RFG 1251 Generator

User Manual

5706058-A

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User Manual

RFG 1251 Generator

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ADVANCED ENERGY®

⚠ WARNING

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

Advanced Energy Industries, Inc., (AE) 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 or uses potentially lethal high-voltage, high-current, radio frequency (RF) energy. NEVER DEFEAT INTERLOCKS OR GROUNDS.

All information herein is subject to periodic updates. Inquiries concerning this manual should be directed to AE. Information provided by AE is believed to be correct and reliable. However, no responsibility is assumed by AE unless otherwise expressly taken.

Advanced Energy Industries, Inc.
1625 Sharp Point Drive
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Chapter 1

Introduction

READ THIS SECTION!

To ensure safe operation, you should read and understand this manual before you attempt to install or operate this unit. At a minimum, read and heed the "Safety" section in this chapter.

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**); however they appear as you see them on the unit. Exceptions are port names, which simply begin with a capital letter (User port).
- Functions appear in boldface lowercase letters (**analog input filtering**).
- Commands appear in small, bold capital letters (**START**)

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

- GS

- Non-ionizing radiation

1030

- Hot surface

1309

SAFETY

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

- Ensure that this unit is properly grounded.
- Ensure that all cables are properly connected.
- Verify that input line voltage and current capacity are within specifications before turning on the power supplies.

- Use proper ESD precautions.
- 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.

PRODUCT SAFETY/COMPLIANCE

Note: This product is designed to meet and is tested for compliance to the following standards and directives.

Directives

The following tables list the Electromagnetic Compatibility (EMC) and Safety directives.

Table 1-1. Electromagnetic Compatibility (EMC)

Directive	Description
89/336/EEC 92/31/EEC	EC Council directive on the approximation of the laws of the Member States relating to electromagnetic compatibility (EMC Directive).
47 CFR Part 18	Code of Federal Regulations - Limits and Methods of Measurement of Radio Interference Characteristics of Industrial, Scientific, and Medical Equipment.

Table 1-2. 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).

Standards

This device has been tested for and complies with the following Safety and EMC standard(s):

- EN 50178
- EN 50082-2
- EN 55011 (Class A, Group 2)(CISPR 11)
- 47 CFR Part 18

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.

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 overvoltage 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.
- To provide the required over-current protection, install and operate this device with an AE-approved circuit breaker on the ac input.

Theory

GENERAL DESCRIPTION

The RFG 1251 generator is a 13.56 MHz RF generator capable of providing up to 1250 W into a 50 Ω, non-reactive load. The RFG 1251 generator provides high accuracy power regulation and incorporates internal protection limits permitting safe and reliable operation. The RFG 1251 generator is certified to the CE Mark and GS Mark safety and emissions requirements.

The generator is controlled through a 25-pin analog/digital user port. The output of the generator is regulated on forward power or delivered power (forward minus reflected) (refer to the interface signal description for *pin 8* in Chapter 4). The compact nature of the RFG 1251 generator permits it to be mounted directly on the tool.

The RFG 1251 generator is designed for use with three-phase, 208 Vac input power. The RFG 1251 generator uses water as a cooling medium and provides control signals for powering an externally-mounted water flow solenoid. When the RF output is disabled, the cooling water flow may be shut off to conserve water.

A series-wired, loop-through interlock string is provided through the 25-pin User port connector. The RF output connector has an interlock switch that is wired in series with pins on the User port connector. The switch closes when the mating RF cable is attached. These interlocks prevent the application of RF power in the event of abnormal system conditions.

The RFG 1251 generator contains circuitry to protect itself in the event of the following abnormal conditions:

- High reflected power conditions. Output power fold-back (forward power limiting) occurs under the control of the generator protection circuits.
- Excessive internal temperature (typically caused by the lack of cooling water or excessive ambient operating temperature)
- Any combination of input ac line phase drop out
- Input line brown out (under voltage) or over voltage

THEORY OF OPERATION

Figure 2-1 and Table 2-1 outline the theory of operation.

