THE ADVANCED ENERGY® PE 1000 GENERATOR

User Manual

PN: 5700184-D
April 1990

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ADVANCED ENERGY INDUSTRIES, INC

1600 Prospect Parkway
Fort Collins, Colorado 80525
(303) 221-4670
Telex #45-0938

PN: 5700184-D
April 1990

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. All parts and labor carry our standard 1-year warranty.

For **Customer Service**, call:

AE, Colorado office	(303) 221-0108 (24-hour line) ***Fax:*** (303) 221-5583
AE, California office	(408) 263-8784 (8 a.m. to 5 p.m. Pacific Standard Time — California only) ***Fax:*** (408) 263-8992
AE, Japanese office	81 (03) 3222-1311 ***Fax:*** 81 (03) 3222-1315
AE, German office	49 (0711) 777-87-18 ***Fax:*** 49 (0711) 777-87-00
all others	contact your local service center—see the list on the next page

In the interest of providing even better equipment, Advanced Energy Industries, Inc., reserves the right to make product changes without notification or obligation.

For more information, write Advanced Energy Industries, Inc., 1600 Prospect Parkway, Fort Collins, CO 80525.

AE Service Centers

Company Name	Phone/Fax Numbers
Vacutec AB Sweden	46 (0) 40-437270 ***Fax:*** 46 (0) 40-435538
Gambetti Kenologia snc Italy	39 (02) 9055660 ***Fax:*** 39 (02) 9052778
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Returning Units for Repair

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

If you return a unit without first getting authorization from Customer Service, and that unit is found to be functional, you will have to pay a retest and calibration fee, and all shipping charges.

Upgrading Units

AE will upgrade older units for a fee (a percentage of the current list price, based on the age of the unit. Such an upgraded unit will carry a 6-month warranty (which will be added to any time remaining on the original warranty).

WARNING

SAFE OPERATING PROCEDURES AND PROPER USE OF THE EQUIPMENT ARE THE RESPONSIBILITY OF THE USER OF THIS SYSTEM.

Advanced Energy Industries, Inc., provides information on its products and associated hazards, but it assumes no responsibility for the after-sale operation of the equipment or the safety practices of the owner or user.

This equipment produces potentially lethal high-voltage, high-current, radio frequency (RF) energy. You should read this manual and understand its contents before you attempt to hook up or operate the equipment it describes. Follow all safety precautions. **Never defeat interlocks or grounds.**

DANGER! 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.

DO NOT BE CARELESS AROUND THIS EQUIPMENT.

CONGRATULATIONS ...

On your purchase of AE's PE series generator, designed for hard use in a vacuum environment. Advanced circuit design and calibrated instrumentation make these units the most accurate, most efficient, and most versatile in the world today.

Since 1981, AE's power supplies and controllers have been contributing to a broad range of advanced technological processes such as semiconductor fabrication, optical coating, printed circuit manufacturing, glass coating, and data storage media plating. In the United States, Europe, and Asia, Advanced Energy Industries, Inc., is known for its quality products and strong customer support.

CONTENTS

READ THIS PAGE!

We know that some of you want to start the PE now and that you don't feel you have the time to read the entire manual. Below is a list of the subsections you will need to read in order to get started. We also think that you will find Overview of the Manual (page iii) and Interpreting the Manual (page v) useful. They are very short sections, and are intended to guide you through the manual.

Overview of the Manual explains the organization of the manual, so that you can more quickly find what you need. Interpreting the Manual explains the type conventions (what it means when a word appears in capitalized italic type, for instance), and what the three icons (symbols) mean.

OVERVIEW OF THE MANUAL

The main table of contents is an outline of the major topics covered in the manual. It contains only the chapter titles and the major sections within each chapter so that you can skim it and get a general idea of what is contained here, without having to look at a lot of headings. Throughout the manual, the chapter titles are printed at the top right-hand corner of each odd-numbered page.

When you turn to a chapter, you will find a detailed table of contents that lists each subheading in the chapter. This will show you which page contains the information you are looking for.

Part 1, Getting to Know Your PE 1000 Generator, contains two chapters: What It Is and How It Works. What It Is describes the PE's basic features and specifications, and discusses four typical applications.

How It Works contains a functional block diagram, a description of the front panel controls and status indicators, and important information on connectors and signal descriptions.

Part II, Operating Your PE 1000 Generator, also contains two chapters: Preparing for Use and Choosing Modes. Preparing for Use provides information on unpacking, cooling and spacing, and making connections. Choosing Modes/Settings tells you how to select remote operation for the control functions and describes operating procedures for local and remote mode.

Part III, Servicing Your PE 1000 Generator, contains one chapter, Calibration and Troubleshooting. This chapter tells you how to adjust the PE and service minor problems.

Part IV, The Advanced Energy® Load-matching Module, describes the load-matching module and tells you how to install it.

Part V, Learning More About Your PE Generator, contains a detailed description of grounding techniques.

INTERPRETING THE MANUAL

Type Conventions

To help you quickly pick out what is being discussed, the manual presents certain words and phrases in type that is different from the rest of the text. Pin and line names appear in capitalized italics (*POWCOM*). Labels that are on the PE (switches, indicators, etc.) appear in boldface capital letters (**PLASMA**). Connector names begin with a capital letter (User connector). Functions are printed in boldface lowercase letters (**on/off**).

How to Use the Symbols

Safety notes. Important safety information concerning potential harm to people.

Warning notes. Important notes concerning possible harm to this unit or associated equipment.

Operating notes. More thoughts on how to use the extended features provided.

PART I

GETTING TO KNOW YOUR PE 1000 GENERATOR

PART I

CONTENTS

PART I

GENERAL DESCRIPTION

Power Regulation

The PE regulates power: The output power stays constant while the current and voltage vary within the ranges specified by the internal circuitry. The output power level is determined by a 10-turn potentiometer on the front panel (the **LEVEL** knob) or by an input signal sent to the User connector. The front panel **PLASMA** LED lights when over 1% of the current specified by the current range is reached. Under normal conditions, 1% of full-scale current is sufficient to ignite a plasma.

Interfaces

You can control the output and monitor the operation of the PE from the front panel (local mode) or from a remote location (remote mode). You can combine local and remote modes to create an interface to meet your specific needs. For example, you can turn the output on and off from the front panel while setting the output power level from a remote location. You can monitor power, voltage, current, and setpoint simultaneously in both modes.

Monitor

The PE measures the actual current and voltage at the output connector and uses these values to calculate the actual power. Actual current, voltage, and power are displayed on the front panel **MONITOR** meter and signals representing these values are available at the User connector.

Setpoint

You specify the desired power level with the **LEVEL** knob or through the User connector. The PE calculates the actual output power at the output connector and displays this value on the **MONITOR** meter. If the desired level and the actual level are within 0.2% of each other, the unit is operating within setpoint. This is indicated on the front panel by a solidly lit **SETPOINT** LED. If these values differ by more than 0.2%, the unit is out of setpoint, and the **SETPOINT** LED flashes. Therefore, although the desired power level is not indicated on the front panel, the actual power indicates the desired level when you are within setpoint.

PART I

TYPICAL APPLICATIONS

The PE should be properly grounded through its input power ac ground. Additionally, you must take care that the cable shielding is connected properly. This is the best way to minimize, if not eliminate, RFI (radio frequency interference) problems. In some cases, RFI will cause chattering valves or other erratic behavior.

The next pages contain illustrations and discussions of special considerations for four typical applications of the PE generator.

Plasma Etching/Deposition

This figure shows a typical chamber configuration for plasma etching and plasma deposition systems. This system could be either single wafer or batch.

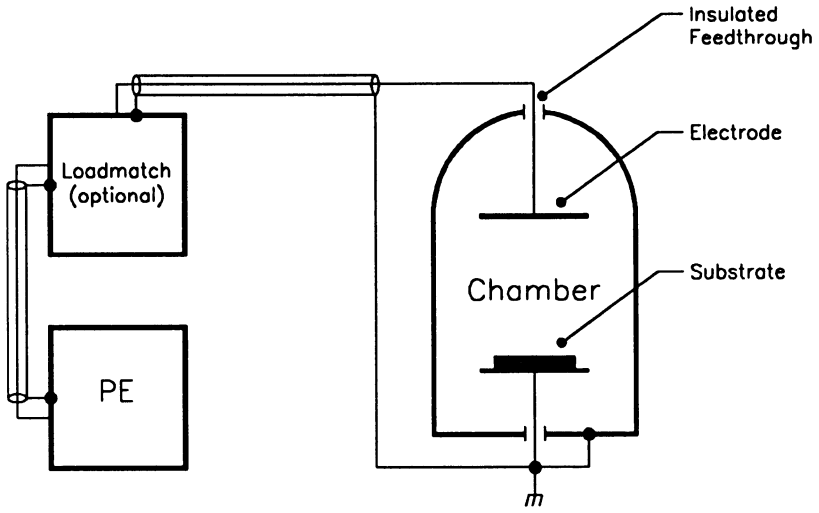


Figure 1-1. Typical configuration for plasma etching/deposition.

