

**PLASMA PROCESS GROUP, INC.**

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RFN  
Radio Frequency Neutralizer Manual



plasma process group

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7330 Greendale Road, Windsor CO 80550 USA  
Phone 970-663-6988 • Fax 970-669-2312

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## Introduction

*Thank you for purchasing a radio frequency neutralizer from Plasma Process Group!*

This Manual covers the installation and operation of our RFN and RFN matching network.

The radio frequency neutralizer, RFN, was developed as a filament-less electron source. The RFN utilizes a radio frequency discharge to create electrons which can then be emitted into a vacuum environment. The RFN utilizes an inert gas such as Argon to create the electrons. With proper care, the RFN has been a proven workhorse in demanding production environments. For a system built to specification, the RFN operation should exceed over 1000 hours of operation before maintenance is required.

For this manual, theory of operation, maintenance, and troubleshooting suggestions are discussed. For the interested reader, we encourage a review of the introductory chapters for the following references [1-3]. For any technical assistance, please contact us.

We at Plasma Process Group hope that using your new RFN will produce rewarding results.

## **Limited Warranty**

Our workmanship warranty:

All equipment manufactured and sold by Plasma Process Group Inc is warranted to be free of defects and workmanship when shipped. The warranty on all equipment is for one year commencing (a) on final acceptance or (b) 30 days from shipping, whichever occurs first. This warranty covers the cost of parts and labor. Expendable and consumable items, such as grid assemblies, RFN collectors and discharge chambers are excluded from this warranty. This warranty supersedes all other warranties, expressed or implied. Plasma Process Group Inc assumes no contingent liability for damages or loss of production.

Expendable items, including, but not limited to, grid assemblies, RFN collectors, discharge chambers, filaments, fuses, o-rings and seals are specifically excluded from the foregoing warranties and are not warranted.

Seller assumes no liability under the above warranties for equipment or system failures resulting from (1) abuse, misuse, modification or mishandling; (2) damage due to forces external to the equipment including, but not limited to, flooding, power surges, power failures, defective electrical work, transportation, foreign equipment/attachments or Buyer-supplied replacement parts or utilities or services such as process gas; (3) improper operation or maintenance or (4) failure to perform preventative maintenance in accordance with Seller's recommendation (including keeping an accurate log of preventative maintenance). In addition, this warranty does not apply if any equipment or part has been modified without the written permission of Seller.

# Technical Contact Information

*For Service or Repair contact:*

Plasma Process Group Inc (PPG)  
[www.plasmaprocessgroup.com](http://www.plasmaprocessgroup.com)

*Please supply the following information:*

- Product
- Model and serial number
- Date Purchased
- Detailed description of problem
- Contact person

If the product is to be returned to PPG for repair you will be assigned a **Return Authorization** number (RA), warranty status of the equipment and shipping information to return the product. The RA number should be attached to the outside of the shipping container. A purchase order number should be included should the equipment not be under warranty. After PPG receives the equipment a firm quote and estimated repair time will be given prior to work being started.



## Theory of Operation

The function of the radio frequency neutralizer (RFN) is to produce and emit electrons. These electrons are typically important to minimize space-charge issues downstream from an ion beam source. The RFN also assists with minimizing surface charge issues such as arcing and dielectric breakdown. Typically, more electrons are emitted from the neutralizer than ions from the source. This is done to minimize and/or eliminate the space or surface charging that may occur. In most situations, electrons from the neutralizer do not directly combine with the ions in the beam to form high energy neutrals. The RFN consists of five (5) key elements:

RF coil, discharge chamber, gas isolator, collector and keeper.

Presented in Figure 1 is a schematic of the RFN. Basically, the RFN is operated by introducing the working gas into the **discharge chamber** via the **gas isolator**. Power is then applied to the **RF coil** to create a discharge. Electrons are extracted from the discharge and are attracted to the **keeper**. Ions in the discharge are attracted to the **collector**.

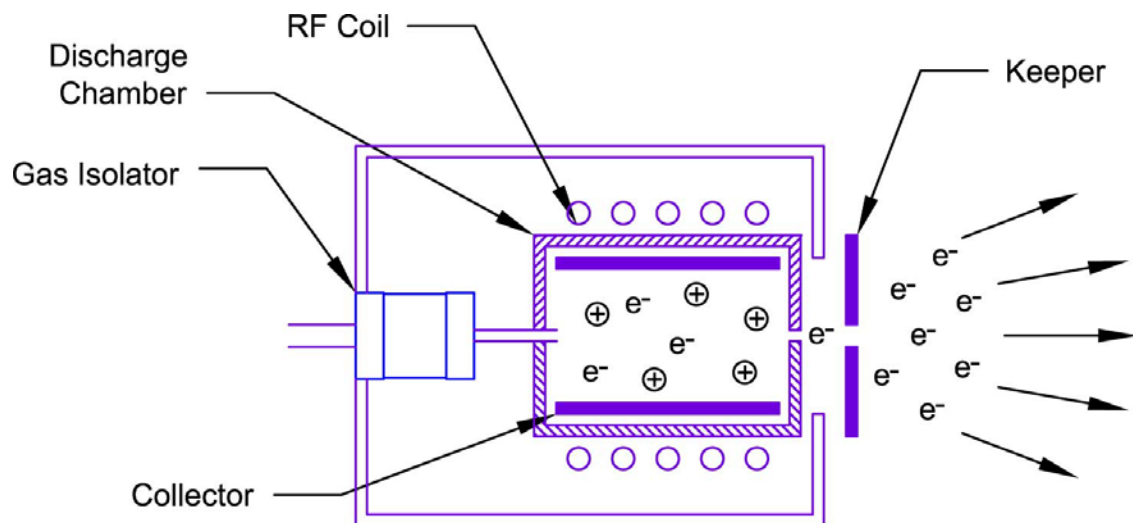


Figure 1. Cross section schematic of the RFN.

## RFN Parameter Definitions

As electrical devices, RF neutralizers require power supplies. Presented in Figure 2 is the electrical connection schematic for the RFN.