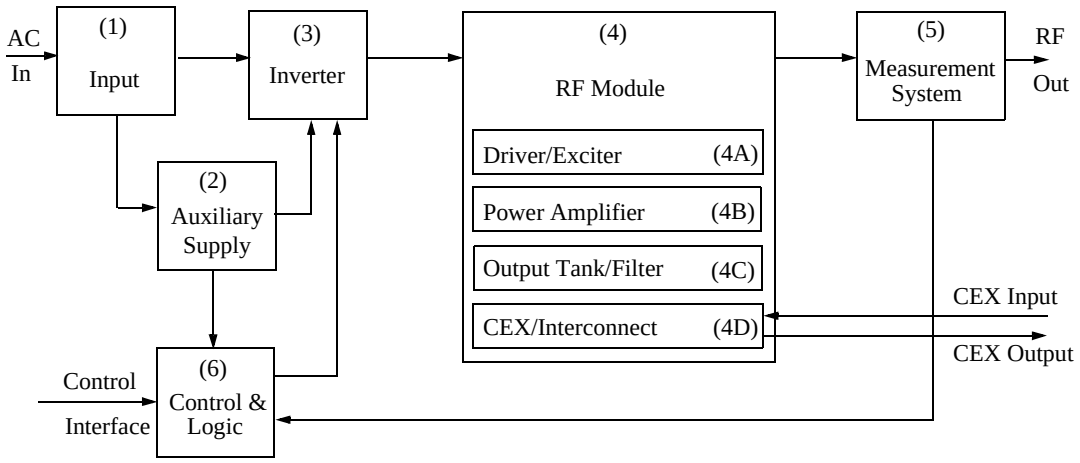

Figure 2-1. RFG 1251 simplified block diagram

Table 2-1. Block Diagram Explanation

(1) Input	In the input section, 208 Vac, 3ϕ, line voltage is routed through a circuit breaker and line filter to a 3ϕ contactor and the input of an auxiliary supply (2). 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 to the inverter section (3).
(2) Auxiliary Supply	The auxiliary supply provides dc power to control and logic circuits throughout the unit. Its switching design operates at 220 kHz and generates approximately 250 W of power at 30 Vdc, 24 Vdc, ±15 Vdc, and 5 Vdc. It also supplies limited 24 Vdc and 15 Vdc power to the Control connector for external use.
(3) Inverter	The inverter provides variable-amplitude dc power to the RF power amplifier (4). It consists of two assemblies: the phase control card and the switch card. The inverter uses MOSFET transistors as switches to convert the 300 Vdc bus from the input section to a variable 0 to 200 Vdc signal. A 0 to 10 Vdc analog signal from the control section (6) regulates the dc voltage. At full-rated power, this section must supply up to 1700 W to the power amplifier (4B).

Table 2-1. Block Diagram Explanation

(4) RF Module	The RF module converts dc energy from the inverter to 13.56 MHz and efficiently delivers it to a 50 Ω load. It consists of four sections mounted on the main cold plate; the driver/exciter (4A), the power amplifier (4B), the output tank/filter (4C), and the CEX/interconnect card (4D). 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 provides a buffered 13.56 MHz signal capable of driving the power amplifier (4B). It 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 mishandling or failures in succeeding stages. It can provide at least twice the power required to drive the power amplifier to full-rated output power.
(4B) Power Amplifier	The power amplifier (PA) uses the dc power from the inverter (3) to boost the signal from the driver/exciter (4A) to the required output level. The power amplifier consist of an AE proprietary, hybrid module. The efficient operation of this section results in low heat dissipation which allows a compact arrangement of components. The PA has a built-in 65% headroom for reliability when operated into plasma loads. It uses a new class of operation patented by AE.
(4C) Output Tank/ Filter	This 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 variability due to operating conditions or manufacturing tolerances. This provides the RFG with extremely stable operating characteristics.
(4D) CEX/Interconnect	This section contains the common exciter (CEX) circuitry and routes the dc and RF drive signals among the various modules that comprise the RF module. The CEX option provides the ability to phase lock the outputs of two or more RFG generators together. In units equipped with this option, a 13.56 MHz signal of appropriate amplitude applied to the CEX input connector becomes the reference signal for a phase-locked loop contained on this card. When no CEX input signal is present (or units without the CEX option), the crystal oscillator contained on this card provides the 13.56 MHz reference. The 13.56 MHz signal is routed to the input of the driver/exciter module (4A).

Table 2-1. Block Diagram Explanation

(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 and two channels of processing electronics. The directional coupler samples voltages that are proportional to the square root of the forward and reflected power. It has a flat coupling coefficient that provides accurate measurements into any load. The processing electronics consist of an input filter, a multiplier for squaring the voltage signals, a low-pass filter, and a scaling OP AMP. The measurement system provides inherent linearity and a wide dynamic range. It is calibrated using a computerized test station. Once calibrated, no adjustments are required or provided in this module or in the rest of the unit.
(6) Control and Logic	The control and logic module accepts analog and digital commands from the operator and processes internal feedback signals to control the generator. It also provides status information to the operator. The control and logic module 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 (3) and hence the output of the power amplifier (4B). This module also provides the control of the water solenoid.