Reactive Ion Etching

This illustration shows a typical configuration for reactive ion etching. Having a powered lower electrode instead of a powered upper electrode presents no unique electrical hook-up problems. The same care regarding good RF grounding and good mechanical connections is required in this application as is required in any application.

This application typically involves lower pressures than are used for plasma etching, and hence it has a different impedance. With lower pressure also comes the potential for a more difficult "strike voltage."

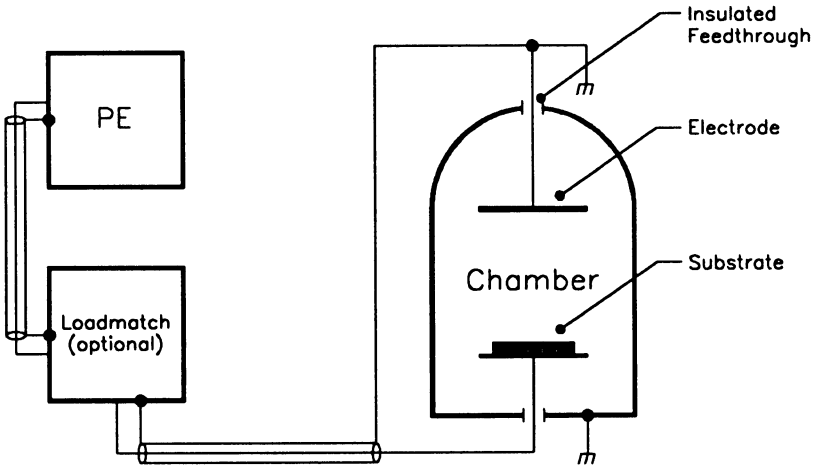


Figure 1-2. Typical configuration for reactive ion etching.

RF Sputtering

This illustration shows a typical sputter application, where the target shield, substrate, and chamber walls are referenced to ground. This could be a planar magnetron or an "S" gun installation.

Improper grounding of the PE will result in RFI, which is often evidenced in this application by chattering valves or your computer behaving erratically.

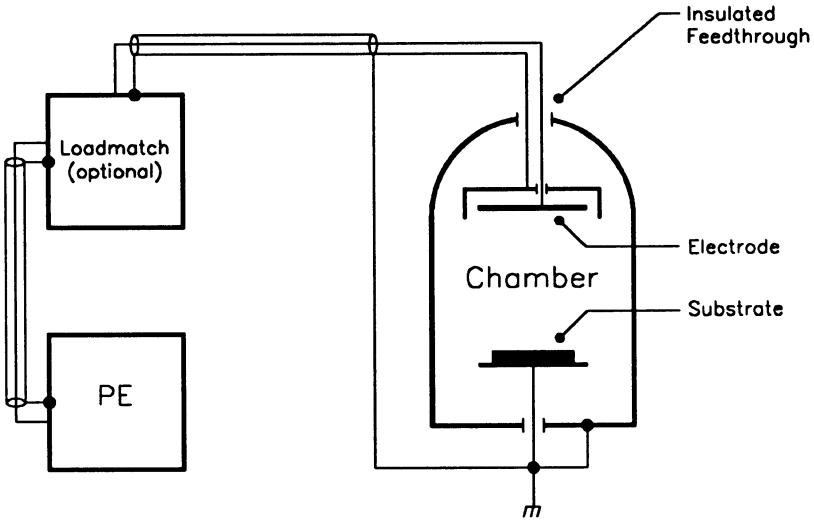


Figure 1-3. Typical configuration for RF sputtering.

DC Sputtering with RF Bias

WARNING! You must place an ac blocking filter in series with the output of the dc power supply if your system uses a dc power supply in combination with an ac power supply that has an output frequency greater than 50 kHz.

In this application (see the illustration on the next page), proper installation of the RF generator is critical to proper operation of the system. Proper installation includes good, solid RF grounding and dc installation.

An RF filter should be put on the dc input to the chamber. Radio frequencies will wreak havoc with the typical dc magnetron power supply.

The purpose of this type of installation is to elevate the potential on the biased substrate. With proper installation and programming the PE will be able to control the developed dc bias on the substrate.

This extra control parameter (RF bias) may provide higher deposition rates or better film structure. The results will vary with each application. Biasing alters the ion and acceleration potentials, and these altered potentials provide the desired results.

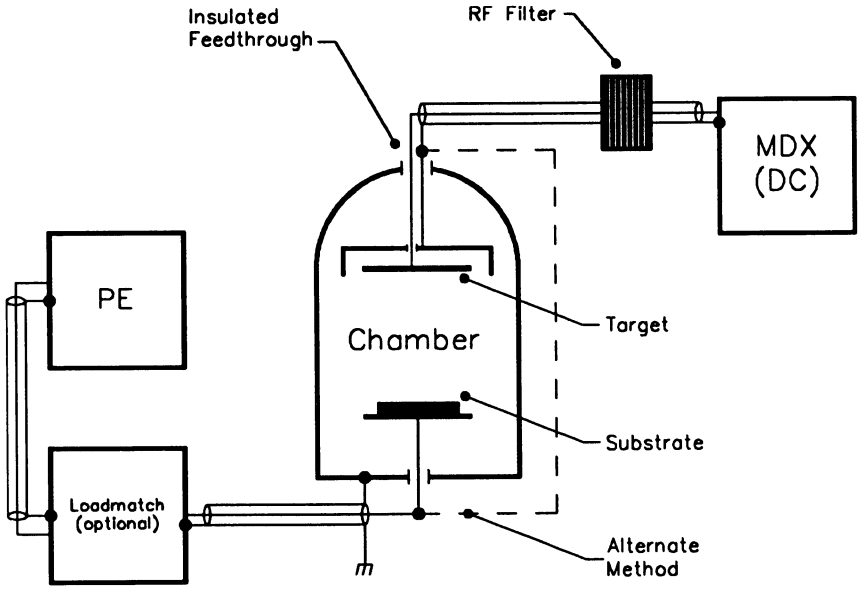


Figure 1-4. Typical configuration for dc sputtering with RF bias.

SPECIFICATIONS

Functional Specifications

Controlling Modes	Local (through the front panel), remote (through the User connector).
Control Signal Sources	Power output can be controlled by internal analog signals entered from the front panel, or by external analog signals provided from the User connector.
Power Output	Low-frequency output controlled in constant power regulation.
Interlock Supervision	When connected to a safety switch, the interlock string disables the unit if the switch is opened.
Status Indicators	LEDs on the front panel show the status of interlocks, output enable, plasma ignition, and setpoint level. Remote or local control is also shown.
Fault Conditions	Overtemperature and high and low voltage conditions shut off the output power. An arc condition momentarily shuts off the output power.
Load-matching Transformer	Optional load-matching transformer. The transformer's taps allow the PE to efficiently transfer power to a wide range of loads.

Physical Specifications

Input Voltage	115 V ac ± 10%; 50/60 Hz; single phase.
Input Current	13 A nominal (full power); 0.70 power factor; 15 A fuse.
Output Power	1250 W at 550 V nominal output.
Output Frequency	40 kHz ± 100 Hz.
Measurement Accuracies	Power: ± 2% of full scale. Voltage: ± 2% of full scale. Current: ± 2% of full scale.
Repeatability	Power: ± 0.25% of full scale. Voltage: ± 0.25% of full scale. Current: ± 0.25% of full scale.
Power Regulation	± .25% over line and load variations.
Ambient Temperature:	
Operating	Minimum 0°C, maximum 40°C (maximum value of average over 24 hr.: 35°C). If the units are enclosed in cabinets, the operator will ascertain the temperature at the place of installation and ensure that the maximum ambient temperature is not exceeded.
Storage	Minimum -25°C, maximum 55°C.
Transportation	Minimum -25°C, maximum 55°C (for short periods of up to 24 hr., the maximum is 70°C).
Coolant Temperature	Air (gas) minimum 0°C, maximum 35°C.
Coolant Flow Parameters:	
Contamination	Cooling air should be free of corrosive vapors and particles, conductive particles, and particles that could become conductive after exposure to moisture.

Humidity	15-85% relative humidity; no condensation or icing.
Atmospheric Pressure:	
Operating	800 mbar minimum (approx. 2000 m above sea level).
Storage	800 mbar minimum (approx. 2000 m above sea level).
Transportation	660 mbar minimum (approx. 3265 m above sea level).

Cooling	0°C to 45°C ambient; 9 inches of clearance to rear of unit required; 1 inch clearance on sides and top of unit.
Humidity	0%-92% noncondensing.

CONTENTS

PART I

THEORY OF OPERATION

The PE converts ac line power into rectified dc voltage. The dc voltage provides an unregulated source for high-frequency inverters. The inverters convert the unregulated dc voltage to high-frequency ac voltage.
The following sections describe the functional units of the PE power supply. Below is the PE block diagram.

