PowerWorks

70LM Microturbine

Operating Manual

Part No. **85031011**
Revision A-6/10/02

70LM Microturbine

Operating Manual

Energy Systems

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The PowerWorks line of products was developed with the assistance of the Gas Research Institute, Southern California Gas Company and New York Gas Group.

PowerWorks 70LM Microturbine

Operating Manual

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1 IMPORTANT SAFETY INSTRUCTIONS

SAVE THESE INSTRUCTIONS

THIS MANUAL CONTAINS IMPORTANT INSTRUCTIONS FOR POWERWORKS 70L SERIES MICROTURBINES THAT SHOULD BE FOLLOWED DURING OPERATION OF THE GENERATOR AND BATTERIES.

Safety Instruction Conventions in This Manual

Safety instructions in this manual are bold-faced for emphasis. The signal words **DANGER**, **WARNING** and **CAUTION** are used to indicate the hazard seriousness levels explained below.

Be sure to read and understand this manual and all safety instructions before proceeding with installation.

Indicates the presence of a hazard that WILL cause serious injury, death or property damage if ignored.

Indicates the presence of a hazard that CAN cause serious injury, death or property damage if ignored.

Indicates the presence of a hazard that WILL or can cause injury or property damage if ignored.

Indicates important setup, operating or maintenance information.

General Safety Precautions

The PowerWorks microturbine requires specialized professional expertise in order for it to be properly serviced and maintained. The owner, user, or operator of the PowerWorks microturbine is hereby notified and forewarned that ANY FAILURE TO OBSERVE COMMON SAFETY PRECAUTIONS AND THOSE SET FORTH HEREIN MAY RESULT IN INJURY OR DAMAGE TO PERSONS OR PROPERTY.

DO NOT START OR OPERATE ANY POWERWORKS MICROTURBINE UNTIL AFTER IT HAS BEEN PROPERLY COMMISSIONED BY INGERSOLL-RAND ENERGY SYSTEMS.

Ingersoll-Rand Energy Systems expressly disclaims responsibility and liability for any injury and damage caused by failure to observe common precautions or by failure to exercise the ordinary caution, common sense and due care needed to install or operate the unit even though not expressly specified in this document.

Furthermore, failure to heed the warnings, danger notices and notes in "Important General Safety Notices" or use of the machine outside the operating conditions specified in this manual and in *PowerWorks Planning and Installation Manual*:

a Is not approved by Ingersoll-Rand Energy Systems

b May impair the safety of users, other persons, and property,

c May prejudice any claims made against Ingersoll-Rand Energy Systems, and

d Voids any product or service warranty made by Ingersoll-Rand Energy Systems.

Important General Safety Notices

THE FOLLOWING ARE NOT PERMITTED:

Use of the machine where there is any actual or foreseeable risk of hazardous levels of flammable gases or vapors

Use of the machine with other than the specified fuel

Use of the machine fitted with components not approved by Ingersoll-Rand Energy Systems

Use of the machine with safety or control components missing or disabled

Connection to an electrical supply of incorrect voltage and/or frequency.

The use of repair parts other than those included within the Ingersoll-Rand Energy Systems approved parts list may create hazardous conditions over which Ingersoll-Rand Energy Systems has no control. Therefore Ingersoll-Rand Energy Systems cannot and will not be held responsible for equipment in which non-approved repair parts are installed and you agree to indemnify and hold Ingersoll-Rand Energy Systems harmless against any damage, loss, cost or expense caused by the operation of any PowerWorks microturbine that contains non-approved repair parts or has been subject to non-approved maintenance.

Internal parts during operation and shortly after shutdown are at temperatures which can cause severe injury. Do not attempt to service any parts or remove panels prior to allowing the unit to cool as outlined in the operating and maintenance instructions.

Do not operate the PowerWorks unit unless you have fulfilled the specific intertie protection requirements of your local power company.

When operating in REMOTE ENABLE MODE, the machine may start suddenly at any time. Observe all required safety precautions any time the enclosure panels are removed as outlined in the operating and maintenance instructions.

Before opening the enclosure for any reason other than checking coolant levels, shut down the unit, wait for the coolant pump to stop running, disconnect the PowerWorks unit from external power by turning off and locking the external disconnect module, and follow all other instructions in “Maintenance Shutdown” on page 73

Internal Battery Supply

The PowerWorks microturbine contains a 12-volt lead-acid battery for powering the coolant backup system if external power is interrupted. It also has a 3.6-volt lithium battery within the BCM (base control module) for memory backup.

These batteries are not customer-serviceable and should be replaced, removed or disconnected only by trained Ingersoll-Rand Energy Systems personnel.

Servicing of the batteries is to be performed or supervised by personnel knowledgeable of batteries and the required precautions. Keep unauthorized personnel away from the batteries.

When replacing the batteries, use the same number and the following types of batteries: one 12-volt, 48 Ah, sealed, non-vented lead-acid battery with over-pressure relief for the coolant backup system, and one 3.6 V, 0.95 Ah, lithium battery for BCM memory backup.

Do not dispose of battery or batteries in a fire. The battery is capable of exploding.

Do not open or mutilate the battery or batteries. Released electrolyte has been known to be harmful to the skin and eyes and to be toxic.

A battery presents a risk of high short circuit current. The following precautions are to be observed when working on batteries:

1. **Remove watches, rings, or other metal objects,**
2. **Use tools with insulated handles.**

Safety Decals and Symbols

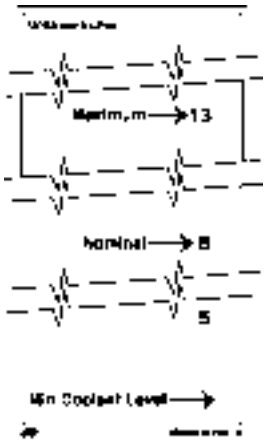
Depending on manufacturing location, the PowerWorks microturbine and manuals may display symbols shown in this section. Systems for use within the European Community must display the appropriate ISO safety symbols in this section. Read and understand thoroughly. Heed all warnings and follow instructions. If you do not understand a symbol, consult your supervisor or contact Ingersoll-Rand Energy Systems.

Text Decals

(WARNING: Electrical shock risk)

(WARNING: Magnetic field)


WARNING
Use of incorrect coolant can cause severe system failure.
Only use:
MEGACOOL


Maximum 13
Nominal 8
5


NOTICE
PowerWorks. OPERATING PROCEDURE
Before installing, operating or performing any maintenance on this unit, read and understand the instructions in the operator's instruction manual.
Before Starting
Starting
Stopping
Emergency Stopping


Fuel vent
Fuel inlet


NOTICE
A minimum of 3 feet clearance on all sides and top are required.
Refer to Instructions / Operators Manual before performing any maintenance.
Do not operate with louvers blocked.

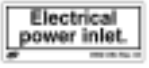

WARNING
Plumb coalescer vent outdoors.


WARNING
Use of incorrect coolant can cause system contamination.
Only use:
BOOSTERCOOL


WARNING
Plumb fuel vent outdoors.


Water outlet
Water inlet


Lift here.
Unit must be lifted with fork lift.


Electrical power inlet.

ISO Safety Symbols

WARNING: Electrical shock risk.

WARNING – Rotor magnetic field can affect pacemakers.

WARNING – Hot surface.

Emergency stop.

On (power).

Off (power).

POWER INLET

WATER IN

WATER OUT

2 Introduction

Purpose of This Manual

This manual provides general instructions for operating an Ingersoll-Rand Energy Systems PowerWorks 70L series microturbine. Operation includes starting the microturbine, shutting it down, performing routine maintenance, and troubleshooting operational problems not requiring an Ingersoll-Rand Energy Systems technician.

For installation instructions and requirements, refer to the separate *PowerWorks Planning and Installation Manual*. For yearly maintenance procedures, refer to *PowerWorks Owner Maintenance Manual*.

Maintenance, repairs and overhauls not covered in this manual or the manuals above should be referred to an authorized Ingersoll-Rand Energy Systems service organization. Contact Customer Service at Ingersoll-Rand Energy Systems (see page 19) for more information.

DO NOT START OR OPERATE ANY POWERWORKS MICROTURBINE UNTIL AFTER IT HAS BEEN PROPERLY COMMISSIONED BY INGERSOLL-RAND ENERGY SYSTEMS.

Manual Organization

This manual is organized into the following chapters:

1 **Important Safety Instructions** Safety instructions, symbols, and conventions used for safety notices in this manual.

2 **Introduction** Purpose of this manual and how it is organized.

3 **General Information** General PowerWorks microturbine description, model numbering, nameplate information, abbreviations, acronyms, and customer service contact information.

4 **Technical Description** Descriptions of PowerWorks microturbine applications, principles of operation, and internal components.

5 **Control Panel Keys, Buttons and Indicators** Locations and functions of buttons, keys, indicator lights, and graphic display on the control panel.

6 **Using the Graphic Display** Instructions for navigating and viewing information on the graphic display and for changing operating settings displayed there.

7 **Startup and Shutdown** Step-by-step procedures for checking, starting, stopping and restarting the PowerWorks unit.

8 **Keeping Operating Records** Suggestions for maintaining operating logs and records.

9 **Maintenance** Procedures for performing routine maintenance.

10 **Troubleshooting** Solutions to operating problems caused by equipment and conditions external to the PowerWorks unit and not requiring an Ingersoll-Rand Energy Systems service technician.

3 General Information

General Description

The Ingersoll-Rand Energy Systems PowerWorks 70L series microturbine (Figure 1) is a compact, gas-turbine-powered, 70 kW generator for base load or peak shaving applications.

PowerWorks microturbines feature an optional exhaust heat recovery heat exchanger that makes waste heat from fuel combustion available for hot water heating, space heating and other uses. In addition to high efficiency, the microturbine offers long life (80,000-hour engine design life) and low emissions under normal operating conditions.

For more detailed description of the PowerWorks microturbine and its components, see “Technical Description” on page 21.

Figure 1. PowerWorks 70L series microturbine

Model Numbering and Nomenclature

PowerWorks microturbine model designations indicate nominal power rating, generator type and fuel as shown in Figure 2.

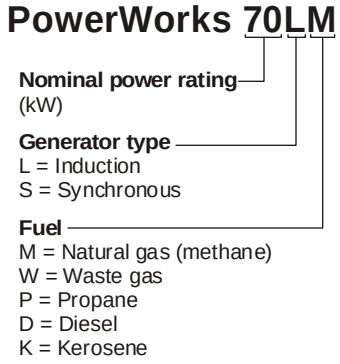


Figure 2. Model designations

Nameplate Information

The PowerWorks microturbine nameplate (Figure 3) is attached to the outside of the enclosure and indicates model number, serial number and selected performance information for the PowerWorks system and its electric generator. Do not remove the nameplate.

Table 1 defines nameplate terms for the PowerWorks unit as a system and for the generator within the PowerWorks unit.

! Note

PowerWorks generator ratings may be different from the PowerWorks system ratings, which are measured at the PowerWorks unit power terminals. External equipment should be sized for the PowerWorks system ratings, not for the generator ratings.