Specifications

PHYSICAL SPECIFICATIONS

Table 3-1. Physical Specifications

Size	12.7 cm (H) x 17.8 cm (W) x 38.1 cm (D) 5.0″ (H) x 7.0″ (W) x 15.0″ (D) (excluding handles, switches, and connectors)
Weight	12.7 Kg (28 lb) maximum
Connector/Cable Specifications	
RF Output Connector	N female
AC Power Input	5-pin, male, bulkhead-mounted, Harting series Han-Q
Chassis (EMI) Ground	8-32 tapped hole
User Port Connector	25-pin, subminiature-D, female
Coolant Connectors	0.25″ push-in fittings (for 0.25″ O.D. tubing)
Coolant Control Connector	2-pin, miniature power jack

ELECTRICAL SPECIFICATIONS

Table 3-2. Electrical Specifications

Input Power Specifications	
Line Voltage	178 to 229 Vac (nominal 208 V), 3ϕ, no neutral connection
Line Frequency	47 to 63 Hz
Line Current	8 A / ϕ, typical (at full-rated RF output power)
Overcurrent Protection	15 A circuit breaker on rear panel

Table 3-2. Electrical Specifications

Power Factor	Minimum 0.85 with full rated output into 50 Ω, non-reactive load
RF Output Specifications	
Full Rated Output Power	1250 W minimum into a 50 Ω, non-reactive load
Output Power Range	6.25 to 1250 W
Frequency	13.56 MHz, ± .005%
Regulation	± 1% of setpoint or 0.2 W (whichever is greater) into a 50 Ω load
Power Repeatability (same generator)	± 0.5% of setpoint or 0.2 W (whichever is greater) into a 50 Ω load
Harmonics	At full rated output, all harmonics are > 55 dBc below the RF output signal when operated into a 50 Ω, non-reactive load.
Spurious Signals	At full rated output, all non-harmonic spurious and noise signals are > 40 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

ENVIRONMENTAL SPECIFICATIONS

Table 3-3. Climatic Conditions

	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 1K 35% to 95% +1 g/m^3 to 29 g/m^3	Class 3K3 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

Table 3-4. Environmental Specifications

Coolant Requirements	
Temperature	+5°C to +30°C (+41°F to +86°F) inlet temperature
Flow Rate	3.79 lpm (1 gpm) minimum

Table 3-4. Environmental Specifications

Pressure	5.17 bars (75 psi) maximum inlet water pressure
Contaminates	• The following specifications are recommended for the water used to cool the RFG 3001 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.

Chapter 4

Connectors, Indicators, and Controls

USER PORT

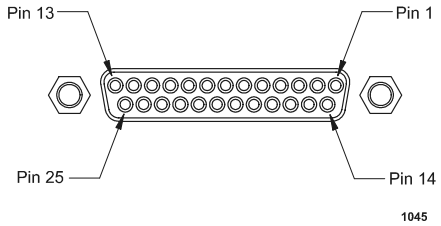

Figure 4-1. User port connector

Connector type: 25-pin, subminiature-D, shielded, female

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

Table 4-1 provides the connector pinouts for the User port connector.

The 25-pin User port on the RFG 1251 generator 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 4-1 provides descriptions of the signal types used in the RFG 1251 generator.

Table 4-1. User Port 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 as defined in Table 4-2.
Analog Inputs	The setpoint signal from the user (*pin 5*) is a 0 to 10 V signal scaled to represent the desired 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 (cable capacitance plus 1000 pF at the EMI filter in the generator).
Digital Outputs	The status signals provided by the generator (*pins 14, 20, 22, 24*, and *12*) are opto-coupled with NPN transistor outputs (industry type 4N37). The collector and emitter of each transistor are provided to the user interface. 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 Table 4-2 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 510 Ω resistor. A signal level of 4 to 30 V applied to *pin 4* enables the RF power.
Interlock	The interlock signals (*pins 10* and *23*) provide the dc power to close the ac contactor in the generator. *Pin 10* is tied to the generator's +24 to 30 V through a current limiting circuit. *Pin 23* is series wired with the interlock switch on the RF output connector and then tied to the contactor coil driver circuit. Connecting *pin 10* to *pin 23* closes the contactor, enabling ac power to the RF circuits.

Table 4-2. User Port Pins

Signal Pin	Return Pin	Signal Name	Signal Type	Signal Description
14	*1*	*SETPOINT STATUS*	Digital Output	A low-impedance path between these pins indicates that an internal power limit has been encountered. When RF power is enabled, a high impedance path between these pins indicates that the generator is “at setpoint”.
2	*15*	*REFL PWR MONITOR*	Analog Output	This 0 to 10 V signal represents the reflected power as measured at the output of the generator. This signal is scaled to represent 0 to 1250 W.
3	*16*	*FWD/DELV PWR MONITOR*	Analog Output	This 0 to 10V signal represents the forward or delivered power as measured at the output of the generator. See *pin 8* for power regulation mode selection. This signal is scaled to represent 0 to 1250 W.
4	*17*	*RF PWR ON*	Digital Input	This signal is used to control the RF output of the generator. A voltage level of 4 to 30 V on *pin 4* enables the RF power. If *pin 4* is open or grounded, RF power is disabled. Note that the return pin (*pin 17*) is common to both this signal and to the PWR REG MODE signal (see *pin 8*).
5	*18*	*SETPOINT*	Analog Input	This 0 to 10 V signal defines the desired setpoint for the generator's RF output. It is scaled to represent 0 to 1250 W.
6	*19,21*	*+24V DC*	Reference Voltage	This dc voltage may be used for controlling the RF power through *pin 4* (*pin 6* may be tied to *pin 4* to enable the RF power). The maximum current capacity for this signal is 50 mA.
20	*7*	*RF STATUS*	Digital Output	A low impedance path between these pins indicates that the RF power is present at the output of the generator. The interlock loop must be closed and the **RF PWR ON** signal must be active to enable RF power.

