P5-NPOI Finalized Testing Plan

Northern Arizona University

ME486C-006

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Client: Jim Clark

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\*LOGO REMOVED DUE TO PARTNER ISSUES

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**Design Requirements Summary**

The customer needs and engineering requirements for NPOI capstone were about the functionality of the seal plates as well as the whole FDL tank system. Client Jim Clark wanted the system to be friendly assemble/dissemble by one person within an hour. Therefore, the seal plates requirements were less than 35lbs and had optical supports attached on. The seal plates needed to be able to withstand the vacuum force at 1m Torr as well as during standby at 760 torr. The deflection of seal plates would be less than 0.010” and the drift also less than 0.001 in/month to keep the seal plates usable and not interfere with the data collection from FDL tank.

Other requirements were about the snoot system. The new snoot adjustment was designed to be adjustable within 0.5”. Moreover, the team designed a new snoot system with two attached parts on both sides and a removable middle snoot for easy disassemble. Snoot alignment was an important factor in designing because the laser line had to be able to travel inside the snoot.

For Spring 2023, the team could only do the 35% scale of the FDL system due to the partnership transition. Therefore, the new CN/ERs were modified to fit with the new system. The 35% scale had to display the function of the new FDL system with seal plates and snoot adjustment the same way they performed as real material built. The technical requirements such as deformation and deflection were only able from the simulation on Solid works. Those requirements could not be tested in real life and would not be included in the testing plan.

**Top Level testing Summary**

The P5-NPOI Capstone team has developed a testing plan to verify the scaled prototype functionality of the Customer and Engineering requirements. The testing plan for each specific applicable requirement is shown below. Due to a modification plan made to the capstone, 3 requirements are not able to be tested. This is due to site partner conflicts which have not allowed site access and not allowed the team to access the required hardware for full scale testing. List tests to be performed and create a chart as shown in rubric sheet.

Table 1: Tests and Relevant Design Requirements

|  |  |
| --- | --- |
| Experiment/Test | Relevant Design Requirement |
| 1. Front Seal Plate Weight
 | CR/ER 1 |
| 1. Rear Seal Plate Weight
 | CR/ER 1 |
| 1. Front Seal Plate Deflection
 | CR/ER 5 |
| 1. Rear Seal Plate Deflection
 | CR/ER 5 |
| 1. Snoot Plate Adjustment
 | CR/ER 4 |
| 1. Snoot x/y Adjustment (combined)
 | CR/ER 4 |
| 1. Rear Seal Plate Sight Port Count
 | CR/ER 7 |
| 1. Allow Laser in & out of Scaled System
 | ER 8 (**NEW**, allow light into and out of the system without clipping. Allow full adjustment of parts) |

Customer Requirements and Engineering requirements 2,3,6 will not be tested due to modification of the Capstone project in January 2023. The requirements that cannot be tested due to the modification plan are listed below.

 - CR/ER 2: Disassembly less than 1 Hour

 - CR/ER 3: Seals to Vacuum and ATM

 -CR/ER 6: Drift less than 0.001 in/month

**Detailed Testing Plan**

The following tests will be performed to quantify the system requirements and be compared to the Engineering Requirements Technical Targets to fully verify the design meets the clients’ requirements. The client (Jim Clark) will be talked to obtain approval on these values for final approval of design.

**Test 1,2:** Seal Plate Weight

The plan for determining the weight of each respective seal plate is to use SolidWorks properties function to automatically calculate the estimated weight of the part. The engineering/customer requirement is specified for the seal plate weight to be under 35 pounds.The team will implement the 6061-T651 aluminum spec sheet values to define the density correctly. For each individual seal plate, the value will be recorded and compared to the engineering requirement. This test will isolate the seal plates individually, with no attachments. This test will require SolidWorks CAD package and the material specification sheet from the material provider. The team will be looking for a seal plate weight below 35 pounds. The team will calculate the weight per [1] to verify the SolidWorks output. ρ

$$W=∀\*ρ [1]$$

**Test 3,4:** Seal Plate Deflection

The deflection test will determine if the seal plates are sufficient to allow for optical/vacuum use within the bending requirements. The CR/ER requirement is specified at <0.010” deflection. The team will verify that the maximum deflection of any unit cell of the Seal plate meets the design requirements. Specifically, that the max deflection is under 0.010”, in any direction. The equipment needed for this test is the SolidWorks Simulation function (static structural) and a knowledge of the correct boundary conditions application. The variables which will be isolated from measurement are the rear bolt hole edges, being the fixed boundary conditions, and the respective standard atmospheric pressure (14.7 psia) induced on the front surface. The deflection variable will be calculated via SolidWorks in this test, due to complex geometry the SolidWorks output will be used as the test value. The steps to complete this test are listed below.

1. Import the 3D model into SolidWorks.
2. Define the manufacturer's material properties.
3. Start a static structural simulation.
4. Define the rear bolt hole edges as fixed conditions.
5. Place the appropriate Pressure condition at acting front face locations.
6. Verify all inputs are meet and correct for solving.
7. Mesh the part (fine mesh).
8. Run the simulation.
9. Identify maximum deflection and location.
10. Take a photo displaying deflections and deformed shape.
11. Redo 1-9 for the other seal plate.

