USER MANUAL

RFG 5500 F47

5705805-A

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User Manual

RFG 5500 F47

5705805-A

ADVANCED ENERGY®

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Introduction

READ THIS SECTION!

We know that some of you want to operate the RFG 5500 generator now and that you don't feel you have the time to read the entire manual. Below is a list of manual sub-sections you must read before getting started.

- "Theory of Operation" on page 2-1
- "Electrical Specifications" on page 3-2
- "Operator Panel Functions" on page 4-5
- "First Time Operation" on page 6-1

In addition, we recommend that you scan "Interpreting the Manual" on page 1-1. This section explains the type conventions (what it means when a word appears in capitalized italic type, for instance) and icon (symbol) definitions.

INTERPRETING THE MANUAL

Type Conventions

To help you quickly find what is being discussed, the manual presents certain words and phrases in type that are different from the rest of the text. We use the following type conventions:

- Pin and signal names appear in capitalized italics (*DUTY CYCLE.A*).
- Labels that are on the unit (switches, indicators, etc.) generally appear in boldface capital letters (**MODIFY**). Exceptions are port names, which simply begin with a capital letter (User port).
- 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.

We include 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

- Short circuit protected

1024

- High voltage

1028

- Protective earth ground

1029

- Chassis ground

1069

- Warning (refer to manual)

1027

- CE label

1020

- Non-ionizing radiation

1030

- Hot surface

1309

- NRTL

1154

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.
- 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.

Note: The RFG 5500 generator provides the one interlock capability listed below. The series-wired loop is provided to shut down the RF output in the case of an equipment malfunction or improper system configuration. A series resistance of less than 15 ohms is required to satisfy the interlock criteria.

PRODUCT SAFETY/COMPLIANCE

Certain options of this unit have been tested for and comply with the following safety and Electromagnetic Compatibility (EMC) standards and directives:

Safety and Compliance Directives and Standards

Certain options of this unit have been tested for and comply with the following safety and Electromagnetic Compatibility (EMC) standards and directives:

Table 1-1. *Electromagnetic Compatibility (EMC) Directives*

Directive	Description
89/336/EEC	EC Council directive on the approximation of the laws of the Member States relating to electromagnetic compatibility (EMC Directive)

Table 1-2. *Electromagnetic Compatibility (EMC) Standards*

Standard	Description
47 CFR Part 18	Code of Federal Regulations—Limits and methods of measurement of radio interference characteristics of industrial, scientific, and medical equipment
EN 61000-6-2	Electromagnetic Compatibility (generic immunity standard—industrial)
EN 55011	Limits and methods of measurement of radio disturbance characteristics of industrial, scientific, medical (ISM) radio frequency equipment (Class A, Group 2) (CISPR 11)

Table 1-3. *Safety Directives*

Directive	Description
73/23/EEC	EC Council directive on the harmonization of the laws of the Member States relating to electrical equipment designed for use within certain voltage limits (LVD - Low Voltage Directive)

Table 1-4. *Safety Standards*

Standard	Description
ANSI/ISA 82.02.01	Safety standard for electrical and electronic test, measuring, controlling and related equipment—general requirements (harmonized standard to IEC publication 1010-1)
EN 50178	Electronic equipment for use in electrical power installations
EN 61010-1	Safety requirements for electrical equipment for measurement, control, and laboratory use
SEMI S2-0200	Environmental, health, and safety guidelines for semiconductor manufacturing equipment
SEMI S2-93	Safety guidelines for semiconductor manufacturing equipment
SEMI F47-0200	Specification for Semiconductor Processing Equipment Voltage Sag Immunity
CSA C22.2 No. 107.1-95	General use power supplies—industrial products
UL 1012	Power units other than class 2

This device must be installed and used only in compliance with the standards listed in addition to VDE 0113, EN 60204 (IEC 204), and applicable requirements.

For more information, refer to the letter of conformance (US) or declaration of conformity (EU) accompanying the product.

The RFG 5500 generator is designed to meet the SEMI F47-0200 specification for semiconductor processing equipment voltage sag immunity. The generator will maintain full functionality throughout any single F47 event, with no loss of setpoint. The generator may limit or terminate its output power if a given line sag event exceeds the magnitude or duration defined in SEMI F47. The generator will report a setpoint status fault to the system if it is unable to maintain setpoint as a result of an excessive ac line sag condition.

Installation 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

To be in compliance with the stated directives and standards, you must meet the following conditions of use.

- This device must be used in an over voltage category II installation only. Install and operate this device with an approved isolation transformer on the ac input.
- Before making any other connection, connect the auxiliary Protective Earth ground conductor on the rear panel.
- Use only a shielded cable on the input power connector.
- Use only a shielded power cable on the output power connector.
- Install and operate this device only in a pollution degree 2 or better environment, which means an indoor location such as a computer room, office, or factory floor where only non-conductive pollution occurs during operation. Occasionally, a temporary conductivity caused by condensation occurs when the device is not operating.
- Non-standard connectors for input and/or output power must be inaccessible to the user.

Theory

GENERAL DESCRIPTION

The Advanced Energy Industries, Inc. (AE) model RFG™ 5500 generator, product is a 13.56 MHz RF generator designed to regulate its output power based on forward power. The RFG 5500 generator will provide up to 5000 watts into a 50-Ohm, non-reactive load. This particular RFG 5500 generator includes a clamp circuit to guarantee that the RF output will be less than one watt if the requested setpoint is zero. This generator also provides “setpoint tracking” that allows the RF output to closely track the user's setpoint for controlled ramping.

The RFG 5500 option 115 is designed to meet the SEMI F47-0200 specification for semiconductor processing equipment voltage sag immunity. The generator will maintain full functionality throughout any single F47 event, with no loss of setpoint.

The unit is controlled through a 15 pin analog/digital user port. There is no operator control panel provided on this unit. A numeric display and eight status LEDs are visible from the front of the unit for monitoring the generator functions. The RFG 5500 generator provides common exciter (CEX) operation allowing two or more generators to be frequency locked to each other and/or to a common system clock.

The RFG 5500 generator is designed for 19-inch rack mounting with a panel height of 7 inches. AC power for the RFG 5500 generator is to be supplied from a 4 wire (3 phase with ground), 208 VAC (nominal), 47 to 63 Hz. power source. No neutral connection is required. The unit is water cooled with no provisions or requirements for forced air cooling.

THEORY OF OPERATION

The RFG 5500 Generator is a highly efficient, intelligent source of 13.56 MHz power. Figure 2-1 and Table 2-1 outline the theory of operation.

The RFG 5500 RF generator is based on the proven design of the RFG 3000. In the RFG 5500 generator, two RFG 3000 generators are combined to produce an efficient, high-power output. Figure 2-2 and Table 2-1 outline the theory of operation. The theory of operation for the RFG 3000 begins on page 2-4.