Table 4-2. User Port Pins

8	*17*	*PWR REG MODE SEL*	Input	This signal is used to control the desired power regulation mode. If *pin 8* is open or grounded, the generator regulates on forward power. A voltage level of 4 to 30 V on *pin 8* selects delivered power mode. Delivered power is defined as "forward power minus reflected power". Note that the return pin (*pin 17*) is common to both this signal and to the RF PWR ON signal (see *pin 4*).
22	*9*	*OVERTEMP*	Digital Output	A low impedance path between these pins indicates that an overtemperature condition has been detected by the generator. Refer to the troubleshooting section of the user manual for detailed information on this fault condition.
10	*23*	*INTERLOCK*	Input	These pins are part of a series interlock string which must be closed to enable ac power in the generator. A contact resistance of 15 Ω or less across these pins closes the loop. *Pin 10* is connected to +30 V in the generator.
24	*11*	*AC ON*	Digital Output	A low impedance path between these two pins indicates that ac power is available within the generator. AC power cannot be enabled unless the interlock loop is closed.
12	*25*	*CEX LOCK*	Digital Output	A low impedance path between these two pins indicates that the generator is frequency locked to the CEX input signal. A high impedance path indicates that there is either no input signal or it does not meet the required specifications (see note below).
13	*19,21*	*+15V DC*	Reference Voltage	This is a regulated dc voltage with a maximum current capacity of 50 mA. This signal can be used for controlling RF power (*pin 13* can be jumpered to *pin 4*).
19,21	*N/A*	*GROUND*	Ground Reference	These two pins are referenced to the signal and chassis grounds in the generator.

Interface Cabling Requirements

The cable used to connect the generator's 25-pin User port to the system controller must be a shielded, 25-wire I/O cable. Twisted-pair wiring is highly recommended but 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. 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 1251 generator must be tied to a local earth ground through an adequately sized grounding strap.

Interface Schematics

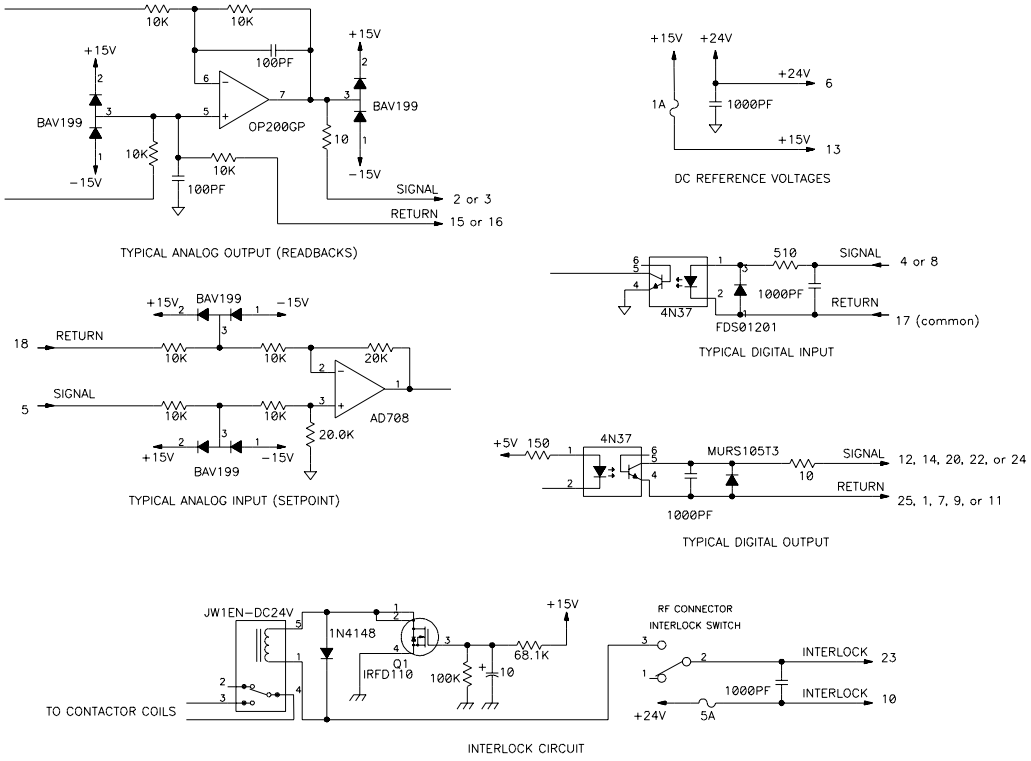

Figure 4-2. Interface schematics

WATER CONTROL CONNECTOR

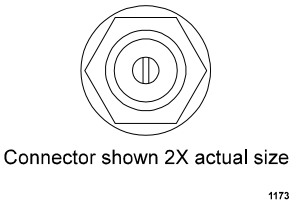

Figure 4-3. Water control connector

Connector type: 2-pin miniature power jack (Switchcraft P/N 712A)

