21F03

Vacuum Manifold Project Finalized Testing Plan

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Contents

1. Design Requirements 3
    1.1 Customer Requirements (CRs) 3
    1.2 Engineering Requirements (ERs) 3
    1.3 Table Summary of Design Requirements 4
2. Top Level Summary 4
3. Detailed Testing Plans 4
    3.1 Experiment 1: Front Plate Disassembly/Reassembly Time 4
        3.1.1 Test/Experiment Summary 4
        3.1.2 Procedure 4
        3.1.3 Results 5
        3.1.4 Conclusion 5
    3.2 Experiment 2: Leak Rate Test 5
        3.2.1 Test/Experiment Summary 5
        3.2.2 Procedure 5
        3.2.3 Results 5
        3.2.4 Conclusion 6
    3.3 Experiment 3: Cable Passthrough Setup 6
        3.3.1 Test/Experiment Summary 6
        3.3.2 Procedure 6
        3.3.3 Results 6
        3.3.4 Conclusion 6
4. Specification Sheet Preparation 8
5. QFD 8

1. Design Requirements

1.1 Customer Requirements (CRs)

The first and most important customer requirement is safety (CR1). The volume of evacuated space at NPOI represents an increased opportunity for catastrophic failure. Any sudden breach to the vacuum system could result in serious injury to nearby people and damage to the vacuum protected optics inside the system.

The next requirement is increasing the reliability and service life over the old system (CR2). The Fast Delay Lines (FDL) are a mission critical component to NPOI. If the carts are not held in vacuum, the system cannot be operated, and no data collection can occur. The vacuum manifold is the component responsible for maintaining FDL vacuum and therefore is a critical component of the interferometer.

Our client pointed out the necessity for regular system maintenance and instituted a requirement for maintenance accessibility (CR3). The previous vacuum manifold had to be physical disconnected from the FDL tanks when cart maintenance was required. This operation was time intensive, required skilled personnel, and presented a risk to the overall system. The new manifold must allow for cart access and decrease the disassembly of optical and vacuum components.

The fourth requirement is the that the team is to stay within the budget allocated to us by NPOI (CR4). This is desired because it challenges us to create something meaningful from limited resources and it also ensures that the materials used could be replaced without great cost to NPOI in the future if needed.

The fifth requirement is that the new manifold should be easy to use (CR5). This is desired because it would be a hassle for the client to have to retrain his employees in the operation of the system.

The last requirement is to allow for future project integration (CR6). The NPOI instrument is not only an operational observatory, but a testing ground for new and exciting types of experiments and technology. It is unknown what requirements future programs might have for the NPOI facility; therefore, it is necessary to provide integration and access points within our design.

1.2 Engineering Requirements (ERs)

The first engineering requirement is factors of safety (ER1). This ER is used to adhere to the clients wish that the new manifold system is safe. Due to the budget constraints requested by our client, the team decided that a FS of 2.5 ± .5 would be the target value.

As mentioned, this project is constrained by the available money at hand and as such to account for CR4 the second ER is project cost (ER2). In total the team can spend up to 14000$ USD with the potential for additional funds from NPOI to cover any extra costs that come from additional features requested by the client. For the purposes of this ER the goal was set as 10000 ± 4000 USD.

As CR2, CR3, and CR5 all pertain to the efficient operations of the manifold both during normal operation as well as when they are down for regular maintenance, the third ER of minimize downtime (ER3) was created to cover them. During actual maintenance work performed on the FDL that requires the removal of the front plate it is hoped that the time needed to remove and reinstall the front plate will be 2 ± 1 hours. During regular operations of the FDL's it is expected that our manifold will not cause any major delays compared to the old system. As discussed with our client the time needed to recreate the vacuum inside the FDL's is allowed to take longer than the older system.

As CR2 covers a broad range of applications the fourth ER of leak rate (ER4) was also created. The old manifold at NPOI was able to stay withing operational vacuum pressures for five days when the vacuum pump was shut off. It is expected that our new system should be able to hold a vacuum for 5±1 days when the vacuum pump is not in use.

Because CR6 is more subjective in what it requires us to do there is no ER associated with it.