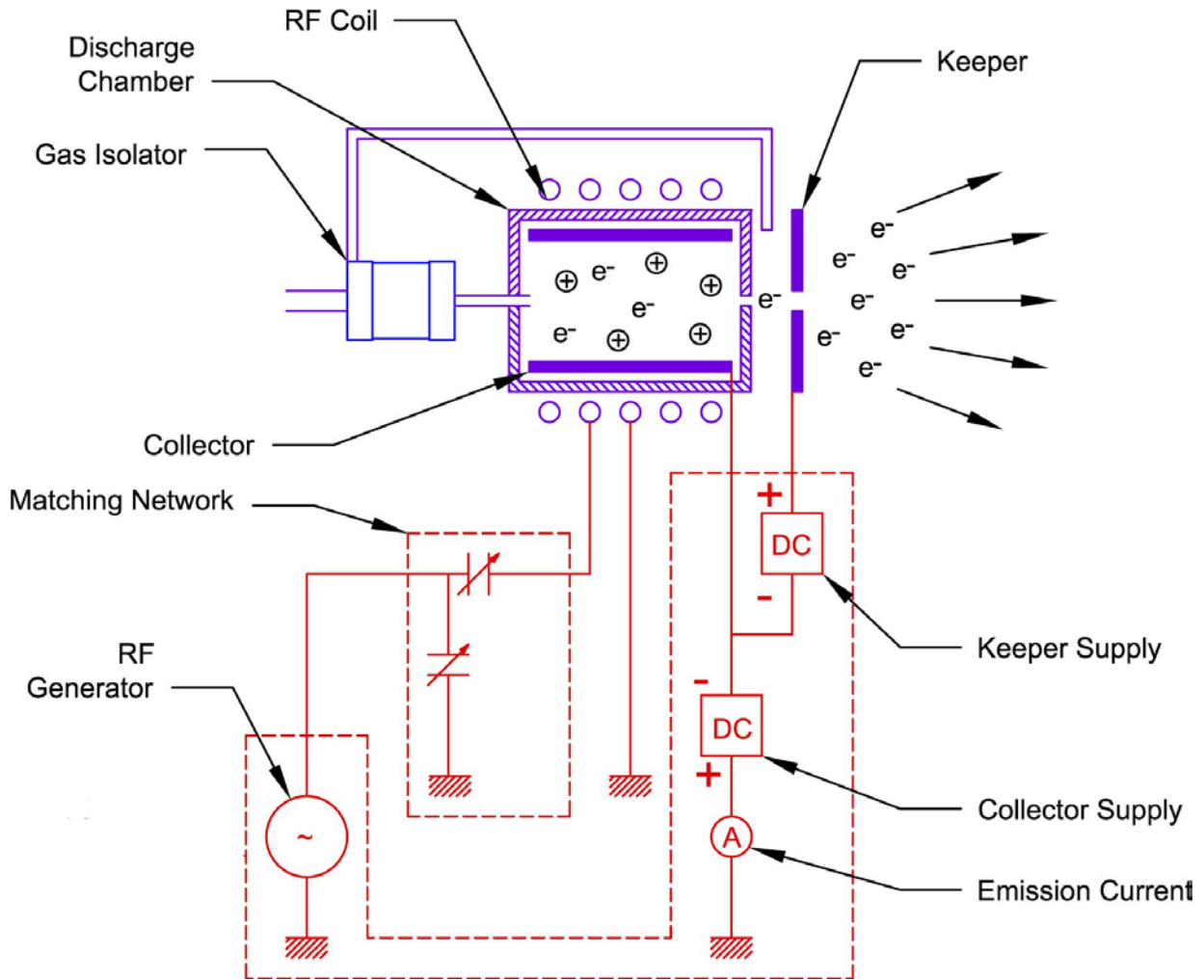


Figure 2. The electrical layout schematic for RF neutralizer.

The RF coil is excited using an RF generator and matching network. The matching network utilizes a load and tune capacitor with one end of the RF coil connected to ground. The matching network is set to maximize the forward RF power. The keeper is biased positive with respect to the collector using the keeper supply. In order to emit electrons, the discharge is biased negative with respect to ground using the collector supply (sometimes referred to as the emission supply).

The IBEAM combines the RF generator, keeper and collector power supplies. The RF generator power range is 0 to 100 W. The function of the keeper supply is to sustain, or keep, the discharge. The keeper power supply is a current regulated supply and typically operates at about

300 mA under normal conditions. The collector supply will regulate its voltage to achieve the desired emission current. The RF neutralizer can emit between 100 to 900 mA of current. Additional power supply details presented in Table 1 and typical values are presented where appropriate.

Table 1. RFN power supply and operational parameters.

| Parameter                    | Definition  | Unit |
|------------------------------|---|------|
| <b>RF Neutralizer (RFN)</b>  |   |      |
| RFN Forward Power            | The RF power applied to the matching network (0 to 100 W).      | W    |
| RFN Reflected Power          | The RF power reflected from the matching network.               | W    |
| Neutralizer Emission Current | The electron current emitted by the neutralizer (100 to 900 mA) | mA   |
| Emission Voltage             | The voltage applied between the collector and ground.           | V    |
| Keeper Current               | The current between the keeper and collector (300 mA).          | mA   |
| Keeper Voltage               | The voltage applied between the keeper and collector (<25 V).   | V    |
| Gas flow                     | The amount of gas supplied to the RFN (5 sccm of Argon)         | sccm |

Under normal operation, the IBEAM regulates the RF power for a particular emission current. Increasing the RFN forward power will increase the plasma density in the discharge chamber. At higher RF forward powers, the RFN can readily emit more electrons. For lower emission currents, the RF forward power is decreased. Below are typical emission current ranges and the forward power applied.

| <u>Neutralizer emission current</u> | <u>RF forward power</u> |
|-------------------------------------|-------------------------|
| 100 mA to 299 mA                    | 30 W                    |
| 300 mA to 599 mA                    | 40 W                    |
| 600 mA to 900 mA                    | 60 W                    |

## Starting sequence

The RF neutralizer is started by performing these steps. Steps 2 thru 6 are controlled by the power supply. Starting issues with the RFN are discussed in Chapter 6.

- STEP 1. Turn on RFN gas and allow for a 5 min purge.
- STEP 2. Apply starting RF power (start cycle).
- STEP 3. Apply emission voltage to see if RFN has started (run cycle).
- STEP 4. Repeat step 2 if RFN has not started (10 times before alarm).
- STEP 5. If RFN has started, warm up at 65 W, 500 mA for 5 minutes.
- STEP 6. Decrease RFN forward power to normal range for a given emission current.

## Maintenance

Over time, several components will show indications of wear and require replacement. The most common item is the collector. During normal operation, the temperature of the collector is approximately 350°C. Consequently, the collector is susceptible to oxidation when the vacuum system is vented. When the collector becomes oxidized, the RFN is more difficult to start and has difficulty in achieving the desired emission current. In order to prolong the life of the collector, it is highly recommended that the gas flow remain on while the RFN is exposed to atmospheric conditions. The collector is typically replaced when the desired emission current cannot be achieved. The collector is considered a consumable item with an approximate life of 1000 hours.

Other items which wear are the discharge chamber and gas isolator. Depending upon how extreme the RFN is operated, the discharge chamber orifice (small hole near the keeper) will begin to enlarge. If the orifice becomes too large, the RFN will not achieve a stable emission current. Similarly, the gas isolator may, overtime develop leaks at the metal to ceramic interface. These gas leaks will degrade the RFN performance. It is recommended to check these items when the collector is replaced. These items have an approximate life of 3000 hours.

Due to the RF nature of the neutralizer, it is important to realize that any movement of the collector or antenna will also effect the matching network tuning. Basically, if the collector or antenna moves due to a heat load, the matching network will be out of tune and the RFN reflected power will increase. It is recommended to take care with installing the collector to ensure it does

not move when heat is applied. The matching network is originally set up so the RF forward power will maximize for either a cold or hot RFN.

## References

- [1] Chen, F. F. Introduction to Plasma Physics and Controlled Fusion, V. 1, pp. 1-51, Plenum Press, New York, 1984.
- [2] Lieberman, M. A., A. J. Lichtenberg Principles of Plasma Discharges and Material Processing, pp. 1-124, John Wiley and Sons, New York, 1994.
- [3] Cecchi, J. L. “*Introduction to Plasma Concepts and Discharge Configurations*,” Handbook of Plasma Processing Technology, pp. 14-69, Noyes Pub., New Jersey, 1990.



## Set up and Installation Procedures

Installing and operating the RF neutralizer requires good safety practice. The RFN power supply must be turned OFF before performing ANY electrical connections. All warnings and cautions must be observed. The power supply should NEVER be operated with ANY of its output connections MISSING or IMPROPERLY attached. READ ALL INSTRUCTIONS before connecting power.



### **CAUTION**

Danger of High Voltage and Personal Injury.



**Danger  
of death**

### **WARNING**

ALL POWER OUTPUTS CAN BE LETHAL  
DO NOT REMOVE THE MATCHING NETWORK COVER.  
THERE ARE NO SERVICABLE PARTS INSIDE.



### **WARNING**

ELECTRICAL SHOCK HAZARD

**▲ DANGER**



High voltage

### **WARNING**

The power supply produces high voltage outputs. Do not operate unit with missing or improper connections. The unit's interlock needs to be incorporated into the facility/system interlock string. There are no serviceable parts inside the unit. Do not remove unit cover.

## RFN and matching network layout

For most applications, the RFN is mounted to a Conflat® style flange as depicted in Figure 3. The RFN body is supported by a shaft. The gas line connection on the vacuum side is a 1/8" Swagelok® union. The matching network is on the atmospheric side. On one side of the matching network are the adjustment knobs for tune capacitors C1 and C2.

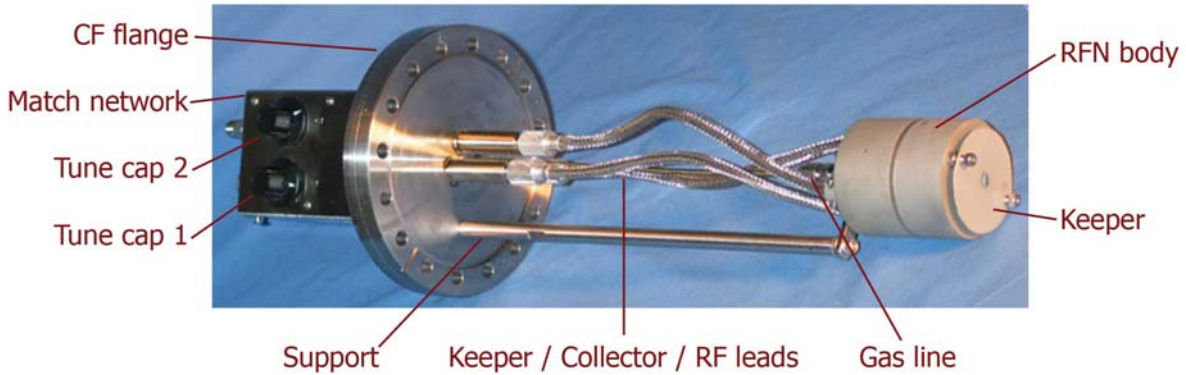


Figure 3. RFN, flange and matching network.