RFG 5500 Block Diagram

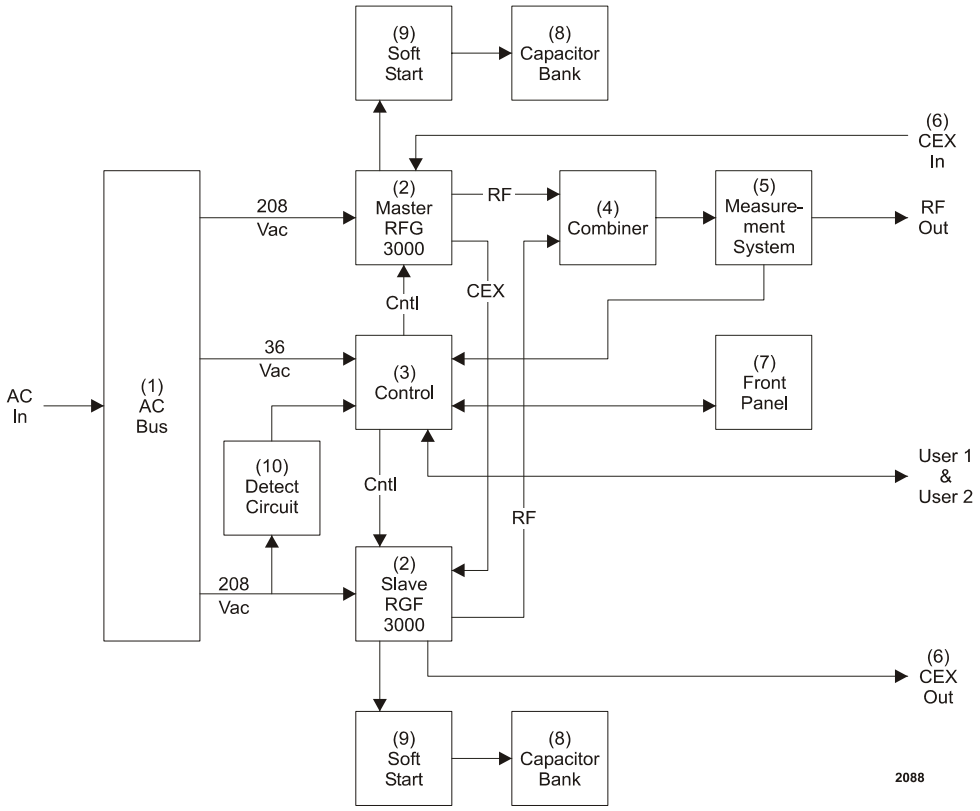

Figure 2-1. *Simplified functional block diagram of an RFG 5500*

Table 2-1. *RFG 5000 Block Diagram Explanation*

(1) AC Input	In the input section 3 ϕ, 208 V ac line voltage is routed through a circuit breaker and then to the ac bus (1). The bus then delivers this voltage to the two RFG 3000 generators (2), and provides 36 Vac for power for the control card (3).
(2) RFG 3000	The RFG 3000 generator is a highly reliable, efficient source of power. For the theory of operation, see page 2-4.

Table 2-1. *RFG 5000 Block Diagram Explanation*

(3) Control Card	The control card supervises the functioning of the two RFG 3000 generators. The RFG 3000 generators contain all of their normal control and protection circuitry; the control card provides the system-level control and protection circuitry. The control card monitors and displays (on the card) the status of the two RFG 3000 generators and provides the necessary control signals to keep them operating in harmony. System forward and reflected power feedback is provided to the control card from the measurement system (5), and the system forward and reflected power control loop functions are performed on this card. The two RFG 3000 generators must be both frequency and phase-locked. One of the RFG 3000 generators acts as the master and provides the frequency-lock signal to the slave generator, thus locking the two outputs together. The phase relationship between the two RFG 3000 generators is adjusted on the combiner (4).
(4) Combiner	The combiner is a highly efficient module that combines the power from the two RFG 3000 generators to produce up to 5500 W of output power. The combiner is built using proprietary technology.
(5) Measurement System	The measurement system used in the RFG 5500 generator is identical to that used in the RFG 3000 generator. Refer to Table 2-2.
(6) CEX Input and Output (available on certain options)	The common exciter circuitry provides a means to frequency lock the outputs of two or more RFG 5500 generators.
(7) Front Panel	The front panel allows the operator to monitor the basic the functions of the RFG 5500 generator. Refer to Table 4-3 for a description of the front panel features.
(8) Capacitor Bank	The capacitor bank provides energy storage for the rectified ac input. This storage bank allows the RFG 5500 to operate through ac line voltage sags without loss of functionality.
(9) Soft Start	The soft start circuit allows the capacitor bank to charge slowly when ac power is first applied. Without this circuit, the inrush current would be excessive and the capacitors would be damaged.
(10) Detect CKT	The detect circuit monitors the ac line voltage, watching for line sags and loss of ac and brownout conditions. In the case of line sags (single phase events), the Detect Circuit tracks the length of the sag and alerts the Control Card if an event has reached its limit. If all ac phase drop below spec, the Detect Circuit alerts the Control Card to shut the generator down.

RFG 3000 Block Diagram

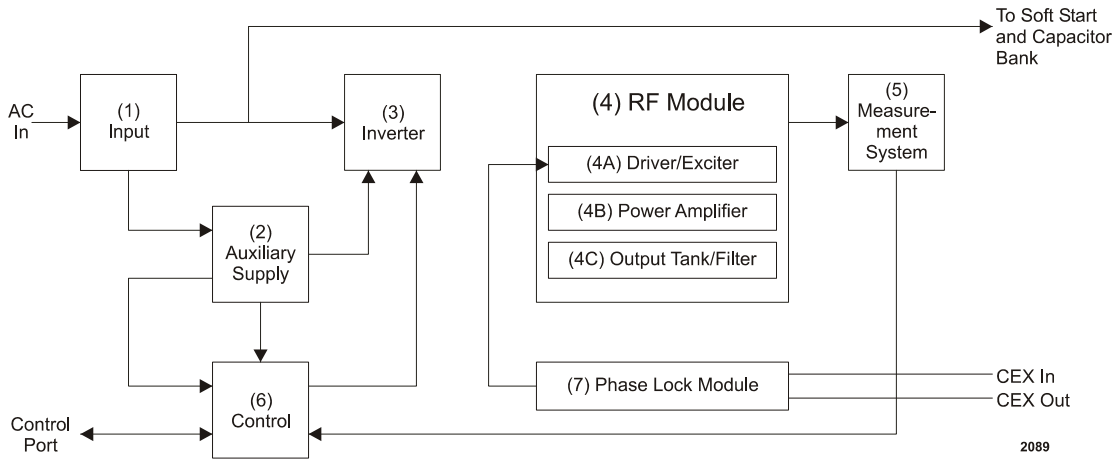

Figure 2-2. *RFG 3000 block diagram*

Table 2-2. *RFG 3000 Block Diagram Explanation*

(1) Input	In the input section, 208 Vac, 3ϕ voltage is routed to a 3ϕ contactor and the input of the auxiliary supply. The contactor, when closed, delivers the line voltage to a diode bridge, where it is rectified to 300 Vdc. The 300 Vdc bus is provided for the inverter section (3) and is routed outside of the RFG 3000 to an external capacitor bank for energy storage. See Table 2-1, “RFG 5000 Block Diagram Explanation,” on page 2-2.
(2) Auxiliary Supply	The auxiliary supply section provides dc power to control the circuits throughout the generator. The RFG’s switching design operates at 220 kHz and generates approximately 250 W of power at 24 Vdc, ±15 Vdc, and 5 Vdc.
(3) Inverter	The inverter section provides variable-amplitude dc power to the RF power amplifier. The inverter uses MOSFET transistors as switches to convert the 300 Vdc bus from the input section to a variable 0 to 200 Vdc analog signal. A 0 to 10 Vdc analog signal from the control section regulates the dc voltage. At full-rated power, this section supplies up to 4000 W to the power amplifier.

Table 2-2. *RFG 3000 Block Diagram Explanation*

(4) RF Module	The RF module section converts dc energy from the inverter to 13.56 MHz and efficiently delivers it to a 50 Ω load. The RF module consists of three sub-sections mounted on a water-cooled coldplate: the driver/exciter (4A), the power amplifier (4B), and the output tank/filter (4C). The RF module uses a space- and power-efficient design that is made possible by proprietary circuitry developed at Advanced Energy Industries, Inc.
(4A) Driver/Exciter	The hybrid driver/exciter sub-section produces a buffered 13.56 MHz signal capable of driving the power amplifier. The driver/exciter is driven from a crystal oscillator and contains three stages of amplification. The driver/exciter is designed to drive extremely low impedance loads and is short-circuit protected to prevent damage due to misuse or system-related arcs.
(4B) Power Amplifier	The power amplifier sub-section uses the dc power from the inverter to boost the signal from the exciter to the required output level. The power amplifier is an AE proprietary, hybrid module. The efficient operation of this section results in low heat dissipation allowing a compact arrangement of components. The RFG 3000 uses two power amplifiers in direct parallel. The power amplifier is designed with 100% headroom.
(4C) Output Tank/filter	This sub-section removes unwanted harmonics generated by the power amplifier and matches the impedance of the amplifier to a 50 Ω load. The planar photolithographic techniques used in the output tank circuitry eliminate air coils and their associated variablity due to operating conditions and manufacturing tolerances. These techniques provide the RFG 3000 with extremely stable operating characteristics.
(5) Power Measurement System	This section provides stable, precise, analog signals representing the forward and reflected power measured at the output connector. The measurement system consists of a microstrip directional coupler, an RF-to-dc converter, and analog correction circuitry. The directional coupler samples the forward and reflected power. The RF-to-dc converter provides constant dc voltages that are stable over wide variations of load impedance and temperature. The analog correction circuitry adjusts the output of the directional coupler to allow for manufacturing tolerances providing a linear output voltage as a function of power.

