

ROCKSAT-XN SPARK

Assembly Instructions for Laboratory Model

M. J. Bailey, S. S. Lawson, M. J. Schwab, J. N. Stefancik, C. A. Romero-Talamás
Dusty Plasma Laboratory
University of Maryland, Baltimore County
1000 Hilltop Circle, Catonsville MD 21250



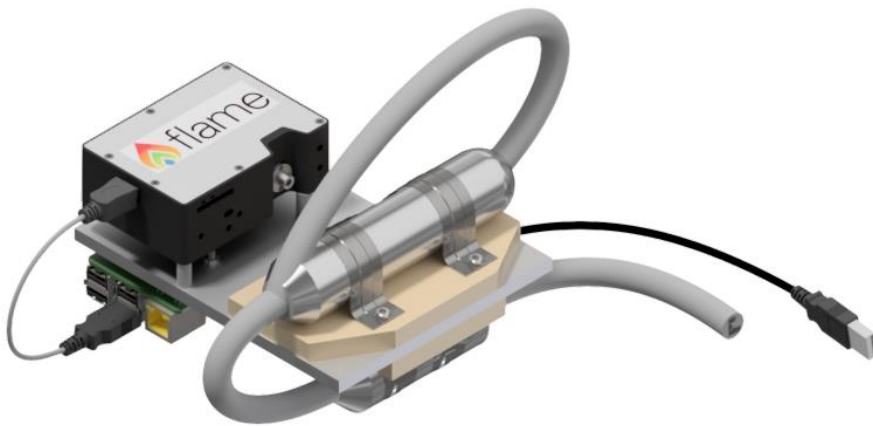


Figure 1: The Completed Spark Gap Device Assembly. The device shown is the laboratory model, for use in ground-based testing.

Table of Contents

Part I.....	4
Part II	5
Part III.....	8
Part IV.....	9
Part V	13
Part VI.....	21
Part VII	24
Part VIII	25
Part IX.....	28
Part X	29
Citations	30
Appendix A.....	31



Part I

Acronyms

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DPL	Dusty Plasma Lab
KPIF	Keith Porter Imaging Facility
MMC	McMaster-Carr Supply Company
UMBC	University of Maryland Baltimore County
LTM	Laboratory Test Model
SGA	Spark Gap Assembly



Part II

Bill of Materials

Part	Supplier	Supplier ID #	DPLX Part #	Quantity	Assembly Parent
M3 SS Hex Nut	MMC	91828A211	N/A	8	4-Spark Gap 4-Transformer
M3X.5mm SS Phillips Flat Head 12mm	MMC	92010A122	N/A	8	4-Spark Gap 4-Transformer
M3X.5mm SS Phillips Flat Head 14mm	MMC	92010A787	N/A	14	8-Spark Gap 6-Transformer
4-40 SS Hex Nut	MMC	91841A005	N/A	7	Final Assembly Ocean Optics Flame Raspberry Pi
4-40 1" SS Phillips Round Head Screw	MMC	91772A115	N/A	7	Final Assembly Ocean Optics Flame Raspberry Pi
Steel Clamp	MMC	9429T360	N/A	4	2-Spark Gap 2-Transformer
Aluminum Foil Wrap	Giant	NA	P433	1	Spark Gap
Baffle Inner	Keith Porter Imaging Facility	NA	P434	2	Spark Gap
Baffle Outer	Keith Porter Imaging Facility	NA	P435	2	Spark Gap
Electrode	UMBC Mechanical Engineering Dept.	NA	P436	2	Spark Gap



Electrode Set Screw	UMBC Mechanical Engineering Dept.	NA	P437	2	Spark Gap
Ferrite Choke	eBoot (AMAZON)	EBOOT-CABLE-CLIP-01	N/A	2	Transformer
Quartz Tube	GREATGLAS, Inc.	NA	P438	1	Spark Gap
G10 Spark Gap Shielding Top	ePlastics	G10NAT0 .02X12X12	P439	1	Spark Gap
G10 Spark Gap Shielding Middle	ePlastics	G10NAT0 .250X12X12	P440	1	Spark Gap
G10 Spark Gap Shielding Bottom	ePlastics	G10NAT0 .02X12X12	P441	1	Spark Gap
Transformer	WALFRONT (AMAZON)	43312-4044	N/A	1	Transformer
G10 VIPE Shielding Top	ePlastics	G10NAT0 .250X12X12	P442	1	Transformer
G10 VIPE Shielding Middle	ePlastics	G10NAT0 .250X12X12	P443	1	Transformer
G10 VIPE Shielding Bottom	ePlastics	G10NAT0 .250X12X12	P444	1	Transformer
Viton Insulation	Small Parts (AMAZON)	5VFSG-062-12	P445	1	Spark Gap
Viton Insulation	Small Parts (AMAZON)	5VFSG-125-12	P446	1	Transformer
Wire Shielding	Electriduct	BSFN-050-10	P447	1	Spark Gap Transformer
Lab Base Plate Small PV	UMBC Mechanical Engineering Dept.	NA	P448	1	Base Plate
Raspberry Pi Standoffs Delrin	MMC	8579K12	N/A	4	Final Assembly

Commented [D2]: Need to find suppliers for G10

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Ocean Optics Standoffs Delrin	MMC	8579K12	N/A	3	Final Assembly
High Voltage Flex Wire	MMC	9620T14	N/A	As Needed	Spark Gap Transformer



Part III

Vendors/Suppliers

- MSC Direct Industrial Company
<https://www.mscdirect.com/>
- McMaster-Carr Supply Company
<https://www.mcmaster.com/>
- Formlabs Inc.
<https://formlabs.com/>
- Keith Porter Imaging Facility
<https://kpif.umbc.edu/>
- UMBC Mechanical Engineering Dept.
<https://me.umbc.edu/>
- GREATGLAS, Inc.
<http://www.greatglas.com/>
- Electriduct, Inc
<https://www.electriduct.com/>
- ePlastics
<https://www.eplastics.com/>
- WALFRONT
https://www.amazon.com/Voltage-Transformer-Temperature-Frequency-Generator/dp/B076V2DVR2/ref=sr_1_13?s=electronics&srs=16566127011&ie=UTF8&qid=1533564403&sr=1-13
- Small Parts
https://www.amazon.com/Viton-Fluoroelastomer-Sheet-Gasket-Black/dp/B0075ZN4RE/ref=sr_1_fkmr2_3?ie=UTF8&qid=1533565842&sr=8-3-fkmr2&keywords=0625+viton+sheet

Commented [D6]: Update suppliers for G10

Commented [JS7R6]: ePlastics

Commented [D8R6]: Added them



Part IV Transformer Assembly

Step 1

- Assemble the G10 shielding for the VIPE transformer.
- Insert -92010A122 M3 12mm Screws into the VIPE Insulation Middle Part (Figure 1).
- Insert -92010A787 M3 14mm Screws into the VIPE Insulation Middle Part (Figure 1).
- 12mm screws face up and will be used to fasten two clamps. The 14mm screws will be used to connect this piece to the baseplate.
- 12mm Screws are shown in the top and bottom of the picture 14mm are in the center.