The results of this test will be a deflection value at a specified location on the Seal plate, the team will be looking for <0.010” maximum deflection. The deflection maximum should be located at the center of the plate, due to the nature of the boundary conditions. A deflection of scaled opposite value will be found on the plate edges due to the boundary condition bending style. Although values for positive and negative deflections will be determined. This test will conclude with approval of the seal plates or rejection due to large deflection.

**Test 5:** Snoot Plate Adjustment

The snoot plate adjustment will verify that the plate can be adjusted to center the input/output beam in the respective through holes. The CR/ER requirement is specified as adjustable within the ± 0.5” range. This will verify that the beam has adjustment to not be clipped if the beams are shifted before entering the system. The equipment required for this test are tape measure, dial calipers, clamps, 1-2-3 Block and a flat surface plate. The delta from minimum to maximum adjustment will be tested to verify the prototype functions at 35% scale of the actual model. The delta distance will be isolated for this test. The scaled distance will use [2] to calculate the prototype distance to be measured.

$$∆\_{prototype}=∆\_{fullScale}\*0.35 [2]$$

The steps to perform this test are listed below…

1. Take the front seal plate and snoot plate assembly and fix to the surface plate using toe clamps or screws through the seal plate mounting holes into the surface plate. The front face of the seal plate will be facing upward. Gravity holds the snoot plate on the seal plate.
2. Loosen the snoot plate hardware to allow translation motion in X and Y.
3. Verify hardware will not affect the translation motion.
4. Use a surface plate datum to specify as zero. This is a 1-2-3 machinist block that is clamped to the surface plate, having a flat edge perpendicular to the direction of measurement.
5. Move snoot plate to X min and measure a value, move snoot plate to X max and measure a value.
6. Find the delta of the min and max values, this is the X adjustment range, record delta.
7. Redo Steps 1-6 for the Y direction adjustment
8. Redo steps 1-7 for the other FDL Front Plate (FDL 1 & FDL 6 Tested)

The results the team is looking for is a about 0.100” delta in the X and Y direction. This result will allow the team to verify that the full-scale model has appropriate adjustments for practical use at NPOI.

**Test 6:** Snoot x/y Adjustment (combined)

The Christmas tree/snoot adjustment fixture will be tested to verify that the snoots within the inner room can be adjusted to ensure the input/output beam can be un-clipped as it travels through the system. This test will verify the CR/ER specifically if there is ± 0.5” of adjustment within the design, although a scaled value is calculated using [1]. The test will require a surface plate, tape measure, dial calipers, clamps, and 1-2-3 machinist block. These materials will allow for a datum to be set and values to be backed out from the results. The variable which will be isolated is the snoot tube height from the top of the surface plate. Delta distances will be calculated from this test using minimum minus maximum values. The steps for this test are listed below…

1. Assembly snoot adjustable fixture with hardware and place on the surface plate, as shown in the CAD model.
2. Fix the system to the surface plate via clamps or bolts.
3. Set up the 1-2-3 machinist block as the datum point.
4. Set the fixture large snoot plate and individual snoot plates to the loose configuration, allowing translation in the x-z plane.
5. Move all adjustments to the lowest possible value (ymin).
6. Measure the absolute minimum value from the datum and record.
7. Move all adjustments to the highest possible value from the datum and record.
8. Calculate the delta value.
9. Redo 3-8 for the x direction motion.

The results the team is looking for is a delta translation of 35% of the ± 0.5” or greater. This test will output 2 delta values for x translation and y translation. The value will be compared with the scaled adjustment value to verify the adjustment is meeting the design requirements.

**Test 7:** Rear Seal Plate Sight Port Count

This test will verify that the rear seal plate has sufficient sight ports. The CR/ER is specified to have 2+ sight ports on the rear seal plate. No equipment will be required. Isolated variable will be quantity of vacuum windows possible on the rear seal plate. No calculations will be made for this test. The team will view the rear seal plate and count how many locations a 6-bolt Polycarbonate Window can be placed in. The team is looking for a quantity of 2+, which should be met from the physical nature of the rear seal plate.

**Test 8:** Allow Laser in & out of Scaled System

The laser test will implement a laser and mirror system to input and output light from the scaled prototype, specifically testing if the system can allow light through the system without clipping. The test will test all the adjustments, in parallel to ensure the adjustments are large enough to allow input and output beams for Metrology light and stellar light. This test requires many components listed below…

1. Laser (Class 2 or under).
2. 2x 1” Mirror Mounts.
3. 2x 1” Silver Mirrors (damage threshold well below laser output power).
4. 2x Mirror Mount Placement Adaptor to FDL Tank (1 Stellar Beam, 1 Metrology Beam). \*Designed and 3D printed.
5. 2x Laser Stand (1 Stellar Beam, 1 Metrology Beam). \*Designed and 3D printed.
6. 2x Target Cards (1 for Metrology and 1 for Stellar).
7. Mounting Hardware (8-32 screws 2x and various small screws).