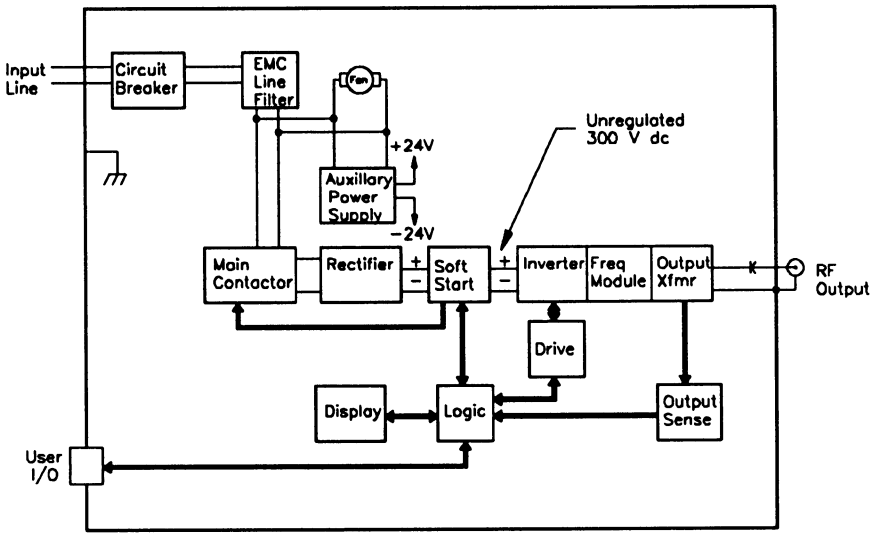


Figure 2-1. PE block diagram.

Circuit Breaker/EMC Filter

The circuit breaker located on the rear panel automatically protects the system wiring in the event of a failure. In some units a fuse is used instead of a circuit breaker. The internal EMC filter reduces the amount of high-frequency noise conducted to the power lines.

Main Contactor/Rectifier

The main contactor applies incoming ac voltage to the rectifier. The rectifier converts the ac input to unregulated dc voltage.

Soft Start

The soft start circuit prevents large surge currents on the input line when the output power is enabled. The circuit uses a 50 Ω resistor to charge the dc filter capacitor and then shorts this resistor when the dc filter capacitor is charged to the normal operating level. The dc filter capacitor provides a low stable input impedance for the dc-to-ac regulator.

Auxiliary Power Supply

The auxiliary power supply is a 50/60 Hz transformer with an isolated 40 V ac center-tapped winding. The secondary winding generates ±24 V dc to power the control electronics.

Drive Board

The drive board provides isolation between the control logic and the inverter.

Inverter/Frequency Module/Output Transformer

The inverter chops the dc voltage into a square wave ac voltage that passes through a series resonant circuit to produce a sine wave. This sine wave passes through an isolation (output) transformer.

Output Sense

The output sense converts and isolates output voltage and current to logic levels.

Display/User Connector

The display provides status information and control from the front panel. The User connector provides monitoring and control for a remote interface.

Logic

The logic provides fault protection, on/off control, and power regulation.

CONNECTORS

Input Power Connector

The ac line connection is made through a 9-ft. power cord and a standard 115-V wall plug. Figure 3-2 on page 3-8 shows the location of the input cord.

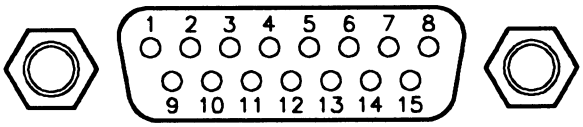
Output Power Connector

The UHF female output connector on the PE rear panel uses a standard UHF male plug and RG-8 coaxial cable. There is no practical limit to the length of the cable. Figure 3-2 on page 3-8 shows the location of the output connector.

The UHF male connector and cable are not provided with the PE but are available through AE's Customer Service Department. AE part numbers: 4801061 (cable) and 3521003 (connector).

User Connector

The User connector, located on the rear panel, is a 15-pin, male, D subminiature, insulated connector. The User connector is shown below. A female cheater plug is shipped with the unit. The cheater plug is wired to allow operation from the front panel. See page 3-10 for details on the User connector.



Analog output signals are 0-5 V dc in reference to *SIGCOM* and have 100 Ω of impedance. An analog input is a 0-5 V dc signal referenced to *XSIG.A-*. Both *XSIG.A-* and *XSIG.A+* must operate between 0 V and 10 V in reference to *SIGCOM*.

All input digital logic levels are as follows:

Low:
-15 V dc to 3 V dc
Note: A contact closure to *POWCOM* is a sufficient low-logic level.

High:
11 V dc to 30 V dc
Note: An open to the inputs is a sufficient high-logic level.

The Pin-description Table below gives a brief description of each pin; for a more detailed discussion, see the page number referenced with each pin. Note: An ".A" appended to a pin name indicates an analog signal; a ".D" indicates a digital signal. A bar over a signal name indicates the signal is true when low.

Pin-description Table

Pin	Name	Description	Refer to
1	*POWCOM*	digital common	p. 3-11
2	*+24V*	can be either digital or analog, unregulated 24-V supply	p. 3-11
3	unassigned		
4	*XV.A*	voltage out, output, 0-5 V	p. 3-11
5	*XSIG.A-*	program level (-), input, 0-5 V, used with *pin 13*	p. 3-11
6	*$\overline{XSPT.D}$*	setpoint, output, 0-15 V	p. 3-11
7	*$\overline{INTLK.D}$*	interlock, input, low -15 V dc to 3 V dc (a contact closure to *POWCOM* is sufficient low-logic level), high 11-30 V dc	p. 3-11
8	unassigned		
9	*SIGCOM*	analog common	p. 3-12
10	unassigned		
11	XI.A	current out, output, 0-5 V	p. 3-12
12	*XP.A*	power out, output, 0-5 V	p. 3-12
13	*XSIG.A+*	program level (+), input, 0-5 V, used with *pin 5*	p. 3-12
14	*XOFF.D*	source off, input, low -15 V dc to 3 V dc (a contact closure to *POWCOM* is sufficient low-logic level), high 11-30 V dc, used with *pin 15*	p. 3-12

Pin	Name	Description	Refer to
15	*$\overline{XSON.D}$*	source on, input, low -15 V dc to 3 V dc (a contact closure to *POWCOM* is sufficient low-logic level), high 11-30 V dc, used with *pin 14*	p. 3-13

FRONT PANEL CONTROLS

The controls described below allow operation of the PE from the front panel. Figure 2-2 on page 2-10 shows the front panel.

POWER

Turns line power to the PE on and off.

OUTPUT

ON turns the output power on if all interlocks are satisfied and *XOFF.D* (*pin 14*) is tied to ground (*POWCOM, pin 1*). When the output is turned on, the PE produces the power specified with the **LEVEL** knob. **ON** works only in local mode.

OFF turns the output power off and resets the interlock string after the interlock conditions have been satisfied. **OFF** resets in both local and remote modes. In remote mode, if **output on/off** is configured for two-wire control, the power remains off only as long as the switch is held in the **OFF** position. See page 3-14 for more information on remote control for **output on/off**.

LEVEL

Selects the desired power level. The **LEVEL** potentiometer has 10 turns and can be locked in position by rotating the locking skirt clockwise.

REMOTE/LOCAL (LEVEL)

Determines whether the desired power level is controlled from the front panel or the User connector. To select the desired mode, rotate the two-position switch with a standard screwdriver. For more information on selecting remote and local mode, see page 4-3.

REMOTE/LOCAL (OUTPUT)

Determines whether the output power is turned on and off from the front panel or the User connector. To select the desired mode, rotate the two-position switch with a standard screwdriver. For more information on selecting remote and local mode, see page 4-3.

DISPLAY

Displays actual output voltage, current, or power on the **MONITOR** meter. The middle or neutral position displays power in kilowatts. The upper and lower positions display voltage and current, respectively. The PE measures voltage and current at the output connector and uses these values to calculate power.

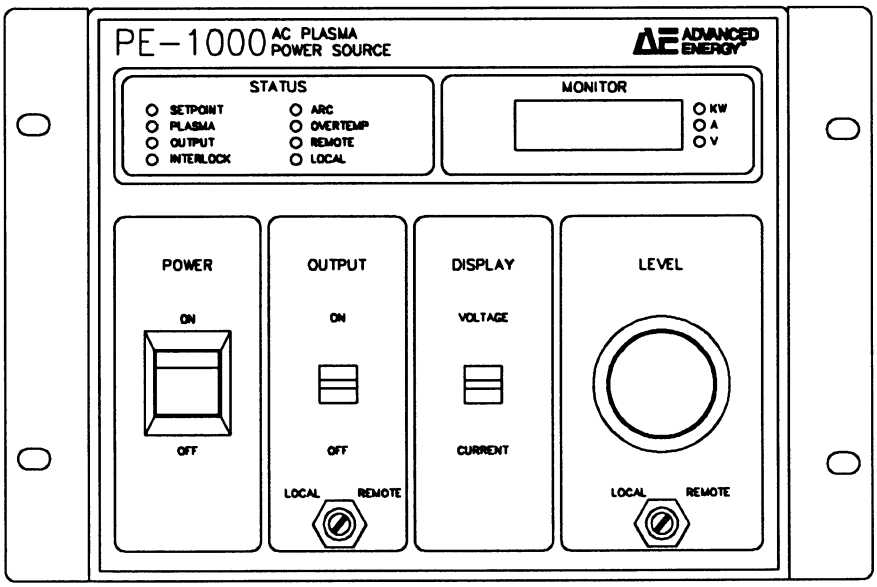


Figure 2-2. PE front panel.