Table 2-2. *RFG 3000 Block Diagram Explanation*

(6) Control	The control section accepts analog and digital commands from the RFG 5500 control card and processes internal feedback signals to control the RFG 3000. This section also provides status information back to the RFG 5500 control card. The control section monitors the forward power signal from the measurement system and compares it to the requested setpoint. Any resulting error signal is used to adjust the variable 0 to 200 Vdc output of the power inverter and hence the output of the power amplifier.
(7) CEX Phase Lock Module	The CEX section accepts an external 13.56 MHz signal to which the generator can be frequency locked. The CEX circuitry filters and detects the amplitude of the incoming signal. If the amplitude is within the range of -1 to 10 dBm and the frequency is within the capture range of the generator's phase-locked loop, the external signal replaces the internal reference oscillator. The signal supplied to the RF driver stage is therefore frequency-locked to the external signal source. A sample of the RF exciter signal is buffered and supplied to the CEX output port.

Specifications

PHYSICAL SPECIFICATIONS

Table 3-1. *Physical Specifications*

Size	17.8 cm (H) x 48.3 cm (W) x 58.4 cm (D) (7” (H) x 19” (W) x 23” (D))
Weight	52.2 Kg (115 lb.) maximum
Mounting	Rack mounting ears provided for standard 19” instrumentation rack. Side handles are provided to assist in lifting. Front panel handles are provided to assist inserting and removing from the rack cabinet.
Clearance	Clearance of 6” at rear of panel required for interconnects. No additional clearance about unit for ambient air flow is required.
Connector/Cable Specifications	
RF Output Connector	Type LC Female
AC Input Power	15’ 4.6 m (15’), 4-wire cord (SO, 8/4, 90C type, or equivalent) with Hubbell CS8365C connector.
Circuit Breaker Lockout	A bracket for holding the breaker handle in the on or off position is included. For safety during system maintenance.
User Port Connector	15-pin, subminiature-D, female
Coolant Connectors	0. 5” female NPT
RF Grounding Connector	¼-20 ground stud located on the rear of the unit
CEX Input Connector	Type BNC female
CEX Output Connector	Type BNC female

ELECTRICAL SPECIFICATIONS

Table 3-2. *Electrical Specifications*

Input Power Specifications	
Line Voltage	187 to 229 Vac (nominal 208 V); 3 ϕ

Table 3-2. *Electrical Specifications (Continued)*

Line Frequency	47 to 63 Hz
Line Power	8300 W at full rated RF output power (AC to RF efficiency, 60%).
Line Current	28 A/ϕ typical at 5 kW
Over-current Protection	50 A circuit breaker
CEX Specifications	
CEX Input	
Signal Amplitude	-1 dBm minimum, + dBm maximum
Frequency	13.56 MHz, ±0.005%
Impedance	50 Ω ±2 Ω
CEX Output	
Signal Amplitude	+3 dBm minimum, +10 dBm maximum
Impedance	50 Ω ±2 Ω
RF Output Specifications	
Frequency	13.56 MHz ±0.005%
Full Rated Output Power	5000 W forward power minimum into a 50 Ω non-reactive load
Output Power Range	100 to 5000 W. RF is zero watts if the requested setpoint is 0.
Output Impedance	50 Ω for maximum power transfer. (See Figure 3-1 for power derating into non-50 Ω loads.)
Setpoint Tracking Rate	The RF output tracks the setpoint input with slew rates of up to 100 V/sec with ≤5% accuracy. Under these conditions, the overshoot of the RF output does not exceed 5% and the settling time does not exceed 200 msec.
Warm-Up Time Delay	< 500 ms from AC On to RF On
Regulation	Forward power regulated at 1% of setpoint or ±5 W (whichever is greater) into a 50 Ω load
Response Time	< 40 ms rise and fall time from RF on or RF off.
Reflected Power Limit	Automatic foldback (forward power limiting) occurs if the reflected power at the generator output exceeds 1000 W. The generator is capable of generating 850 W of reflected power into an open circuit.
Harmonics	At full rated output, all harmonics are -55 dBc (below the RF output signal) when operated into a 50 Ω, non-reactive load.

Table 3-2. *Electrical Specifications (Continued)*

Spurious Signals	Non-harmonic spurious and noise signals are -50 dBc (below the RF output signal) when operated into a 50 Ω non-reactive load.
Transient Response	Less than 0.1% change in output power for a 10% change in the ac line voltage
Command Power Repeatability	< 0.5% over time for same generator, ±1% generator to generator
Demonstrated Open Loop Power	10 kW into a 50 Ω load
Power Margin	100%

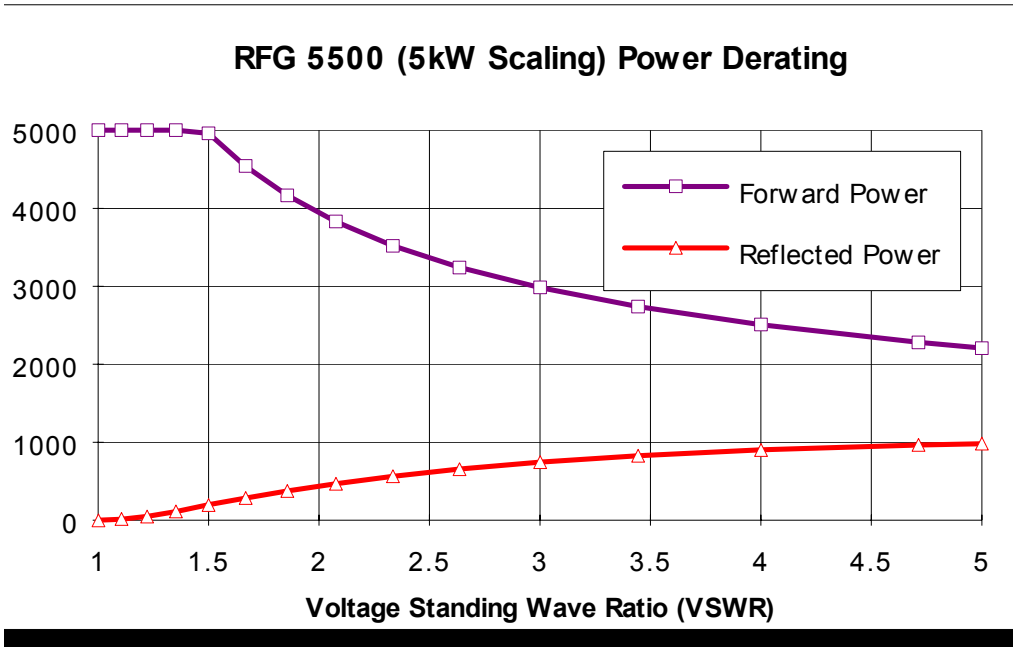

Figure 3-1. *Output Power Derating Curve*

COOLING SPECIFICATIONS

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Table 3-3. *Cooling Specification*

Heat Removal	11,270 BTU/hr. (3300 W) at full-rated RF output power
Temperature	+5° C to +25° C (+41° F to +77° F) inlet temperature

Table 3-3. *Cooling Specification (Continued)*

Flow Rate	15.1 lpm (4 gpm) minimum
Pressure	100 psi (6.9 bars) maximum inlet pressure
Contaminates	The following specifications are recommended for the water used to cool the RFG 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 less than 250 ppm • Specific resistivity of 2500 Ω/cm or higher at 25° C • Total dissolved solids (TDS) as estimated by the following: $TDS \leq \frac{640{,}000}{\text{specific resistivity } (\Omega/\text{cm})}$

⚠ **WARNING:**
Do not use de-ionized water for cooling purposes. De-ionized water causes both corrosion and erosion of cooling manifolds.

