USER MANUAL

Inductively Coupled Plasma Source (ICP)

5707016-B

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User Manual

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ADVANCED ENERGY®

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PRODUCT USAGE STATEMENT

WARNING:

Read this entire manual and all other publications pertaining to the work to be performed before you install, operate, or maintain this equipment. Practice all plant and product safety instructions and precautions. Failure to follow instructions can cause personal injury and/or property damage. All personnel who work with or who are exposed to this equipment must take precautions to protect themselves against serious or possibly fatal bodily injury.

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CUSTOMER FEEDBACK

Advanced Energy's technical writing staff has carefully developed this manual using research-based document design principles. However, improvement is ongoing, and the writing staff welcomes and appreciates customer feedback. Please send any comments on the content, organization, or format of this user manual to:

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Introduction

READ THIS SECTION!

To ensure safe operation, read and understand this manual before attempting to install or operate this unit. At a minimum, read and heed “Safety” on page 1-3 of this chapter.

INTERPRETING THE MANUAL

The following sections explain the type conventions, icons, and symbols that appear in this manual.

Type Conventions

To quickly identify certain words and phrases in type that differ from the rest of the text, please note the following type conventions:

- Pin and signal names appear in capitalized italics (*DUTY CYCLE.A*).
- Technical terms appear in italicized letters when introduced in the text.
- Unit labels (switches, indicators, etc.) generally appear in boldface letters as they are labeled on the unit (**MODIFY**).
- Functions are printed in boldface lowercase letters (**analog input filtering**).

Icons (Symbols)

This symbol represents important notes concerning potential harm to people, this unit, or associated equipment. It is found whenever needed in the manual.

Advanced Energy® includes this symbol in Danger, Warning, and Caution boxes to identify specific levels of hazard seriousness.

DANGER:

This box identifies hazards that could result in severe personal injury or death.

WARNING:
This box identifies hazards or unsafe practices that could result in personal injury.

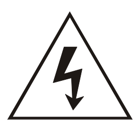
CAUTION:
This box identifies hazards or unsafe practices that could result in product or property damage.

The following symbols could appear on labels on your unit.

- Hazardous voltage

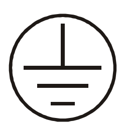
1332

- High voltage



1028

- Protective earth ground



1029

- Warning (refer to manual)

1027

- CE label

1020

- Non-ionizing radiation

1030

- Hot surface

1309

SAFETY

Do not attempt to install or operate this equipment if you have not first acquired proper training.

- Ensure that this unit is properly grounded.
- Ensure that all cables are properly connected.
- Verify that input line voltage and current capacity are within specifications before turning on the power supplies.
- Use proper ESD precautions.
- Operate this device only within the specified range of vacuum pressure, delivered power, and duty cycle.
- BE CAREFUL AROUND THIS EQUIPMENT.

> **WARNING:**
> **RISK OF DEATH OR BODILY INJURY. Disconnect all sources of input power before working on this unit or anything connected to it.**

> **WARNING:**
> **Excessive ozone could be generated by components within the unit if you operate it beyond specified pressure ranges.**

PRODUCT SAFETY/COMPLIANCE

This product is designed to comply with the following standards and directives.

Directives

This product is a component and has no intrinsic function. It must be used with a high voltage power supply that is compliant with applicable requirements, and it must be incorporated into a larger system that provides appropriate safety measures.

This device must be installed and used only in compliance with applicable requirements.

Installation Requirements

This unit must be installed according to the following requirements.

> **WARNING:**
> **Operating and maintenance personnel must receive proper training before installing, troubleshooting, or maintaining high-energy electrical equipment. Potentially lethal voltages could cause death, serious personal injury, or damage to the equipment. Ensure that all appropriate safety precautions are taken.**

Conditions of Use

This product is a component and has no intrinsic function. It must be used with a high voltage power supply that is compliant with applicable requirements, and it must be incorporated into a larger system that provides appropriate safety measurements.

Theory

GENERAL DESCRIPTION

Advanced Energy's new Inductively-Coupled Plasma (ICP) Source generates a high-density plasma for the remote delivery of activated gaseous species. The compact unit easily adapts to either new or existing vacuum systems. The primary benefits of the ICP source include:

- **Reactive Sputtering**—Enhanced rates of deposition, improved film stoichiometry, reduced target arcing, and expanded domain of operation for deposition of oxides, nitrides, and similar dielectric coatings
- **Surface Treatment and Plasma-Enhanced Chemical Vapor Deposition**—Remote generation of reactive species for altering surface properties of materials by reactive substitution (i.e., surface oxidation), reactive etching, plasma-enhanced chemical vapor deposition (PECVD), and low energy ion sputtering

The ICP source is designed primarily for applications where a remote source of atomic oxygen or reactive nitrogen is desired, but may also be configured for operation with fluorine-bearing compounds. The air- and water-cooled plasma source contains its own compact fixed match and uses a remote power supply (AE's HFV series variable-frequency power supply.) This robust and versatile plasma source gives process engineers great flexibility and control of a wide range of reactive plasma chemistries at a number of critical points within the process stream.

THEORY OF OPERATION

Figure 2-1 shows a schematic diagram of the ICP source. The source has a 3" OD discharge tube that is sealed with elastomer O-rings at each end. The discharge tube is made of materials that block ultraviolet light radiation emitted by the gas discharge, thereby preventing the generation of harmful ozone within the ICP source chassis and work environment. The discharge tube may be readily removed and serviced, as necessary, by removing the end flanges without opening the ICP source enclosure or disrupting any electrical components.

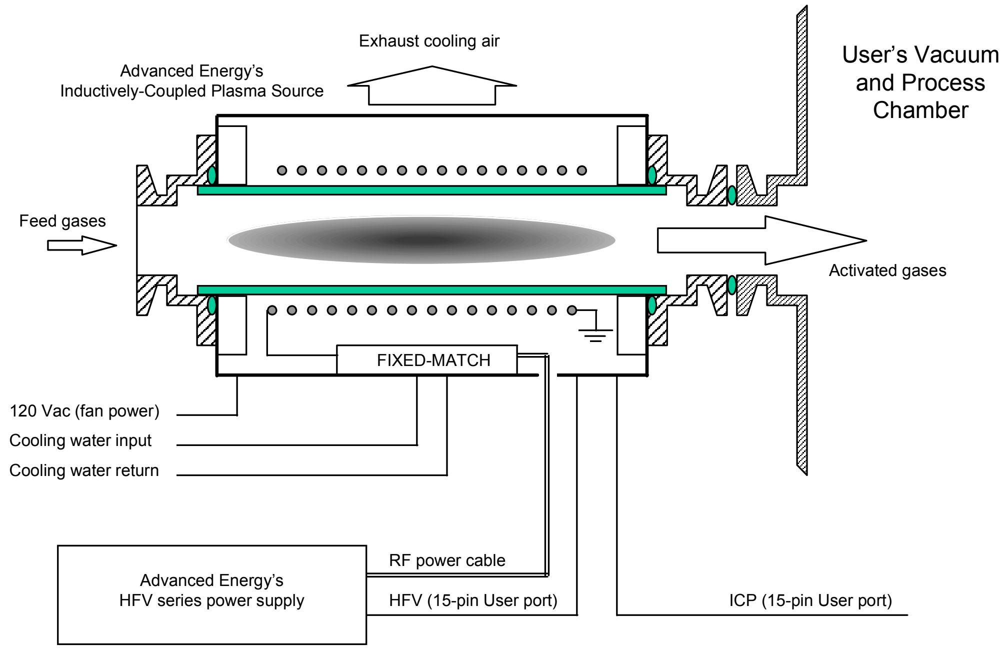


Figure 2-1. *ICP source schematic*

An induction coil is used to apply power to a plasma in the source by means of induced RF electric fields. The electrically conductive plasma of the ICP source is essentially a single-turn, secondary current path with respect to the primary induction coil. High RF current levels on the primary coil are required to drive the heating fields and currents within the plasma body. Thus, a resonant RF power matching circuit in the form of a series and shunt capacitor is required to facilitate high RF currents (10 s of Amperes) on the induction coil and to match the complex impedance of the loaded resonant circuit to the 50 Ω output and 50 Ω cable from the RF generator. Naturally, the load impedance of the ICP source dynamically changes with respect to gas flow, gas composition, vacuum pressure, and power.

The ICP source has been configured to operate with AE's HFV series RF generators. This power supply is a variable frequency generator (1.765 to 2.16 MHz) that uses direct digital synthesis (DDS) to minimize the reflected power for a given load impedance. The DDS tuning features of the HFV sense the state of forward and reflected power at the generator as a result of the ICP source's load impedance and provide dynamic adjustments to the RF frequency in order to minimize reflected RF power on the transmission line and to provide effective power transfer to the ICP load. (Refer to the HFV user manual supplied with your ICP source for more details on its installation, operation, and programming features.)

The ICP source uses a FixedMatch® element that has been optimized for gas chemistries, pressures, and power levels commonly used by that particular ICP source. However, if the impedance of the ICP falls outside the typical ranges of operation, the fixed match may be discretely “trimmed” by adding additional capacitance to the shunt or series capacitors. (Contact AE before considering or requesting such changes, as poor matching and/or dynamics may be caused by conditions not associated with the ICP source. See “AE Global Support” on page 6-9.)

Tube materials and fixed match may be pre-specified to accommodate a wide variety of gases and gas mixtures, including, but not limited to, N_2, O_2, Ar, He, water vapor (H_20), and mixtures thereof.

APPLICATION TO VACUUM PROCESSING

The following figures illustrate the application of the ICP source to several vacuum-based processes as discussed in the General Description.

Reactive Sputter Deposition

Figure 2-2 illustrates the use of an ICP source to enhance a typical reactive sputter deposition system used for deposition of oxide and nitride films such as aluminum oxide, aluminum nitride, or silicon dioxide.