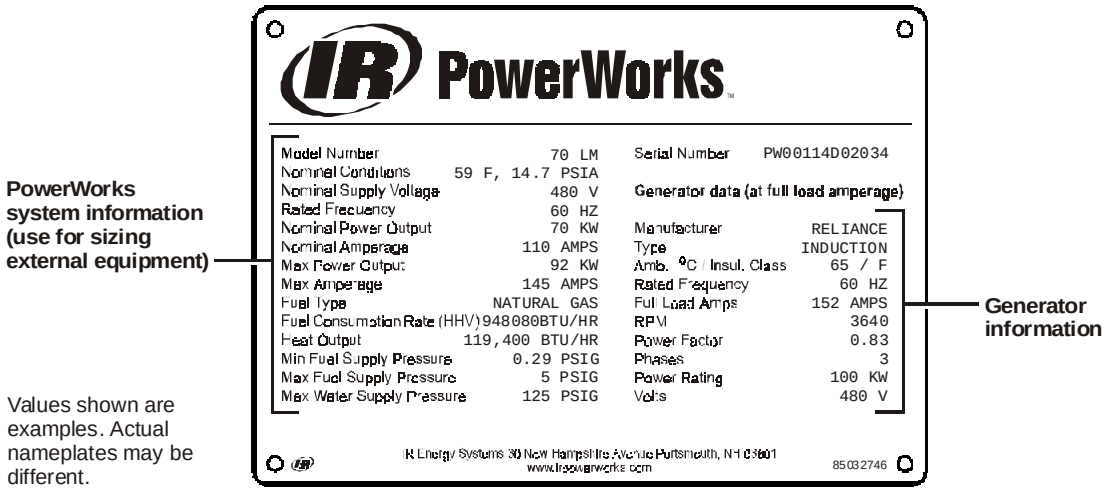


Figure 3. Sample nameplate

Table 1. Nameplate Terminology	
Term	***Definition***
Model Number	See “Model Numbering and Nomenclature” on page 16
Serial Number	Unique identifier code assigned during manufacture
Nominal Conditions	Nominal performance temperature, relative humidity and atmospheric pressure
Nominal Supply Voltage	Voltage at PowerWorks nit power terminals at nominal operating level
Rated Frequency	Power frequency at PowerWorks unit power terminals
Nominal Power Output	Power output at nominal operating conditions
Nominal Amperage	Output current at nominal operating conditions
Max Power Output	Maximum net electric power measured at PowerWorks unit output leads
Max Amperage	Gross amperage maximum as measured at generator leads
Fuel Type	Fuel (natural gas, waste gas, propane, etc.)
Fuel Consumption Rate (HHV)	Fuel consumption at nominal operating conditions (high heat value)
Heat Output	Heat supplied to ambient air at nominal operating conditions
Min Fuel Supply Pressure	Minimum fuel pressure required for rated power output
Max Fuel Supply Pressure	Maximum fuel supply pressure capacity of regulators or other internal components
Max Water Supply Pressure	Maximum heat recovery system water inlet pressure
Generator Data **Note:** The nameplate terms below apply to the PowerWorks unit internal electric generator **at its full-load amperage**. Values for these parameters may be different from the PowerWorks system values above.	
Term	***Definition***
Generator Manufacturer	Generator manufacturer name
Generator Type	Generator design (induction, synchronous, etc.)
Generator Amb. ºC/Insul. Class	Maximum generator ambient temperature rating and insulation classification
Generator Rated Frequency	Generator frequency rating
Generator Full Load Amps	Generator rated maximum current output
Generator RPM	Generator speed
Generator Power Factor	Generator power factor
Generator Phases	Number of generator phases
Generator Power Rating	Generator maximum power output rating
Generator Volts	Generator nominal voltage

Abbreviations and Acronyms

A	ampere
Ah	ampere-hour
BTU	British thermal unit
cm^2	square centimeter
CT	current transformer
cu ft	cubic foot
dBa	decibels, measured with the “a” weighting filter
DCS	distributed control system
ft	foot
gal	gallon
HHV	high heat value
hr	hour
Hz	hertz
in.	inch
ips	inches per second
ISO	international standards organization
kg	kilogram
kPa	kilopascal
kVA	kilovolt-ampere
kVAR	reactive kilovolt-ampere
kW	kilowatt
kWh	kilowatt-hour
L	liter
lb	pound
lbm	pound mass
LHV	low heat value
m	meter
mA	milliampere
mg	milligram
min	minute
mm	millimeter
MWh	megawatt-hour
PF	power factor
ppmv	parts per million by volume
psi	pounds per square inch
psig	pounds per square inch, gauge
RH	relative humidity
RTD	resistance temperature detector
rpm	revolutions per minute
s	second
sq ft	square foot
UCM	universal communication module
Vac	volt, alternating current
Vdc	volt, direct current
VFD	variable frequency drive
WC	water column height

Definitions

Code Set of formal regulations specifying procedures or minimum standards.

Cogeneration Process of generating electrical energy and heat energy from the same unit or plant.

ISO conditions Reference temperature, pressure and humidity at which gas turbines and other devices are rated for performance. These conditions are 59ºF, 14.7 psig, 60% relative humidity (15ºC, 101 kPa, 60% RH).

Recuperator Heat exchanger designed for transferring heat from turbine exhaust gas to turbine inlet air for the purpose of increasing efficiency.

Disclaimer

Nothing contained in this document extends or creates any promise, warranty or representation, expressed or implied, regarding the Ingersoll-Rand Energy Systems products described herein. Any such warranties or other terms and conditions of sale or use of products shall be in accordance with the standard terms and conditions of sale or use for such products, which are available upon request.

Ingersoll-Rand Energy Systems reserves the right to make changes and improvements to products without notice and without incurring any obligation to make such changes or add such improvements to products sold previously.

This machine has been designed and supplied for use only within the installation and operating conditions specified in this manual and in *PowerWorks Planning and Installation Manual*. **If in doubt about the suitability of this machine for specific conditions or applications, contact your Ingersoll-Rand Energy Systems applications engineer or Customer Service at Ingersoll-Rand Energy Systems (below).**

The design of this product and certain features within it are covered by patents held by Ingersoll-Rand Energy Systems and patents pending.

Contacting Customer Service

For operating information not provided in this manual, call Customer Service at Ingersoll-Rand Energy Systems (toll-free):

1-866-460-8903

4 Technical Description

The Ingersoll-Rand Energy Systems PowerWorks 70L series microturbine (Figure 4) is a compact, gas-turbine-powered, 70 kW induction generator for base load or peak shaving applications.

For highest possible efficiency, PowerWorks microturbines offer an optional heat recovery heat exchanger that makes waste heat from fuel combustion available for hot water heating, space heating and other uses.

In addition to high efficiency and long life, PowerWorks microturbines produce low emissions under normal operating conditions. The clean exhaust is the result of a unique, patented combustor design that assures complete combustion of virtually all fuel entering the system.

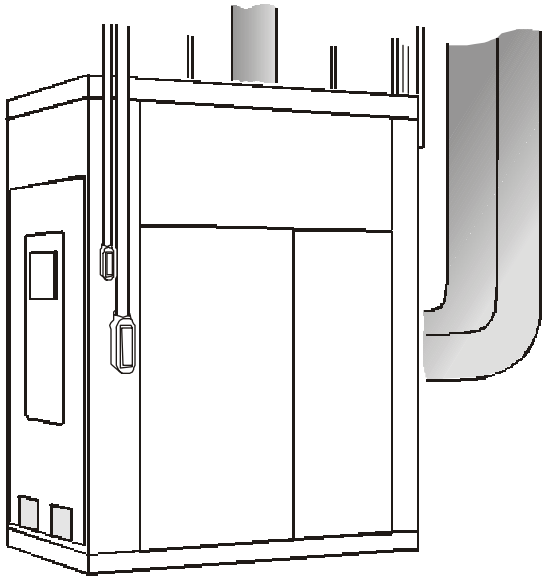


Figure 4. Installed PowerWorks microturbine

Typical Applications

PowerWorks microturbines can be used in any application that benefits from reduced consumption of utility power. In addition, the optional heat recovery system can supply heat energy for many commercial and industrial applications.

The PowerWorks unit can run continuously to offset utility power or operate only during peak demand periods when electric rates increase. When the PowerWorks unit is operating, heat energy recovered from the turbine exhaust is available for additional energy savings.

Typical applications of PowerWorks units include the following:

- Oil refineries
- Multifamily dwellings
- Ice rinks
- Schools and colleges
- Retail stores
- Food markets
- Commercial laundries
- Wastewater treatment facilities
- Hotels and motels
- Commercial greenhouses
- Athletic facilities
- Healthcare facilities
- Shopping malls
- Manufacturing facilities
- Landfills

Heat energy recovered from the microturbine exhaust can be used for hydronic space heating, domestic hot water heating, and industrial process water heating. For example, Figure 5 shows a PowerWorks unit installed to provide electric power and space heating.

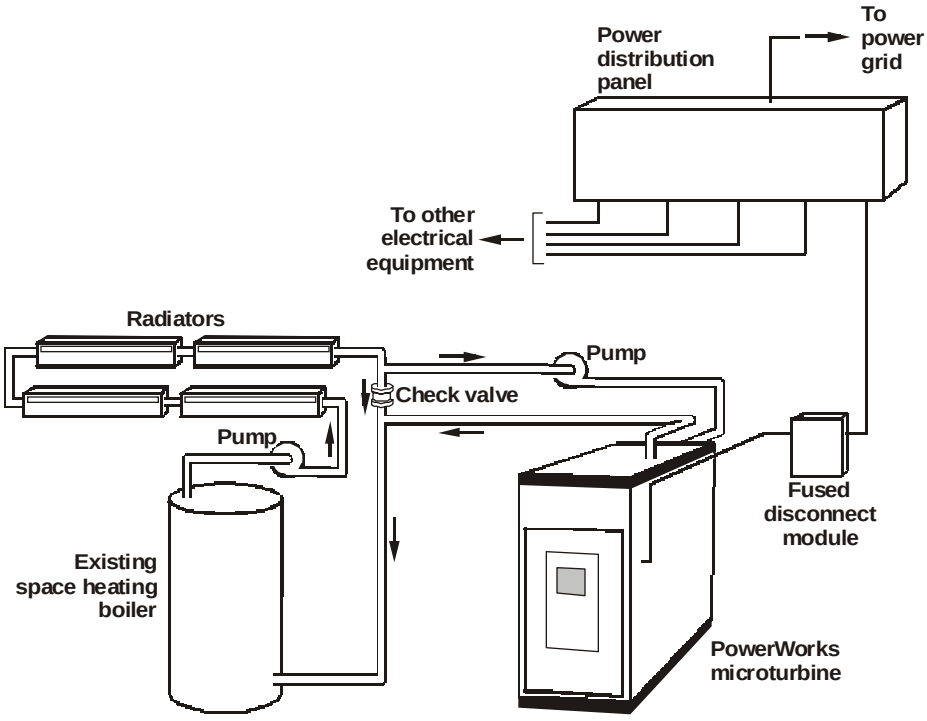


Figure 5. Example PowerWorks microturbine application

Model 70LM Specifications

Some of the specifications below are based on currently available test data. Actual results may be different because of installation configuration differences and environmental conditions. Ingersoll-Rand Energy Systems reserves the right to change the design and specifications without notice.

These values are not intended for sizing power circuit conductors or other components. See *PowerWorks Planning and Installation Manual* for generator specifications and other installation requirements.

Rated Electrical Output	Nominal	70 kW @ ISO conditions (59ºF, 60% RH, 14.7 psi)
	Maximum (±5 kW)	92 kW (at 0ºF and .8 facility power factor)
	Voltage	480 Vac, 3-phase, 60 Hz
Performance	Electrical efficiency (±2 percentage points):	28% LHV
	Heat rate (HHV, ±2%):	13,550 BTU/kWh
Heat Recovery	Example:	273,000 BTU/hr at 20 gal/min and inlet water at 150ºF
Emissions	NOx:	<9 ppmv at 15% O_2 <0.413 lbm/MWh (187 g/MWh)
	CO:	<9 ppmv at 15% O_2 <0.252 lbm/MWh (114 g/MWh)
Generator	Connection:	Wye, 4-wire ungrounded
	Maximum ambient temperature rating:	150ºF (65ºC)
Physical	Dimensions:	71.2 L x 42.6 W x 87.4 H in. (1810 L x 1080 W x 2220 H mm)
	Weight:	4100 lb (1860 kg)
Misc	Noise:	78 dBa at 1 m

Power Cycle

The compact, high-efficiency PowerWorks microturbine is a two-shaft recuperated system which drives an electric generator.

The PowerWorks microturbine power cycle is shown schematically in Figure 6. Air enters the unit and is compressed by the gas generator compressor, raising its pressure to about 35 psig (241 kPa). This compressed air enters the recuperator, where turbine exhaust preheats it to about 1000ºF (540ºC). Upon entering the combustor, the air mixes with fuel and the air-fuel mixture burns to produce compressed gas at about 1600ºF (870ºC).