STATUS INDICATORS

The PE power supply can be monitored by checking the following **STATUS** LEDs on the front panel.

INTERLOCK	Lights when all interlocks are satisfied. Flashes when the interlock chain is broken. After establishing the interlock chain, the interlock LED flashes until it is reset with either the **OUTPUT** switch or the *XOFF.D* signal *(pin 14)*. Goes out when the User connector is not connected, the **OUTPUT OFF** momentary rocker position is actuated, or *XOFF.D (pin 14)* is active (high).
OUTPUT	Lights when the main contactor is closed, and the power supply is ready to deliver power.
PLASMA	Lights when more than 1% of the full-scale output current has been reached (normally indicates plasma ignition).
SETPOINT	Lights when the output power is within 0.2% of the desired output power level. Flashes when there is a plasma indicated, but output power is further than 0.2% from the desired output power level. Goes out when unit produces less than 1% of full-scale output current.
LOCAL	Lights to indicate that the unit is being controlled through the front panel.
REMOTE	Lights to indicate that the unit is being controlled through the User connector.

OVERTEMP	Flashes when the temperature of the unit exceeds the factory-set limit. This condition causes the unit to turn off until the temperature sensor cools and the supply is reset by setting the **OUTPUT ON/OFF** switch momentarily to **OFF**. Goes out when the operating temperature is normal.
ARC	Lights when an arc or an abnormally low process impedance occurs. The supply turns off within 0.1 ms of sensing this condition, withdraws the energy from the output power components, and in 3 ms reapplies power. The **ARC** indicator lights for 1 sec. after such an event is sensed.

PART II

OPERATING YOUR PE 1000 GENERATOR

PART II

CONTENTS

SETTING UP

Unpacking

Unpack and inspect your power supply carefully. Check for obvious physical damage. If you do see signs of shipping damage, contact Advanced Energy Industries, Inc., and the carrier immediately. Save the shipping container for submitting necessary claims to the carrier.

Cooling Requirements

For the PE to be sufficiently cooled, the rack must be configured to:

- bring in ambient-temperature air (45°C maximum)
- distribute input air to the power supplies
- prevent air from recirculating outside of each power supply
- exhaust the hot air from the rack with minimal airflow restriction

WARNING! Prevent exhaust air from circulating back and becoming input air.

You may need to add air baffles to the rack to prevent exhaust air from recirculating.

Spacing Requirements

- The clearance between either side of the PE and the enclosure must be 3 inches (76 mm).
- The clearance between the top of the PE and the top of the enclosure must be 1 inch (25 mm).
- The clearance between the rear of the PE and the enclosure must be 9 inches (229 mm), with adequate ventilation.

Figure 3-1 on page 3-6 illustrates the spacing requirements for PE units stacked in a rack.

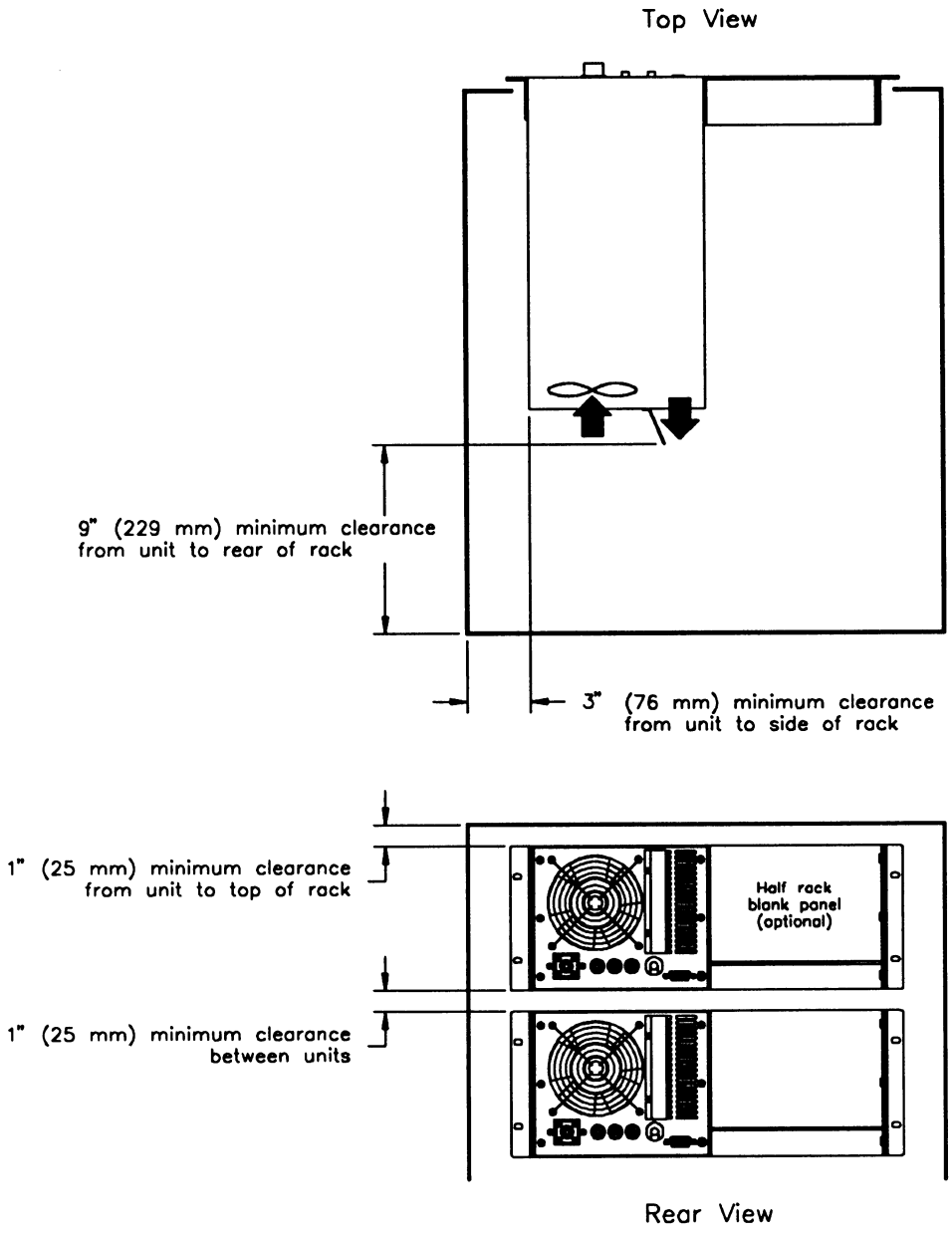


Figure 3-1. Rack configuration.

MAKING REAR PANEL CONNECTIONS

Grounding

A protective earth terminal stud is located to the right of the User connector (see foldout of rear panel, page 3-8). Attach the ground stud to the system ground with at least 14 guage, stranded wire. For more information on grounding, refer to the Hook-up notes on page Grnd-1.

DANGER! Connect the protective earth terminal on the PE rear panel to protective earth/ground before making any other connection.

For optimum performance, ground the chassis stud to the chamber ground.

Connecting Input Power

The PE 1000 requires 115-V, single-phase, 50/60 Hz input power. To connect the input, place the POWER switch in the OFF position and attach the line cord to the 115-V, single-phase with ground. Figure 3-2 shows the PE rear panel.

WARNING! Once connections are complete, lethal voltages are potentially present at the output connector. Be sure this connector is terminated and follow normal safety precautions when the system is operating.

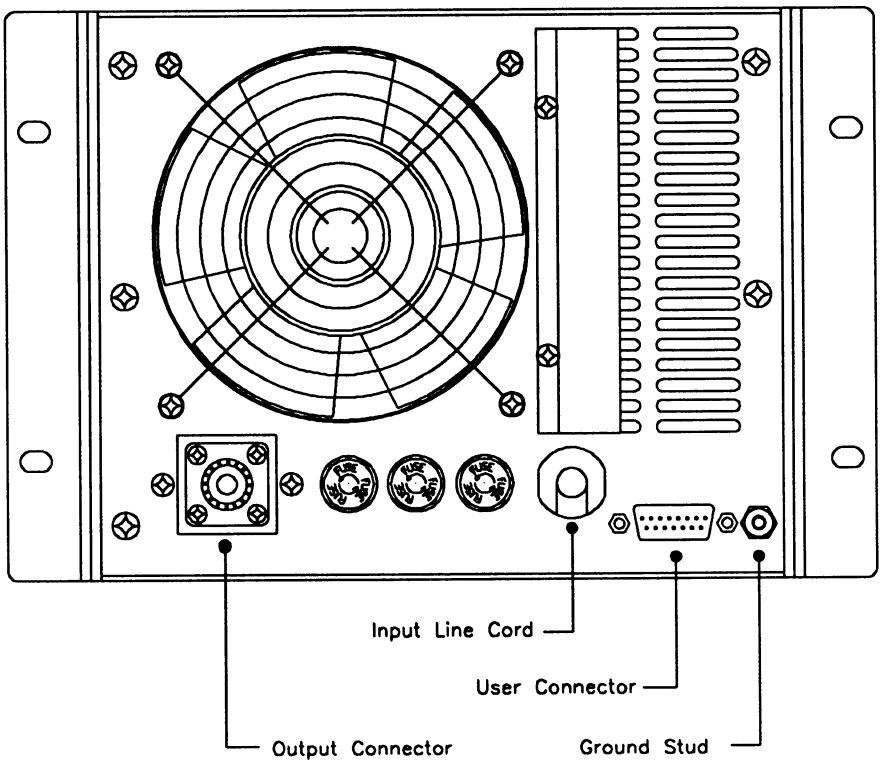


Figure 3-2. PE rear panel.