Signal characteristics: +24 Vdc switched power source for an external coolant control solenoid

Table 4-3. Water Control Connector Pins

Signal Pin	Name	Description
1 (Center Pin)	*SOLENOID CONTROL*	+24 Vdc (700 mA, maximum) when the solenoid is enabled
2 (Outer Pin)	*GROUND*	Solenoid return

AC POWER CONNECTOR

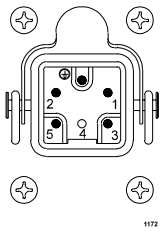

Figure 4-4. AC power connector

Table 4-4. AC Power Connector Pins

Pin	Description
1	208 V Phase
2	208 V Phase
3	208 V Phase
4	Not Used
5	EMI Shield Ground (this pin is not to be used as a current carrying conductor - this pin is intended for grounding the EMI (Faraday) shield in the mating power cord if a shielded cable is required)
GND	Safety/Earth Ground (green/yellow wire)

Note: The three ac line phases may be wired in any order.

STATUS INDICATORS

The RFG 1251 generator provides the following status indicators located on the connector panel:

Table 4-5. Status Indicators

AC ON	This green LED indicates that ac power is available within the generator.
RF ON	This green LED indicates that the RF output is enabled. Depending on the setpoint value, RF power may be present at the output connector. Following an ac power up of the generator, RF power is inhibited until the RF ON CMD signal is transitioned from off-to-on.
Interlock Open	This yellow LED indicates that the required interlock criteria have not been satisfied and, subsequently, RF power is inhibited. If the interlock loop is closed, the RF output is enabled at the next off-to-on transition of the RF ON CMD signal on the User port. The LED remains lit as long as the interlock loop is open.

Table 4-5. Status Indicators

Power Limit	This yellow LED indicates that the generator is unable to supply the requested power level due to a limiting condition in the generator. Power limits can be caused by load mismatches (high reflected power) or excessive internal power dissipation limits. Power limits do not disable the RF output of the generator.
Overtemp	This yellow LED indicates that the generator has detected an overtemperature condition and has inhibited its RF power. Cooling water flow is enabled whenever this condition exists. After the overtemperature condition is resolved, output power may be restored by cycling RF power off and then back on again (the RF output will not be enabled until the next off-to-on transition of the RF ON CMD signal on the User port). Once activated, the LED remains lit until both the overtemperature condition subsides and the RF ON CMD signal is de-activated.

Note: The RFG 1251 generator contains a high-temperature shutdown sensor which shuts off all circuitry in the generator if the internal temperature exceeds a potentially damaging level. This shutdown is designed to protect the generator in the event of extreme, out-of-spec operating conditions. If such a shutdown occurs, all indicators on the unit are extinguished. If the unit is allowed to cool down, the generator powers back on without the need for operator intervention. The RF output is not enabled until the next off-to-on transition of the RF ON CMD signal.