The hot compressed gas from the combustor expands while passing through the gas generator turbine to drive the gas generator compressor. The heated gas then passes into the power turbine, which drives the electric generator through a gearbox.

Exhaust from the power turbine enters the recuperator, where it preheats the combustion air. If the PowerWorks unit is equipped for heat recovery, the exhaust also passes through an air-to-water heat exchanger. In this heat exchanger, the exhaust gives up additional heat to circulating water for domestic hot water, space heating or another application external to the PowerWorks unit. The exhaust gas then exits from the enclosure and the building through the exhaust duct.

The power cycle components shown schematically in Figure 6 are arranged in the enclosure as shown in Figure 7. External connections for inlet air, exhaust, heat recovery water, electric power, control wiring and venting are shown in Figure 8.

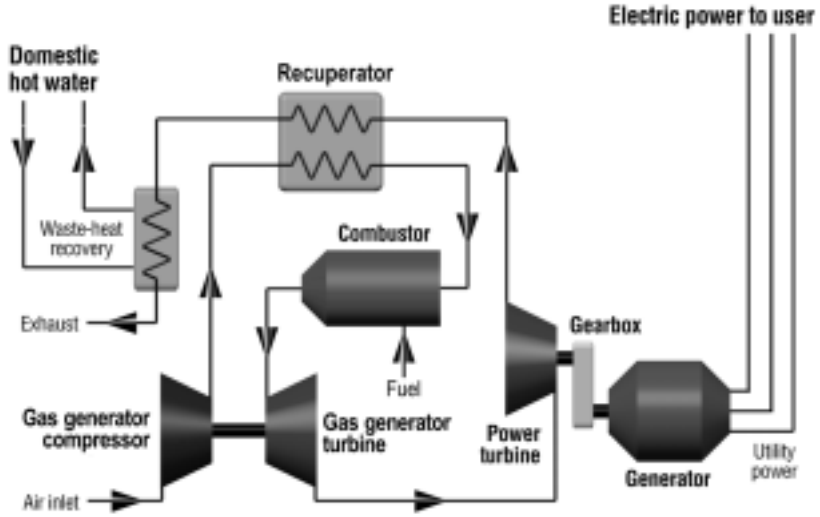


Figure 6. Power cycle schematic

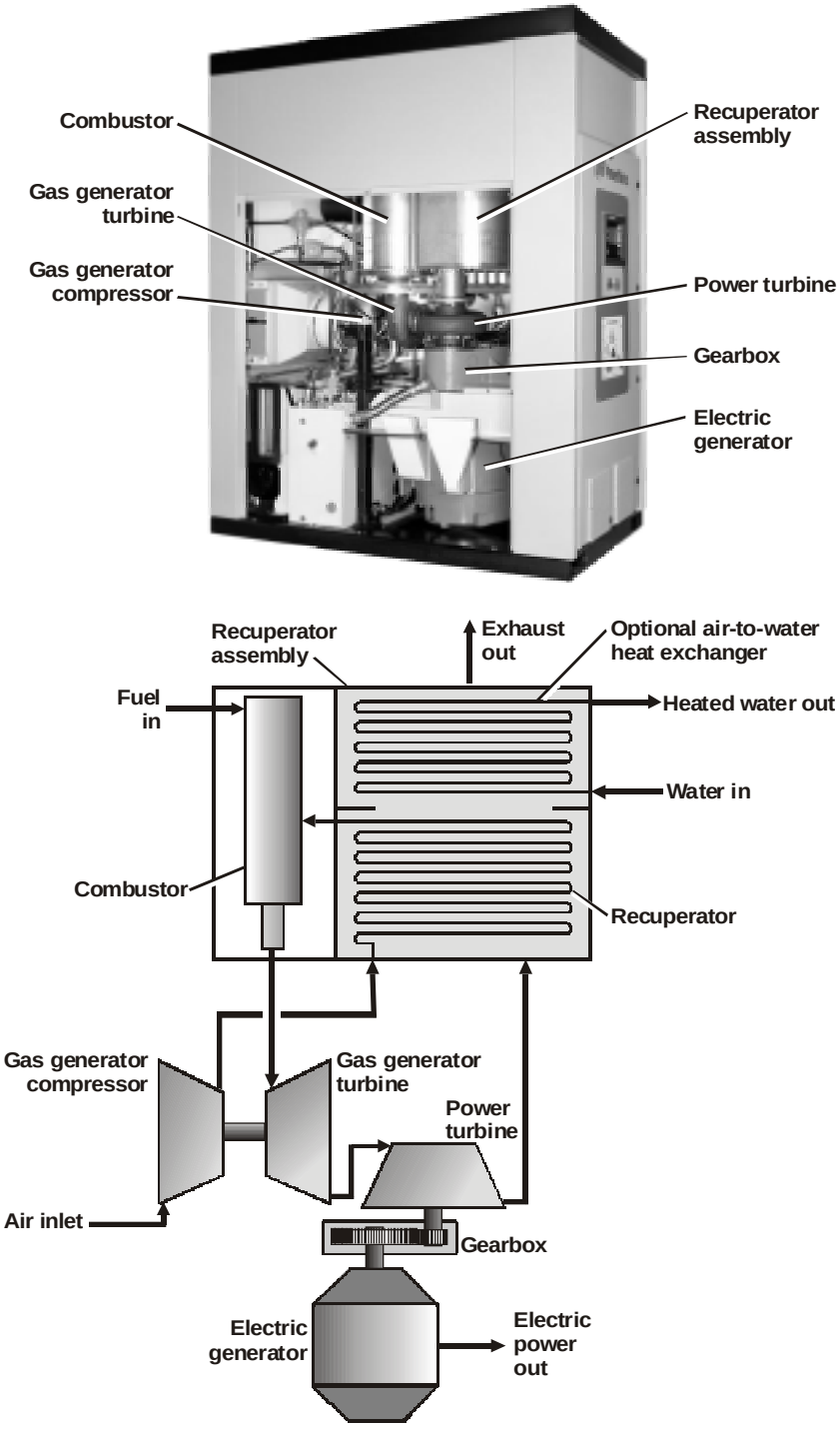


Figure 7. Power cycle component locations

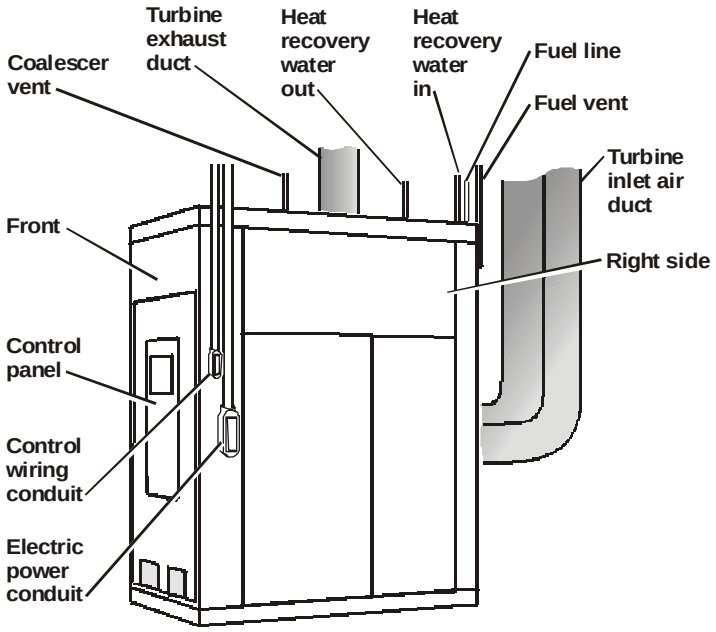


Figure 8. PowerWorks microturbine external connections

Engine Core

The engine core (Figure 9) includes the gas generator assembly and the power turbine. The gas generator assembly includes the gas generator compressor, the gas generator turbine and the starter.

As shown in Figure 9, the gas generator shaft and the power turbine shaft rotate independently. This two-shaft engine design reduces stress on engine components and extends engine life.

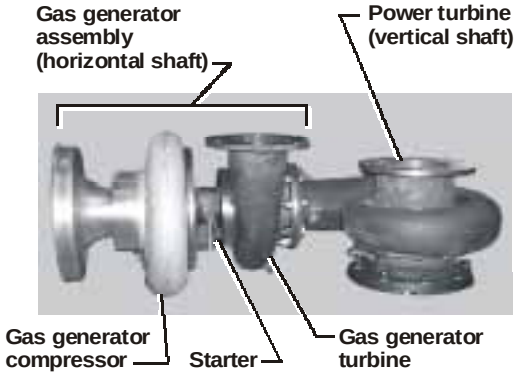


Figure 9. Engine core components

Gas Generator Assembly

The gas generator assembly (Figure 9 on page 27), which consists of the gas generator turbine and the gas generator compressor, provides 35-psig air to the recuperator and the combustor as shown in Figure 6 on page 25. The gas generator turbine is driven by 1600ºF (870ºC), 35 psig (241 kPa) gas directly from the combustor, and it runs at about 70,000 RPM. The shaft of the gas generator turbine powers the compressor side of the gas generator.

The turbine cooling and lubricating system (described in more detail on page 31) cools and lubricates the gas generator turbine and compressor bearings.

The gas generator assembly also contains the starter, located in the gas generator bearing core. The starter is described in more detail on page 32.

Recuperator Assembly

The recuperator assembly (Figure 10) increases PowerWorks efficiency with an exhaust-to-air heat exchanger that preheats combustion air with turbine exhaust air. For additional energy and space efficiency, the combustor (described in the following section) is integrated into the recuperator assembly.

Figure 10. Recuperator assembly

Combustor

The combustor, integrated into the recuperator assembly described in the previous section, burns fuel to raise the temperature of air entering the gas generator turbine from 1000ºF (540ºC) to a nominal temperature of 1600ºF (870ºC).

Fuel is introduced under pressure at the top of the combustor (Figure 11) where it mixes with compressed, heated air from the recuperator. This air enters the combustor through many small ports precisely located and sized to achieve the complete combustion necessary for efficient operation and low exhaust emissions.

Located near the fuel inlet at the top of the combustor, the ignitor produces an electric spark to ignite the air-fuel mixture during startup and until conditions allow self-sustained combustion.

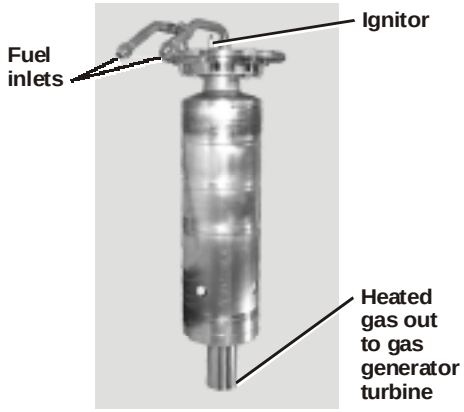


Figure 11. Combustor removed from recuperator

Power Turbine Assembly

The power turbine (Figure 9 on page 27) converts pressure into mechanical energy to drive the generator. The power turbine is a radial inflow design for high efficiency and compact size.

The power turbine is driven by hot gas from the gas generator turbine and rotates at about 44,000 RPM. The turbine cooling and lubricating system (described in more detail on page 31) provides cooling and lubrication for the power turbine bearings.

Gearbox

Located between the power turbine and the electric generator, the gearbox allows the 44,000 RPM power turbine shaft to drive the electric generator shaft at 3620 RPM (approximate 12:1 reduction). The gearbox contains a pinion gear connected to the turbine shaft and a large helical gear attached to the generator shaft.

The gearbox is cooled and lubricated by the cooling and lubricating system, described on page 31.

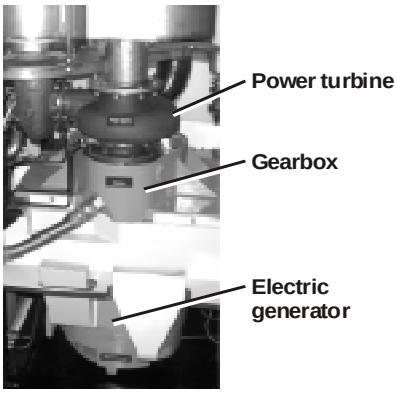


Figure 12. Gearbox location

Electric Generator

The electric generator within the PowerWorks unit (Figure 7 on page 26) is a simple, rugged, reliable power source. It produces electrical energy in the generator rotor by rotating a magnetic field in the stator (stationary windings around the outside of the generator).