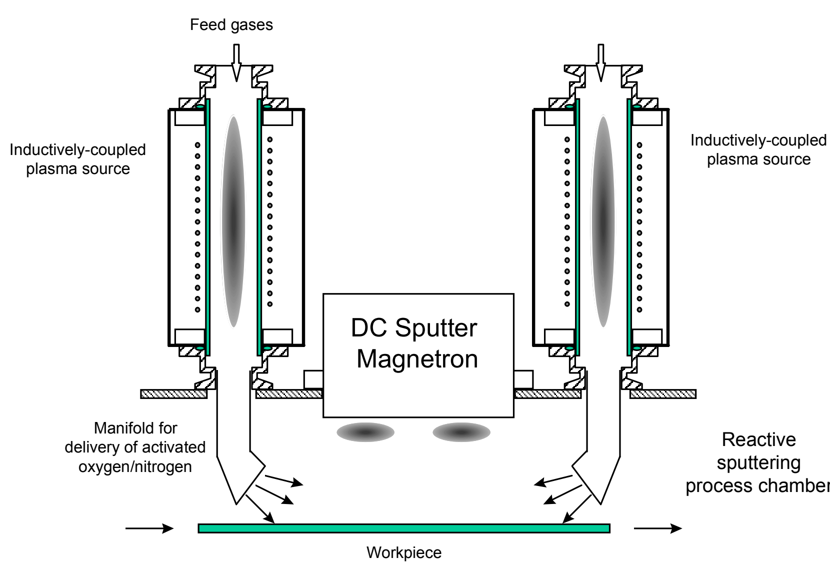


Figure 2-2. *A typical reactive sputter deposition system*

In conventional reactive sputter deposition, a dc-power magnetron is used to sputter metals from bulk-material targets in the presence of O_2 or N_2 feed gases alone or in combination with inert carrier gases such as argon. Metal species arrive at the work piece, along with activated oxygen and nitrogen atomic or molecular species, to form the films. The desired film stoichiometry and other properties are controlled by balancing the arrival rate of metal, oxide, and/or nitride species, among other parameters. Since the oxygen or nitrogen atomic or molecular species are activated by the plasma in the vicinity of the magnetron, a dielectric layer may form on the magnetron target, a condition that is often referred to as *target poisoning*. If the rate of insulating film growth on the target exceeds the sputter rate of material from the target, the electrical operation of the dc magnetron is disrupted. As such, target poisoning restricts the sputtering rate of material, the deposition rate of films, and the stoichiometry properties of the film.

The ICP source may be used to enhance the reactive sputter deposition process by providing a high flux of dissociated gases, metastable, and other reactive species prior to their injection into the sputter deposition process. The pre-activated gases are allowed to flow into the deposition process chamber through a high-conductance distribution manifold, preferably made of quartz, pyrex, alumina or similar dielectric, vacuum-compatible material. The manifold introduces the activated gases in close proximity to the work piece surface. When compared to conventional reactive sputter deposition, the use of the ICP source results in:

- Reduced probability of target poisoning when depositing dielectric films at high deposition rates
- Reduced O_2 and N_2 gas flows for the process
- Improved film qualities such as hardness, visible light transmission, and material stoichiometry
- A wider range of DC magnetron operation

Moreover, since the ICP source is a non-electrode, high density plasma source, it requires little preventative maintenance when used in production.

Surface Treatment and Plasma Enhanced Chemical Vapor Deposition (PECVD)

Figure 2-3 shows an ICP source used to assist in surface treatment and plasma enhanced chemical vapor deposition (PECVD) processes. In this application, working gases are activated by the ICP source, which is closely coupled to the processing vacuum chamber. The activated gases generated by the ICP source are allowed to diffuse to the work piece surface where they may facilitate etching, chemical substitution reactions, cleaning or ashing of the surface of the work piece. To assist in PECVD processes, chemically active and/or inert carrier gases are introduced through the ICP source. The activated species may be combined with additional depositing gases or vapors injected downstream of the ICP source and in proximity to the work piece.

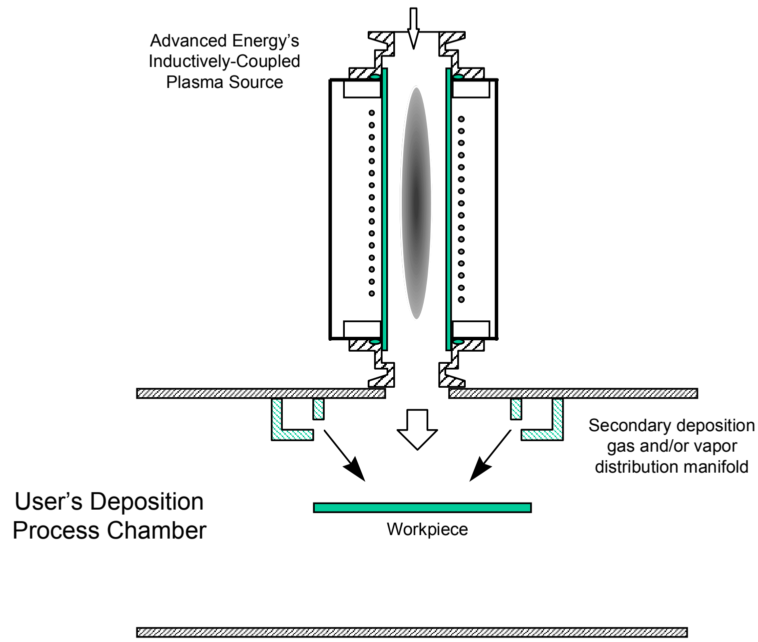


Figure 2-3. *Surface treatment and PECVD*

Specifications

FUNCTIONAL SPECIFICATIONS

Table 3-1describes the functional specifications for the ICP Source.

Table 3-1. *Functional Specifications*

Description	Specification
Delivered RF Power	
Continuous Operation	2 kW with 23°C ambient air (De-rated for higher ambient air temperatures by 25 W / °C above 23°C)
Cycled ON/OFF with Duty Cycle	2 kW net time averaged power. Up to 3 kW peak power with 1 min ON time
Gas Compatibility and Operating Pressure *	
AE# 3151800-001 Pressure measured at inlet flange	Oxygen compatible Ar—2 to 200 mT O_2, N_2, and He—2 to 200 mT** (alone or in combination)
* Ranges of operation may be modified; contact AE for details. **Pressure for ignition is approximately 10 mT	

PHYSICAL SPECIFICATIONS

Table 3-2 describes the physical specifications of the ICP Source.

Table 3-2. *Physical Specifications*

Description	Specification
Size	28.3 cm (H) x 48.3 cm (W) x 23.5 cm (D); 11.125” (H) x 19” (W) x 9.25” (D)
Weight	≤ 15.9 kg (≤ 35 lb)
Materials	
Chassis and flanges	Aluminum
Water-cooled end flanges	Nickel-plated brass or anodized aluminum
Discharge Tube	AE# 3151800-001—Vycor™
Induction Coil	Silver-plated copper

Table 3-2. Physical Specifications (Continued)

Description	Specification
Connector/Cable Specifications	
RF input	HN-type
AC input	120 Vac
User Port	15-pin, shielded, male, subminiature-D
Generator Port	15-pin, shielded, female, subminiature-D
Coolant	¼” Female, threaded, NPT
Vacuum Components	
O-rings (2)	AE# 3151800-001—Silicone rubber (orange)
Flanges	ISO KF50 (50 mm quick-flange connection)

ELECTRICAL SPECIFICATIONS

Table 3-3describes the electrical specifications for the ICP Source.

Table 3-3. Electrical Specifications

Description	Specification
RF Power Specifications	
Frequency	1.765 to 2.160 MHz
RF Power	2 kW continuous; 3 kW peak
AC Power Specifications	1 ϕ, 120 Vac, 1 A

OPERATIONAL SPECIFICATIONS

Table 3-4 describes the operations specifications for the ICP Source. For processes requiring different or extended ranges of operation than those listed, contact Advanced Energy Industries.

Table 3-4. Operational Specifications

AE Model #3151800	Reactive Sputtering	Surface Clean and PECVD
Total gas flow rate	≤ 100 sccm	≤ 2 sLm
Pressure range (measured at inlet)	2 to 200 mT	2 to 200 mT (Option 001)
Peak RF Power	3 kW	3 kW
Continuous and net time-averaged RF Power	2 kW	2 kW

Table 3-4. Operational Specifications (Continued)

AE Model #3151800	Reactive Sputtering	Surface Clean and PECVD
Duty Cycle at Peak RF Power	up to 66%	up to 66%
Minimum / Maximum ON time at peak RF power	min—10 sec max—3 min	min—10 sec max—3 min

ENVIRONMENTAL SPECIFICATIONS

Table 3-5 and Table 3-6 describe the environmental specifications for the ICP Source.

Table 3-5. Climatic Specifications

	Temperature	Relative Humidity	Air Pressure
Operating	Class 3K3 0°C to +40°C +32°F to +104°F	Class 3K2 10% to 85% [1] +2 g/m^3 to +25 g/m^3	Class 3K3 80 kPa to 106 kPa 800 mbar to 1060 mbar (approximately 2000 m above sea level)
Storage	Class 1K4 -25°C to +55°C -13°F to +131°F	Class 1K3 35% to 95% +1 g/m^3 to +29 g/m^3	Class 1K4 80 kPa to 106 kPa 800 mbar to 1060 mbar (approximately 2000 m above sea level)
Transportation	Class 2K3 -25°C to +70°C -13°F to +158°F	Class 2K3 95%[2] +60 g/m^3 [3]	Class 2K3 66 kPa to 106 kPa 660 mbar to 1060 mbar (approximately 3265 m above sea level)

[1] Non-condensing

[2] Maximum relative humidity when the unit temperature slowly increases, or when the unit temperature directly increases from -25°C to +30°C

[3] Maximum absolute humidity when the unit temperature directly decreases from +70°C to +15°C

Table 3-6. *Cooling Specifications*

Description	Specification
Coolant Requirements	
Air Temperature	+15°C to +30°C (+59°F to +86°F) inlet temperature
Water Flow Rate	1.0 lpm (0.26 gpm) minimum
Water Pressure	5.2 bars (75 psi) maximum inlet pressure
Contaminates	The following specifications are recommended for the water used to cool the HFG 5000 generator: • pH between 7 and 9 • Total chlorine < 20 ppm • Total nitrate < 10 ppm • Total sulfate < 100 ppm • Total dissolved solids < 250 ppm • Total hardness expressed as calcium carbonate equivalent or less than 250 ppm • Specific resistivity of 2500 Ω/cm or higher at 25°C • Total dissolved solids (TDS) as estimated by the following: $\text{TDS} \leq \dfrac{640{,}000}{\text{specific resistivity } (\Omega/\text{cm})}$

WARNING:
Do not use de-ionized (or triple-distilled) water for cooling purposes. De-ionized water causes both corrosion and erosion of cooling manifolds.

Connectors, Indicators, and Controls

USER CONTROL CONNECTIONS

The user controls the HFV generator (and ICP source) through connections to 15-pin, subminiature-D ports on the ICP source assembly. The User port connection from the HFV is connected to the Generator port of the ICP source. The signals of the ICP source User port are identical to those of the HFV generator User port. This connection is made in order to interlock the ICP source with the operation of the HFV generator by means of a series interlock connection between *pin 11* of both the Generator port and User port on the ICP source.

Generator Port

Figure 4-1 shows the Generator port connector.

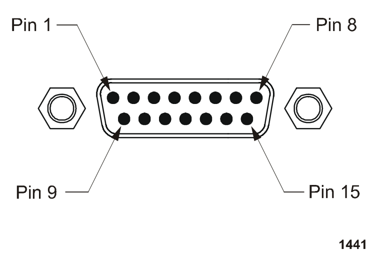


Figure 4-1. *Generator port connector*

The Generator port is a 15-pin, shielded, male, subminiature-D connector. Refer to the User port connector description of the HFV 8000 or HFV-L 3 kW generator manual for specifications and functions of signal and return pins.