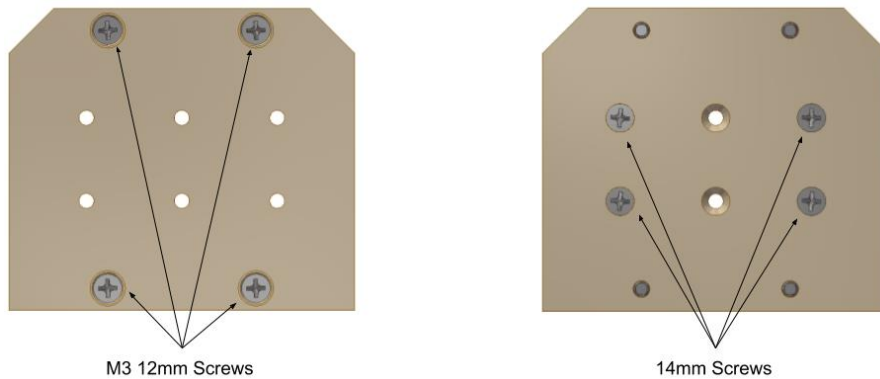


Figure 2

- These screws must be flush with the surface of the insulating plate, otherwise the assembly could become misshapen.
- Only four screws are necessary to fasten the G10 to the baseplate for the LTM.

Step 2

- Install the VIPE Insulation Bottom.
- Insert the VIPE Insulation Bottom over the 4 screws that are on the bottom of the VIPE Insulation Middle.

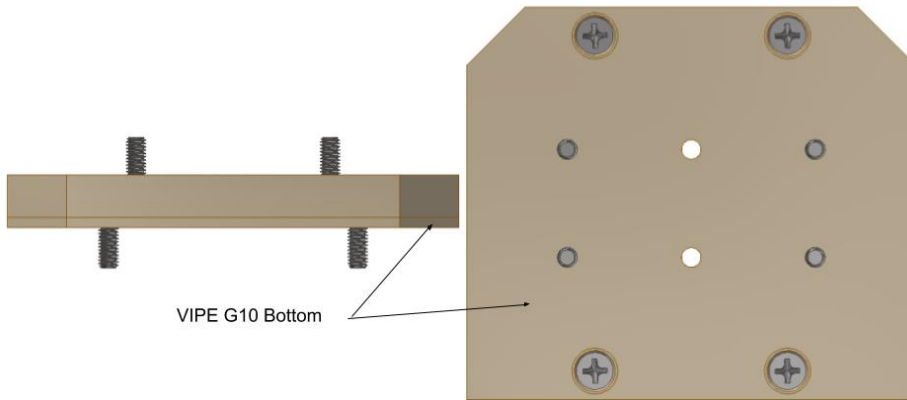


Figure 3

Step 3

- Install the Shielding plates to your mounting surface.
- The baseplate has recesses on the opposing side for the hex nuts
- Attach the four screws that pass through the shielding material to the baseplate using four 91828A211 M3 SS Hex Nuts. There must be no part of the screw or nut that extends out from the baseplate on the opposite side. It is critical to know the transformer and the spark gap are located on opposite sides of the plate with the transformer installed first.

Commented [JS9]: Also superfluous.

Commented [D10R9]:

Commented [D11R9]: Resolved

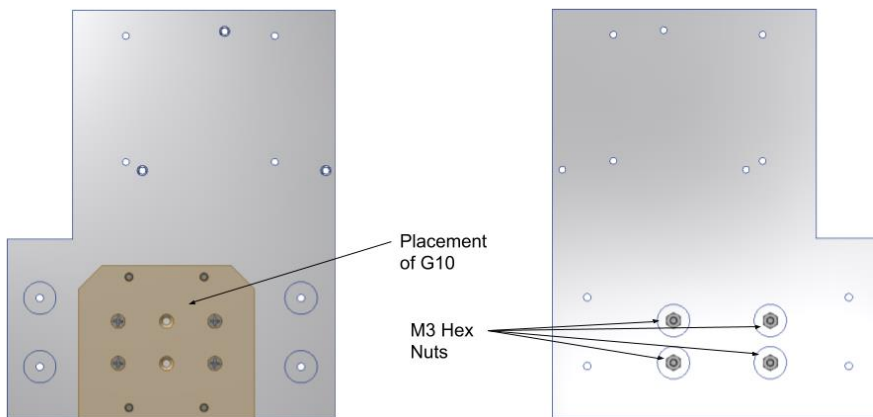


Figure 4

Step 4

- Install the VIPE Shielding Top.
- Place the VIPE Shielding Top over the four screws and set this assembly aside.
- The 12mm screws should be sticking out of the top.

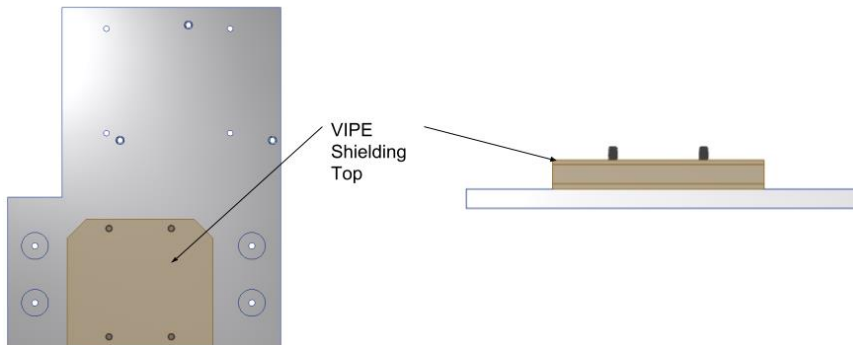


Figure 5

Step 5

- Connect two wires to both ends of the transformer, making sure the step up in voltage is going in the correct direction for the transformer you are using.
- These wires should be around 3 inches long.
- The transformer now has four wires soldered to it.
- Wrap solder joints with shrink plastic.