The generator is an induction type, which creates a magnetic field using 3-phase power from the power grid. As a result, the voltage and frequency of generator power are determined by the voltage and frequency of the power grid.

Because induction generators need external power, they will not operate unless connected to the power grid. This makes them unsuitable for use as backup power sources. (The model 70SM, which has a synchronous generator, is capable of operating without external power.)

Under normal conditions, the generator rotates at about 3620 RPM. An automatic lubrication system injects grease into the generator bearings at intervals based on running time.

Turbine Cooling and Lubricating System

The turbine cooling and lubricating system (Figure 13) performs the following functions:

- Cools and lubricates the gas generator and power turbine bearings.
- Lubricates and cools the gearbox components.
- Provides high pressure coolant for the starter (see page 32).
- Delivers waste heat from the turbine coolant to heat recovery water via a coolant-to-water heat exchanger (units equipped with the optional heat recovery system).

The cooling and lubricating system has three pumps for the coolant:

- 480 Vac pump for normal coolant circulation.
- 480 Vac high pressure pump for delivering coolant to the starter.
- 12 Vdc pump for coolant circulation when AC power is off or disconnected.

The system includes a coolant tank with an approximate working capacity of 5 gallons (19 L). This tank is equipped with an electric heater for maintaining a coolant temperature that assures reliable starting. The control system prevents the microturbine from starting until the coolant reaches a preset minimum temperature.

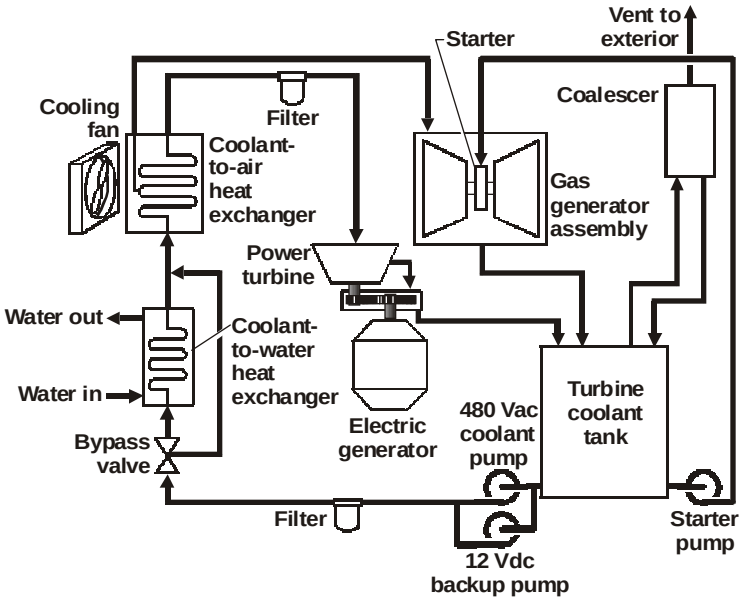


Figure 13. Turbine cooling and lubricating system schematic

A two-stage coolant-to-air heat exchanger with a thermostatically controlled fan extracts heat from the coolant and exhausts it to the room through an opening on the top of the PowerWorks unit. If necessary, air from this heat exchanger can be ducted outside to reduce heat load to the room. (See *PowerWorks Planning and Installation Manual* for more information about ducting air from this heat exchanger.)

PowerWorks units equipped with the optional heat recovery (cogeneration) system also have the coolant-to-water heat exchanger shown in Figure 13. The coolant-to-water heat exchanger extracts heat from the coolant and delivers it to water circulating through the PowerWorks unit. When the heat recovery system is disabled or the circulating water reaches its setpoint, turbine coolant bypasses the heat exchanger to minimize heat transfer to the water. See “Optional Heat Recovery System” on page 40 for more information.

The cooling and lubricating system also includes a backup battery that powers the 12 Vdc coolant pump for 15 minutes if the unit is disconnected from 480 Vac power or if grid power fails.

The coolant in the PowerWorks system is Ingersoll-Rand MegaCool™, a proprietary polyol ester formulated for PowerWorks microturbines. Two filters in the coolant circuit keep the coolant clean between service intervals.

The cooling and lubricating system is vented outside the building through a vent line equipped with a coalescer, which filters any coolant mist from vented gases.

Starter

The PowerWorks unit has a hydraulic starter located in the gas generator turbine assembly (Figure 9 on page 27). A high pressure coolant jet from a dedicated starter pump directs coolant at a drive turbine, sometimes called a Pelton wheel, on the gas generator shaft. This drive turbine accelerates the gas generator turbine and compressor (described in “Gas Generator Assembly” on page 28) to about 6000 RPM, providing enough air to the combustor for fuel ignition and startup.

Fuel System

As shown in the simplified schematic in Figure 14, the fuel system delivers fuel to the combustor, where the fuel mixes with air for combustion. (See page 29 for more about the combustor.) The fuel system precisely controls fuel flow to the combustor for achieving high efficiency. The fuel system also controls the pressure of fuel delivered to the combustor by electronically varying fuel booster speed.

The fuel booster (Figure 15) raises pressure of fuel from the supply line to the level required by the combustor. The fuel booster is a screw-compressor design, which uses Ingersoll-Rand BoosterCool™ coolant for cooling, lubrication and sealing. The separator removes any coolant added to the fuel by the booster, and the coolant is filtered and cooled as it circulates between its reservoir in the separator and the booster.

During startup, both the main fuel valve and the pilot fuel valve (Figure 14) are open to provide the optimum air-fuel mixture for ignition. When the turbines achieve adequate speed, the pilot fuel valve closes and only the main fuel valve remains open. At shutdown, the main fuel valve closes and the vent valve opens to relieve pressure in the separator and the fuel lines.

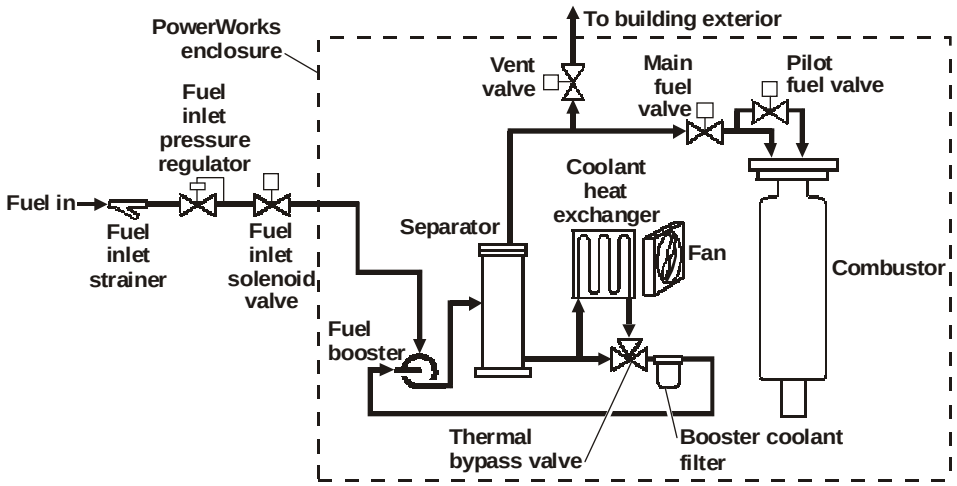


Figure 14. Fuel system simplified schematic

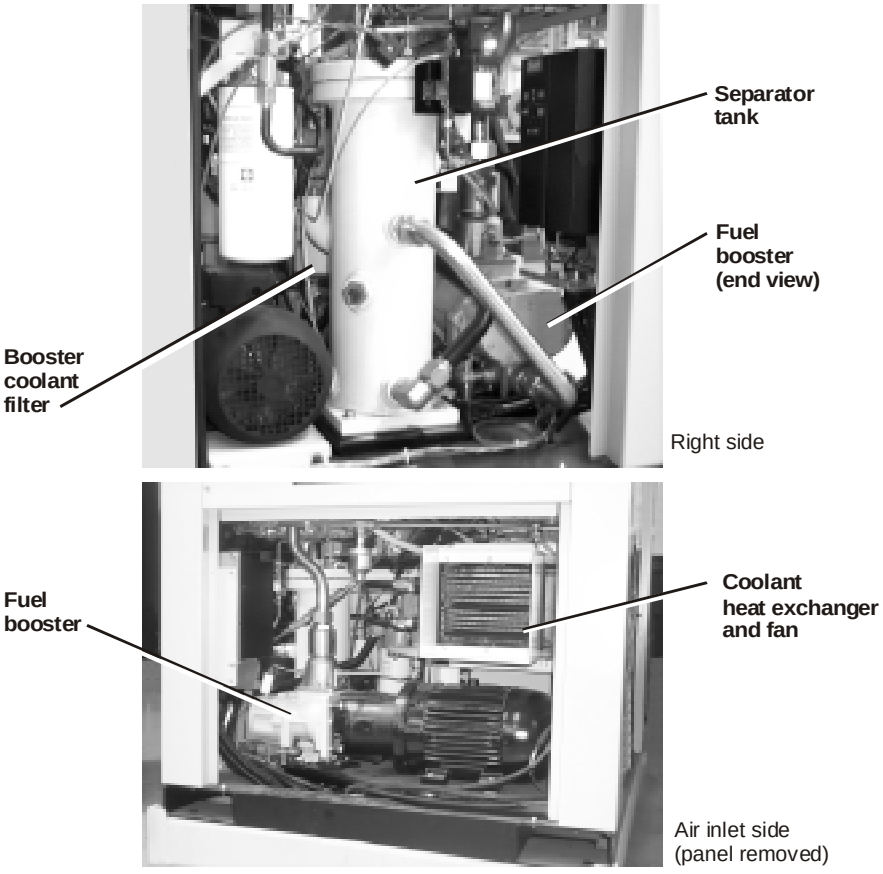


Figure 15. Major fuel system components

Sensors and Controller

The PowerWorks microturbine features a comprehensive array of sensors that constantly monitor temperatures, pressures, speeds, electrical output and other conditions. A digital controller called the base control module (BCM) within the PowerWorks unit adjusts fuel flow, heat exchanger modes and other variables based on the data provided by these sensors. When the BCM detects conditions outside of the operating specifications or setpoints, it displays an alarm message on the control panel and automatically shuts down the microturbine if necessary.

The output of the sensors can be viewed on the control panel display. Refer to “Graphic Display Data Listing” on page 95 for a list of available data. “Viewing the Data, Information and Settings” on page 47 explains how to view the data.

Electric Power Circuit

PowerWorks microturbines deliver 480-volt, three-phase electric power to a facility's distribution bus (Figure 16 on page 36). An external fused disconnect between the distribution bus and the PowerWorks unit allows the unit to be disconnected from electric power during service, extended shutdown or emergencies. This fused disconnect is usually wall-mounted within sight of the control panel.

A typical PowerWorks unit installation also includes an external grid protection module. This module monitors electric power characteristics in the line connecting the PowerWorks unit to the distribution bus or external power grid. In the event of a fault within the PowerWorks unit or in the electric power grid, the protection module signals the PowerWorks unit to disconnect from the electric power circuit and shut down. When this happens, "Main Breaker Trip" appears in the event log on the control panel. (See page 48 for more information about viewing the event log.)

Note

Electric power wiring and equipment configurations vary widely. Refer to the interconnect diagram for your facility to determine how your PowerWorks unit is wired to the distribution bus. If necessary, contact your local utility for specific intertie protection requirements in your location.

Induction generator models must be connected to an external 480 Vac electric power source to start and continue running. (See page 16 for a description of PowerWorks model designations.) When disconnected by opening the fused disconnect or if the external electric power source fails even momentarily, the PowerWorks unit automatically shuts down and displays "Grid Connect Loss Trip" or "Main Breaker Trip" in the event log on the control panel.