User Port

Figure 4-2 shows the User port connector.

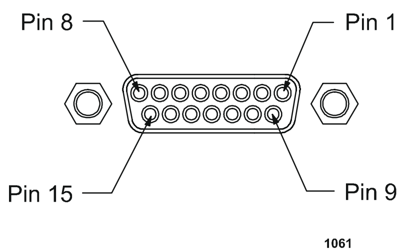


Figure 4-2. *User port connector*

The User port is a 15-pin, shielded, female, subminiature-D connector. Refer to the User port connector description of the HFV 8000 or HFV-L 3 kW generator manual for specifications and functions of signal and return pins.

Interlocks and Conditions

The ICP source is interlocked to the operation of the HFV generator by means of three NC switches within the ICP source. The ICP source interlock signals are in series with the user's interlock signal on *pins 11* and *12* of the User port. Figure 4-3 illustrates the interlocking connection from *pin 11* of the Generator port on the ICP source.

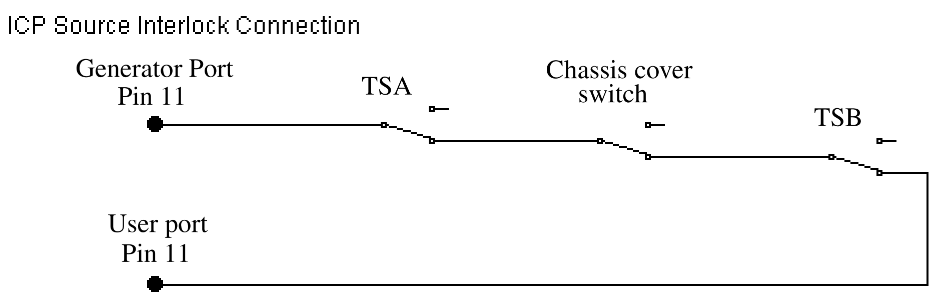


Figure 4-3. *Interlock connections*

Interlock loop is CLOSED when:

- Thermoswitch A—CLOSED (below 65° to 67°C)
- Chassis cover switch—CLOSED
- Thermoswitch B—CLOSED (below 65° to 67°C)
- User Port Connections (*Pin 11* to *Pin 12*)—CLOSED

Note: External series resistance between *pin 11* and *pin 12* must be 15 Ω or less. *Pin 11* is tied to +15 Vdc by a resettable fuse in the HFV power supply.

Installation, Setup, and Operation

UNPACKING

Unpack and inspect your ICP source carefully. Check for obvious physical damage. If no damage is apparent, proceed with the unit connections. If you do see signs of shipping damage, contact Advanced Energy Industries, Inc., and the carrier immediately (see “AE Global Support” on page 6-9). Save the shipping container for submitting necessary claims to the carrier.

GROUNDING

Grounding is supplied by the RF generator at its RFI mounting hole, or stud. (Refer to the installation instruction of the RF generator.) Additional grounding of the ICP source may be made at any one of the six #10-32 mounting holes on the back of the ICP source assembly. A suitable chassis ground connection made to any of these fittings can prevent or minimize radio frequency interference. However, this grounding connection should not be used as the primary grounding point for the RF generator or in substitution for the grounding RFI mounting point on the generator.

Note: For more information about grounding, refer to the AE Application Note titled Grounding p/n 5600031A. You can find this AE Application Note on AE’s web site (http://www.advanced-energy.com), or you can request a copy by calling Global Support (see “AE Global Support” on page 6-9).

The three-pole ac connection that drives the cooling fans on the ICP source can serve as an additional ac power ground.

⚠ **WARNING:**
To ensure proper grounding and installation, use only AE approved RF cables (AE pn 1345767) between the HFV generator and the ICP source.

SPACING REQUIREMENTS

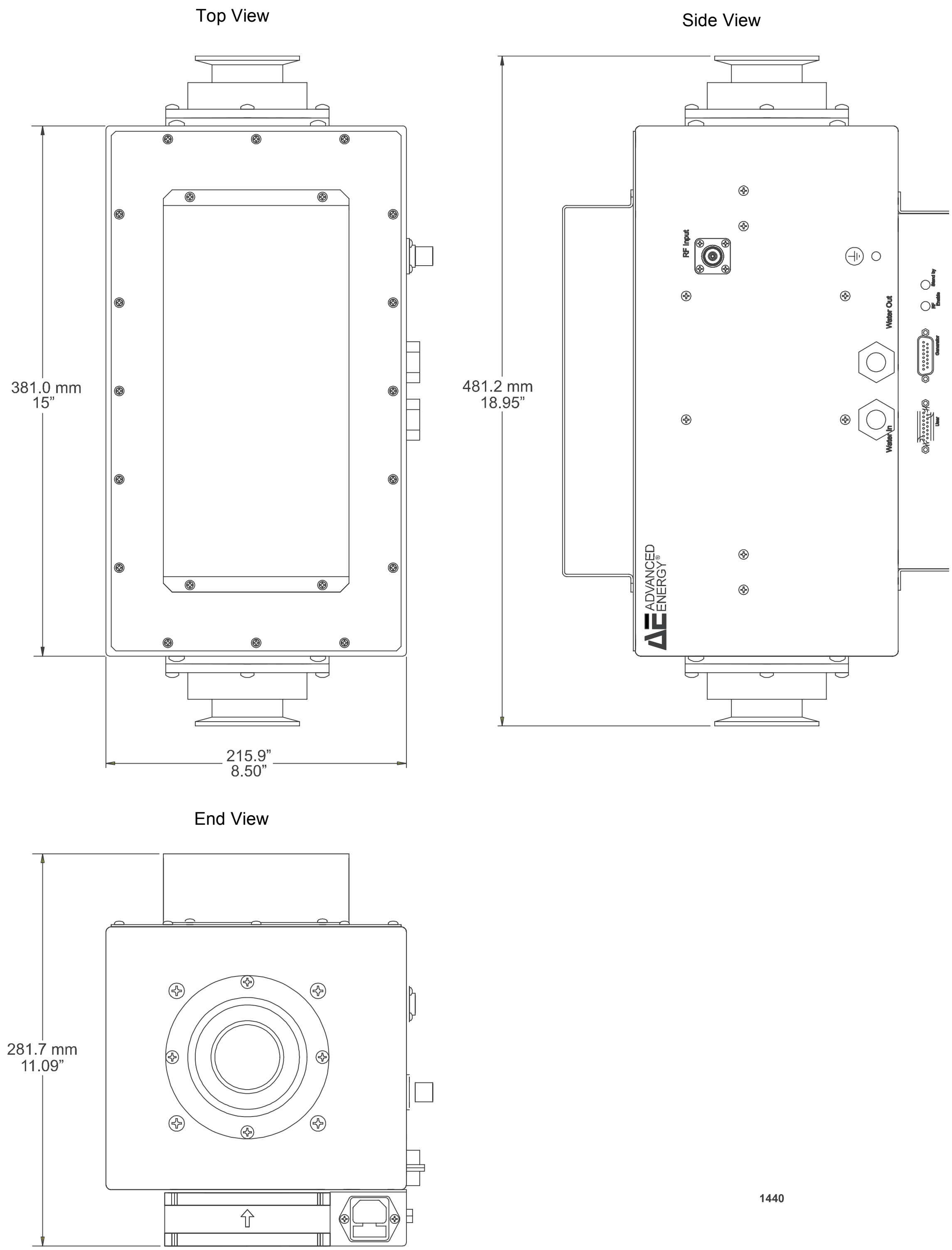


Figure 5-1. *ICP source spacing requirements, mounting holes, and connections*

PHYSICAL INSTALLATION AND VACUUM CONNECTIONS

Physical Installation

The ICP source should be orientated in one of three positions for effective air cooling: vertical, horizontal with upward air flow, or horizontal with lateral air flow. These orientations are displayed in Figure 5-2 through Figure 5-4. Failure to mount the ICP source in one of the three orientations shown could result in ineffective air cooling of the device and diminish the operable range of net time-averaged power. Also, a clear space of at least 6.0" wide should be allowed at the air intake (fan intake) and exhaust sides of the chassis for effective air cooling.

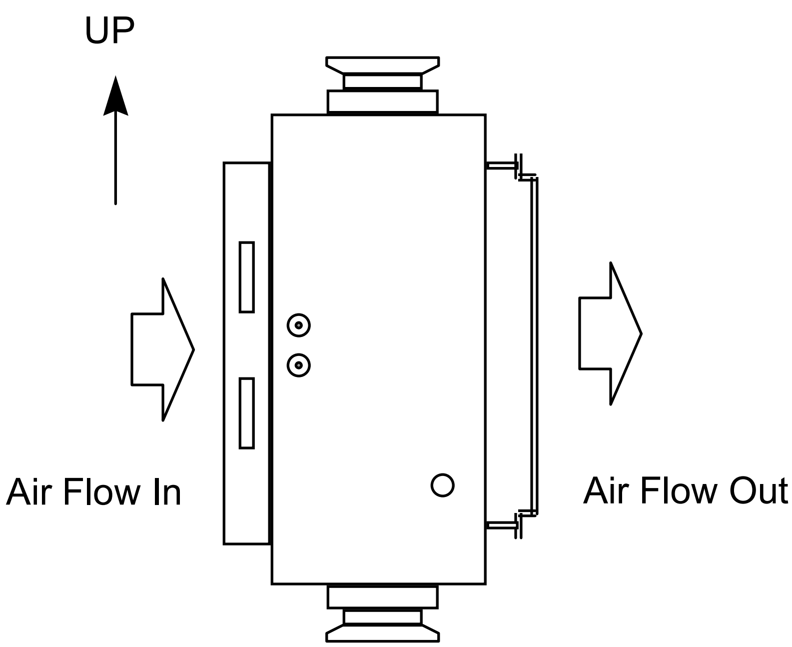


Figure 5-2. *Vertical placement*

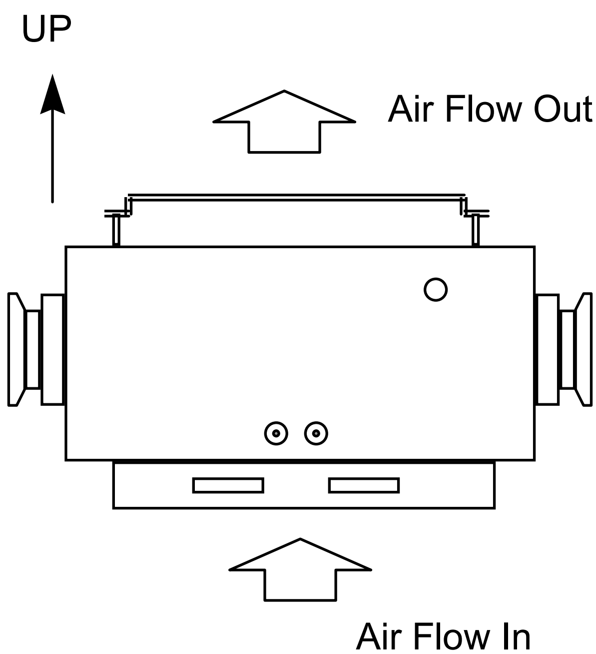


Figure 5-3. *Horizontal placement - upward air flow.*

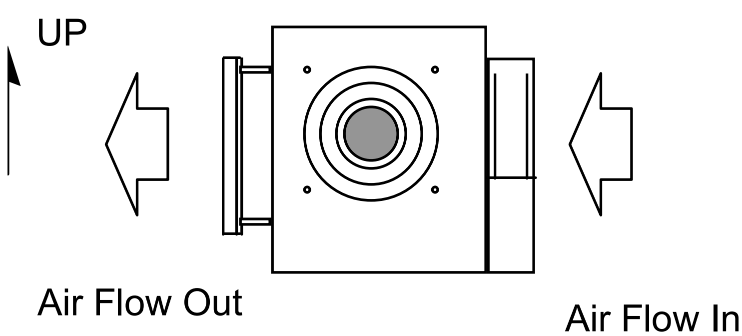


Figure 5-4. *Horizontal placement - lateral air flow*

The ICP source should be supported by a GROUNDED, customer–supplied mounting bracket or plate from the six #10-32 screw hole locations on the back side of the ICP source. Refer to Figure 5-1 on page 5-2 for mounting dimensions. The ICP source should not be supported only by its end-flange fittings.