ENVIRONMENTAL SPECIFICATIONS

.

Table 3-4. *Climatic Specifications*

	Temperature	Relative Humidity	Air Pressure
Operating	Class 3K3 5°C to +40°C +41°F to +104°F	Class 3K2 10% to 85% (Note 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% (Note 2) +60 g/m^3 (Note 3)	Class 2K3 66 kPa to 106 kPa 660 mbar to 1060 mbar (approximately 3265 m above sea level)

Note 1 Non-condensing
Note 2 Maximum relative humidity when the unit temperature slowly increases, or when the unit temperature directly increases from -25°C to +30°C
Note 3 Maximum absolute humidity when the unit temperature directly decreases from +70°C to +15°C

Connectors, Indicators, and Controls

SIGNAL DESCRIPTIONS

USER PORT

The User port is a 15-pin, shielded, female, subminiature-D connector.

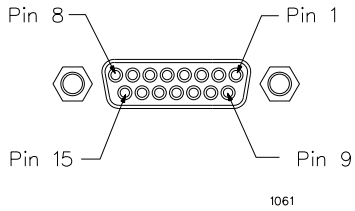


Figure 4-1. *User port connector*

Unless otherwise specified, all analog signals are 0-10 V while all digital signals are opto-coupled (digital inputs require 4-30 volts for a logic high while digital outputs are open-collector signals with return lines non-referenced to ground).

Table 4-1. *User Port Pin Descriptions*

Pin	Return Pin	Name	Signal Type	Description
1	*6*	*SETPOINT STATUS*	Digital Output	A logic high level (+5 V) indicates that an internal power limit has been encountered. When RF power is enabled, a low level (0 V) indicates that the generator is “at setpoint.”
2	*6*	*REFL PWR MONITOR*	Analog Output	This signal represents the reflected power as measured at the output of the generator. This signal is scaled at 1 kW per V. The maximum reflected power is 1 kW.

Table 4-1. *User Port Pin Descriptions*

Pin	Return Pin	Name	Signal Type	Description
3	*6*	*FWD PWR MONITOR*	Analog Output	This signal represents the forward power as measured at the output of the generator. This signal is scaled at 1 kW per V.
4	*6*	*RF PWR ON*	Digital Input	This signal is used to activate the RF output of the generator. A voltage level of 4 V to 30 V on *pin 4* enables the RF power. If *pin 4* is open or grounded, RF power is inhibited. Following an over temperature or line sag shutdown, the RF output of the generator will be disabled until the RF PWR ON signal is transitioned from off-to-on.
5	*6*	*SETPOINT*	Analog Input	This 0 to 10 V signal defines the desired setpoint for the generator's RF output and is scaled to represent 0 to 5000 W.
6		*GROUND*	Ground Reference	This pin is referenced to the signal/ chassis ground in the generator.
7	*6*	*RF ON STATUS*	Digital Output	A logic high level (+5 V) indicates that the RF power is present at the output of the generator. A logic low level indicates that RF power is inhibited. The interlock loop must be closed and the RF PWR ON signal must be active to enable RF power.
8	*6*	*EXTERNAL BIAS*	Reference Voltage	This pin is tied to the generator's +15 Vdc through a 5.62 kΩ resistor. The intended use of this pin is for notifying the user that ac power is enabled within the generator.
9	*6*	*RF ON BIAS*	Reference Voltage	This pin is tied to the generator's +15 Vdc through a 1.21 kΩ resistor. The intended use of this pin is to enable RF power by externally jumpering it to *pin 4*.
10	*6*	*RESERVED*		Reserved for future use

Table 4-1. *User Port Pin Descriptions*

Pin	Return Pin	Name	Signal Type	Description
11	*6*	*INTERLOCK*	Interlock	This pin is part of a series interlock string which must be satisfied to enable ac power in the generator. *Pin 11* must be grounded to enable RF power (a contact resistance of 750 Ω or less to ground will satisfy the interlock criteria).
12		*RESERVED*		Reserved for future use
13		*RESERVED*		Reserved for future use
14		*RESERVED*		Reserved for future use
15		*RESERVED*		Reserved for future use

User Port Electrical Characteristics

The User port on the RFG 5500 provides analog and digital signals for control and monitoring of the generator functions. Figure 4-2 shows the electrical diagrams for the interface circuitry in the generator. Table 4-2 provides a description of the signal types used in the RFG 5500.

Table 4-2. *RFG 5500 Signals*

Analog Outputs	The analog readback signals from the generator (*pins 2* and *3*) are driven by precision, low-offset operational amplifiers (industry type OP200GP). These devices are capable of driving high-capacitance loads such as those expected in shielded interface applications. The user's receiver must present a 10 kΩ (or greater) impedance to these signals. The readback signals, which represent the forward and reflected power as measured at the output of the generator, are scaled to 1 V per kW.
Analog Input	The setpoint signal from the user (*pin 5*) is a 0 to 10 volt signal scaled to represent the desired forward power from the generator (refer to the signal description table for details). The driver circuit must be capable of operating into a high capacitance load condition.
Digital Outputs	The status signals provided by the generator (*pins 1* and *7*) are opto-coupled with NPN transistor outputs (industry type 4N37). The emitter of each transistor is biased to ground with a 2 kΩ resistor. The collector of each transistor is tied to +5.1 V in the generator. Each transistor can provide a minimum of 8 mA of collector current and may be operated with a collector-to-emitter voltage of up to 30 V. Refer to the attached signal description table for signal definitions.
Digital Input	The RF PWR ON control signal (*pin 4*) is opto-coupled (industry type 4N37). The user's signal drives the LED in the opto-coupler through a 1 kΩ resistor. A signal level of 4 V to 30 V applied to *pin 4* enables the RF power.
Interlock	The interlock signal (*pin 11*) is opto-coupled (industry type MOC207). The anode of the LED in the opto-coupler is tied to +15 V in the generator through a 475 Ω resistor. The user's signal is tied to the cathode. Grounding *pin 11* (contact resistance of less than 1.2 kΩ ohms) energizes the contactor that enables ac power within the generator.

