NPOI Nitrogen Distribution

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Midpoint Review

Document

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Table of Contents

Chapter 1. Introduction

1.1 NPOI Description

The U.S. Naval Observatory (USNO) does research for the Naval Research Laboratory in providing position, navigation and timing for the U.S. Department of Defense. Our sponsor, the Navy Precision Optical Interferometer (NPOI), works under the USNO. The NPOI has its site located just east of Flagstaff, AZ in Anderson Mesa. The research done in this facility involves precise observations of the astronomy needed for navigation use.

On behalf of NPOI, our clients Jim Clark and Steve Winchester have requested an improved nitrogen supply system. This nitrogen supply is used to operate pneumatic actuators at several stations and to purge any humidity or debris from the siderostat mirrors. It consists of three 250m arms that have observatory like mirrors along each arm. By utilizing an array, the optical surface being studied is effectively the diameter of the whole facility. Using the mirrors at the ends of the array has an equivalent effect of employing the use of a 600meter diameter solid mirror. These mirrors are used to direct optical light, the visible light spectrum, into a lab facility that further studies the image.

To operate and manage this system of mirrors, each station is equipped with a gaseous nitrogen supply. This nitrogen is used to purge the mirrors of any moisture buildup that may ruin the mirrors. Nitrogen is pumped directly onto the mirror surface whenever the array is not in use, which keeps water from accumulating on the very delicate reflective surface. Aside from this, the nitrogen is also employed for a series of pneumatic actuators. Pneumatically operated covers that open and close once per day are used to protect all of the siderostat mirrors. Using an air compressor near the equipment would induce vibrations that can affect the astronomical readings, so nitrogen is used to power the actuators. Pneumatic actuators are also used to operate gate valves that are placed inside the vacuum tubes that direct light into the facility.

In its current configuration, NPOI uses a tank of gaseous nitrogen at each location. This system is labor intensive and time consuming since the tanks run out quickly and requires a replacement rather than on-site refilling. As a result, NPOI has requested a central nitrogen supply and distribution that is supplied by a 1000L Dewar tank and has the ability to feed every station in the array.

1.2 Prototype Overview

In an effort to simulate the final design, the team is in the process of building a prototype on a small section of the NPOI site. This test section will run along the west arm of the interferometer array, a length of ~100 ft. The test section will include one imaging station, astrometric hut, and gate valve station, all of which require a different pressure and volumetric flow rate of nitrogen. Rather than using the 1000L Dewar, the prototype will use a single tank of gaseous nitrogen with a standard regulator. Since the prototype is only along a ~100ft section, a 100ft coil will be placed in the supply line to help simulate the length of the arm. In addition to the coil, two reservoir tanks will also be attached to the supply line to test the abilities of these tanks in a real world environment.

Chapter 2. Building Progress

2.1 Construction Overview

In the last several weeks, the team has made several trips to the NPOI site to work on the prototype. The staff on site has provided a nitrogen tank, tubing, reservoir tanks, regulators, polyvinyl hose, and all of the necessary fittings for the project. Attachment of any fittings to the copper supply tubing requires soldering of all joints. This process is done using a handheld MAPP gas torch with a flame temperature of ~3400ºF. Due to this high temperature, soldering cannot be done inside of the climate controlled astrometric hut or near the wires in the cable tray. After discussing this situation with the NPOI staff, the decision was made to install the nitrogen tank directly after the astrometric hut and running the tee back into the building. On the week of February 24, this tank was installed and secured near the building.

2.2 Astrometric Hut

The first goal of building the prototype was to finish the astrometric hut. Providing the hut with nitrogen required a double-precision low pressure Harris regulator with ¼in barb fittings set at 9PSI feeding ¼in polyvinyl hose into the building. A 0.004in orifice was then attached to the end of the polyvinyl hose and placed near the mirror surface. Although there are two mirrors that require purging in the astrometric hut, the NPOI staff requested that only a purge on the second mirror be installed so as to not affect the astronomers' nightly viewing by adding a different purge system to the commonly used mirror. A flow rate of 1CFH is extremely small, which became a problem when the team first attempted to set the tank regulator to 40PSI and the inline regulator to 9PSI, respectively. Pressure does not drop off very quickly when it is flowing through a 0.004in orifice, so it takes several minutes to achieve a pressure reading of 9PSI. This extended setup time will be accounted for in future build days that are related to the purge systems.

Figure 2.2.1- Nitrogen tank installed near astrometric hut.