Vacuum Connections

After unpacking and mounting the ICP source, remove any protective covers from the end-flange fitting. Keep the end-flanges free of dust, dirt, or unwanted greases when handling. Scratches, dirt, and debris on the end-flanges can corrupt or destroy the vacuum-sealing integrity of the flange. Avoid allowing dust or any foreign object to enter the discharge tube during installation. If it is necessary, the sealing surfaces of the end-flange fittings may be cleaned with a diluted isopropyl alcohol solution and dust free wipe per usual vacuum practice.

⚠ **WARNING:**
Do not use alcohol as a cleaning solvent in the presence of open flames or where sparks or arcs occur.

The ICP source vacuum connections should be made prior to making cooling water connections and all other electrical connections.

The end-flanges have the following type of standard vacuum coupling interfaces. Other flange sizes may be available upon request.

Table 5-1. *Available ICP Source End-Flange Configurations*

Flange Type (material)	Flange OD (inches)	Vacuum Tube/ Centering Ring ID (inches)	Sealing Gasket
ISO KF-50 (aluminum)	2.95	2.10	captured elastomer
Note: All dimensions are nominal ISO: International Standards Organization; KF: Klein Flange			

Once the ICP source is mounted and sealed, the source may be brought under vacuum. Base vacuum pressures will depend on the user's vacuum system capabilities. (Refer to "Troubleshooting" on page 6-1, should you observe any significant vacuum leaks as a result of the installation of your ICP source.)

CONNECTING COOLING WATER

The ICP source is water-cooled. Do not operate it until the water is connected and the cooling requirements are met. The ICP source requires two ¼" NPT fittings for input and output flow (refer to Figure 5-1 on page 5-2).

WARNING:
If you are connecting multiple units in series, be sure that the input water temperature to all units is less than the maximum input water temperature.

WARNING:
Do not use de-ionized water for cooling purposes.

Connect the input and output connections and tighten securely. Turn on the water and ensure that there are no leaks at the connections or within the ICP source chassis. Be sure that the flow rate and the temperature are within the minimum specifications required to operate your ICP source (see Table 3-6 on page 3-4).

WARNING:
Ensure that there are no water leaks in the cooling system before connecting input RF or ac power.

Note: Keep the water cooling system running as long as the associated RF generator is on and capable of delivering power to the unit.

CONNECTING CABLES AND CONNECTORS

WARNING:
RISK OF DEATH OR BODILY INJURY. Disconnect all sources of input power before working on this unit or anything connected to it.

Before making any input power connections to the ICP source, turn off system circuit breakers supplying input power to the RF generator. Ensure that the circuit breaker on the RF generator is also in the OFF position.

Connecting Generator and User Port Connections

With the RF generator power off, the connections are made from the RF generator User port to the ICP source Generator port with the supplied 15-pin cable. The user then makes the connection to the ICP source User port. The functions of the pins of the ICP source User port connection reflects those functions of the RF generator User port connections. Please refer to the “Interconnect Schematics” for the RF generator supplied with your ICP source.

Connecting Power Inputs

⚠ **WARNING:**
RISK OF DEATH OR BODILY INJURY. Disconnect all sources of input power before working on this unit or anything connected to it.

Complete the following steps to connect the input power to the ICP source.

1. Inspect the center conductor on the RF coaxial cable that mates to the ICP source to be certain that the center conductor has not been damaged in any way or unduly extruded into the cable assembly.
2. Thread the HN-type RF connection of the power cable to the HN-type RF input connection of the ICP source securely.
3. Connect the RF power cable to the AE RF generator per its instructions. (Refer to the HFV manual.)
4. Connect the supplied three-wire ac power cord to the ICP source service panel.
5. Connect the ac power cord to a 115 Vac power source.

   Note: The cooling fans will be operable when ac power is supplied to the fans. If the fans do not operate immediately, halt the installation of the ICP source and refer to “Troubleshooting” on page 6-1 to resolve the problem.

⚠ **WARNING:**
Use the three-wire ac power cord with the ground prong as supplied, or an equivalent. Do not remove the ground prong or attempt to defeat it with an adaptor.

Note: Connections must be made securely to prevent excessive RF emissions.

OPERATION

Operating Overview

The ICP source is an electrical load device that works in concert with the AE HFV series RF generator to ignite and sustain a discharge. The HFV is a variable frequency generator (1.765 to 2.16 MHz) that senses forward and reflected power levels and makes dynamic adjustments to its operating frequency in order to provide the setpoint power to the ICP source and to minimize reflected power levels for efficient power conversion.

The ICP source has been configured and optimized to operate effectively over a range of power and pressure. This range of operation is determined by the following:

- Frequency band of the HFV generator
- Discharge tube scale and induction coil design
- Series and shunt capacitance of the passive fixed match network
- Gas flow, pressure, and chemistry and intrinsic plasma dynamics of such gas mixtures

After installation of your ICP source, check the condition of the plasma source and its installation by operating it under a set of reference conditions. The following operational notes discuss how to examine the ICP source operation by examining a) the frequency response, and b) the reflected power response of the HFV generator. By dialing in these reference conditions, you may use the response of the HFV to determine if your ICP is operating properly.

However, please note that these operational notes and reference conditions should be treated as guidelines to operating your ICP source. Different users will have different vacuum systems, gas mixtures, and pumping speeds. As a result, your ICP source and HFV generator may respond somewhat differently and deviate from the reference conditions.

Once the unit is connected and the appropriate vacuum conditions are set, the HFV power supply is turned on and enabled. As soon as the user provides the setpoint power signal to the ICP source/HFV set, the HFV generator provides forward power and proceeds through its electronic tuning algorithm in order to ignite the discharge and minimize reflected power.

First Time Operation

You need to supply the following provisions to test the ICP source installation against the recommended operation guidelines.

- A vacuum pressure gauge, such as a capacitance manometer, located within 30 cm of the inlet to the ICP source

- An effective vacuum pumping speed of at least 50 l/sec at the exhaust of the ICP source
- A source of Ar, O_2, or N_2 gas with a mass flow controller rated at between 20 and 500 sccm

Figure 5-5 depicts a typical installation and provisional user vacuum equipment and connections.

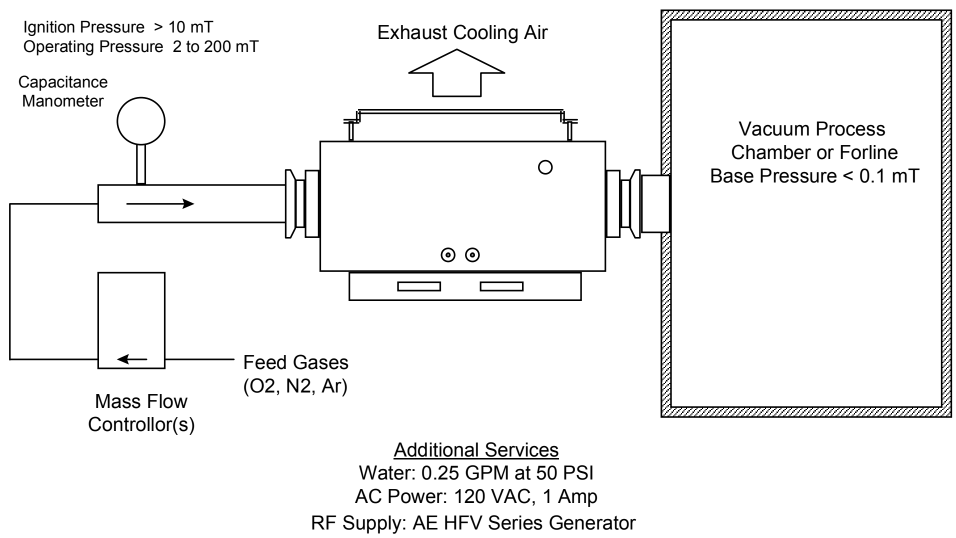


Figure 5-5. *Typical installation*

WARNING:
Do not attempt to ignite the ICP source at inlet pressures below 10 mTorr or under zero flow or uncontrolled gas flow conditions. It is strongly advised that you interlock the operation of the ICP source and HFV generator against active gas flow and minimum pressure set-points per usual vacuum processing practices. Failure to do so may lead to atmospheric arcs within the ICP source assembly and damage to the ICP source unit.

WARNING:
Read all of the following instructions before proceeding with the initial operation of the ICP source and HFV generator.

Complete the following steps to initially turn on and operate the ICP source for O_2 and/or N_2 service as applicable to AE Model #3151800-001.

1. Check to ensure that the ICP source fans are operating and unobstructed, and that sufficient cooling water is flowing to the unit.
2. Verify that the ICP source is under vacuum with a base-pressure of less than 5 mTorr with no flowing gases.
3. Provide a gas flow of either Ar, N_2 or O_2 to provide an inlet pressure of between 10 and 100 mT.
4. Follow the start-up procedure for the HFV generator.

   Note: If any problems arise during the proceeding process steps, shut off the HFV power supply and refer to the Troubleshooting section of the HFV manual.

   a. Make sure the **STANDBY/STOP** switch on the HFV front panel is in the stop position.
   b. Select **load power regulation** by means of the selector switch on the rear of the generator.
   c. Connect your User port cable to the User port of the ICP source to access the user functions of the HFV generator.
   d. Turn on the power to the generator from the circuit breakers on the rear of the generator.