CONNECTOR PANEL

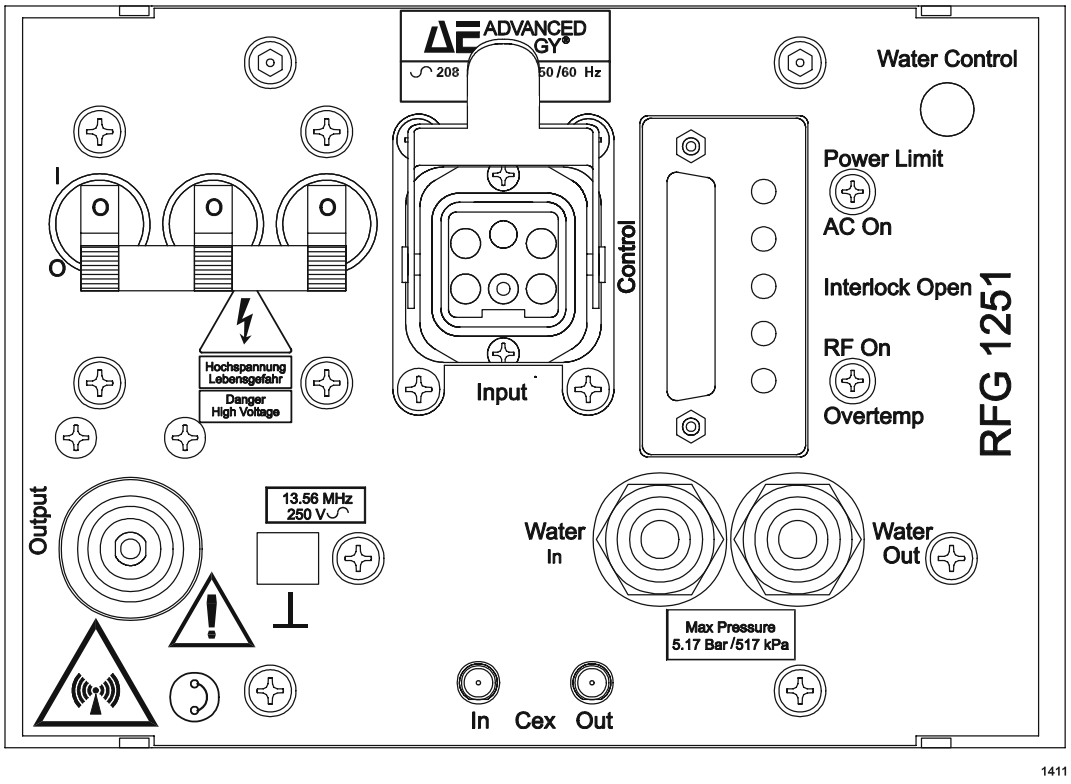

Figure 4-5. RFG 1251 panel

Installation

SETTING UP

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 unit provides an RFI ground threaded hole. A suitable chassis ground connection made at this point prevents or minimizes radio frequency interference.

Note: For more information about grounding, refer to AE Application Notes titled Grounding p/n 5600031A.