2.3 Supply Line

As is the plan for the final design, cleaned and capped ½in copper tubing is used for the supply line of this prototype. After measuring the cable tray between the astrometric hut and the imaging station, it was predicted that 85ft of tubing would be required; so two 50ft rolls were allotted for this. When copper tubing is purchased as a roll, it comes with a soft temper that allows it to easily bend into the desired shape. Between the astrometric hut and imaging station there are only two major bends, one that allows the cable tray to go around a dome elevator and another that allows the cable tray to clear the box containing the gate valves and related equipment. Due to the small amount of bends and cover plates that go over the top of the cable tray, the supply tubing was installed in less than an hour.

After installing the tubing in the cable tray, the tee fittings that will supply nitrogen to each station as well as the inlet from the tank were soldered in. In an effort to reduce time spent on site, the inlet and tee for the astrometric hut were soldered together as one piece beforehand, so only one solder joint was required to attach both pieces to supply line.

Figure 2.3.1- Inlet/Astrometric hut tee fitting.

This piece, as well as the tee for the gate valves and the tube-NPT adapter for the imaging station was successfully soldered in place the week of March 3. Currently, the supply line is completed with the exception of the coil, tanks, and rigid mounting brackets.

Chapter 3. Plan for Finishing Prototype

3.1 Securing Supply Line

NPOI is located atop Anderson Mesa, which causes increased wind speed and decreased temperatures when compared to Flagstaff. As a result of this increased wind speed, the supply line must be securely mounted so it is not able to move and scrape inside the cable tray. If the tubing sat freely in the tray, it is likely that a hole would wear in the tubing rendering the entire arm useless. However, due to the low temperatures, the tubing must not be mounted so securely that it prevents thermal expansion/contraction in the line. Stainless steel loop clamps using an EPDM cushion with a ⅝in hole will be tight enough to prevent lateral movement from the wind, but still allow the axial movement from thermal expansion/contraction. These clamps will be ordered from McMaster-Carr as soon as possible and installed as the last step of construction. Installation of these clamps will require drilling holes in the cable tray to secure the clamps with stainless steel fasteners.

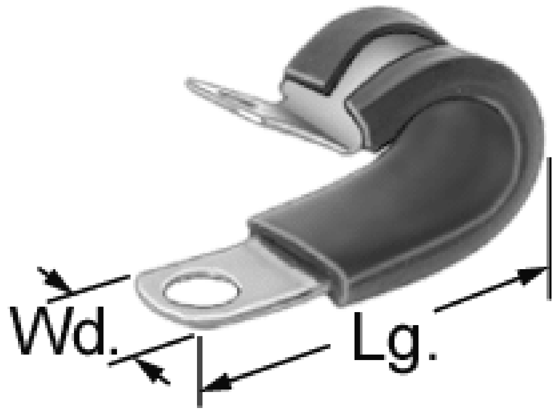


Figure 3.1.1- Loop clamp with EPDM cushion. [1]

3.2 Gate Valves and Imaging Station

The main supply line is complete, which means that the fittings leading into the gate valves and imaging station have been soldered into place. It is now necessary to attach one angle valve and one regulator for the gate valve and two regulators for the imaging station, respectively. These previously listed components will be connected by several feet of ¼in polyvinyl hose. All regulators have been set up to be in-line with ¼in barb fittings to attach to the polyvinyl hose. The regulators at the gate valves and imaging station actuators will be set to 40PSI, while the imaging station purge regulator will be set to 9PSI. Hose clamps are required at all barb fittings to reduce the chance of leaks when the system is pressurized to 50PSI.

3.3 Tanks and Coil

To help compensate for not installing the prototype on the full 250m arm, a coil will be soldered inline with the main supply line. This will consist of a single 100ft long copper coil. The coil will be installed in series with the supply line, which involves cutting into the main supply line and soldering both ends of the cut main supply line to the two ends of the coil. This shall be done using the same system of converting from copper tubing to polyvinyl tubing so the coil can rest safely away from the array system. The concrete pad that this coil is placed is no more than 15ft from main supply line. Both reservoir tanks will be installed in the same fashion. However, rather than installing inline, it will use only one tee connection using the same system of tube to NPT to barbed fittings.

Figure 3.3.1- Coil location relative to gate valves and cable tray.

Chapter 4. Prototype Testing

4.1 Pressure Testing of Fittings and System

To check for leaks in the current main supply line, the system has been charged to a pressure of 40PSI. This has been left with the valve to the supply tank completely closed. If there are any substantial leaks in the system, it shall be apparent by a pressure drop noticed over a period of one week. Once the whole system has been installed into the prototype this same style of pressure testing will take place with all valves closed.