1.3 Table Summary of Design Requirements

Table 1: Short Description of CR's

Customer Requirement	Description
CR1	Safety
CR2	Reliability
CR3	Maintenance
CR4	Cost
CR5	Ease of Use
CR6	Future Integration

Table 2: Short Description of ER's And CR They Satisfy

Engineering Requirement	Description	Satisfies Which Customer Requirement
ER1	Value above normal operation that object can handle	CR1
ER2	Total cost of the Project	CR4
ER3	Time it takes to do maintenance on manifold	CR2, CR3, CR5
ER4	How long manifold can hold vacuum	CR2

2. Top Level Summary

Table 3: Experiments and Relevant Design Requirements

Experiment / Test	Relevant Design Requirements
Front Plate Disassembly Time	CR3, CR5, ER3
Leak Rate Test	CR2, ER4
Cable Passthrough Setup	CR3, CR5, ER3
Cable Continuity Test	CR1, CR2, ER3
Pressure Gauge Calibration	CR2,CR3, ER3

3. Detailed Testing Plans

3.1 Experiment 1: Front Plate Disassembly/Reassembly Time

3.1.1 Test/Experiment Summary

The purpose of this experiment is to evaluate the time it takes for the normal maintenance procedure of removing and reinstalling the front plate of one of the FDL tanks. In addition, this test will also ensure that the crane that is used to move the plates can still be used efficiently around the final section of the manifold that goes to the vacuum pump. This test is intended to answer how well ER3 can be accomplished with our new manifold design and whether it satisfies CR3 and CR5.

3.1.2 Procedure

Because the tanks will be under vacuum the start of the test will be once we initiate the isolation of the other tanks with the QF 50 pressure valves from the manifold system. With the other tanks isolated from the system the tank that will have its plate removed can start the process of returning to atmospheric pressure. During the time that the tank is venting, two people will be needed to move the crane used to lift the plate. Once the tank has reached atmospheric pressure the crane can be attached to the eyebolt on the plate and the bolts holding the plate undone. The plate will then have to be moved somewhere appropriate while avoiding hitting the rest of the manifold. Once finished the timer can be stopped. The second phase is to essentially do the same procedure but in reverse with the timer being stopped once the snoots have been reattached with their coverings. Adding the two times together will get the final time which can then be compared to previous times on the old manifold.

3.1.3 Results

The expected result from this test is that the time needed to perform this task should be less than before because some complexity of the procedure has been removed. This is mainly since the manifold no longer needs to be removed from the snoots. Because this test does relay heavily on human factors the range of times that can be experienced doing this can vary.

3.1.4 Conclusion

In conclusion the purpose of this test to compare the front plate disassembly/ reassembly to CR3, CR5, and ER3. This is a vital investigation into what is required when taking off and putting back on the front plates.

3.2 Experiment 2: Leak Rate Test

3.2.1 Test/Experiment Summary

This test aims to see how long our vacuum manifold can maintain operating pressures when the vacuum pump is unavailable. This test will be used to directly answer ER4 as well as provide more information for CR2.

3.2.2 Procedure

This test has a rather simple setup. First the manifold will be brought down to the normal operating pressures for NPOI. Once this pressure is reached it will be maintained for a period of at least a day to ensure that no air pockets have been left inside the tank. After this time interval the vacuum pumps will be turned off and the valve connecting them to the manifold will be closed. Once this happens that tank will slowly begin to build up pressure again and this can be observed directly with the pressure gages that are installed on the manifold. These gages will be used to figure out when the tanks have reached 30 mTorr which is the largest operating pressure that the FDL's can use. Once this pressure is reached the time it took to reach it will be recorded and then compared to the old manifold.

3.2.3 Results

The expected result is that our manifold might reach that 30 mTorr cutoff pressure sooner than the older manifold. This expectation exists because our manifold has more joints than the previous version which allows air to enter the tank quicker. Although the leak rate might be faster it is believed that it will still be able to hold the vacuum rating for a long time do too the large volume of air that is needed to fill the FDL tanks to reach the cutoff pressure.

3.2.4 Conclusion

In conclusion the purpose of this test to compare the leak rate of the manifold design to CR2, and ER4. Which a vital investigation that will determine if the new vacuum manifold is able to efficiently and effectively pull a vacuum.

3.3 Experiment 3: Cable Passthrough Setup

3.3.1 Test/Experiment Summary

As part of expected maintenance in the future for the manifold, it is expected that the cables in the electrical passthrough will eventually need to be replaced. The purpose of this test is to understand how efficiently one of these cable bundles can be replaced using our new manifold. This test will further help to answer ER3 as well as CR3, CR5.

3.3.2 Procedure

Like the test before, a timer will be used to see how long it takes a person to remove the old cable bundle and replace it with a new one. Once the cable has been correctly installed the timer can be stopped. From that time an additional amount will need to be added to account for the time it would take to fix one of the cables in the bundle. As each bundle contains 36 pins and takes three hours to build it completely, this means that if one cable needed to be replaced that would be an additional five minutes for the final time. This final time can then be compared to other instances where the old manifold needed a cable(s) fixed by applying the appropriate amount of five minute modifiers.