The connections to the matching network are shown in Figure 4. The adjustment knobs for C1 and C2 are typically taped to protect from unwanted movement. The gas line connection on the atmospheric side is a 1/4" VCR style. The power supply electrical connections are on the top of the matching network.

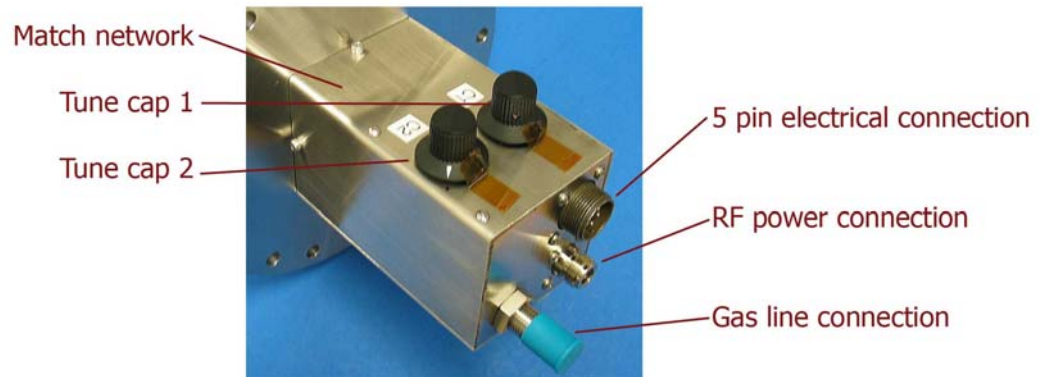


Figure 4. Matching network connections.

## Mounting the RFN flange and gas line

The RFN Conflat® flange should be mounted to the vacuum system using standard OFE copper gasket. Bolts and nuts should be 300ss hexagonal style. For 0.250-28 UNF type the torque should be about 12 lb-ft.

The gas line to the RFN should be 300ss tubing. The gas line connection to the matching network is ¼” VCR style and will require a VCR gasket. It is important the gas supply line is vacuum certified (can hold vacuum) and is not fabricated from copper, nylon, or other plastic. Any contamination in the gas supply line will contaminate the collector and diminish RFN performance.

After mounting the RFN flange and gas line, standard Helium leak detection testing is recommended to ensure proper mounting has been performed.

## Cooling

The RFN matching network cooling requirement is to keep it at room temperature with normal ventilation. Normal environmental operating temperature is 25 to 30°C.

The RFN body inside the vacuum system will achieve a temperature close to 350°C. During normal operation it will radiate its heat to other components in the vacuum environment. The RFN body does not require special cooling. Shielding can be placed adjacent to the RFN provided the shielding is not in contact with the RFN keeper.



### **CAUTION**

Do not allow shielding adjacent to the RFN body to come in contact with the keeper as electrical shorting will occur.

## Electrical connection setup

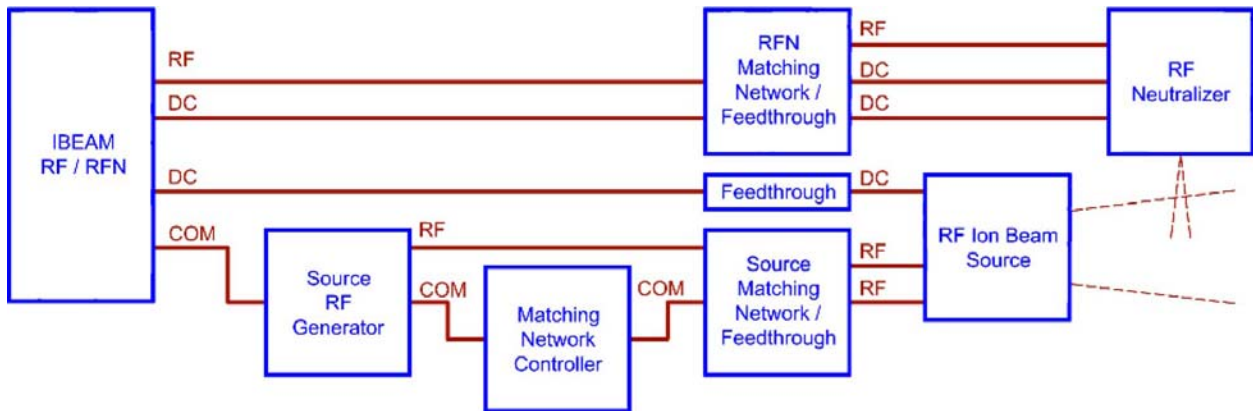


Figure 5. Electrical schematic connections.

## Installation procedure

- STEP 1. Install the Conflat® flange and connect the gas line.
- STEP 2. Helium leak check flange and gas line connection.
- STEP 3. Attach the neutralizer cables to the output connections (Figs. 4 and 5).
- STEP 4. Finish installing the ion beam source (see RF source manual).
- STEP 5. Connect the input power (see IBEAM manual).
- STEP 6. Connect the interlock (see IBEAM manual).
- STEP 7. Turn the main ON/OFF switch to ON.
- STEP 8. Purge the gas line for 5 minutes.
- STEP 9. The unit is ready for power up and operation (See Chapter 4).

## Operation

This section describes basic operation of the RFN. It is recommended to examine the power supply manual for a description on its operation.

### Starting sequence

After the RFN is installed as described in Chapter 3, the RFN is ready for operation. To turn the RFN ON, press the SOURCE button on the IBEAM power supply. The RF neutralizer is started by performing these steps. Steps 2 thru 6 are controlled by the power supply.

- STEP 1. Turn on RFN gas and allow for a 5 min purge.
- STEP 2. Apply starting RF power (start cycle).
- STEP 3. Apply emission voltage to see if RFN has started (run cycle).
- STEP 4. Repeat step 2 if RFN has not started (10 times before alarm).
- STEP 5. If RFN has started, warm up at 65 W, 500 mA for 5 minutes.
- STEP 6. Decrease RFN forward power to normal range for a given emission current.

After the RFN is warmed up for 5 minutes as determined by the internal timer on the power supply, the RF forward power will then adjust according to the emission current request.

| <u>Neutralizer emission current</u> | <u>RF forward power</u> |
|-------------------------------------|-------------------------|
| 100 mA to 299 mA                    | 30 W                    |
| 300 mA to 599 mA                    | 40 W                    |
| 600 mA to 900 mA                    | 60 W                    |

## Power supply adjustments

The IBEAM RF/RFN will have certain adjustments that pertain to the RFN. The options for each module in the main display will utilize abbreviations. The following is a listing of these abbreviations, the corresponding parameter and description. The specific module and acceptable range are also provided. The RFN check-out sheet should be consulted for typical values.

| Module      | Abbreviation | Parameter and description   | Acceptable Range     |
|-------------|--------------|---|----------------------|
| Neutralizer | EI           | <b>Emission Current</b><br>The electron emission current from the RFN.  | 100 to 900 mA        |
| Neutralizer | RFN FWD      | <b>Neutralizer RF forward power</b><br>RF power that controls the emission current.   | 30 to 75 W           |
| Neutralizer | RF KPR       | <b>Keeper current and voltage</b><br>The status of the keeper supply  | 300 mA<br>19 to 25 V |
| Control     | SETUP        | Select to change global parameters listed below   |                      |
| Control     | E/B RATIO    | <b>Emission to beam current ratio</b><br>Neutralizer emission will ramp to the E/B ratio times beam current. Recommended is 125%. | 0 to 200%            |
| Control     | RFN TUNE UP  | Allows the user to adjust C1 on the RFN matching network. RFN gas should be off.  | enable/disable       |
| Control     | RFN BURN IN  | Allows the user to run just the RFN.  | enable/disable       |

Within the neutralizer module, the status of the keeper power supply can be periodically checked. By accessing the RF KPR display and pressing the UPDATE button, the keeper current and voltage are displayed. For a good collector, the keeper current should be 300 mA and the voltage should be about 22 V. As the collector starts to age, the keeper current will decrease and the voltage will increase. It can be useful to check the status of the keeper supply to determine if the collector needs to be replaced.