      Note: The front panel display of the generator should now be active, and the **LOAD REGULATION** indicator should be lit.

   e. Turn the **STANDBY/STOP** switch on the front panel to the standby position. The generator should now be under control of the User port.
5. On the User port connection, provide a closed connection between *pins 11* and *12* to satisfy the interlock. The **INTERLOCK** indicator LED on the HFV front panel should be lit.
6. On the User port connection, provide a closed connection, between *pins 4* and *9* to satisfy the RF enable condition. The **RF ENABLE** indicator LED HFV front panel should be lit.
7. On the User port connection, provide a 3 to 5 Vdc (max of 10 Vdc) signal between *pins 5* and *6* to initially start the HFV power supply and ICP source. This should correspond to a load power of about 900 to 1500 W.

The ICP source should be ignited, as made evident by a dim glow from within ICP source assembly. Within about a second, the HFV should scan in its frequency range in order to find that frequency that allows the setpoint power to be delivered to the ICP source. Once this condition is met, the **SET POINT** indicator LED on the HFV front panel should be lit. Shortly thereafter, the HFV generator should continue to tune to a frequency between 1765 and 2160 kHz, as indicated on the front panel of the generator, and a minimum point of reflected power (typically less than 500 W).

The HFV generator is configured to continuously adjust its frequency to minimize the level of reflected power, even after the load power setpoint condition has been met. This is referred to as the *Continuous Tune Mode*. As such, the user may see slight dynamic deviation in the HFV operating frequency of about 10 to 50 kHz. Such deviation should not influence the operation or output performance of the ICP source.

Note: Other tune modes are available on AE's HFV series generators. Consult AE for details if continuous tune mode is not appropriate for your applications (see "AE Global Support" on page 6-9).

Normal operation of the ICP source may be stopped and re-started by means of the RF enable signal, or RF power setpoint signal, and interlock signal, or manually by means of the **STOP/STANDBY** switch on the HFV front panel.

Normal Operation

Figure 5-6 through Figure 5-9 show contour plots of RF frequency and reflected power against setpoint load power and inlet pressure for Ar and O_2 that are exemplary of normal operation. Depending on the installation and pumping speed of your vacuum system, the exact values of frequency and reflected power in your installation may deviate from these exemplary response surfaces. As such, the following data should be used as a guide to anticipate the ICP source's response and range under normal operation.

There may be applications where it is necessary to work outside the normal range of operation as depicted in Figure 5-6 through Figure 5-9. In such cases, it is possible to make adjustments to the ICP source's fixed match component to extend the normal range of operation. Please consult AE Global Support for service and support for more details to alter or extend the range of operation of your ICP source (see "AE Global Support" on page 6-9).

Figure 5-6 and Figure 5-7 show the exemplary response of HFV frequency and reflected power for argon gas in the ICP source under continuous tune and load power regulation.

- Figure 5-6 shows the frequency response versus load power setpoint and inlet pressure.
- Figure 5-7 shows the reflected power response versus load power setpoint and inlet pressure.

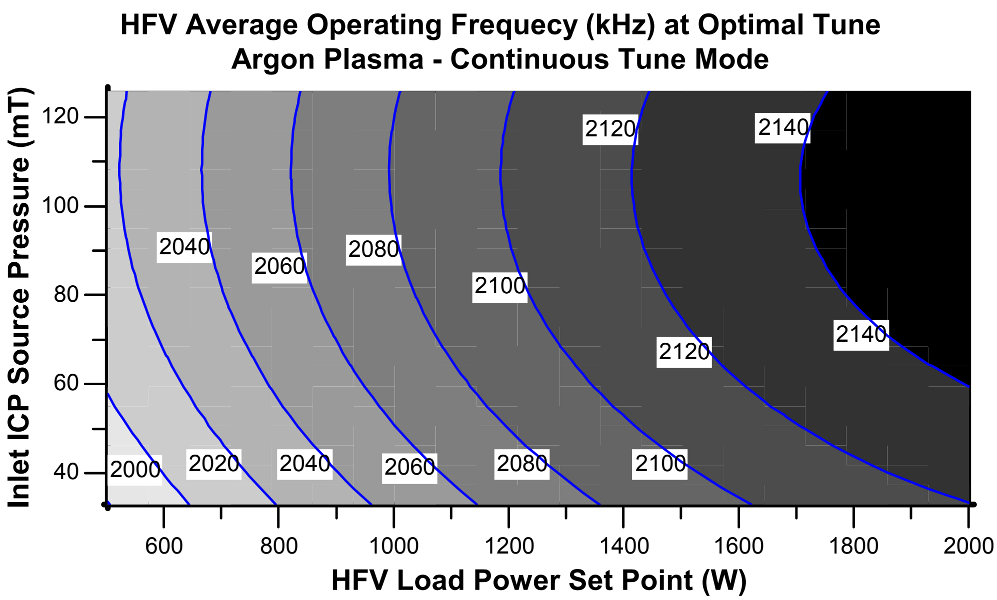


Figure 5-6. *Frequency response vs. load power setpoint and inlet pressure*

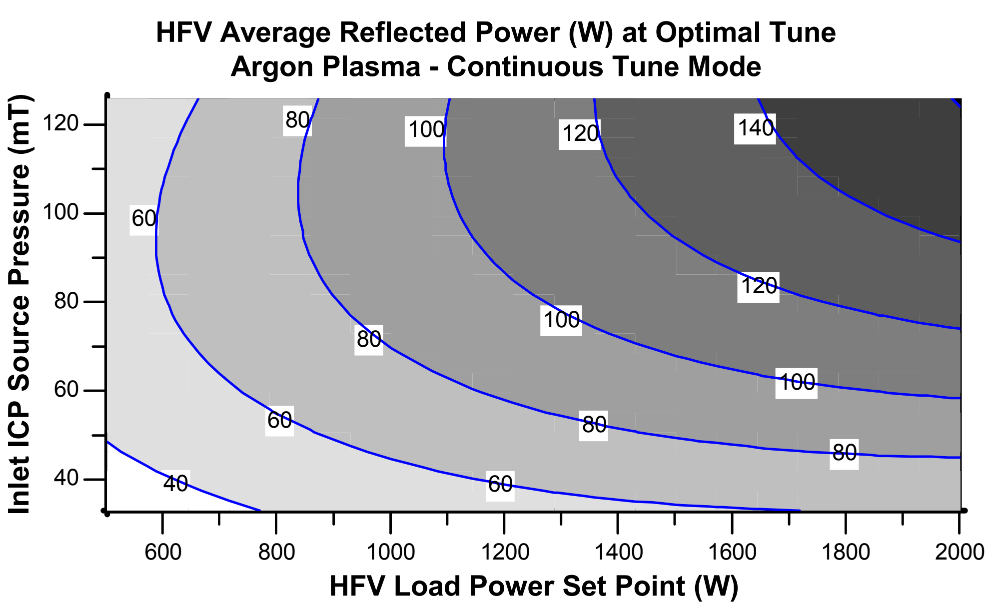


Figure 5-7. *Reflected power response vs. load power setpoint and inlet pressure*

Figure 5-8 and Figure 5-9 show the exemplary response of HFV frequency and reflected power for oxygen gas in the ICP source under continuous tune and load power regulation.

- Figure 5-8 shows the frequency response in kHz versus load power setpoint and inlet pressure.
- Figure 5-9 shows the reflected power response in Watts versus load power setpoint and inlet pressure.

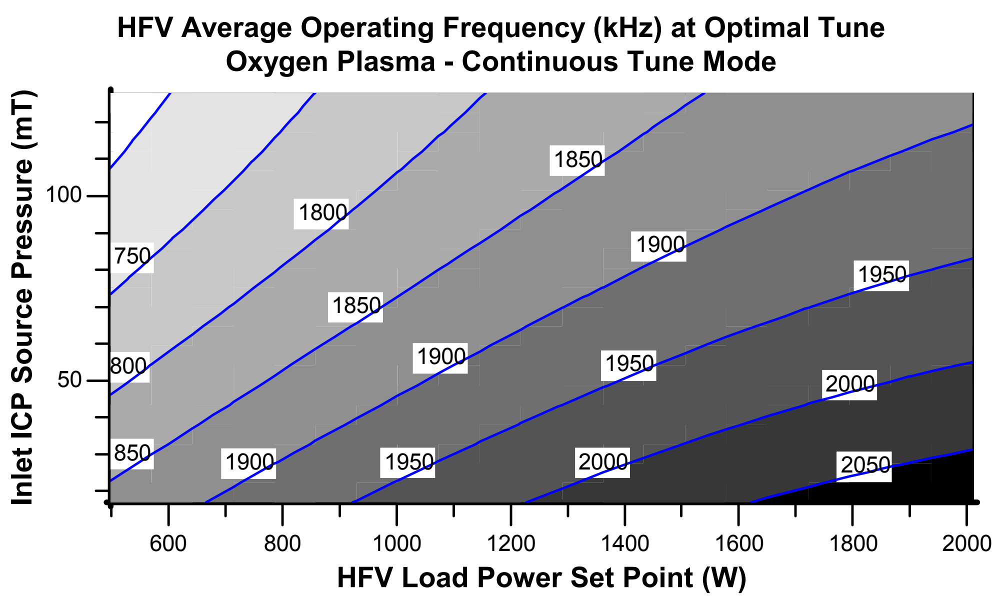


Figure 5-8. *Frequency response vs. load power setpoint and inlet pressure*

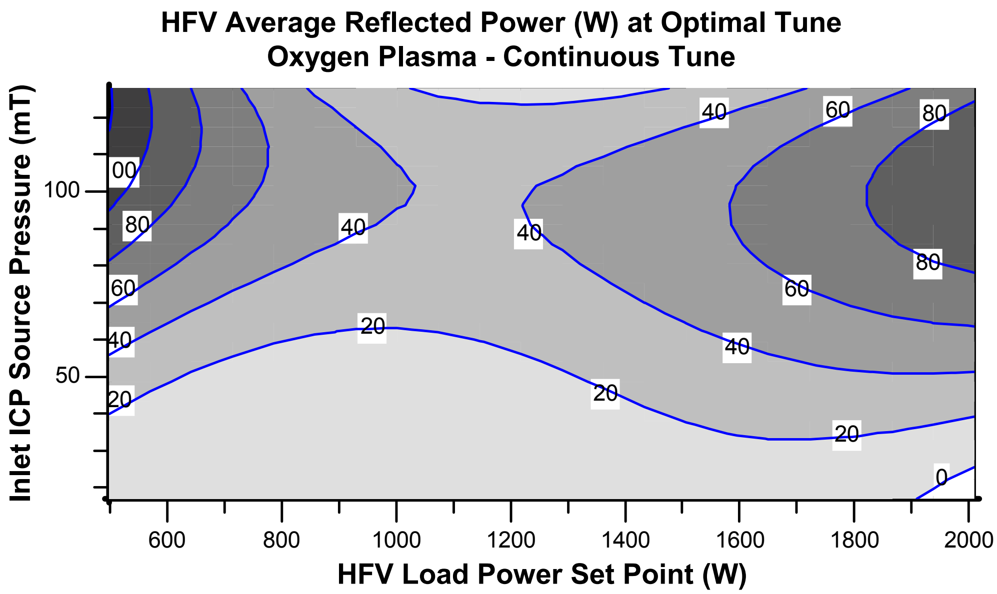


Figure 5-9. Reflected power response vs. load power setpoint and inlet pressure

MAINTENANCE

Wear of ICP Source Components

The ICP source requires very little maintenance and in some applications could operate for an indefinite period of time before it ever requires maintenance. However, depending upon your operating conditions and operating gases, the ICP source discharge tube could slowly "sputter" erode by ion bombardment of the ICP source discharge. Also, long term operation of the ICP source could lead to slow chemical or slow thermal deterioration of the sealing O-rings. Thus, occasionally it may be necessary to perform preventative maintenance or to replace the O-ring seals and/or the discharge tube.