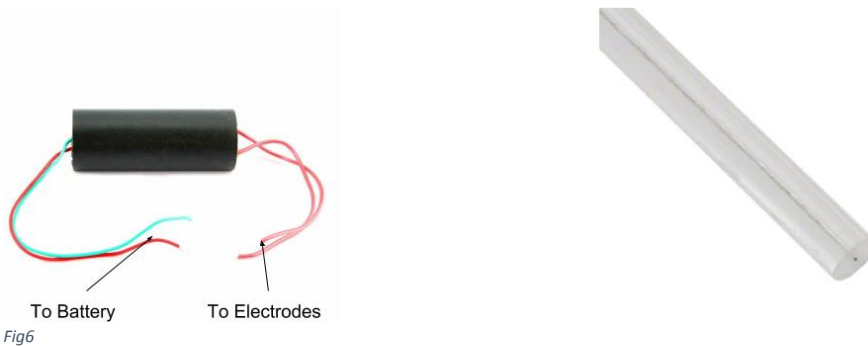
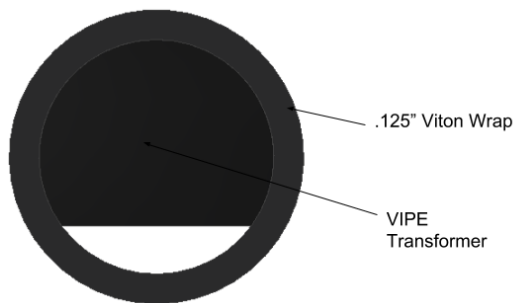


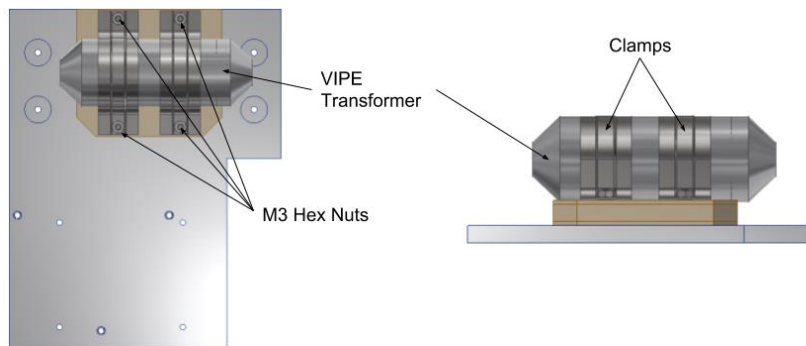
Fig6

Step 6

- Wrap the transformer in 0.125in Viton.
- Wrap the transformer in wire mesh shielding.
- Cut a 6 - 7 inch length of the wire mesh shielding.
- Insert the Transformer into the mesh shielding, making sure about 1.5 inches hangs over each end of the Transformer.

**Step 7**

- Install the mesh-wrapped transformer into the VIPE shielding subassembly.
- Fasten the transformer to the G10 shielding.
- Center the transformer on the G10 shielding and install four 91828A211 M3 hex nuts and two clamps over the shielding.

*Figure 7*

Part V Spark Gap Assembly

Step 1

- Insert four 92010A787 M3 14mm Screws into the Spark Gap Insulation Middle Part.
- Insert four 92010A122 M3 12mm Screws into the Spark Gap Insulation Middle Part.
- 12mm screws face up and will be used to fasten two clamps. The 14mm screws will be used to connect this piece to the baseplate.
- These screws must be flush with the surface of the insulating plate, otherwise components in the assembly can yield.

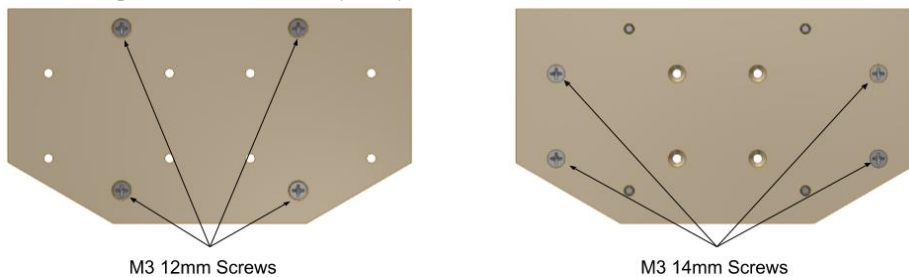


Figure 8

Step 2

- Install the Spark Gap Insulation Bottom.
- Insert the Spark Gap Insulation Bottom over the eight screws that are on the bottom of the Spark Gap Insulation Middle.

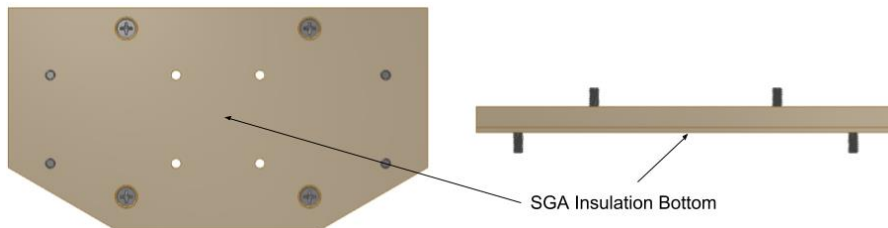
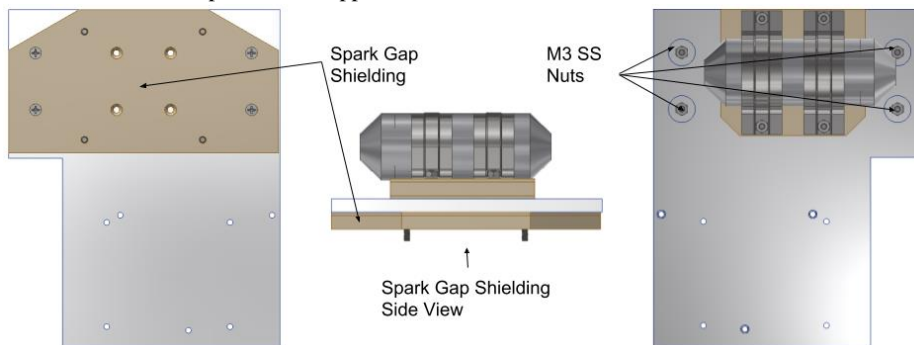


Figure 9

- The Spark Gap Shielding Bottom shall fit over the screws easily. If this piece forces any of the screws into a non-orthogonal orientation to the plate, the rest of the installation will be difficult.