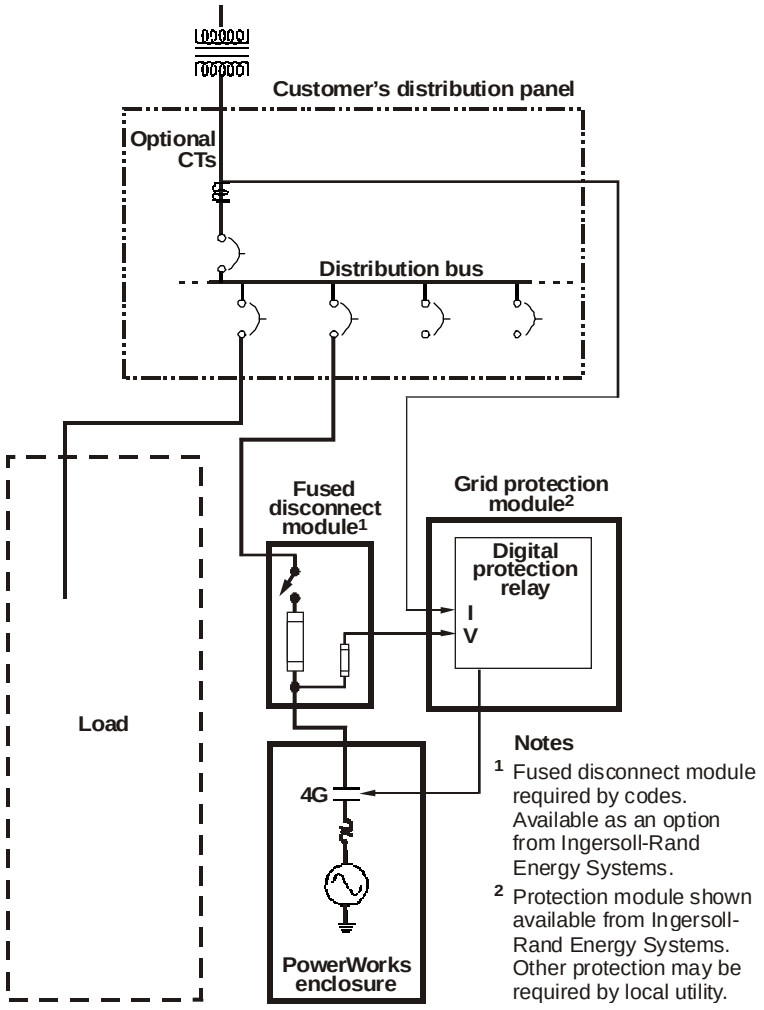


Figure 16. Typical connection to distribution bus

Control and Monitoring

The PowerWorks unit has three types of control and monitoring systems (Figure 17):

- Local
- Hard-wired remote (some features optional)
- Serial remote (optional)

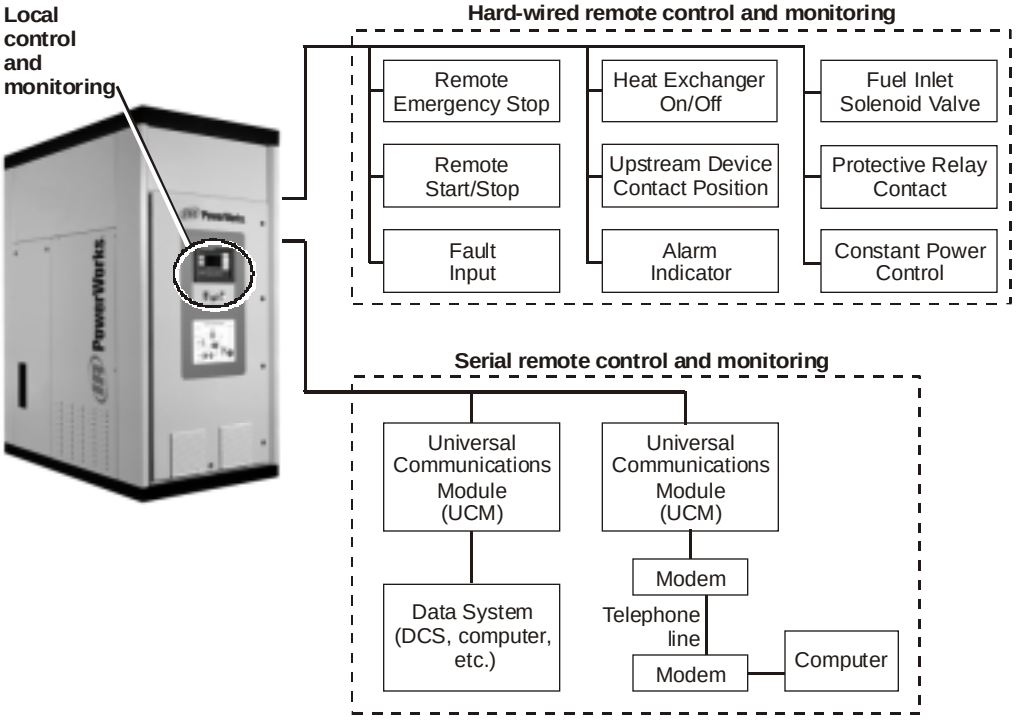


Figure 17. Control and monitoring systems

Local Control and Monitoring

The PowerWorks unit can be controlled (turned on, turned off, reset, etc.) from the control panel on the unit (Figure 18). The control panel also has a display for viewing operating data, event log entries, and for changing setpoints and control mode. For more information, refer to “Control Panel Keys, Buttons and Indicators” on page 43.

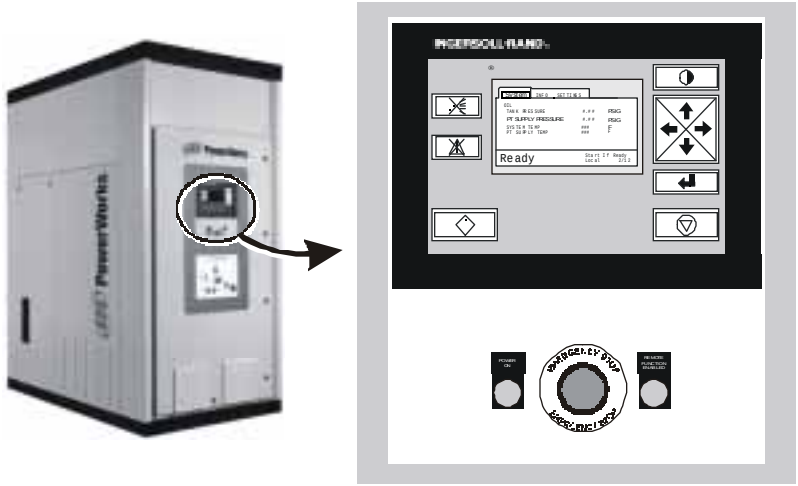


Figure 18. Control panel

Hard-Wired Remote Control and Monitoring

The PowerWorks unit has several external control circuits wired during installation for integrating the unit into a facility:

Remote Emergency Stop – Allows emergency stop pushbuttons, usually located near exit doors or as required by code, to shut down the PowerWorks unit in an emergency.

Remote Start/Stop – (Optional) Enables a remote device, such as a switch on a control panel in another room, to start and stop the PowerWorks unit.

Fault Input – Allows a customer-supplied supervisory device such as a fire alarm to shut down the PowerWorks unit.

Heat Exchanger On/Off - Allows a thermostat, aquastat or other switch to control transfer of turbine exhaust heat to water circulating through the PowerWorks unit. When this circuit opens, the air-to-water heat exchanger moves out of the exhaust gas path and turbine coolant bypasses its heat exchanger, minimizing thermal energy transferred to heat recovery water.

Upstream Device Contact Position – Provides a connection for a customer-supplied auxiliary contact that opens whenever the main breaker upstream from the PowerWorks unit opens. This circuit allows the PowerWorks unit controller to detect a disconnect from the 480 V power circuit and initiate a shutdown.

Alarm Indicator – Energizes an indicator light or other device on a remote panel to indicate a fault detected by the PowerWorks unit.

Fuel Inlet Solenoid Valve – Energizes or de-energizes the external fuel inlet solenoid valve to open or close the fuel supply during startup and shutdown sequences.

Protective Relay Contact – Allows an external digital protection relay to shut down the PowerWorks unit when a fault condition is detected in the power circuit (abnormal voltage, current or phase conditions, power loss, etc.) This circuit is described in more detail in "Electric Power Circuit" on page 35.

Constant Power (Kilowatt) Control – (Optional) Allows power output to be set via the power setpoint on the PowerWorks control panel. Also allows a customer-provided external device to control power output via a 4-20 mA signal.

Serial Remote Control and Monitoring

The PowerWorks microturbine is capable of supporting several optional remote control and monitoring functions via an external universal communications module (UCM) and a serial communications port. These options are described in more detail in "Optional Serial Remote Control and Monitoring" on page 41.

Enclosure

The PowerWorks unit enclosure is insulated to prevent excessive heat and noise from escaping from the PowerWorks unit. It also protects operators and other personnel from contact with moving components and hot surfaces.

Never operate the PowerWorks unit when enclosure panels are open or removed except when checking coolant levels. Failure to observe this warning can result in burns or other injuries.

Internal ventilation paths require the enclosure panels to be installed for proper cooling air circulation. Operating the system with panels removed may cause the system to overheat and shut down.

Optional Heat Recovery System

The optional heat recovery system is a major contributor to the overall efficiency of the PowerWorks unit. The heat recovery system consists of two heat exchangers that extract heat energy from the turbine exhaust and turbine coolant and deliver it to the water circulating through the unit. This heated water is piped out of the PowerWorks unit for domestic hot water, space heating (Figure 19), or industrial processes.

The water circulating pump for the heat recovery system is external to the PowerWorks unit and is supplied by the customer. This pump must provide a minimum flow whenever the PowerWorks unit is operating to prevent damage to the heat exchanger. (See *PowerWorks Planning and Installation Manual* for more information about minimum flows and designing heat recovery system components outside the PowerWorks unit.)

Water temperature control is provided by moving the exhaust-to-water heat exchanger out of the exhaust gas path when temperature limits are reached. Turbine coolant circulation through a coolant-to-water heat exchanger is also diverted when necessary to reduce heat transfer to the water.

Sensors and controllers within the PowerWorks unit engage and disengage the heat exchangers based on an inlet water temperature setpoint (adjustable via the control panel) and the difference between inlet and outlet water temperatures. If necessary, an aquastat or other device external to the PowerWorks unit and supplied by the customer can also be used to engage and disengage the heat exchangers to maintain a desired temperature in a hot water tank or other location in the external heat recovery loop.

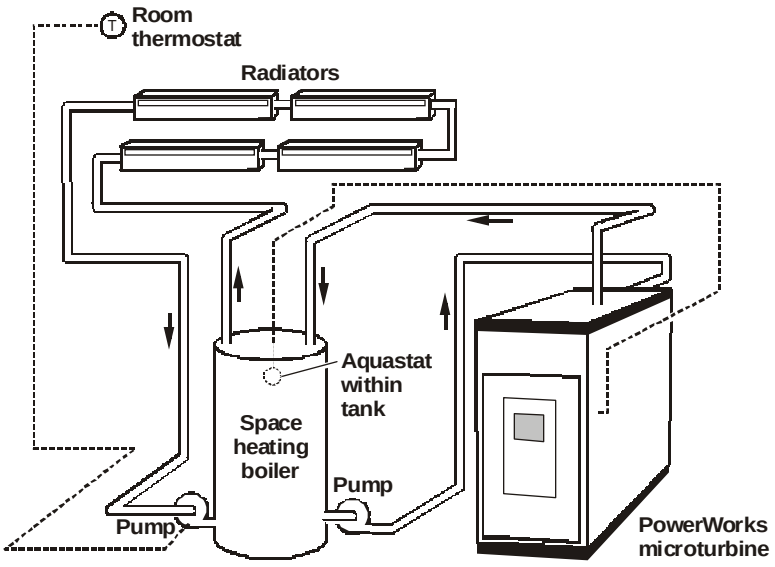


Figure 19. Typical heat recovery system schematic

Optional Serial Remote Control and Monitoring

The PowerWorks microturbine is capable of supporting several optional remote control and monitoring functions (Table 2) via an external universal communications module (UCM) and a serial communications port. These functions allow remote monitoring of microturbine operating data such as total operating hours, number of starts, generator speed, and heat recovery water inlet and outlet temperatures. The PowerWorks unit can also be started, reset and stopped using digital commands from a remote location.