The IBEAM has several different modes of RFN operation available to the user. These are listed below with a description.

RFN TUNE UP – Used to tune the matching network, described in Chapter 6.

RFN BURN IN – Used to condition a new collector, described in Chapter 6.

Manual or Local mode – EI is adjusted by using the E/B ratio.

## Operation example

The following is a step by step example of operating the RFN.

### Step 1) **Pumpdown.**

The RFN requires a high vacuum environment for proper operation. As there are several different types of vacuum systems, general guidelines will be presented. Also, the vacuum environment will depend upon the application for the RFN. The required pumping speed of the vacuum system will depend upon how much process gas is used by the RFN and the vacuum environment required for the process. Problems may arise with operation of the RFN at higher pressures. Presented in Table 4.1 are general vacuum specifications guidelines.

Table 4.1. Vacuum specifications.

| Specification                                  | Value                       | Comments                                   |
|--|-----------------------------|--|
| Chamber base pressure                          | $10^{-6}$ Torr              | Lower is OK                                |
| Chamber operating pressure when the RFN is on. | $10^{-5}$ to $10^{-3}$ Torr | Plasma short may occur at higher pressures |
| Typical pumping speed                          | 1000 l/s (air)              | Process dependent.                         |

### Step 2) **Turn the process gas on.**

After the vacuum chamber has achieved its base pressure, turn on the RFN and source gas. The amount of gas is typically measured in standard cubic centimeters per minute, or sccm. It is recommended to wait 5 to 10 minutes after the gas has been turned on in order to purge the gas line. Recommended flow rates for a system using a 1000 l/s pump are presented in Table 4.2.


Table 4.2. Typical gas flow rates for a 1000 l/s pumping station.

| Specification | Value        | Comment            |
|---------------|--------------|--------------------|
| RFN           | 5 sccm Argon | Typical flow rate. |

Step 3) **Turn on the water cooling.**

Turn on the source water cooling at this time. The water cooling must have a flow switch connected to the interlock string. If the source cooling stops flowing, the power supply output will shut off.

Step 4) **Turn the source on and allow it to warm-up.**

|   |  |
|---|--|
|  | <h2>CAUTION</h2> <p>Make sure all electrical connections have been properly made and that the power supply interlock has been satisfied.</p> |
|---|--|

Turn the power supply on.

Set the BV PULSE and BV IDLE to the recommending starting conditions in Table 4.3.

Table 4.3. Recommending starting conditions.

| Source       | BV PULSE      | BV IDLE    | Start RF power |
|--------------|---------------|------------|----------------|
| 12 cm Source | 750 to 1000 V | 25 to 45 V | 200 W          |
| 16 cm Source | 750 to 1000 V | 25 to 45 V | 200 W          |

Turn on the source by pressing the SOURCE button. When the SOURCE button is pressed, the power supply will begin to start the RFN. The RFN starts by applying RF power while the start / run relay is toggled. Once the RFN establishes a discharge between its keeper and collector, the RFN will go into a 5 minute warm-up period. As soon as the RFN has started, RF power is then applied to the source. When the RF power reaches the RF starting power, the BEAM and ACCEL are pulsed to the BV PULSE setting which should start the discharge inside the source. The BEAM and ACCEL are then ramped down to the BV IDLE setting. The source has started.

An established plasma discharge is indicated by a current displayed in the BEAM module. If the BEAM current is less than the START I the IBEAM will indicate the source discharge has extinguished and display an error.

The recommended warm up period is 10 minutes. As the source heats it may release trapped water vapor gases which may result in a temporary increase in chamber pressure. Presented in Table 4.4 are typical source warm up conditions. If the discharge cannot be established, or other starting issues arise, please refer to Chapter 6 - Troubleshooting.

Table 4.4. Typical warm up data.

| Source | Gas       | Pressure         | Beam |     | Accelerator |     | Source RF |     | Neutralizer |          |
|--------|-----------|------------------|------|-----|-------------|-----|-----------|-----|-------------|----------|
|        |           | $\times 10^{-4}$ | I    | V   | I           | V   | FWD       | REF | RF          | Emission |
|        |           | (Torr)           | (mA) | (V) | (mA)        | (V) | (W)       | (W) | (W)         | (mA)     |
| 12 cm  | 8 sccm Ar | 4.8              | 90   | 40  | 0           | 0   | 200       | 3   | 40          | 500      |
| 16 cm  | 12sccm Ar | 6.5              | 19   | 40  | 0           | 0   | 200       | 5   | 40          | 500      |

Step 4) **Set the beam conditions and turn the beam on.**

Set the beam and accelerator voltage for the desired condition. Optimized beam and accelerator voltages will be specific for a given process. Recommended conditions for typical applications are presented in Table 4.5. The comments in Table 4.5 are for standard grids. Grids can be customized for ion beam directional control.

Table 4.5. Typical beam and accelerator voltage settings.

| Application                    | Beam V | Accel V | Comments            |
|--------------------------------|--------|---------|---------------------|
| Low energy etch or assist beam | 300 V  | 700 V   | Beam is spread out. |
| Low rate sputtering            | 750 V  | 300 V   | Beam is mid sized.  |
| High rate sputtering           | 1250 V | 250 V   | Beam is focused.    |

Next, select how the beam current will be controlled, that is, either MANUAL, LOCAL or REMOTE. In order to select which mode to run press the MODE button. A description of these modes is listed in Table 4.6. For troubleshooting source problems, MANUAL mode is recommended. For most applications, LOCAL mode is useful for running a process.

Table 4.6. Definition of the power supply operational MODES.

|        |   |
|--------|---|
| MANUAL | The operator can adjust the cathode current for beam current control.               |
| LOCAL  | The operator selects a beam current and the power supply regulates cathode current. |
| REMOTE | Same as LOCAL, except that a computer is controlling the power supply.              |

If MANUAL MODE is selected, when the BEAM button is pressed, the extracted beam current is determined by the given discharge conditions. Beam current is increased or decreased by adjusting the source RF power.

If the LOCAL mode is selected, a target value for beam current can be set in the BEAM module. When the BEAM button is pressed, the power supply will regulate the discharge current by adjusting the source RF power to extract the target beam current.

#### Step 5) **Adjusting the beam conditions.**

The beam current and voltage can be adjusted while the beam is on. However, for some conditions, the beam may need to be turned off while keeping the source on. Also, switching between MANUAL and LOCAL power supply modes may be necessary to achieve desired beam conditions. Some beam currents may not be achievable at various beam voltages (e.g. high beam current at low beam voltage). Please consult the source check out sheet for the nominal range of beam currents and voltages.

If there are issues with the beam current and voltage please consult the power supply or source manual.

#### Step 6) **Neutralizer operation.**

When the BEAM button is pressed, the neutralizer emission current will change. If the power supply is in MANUAL or LOCAL mode, the emission current will adjust to the E/B ratio where the E/B ratio is emission current to beam current ratio. For typical applications, E/B is set to 125% or greater. At this condition, the emission of electrons from the neutralizer is more than the beam current. This will assist with the downstream conditions and minimize surface charging and arcing.

#### Step 7) **Turning the source off and cool down.**

The beam and source are shut off by pressing the source button. The power supply can be then turned off. It is recommended to leave the process gas running while the source cools for 10 minutes. It is recommended cooling the source about 20 minutes before the vacuum chamber is vented. Always leave the RFN gas on while venting as this will help prolong the RFN collector life.

## Maintenance



### **Caution**

It is strongly recommended that extreme care be taken to avoid contamination of the RFN and its components.

All of the RFN sub-assemblies have been rigorously cleaned. Common vacuum practice is recommended while handling the neutralizer components. This requires that the operator use latex/or non-latex type gloves to prevent finger oil from contaminating the surfaces of the parts. Eye protection should be worn at all times. Care should be taken to minimize particulate contamination such as hair and dust while the RFN is being assembled and installed.

The installation section is divided into:

- A. Identification of key RFN components and sub-assemblies.
- B. Assembly and disassembly.