The following steps describe how to service or replace the discharge tube and O-rings if preventative maintenance is required or in the unlikely event that the discharge tube or O-ring should suddenly fail.

Removing the O-Ring Seals and Discharge Tube

The removal of the discharge tube and O-rings is a relatively simple task but does require some preparation. The following materials are recommended:

- Phillips-head screw driver

- Dust- and lint-free wipes as used in clean room environments
- Isopropyl alcohol or similar solvent used for cleaning vacuum components
- Dust- and powder-free clean gloves for clean room environments and handling vacuum components

DANGER:

Ensure that the circuit breaker on the RF generator is also in the OFF position. Disconnect all electrical connections from the ICP source assembly, including all RF, ac, and dc power, or signal connections, including User/Generator Port connections.

Note: It is not necessary to disconnect water cooling connections to the ICP source when performing this maintenance operation. However, it is recommended that the flow of cooling water should be turned OFF to avoid undue condensation on the ICP source assembly in humid environments. Such condensation could introduce unwanted water into your vacuum system.

Use the following steps to remove the O-ring seals and cylindrical discharge tube from the ICP source assembly. Refer to Figure 5-10 on page 5-19.

1. Vent the ICP source to atmosphere and remove it from its vacuum installation.
2. Remove the end flanges by loosening and removing the four #10-32 stainless steel screws from each end of the assembly.

   Note: **Important**—It is best to loosen each screw about 2 to 4 turns and then move to each screw in a rotational sequence around the end flange rather than to completely remove each screw individually from the assembly. This measure helps to release pressure on the O-ring seal evenly, preventing the end flange from resting against the end of the discharge tube and placing undue stress on the tube.

3. Using clean room gloves, gently rotate approximately 30° the ICP source discharge tube to make certain the O-rings have not seated to the surfaces of the ICP sealing grooves.
4. Using clean room gloves, gently apply pressure to one end of the discharge tube with one hand while securing the lateral motion of the discharge tube with the other. This is done to loosen the O-ring seal on the surface of the discharge tube.
5. After moving the discharge tube laterally about 1 cm, the user should be able to remove one of the O-rings.

   Note: The O-rings are stretched over the cylindrical discharge tube and will present some tension to lateral displacement of the discharge tube. Do not attempt to over-force the tube in the assembly.

6. With one O-ring removed, gently and cautiously draw the discharge tube out of the assembly. Do not angle or twist the tube in the assembly. Be careful not to mechanically shock the discharge tube in the assembly to remove it or dislodge. The discharge tube is especially susceptible to chipping or shattering at its ends.
7. Inspect the discharge tube for wear, cracks, and deposits along its interior and exterior surfaces.
8. If available, use a bore gauge to examine the level of erosion or deposits along the interior wall of the discharge tube. Look for visible signs of O-ring galling on the exterior surface of the tube.
9. Replace the tube if the wall has lost more than 1 mm of thickness from its interior diameter. Clean or replace the tube if it appears that deposits could generate flakes or particulates that are undesirable in your process. Clean or replace the tube if the O-ring material has galled or fused to its sealing surfaces.
10. Inspect the O-rings for cracking, hardening, tearing and thermal or chemical decomposition. Replace the O-rings if any such damage is observed.

Cleaning the Discharge Tube

The discharge tube may be cleaned if deposits form on its interior wall and cannot be removed by plasma etching, plasma ashing, or other operating vacuum processing means. The method of cleaning your ICP discharge tube depends on the model of your ICP source and the discharge wall materials.

Alumina or sapphire discharge tube materials should be cleaned as any ceramic material. Vycor™ and other silicon-dioxide and silica-based materials should be cleaned as any conventional, high purity glassware or quartz materials. After cleaning, the discharge tube should be rinsed in distilled water, air dried, rinsed in isopropyl alcohol, and dried again per conventional vacuum equipment practices. Such cleaning protocols vary from user to user and from application to application.

Note: When cleaning the discharge tube, use care to avoid mechanically stressing or shocking the tube.

LIST OF REPLACEMENT PARTS

Contact AE Global Support for replacement parts (see “AE Global Support” on page 6-9).

Table 5-2. *Replacement Discharge Tube and O-rings*

ICP Source Model	Part Description	AE Part Number
3151800-001	O-ring, Silicone, Orange ASM #335	274146

Table 5-2. Replacement Discharge Tube and O-rings

	Discharge Tube, Vycor™	2161023-02
	Discharge Tube, Alumina	2161022
Note: O-rings and discharge tube may be purchased from AE.		

Replacing the Discharge Tube and Seals

Complete the following steps to replace the O-ring seals and cylindrical discharge tube from the ICP source assembly (refer to Figure 5-10 on page 5-19).

1. Prepare the clean discharge tube, end flanges, and hardware for assembly.
2. Prepare the O-rings for assembly. This may include applying a thin layer of high temperature vacuum grease to the surface of the O-rings; however, it is not necessary and may not be recommended for certain high-purity, ultra-high vacuum applications.
3. Stretch and slip one O-ring over one end of the discharge tube and locate the O-ring about 0.5 cm from the end. (Carefully remove any excess vacuum grease from the exposed end of the discharge tube if necessary.)
4. Gently insert the discharge tube into the ICP source assembly, using care to avoid mechanically shocking the end of the discharge tube. Allow the end of the discharge tube that has no O-ring to extend about 1 cm beyond the assembly.
5. Begin installing an end-flange on the end of the discharge tube that has the O-ring, using four (4) #10-32 stainless steel screws. This will secure the discharge tube in place while you install the second O-ring. Do not fully tighten the end-flange in place yet.

   Note: **Important**—It is best to tighten each screw about 2 to 4 turns and then move to the adjacent screw in a rotational sequence about the end flange rather than to tighten each screw individually. This measure helps to apply even pressure on the O-ring seal and prevents the end flange from resting against the end of the discharge tube and placing undue stress on the tube.

6. Stretch and slip the second O-ring over the end of the discharge tube. Press this second O-ring down into the sealing slot of the ICP source assembly. (Carefully remove any excess vacuum grease from the exposed end of the discharge tube if necessary.)
7. Begin installing the second end-flange with the remaining four #10-32 stainless steel screws. Do not fully tighten the end-flange in place yet.

   Note: **Important**—It is best to tighten each screw about 2-4 turns and then move to the adjacent screw in a rotational sequence about the end flange rather than to tighten each screw individually. This measure helps to apply even pressure on the O-ring seal and prevents the end flange from resting against the end of the discharge tube and placing undue stress on the tube.

8. Visually inspect the lateral centering of the discharge tube by looking into the end flanges. If the tube appears to be well centered in the discharge assembly, tighten down both end flanges.
9. If the discharge tube is not well centered, remove the end flanges, leaving the O-rings in place. Attempt to re-center the discharge tube and then repeat steps (5), (7), and (8).
10. Re-install the ICP source into your vacuum system and make any vacuum leak checks that are appropriate for your system and application.
11. Re-connect the ICP source per installation and operation instructions described in this manual.

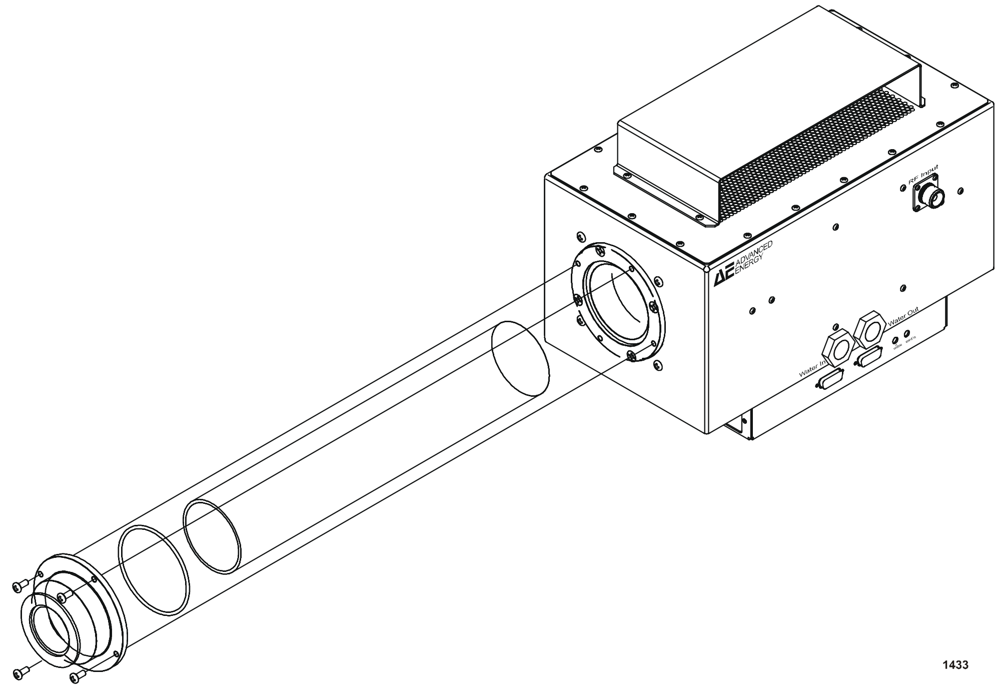


Figure 5-10. *Isometric drawing of ICP source for discharge tube and sealing O-ring*

Troubleshooting, Maintenance, and Global Support

BEFORE CALLING AE GLOBAL SUPPORT

> ⚠ **WARNING:**
> **RISK OF DEATH OR BODILY INJURY. Disconnect all sources of input power before working on this unit or anything connected to it.**

Checks with the Power Off

1. Ensure the power to the HFV generator is off, as well as ac power to the ICP source.
2. Check for visible damage to the unit, cables, and connectors.
3. Ensure all unit connectors are installed correctly and are fastened tightly.
4. Check to determine whether any system-related circuit breakers have been tripped.
5. Ensure there is input power to both the generator and the ICP source, and ensure the input power meets specifications.
6. Ensure ground connections are adequate and secure.
7. Ensure that vacuum connections are leak-free and that vacuum pressure and gas flow conditions meet specifications.