Step 3

- Install the Shielding plates to your mounting surface.
- The baseplate has four recesses on the opposing side for the hex nuts.
- Attach the four screws that pass through the shielding material to the baseplate using four 91828A211 M3 SS Hex Nuts. There must be no part of the screw or nut that extends out from the baseplate on the opposite side.

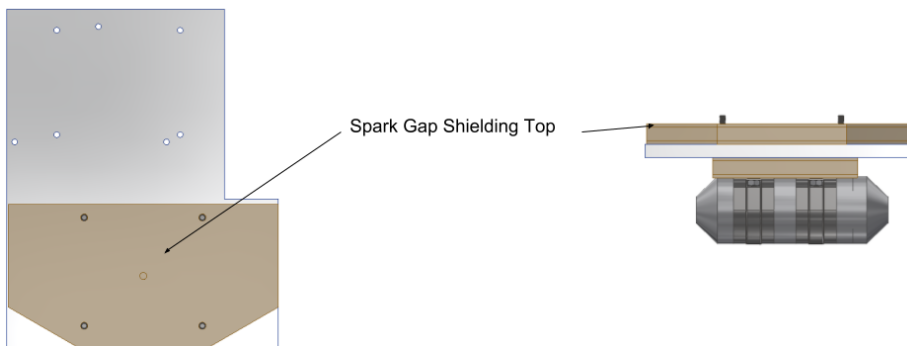
*Figure 10*

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Commented [D13R12]: Resolved

Step 4

- Place the Spark Gap Shielding Top over the four screws and set this subassembly aside.

*Figure 11*

- Ensure that the screw holes of the insulation layers line up correctly. If the screw holes do not line up this can cause the screws to become misaligned for clamp installation.
- If misalignment occurs additional alterations to the existing part must be made, or manufacture a new part.

- The clamps used to secure the Spark Gap are fastened using the four screws sticking out of the top of the G10 shielding plates and need to be in the correct position to make the clamp installation easy.
- Set the assembly aside and continue to the next step.

Step 5

- Gather two electrodes, two inner baffles, and two outer baffles.
- Insert an electrode into the small inner baffle. The large ring section (Largest diameter section) of the electrode must be towards the front of the inner baffle as shown (Fig 12).
- The threaded hole for the set screw must remain unobstructed. If the baffle obstructs part of the hole, file down the obstruction carefully until the screw sits properly in the threads.
- Take extreme care when sanding/filing baffles to fit inside of the quartz tube. Proper fitment should be **snug**, not overly tight or loose.

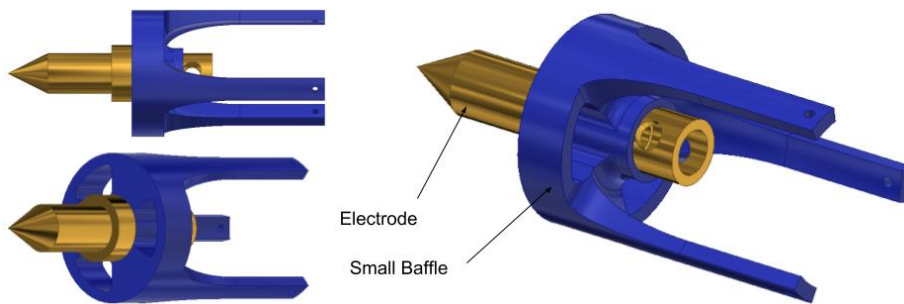


Figure 12

Step 6

- Connect the two wires that go to the transformer into the two electrode assemblies by inserting them through into the rear bore of the electrode. The insulated portion of the wires should be approximately 6 inches in length. Cut a reasonable length of wire to have a section of uninsulated wire as well. The uninsulated wire should run through the set screw hole of the electrode and through the center of the set screw. Pull a reasonable length of uninsulated wire through the set screw, as this will get soldered to the set screw.
- Install set screw with wire inside before soldering the uninsulated wire to the set screw. **Do not** solder the wire to the set screw in this step. Soldering will be completed in later steps.

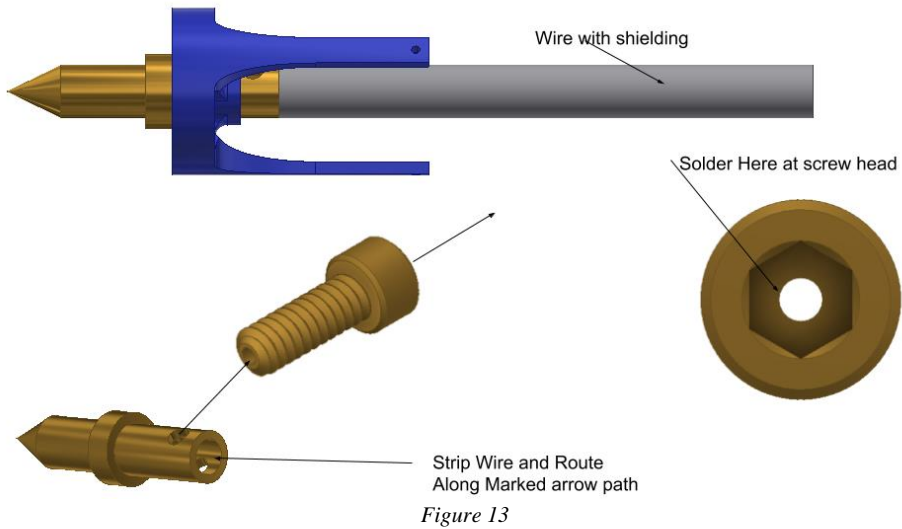


Figure 13

Step 7

- Insert the inner baffle and electrode into the outer baffle. The three prongs of the inner baffle must line up with the similarly sized holes in the outer baffle. The holes in the prongs of the inner baffle must be completely clear on the opposite face of the outer baffle.
- Run small gauge wire through the three small holes in the inner baffle to hold the assembly together. It is sufficient to wrap the small gauge wire twice to secure the baffles in place.
- Solder the wire to the set screw at the screw head. Cut off any excess wire when complete.
- Refer to Figure 14 for appropriate assembly of the securing wire.