## Components

In this section, the RFN components are illustrated and assembly instructions then follow.

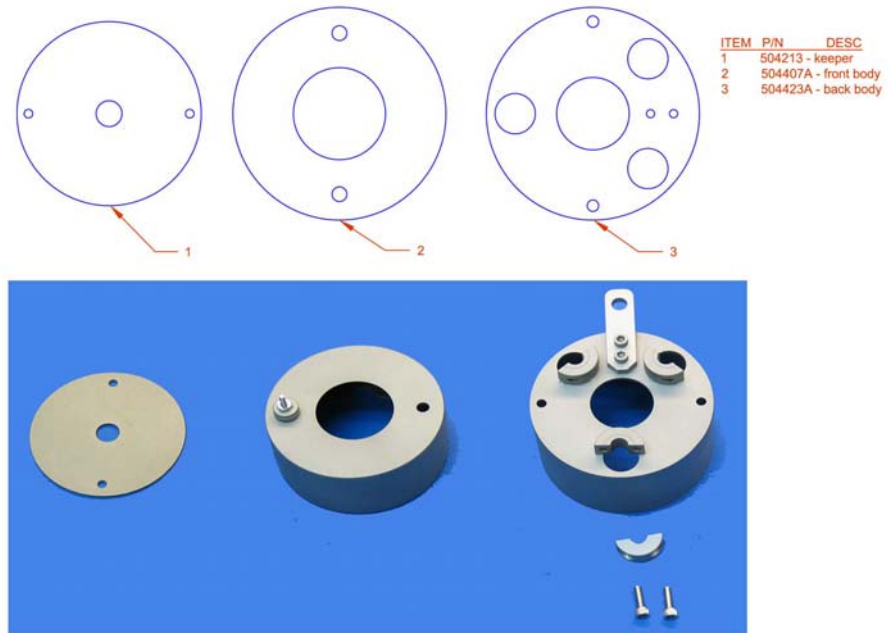


Figure 6. Keeper and body

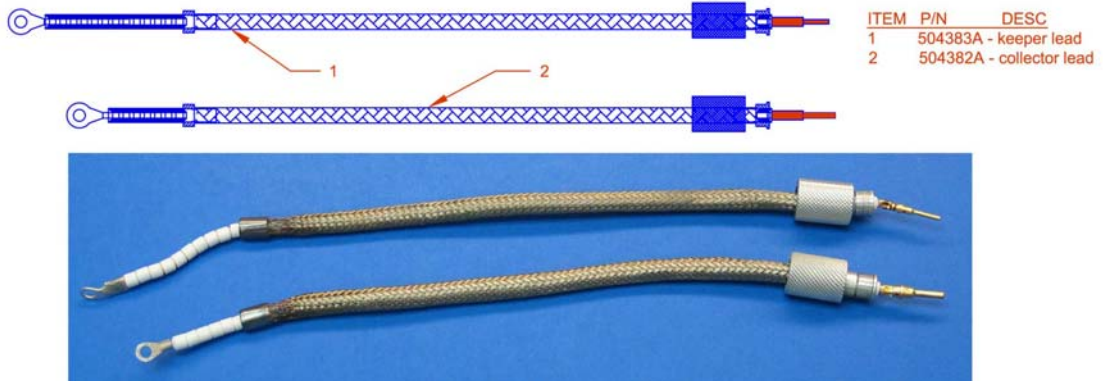


Figure 7. Keeper and collector electrical leads.

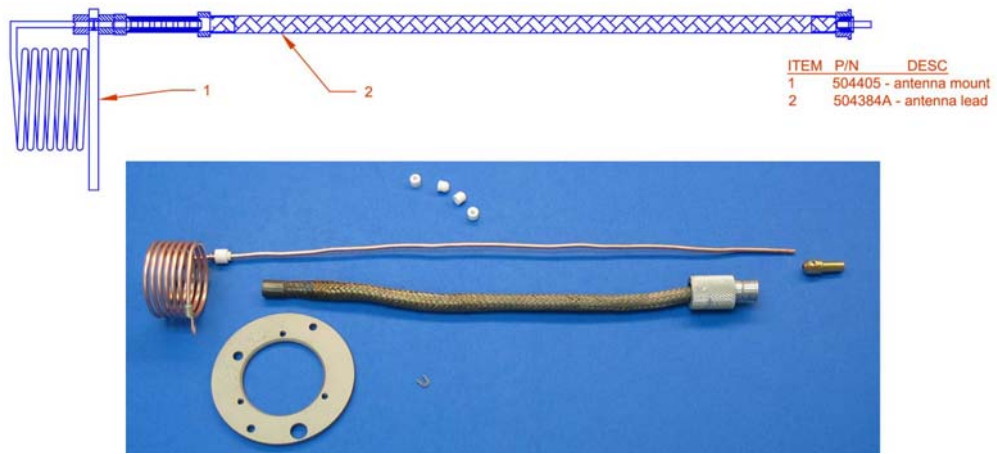


Figure 8. Antenna and associated hardware.

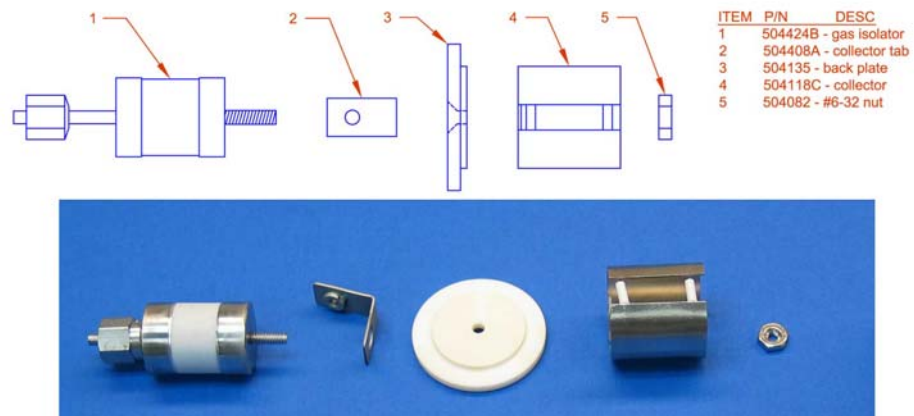


Figure 9. Gas isolator and collector assembly

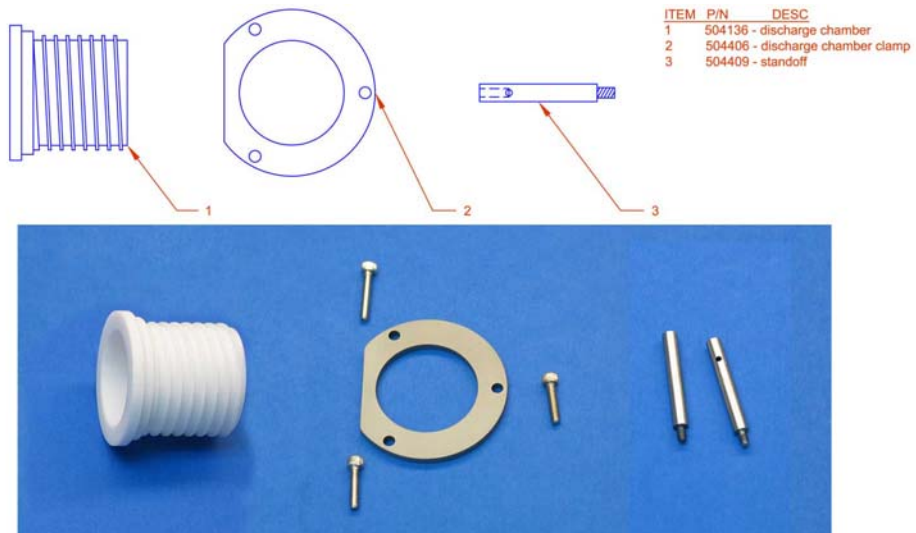


Figure 10. Other parts

## Assembly and disassembly

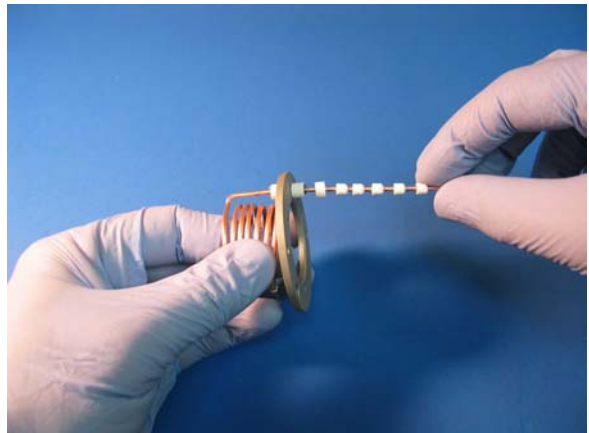
This section describes the assembly of the RFN. To disassemble, the procedure is reversed.