The components needed will allow for laser light to be produced and reflected properly through the designed FDL Interface. The laser diameter will not be collimated to a larger size due to cost and supply chain constraints of lenses; the size will be kept from the laser output lenses. The full interface system will be aligned to the laser beam path set by the laser stand, the laser stand will ensure proper placement of beam. No variables will be calculated, but a visual interpretation of the system function will be shown. The steps to perform this beam verification test are listed below…

1. Design the mirror mount placement adaptor for Stellar and Metrology beams, this will be 2 separate designs, using the same 2 mirror mounts. The mirror mounts will be swapped for separate demonstrations.
2. Design the Laser Stand to input the beam properly to the stellar or metrology beam input. The laser will be swapped for separate demonstrations.
3. Assemble the mirror mounts onto the adaptor and assemble the laser into the stand.
4. Place the adaptor in the correct location for stellar beam, fix to the FDL tank, then add the silver mirrors to the mirror mounts. Due to the silver mirror coating being very delicate, only 1 person will assembly/align the test. A mask and rubber gloves will be worn to minimize mirror scratches/imperfections from occurring.
5. Place the laser in the designated location, having the output facing inward to the FDL interface system.
6. Turn the laser on and complete the optical alignment process for a 2 mirror ‘retroreflector’ setup. Following standard optical alignment procedures outlined in ‘Alignment of Optical Systems using Laser’ by David M. Benton.
7. The alignment process will adjust the mirror mount tip/tilt screws to align the beam from 1st mirror incident to the second mirror incident, then to a target card placed on the output of the FDL interface.
8. If clipping occurs after alignment, adjustment of the various interface parts will be completed to allow the full beam to exit the system.
9. Verify full beam output visualizing the output target illuminated by the output laser.
10. Redo steps 3-9 for the metrology beam laser system.

The team is looking for the result that the beam will enter and exit properly without any clipping or full blockage of the beam. The completion of this test will verify the scale prototype functions as a true 35% scale model, neglecting the vacuum of the FDL’s. The anticipated range of results are not clipping (full beam), partial clipping (left/right edge clip), or full beam blockage. The team will ensure the beam enters and exits the FDL interface properly and is not clipped in any way.

**Specification Sheet Preparation**

The specification sheets are for the customer to give acceptance whether the customer requirements are met or not. Table 2 includes all customer needs that Jim Clark wanted P5-NPOI to complete

Table 2: Customer Requirements Summary Table

|  |  |  |
| --- | --- | --- |
| Customer Requirement | CR Met? | Client Acceptable? |
| CR1 - Lightweight |  |  |
| CR2 – User/technician Friendly | N/A | YES |
| CR3 – Seals to Vacuum | N/A | YES |
| CR4 – Stable Alignment | N/A | YES |
| CR5 – Small Deformations |  |  |
| CR6 – Adjustable Frame | YES |  |
| CR7 – Sight Ports | YES |  |
| CR8 – Allow Laser Light in/out of system |  |  |

Table 3 includes the engineering/technical requirements. Some engineering requirements could not be completed due to the change in materials made with 35% scale from the original.

Table 3: Engineering Summary Table

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Engineering Requirement | Target | Tolerance | Measured/Calc Value | ER Met? | Client Acceptable? |
| ER1 – SP Less than 35 pounds | <35 lbs. | ±0.5 lbs. | Front-Rear- |  |  |
| ER2 – Disassemble in < 60 minutes | < 60 minutes | ±5 min. | N/A | N/A | YES |
| ER3 – Seals Tank in Vacuum and ATM | Seals Tank | N/A | N/A | N/A | YES |
| ER4 – X-Y Adjustment of ±0.5” (Scaled=0.175”) | ±0.0875” or greater | ±0.010” | -VERTICAL TREE=5/8” -PISTON STAND=N/A-VERTICAL PLATE=¼"-HORIZONTAL PLATE=¼"-SNOOT PLATE=0.15”-SNOOT PISTON=0.25”\*Total displacement value given. |  |  |
| ER5 – SP Deformation < 0.01” | <0.010” | ±0.001” | Front-Rear- |  |  |
| ER6 – Drift less than 0.001 in/month | < 0.001 in/month | ±N/A | N/A | N/A | N/A |
| ER7 – 2+ Sight Ports | 2+ Windows | No Tolerance | 1-3 available for use. | YES | YES |
| ER8 – Unclipped Laser through system | Unclipped Laser Beam | N/A | Unclipped or Clipped upon alignment? |  |  |

**QFD (House of Quality)**

The QFD included below is used to ensure that the customer needs are met throughout the development process. It uses various systems to assign value to the respective aspects of design to determine the most crucial engineering requirement. This is especially important as we implement our testing plan. Each test is meant to directly evaluate each customer's need, which can be seen in the detailed testing plan section above. The completed QFD is included at the end of the report.