4.2 Operation of Components

After everything is hooked up we must operate all components and make sure they work properly. The goals for final operation include:

- Actuators open/close lizard head at an appropriate pace.

- Gate valves must operate instantaneously.
- Purging of siderostat mirrors keeps a constant flow rate of 1CFH.
- Less than 1PSI pressure drop in main supply line.

Once all components are installed and fittings verified to be free of leaks, all components will be operated while checking pressure at several locations in the system. Valves will be installed at the reservoir tanks so the performance of these tanks can be physically evaluated. If all items work well., it will prove that the prototype design, with the 100ft coil to simulate the entire length of one arm, can operate effectively. Any changes that are made to the prototype to improve performance will be noted and can be proposed to further the process of approval to build the system in its entirety throughout the NPOI site.

4.3 Comparison to Numerical Modeling

A MATLAB code was created several months ago to predict the pressure drop and equivalent length of the supply line as it passes through the bends, tees, and valves. This calculation is dependent on the flow diameter, loss coefficient of components, line pressure, and length of tubing. Since pressure drop is more dependent on flow rate than length, the maximum pressure drop occurs when operating the gate valves, which are located 50ft from the inlet rather than at the imaging station, which is 185ft away.

Table 4.3.1- MATLAB code inputs and outputs for imaging station

	Quantity	Description
Diameter	0.555	Flow diameter (ID)
Line tees	4	Passing straight through tee
Branch tees	0	Passing through 90º bend
Valves	1	Angle valve K= 2
Curves	2	Big bends in cable tray
Line pressure	40	Pressure [PSI]
Flow rate	9	Max flow rate in line [CFH]
Line length	56	Actual length [m]
Pressure drop	**0.1092PSI**	**Output**

Equivalent length	**63.92m**	**Output**

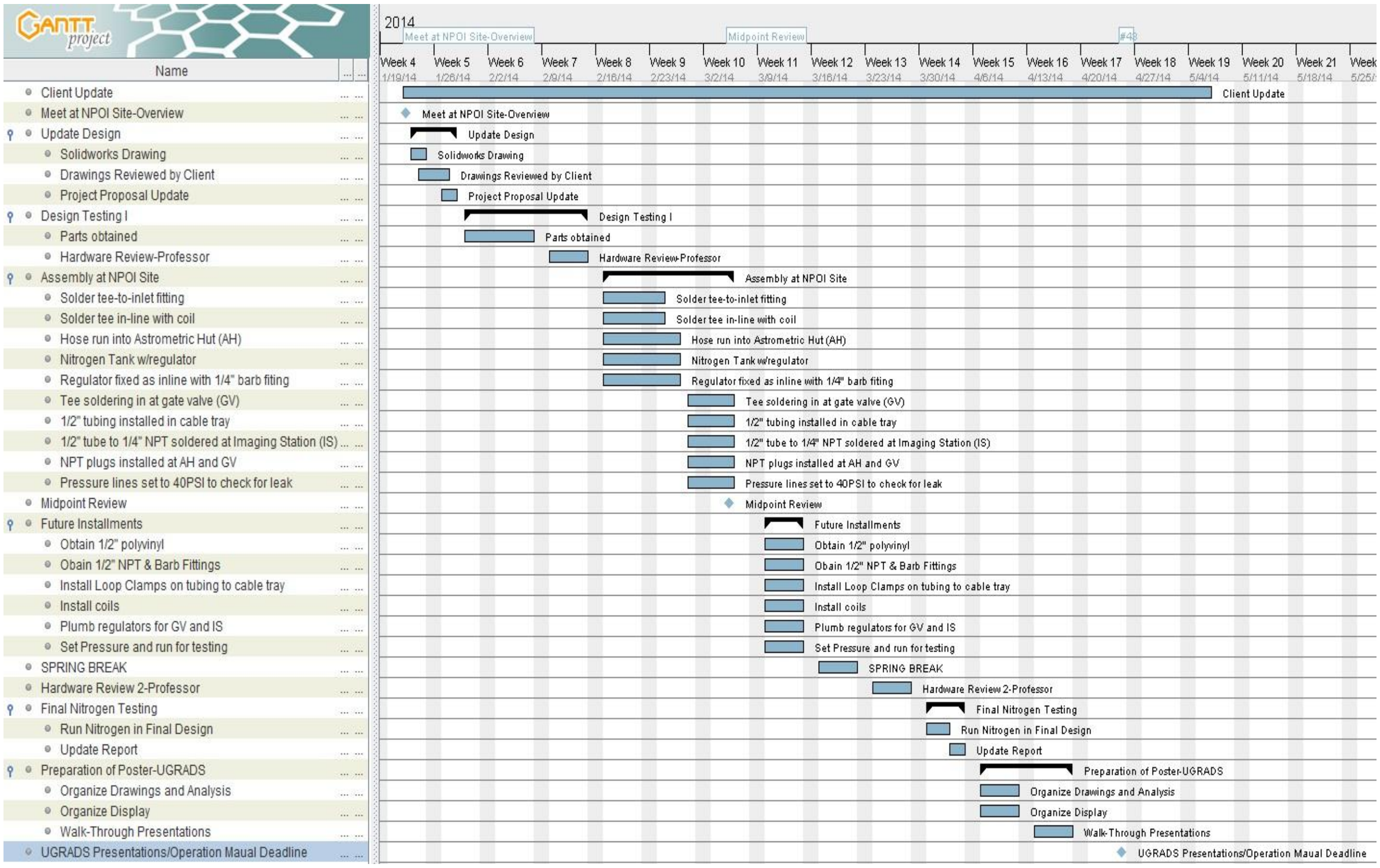
Table 4.3.2- MATLAB inputs and outputs for gate valves