- 1) Attach the gas isolator, collector tab, alumina back plate and the collector. Align the collector tab with the gap in the collector as shown in Picture 5.1. Make sure collector and back plate edge are in alignment too. Tighten 6-32 screw with torque of 15 in•lbs.



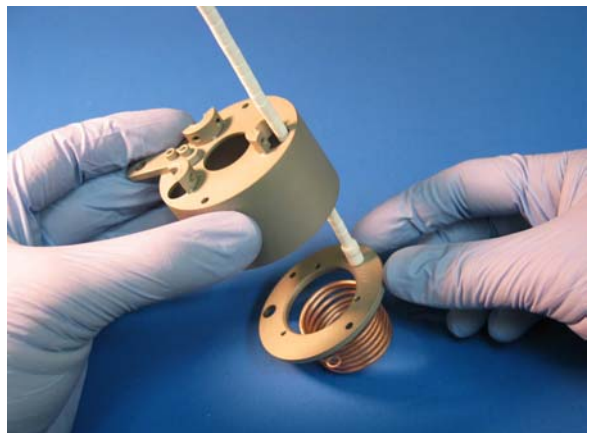
Picture 5.1 – Gas isolator assembly

- 2) Next, assemble the antenna lead and the antenna mount plate as depicted in Picture 5.2. Place a #2 male insulator on the antenna first. Feed the antenna thru the mount plate, and slide another #2 male insulator (facing opposite) on antenna. Secure using a slip ring. Install a #2 flat insulator followed with 49 wire bead insulators.



Picture 5.2 – Antenna and mount plate.

- 3) Install the back body onto the antenna lead as shown in Picture 5.3.



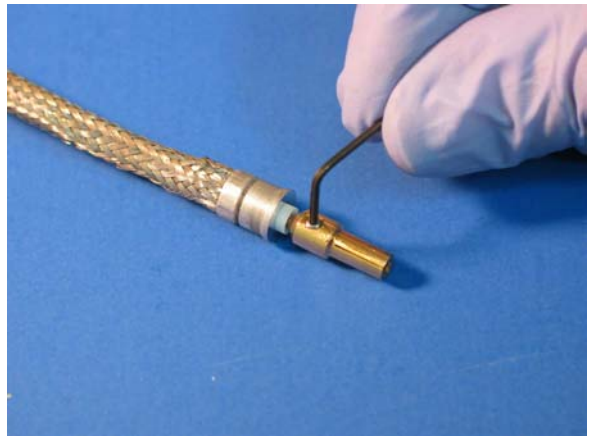
Picture 5.3 – Installing the back body.

- 4) Finish assembling the antenna lead by sliding its connector, followed by the shielding as shown in Picture 5.4.



Picture 5.4 – Antenna assembly continued.

- 5) Install one final wire bead at the lead tip. Secure RF female connector as depicted in Picture 5.5.



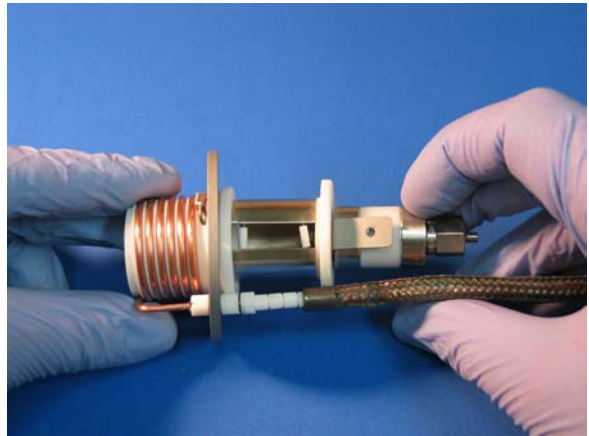
Picture 5.5 – Antenna assembly continued.

- 6) Thread the discharge chamber onto the antenna as illustrated in Picture 5.6. The thread should stop at the termination lug.



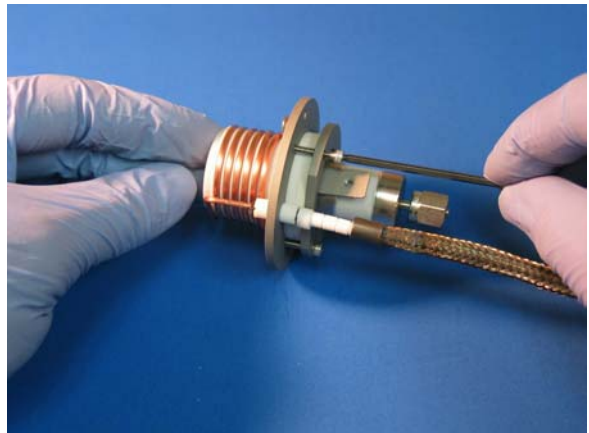
Picture 5.6 – Installing the discharge chamber.

- 7) Install the gas isolator / collector assembly into the discharge chamber as shown in Picture 5.7. The collector tab should be orientated 45° CW from the antenna location. The collector needs to be pushed into the discharge chamber to ensure a tight fit. If the collector slides into the discharge chamber with ease, it will move when heated and the RFN will not easily tune.



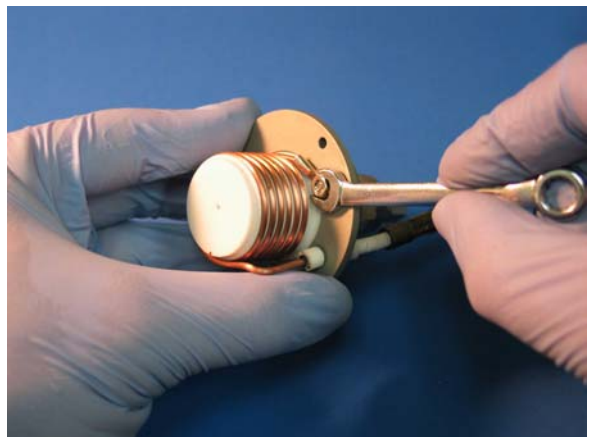
Picture 5.7 – Installing the collector.

- 8) Secure the gas isolator / collector assembly using the discharge chamber clamp as depicted in Picture 5.8. Use a 4-40 screw 0.625”L to go thru the antenna mount plate and antenna termination lug. Use a 4-40 screw 0.500”L for the other two connections.



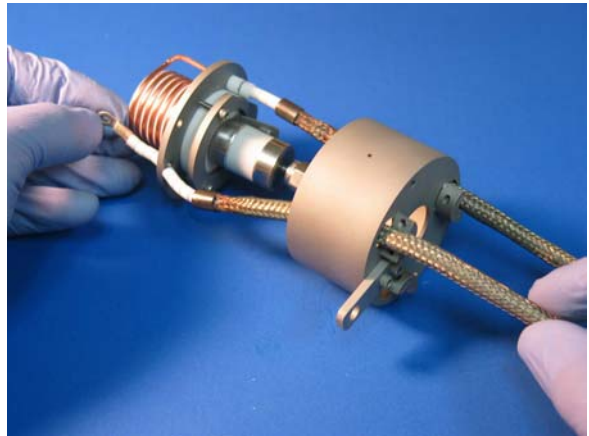
Picture 5.8 – Antenna assembly continued.

- 9) Thread a 4-40 nut over the antenna termination lug and secure tight using a wrench as illustrated in Picture 5.9.



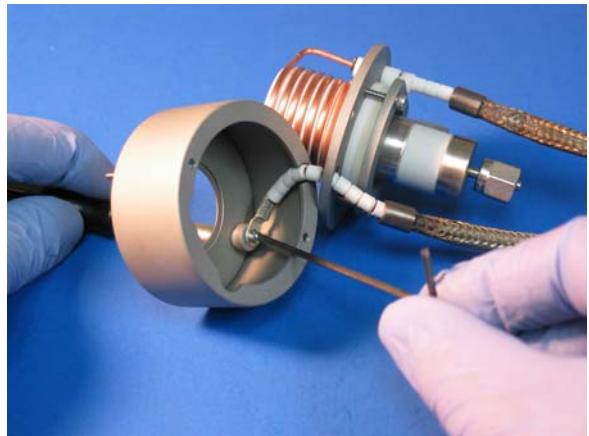
Picture 5.9 – Tighten the antenna lug.