3.3.3 Results

The expected result is that our method is much quicker. In the previous cable interface, an epoxy like substance was used to hold the cables in place and ensure a vacuum seal. The process of removing and reinstalling a cable form this epoxy was time consuming. Because we are using industry slandered parts, with an employee that has experience making these cable bundles an entire new cable bundle can be fabricated within three hours to be put onto the manifold. As the failure of an entire cable bundle is unlikely only a few wires at most will have to be replaced which can be done within an hour if given to the correct person.

3.3.4 Conclusion

In conclusion the purpose of this test to compare the pressure cable passthrough setup to CR3, CR5, and ER3. This is a vital experiment that will explore the future maintenance of the cable passthrough setup.

3.4 Experiment 4: Cable Continuity Test

3.4.1 Test/Experiment Summary

The purpose of this experiment is to evaluate the manufacturing of the inner and outer FDL electronic cables. This is done to ensure that the design is safe, reliable, can be maintain a vacuum feasible, and can be maintenance with ease. The design consists of two components the outer cables and the inner cables. For the inner cables, the maintenance procedure entails taking the snoot and the front plate off of the FDL tanks in order to access the electronic components within the tanks. This test will also ensure that the connection between the inner and outer cables is continuity. This will be completed using a digital multimeter. This test is intended to answer how well ER 3 can be accomplished as well as how well the design supports CR1 and CR2.

3.4.2 Procedure

Overall the continuity test for the two cable components is very simple. It is a two person job that requires testing at one end of the outer cable and testing at other end of the inner component. The inner and outer components are connected to each other in the center of the cable extensions. Using a digital multimeter, each person takes either the red or black lead and one end of the cable. Each person will touch the lead to one of the 36 pins at the same time, starting at pin 1 and moving in ascending order.

3.4.3 Results

The expected result from this test is that as the leads touch the same pin on either end of the inner and outer cable, the multimeter will make a beeping noise. Once the noise is made, the next pin will be tested, and so on. Once all pins have been tested and beeped, you know that the cable is continuous.

3.4.4 Conclusion

In conclusion the purpose of this test to compare the cables to ER3, CR2 and CR1. Which is vital in the investigation into the manufacturing and functionality of the electrical cables.

3.5 Experiment 5: Pressure Gauge Calibration

3.5.1 Test/Experiment Summary

The purpose of this experiment is to evaluate the maintenance and reliability of the purchased pressure gauges. This is done by connecting the gauges to a mass-spectrometer and taking reading at atmospheric pressure and the pressure within a vacuum. This test will ensure that the gauges purchased are functional and operational, ultimately ready to use on the new manifold. This test is intended to answer how well ER3 can be accomplished with the new gauges and whether the new devices are reliable for its intended use.

3.5.2 Procedure

This procedure will need to be completed for the pressure gauges for each of the FDL tanks, which is total of six times. Each gauge is placed on the mass-spectrometer, and a pressure reading will be be taken from the display boxes connected to the pressure lines. Without a vacuum the pressure should read approximately 585 torr. If a different value is I'd played, then a screw must be turned in the display box until the desired value is reach. Then the gauge will be connected to the mass-spectrometer with a flange clamp and a vacuum will be pulled. Once a complete vacuum is pulled the value displayed on the box should be 0. If that is not the case then a screw within the display box with be turned until the desired value is obtained. Then repeat the previous steps to ensure the same values are obtained.

3.5.3 Results

The expected result from this test is that after following the procedure the correct pressure is being red for the different circumstances (at atmosphere or at a vacuum). This will ensure that when the pressure gauges go onto the new vacuum manifold there are ready and able to give the correct pressure reading within the manifold.

3.5.4 Conclusion

In conclusion the purpose of this test to compare the pressure gauges to ER3 and CR2. The correct and accurate pressure reading taken as the vacuum is being pulled is vital because it can signify if there is an issue and it can pin point that issue. Such as a leak.

4. Specification Sheet Preparation

Table 4: CR Summary Table

Customer Requirement	CR Met (✓ or X)	Client Acceptable (✓ or X)
CR1 - Safety		
CR2 - Reliability		
CR3 - Maintenance		
CR4 - Cost		
CR5 - Ease Of Use		
CR6 - Future Integration		

Table 5: ER Summary Table

Engineering Requirement	Target	Tolerance	Measured /Calculated Value	ER Met (✓ or X)	Client Acceptable (✓ or X)
ER1 - Factor Of Safety	2	±0.5			
ER2 - Cost	10000$	±4000$	11678.04		
ER3 – Minimize Downtime	2 hr	±1 hr			
ER4 – Leak Rate	5 days	±1 day			

5. QFD

Please see attached PDF in the submission