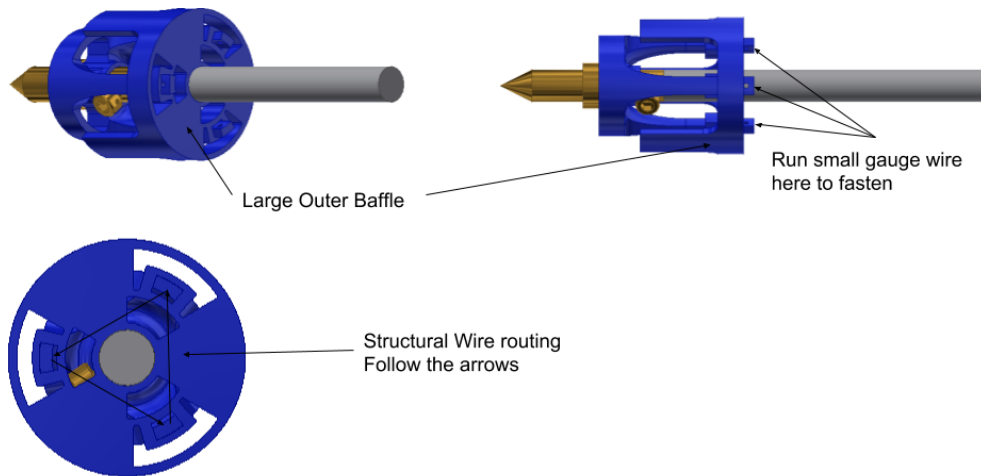


Figure 14

Step 8

- Wrap quartz tube in aluminum foil and 0.0625in Viton.
- Take a small piece of aluminum foil and completely wrap the quartz tube. Ensure the ends remain open.
- Wrap the Viton around the tube. The Viton must have a section precut for the view window. Use electrical tape to hold the Viton together around the tube.
- Remove the foil from the viewing window. Take extreme care to not scratch the quartz tube while cutting foil from the window.

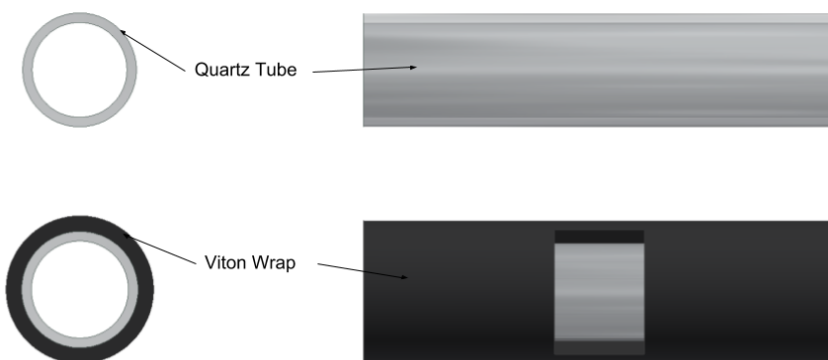
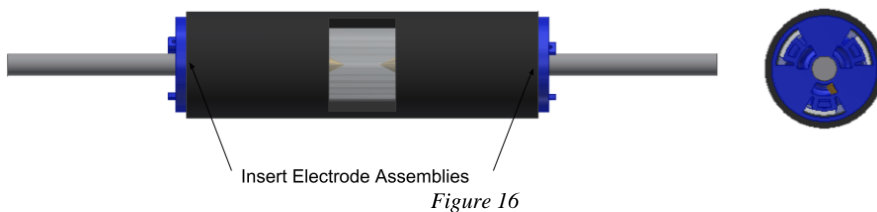


Figure 15

Step 9

- Carefully insert the electrode assembly into the quartz tube. The outer baffle must be flush with the end of the quartz tube. The outer baffle prongs must go on the outside of the quartz tube and on the inside of the Viton.
- During assembly, take care to minimize damage to the foil wrap between the quartz and Viton.
- The tips of the electrodes should be visible within the viewing window.

**Step 10**

- Cut a 6 - 7 inch length of the wire mesh shielding.
- Insert the Spark Gap Assembly into the mesh shielding ensuring approximately 1.5 inches of the mesh hangs over each end of the Spark Gap.

Step 11

- Place the Spark Gap previously assembled and place it on the G10 Shielding assembly completed in Step 4.
- Ensure the viewing window is facing the direction of the payload (pointing towards the spectrometer) and is parallel to the baseplate.
- Place two clamps over the Spark Gap. They should fit over the four screws sticking out of the shielding.
- Using four 91828A211 M3 hex nuts, install the clamps. The fitment of the clamps should be extremely snug, as the spark gap **cannot** move once installed.

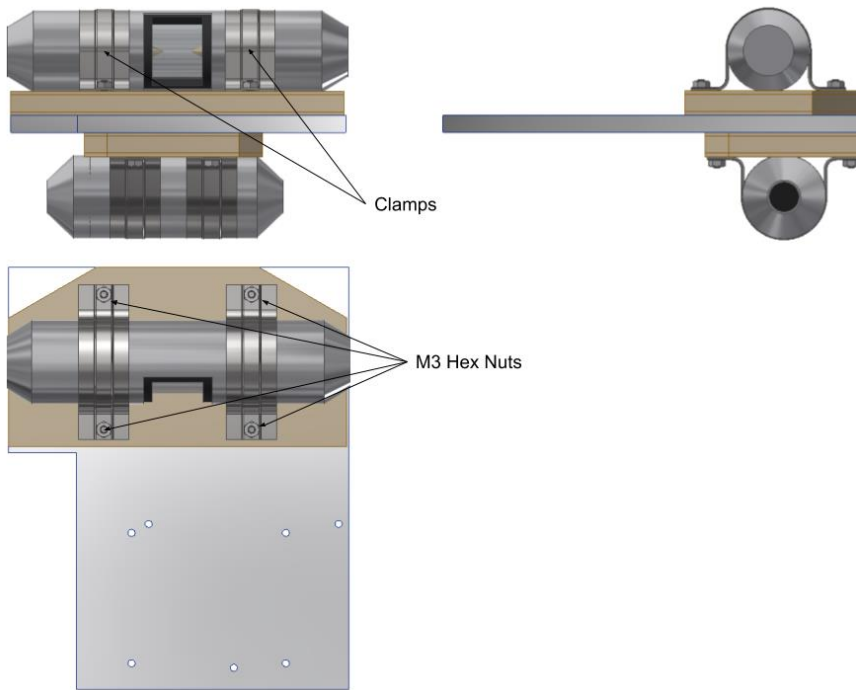


Figure 17: The installed Spark Gap Device. Note: these images do not show the wires that were installed in the Spark Gap in previous steps.