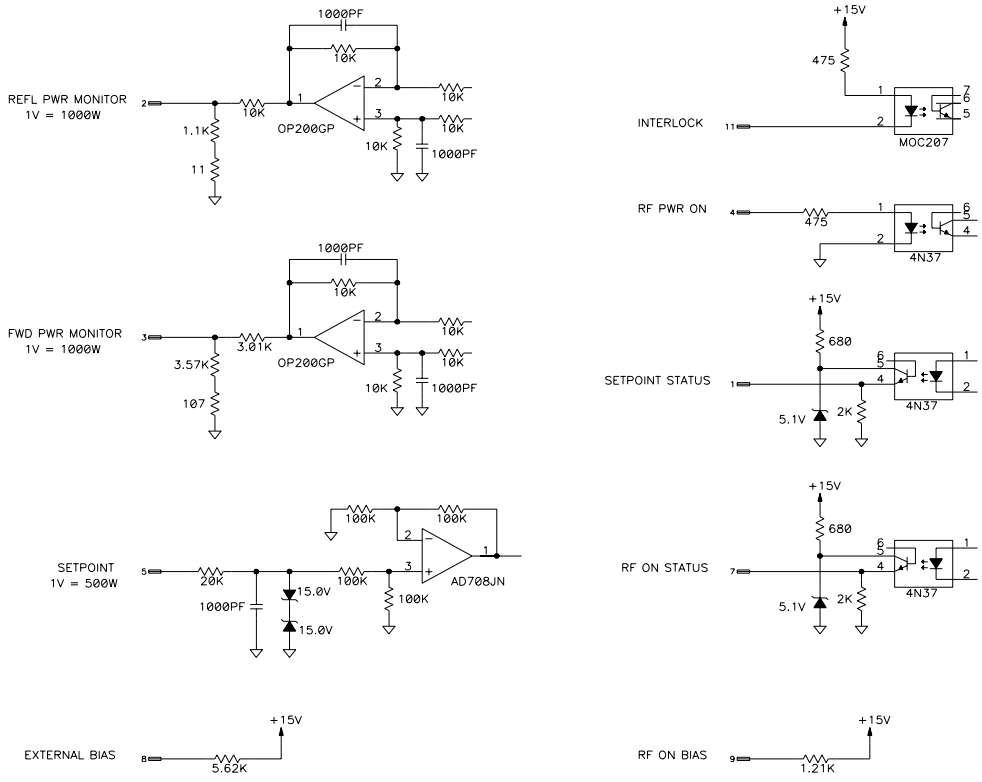


Figure 4-2. *User Port Electrical Diagrams*

Interface Cabling Requirements

The cable used to connect the generator's 15-pin User Port to the system controller must be a shielded, 15-wire I/O cable. Twisted-pair wiring may be used but this is not mandatory. Signal losses should be minimized by keeping the cable length as short as possible. The maximum recommended cable length between the generator and the controller is 35 feet (10.7 meters). To minimize interference from adjacent electrical equipment, the EMI shield in the cable must be terminated to the metal shells of the cable's D connectors. Additionally, the chassis of the RFG 5500 generator must be tied to a local earth ground through an adequately sized copper grounding strap.

OPERATOR PANEL FUNCTIONS

The RFG 5500 generator does not have an operator control panel. All power, control, and water connections are made at the rear of the unit.

A numeric display and eight status LEDs are provided on the front of the unit for monitoring the basic generator functions. Table 4-3 provides a description of the operator panel functions.

Table 4-3. *Operator Panel Functions*

DISPLAY	3-digit numeric display (seven-segment) used to display one of three selected generator functions (see definition of the DISPLAY SELECT switch below).
DISPLAY SELECT	This momentary push button switch is used to select the desired parameter for display (subsequent depressions of the switch cycle through the three selections). There are three LEDs adjacent to the switch for indicating the currently selected display mode. The displayable parameters are: • Setpoint • Fwd/Load Pwr (fwd pwr only, for RFG 5500) • Rel Pwr
INDICATORS	
AC ON	This GREEN LED indicates that ac power is available within the unit, all three phases are present, the main contactor is energized, the ac voltage to the inverter section is within the allowable voltage range, and all interlock criteria are satisfied. When this indicator is lit, the unit is ready to supply RF output power.
RF ON	This GREEN LED indicates that RF power is on (enabled). Depending on the selected setpoint value, RF power may or may not be present at the output connector. In the event of a significant ac line sag (in excess of a SEMI F47 sag event), the RFG 5500 may terminate its RF output. In this case, the RF ON signal and LED indicator will go inactive. RF power can be restored by toggling the RF PWR ON signal (pin 4) off and then back on.

Table 4-3. *Operator Panel Functions*

DISPLAY	3-digit numeric display (seven-segment) used to display one of three selected generator functions (see definition of the DISPLAY SELECT switch below).
ALARM	This ORANGE LED indicates that the unit is unable to satisfy the requested setpoint power due to some limit or alarm condition in the generator. The conditions that can cause an alarm are high VSWR, over-temperature, excessive ac line sags and internal power limits. In the event of an over-temperature condition or a shutdown due to an excessive ac line sag, the RF On command must be toggled to reset the fault.
Watts	This GREEN LED indicates that the value being displayed is in watts. For the RFG 5500, this indicator is always lit.
X 1000	This GREEN LED indicates that the value being displayed has been scaled and must be multiplied by 1000. For the RFG 5500, this indicator is always lit.