Consult your supervisor or facility engineer to determine whether your PowerWorks unit is set up for remote control and monitoring and to obtain instructions for controlling and monitoring through serial communications.

Table 2. Remote Functions

Floating-point read-only output:

- Fuel booster coolant temperature entering booster
- Fuel orifice discharge pressure
- Water inlet temperature
- Water outlet temperature
- Gas generator compressor discharge pressure
- Turbine coolant temperature entering coolant-to-air heat exchanger
- Gas generator compressor inlet temperature
- Turbine outlet temperature
- Compressor discharge temperature
- Turbine coolant tank pressure
- Power turbine coolant temperature
- Power turbine coolant pressure
- Gearbox housing vibration
- Intake air filter differential pressure
- Gas generator spindle rpm
- Fuel temperature entering fuel booster
- Separator differential pressure
- Electric generator rpm
- Running hours
- Number of starts
- Power-on hours

Digital read-only values:

- Operational Fault
- Engine running
- Generating electricity

Digital write-only command values:

- Remote start
- Remote stop
- Acknowledge fault
- Remote Reset

Startup Sequence

Table 3 describes the internal sequence of events and the corresponding operating states displayed on the graphic display during a normal startup.

For startup instructions, refer to page 58.

Table 3. Startup Operating States

Seq. No.	*Control Panel Status Indication*	*Description*
1	Ready	Sensors indicate that all internal systems are ready for startup. Awaiting Start command from control panel or remote control system.
2	Prestart	Start key pressed or startup initiated by remote control. Cooling and lubricating pump starts. Prestart purge cycle executes.
3	Fueling	Fuel booster starts.
4	Lighting	Fuel pressure reaches preset starting pressure. Ignitor starts. Sensors detect flame in combustor.
5	Ramping	Fuel booster increases speed to raise turbine inlet temperature and generator shaft speed. Main breaker closes to connect to grid when correct generator speed is detected.
6	Loading	Main breaker closure confirmed. Starter deactivates. Ignitor de-energized.
7	Generating	Fuel control determined by turbine inlet temperature or power output. Normal heat recovery control starts after 5-minute delay. Unit maintains stable operating conditions.

5 Control Panel Keys, Buttons and Indicators

Control Panel Description

The control panel (Figure 20) has a graphics display, navigating and command keys and buttons, and indicator lights. This control panel allows the operator to start and stop the PowerWorks microturbine, view operating information, and change operating settings such as power output and temperature setpoints. Detailed descriptions of control panel keys, buttons and indicators are in Table 4.

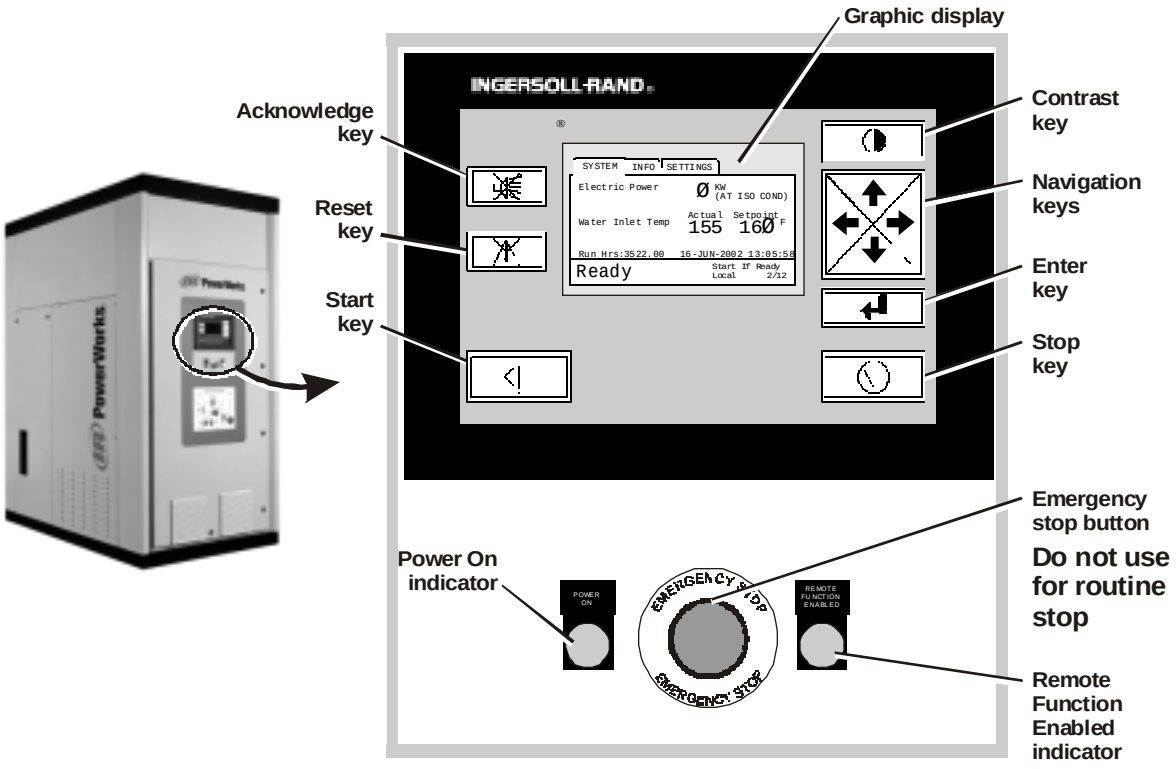
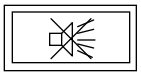
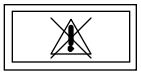
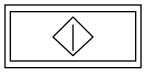
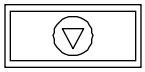
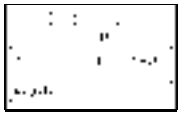
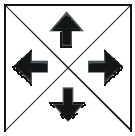


Figure 20. Control panel

Table 4. Key, Button and Indicator Functions		
Key, Button or Indicator	***Name***	***Function***
	Acknowledge key	Acknowledges and silences an alarm.
	Reset key	Clears all trip latches. Must be pressed after a trip condition to restart the microturbine.
	Start key	Starts the microturbine.
	Stop key	Initiates a normal stop sequence. **Note:** Do not use the Emergency Stop button for normal stop.
	Contrast key	Changes display contrast for optimum viewing under a variety of lighting conditions.
	Graphic display	LCD display for viewing system data, operating information and operating settings. See “Graphic Display Description” on page 45 for more information.
	Navigation keys	Right and left navigation keys move from one folder to another on the graphic display. Up and down navigation keys move among pages of the currently displayed folder. See “General Graphic Display Navigation” on page 46 for more information.
	Enter key	Activates and deactivates the navigation mode on the graphics display. Navigation mode (indicated by highlighted folder names on the display) allows navigation through folders and pages via the navigation keys (above). Deactivating navigation mode allows scrolling through longer pages via the navigation keys or changing settings. (See “Using the Graphic Display” on page 47.)
	Emergency Stop button	Immediately shuts down all microturbine components. **Note: Do not use for normal, routine stop.** Use Stop key (above) for routine stop.

(Table continues on next page.)

Table 4. Key, Button and Indicator Functions (continued)		
Key, Button or Indicator	**Name**	**Function**
	Power On indicator	Lighted when 480 V power is connected to the microturbine.
	Remote Function Enabled indicator	Lighted when Remote Control by Dry Contact or Remote Control by Serial Comm's is enabled. (See "Changing the Control Mode" on page 51 for more information.)

Graphic Display Description

Data and settings on the graphic display (Figure 21) are arranged among three folders: System, Info and Settings. In addition, the status bar visible on all folders and pages provides important operating information.

Each folder on the display has multiple pages of data or settings. The folders, pages and status bar are described in detail in the Appendix on page 95. Detailed instructions for viewing the folders and pages and changing operating settings are in Chapter 6 (page 47).

Note

Parameters displayed and their organization are subject to change because of variations in PowerWorks microturbine configurations and software updates.

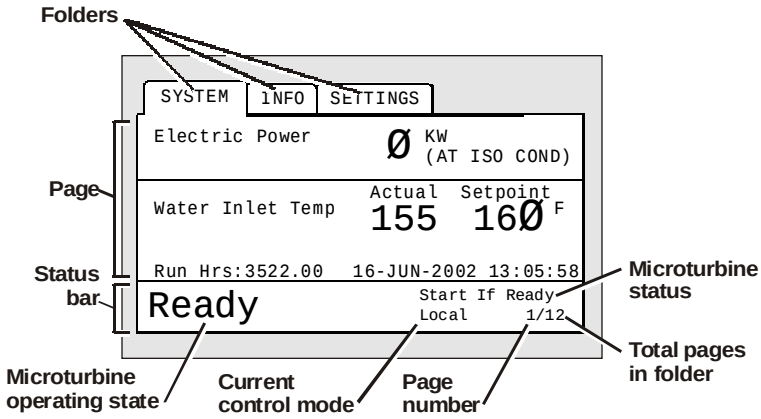


Figure 21. Graphic display details

Graphic Display Navigation

Use the right and left navigation keys (Figure 20 on page 43) to move among the folders of the graphic display. Use the up or down navigation keys to move among the pages of a folder.

For more detailed navigation instructions, see “Using the Graphic Display” on page 47.

Remote Control and Monitoring

The PowerWorks unit can be started and stopped using the optional hard-wired remote control and monitoring system (described on page 38) and the optional serial remote control and monitoring system (described on page 41). Configurations of these systems and procedures for using them are customized for the location and application requirements.

See your supervisor or contact Customer Service at Ingersoll-Rand Energy Systems (page 19) for procedures applying to your PowerWorks unit.

6 Using the Graphic Display

Viewing Data, Information and Settings

Data and information available on the graphic display (Figure 22) are organized among three folders:

- SYSTEM
- INFO
- SETTINGS

Each folder contains several pages of data, information or settings. For detailed descriptions of folder contents, see the Appendix on page 95.

To view a folder other than the one currently displayed, press the right or left navigation key (Figure 22) until the desired folder appears. When the desired folder is visible, advance through its pages by pressing the up or down navigation key. The current page number is displayed in the lower right of the display along with the number of pages in the current folder.

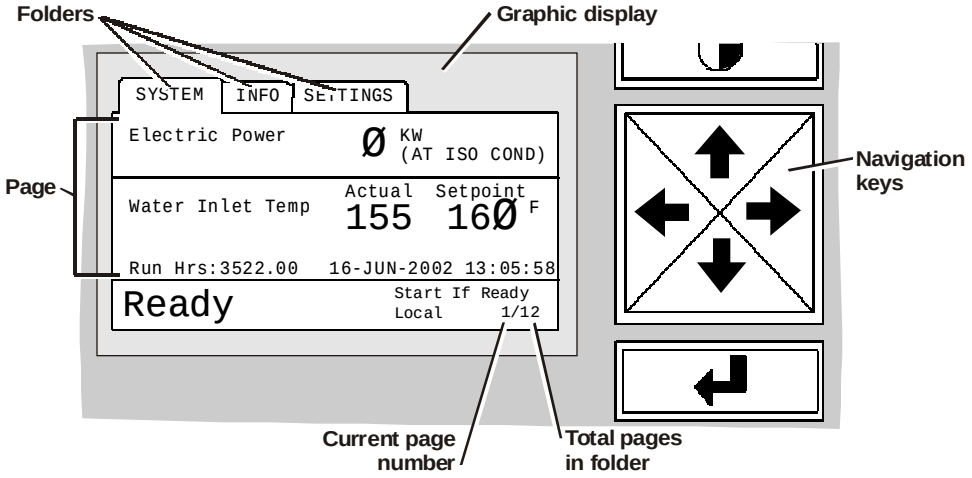


Figure 22. Graphic display navigation

Adjusting Display Contrast

If necessary, you can change the contrast of the graphic display for optimum viewing under the current room lighting conditions. Step through the 16 available contrast levels by pressing the Contrast key (Figure 23).