DIMENSIONAL INFORMATION

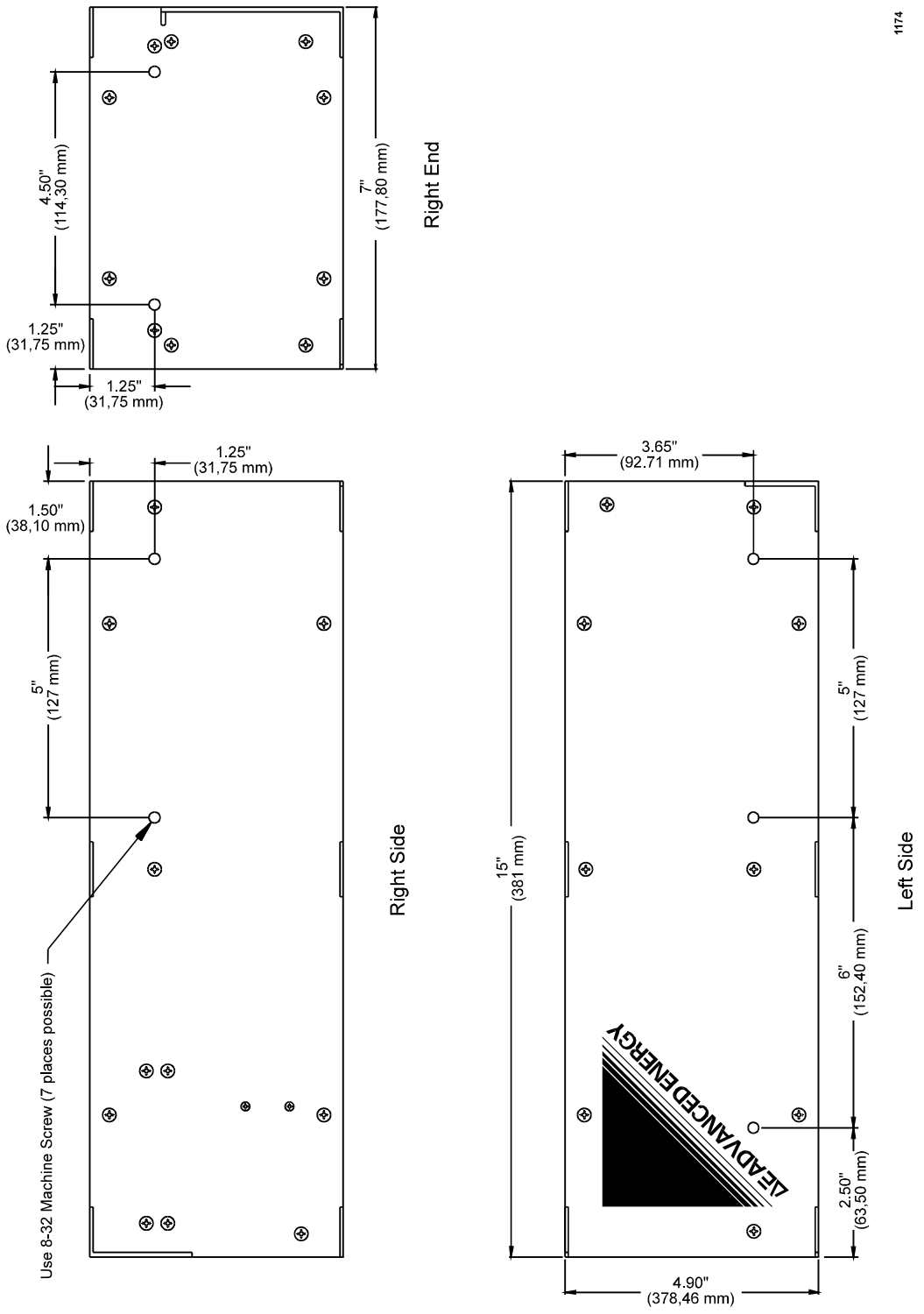

Figure 5-1. RFG 1251 dimensions

CONNECTING COOLING WATER

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

> ⚠ **WARNING:**
> **If you connect the cooling water on multiple units in series, be sure that input water temperature to all units is less than the maximum input water temperature.**

Connect the input and output water connections. Turn on the water and ensure that there are no leaks. Be sure that the flow rate, water temperature, and pressure are within the specifications required to operate your RFG 1251 generator.

Note: Keep the water-cooling system running as long as the rear circuit breaker is on. Overheating can occur even if RF is not being produced, because the auxiliary power supply is also water-cooled.

Install the water control solenoid assembly if you wish to control the water flow.

CONNECTING INPUT POWER

> ⚠ **DANGER:**
> **Before making any input line power connection, turn off building circuit breakers supplying input power to the RFG 1251 generator. Also, ensure that the circuit breaker on the RFG 1251 is in the OFF position.**

Check to be sure the input power is within the specifications shown in Chapter 3.

Connect a power cord with its mating Harting connector to the generator and lock the latching lever. The power cord should meet the electrical specifications found in Table 3-2 with four 14 AWG wires and an EMI shield. Connect the wires per Table 4-4.

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.**

Be sure that the input power is turned off at the circuit breakers on the generator.

Install the output power cable connector. Be sure to tighten the connector to ensure that the interlock switch is closed.

Operation

FIRST TIME OPERATION

After the generator is properly installed on the system and all power, interface, and cooling water connections have been verified, the following series of tests can be performed to verify proper operation of the unit. If desired, the RF output of the generator can be connected to a 50 Ω dummy load for this initial testing. If, at any point during this test sequence, the generator does not perform as specified, an attempt should be made to identify and resolve the problem. If the problem cannot be resolved, contact AE Customer Service for assistance.

1. Before applying ac power to the unit, verify that the User Port signals are set as follows:
   - *RF PWR ON* must be disabled (*pin 4* must be open or grounded).
   - The *SETPOINT* input (*pin 5*) must be set to zero volts.
   - The *PWR REG MODE* signal (*pin 8*) should be set for the desired power regulation mode required by the system (*pin 8* open or grounded selects forward regulation mode, *pin 8* pulled high selects delivered power mode).
   - The *INTERLOCK* pins on the User Port (*pins 10* and *23*) must be connected together (maximum contact resistance of 15 Ω).
2. Apply 208 Vac power to the generator and activate the circuit breaker on the RFG 1251. Verify that the green *AC ON* indicator is lit on the generator and that the *AC ON* status signal is active on the User Port (low impedance between *pins 24* and *11*). All other LED indicators should be extinguished at this time.
3. Enable the RF output by applying a 4 to 30 Vdc signal to *pin 4* (*RF PWR ON*). Verify that the *RF ON* indicator lights on the generator and that the *RF STATUS* signal on the User Port is active (low impedance between *pins 20* and *7*
4. Verify that the analog readback signals from the generator are indicating 0 W of forward/ delivered power (*pin 3*) and 0 W of reflected power (*pin 2*). The voltages on these pins should not exceed 0.010 V when the requested setpoint (*pin 5*) is 0.
5. Increase the *SETPOINT* signal (*pin 5*) to 1.0 V (equivalent to 125 W of RF power). Verify that the *FWD/DELV PWR MONITOR* signal (*pin 3*) indicates the existence of RF power and that no error conditions are reported (check the LED indicators as well as the status signals on the User Port). If the generator is being operated into a near-50 Ω, resistive load, the *FWD/DELV PWR MONITOR* signal should track the setpoint signal within 10 mV and the *REFL PWR MONITOR* signal (*pin 2*) should remain essentially at 0.
6. Continue to increase the *SETPOINT* signal while verifying that no error conditions are reported and that the *FWD/DELV PWR MONITOR* signal tracks the setpoint value. The maximum allowable setpoint voltage is 10 V (representing a full scale RF output of 1250 W).