Checks with the Power On

1. Check the unit's input and remote power connections to ensure the proper power is being supplied to the unit.
2. Check the LEDs on all units to determine that the proper ones are lit.
3. Check for fan operation and air flow on the ICP source.

TROUBLESHOOTING

Faults with the ICP source may be a result of either the HFV generator or the ICP source. The following troubleshooting guide is for faults that are related to the ICP source. Please refer to troubleshooting guide for the HFV for problems related to the generator.

Troubleshooting the ICP Source

The following fault tree (in Figure 6-1 through Figure 6-3) and Table 6-1 will assist you in identifying the source of difficulty, should your ICP source fail to operate properly. To use the tree, identify the problem you are experiencing and then use the numeric cause and correction reference in Table 6-1 on page 6-6.

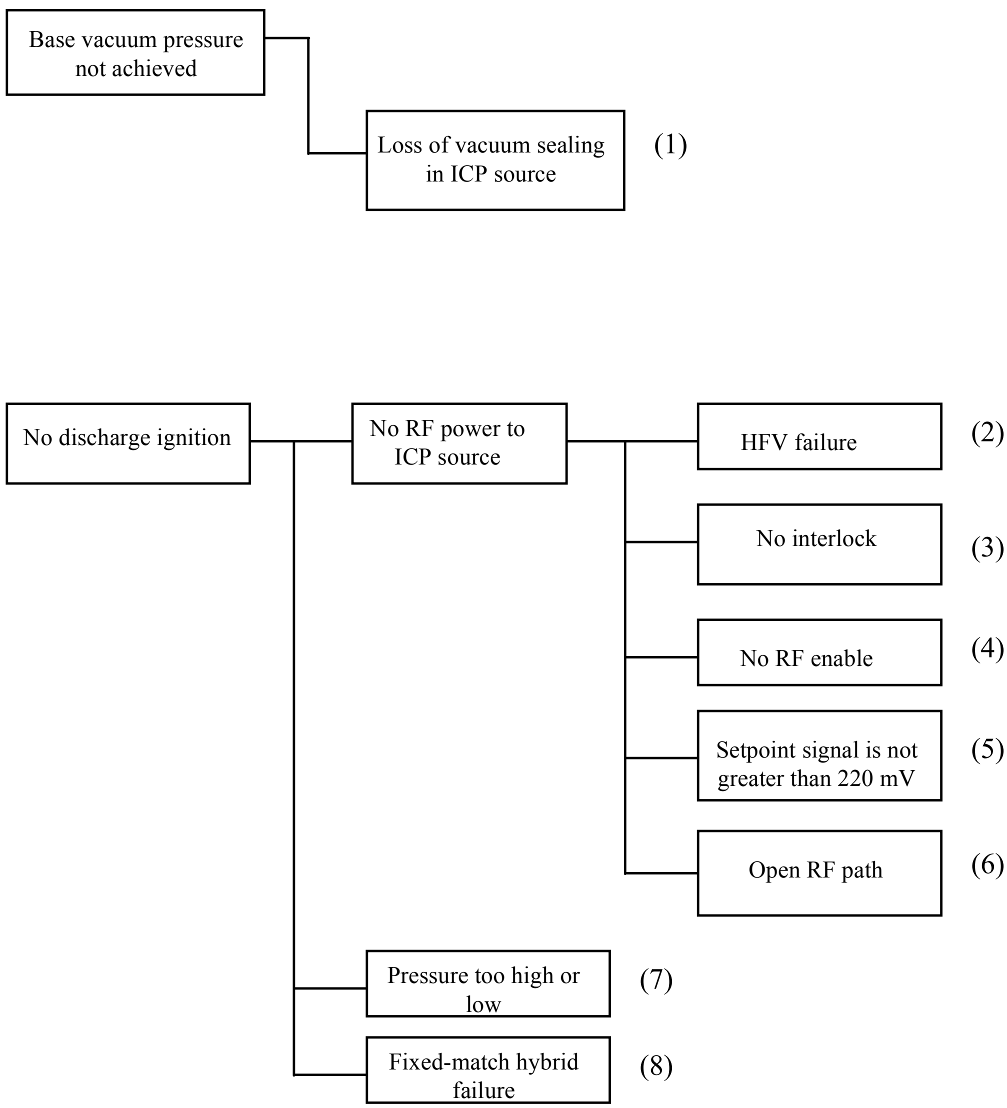


Figure 6-1. *Fault tree*

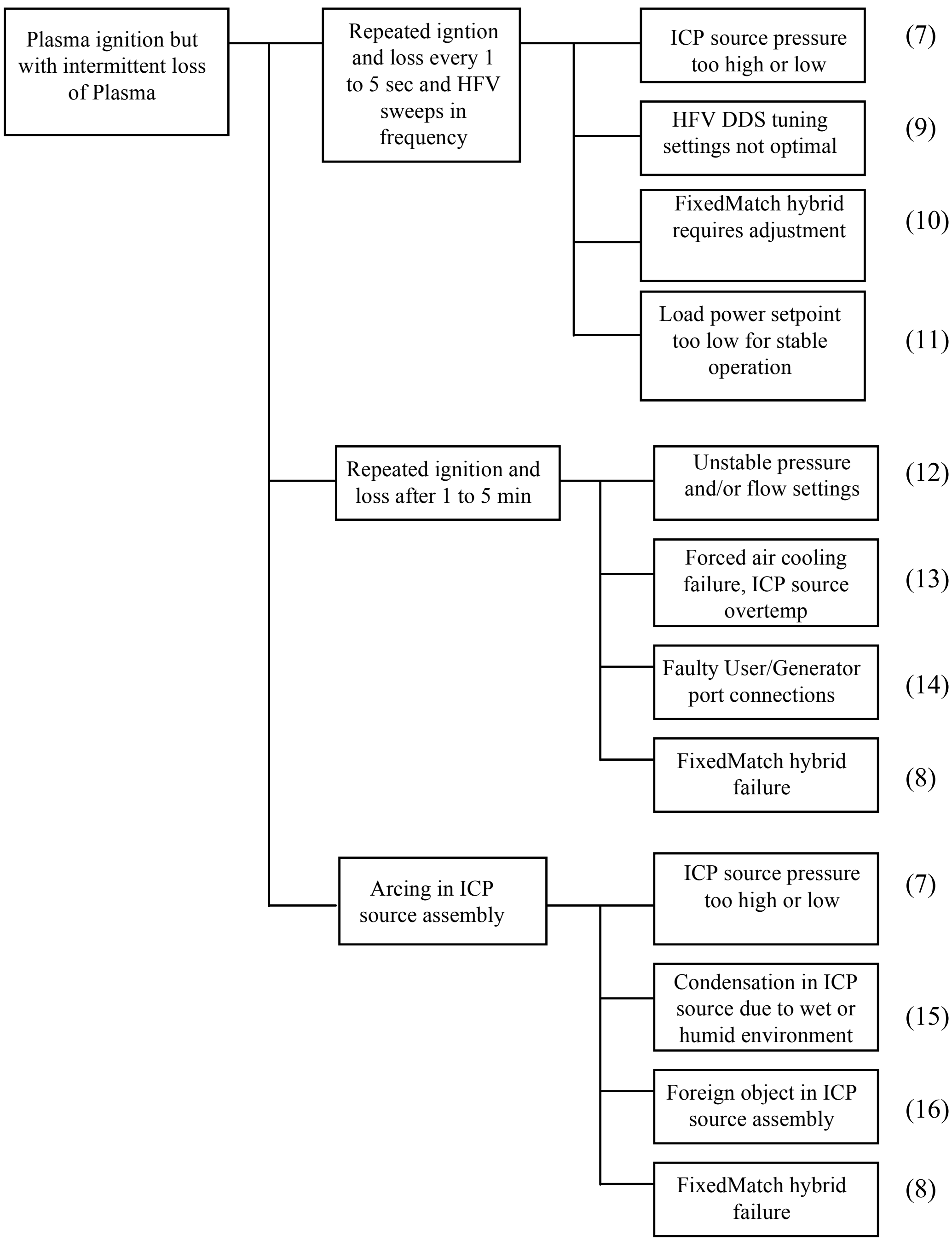


Figure 6-2. *Fault tree (continued)*

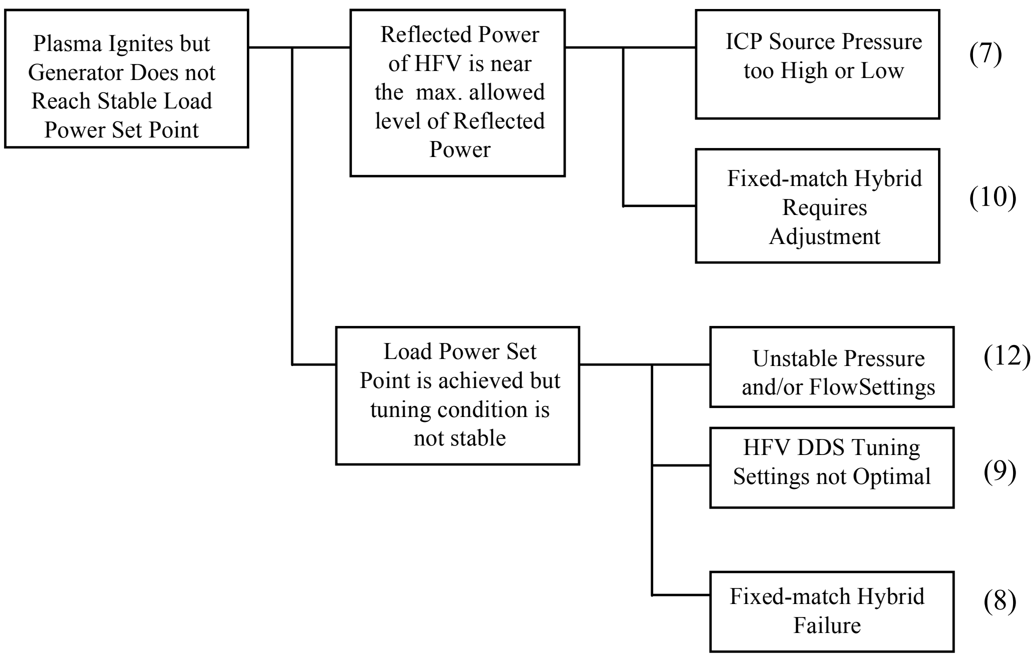


Figure 6-3. *Fault tree (continued)*

Table 6-1. *Fault Tree Causes and Corrections*

Identification	Probable Cause and Correction
(1) Loss of vacuum sealing	Due to extreme thermal or mechanical shock, the ICP source discharge tube has fractured, or the O-ring seals around the discharge tube have developed a leak. Check for vacuum leaks around the ICP source. Safely disconnect the ICP source and power supply, remove the ICP source from the vacuum system, remove the end-flanges, and inspect the O-rings and discharge tube. Refer to “Removing the O-Ring Seals and Discharge Tube” on page 5-14 for the procedure to inspect and replace O-rings and/or discharge tube components if necessary. Also check for condensation within the unit, which may have led to thermal shocks on the discharge tube.
(2) HFV failure	The failure is related to the function of the HFV. Safely disconnect the HFV from the ICP source and troubleshoot the HFV per recommendations in the HFV manual.
(3) No interlock	Closure of the *interlock loop* (*pin 11* to *12* of the 15-pin User port) is necessary to activate the HFV generator. Verify that the User/Generator port connections are securely attached and ensure that the loop is closed. Make certain the ICP source chassis is closed and that internal temperature of the ICP is below 65^{o} C. Ensure that interlock conditions on the HFV are satisfied. The front panel **Interlock OK** LED is lit on the HFV unit when the interlock loop is closed.
(4) No RF enable	Closure of the *RF Enable loop* (*pin 4* to *9* of the 15-pin User port) is necessary to command the RF power. Verify that the User/Generator port connections are securely attached to ensure the loop is closed. The front panel **RF ON** LED is lit on the HFV unit when the *RF enable loop* is closed.
(5) Load power setpoint signal is less than 220 mV	If the RF command is enabled, the setpoint signal needs to be greater than 220 mV in order for the RF to be turned on.
(6) Open RF path	Bad cables, worn connectors, and damaged components in the ICP source unit are some examples of conditions that prevent power delivery. A limited test can be done by replacing the ICP source with a 50-Ω dummy load to test the RF cable connections.