FRONT PANEL

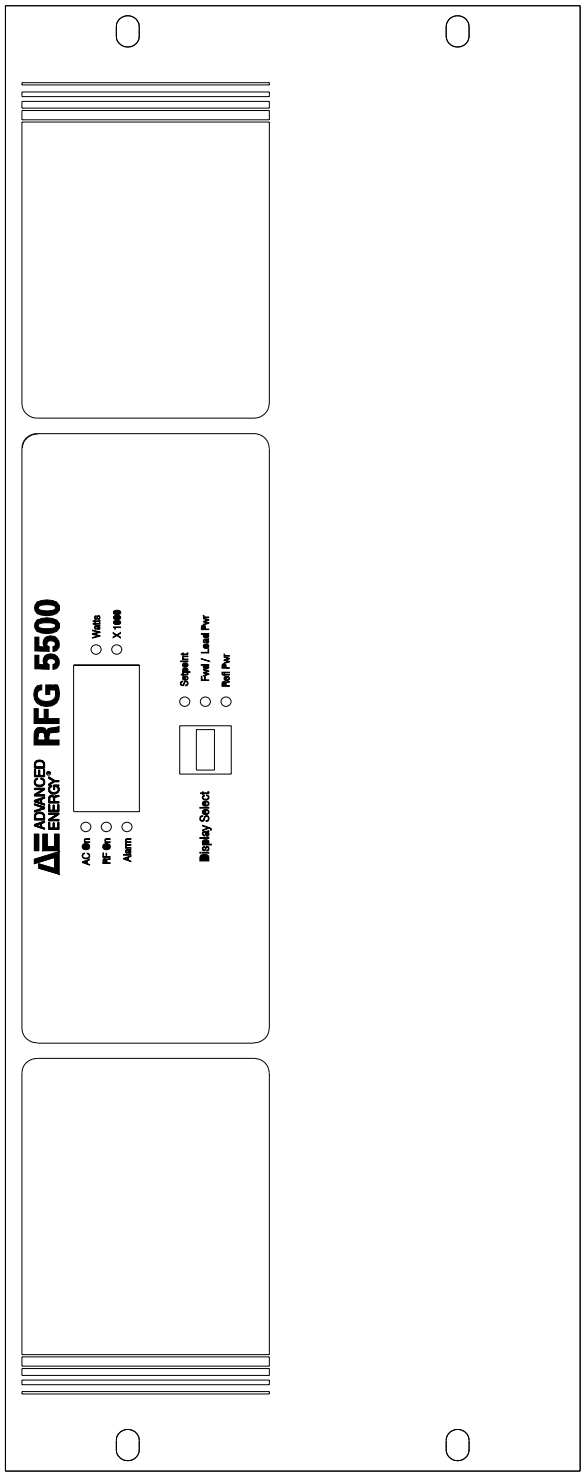


Figure 4-3. Front panel

REAR PANEL

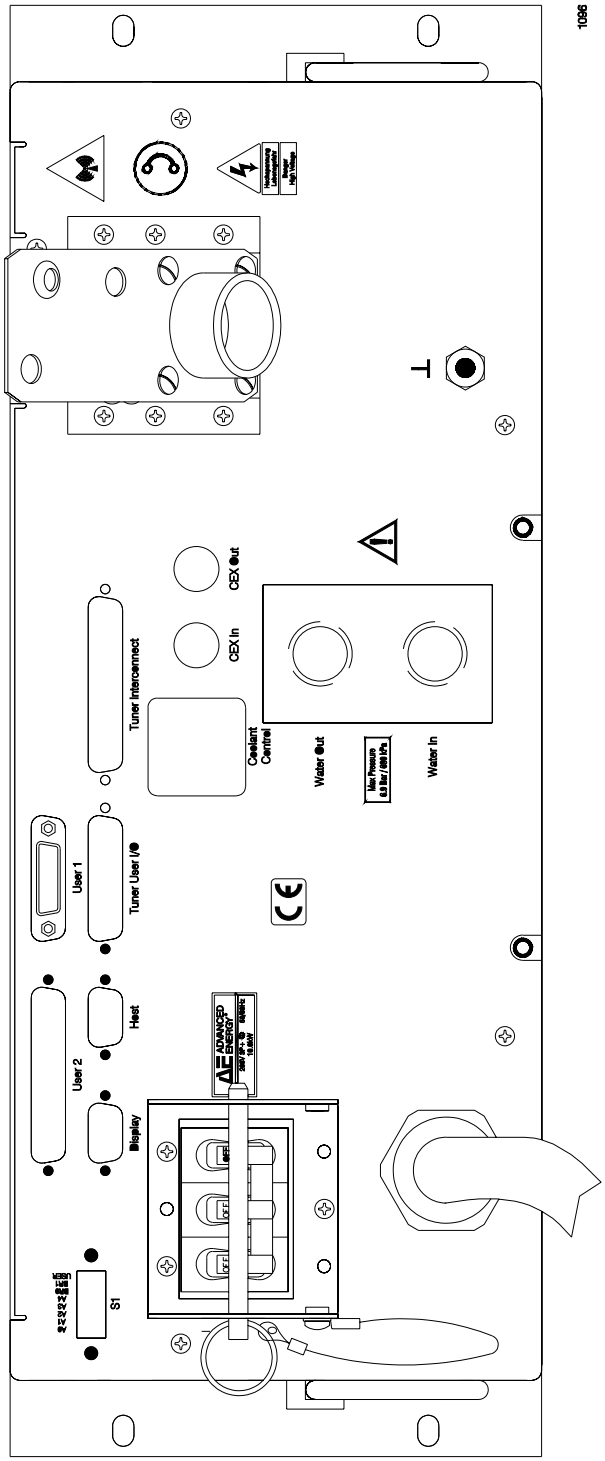


Figure 4-4. Rear panel

Installation

UNPACKING

Unpack and inspect your generator 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. Save the shipping container for submitting necessary claims to the carrier.

GROUNDING

The RFG 5500 provides an RF (EMI) ground stud. It is mandatory that a suitable ground connection be made to this stud to prevent or minimize radio frequency interference. We recommend copper strap material 0.5” or wider.

> ⚠ **WARNING:**
> **Before making any other connection, connect the auxiliary Protective Earth ground conductor on the rear panel.**

MOUNTING

Figure 5-1 provides the mounting hole dimensions as well as dimensions of the unit to aid in installation.

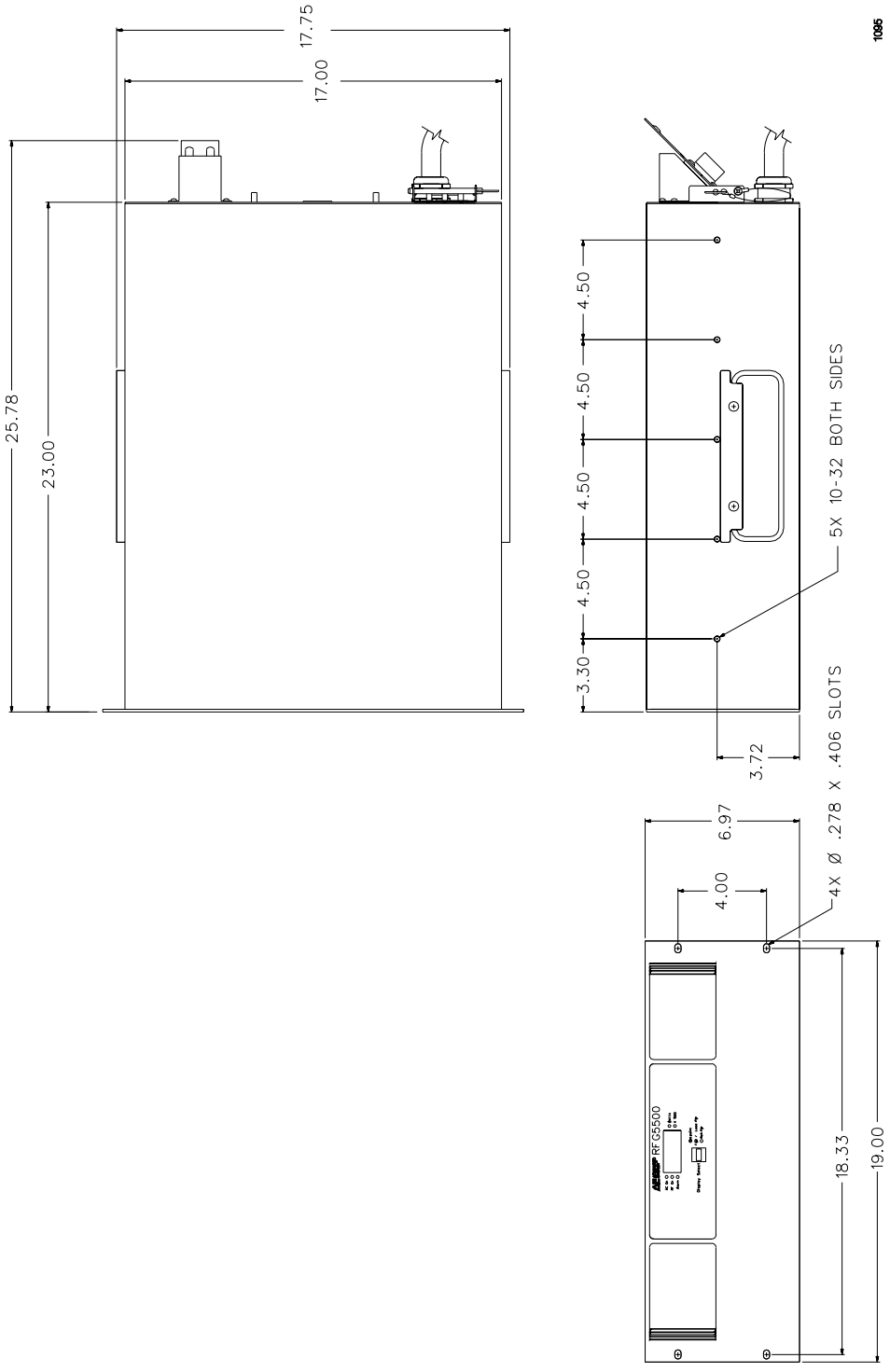


Figure 5-1. *Mounting dimensions*

CONNECTING COOLING WATER

This unit is water cooled. Do not operate it until water is connected and the cooling requirements are met.

> ⚠ **WARNING:**
> **Do not use de-ionized water for cooling purposes. De-ionized water causes both corrosion and erosion of cooling manifolds.**

Connect the input and output water connections and tighten securely. Turn on the water and ensure that there are no leaks. Be sure that the flow rate and temperature are within the minimum specifications required to operate your RFG 5500 generator.

CONNECTING INPUT POWER

> ⚠ **WARNING:**
> **Connect the cooling water and ensure that the unit operates without leaking before connecting the input power.**

> ⚠ **WARNING:**
> **Before making any input line power connection, turn off building circuit breakers supplying input power to the RFG 5500. Also, ensure that the circuit breaker on the rear panel is in the off or "0" position.**

Mate the Hubbell CS8365C connector with the ac power source by aligning the keyed pins, inserting the power cord connector until it is fully seated, and then rotating the connector clockwise until it is securely latched.

CONNECTING OUTPUT POWER

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

DANGER:
Once the connections are complete and power is turned on, lethal voltages are present at the output connector.Be sure this connector is terminated and follow normal safety precautions when the system is operating.

DANGER:
Before connecting or disconnecting the RF output cable, make sure the ac power is turned off (the circuit breaker should be in the off or "0" position).

Attach the mating RF cable connector to the generator by threading it onto the generator's output connector. Make sure the mating connector is completely engaged and fully tightened before proceeding.

Output Power Cable Recommendations

The recommended RF cable for the RFG 5500 is type RG 393 because of its high insulative values, small size, and high reliability.

CONNECTING USER PORT

Connect this 15-pin, subminiature-D, shielded, female connector (labeled User1) to your control unit. If this cable is disconnected, RF output power will not come on.

Interface Cabling Recommendations

The cable used to connect the generator's 15-pin User port to the system controller must be a shielded, 15-wire I/O cable. Twisted-pair wiring may be used but this is not mandatory. Signal losses should be minimized by keeping the cable length as short as possible. The maximum recommended cable length between the generator and the controller is 10 m (33'). To minimize interference from adjacent electrical equipment, the EMI shield in the cable must be terminated to the metal shells of the cable's D connectors. Additionally, the chassis of the RFG 5500 must be tied to a local earth ground through an adequately sized copper grounding strap.