10) Install the keeper lead thru the back body and antenna mount plate as shown in Picture 5.10.

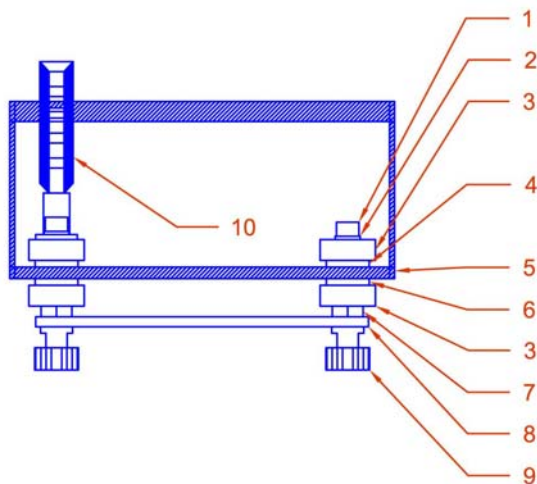


Picture 5.10 – Installing the keeper lead.

11) Secure the keeper lead to the front body as depicted in Picture 5.11. The 2-56 screw needs to go thru the keeper lug and additional hardware as shown in Figure 11. Attach the keeper to the assembly.



Picture 5.11 – Keeper lead attachment.



| ITEM | P/N     | DESC                         |
|------|---------|------------------------------|
| 1    | 504125  | - #2-56 0.750 socket head cs |
| 2    | 504247  | - #2 lock washer             |
| 3    | 504325  | - #2 cup                     |
| 4    | 504134  | - #2 male insulator          |
| 5    | 504407A | - front body                 |
| 6    | 504133  | - #2 flange insulator        |
| 7    | 504327  | - #2-56 nut                  |
| 8    | 504213  | - keeper                     |
| 9    | 504130  | - #2-56 thumb nut            |
| 10   | 504383A | - keeper lead                |

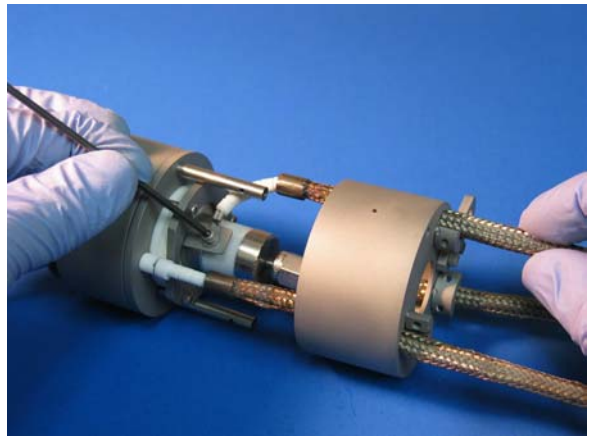
Figure 11. Keeper electrical connection detail.

- 12) Attach the front body to the antenna plate using the standoffs as shown in Picture 5.12.



Picture 5.12 – Front body attachment.

- 13) Install the collector lead thru the back body and secure it to the collector tab using a 6-32 0.125”L screw. The orientation of the collector lead lug should be as shown in Picture 5.13.



Picture 5.13 – Collector lead attachment.

- 14) Attach the back body to the standoffs using two 4-40 0.375”L screws as illustrated in Picture 5.14.



Picture 5.14 – Back body attachment.

- 15) Secure the strain relief clamp collars to each of the leads as shown in Picture 5.15. The neutralizer is ready for attachment to the flange assembly.



Picture 5.15 – Clamp collar attachment.

- 16) Secure the RFN assembly to the flange using a 10-32 0.375”L screw as shown in Picture 5.16. Slide the gas isolator onto the gas line connection at the same time. Tighten the gas line connection using TWO 7/16” wrenches simultaneously. DO-NOT rotate the gas isolator as this may loosen the collector connection.



Picture 5.16 – Attaching the RFN assembly.

- 17) For each electrical lead, insert the pin into the appropriate mating connection on the flange as illustrated in Picture 5.17. It can be beneficial to center the RF lead before the thumb nut is attached. The RFN and flange are ready for instillation on the system.



Picture 5.17 – Electrical lead attachment.



## Troubleshooting

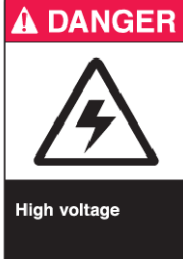
As there are many variables with the RF neutralizer, the troubleshooting is divided into the various stages of operation. First, common issues with the power supply are presented. It is important to be aware of the electrical nature of the RFN. Common issues arise from electrical shorting or openings that disrupt proper operation. These issues may not present themselves easily, say with a multi-meter, as it may be a plasma short or a thermal open that creates the issue.


This chapter is divided into:

Power Supply – Problems that are detected by the power supply.

Neutralizer operation – RF Neutralizer problems.

Special diagnostics and testing.

|   |                  |
|---|------------------|
|  <p>High voltage</p>   | <h3>WARNING</h3> |
| <p>The power supply produces high voltage outputs. For troubleshooting recommendations that require checking electrical connections and continuity <b>TURN OFF ALL POWER SUPPLIES</b> before testing.</p> |                  |

|  |                  |
|--|------------------|
|  <p><b>Danger<br/>of death</b></p>          | <h3>WARNING</h3> |
| <p>ALL POWER OUTPUTS CAN BE LETHAL<br/>DO NOT REMOVE THE MATCHING NETWORK COVER.<br/>THERE ARE NO SERVICABLE PARTS INSIDE.</p> |                  |

## Power Supply Error Codes

The IBEAM will display various error codes in the output displays. These are in the form of letter E followed by two numbers (e.g. E##). The errors may pertain to a particular module or the entire unit. Below is a listing of these codes.

Table 6.1 Problems as detected by the power supply.

| Error | Description  | Possible problems and solutions  |
|-------|--|--|
| 03    | Output of module is lower than requested.          | <ol style="list-style-type: none"> <li>1. Facility voltage is too low – Check facility voltage.</li> <li>2. Electrical connection is poor – Check electrical connections</li> <li>3. Power supply fuse has failed – Check fuses.</li> </ol>  |
| 04    | Output of module is higher than requested.         | <ol style="list-style-type: none"> <li>1. Electrical short – Check electrical connections.</li> <li>2. Plasma short – Check the source and feedthru for electrical wire proximity problems or coated insulators.</li> <li>3. Gas flow is too high – Check gas flow level.</li> </ol>   |
| 05    | Module is in current or voltage limit.             | <ol style="list-style-type: none"> <li>1. Electrical short – Check electrical connections.</li> <li>2. Plasma short – Check the source and feedthru for wire proximity problems or coated insulators.</li> <li>3. Electrical short – Check for flakes or debris.</li> </ol>  |
| 06    | Module is at over temperature.                     | <ol style="list-style-type: none"> <li>1. Cooling issue – Make sure fan is operational and unobstructed.</li> <li>2. Dust buildup – Clean any dust buildup on power supply.</li> </ol>   |
| 10    | RFN failed to start.                               | <ol style="list-style-type: none"> <li>1. RFN operation issue – Check the RFN troubleshooting section in this chapter.</li> <li>2. RFN gas issue – Run the RFN gas for about 5 minutes and try again.</li> </ol>   |
| 20    | Interlock is open                                  | <ol style="list-style-type: none"> <li>1. Water flow – Check water flow.</li> <li>2. Vacuum – Check vacuum interlock.</li> <li>3. Interlock cable is not connected – Check cable and connections.</li> </ol>   |
| 24    | E/B Ratio (emission current to beam current ratio) | <ol style="list-style-type: none"> <li>1. Emission current too low – Check RFN operation.</li> <li>2. Neutralizer location – Neutralizer is too far from beam.</li> <li>3. RFN went out – Check RFN operation.</li> <li>4. IBEAM is in test mode – Check IBEAM RFN test settings.</li> </ol>   |
| 25    | A / B Ratio (accel current to beam current ratio)  | <ol style="list-style-type: none"> <li>1. Accel current is too high – Check alignment of grids.</li> <li>2. Accel voltage is too low – Increase accel voltage.</li> <li>3. Unstable beam condition – Examine data provided with source.</li> <li>4. Grid spacing incorrect – Check grid spacing.</li> <li>5. Debris between the grids – Clean and inspect the grids.</li> <li>6. Leakage current on grid insulators – Clean / replace insulators.</li> </ol> |

## RF Neutralizer Operation

The RF neutralizer is started by performing these steps controlled by the power supply.