Table 6-1. *Fault Tree Causes and Corrections (Continued)*

Identification	Probable Cause and Correction
(7) Pressure too high or low	The ICP source has been configured to operate in a range of inlet pressures. Discharge ignition and reliable HFV tuning may be troublesome if you attempt to operate the source outside this range. Begin operation of the ICP source within the prescribed “normal range” of operation and investigate the ignition performance of the ICP as the inlet pressure is adjusted higher or lower. It may be possible to make adjustments to the FixedMatch of the ICP in order to facilitate pressures outside the factory set range. Contact AE if your process requires such changes (see “AE Global Support” on page 6-9).
(8) FixedMatch hybrid failure	The ICP source uses a FixedMatch to provide a near 50-Ω impedance to the HFV generator. Failure of the FixedMatch affects discharge ignition and operation. To check the condition of the FixedMatch, remove all ac power from the HFV power supply and the ICP source. Remove the perforated top cover of the ICP source, and visually inspect the hybrid for evidence of burns, arcs, open connections, or other damage. If damage is evident or suspected, contact AE for technical support and service (see “AE Global Support” on page 6-9).
(9) HFV DDS tuning settings not optimal	The HFV generator uses Direct Digital Synthesis (DDS) to determine the optimal frequency for driving the ICP source. Program settings have been optimized for normal operation, but not necessarily for all viable ranges of operation. Consult your HFV manual for how to program the DDS settings, or contact AE for technical support and service for your specific needs (see “AE Global Support” on page 6-9).
(10) FixedMatch hybrid requires adjustment	The FixedMatch is designed to accommodate a limited range of ICP source operation. Outside this range, the HFV will run up against its frequency limit, and the forward and reflected power will both rise in order to meet the Load Power Setpoint. It is possible to make adjustments to the FixedMatch of the ICP source in order to facilitate pressures outside the factory set range. Contact AE if your process needs require such changes (see “AE Global Support” on page 6-9).
(11) Load power setpoint too low for stable operation	In some pressure/flow conditions and for certain gases, there is a minimum required power level needed to sustain the plasma in an inductively-coupled state. Increase the setpoint power until the HFV generator settles into a stable RF frequency (±50 kHz) and the reflected power drops below 500 W. If the HFV generator operation is limited by its frequency range (1.765 to 2.16 kHz), refer to identifications (9) and (10) of this table.
(12) Unstable pressure and/or flow settings	The HFV DDS tuning algorithms are always active and can be sensitive to spikes or drop-outs in pressure. Unstable pressure conditions, which are usually sporadic and slow in their variation, will lead to variation in the HFV and ICP source operation.

Table 6-1. *Fault Tree Causes and Corrections (Continued)*

Identification	Probable Cause and Correction
(13) Forced air cooling failure leading to over-temperature fault	Forced air is used to cool the ICP source and protect internal components. Two thermoswitches, which are connected in series with the interlock loop, monitor the ambient air temperature near the top panel of the ICP source. Should the ICP source fans fail, or should the cooling air flow and temperature be inadequate, the thermoswitches will interrupt the HFV (as should be indicated by the **INTERLOCK OK** LED on the HFV front panel).
(14) Faulty User/ Generator port connections	User signals to the HFV are made through the User/Generator connections at the ICP source. Loose connections may interrupt these control and interlocking signals. Inspect and tighten all connections to ensure that these signals are being communicated appropriately.
(15) Condensation in ICP source due to wet or humid conditions	Condensation may occur within the ICP source assembly if the device is maintained under the following collective conditions: • The ICP source is operated in very wet or humid environments. • Chilled cooling water is allowed to flow in the unit when it is not being operated. • Forced-air cooling is turned off while the unit is not being operated. Should the source be activated when condensation has occurred, atmospheric arcing along the induction can result. Make certain that the ICP source is operated within specified environments and that forced air is always present on the ICP source when it is installed in a working system (see "Environmental Specifications" on page 3-3). *Note:* Condensation can also lead to thermal shock and failure of the discharge tube.
(16) Foreign object in ICP source assembly	High RF voltages and currents circulate within the ICP source assembly. ***At no time should a foreign object be inserted or placed within the ICP source.*** Such objects can lead to arcs that may damage the ICP unit and associated equipment.

AE WORLD WIDE WEB SITE

For additional product information and troubleshooting procedures, consult Advanced Energy's World Wide Web site:

- http://www.advanced-energy.com

AE GLOBAL SUPPORT

Please contact one of the following offices if you have questions:

Table 6-2. *Global Support Locations*

Office	Telephone
AE, World Headquarters 1625 Sharp Point Drive Fort Collins, CO 80525 USA	Phone: 800.446.9167 or 970.221.0108 or 970.221.0156 Fax: 970.407.5981 Email: technical.support@aei.com
AE, Voorhees, NJ 1007 Laurel Oak Road Voorhees, NJ 08043 USA	Phone: 800.275.6971 or 856.627.6100 Fax: 856.627.6159
AE, California 491 Montague Expressway Milpitas, CA 95035 USA	Phone: 408.263.8784 Fax: 408.263.8992
AE, Austin 8900 Cameron Road Suite 100 Austin, TX 78754	Phone: 512.231.4200 Fax: 512.719-9042
AE, GmbH Raiffeisenstrasse 32 70794 Filderstadt (Bonlanden) Germany	Phone: 49.711.77927.0 Fax: 49.711.7778700
AE, Japan KK TOWA Edogawabashi Bldg. 347 Yamabuki-cho Shinjuku-ku, Tokyo Japan	Phone: 81.3.32351511 Fax: 81.3.32353580
AE, Korea Ltd. Gongduk Building, 4th floor 272-6 Seohyun-Dong, Bundang-Gu, Sungam Si Kyunggi, 463-050 Korea	Phone: 82.31.705.1200 Fax: 82.31.705.276

Table 6-2. Global Support Locations (Continued)

Office	Telephone
AE, United Kingdom Unit 5, Minton Place, Market Court, Victoria Road Bicester, Oxon OX6 7QB UK	Phone: 44.1869.320022 Fax: 44.1869.325004
AE, Taiwan, Ltd. 10F-6, No. 110, Chung Shan Rd. Sec. 3, Chungho City, Taipei Hsien Taiwan 235	Phone: 886-2-82215599 Fax: 886-2-82215050
AE, China Rm. 910 Anhui Building, No. 6007 Shennan Road, Shenzhen, China 518040	Phone: 86-755-3867986 Fax: 86-755-3867984

RETURNING UNITS FOR REPAIR

Before returning any product for repair and/or adjustment, ***first follow all troubleshooting procedures***. If, after following these procedures, you still have a problem or if the procedure instructs you to, call AE Global Support and discuss the problem with a representative. Be prepared to give the model number and serial number of the unit as well as the reason for the proposed return. This consultation call allows Global Support to determine whether the problem can be corrected in the field or if the unit needs to be returned. Such technical consultation is always available at no charge.

If you return a unit without first getting authorization from Global Support and that unit is found to be functional, you will be charged a re-test and calibration fee plus shipping charges.

To ensure years of dependable service, Advanced Energy® products are thoroughly tested and designed to be among the most reliable and highest quality systems available worldwide.

WARRANTY

Advanced Energy® (AE) products are warranted to be free from failures due to defects in material and workmanship for 12 months after they are shipped from the factory (please see warranty statement below, for details).

In order to claim shipping or handling damage, you must inspect the delivered goods and report such damage to AE within 30 days of your receipt of the goods. Please note that failing to report any damage within this period is the same as acknowledging that the goods were received undamaged.

For a warranty claim to be valid, it must:

- Be made within the applicable warranty period
- Include the product serial number and a full description of the circumstances giving rise to the claim
- Have been assigned a return material authorization number (see below) by AE Global Support

All warranty work will be performed at an authorized AE service center (see list of contacts at the beginning of this chapter). You are responsible for obtaining authorization (see details below) to return any defective units, prepaying the freight costs, and ensuring that the units are returned to an authorized AE service center. AE will return the repaired unit (freight prepaid) to you by second-day air shipment (or ground carrier for local returns); repair parts and labor will be provided free of charge. Whoever ships the unit (either you or AE) is responsible for properly packaging and adequately insuring the unit.

Authorized Returns

Before returning any product for repair and/or adjustment, call AE Global Support and discuss the problem with them. Be prepared to give them the model number and serial number of the unit as well as the reason for the proposed return. This consultation call will allow Global Support to determine if the unit must actually be returned for the problem to be corrected. Such technical consultation is always available at no charge.

Units that are returned without authorization from AE Global Support and that are found to be functional will not be covered under the warranty (see warranty statement, below). That is, you will have to pay a retest and calibration fee, and all shipping charges.

Warranty Statement

The seller makes no express or implied warranty that the goods are merchantable or fit for any particular purpose except as specifically stated in printed AE specifications. The sole responsibility of the Seller shall be that it will manufacture the goods in accordance with its published specifications and that the goods will be free from defects in material and workmanship. The seller's liability for breach of an expressed warranty shall exist only if the goods are installed, started in operation, and tested in conformity with the seller's published instructions. The seller expressly excludes any warranty whatsoever concerning goods that have been subject to misuse, negligence, or accident, or that have been altered or repaired by anyone other than the seller or the seller's duly authorized agent. This warranty is expressly made in lieu of any and all other warranties, express or implied, unless otherwise agreed to in writing. The warranty period is 12 months after the date the goods are shipped from AE. In all cases, the seller has sole responsibility for determining the cause and nature of the failure, and the seller's determination with regard thereto shall be final.

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