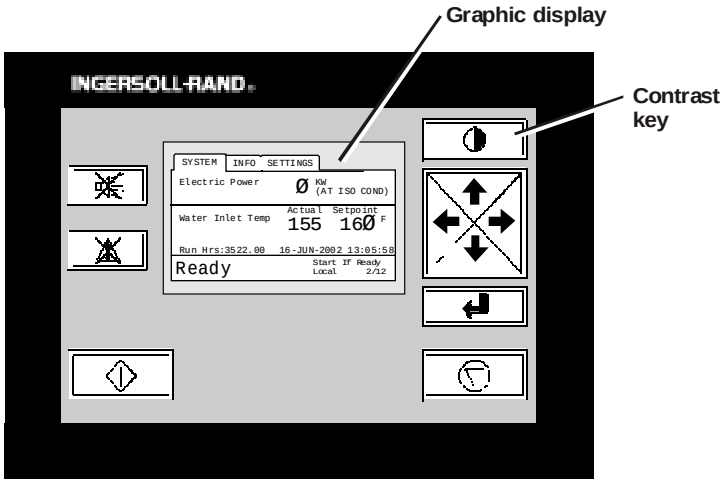


Figure 23. Contrast key location

Viewing the Event Log

The second page of the INFO folder is the event log, which records up to 224 operating events along with the time and date of each (Figure 24). This log is especially useful in troubleshooting.

An alarm or trip event automatically displays the event log. To display the event log manually, press the right or left navigation key until the INFO folder is visible. Then press the up or down navigation key until the event log page appears.

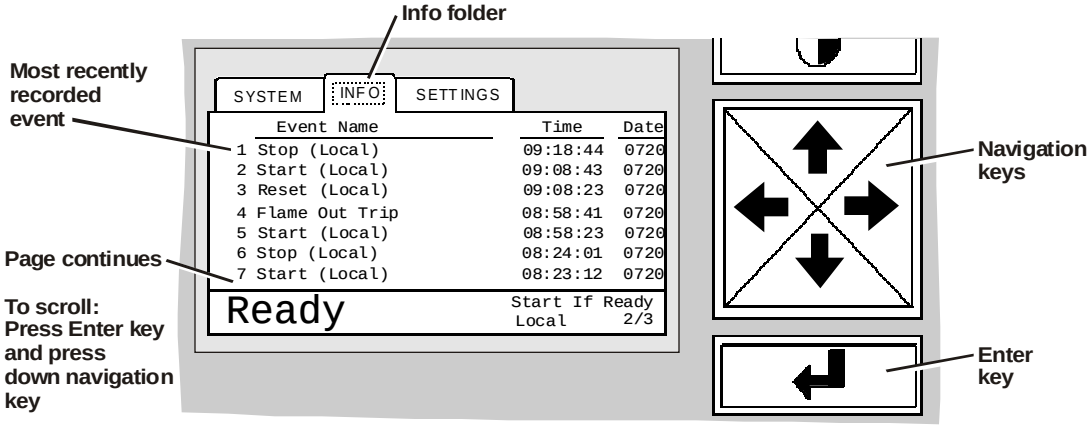


Figure 24. Typical event log page

The most recent event is displayed at the top of the list, and the event log page continues below the lines visible on the display. To scroll, press the Enter key and then press the down navigation key.

For descriptions of event log entries and suggested actions for each, see "Fault Condition Troubleshooting Table" on page 84.

Note

When using the event log to determine the cause of a protective shutdown, note that the most recently recorded event may not be the primary cause of a shutdown.

Enabling or Disabling Edit Mode

Edit mode must be enabled with a password as described below before changing the control mode, power setpoint, heat recovery (cogeneration) mode, or water inlet temperature setpoint. After changing any settings, disable Edit mode to prevent unauthorized changes.

Be sure to keep the password confidential to avoid unauthorized changes. If you need to change the password or have forgotten it, contact Customer Service at Ingersoll-Rand Energy Systems (page 19) for assistance.

To enable Edit mode:

1. Display the Settings folder (Figure 25) by pressing the left or right navigation key.
2. If settings page 1 (Figure 25) is not visible, press the up or down navigation key to display it.
3. Highlight the first Password field by pressing the Enter key.

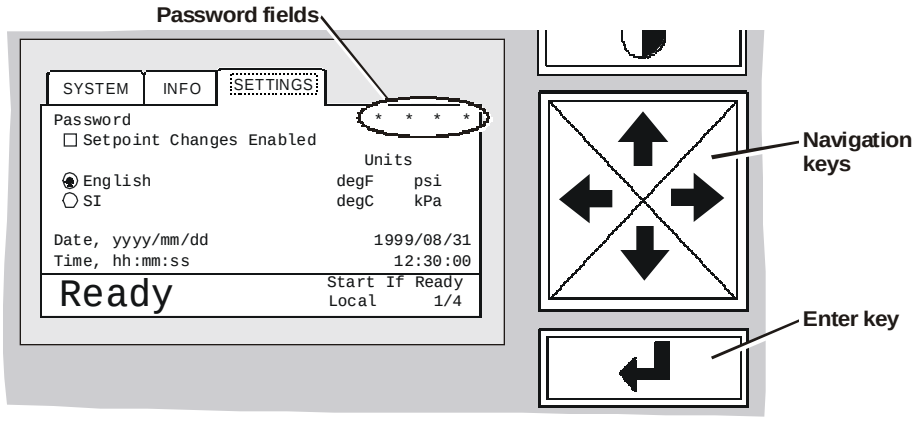


Figure 25. Password fields in Settings folder

4 Press the up or down navigation key until the correct password character appears in the field.

If you do not know the password for your PowerWorks unit, see your supervisor or contact Customer Service at Ingersoll-Rand Energy Systems (page 19).

5 Press the right navigation key to highlight the next password field, then press the up or down navigation key until the correct password character appears.

6 Repeat step 5 until all four password fields are correctly set.

7 Press the Enter key.

An "X" appears in the Setpoint Changes Enabled box, indicating that the controller is in Edit mode. In this mode, you can change the operating settings as described in the following sections.

Note After changing any other settings, disable Edit mode (see next section) to prevent any unauthorized changes.

After 5 minutes of inactivity, edit mode is disabled automatically.

To disable Edit mode:

1 Display the Settings folder (Figure 25 on page 49) by pressing the left or right navigation key.

2 If settings page 1 (Figure 25) is not visible, press the up or down navigation key to display it.

3 Highlight the first Password field by pressing the Enter key.

4 Press the up or down navigation key to change the password character in the password field.

5 Press the right navigation key to highlight the next password field, then press the up or down navigation key to change the password character.

6 Repeat step 5 until all four password fields have been changed.

7 Press the Enter key.

The Setpoint Changes Enabled box becomes blank, indicating that Edit mode is disabled.

Note After 5 minutes of inactivity, edit mode is disabled automatically.

Changing the Remote Control Mode

The PowerWorks unit has three remote control modes available for selection via the control panel:

Remote functions disabled Allows the PowerWorks unit to be started and stopped via the control panel only. Remote start/stop via the hard-wired remote start/stop control (if connected) and serial communications (if installed) is disabled. Monitoring via serial communications (if installed) remains functional.

Remote control by dry contact Allows the PowerWorks unit to be started and stopped via the hard-wired remote start/stop control (if connected) or the control panel. Remote start/stop via serial communications (if installed) is disabled, but monitoring via serial communications remains functional.

Remote control by serial comm's Allows the PowerWorks unit to be started and stopped with digital commands through the serial port of an external universal communication module (if serial remote control and monitoring features are installed) or via the control panel. The hard-wired remote start/stop control (if installed) is disabled, but remote monitoring via hard-wired control circuits (if installed) remains functional.

The currently selected control mode appears in the status bar at the bottom of all graphic display pages (Figure 26). When "Remote functions disabled" is selected, "Local" appears in the status bar. When "Remote control by dry contact" or "Remote control by serial comm's" is enabled, "Remote" appears in the status bar and the Remote Function Enabled indicator on the control panel is lighted.

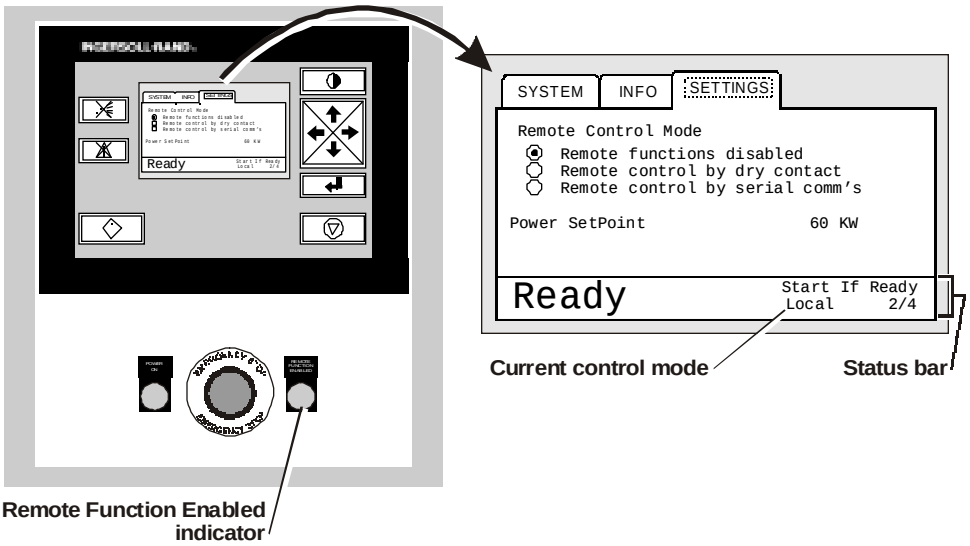


Figure 26. Control mode indicators

To change the remote control mode:

1. Shut down the PowerWorks unit (page 60).

WARNING

Failure to shut down the PowerWorks unit before continuing this procedure may cause unexpected operating behavior.

2. If you have not already done so, enable the Edit mode (page 49).
3. If the Settings folder is not visible, display it by pressing the right or left navigation key (Figure 27).
4. Press the down navigation key until settings page 2 appears (Figure 27).
5. Press the Enter key to highlight the Remote Control Mode line.
6. Press the up or down navigation key to select the desired control mode. (See page 51 for remote control mode descriptions.)
7. Press the Enter key to select the current setting.
8. If you are not making other changes, disable the Edit mode (page 50).

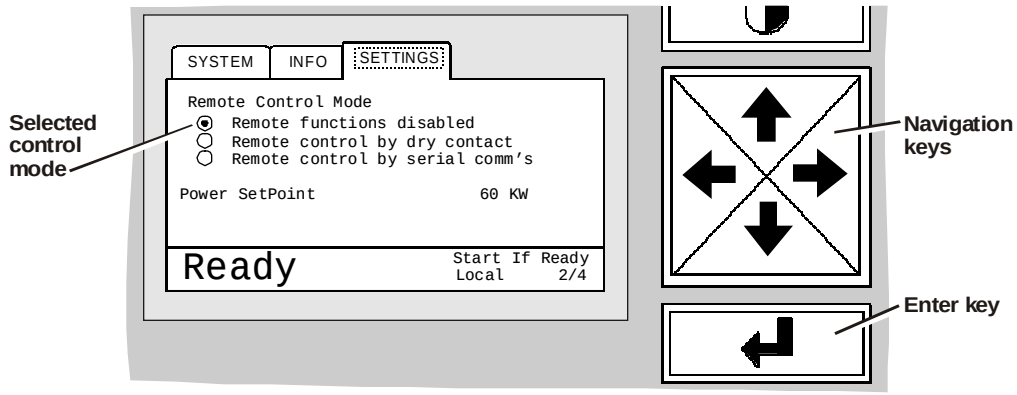


Figure 27. Control Mode setting in Settings folder

Changing the Power Setpoint

The power setpoint on the control panel allows the operator to specify the power output of the PowerWorks unit in kW.