	Quantity	Description
Diameter	0.555	Flow diameter (ID)
Line tees	2	Passing straight through tee
Branch tees	1	Passing through 90º bend
Valves	1	Angle valve K= 2
Curves	1	Big bends in cable tray
Line pressure	40	Pressure [PSI]
Flow rate	25	Max flow rate in line [CFH]
Line length	16	Actual length [m]
Pressure drop	**0.1729PSI**	**Output**
Equivalent length	**20.2067m**	**Output**

Chapter 5. Conclusion

Located on Anderson Mesa in the Navy Precision Optical Interferometer, which is owned by the United States Navy. Currently the site uses many nitrogen tanks spread over several acres. To make this more efficient, a central system of nitrogen supply has been designed. In order to test this design, a prototype is currently being built. Copper tubing was used to fabricate the main supply line. This main supply line has been completely installed and is currently being tested for leaks under pressurized conditions. At each station a tee fitting has been soldered into the main line to supply nitrogen at each station. Connected to these tee fittings will eventually be a system of extra fittings that will convert 1/2in copper tubing to 1/2in polyvinyl hose. Connected inline with the polyvinyl hose will be one ball valve and either one or two regulators, which have all been prepared for installation. All reservoir tanks and lengthening coils will be installed in the same manner. Once the prototype has been completely built measurements of pressures along the system during operation will be checked against the series of MATLAB codes used for the designing process. Further action may or may not be taken following this inquiry.

Appendix A



GANTT project
Name
2014
Meet at NPOI Site-Overview
Midpoint Review
Week 4
Week 5
Week 6
Week 7
Week 8
Week 9
Week 10
Week 11
Week 12
Week 13
Week 14
Week 15
Week 16
Week 17
Week 18
Week 19
Week 20
Week 21
Client Update
Meet at NPOI Site-Overview
Update Design
Solidworks Drawing
Drawings Reviewed by Client
Project Proposal Update
Design Testing I
Parts obtained
Hardware Review-Professor
Assembly at NPOI Site
Solder tee-to-inlet fitting
Solder tee in-line with coil
Hose run into Astrometric Hut (AH)
Nitrogen Tank w/regulator
Regulator fixed as inline with 1/4" barb fiting
Tee soldering in at gate valve (GV)
1/2" tubing installed in cable tray
1/2" tube to 1/4" NPT soldered at Imaging Station (IS)
NPT plugs installed at AH and GV
Pressure lines set to 40PSI to check for leak
Midpoint Review
Future Installments
Obtain 1/2" polyvinyl
Obain 1/2" NPT & Barb Fittings
Install Loop Clamps on tubing to cable tray
Install coils
Plumb regulators for GV and IS
Set Pressure and run for testing
SPRING BREAK
Hardware Review 2-Professor
Final Nitrogen Testing
Run Nitrogen in Final Design
Update Report
Preparation of Poster-UGRADS
Organize Drawings and Analysis
Organize Display
Walk-Through Presentations
UGRADS Presentations/Operation Maual Deadline

References

[1] Rubber Cushioned Loop Clamps. EPDM cushion 300 stainless steel. http://www.mcmaster.com/#pipe-routing-clamps/=qzjqc1