Step 12

- Install ferrite chokes on both sides of the transformer.
- Before connecting the wires between the transformer and the spark gap, cut a length of the wire mesh shielding long enough to cover the wires between the two devices and slide it over the end of the wires of the transformer.
- Solder the two leads from the spark gap to the two leads of the transformer, taking care to attach the correct set of wires coming from the transformer.
- Install shrink fit plastic over the solder joints once cool.
- Extend the wire mesh shielding to cover the wiring.

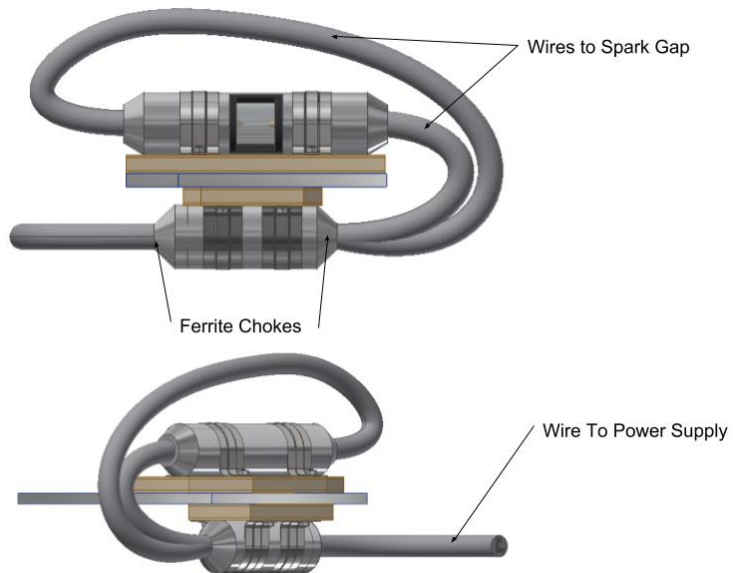


Figure 18: The completed assembly of the Spark Gap device and the Transformer.

Part VI Final Assembly

Step 1

- Using four 0.25-inch Delrin standoffs, four 91772A115 4-40 1-inch SS screws and four 91841A005 4-40 hex nuts install the Raspberry Pi 3 on the base plate. This must be installed on the same side as the transformer.

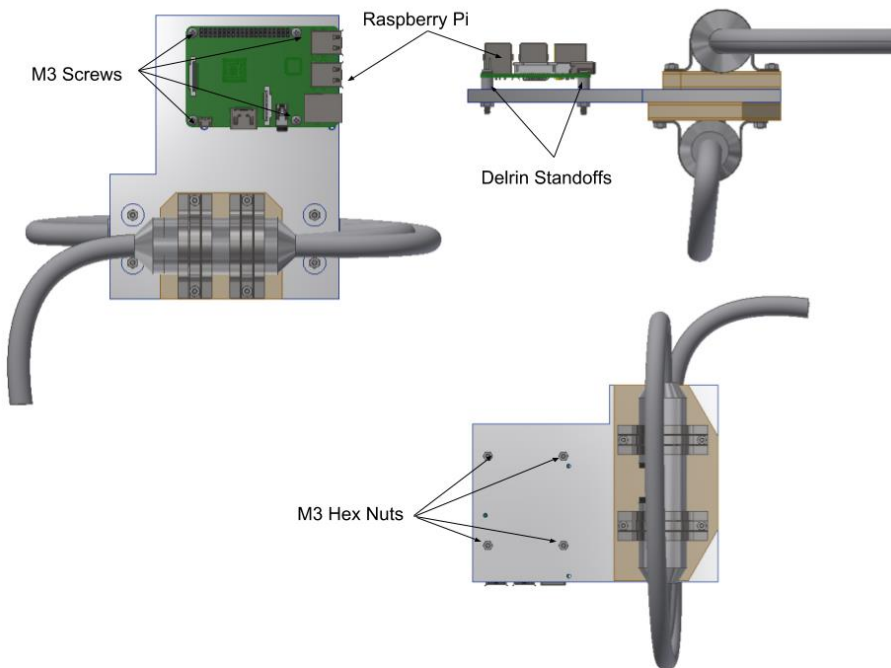


Figure 19: Installing the Raspberry Pi 3

Step 2

- Using the remaining three Delrin standoffs, three 91772A115 4-40 1-inch SS screws and three 91841A005 4-40 Hex Nuts, install the Ocean Optic Spectroscopy Instrument. This shall be installed on the same side as the Spark Gap.
- The viewing window of the Spark Gap **must** line up with the camera of the Ocean Optics Spectroscopy Instrument. *It is critical the two components line up properly to get accurate readings.*