Connecting Output Power

The output power connector requires a standard UHF plug. A typical combination is an Amphenol part #83-822 (Mil PL259) and RG-8 cable. There is no practical limit to the length of the cable. Figure 3-3 shows the RG-8 cable. Use the following instructions to prepare the cable:

1. Strip the cable; be careful not to nick the braid, the dielectric, or the conductor. Tin the exposed conductor.
2. Slide the coupling ring onto the cable. Screw the coupling body onto the cable.
3. Solder the braid through the solder holes in two places. Solder the conductor to the center contact.
4. Clean the cable in a flux bath.
5. Screw the coupling ring on the body.
6. Conduct a high-potential test for the insulation. Hi-pot the insulation to 3 kV dc between the center conductor and the outside shield.

DANGER! When conducting a high-potential test, high voltages are present. Use caution.

The unit is shipped with a dc-blocking capacitor in series with the center lead of the output connector. The capacitor is rated for full-output current and 400 V of dc bias or self bias of either polarity. The output connector shield is normally shipped ungrounded.

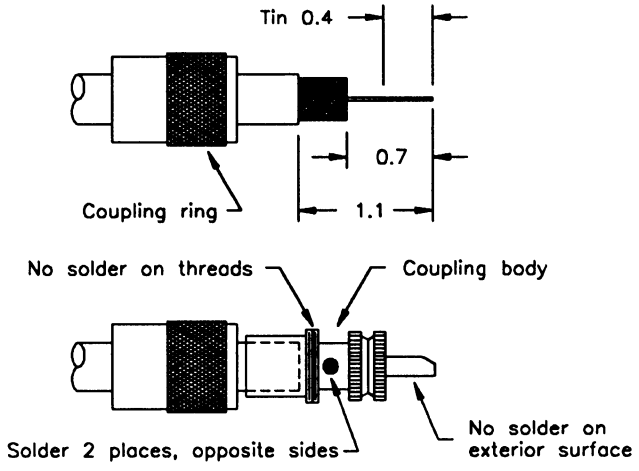


Figure 3-3. RG-8 coaxial cable.

Configuring the User Connector

The user interface for the PE is a 15-pin, male, D-subminiature connector located on the back panel. Figure 3-4 shows the connector. The User connector allows you to control and monitor the PE from a remote interface.

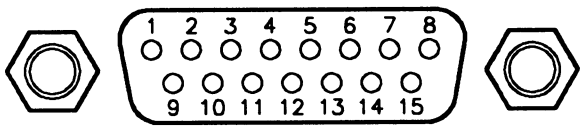


Figure 3-4. 15-pin User connector.

Four signals can be used to control the PE remotely: *XOFF.D* turns the output off, $\overline{XSON.D}$ turns the output on, and *XSIG.A+* and *XSIG.A-* determine the output power level. These signals control the unit when the **OUTPUT LOCAL/REMOTE** and **LEVEL LOCAL/REMOTE** switches are in **REMOTE**. *(XOFF.D* is also used in local mode.)

The front panel **LOCAL/REMOTE** switches are independent, so you can set them in different modes. For example, you can control **output on/off** from the front panel and **output power level** from a remote location.

Four continuous output signals — *XV.A*, *XI.A*, *XP.A*, and $\overline{XSPT.D}$ — can be used to monitor the PE's voltage, current, power, and setpoint. Each of these outputs is an independent signal that can be monitored simultaneously from both the front panel and a remote interface. These signals are not affected by the positions of the **OUTPUT LOCAL/REMOTE** and **LEVEL LOCAL/REMOTE** switches on the front panel.

A detailed description of each signal description begins on the next page. Following the signal descriptions are wiring diagrams that show configurations for the output on/off, output power level, monitoring, setpoint, and interlock signals.

Signal Descriptions: User Connector Pins

The following section gives a detailed description of each pin on the User connector.

pin 1. POWCOM. This signal is a dedicated ground that returns to the internal system ground, then the chassis ground, and finally to the safety ground. All digital connections are referenced to *POWCOM*.

pin 2. 24V. This signal is a source of unregulated voltage between 22 V and 35 V with a 0.25-W, 100 Ω resistor in series. It may be used as a low-current (maximum 50 mA) auxiliary power source (see the discussion of *pin 6*, $\overline{XSPT.D}$).

pin 3. unassigned

pin 4. XV.A. This output signal provides a fully buffered 0-5 V dc signal representing 0 V to the full-scale output voltage of 600 V rms. Its impedance is 100 Ω.

pin 5. XSIG.A-. This input signal and *XSIG.A+* (*pin 13*) are a differential pair that linearly control the output power level of the supply. These signals control the power level when the **LEVEL REMOTE/LOCAL** switch on the front panel (units built after 2/6/89) ***or*** the DIP switch on the logic board (units built prior to 2/6/89) is in the **REMOTE** position. See page 4-3 for more information on selecting remote control. A 0-5 V dc input provides linear control from 0 W to full power. The impedance of this line is 1 MΩ. The common mode range is 0-10 V.

pin 6. $\overline{XSPT.D}$. This output signal confirms that the power supply is delivering power at the programmed setpoint. The $\overline{XSPT.D}$ output is a signal FET switch referenced to *POWCOM*. The switch will sink 500 mA to drive most relays and will withstand 60 V open circuit. There is a 1-W, 57-V zener diode from the $\overline{XSPT.D}$ connection to *POWCOM*; this zener absorbs relay energy and protects the FET. To develop a logic output, place a resistor (2 kΩ minimum) between *pin 2* and $\overline{XSPT.D}$.

pin 7. $\overline{INTLK.D}$. This input signal is a secondary **off** command that turns the unit off in the event of a high-logic level in the interlock line. It is internally pulled up to 15 V dc through a 10 kΩ resistor. The interlock line is typically connected by the operator to a safety switch, or a series of safety switches, referred to as an interlock string. These switches protect people, process, and equipment.

With the interlock string incomplete, the power supply's main contactor will not close. If the interlock string is broken while the contactor is closed, the output power is disabled within 1 ms. The **INTERLOCK** LED flashes when the interlock string is broken. The interlock requirements must be satisfied to reset the **INTERLOCK** LED.

pin 8. unassigned

pin 9. SIGCOM. This signal is a dedicated ground that returns to the internal system ground, then the chassis ground, and finally to the safety ground. All analog connections are referenced to *SIGCOM.*

pin 10. unassigned

pin 11. XI.A. This output signal provides a fully buffered 0-5 V dc signal representing 0 A to the full-scale output current of 2.5 A. Its impedance is 100 Ω.

pin 12. XP.A. This output signal provides a fully buffered 0-5 V dc signal representing 0 W to full-scale output power. Its impedance is 100 Ω.

pin 13. XSIG.A+. This input signal and *XSIG.A-* (*pin 5*) are a differential pair that linearly control the output power of the supply. This control point is active when the **LEVEL REMOTE/LOCAL** switch on the front panel (units built after 2/6/89) ***or*** the DIP switch on the logic board (units built prior to 2/6/89) is in the **REMOTE** position. See page 4-3 for more information on selecting remote control. A 0-5 V dc input provides linear control from 0 W to full power. The impedance of this line is 1 MΩ. The common mode range is 0-10 V.

pin 14. XOFF.D. This input signal duplicates the **off** function of the front panel **OUTPUT ON/OFF** switch. A high logic level (10-30 V dc) overrides all other commands and forces the output off, opens the main contactor, and resets any interlock or overtemperature faults.

XOFF.D. is internally pulled up to 15 V through a 10 kΩ resistor. Circuit delay is less than 1 ms. While *XOFF.D* is active, only the **REMOTE** or **LOCAL** LED will light.

pin 15. $\overline{XSON.D}$. This input signal replaces the **on** function of the front panel **OUTPUT ON/OFF** switch when the **OUTPUT REMOTE/LOCAL** switch on the front panel (units built after 2/6/89) **or** the DIP switch on the logic board (units built prior to 2/6/89) is in the **REMOTE** position. See page 4-3 for more information on selecting remote control. A low logic level (-15 to 3 V dc) turns the supply on. *XOFF.D* must be low for $\overline{XSON.D}$ to be active.