Troubleshooting and Customer Support

BEFORE CALLING AE CUSTOMER SUPPORT

Checks with the Power Off

1. Check for visible damage on the unit, cables, and connectors.
2. Check to ensure that all connectors are installed correctly and tightly fastened.
3. Check the position of all switches and be sure they are in the correct position.
4. Check input power to be sure that it is present and meets specifications.
5. Check ground connections and ensure that they are adequate and secure.

Checks with the Power On

1. Check input power connection to ensure the proper power is being supplied to the unit.
2. Check LEDs and determine that the proper ones are lit. See *First Time Operation* in the preceeding chapter.

OPERATION

FIRST-TIME OPERATION

> ⚠ **DANGER:**
> The RFG 5500 must be hooked up to a properly configured chamber or a 50 Ω resistive load before you turn RF on.

Before powering up the RFG 5500, verify that the ac power connections, the RF output connections, and the cooling water connections are made correctly. Make sure that the cooling water is turned on and that the minimum flow rate and water temperature requirements are satisfied.

To initially turn on your RFG 5500 generator, use the following steps.

- Verify that the *RF Pwr On* signal at the User port (*pin 4*) is disabled and that the *Setpoint* signal (*pin 5*) is set to zero.
- De-activate the generator's interlock loop by leaving *pin 11* unconnected.
- Move the circuit breaker on the rear of the RFG 5500 to the on ("1") position.
  - The display on the front of the generator illuminates and the **Setpoint, Watts**, and **X1000** indicators are lit.
  - All other indicators are unlit.
  - The numeric display indicates 0 W because the setpoint signal is at zero.
- Depress the **DISPLAY SELECT** push button once. The **Setpoint** indicator extinguishes and the **Fwd/Load Pwr** indicator is on.
- Depress the button one more time to select *Refl Pwr* mode (verify that **Fwd/Load Pwr** indicator extinguishes and that the **Refl Pwr** indicator lights). Subsequent depressions of the push button repeatedly cycle through the three display modes.
- Select the **Fwd/Load Pwr** mode before proceeding to the next step.
- Close the interlock loop by grounding *pin 11* at the User port. The **AC ON** indicator illuminates.
- Activate the *RF Pwr On* signal at the User port (*pin 4*). The **RF ON** indicator on the front panel illuminates.
- Slowly increase the setpoint voltage (*pin 5*) while monitoring the front panel display.

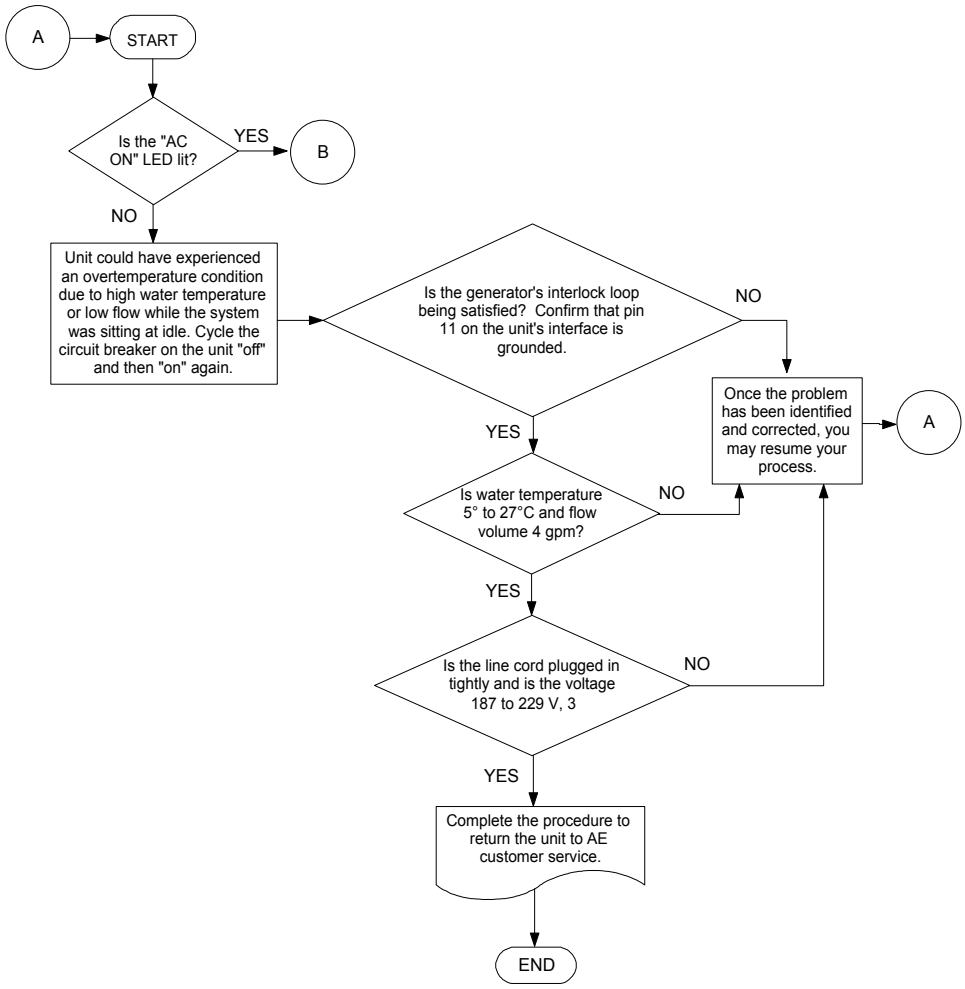
Note: The RFG 5500 incorporates a clamp circuit that guarantees that less than 5 W of RF power is present when the setpoint is zero. This clamp circuit triggers at a setpoint of approximately 50 W so the *Setpoint* signal must be greater than this before a noticeable change in the front panel display occurs.

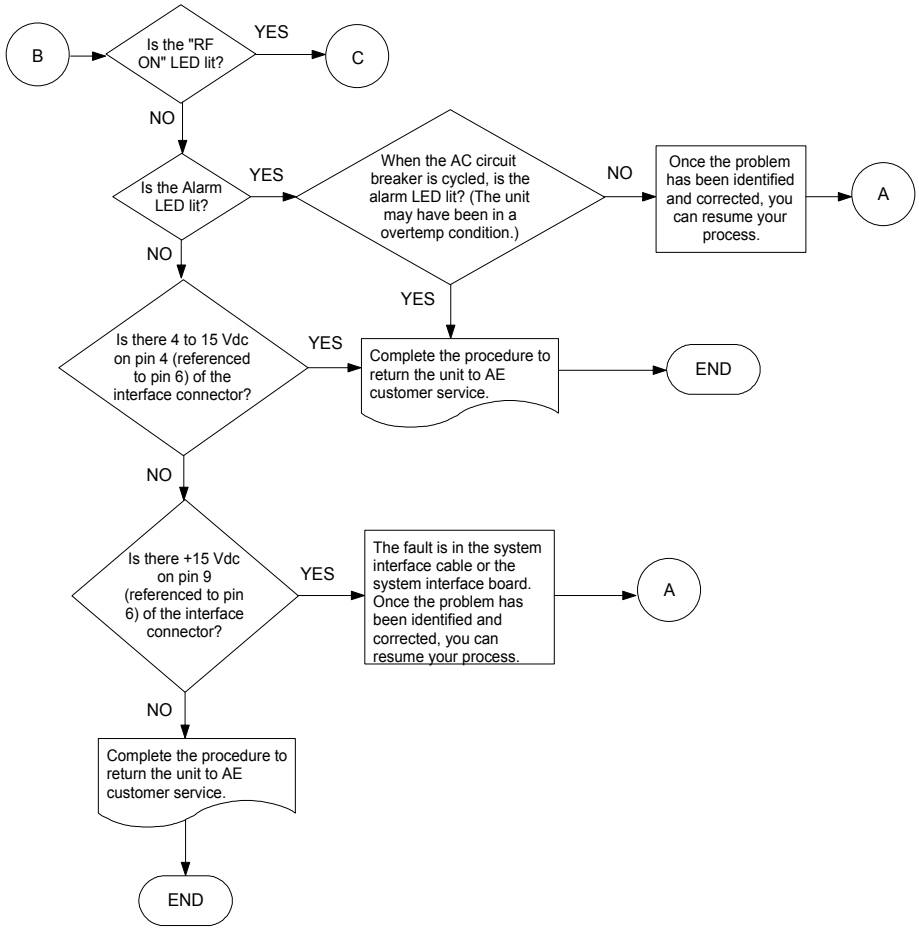
- Continue to increase the setpoint until the display indicates approximately 200 W of power. **Note:** The display is scaled by a factor of 1000, (200 W is displayed as "**.**20").
- Use the **DISPLAY SELECT** push button to display the setpoint value. The forward power and setpoint values should agree with each other within the allowable regulation tolerance of the generator (1%).
- If the displayed forward power and setpoint values are in agreement, continue to increase the setpoint value slowly.
- Stop periodically to verify that the forward power and setpoint values are continuing to track together. Also verify that the reflected power readings remain near zero (this assumes that the test load is purely resistive).
- Continue this process until 5000 W is reached (*Setpoint* signal equals 10 V). At no point during the test should the **ALARM** indicator light. If, for any reason, the generator does not perform properly, shut off the circuit breaker and refer to the troubleshooting section in this manual for further guidance.