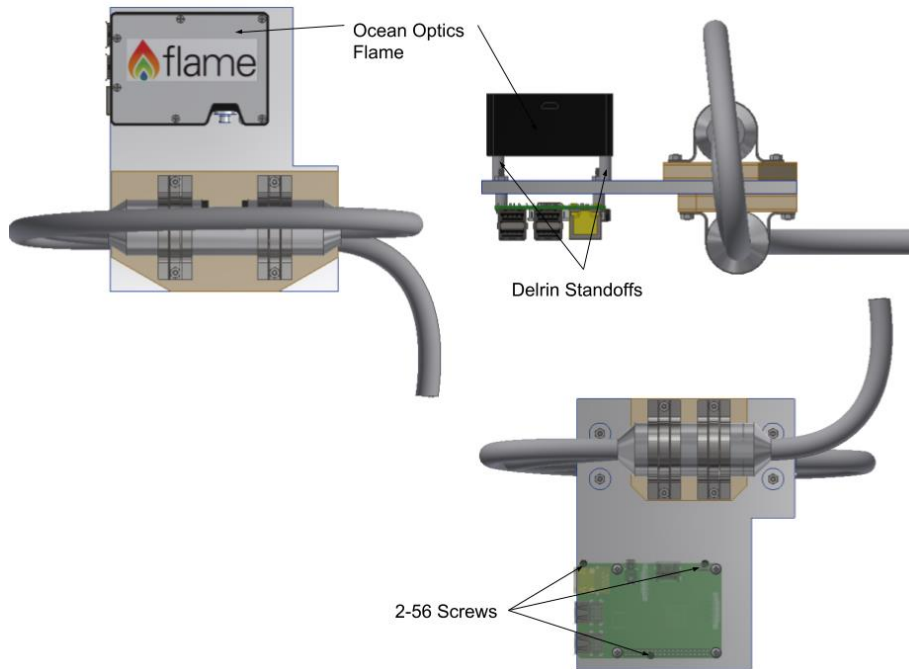


Figure 20: The installed Spectrometer and Raspberry Pi 3

Step 3

- Connect the proper cables to the Raspberry Pi, Ocean Optics Flame and the Transformer. Take all possible caution to minimize cable lengths, as these cables will outgas under vacuum and may cause inaccurate measurements.
- The device is now fully assembled.

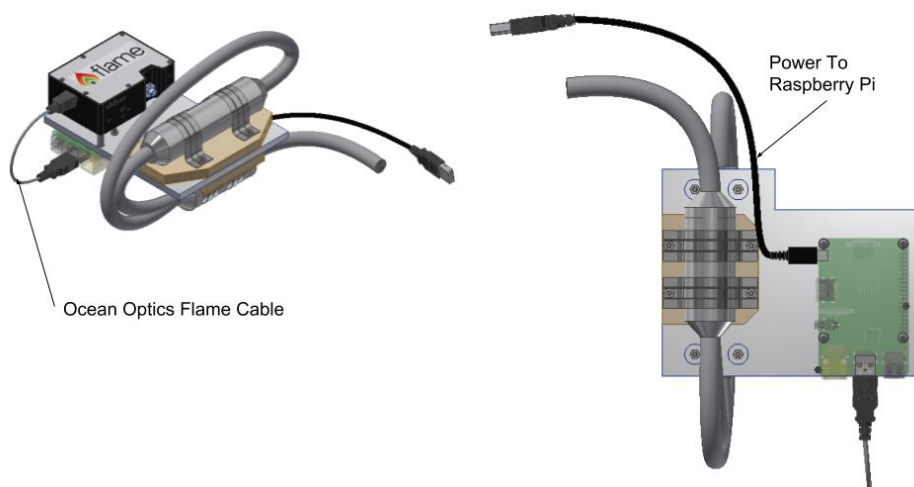


Figure 21: The fully assembled device. Ensure that the control cables are properly connected and fully seated in their respective ports.

Part VII

Technical Drawings

Technical drawings that are necessary for the device are located in **Appendix A**. Please note: Only drawings for parts to be manufactured by conventional means have been included in the appendix. It shall be beneficial to manufacture various parts with additive manufacturing processes.



Part VIII

Setting Up the Raspberry Pi

This section will explain how to set up a Raspberry Pi to operate the Ocean Optics Flame Spectrometer (Note: at the time of writing the software setup described below is NOT compatible with the Ocean Optics USB2000. To interface with an Ocean Optics USB2000 spectrometer use a standard Windows 7 computer with the OceanView software). It assumes one already has a Raspberry Pi 3 or Raspberry Pi 3+ running Raspbian Stretch (both the Lite and Desktop variants are acceptable). A basic familiarity with Linux as well as an understanding of basic Linux console commands (specifically: `$mv`, `$cp`, `$rm`, `$mkdir`, & `$unzip`) is necessary here. All referenced files are included in the same Github repository as this document (UMBC_DPLX_SPARK_2018).

1. Place the file “seabreeze-3.0.11.zip” in the directory `/home/pi/Documents`
2. Unzip the file
3. Run the command `$sudo apt-get install libusb-dev`
4. Locate the file “10-oceanoptics.rules” inside of `/home/pi/Documents/seabreeze-3.0.11/SeaBreeze/os-support/linux` and copy it to the directory `/lib/udev/rules.d`
5. Locate the file “Log.cpp” in `/home/pi/Documents/seabreeze-3.0.11/SeaBreeze/src/common` and delete this file
6. Place the “Log.cpp” file included with this document in the same folder where the faulty “Log.cpp” was just deleted
7. Place the files “demo-getSpectrumLoop.c” and “demo-integrationCalibration.c” in the directory `/home/pi/Documents/seabreeze-3.0.11/SeaBreeze/sample-code/c`
8. Inside of `/home/pi/Documents` create two new directories called “Data_Files” and “codeTesting”
9. Place the files “sparkGapOff.py”, “sparkGapOn.py”, and “intCalibrationManager.py” in the directory `/home/pi/Documents/codeTesting`
10. While inside of the `/home/pi/Documents/codeTesting` directory, run the commands `$sudo chmod +x sparkGapOff.py` and `$sudo chmod +x sparkGapOn.py`
11. Move to the directory `/home/pi/Documents/seabreeze-3.0.11/SeaBreeze` and run the command `$make` (note: this step can take anywhere from 10 to 30 minutes)
12. Within the directory `/home/pi/Documents/seabreeze-3.0.11/SeaBreeze/lib` locate the file “libseabreeze.so” and copy it to the directory `/lib/arm-linux-gnueabi`

The Raspberry Pi Software

Assuming the above instructions have been followed, two separate programs have been set up on the Raspberry Pi. The first is `demo-getSpectrumLoop`. When run, this program will infinitely request new back to back spectrums from the spectrometer, storing these spectrums in text files within the `/home/pi/Documents/Data_Files` directory. Each text file will be titled “SpecData_[number].txt”. For every other spectrum, the program will also toggle one of the Raspberry Pi’s GPIO pins high to serve as a potential trigger to activate the spark gap or other



light source should one desire. The default integration time is 3.5 seconds and the default trigger GPIO pin is 26, however both of these values can be changed by altering the program settings that can be found in the header of the file `demo-getSpectrumLoop.c` (note that after each edit, `$make` will need to be run in the directory `/home/pi/Documents/seabreeze-3.0.11/SeaBreeze/sample-code/c`). To run the program, simply use the command `./demo-getSpectrumLoop` while in the `/home/pi/Documents/seabreeze-3.0.11/SeaBreeze/sample-code/c` directory.