$\overline{XSON.D}$ is internally pulled up to 15 V through a 10 kΩ resistor. While $\overline{XSON.D}$ is active, the main contactor remains closed, and the front panel **OUTPUT** LED lights.

Wiring Options

Front Panel (Local) Control

To control **output on/off** from the front panel, *XOFF.D (pin 14)* and *$\overline{INTLK.D}$ (pin 7)* must be low. A connection to *POWCOM (pin 1)* is a sufficient low-logic level. When controlling **output on/off** in local mode, *$\overline{XSON.D}$ (pin 15)* is disabled.

For local control of **output on/off** the **OUTPUT LOCAL/REMOTE** switch on the front panel must be in the **LOCAL** position. For local control of **output power level** the **LEVEL LOCAL/REMOTE** switch on the front panel must be in the **LOCAL** position.

Remote Control — Output On/Off

You can select either a two-wire or a three-wire configuration for controlling **output on/off** in remote mode. In two-wire configuration, *XOFF.D (pin 14)* and *$\overline{XSON.D}$ (pin 15)* function as one input; in the three-wire configuration, they function independently. To control **output on/off** with three wires, you can use either one three-position, double-pole switch, or two two-position, single-pole switches.

Both *$\overline{XSON.D}$* and *XOFF.D* are pulled up through a 10 kΩ resistor, so an open circuit is a sufficient high-logic level. A contact closure to *POWCOM* is a sufficient low-logic level.

As a safety feature, the **OUTPUT ON/OFF** switch on the front panel will turn the output off while the unit is operating in remote mode. If you use three-wire control, the output remains off until you turn it on again. However, if you use two-wire control, the front panel **OUTPUT ON/OFF** switch keeps the output off only as long as you hold the switch in the **OFF** position.

Two-wire control. In a two-wire configuration, a closed contact switch pulls both $\overline{XSON.D}$ and *XOFF.D* low and turns the output on. An open switch pulls both $\overline{XSON.D}$ and *XOFF.D* high and turns the output off. Figure 3-5 shows the wiring diagram for two-wire control.

DANGER! In a two-wire configuration, the front panel OUTPUT ON/OFF switch keeps the output off only as long as you hold the switch in the OFF position.

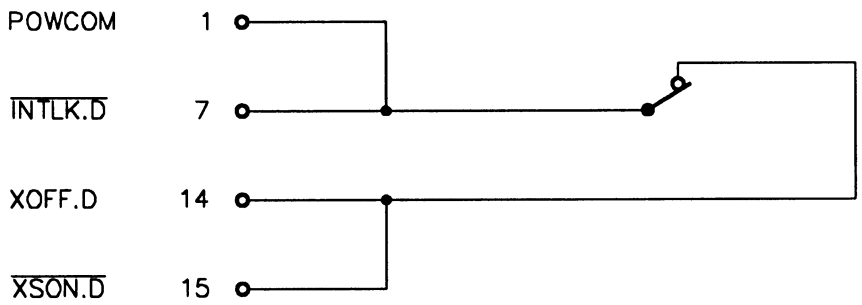


Figure 3-5. Wiring diagram for two-wire control.

Three-wire control: three-qosition, double-pole switch. Figure 3-6 shows the wiring diagram for the three-position switch. Table 3-1 shows the output states that result from the three possible switch positions. As shown in Table 3-1, you turn the output on by making momentary contact at switch B, thus closing the circuit between *XSON.D* and *POWCOM*. You turn the output off by making momentary contact at switch A, thus opening the circuit between *XOFF.D* and *POWCOM*. The stable (middle) position maintains the normal contact positions and the unit remains on or off, depending on your most recent selection.

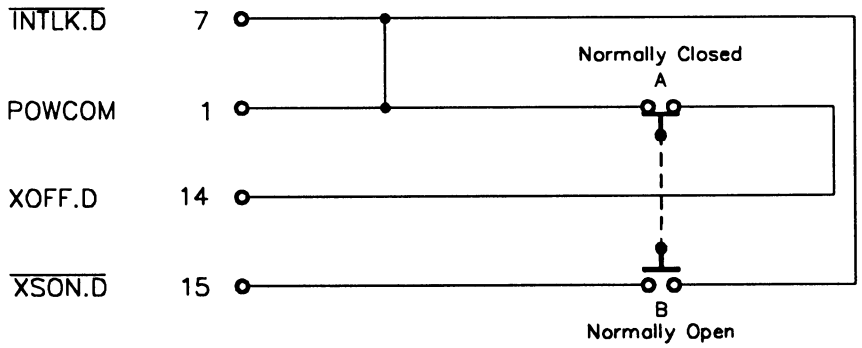


Figure 3-6. Wiring diagram for three-position, double-pole switch.

Table 3-1. Truth table for one three-position switch, showing switch contact states and resulting power output states.

Switch A Positon (Contact State)	Switch B Position (Contact State)	Power Output State
momentary (closed)	momentary (closed)	on
stable (closed)	stable (open)	last state selected
momentary (open)	momentary (open)	off

Three-wire control: two-position, single-pole switch: Figure 3-9 shows the wiring diagram for the two two-position switches. Table 3-2 shows the output states resulting from the four possible combinations of the switch position states. As with the three-position switch, momentary contact at switch B closes the circuit between $\overline{XSON.D}$ and *POWCOM* and turns the output on. Momentary contact at switch A opens the circuit between *XOFF.D* and *POWCOM* and turns the output off.

However, pulling $\overline{XSON.D}$ low turns the output on only if the momentary contact switch between *XOFF.D* and *POWCOM* is in its normal position (closed). Therefore, if both switches are held in their momentary positions, the off switch overrides the on switch.

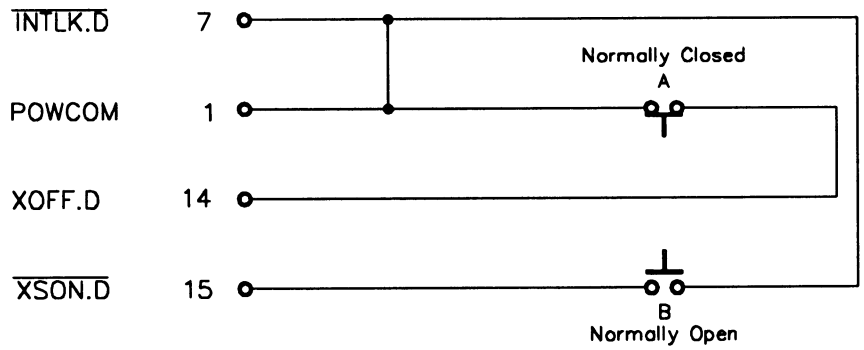


Figure 3-9. Wiring diagram for two two-position, single-pole switches.

Table 3-2. Truth table for two two-position switches, showing the power output states that result from the four possible combinations of the switch contact states.

Switch A Position (Contact State)	Switch B Position (Contact State)	Power Output State
momentary (open)	stable (open)	off
stable (closed)	momentary (closed)	on
momentary (open)	momentary (closed)	off
stable (closed)	stable (open)	last state selected

Remote Control — Output Power Level

The next figure shows how to wire input lines to specify the output power level from a remote interface. The zener diode and capacitor ensure a steady reference voltage for the input signal.

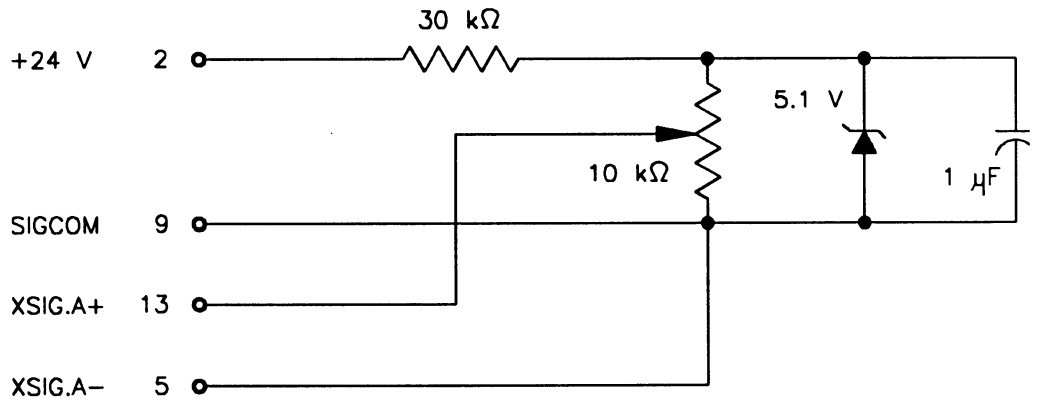


Figure 3-8. Wiring diagram for remotely specifying the output power level.

External Monitoring of Output Signals

The following figure shows how to wire output lines to monitor the voltage, current, and power levels measured at the output connector.