7. Temporarily inhibit the RF output by clearing the *RF PWR ON* signal (*pin 4*). Verify that the **RF ON** indicator extinguishes, the *RF STATUS* signal (*pins 20* and *7*) goes inactive, and the RF output power goes to 0 (as measured at the readback signal, *pin 3*). Re-enable the RF output by activating the *RF PWR ON* signal (*pin 4*). The generator should return to the conditions defined in step 6 above.
8. Temporarily open the interlock loop by removing the contact closure between *pins 10* and *23* on the User Port. You should be able to hear the ac contactor (relay) inside the generator open. Verify that the **RF ON** indicator extinguishes, the **Interlock Open** indicator is lit, and there is no RF power being produced by the generator (*FWD/DELV PWR MONITOR* signal should go to 0).
9. Close the interlock loop again by reconnecting *pins 10* and *23* on the User Port. Verify that the **RF ON** indicator remains off (even though the *RF PWR ON* signal has remained active) and that no RF power is being produced. Verify that the **Interlock Open** indicator extinguishes.

   Note: The RF output remains disabled in this case because, after any disruption in the RF output, the *RF PWR ON* signal must be toggled from off to on before RF power is restored.

10. Toggle the *RF PWR ON* signal (*pin 4*) off and then back on again. Verify that the **RF ON** indicator lights and that RF power is once again present (reference step 6).
11. Return the *FWD/DELV PWR MONITOR* signal to 0 V, disable the RF output by clearing the *RF PWR ON* signal (*pin 4*), and then turn off the generator's circuit breaker.

Troubleshooting and Customer Support

BEFORE CALLING AE CUSTOMER SUPPORT

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

Checks with the Power Off

1. Make sure the power switch is off.
2. Check for visible damage to the unit, cables, and connectors.
3. Make sure all unit connectors are installed correctly and are fastened tightly.
4. Check to determine whether any system-related circuit breakers have been tripped.
5. Make sure there is input power to the unit and make sure the input power meets specifications.
6. Make sure ground connections are adequate and secure.

Checks with the Power On

1. Check the unit's input power connections to ensure the proper power is being supplied to the unit.
2. Check the unit's LEDs to determine that the proper ones are lit

Troubleshooting Tables

Table 7-1. No Power

AC ON LED	RF ON LED	Intlk Open LED	Over temp LED	Power Limit LED	Probable Cause	Action
On	Off	On	Off	Off	The interlock string is open. The RF output cable is not connected or loose. *Pins 10* and *23* on the User port are not connected.	Install and/or tighten the RF output connector. Connect *pins 10* and *23* on the User port. After the condition is resolved, toggle the RF On command off and then back on again.
Off	Off	Off	Off	Off	The circuit breaker is off. The generator had no cooling water for a long period of time resulting in AUX supply shut down.	Turn the circuit breaker on. Check the cooling water for proper operation. Let the generator cool down. The AUX supply will automatically turn back on when cool.
On	On	Off	On	Off	An overtemperature condition has been detected in the generator. Cooling water is probably out of specifications.	Check cooling water and ensure it is within specifications. After overtemperature condion is resolved, toggle RF On command off and then on again.

Table 7-2. The Power Level Doesn't Meet Setpoint

AC ON LED	RF ON LED	Intlk Open LED	Over temp LED	Power Limit LED	Cause	Action
On	On	Off	Off	On	The generator is unable to supply the requested power level due to limiting conditions in the generator. Power limits can be caused by load mismatches.	Adjust the load or reduce the power level.

AE CUSTOMER SUPPORT

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

Table 7-3. 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: 970.407.5334 Email: support@ftc1.aei.com
AE, California 491 Montague Expressway Milpitas, CA 95035 USA	Phone: 408.263.8784 Fax: 408.263.8992 Email: allenv@aew1.aei.com
AE, Massachusetts 228 Oak Hill Circle Concord, MA 01742 USA	Phone: 978.371.1381 Fax: 978.371.0569 Email: pats@ftc2.aei.com
AE, Texas 8601 Cross Park Drive Austin, TX 78754 USA	Phone: 512.231.4200 Fax: 512.719.9042 Email: BrianC@aes1.aei.com
AE, GmbH Raiffeisenstrasse 32 70794 Filderstadt (Bonlanden) Germany	Phone: 49.711.77927.0 Fax: 49.711.7778700 Email: kamel@aeg1.aei.com
AE, Japan KK TOWA Edogawabashi Bldg. 347 Yamabuki-cho Shinjuku-ku, Tokyo Japan	Phone: 81.3.32351511 Fax: 81.3.32353580 Email: tetsu@aej1.aei.com
AE, Korea Ltd. 3rd fl. Zeus Building, 3-16 Yangjae-Dong, Seocho-Ku Seoul, 137-130 Korea	Phone: 82.2.3448.4775 Fax: 82.2.577.0614 Email: hannahc@ftc1.aei.com
AE, United Kingdom Unit 5, Minton Place, Market Court, Victoria Road Bichester, Oxon OX6 7QB UK	Phone: 44.1869.320022 Fax: 44.1869.325004 Email: cathyk@ftc2.aei.com

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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