- STEP 1. Apply starting RF power (start cycle).
- STEP 2. Apply emission voltage to see if RFN has started (run cycle).
- STEP 3. Repeat step 1 if RFN has not started (10 times before alarm).
- STEP 4. If RFN has started, warm up at 65 W, 500 mA for 5 minutes.
- STEP 5. Decrease RFN forward power to normal range for a given emission current.

Troubleshooting RFN starting issues is divided by these steps and suggestions are provided in Table 6.4. If possible, it can be advantageous to view the RFN as it is starting. Special testing procedures are also presented in the next section.

Table 6.4 Problems with the neutralizer.

| Problem description                             | Possible problems and solutions   |
|---|---|
| STEPS 1-3 alarm<br>RFN reflected power high.    | 1. Collector is loose, not connected or changed shape – Repair RFN.<br>2. RFN matching network is out of adjustment – Perform RFN tuning as described in this chapter.  |
| STEPS 1-3 alarm<br>no discharge present         | 1. RFN gas flow is low – Check gas flow rate and loose gas connections.<br>2. Failed keeper fuse – Check keeper fuse.   |
| STEPS 1-3 alarm<br>discharge present            | 1. Keeper has faulty connection or is coated – Check keeper.<br>2. Shielding too close to the RFN – Move shielding.   |
| RFN forward power is low (~15W)                 | 1. RF connection is open – Check all RF connections.<br>2. Collector is loose, not connected or changed shape – Repair RFN.<br>3. RFN matching network is out of adjustment – Perform RFN tuning as described in this chapter.                            |
| Neutralizer emission current lower than normal  | 1. Collector has been oxidized and needs to be replaced.<br>2. RFN gas flow is too low – Check gas flow rate.<br>3. Poor electrical connection – Check all electrical connections.<br>4. E/B ratio is set incorrectly – Check the E/B ratio (Local mode). |
| Neutralizer emission current higher than normal | 1. Neutralizer is electrically shorted – Check electrical connections in cable, feedthru and near RFN.<br>2. E/B ratio is set incorrectly – Check the E/B ratio (Local mode).   |
| Emission current is zero                        | 1. RFN gas is off or low – Check gas operation.<br>2. Failed emission fuse – Check emission fuse.<br>3. Collector or keeper is not electrically connected – Check connections.  |
| Emission current is unstable                    | 1. Collector is new – Reduce RFN forward power<br>2. RFN gas flow is low – Check gas flow rate and loose gas connections.   |

## Special Testing – RFN tuning

The RF neutralizer and matching network are tuned at the factory and should not require any adjustments in the field. However, if necessary, the IBEAM can be set up to perform special testing and tuning of the RFN. These procedures may be required if a new collector was installed in the RF neutralizer.

In the control module there are 2 settings that can be enabled (see Chapter 4). These are RFN TUNE UP and RFN BURN IN. If the IBEAM is in either of these modes, the BEAM button will not turn the BEAM on.

RFN TUNE UP should be used only when the RFN has undergone a refurbishment. This mode allows the RFN forward power to be applied for longer durations so that the match network capacitor C1 (and only C1) can be adjusted. The RFN TUNE UP procedure is:

- STEP 1. Turn RFN gas to off.
- STEP 2. ENABLE the RFN TUNE UP in the IBEAM Control module.
- STEP 3. Press the SOURCE button and note the RFN forward and reflected power.
- STEP 4. Adjust C1 on the RFN match network to maximize forward power.
- STEP 5. Turn the SOURCE button OFF.
- STEP 6. DISABLE the RFN TUNE UP in the IBEAM Control module.

RFN BURN IN should be used only when the RFN has undergone a refurbishment and the RFN TUNE UP has been performed. This mode allows manual control of the RFN forward power and emission current. The RFN BURN IN procedure is:

- STEP 1. Set the RFN gas to 5.0 sccm Ar and turn it on.
- STEP 2. ENABLE the RFN BURN IN found in the IBEAM Control module.
- STEP 3. Set the emission current to 100 mA and RFN forward power to 75 W.
- STEP 4. Press the SOURCE button and allow the RFN to start.
- STEP 5. Allow the RFN to run for 10 min at 100 mA, 75 W.
- STEP 6. Adjust C2 (and only C2) to minimize the RF reflected power.
- STEP 7. Adjust the emission current to 300 mA and RFN forward power to 65 W.
- STEP 8. Allow the RFN to run for 10 min at 300 mA, 65 W.
- STEP 9. Adjust the emission current to 500 mA and RFN forward power to 55 W.
- STEP 10. Allow the RFN to run for 40 min at 500 mA, 55 W.
- STEP 11. Turn the SOURCE button OFF.
- STEP 12. Set the RFN BURN IN to DISABLE in the IBEAM Control module.

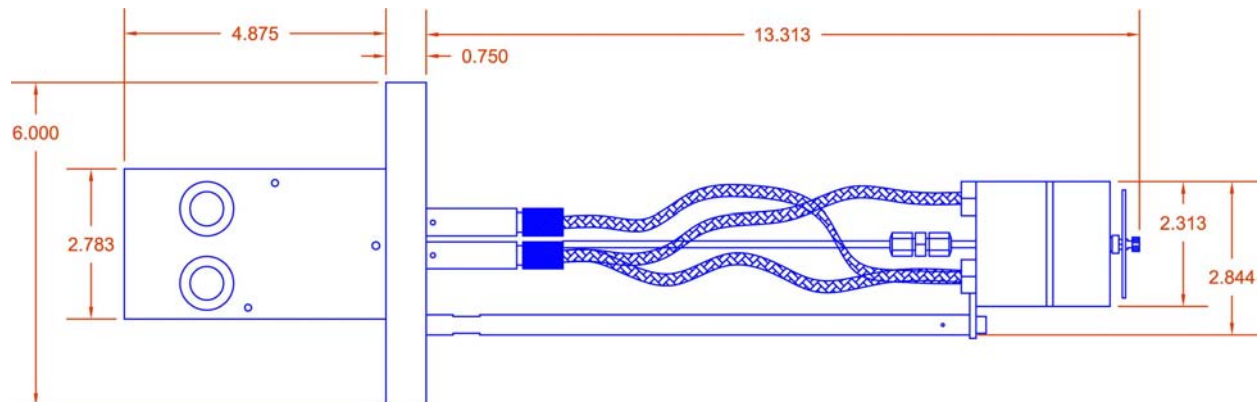
During the burn in procedure, the keeper voltage can be checked in the RFN module window. Press UPDATE periodically to check the keeper voltage remains below 25 V. If the keeper voltage is greater than 25 V, the collector may be oxidized or is not properly connected.

# Specifications

Below are specifications for the RF neutralizer.

|                        |                               |                          |
|------------------------|-------------------------------|--------------------------|
| Power:                 | RF forward                    | 30 to 75 W               |
|                        | RF reflected                  | 0 to 1 W                 |
|                        | Keeper                        | 300 mA, 25 V             |
|                        | Emission                      | 100 to 900 mA            |
| Gas flow requirements: | Argon                         | 5 sccm                   |
|                        | Xenon                         | 1.5 sccm                 |
|                        | Matching network connections: | Neutralizer cable        |
|                        | RF power                      | coaxial type N connector |
|                        | Gas                           | ¼" VCR male              |
|                        | Gas tubing                    | stainless steel          |

Dimensions (inches):



|                         |           |                      |
|-------------------------|-----------|----------------------|
| Vacuum connection type: | Keeper    | #16 male pin         |
|                         | Collector | #12 male pin         |
|                         | RF power  | #12 female connector |
|                         | Gas       | 1/8" Swagelok® union |

|          |            |                                   |
|----------|------------|-----------------------------------|
| Cooling: | Atmosphere | Air cooling, room temp 25 to 30°C |
|          | Vacuum     | Radiant, body temp about 350°C    |