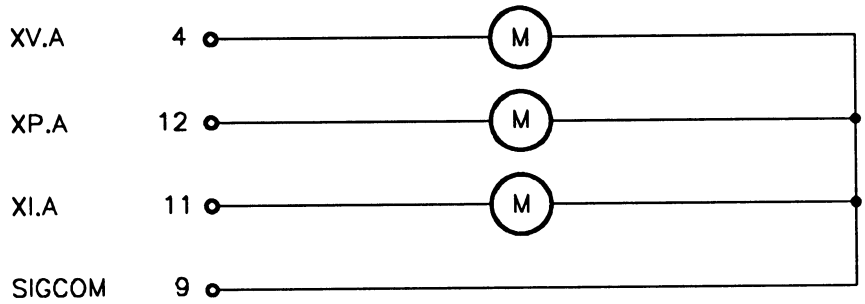


Figure 3-11. Wiring diagram for remote monitoring.

External Monitoring of Setpoint Indicator

The following diagram shows how to wire to a remote indicator to confirm that the PE is delivering power at the programmed setpoint level.

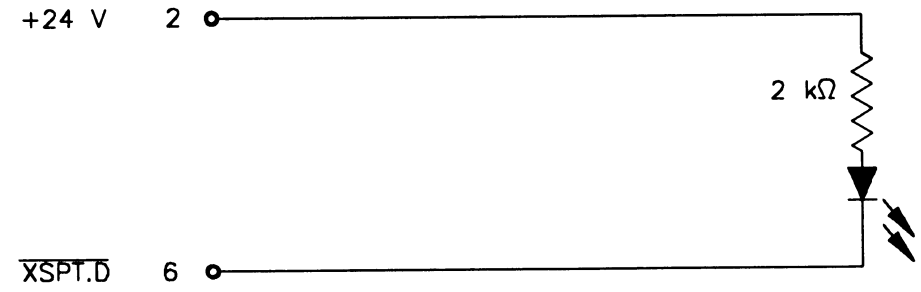


Figure 3-12. Wiring diagram for the setpoint indicator.

Cheater Plug

The cheater plug that came attached to the User connector satisfies the interlocks and disables *XOFF (pin 14)*. The plug makes it possible to run the PE right out of the box, without making any wiring adjustments. You can continue to use this plug if you want to ignore the interlock line. Figure 3-5 shows the wiring diagram for the cheater plug.

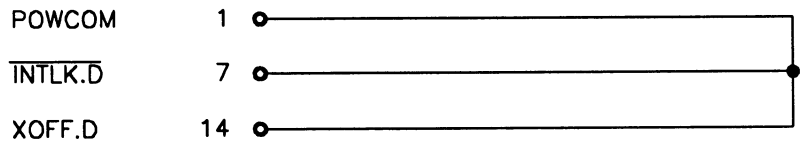


Figure 3-5. Wiring diagram for the cheater plug.

Interlock Connection

The following figure shows how to wire the interlock line by connecting it to remote sensors. For example, a sensor can be connected to a door, a pressure gauge, or a cooling system. If any condition opens a switch, the interlock string is broken and the output will turn off.

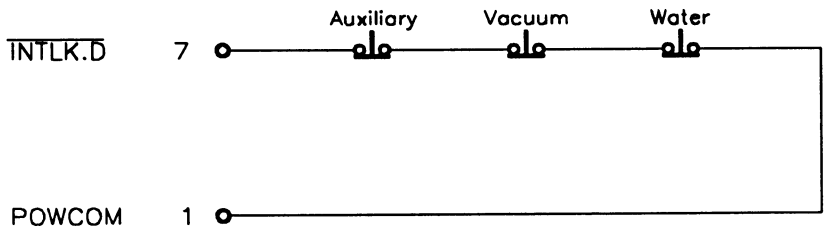


Figure 3-6. Wiring diagram for the interlock string.

CHOOSING MODES/SETTINGS

CONTENTS

Selecting Remote or Local Mode for Control Functions

The **REMOTE/LOCAL** switches on the front panel transfer control of the **output on/off** and the **output power level** control functions to the User connector. For information on configuring the User connector, see page 3-10.

In remote mode, the **output on/off** function can be wired in either a two-wire or a three-wire configuration. In two-wire configuration, *XOFF.D (pin 14)* and *$\overline{\text{XSON.D}}$ (pin 15)* function as one input; in the three-wire configuration, they function independently.

As a safety feature, the **OUTPUT ON/OFF** switch on the front panel will turn the output off while the unit is operating in remote mode. If you use three-wire control, the output remains off until you turn it on again. However, if you use two-wire control, the front panel **OUTPUT ON/OFF** switch keeps the output off only as long as you hold the switch in the **OFF** position. For more information on two-wire and three-wire control, see page 3-14.

DANGER! When the output on/off function is wired in a two-wire configuration, the front panel OUTPUT ON/OFF switch keeps the output off only as long as you hold the switch in the OFF position.

Front Panel Selection

Units built after 2/6/89 have two switches labeled **REMOTE/LOCAL** on the front panel that allow you to select remote or local mode.

If either one of the **LOCAL/REMOTE** switches is in the **REMOTE** position, the **LOCAL** LED on the **STATUS** display turns off and the **REMOTE** LED lights.

1. Turn the **OUTPUT ON/OFF** switch to **OFF**.

2. To select the mode of operation for the **output on/off** function, use a standard screwdriver to rotate the switch under the **OUTPUT ON/OFF** switch on the front panel to either **REMOTE** or **LOCAL**. Figure 2-2 on page 2-10 shows the front panel.

3. To select the mode of operation for the **output power level** function, use a standard screwdriver to rotate the switch under the **LEVEL** potentiometer on the front panel to either **REMOTE** or **LOCAL**. Figure 2-2 on page 2-10 shows the front panel.

Internal Selection

Units built prior to 2/6/89 do not have switches labeled **REMOTE** and **LOCAL** on the front panel. For these units, the control function modes and the **REMOTE** and **LOCAL** LEDs on the front panel are set using internal DIP switches.

1. Before removing the plastic safety shield, turn off the supply and let it sit for 5 min.

2. Unscrew the six phillips screws from the top of the power supply and remove the metal cover.

3. Unscrew the phillips screws from the plastic safety shield and remove the shield.

4. Three small DIP switches will be visible on the logic board. With the supply facing forward, the logic board is located in the middle of the supply and faces toward the right. The left switch controls **output on/off**, the middle switch controls the **REMOTE** and **LOCAL** LEDs on the **STATUS** display, and the right switch controls **output power level**. "Up" or C1 is for local operation and "down" or C2 is for remote operation. The DIP switches may be set in any combination. After adjusting the switches, replace the plexiglass cover.

Operating Procedure — Local Mode

After all power connections are made and the vacuum chamber is prepared, follow these steps for operating the PE in local mode. For information on making input and output power connections, see pages 3-7 and 3-9.

1. Turn the **LEVEL** knob and the locking skirt fully counterclockwise.

2. Turn the **POWER** switch to **ON**.

   At this time, the display **MONITOR**, and the **LOCAL** and **INTERLOCK** LEDs should light.
   If the **REMOTE** LED lights instead of the **LOCAL** LED, see the Troubleshooting section on page 5-7.
   If the **INTERLOCK** LED fails to light, check to see if the interlock string is satisfied.

3. Move the **OUTPUT ON/OFF** rocker switch momentarily to **ON**. You should hear a contactor close, and the **OUTPUT** LED should light.

4. Turn the **LEVEL** knob clockwise until the **MONITOR** reads approximately 10% of full output (100 W). The **PLASMA** and **SETPOINT** LEDs should light.

5. To check the output voltage or current, move the **DISPLAY** rocker switch to either the **VOLTAGE** or **CURRENT** setting.

6. Make sure the **SETPOINT** LED is lit. Gradually advance the **LEVEL** control knob to the desired power level. If the **SETPOINT** LED flashes before the desired power level is reached, check the output voltage on the **MONITOR** display. If the voltage is over 600 V, turn off the supply and see the load matching section on page 6-5.

   If the **ARC** LED is flashing, turn the **POWER** switch to **OFF** and go to the Troubleshooting Guide on page 5-7.

7. When you reach the desired power level, lock the **LEVEL** control knob by turning the locking skirt clockwise. The supply can be turned off and on, and the power will return to setpoint automatically.

Operating Procedure — Remote Mode

After all connections are made and the vacuum chamber is prepared, follow these steps for operating the PE in remote mode. For information on making input and output power connections, see pages 3-7 and 3-9. For information on configuring the User connector, see page 3-10.

1. Turn the **POWER** switch to **ON**.

   At this time, the display **MONITOR**, and the **REMOTE** and **INTERLOCK** LEDs should light.
   If the **INTERLOCK** LED fails to light, check to see if the interlock string is satisfied.

2. Turn the output on by pulling $\overline{XSON.D}$ *(pin 15)* low. You should hear a contactor close, and the **OUTPUT** LED should light.

3. Program the output power level by applying a 0-5 V signal between *XSIG.A- (pin 5)* and *XSIG.A+ (pin 13)*.

4. The **PLASMA** LED should light. If the **ARC** LED is flashing, turn the **POWER** switch off, and go to the Troubleshooting Guide on page 5-7.

5. To check if the unit is operating within setpoint, monitor $\overline{XSPT.D}$ *(pin 6)*. If the unit is within setpoint, the signal will be low. If the unit is out of setpoint, the signal will be open to ground. To pull this signal to an active logic level, you must provide an external pull-up resistor.

