) | 1/2" steel (A36) | 1″ steel (A36) |
| **Adaptor Plate Required** | N/A | For MW testing only (above 90Hz) | Yes (above 90 Hz) |

# 5. Implementation

## 5.1 Navy Standard Drawings

Validation of the final Bookend Fixture designs permitted the creation of fabrication drawing for the small, medium, and large bookend test fixture designs. The designs contain part details, dimensions, materials, hardware, weld types, and fabrication details. The drawings also include pay load limitation and the approved application for each fixture in the General Notes Section. To correspond with MIL-DTL-901 nomenclature, the test fixtures were named Figure 25A (Small Bookend Fixture), Figure 25B (Medium Bookend Fixture) and Figure 25C (Large Bookend Fixture).

AutoCAD files were provided to NSWCCD for inclusion in the next revision of MIL-DTL-901. Once these designs are included in MIL-DTL-901, the bookend test fixtures will be considered a “Navy Standard”, eliminating the need for approval. A working example of the Medium Bookend Test Fixture drawing is shown in Figure 8. The final test fixture drawings are included in Reference 1. Each drawing was tailored to match the format of other standard fixtures included in MIL-DTL-901.

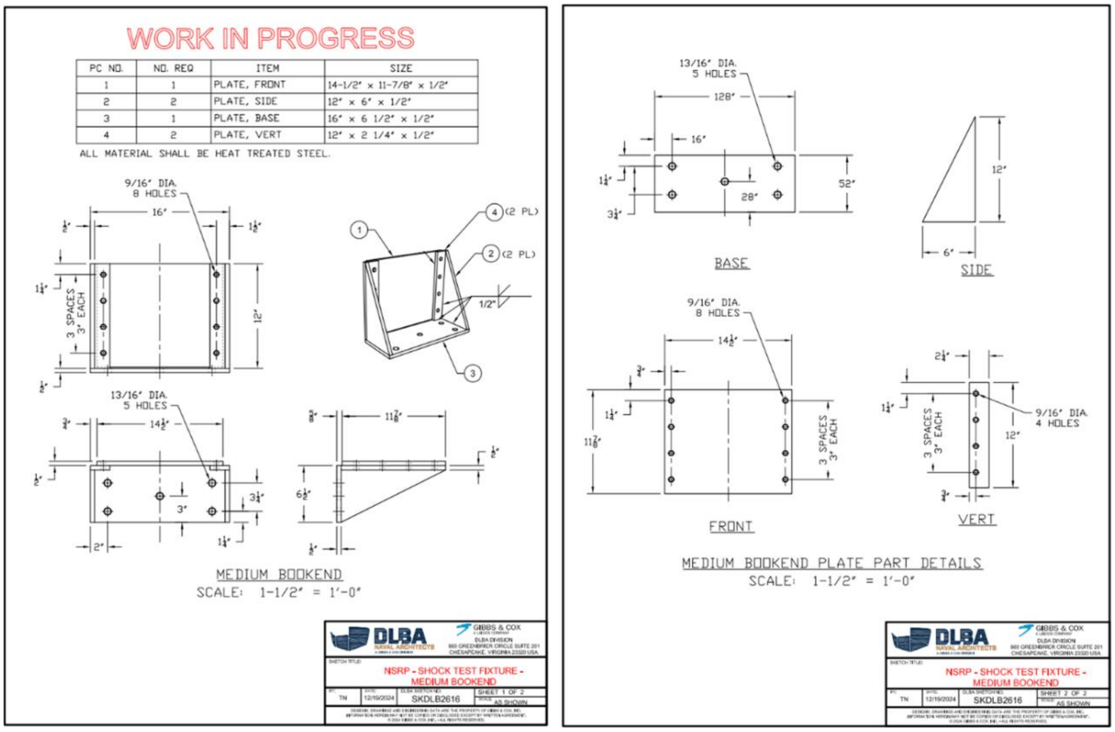


**Figure 8: Example Medium Bookend Test Fixture Drawing**

## 5.2 Technology Transfer

Final project results were presented to the NSRP community during the All-Panel Meeting in Charleston, SC in February 2025. Ingalls Shipbuilding can immediately start utilizing the small and medium bookend fixtures on their lightweight shock machine. All U.S. Navy approved Shock Test Facilities may request the bookend fixture drawings from NSRP to use for lightweight and medium weight shock testing. Until the bookend fixtures are included in the next revision of MIL-DTL-901 as "Standard" fixtures, they are considered "Non-Standard" and may require approval from the Technical Approval Authority. However, since NSWCCD was involved with this project, the "Non-Standard" fixture approval process may be accomplished with verbal approval or via email if NSWCCD is notified and the NSRP drawings are utilized in the shock test procedure.

## 6. Results and Conclusion

The objectives of the NSRP Navy Standard Bookend Fixtures for Shock Testing project were met. Small, medium, and large bookend test fixtures were designed and validated through this yearlong effort of analysis and shock testing. Fabrication drawings and *AutoCAD* files for the fixtures were provided to NSWCCD for inclusion in the next revision of MIL-DTL-901. The bookend fixture designs and drawings will be available for use by all Navy approved Shock Test Facilities and may eliminate up to $10,000 per shock test by avoiding the associated labor, fabrication and approval process for bookend fixtures. The standard bookend fixtures will promote commonality across shock test facilities and improve efficiency for Navy environmental qualification test programs.