The second program is `demo-integrationCalibration`. This program can be used to determine what the optimal integration time is for a given light source. When run, the program will run through a series of integration times from 5 seconds to .025 seconds, generating 10 spectrums for each time. The program will then repeat the process a second time to gather noise. This will generate 560 text files in the directory `/home/pi/Documents/Data_Files`. These text files can then be copied off of the Raspberry Pi to a windows machine (see the `CalibrationFormatter` section for more on using these files). To properly use this program, the spectrometer should be exposed to the light source in a steady manner, before beginning the program. The program should then be started and allowed to run for 17 minutes. After 17 minutes the light source should be turned off and the Raspberry Pi should be allowed to run for another ~17 minutes (or until the program completes). Once this is done, the files can be extracted. To run this program, simply use the command `$python intCalibrationManager.py` while in the directory `/home/pi/Documents/codeTesting`. It is worth noting that in addition to the 560 data files, every time this program is run it will also create a text file titled `DataExists.txt`. This file holds no data but rather serves to prevent accidentally overwriting the data. While this file exists, a new test cannot be run. To run a new test, simply delete this file.

NOTE: If at any time a command run on one or both of these programs fails, try appending “`sudo`” to the front of the command and running it again. For reasons not entirely clear, this is necessary on some Raspberry Pis but not others, even when they were supposedly set up identically.

CalibrationFormatter

Included with this document is a program called `CalibrationFormatter`. This program can be placed in a folder with the 560 text files generated by `demo-integrationCalibration` and run to format the files (note that this must be done on a windows machine). Upon running `CalibrationFormatter` it will read each file and average both the lit and background readings of each integration time. The background average will then be subtracted from the lit average of each (to subtract out noise) and the resulting spectrums will all be saved to a single text file titled `ExcelFormat`. This file can then be imported into excel using “.” as a delimiter to generate columns showing the spectrometer’s noise subtracted average output at each of the tested integration times. These can then be compared to determine the optimal integration time for the given light source.



Making Programs Run on Boot

In several cases (especially when the Raspberry Pi is inside of a vacuum chamber and cannot be readily accessed) it may be beneficial to make a program run automatically as soon as the Raspberry Pi boots up. During the testing procedures laid out in section 10 the demo-integrationCalibration program was set to run automatically on boot so that once the appropriate pressure was reached, the Raspberry Pi could be powered and the test would begin automatically. This section will lay out how any program can be made to run automatically. It is worth noting that where program timing is involved, one should allow between 1 and 2 minutes for the Raspberry Pi to boot before the program will begin (this can vary based on what else is installed on the Raspberry Pi).

To begin, enter the command `$sudo nano /etc/rc.local`. This will open an editor where a text file called `rc.local` can be edited. Used the arrow keys to move down to the final line of the file before “exit 0”. On a new line immediately before the “exit 0”, enter any of the commands described above to start the desired program(s) (should there be multiple commands to run, put each command on a new line). However, in these commands insert the complete filepath to the program’s location before the name of the program. Following this, enter a space and a “&”. As an example, to make demo-integrationCalibration run on startup this line should read “`sudo python /home/pi/Documents/codeTesting/intCalibrationManager.py &`”. Once this is complete, the specified program will automatically run the next time the Raspberry Pi boots.



Part IX Manufacturing

This section contains notes from the designers on how various components were manufactured, and the recommended way to manufacture this device in the future.

Components	Tools Used	Method	Notes
Electrode Holders	SLA Printer Sandpaper Swiss Files	Precise sanding/filing may be required to remove excess print resin and ensure good fit inside of quartz tube	Manufactured at UMBC Due to quartz tube tolerance, baffles may need sanding for good fit
Standoffs (for Raspberry Pi)	Saw Drill Press Lathe	Use saw to cut Delrin to length Use drill press to cut hole for the screw Can also be turned on lathe	Delrin Piece ordered from McMaster Screw diameter = 0.086"
Base Plate	Milling Machine	Manual milling or CNC milling required	CNC Milling recommended due to part complexity and tolerance requirements
G10	Laser Cutter	Machine it or laser cut, depending on thickness	Used 3 smaller laser cut sheets made by hand
Viton for transformer	X-ACTO knife	Cut with X-ACTO knife	Trim excess once installed
Electrodes for Spark Gap	Machined	Turned from round stock on lathe	Manufactured at UMBC
Wire Mesh	Tin snips	Compress to size of transformer to increase the diameter and decrease the length. (Do this before cutting for better fit)	Wear Gloves (Safety Concern for metal splinters)
Clamps	Vice Drill Press Hacksaw	There are ridges on both ends of clamps. Take the vice and tighten to make it flat. Once flat, position it on the pre-cut G10 and mark where the holes should be located on the G10. Use drill to cut 5/32-inch holes.	Take a hacksaw and cut of the excess



Part X

Testing

Testing Conducted with the Flight Spectrometer during July of 2018

Once the laboratory model of the device was assembled, testing was conducted in vacuum chambers both at UMBC and UMD. Each test was conducted in the 5E-5 Torr region. Testing was conducted as follows: The Raspberry Pi was set up so that the demo-integrationCalibration program would run automatically on boot. The entire test rig was then inserted into the vacuum chamber. Exterior wires were run to the leads of the spark gap while an exterior micro-USB line was run to the Raspberry Pi's power port. Both lines were unpowered during this test. The vacuum chamber was then sealed and pumped down. Once the chamber ultimate pressure reached $\sim 5\text{E}-5$ torr, 7.4V was provided to the spark gap, and the Raspberry Pi was powered with 5V and 2.5A. From the moment the Raspberry Pi was powered a stopwatch was manually triggered. When 19 minutes had passed (17 minutes for the test + 2 minutes to allow for boot) the spark gap was depowered. After another 17 minutes the Raspberry Pi was also depowered. With this done the test was complete and the chamber was repressurized. The test rig was then removed, and the data files were pulled from the Raspberry Pi via SSH.

The above procedure was used during the first two tests with the laboratory device. Future tests followed the same procedure with one variation. It was determined that constant power could potentially damage the transformer, thus future tests manually pulsed the power to the spark gap, with 6 seconds on and 6 seconds off. Unfortunately, this method renders the CalibrationFormatter program useless and the data must be formatted manually.



Citations

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Appendix A

Technical Drawings are found on the following pages.