6. If the unit is not within setpoint, check the output voltage. If the voltage is over 600 V, turn off the supply and see the load matching section on page 6-5.

7. Monitor the voltage (*pin 4, XV.A*), current (*pin 11, XI.A*), and power *(pin 12, XP.A)*.

8. Turn the output off by allowing XOFF.D *(pin 14)* to go high.

PART III

SERVICING YOUR PE 1000 GENERATOR

PART III

CALIBRATION AND TROUBLESHOOTING

CONTENTS

CALIBRATION

Zeroing the Display Monitor

The screws used to make the zeroing adjustment are accessible through the holes in the plexiglass cover. **P ZERO** = Power Monitor; **V ZERO** = Voltage Monitor; **I ZERO** = Current Monitor.

1. Before making any zeroing adjustments, turn the **POWER ON/OFF** switch to **ON**, turn the **OUTPUT ON/OFF** switch to **OFF**, and remove the metal cover. Leave the plexiglass cover in place and let the supply sit for at least 3 min.

2. For each value, make the appropriate screw adjustment, using a small standard screwdriver, until the front panel meter reads zero.

3. Replace the top cover and the six screws.

Setting the Maximum Power Potentiometer

The maximum power potentiometer limits the output power to a predetermined value. The potentiometer functions in local or remote level control. The **MAX PWR** potentiometer is accessible through a hole in the plexiglass cover.

1. Use the **LEVEL** knob on the front panel or the appropriate User connector signal to set the power to just above the maximum desired operating level.

2. While operating at this level, turn the control **MAX PWR** potentiometer counterclockwise until the displayed power is at the desired level.

TROUBLESHOOTING GUIDE

These troubleshooting suggestions are only intended to deal with minor problems. Remember to record any pertinent information that may assist AE Customer Service in solving your problem, should these procedures fail to correct it.

Before returning any unit, please call AE Customer Service.

Danger! All servicing functions involving input and output connections can expose you to lethal voltages. Make sure you take proper safety precautions before you troubleshoot the power supply.

Sympton	Action
Front panel displays won't light.	Make certain that the PE is plugged in. Check the fuses on the rear panel. Check for loose external power connections.
No **STATUS** LEDs light except **REMOTE** or **LOCAL**.	Check the User connector for proper connection. Inspect the cable and connector for bent, broken, or recessed pins. Try reconnecting the cable.

Symptom	Action
INTERLOCK LED is flashing.	Make sure that all interlock switches in your system are closed. Check the User connector for proper connection. Use an ohmmeter to check for continuity between *POWCOM (pin 1)* and *$\overline{INTLK.D}$ (pin 7)* on the cable. If there is no continuity, trace the open back through the cable to your system until the open is found. Rectify the problem and reconnect the cable. If there is continuity, the unit should work. Inspect the cable and connector for bent, broken, or recessed pins. Try reconnecting the cable.
INTERLOCK LED won't light.	Check the User connector for proper connection. Use an ohmmeter to check for continuity between *POWCOM (pin 1)* and *XOFF.D (pin 14)* on the cable. If there is no continuity, trace the open back through the cable to your system until the open is found. Rectify the problem and reconnect the cable. If there is continuity, the unit should work. Inspect the cable and connector for bent, broken, or recessed pins. Try reconnecting the cable.
No output, **OUTPUT** LED won't light.	If you are in local mode, make sure *XOFF.D (pin 14)* is pulled low. If you are in remote mode, make sure *XOFF.D (pin 14)* and *$\overline{XSON.D}$ (pin 15)* are pulled to the correct level (see page 3-16 and 3-17 for truth tables).
PLASMA LED won't light.	If the output voltage is 700-900 V, an open load condition may exist. Check all the cable connections between the output of the power supply and the chamber. If the output voltage is not 700-900 V, call AE Customer Service.

Symptom	Action
Cannot achieve desired power level, but neither the **ARC** or **SETPOINT** LEDs are flashing.	Make sure the maximum power adjustment is set correctly. (see page 5-5)
Cannot achieve full output power and the **ARC** and the **SETPOINT** LEDs are flashing.	Disconnect the output cable from the power supply and turn on the output. If the **ARC** LED is still flashing, call AE Customer Service. Check the system or chamber for low impedance to ground. If a low impedance to ground is present, the problem must be corrected before the supply will function properly. Reconnect the power supply to the system. Turn the **OUTPUT** switch to **ON**. If the **ARC** LED is still flashing, lower the power level by 20%. After lowering the power level, if the **ARC** LED is no longer flashing, the power supply and the load voltages may not be properly matched. See the load matching section on page 6-7. If the **ARC** LED is still flashing, call AE Customer Service.
Cannot achieve full power and **SETPOINT** LED is flashing.	Check the output voltage. If it is above 600 V or below 500 V, the power supply and the load voltages may not be properly matched. See the load matching section on page 6-7. If the voltage is between 500 V and 600 V, call AE Customer Service.
OVERTEMP LED is flashing.	Make sure the fans are operating and not blocked. Turn the output off and call AE Customer Service.
Unit is running, but not functioning as expected.	Record all present voltage, current, and power values. Obtain normal voltage, current, and power operating values. Call AE Customer Service.

PART IV

THE ADVANCED ENERGY® LOAD-MATCHING MODULE

PART IV

CONTENTS

GENERAL DESCRIPTION

The load-matching modules used with PE series power supplies are designed as voltage transformers that correctly match the voltage of the power supply to the voltage requirement of the load.

At a given power level and pressure, plasma operates at a fixed voltage level much like back-to-back zener diodes. Load matching is required when this voltage is not in the operating range of the power supply.

An Advanced Energy® load-matching network consists of a multi-tap auto transformer in a separate load-matching module.

The load-matching module can handle the full rated power output of the associated power supply. It is possible to set up the load-matching module in a voltage step-up or voltage step-down configuration. This capability of stepping up or stepping down the supply's output voltage provides increased flexibility.

All of AE's load-matching modules have dc-blocking capacitors in series with the input and the output. These capacitors protect the power supply from excessive dc voltages, which are often present in processes due to the gas type and/or the configuration of the electrodes.

Connecting the Load-matching Module

DANGER! There is a high voltage potential at both the load-matching and the power supply connection points. Exercise extreme caution when working with this equipment.

WARNING! Do not make tap changes to load-matching modules while the unit's output power is on. Applying output power while changing tap settings will damage the load-matching module.

Proper load matching can be accomplished by completing the following procedures:

1. Connect the power supply directly to the load without the load-matching module.

2. Turn the **POWER ON/OFF** and **OUTPUT ON/OFF** switches both to **ON**. Slowly turn the **LEVEL** knob clockwise until the **MONITOR** meter shows the desired operating power level. Then increase the power an additional 10%.

3. If the **SETPOINT** indicator light is not flashing at this power level, a load-matching module is not required.

4. If the **SETPOINT** indicator light is flashing, a load-matching module is required.

   If you have a LM-5K or LM-10KA:
   Attach the power supply to the terminal on the load-matching module labeled **SUPPLY** and the load to the terminal labeled **LOAD**.

   If you have a LM-1.5K, LM-2.5K, or LM-5KA:
   Read the voltage level on the **MONITOR** display by moving the **DISPLAY** switch to **VOLTAGE**.

If the voltage is more than 600 V, connect the load-matching module to step up the voltage by attaching the power supply to the **SUPPLY/STEP UP** terminal and the load to the **LOAD/STEP UP** terminal.

If the voltage is below 500 V, then connect the load-matching module to step down the voltage by attaching the power supply to the **SUPPLY/STEP DOWN** terminal and the load to the **LOAD/STEP DOWN** terminal.

Note: It is important to remember that the load-matching module is designed to match the voltage of the supply to the voltage of the load. Therefore, the operating range of the power supply at full power is 520 V to 580 V.

5. Select tap 1 on the load-matching module.

6. Check the voltage on the **MONITOR** meter. If the voltage is between 520 V and 580 V, then tap 1 is the appropriate tap. If the voltage is not in this range, turn the power supply off, change to tap 2 on the load-matching module, and repeat this process (up to tap 7, if necessary) until the voltage displayed in the **MONITOR** meter is between 520 V and 580 V. Once the appropriate tap has been selected for delivering full power into a given process, that tap can be used from zero to full power.

Warranty Claims

Advanced Energy® 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 authorization number (see below) by AE Customer Service

All warranty work will be performed at an authorized AE service center (see list of contacts at the front of the manual). 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 Customer Service and discuss the problem with them. Be prepared to give them the serial number of the unit and the reason for the proposed return. This consultation call will allow Customer Service 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 Customer Service 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.

Upgrading Units

AE's products are continually changing as ways to improve them are discovered. AE is happy to upgrade older units so that they reflect recent improvements. The fee for upgrading a unit will be a percentage of the current list price, based on the age of the unit. Such an upgraded unit will carry a 6-month warranty (which will be added to any time remaining on the original warranty). Contact Customer Service for specifics on getting an older unit upgraded to the current revision level.

Warranty

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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