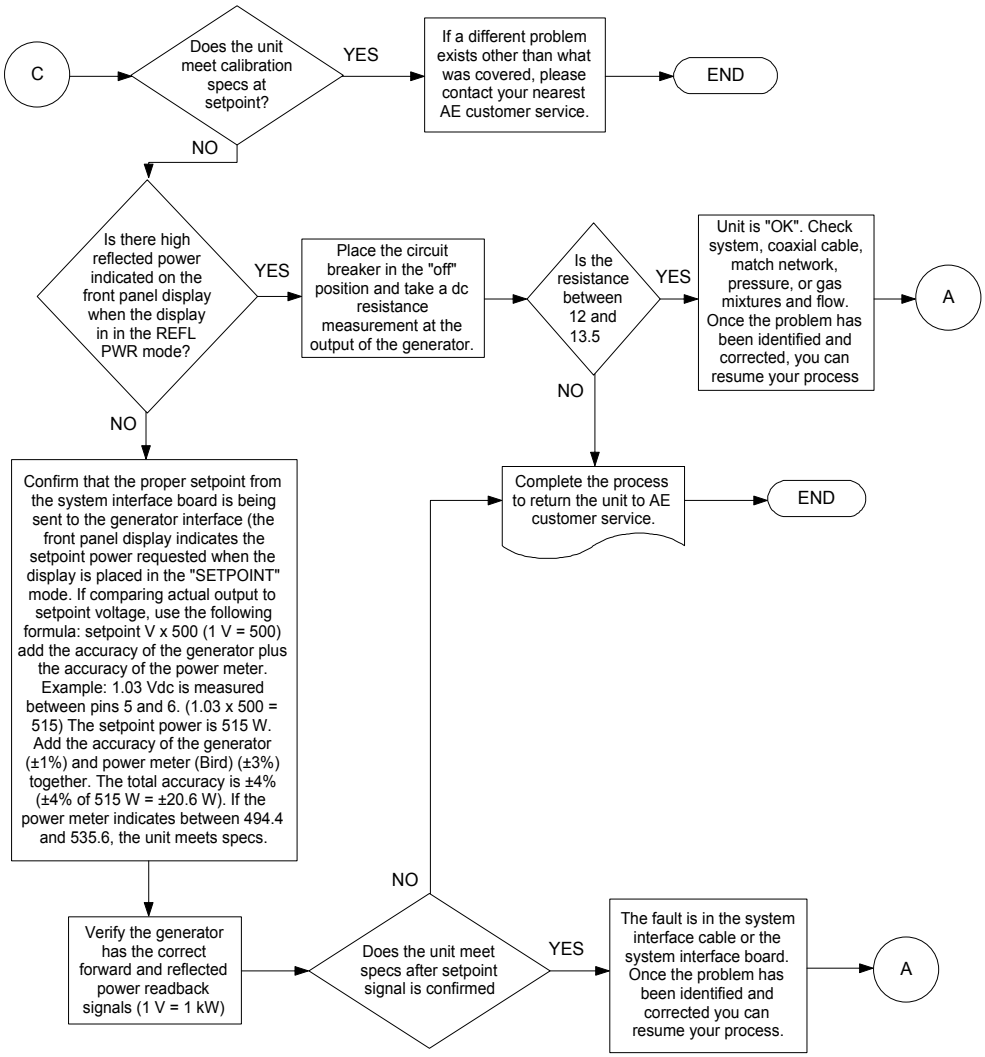
- Inactivate the *RF Pwr On* signal at the User port and verify that the **RF ON** indicator extinguishes. The forward and reflected power readings on the display go to zero, regardless of the value of the *Setpoint* signal.
- Move the circuit breaker to the off (0) position to complete this initial test.
- Turn off the cooling water if no further testing is required.

TROUBLESHOOTING FLOWCHART

The following flowchart will assist you in determining whether the generator is faulty or there are system problems. Be sure to follow this chart completely before sending the generator back in the event you are experiencing difficulties with your installation.




B
Is the "RF ON" LED lit?
YES
C
NO
Is the Alarm LED lit?
YES
When the AC circuit breaker is cycled, is the alarm LED lit? (The unit may have been in a overtemp condition.)
NO
Once the problem has been identified and corrected, you can resume your process.
A
NO
YES
Is there 4 to 15 Vdc on pin 4 (referenced to pin 6) of the interface connector?
YES
Complete the procedure to return the unit to AE customer service.
END
NO
Is there +15 Vdc on pin 9 (referenced to pin 6) of the interface connector?
YES
The fault is in the system interface cable or the system interface board. Once the problem has been identified and corrected, you can resume your process.
A
NO
Complete the procedure to return the unit to AE customer service.
END


C
Does the unit meet calibration specs at setpoint?
YES
If a different problem exists other than what was covered, please contact your nearest AE customer service.
END
NO
Is there high reflected power indicated on the front panel display when the display in in the REFL PWR mode?
YES
Place the circuit breaker in the "off" position and take a dc resistance measurement at the output of the generator.
Is the resistance between 12 and 13.5
YES
Unit is "OK". Check system, coaxial cable, match network, pressure, or gas mixtures and flow. Once the problem has been identified and corrected, you can resume your process
A
NO
NO
Confirm that the proper setpoint from the system interface board is being sent to the generator interface (the front panel display indicates the setpoint power requested when the display is placed in the "SETPOINT" mode. If comparing actual output to setpoint voltage, use the following formula: setpoint V x 500 (1 V = 500) add the accuracy of the generator plus the accuracy of the power meter. Example: 1.03 Vdc is measured between pins 5 and 6. (1.03 x 500 = 515) The setpoint power is 515 W. Add the accuracy of the generator (±1%) and power meter (Bird) (±3%) together. The total accuracy is ±4% (±4% of 515 W = ±20.6 W). If the power meter indicates between 494.4 and 535.6, the unit meets specs.
Complete the process to return the unit to AE customer service.
END
NO
Verify the generator has the correct forward and reflected power readback signals (1 V = 1 kW)
Does the unit meet specs after setpoint signal is confirmed
YES
The fault is in the system interface cable or the system interface board. Once the problem has been identified and corrected you can resume your process.
A

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

Table 6-1. *Customer Support Locations*

Office	Telephone
AE, World Headquarters 1625 Sharp Point Drive Fort Collins, CO 80525 USA	Phone: 970.221.0108 or 970.221.0156 Fax: 970.221.5583 Email: technical.support@aei.com
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: 82.342.705.1200 Fax: 82.342.705.276
AE, United Kingdom Unit 5, Minton Place, Market Court, Victoria Road Bichester, Oxon OX6 7QB UK	Phone: 44.1869.320022 Fax: 44.1869.325004

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 Customer 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 Customer 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 Customer 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 Customer 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 Customer 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 Customer 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 Customer 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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