Note

This feature is functional only on units equipped with the constant power (kilowatt) control option. On units without this option, the power setpoint remains at 98 kW even if the control panel setpoint is changed to a lower value.

To change the power setpoint:

1. If you have not already done so, enable the Edit mode (page 49).
2. If the Settings folder (Figure 28) is not visible, display it by pressing the right or left navigation key.
3. Press the down navigation key until settings page 2 appears (Figure 28).
4. Press the Enter key to highlight the Remote Control Mode box.
5. Press the right navigation key to highlight the Power Setpoint line.
6. Press the up or down navigation key to change the kW setting.
7. Press the Enter key to select the current setting.
8. If you are not making other changes, disable the Edit mode (page 50).

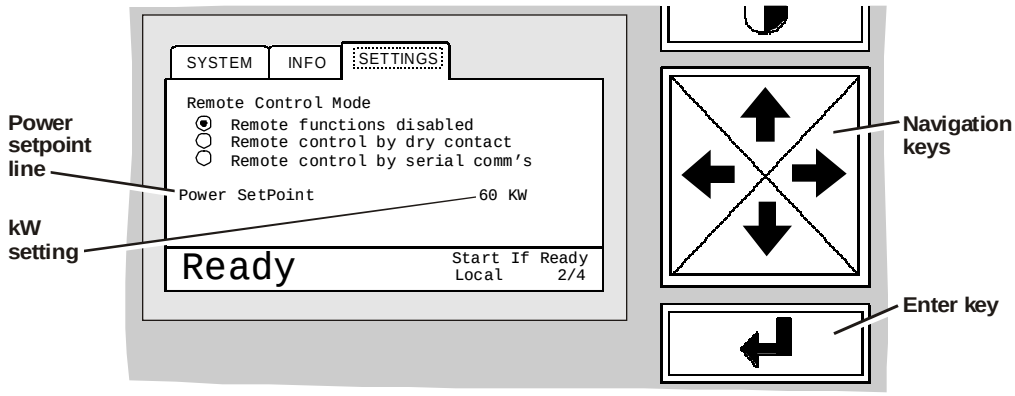


Figure 28. Power Setpoint in Settings folder

Enabling or Disabling Heat Recovery (Cogeneration)

If necessary, the PowerWorks unit can be run with heat recovery (cogeneration) disabled. In heat-recovery-disabled mode, the turbine exhaust bypasses the air-to-water heat exchanger and turbine coolant bypasses the coolant-to-water heat exchanger, minimizing output to the heat recovery system.

CAUTION

To prevent heat exchanger damage, a minimum water flow of 5.5 gal/min (21 L/min) must be maintained through the PowerWorks unit whether or not heat recovery is enabled.

To enable or disable heat recovery:

1. If you have not already done so, enable the Edit mode (page 49).
2. If the Settings folder is not visible, display it by pressing the right or left navigation key (Figure 29).
3. Press the down navigation key until settings page 3 appears (Figure 29).
4. Press the Enter key to highlight the Heat Recovery Disabled box.
5. Press the up or down navigation key to display an "X" in the Heat Recovery Disabled box (heat recovery disabled) or to remove the "X" from the box (heat recovery enabled).
6. Press the Enter key to select the current setting.
7. If you are not making other changes, disable the Edit mode (page 50).

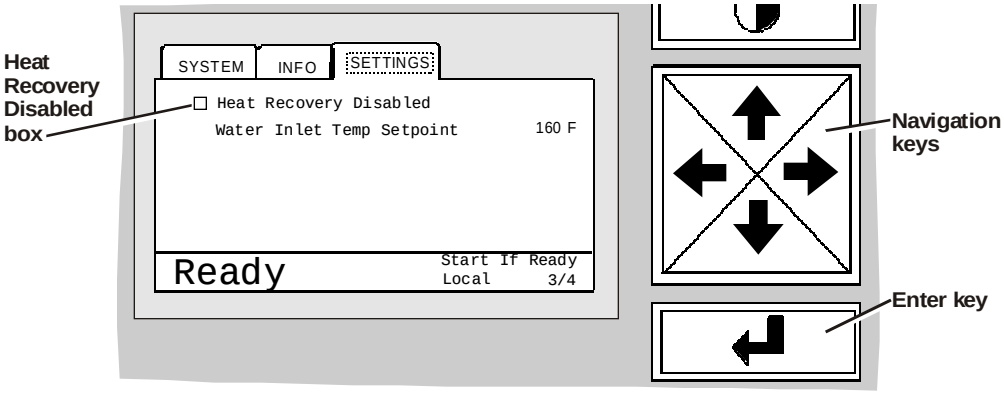


Figure 29. Heat recovery mode in Settings folder

Changing the Water Inlet Temperature Setpoint

Controls within the PowerWorks unit monitor the temperature of the incoming heat recovery (cogeneration) water and disengage the heat recovery heat exchanger when the water temperature rises to a preset value (water inlet temperature setpoint). They also redirect turbine coolant to bypass its coolant-to-water heat exchanger, further reducing heat transfer to the heat recovery water circulating through the PowerWorks unit.

To change the water inlet temperature setpoint:

1. If you have not already done so, enable the Edit mode (page 49).
2. If heat recovery (cogeneration) is disabled, enable it (see page 54).
3. If the Settings folder (Figure 30) is not visible, display it by pressing the right or left navigation key.
4. Press the down navigation key until settings page 3 appears (Figure 30).
5. Press the Enter key to highlight the Heat Recovery Disabled box.
6. Press the right navigation key to highlight the Water Inlet Temp Setpoint line.
7. Press the up or down navigation key to change the temperature setpoint as needed.
8. Press the Enter key to select the current setting.
9. If you are not making other changes, disable the Edit mode (page 50).

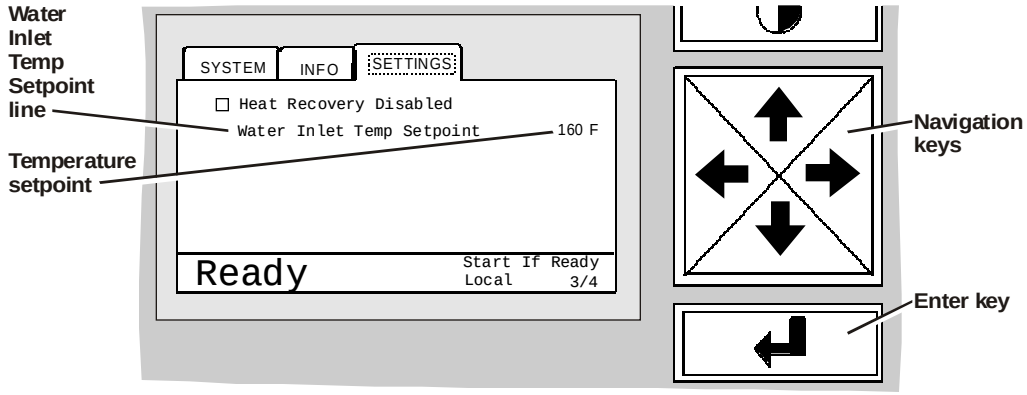


Figure 30. Water inlet temperature setpoint in settings folder

7 Startup and Shutdown

WARNING **DO NOT START OR OPERATE ANY POWERWORKS MICROTURBINE UNTIL AFTER IT HAS BEEN PROPERLY COMMISSIONED BY INGERSOLL-RAND ENERGY SYSTEMS.**

Pre-Start Check

If the PowerWorks unit has been shut down for more than 2 hours, perform these pre-start checks before attempting to restart the unit:

1 If this is the first startup of the day, check the turbine coolant level (page 70) and the fuel booster coolant level (page 72).

2 Verify that the Power On indicator on the control panel (Figure 31) is lighted, indicating that electric power is on.

If the indicator is not lighted, make sure the fused disconnect module (external to the PowerWorks unit and usually visible from the control panel) is on. If the disconnect module is on but the Power On indicator is not lighted, refer to the operating symptom troubleshooting table on page 81 for more information.

3 Verify that the external fuel supply valve is open. (The location of this valve varies from one installation to another. Contact your supervisor or facility engineer if you do not know the location.)

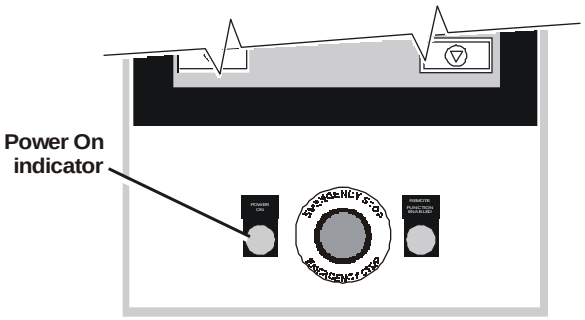


Figure 31. Power On indicator light

4 If the PowerWorks unit has the heat recovery (cogeneration) option, verify that the external heat recovery system water valves are open and water is flowing.

If the water is not on, determine the cause and correct it before continuing.

Note

Heat recovery water system configurations vary greatly among installations. If you do not know how to verify that water is flowing through the PowerWorks unit, consult your supervisor or Customer Service at Ingersoll-Rand Energy Systems (page 19).

WARNING

Starting the system when heat recovery system water is not circulating will damage the heat recovery heat exchanger.

Normal Startup

1 If the PowerWorks unit has been shut down for more than 2 hours, perform the pre-start check in the previous section.

2 Verify that the status bar on the graphic display indicates “Ready” and “Start if ready” (Figure 32).

If messages other than “Ready” and “Start if ready” are visible, refer to the fault condition troubleshooting table on page 84 for corrective action before continuing.

3 Press the Start key (Figure 32).

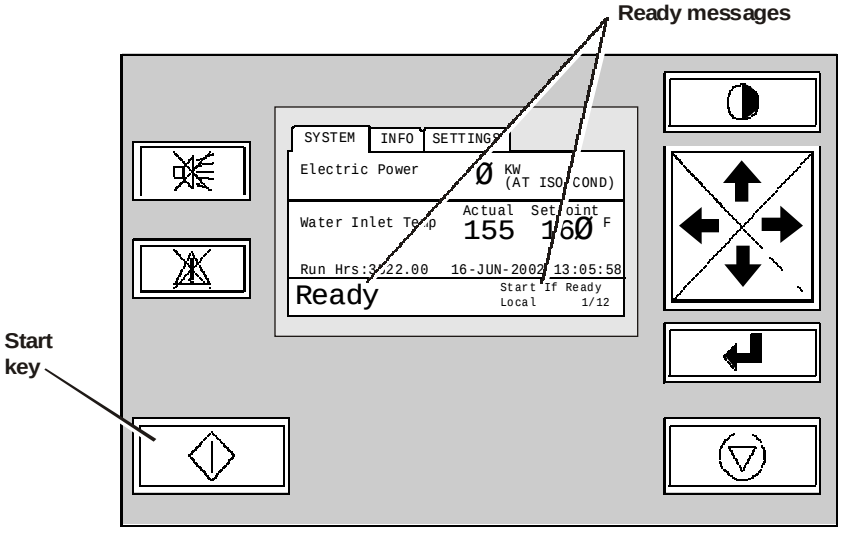


Figure 32. Ready-to-start indicators on control panel

4 Wait for “Generating” to appear on the status bar of the graphic display, indicating that the PowerWorks unit has achieved its normal operating state.

“Generating” may not appear for several minutes, depending on air and turbine coolant temperatures. The graphic display status bar displays several other machine states as the startup sequence proceeds. (See “Startup Sequence” on page 42 for more information.)

Note

If the PowerWorks unit shuts down before “Generating” appears on the display, note the message on the status bar and refer to the fault condition troubleshooting table on page 84 for corrective action. Then reattempt startup by returning to step 3.

Restart After Emergency Stop

If the PowerWorks unit has been shut down by pressing the emergency stop button on the control panel or a remote emergency stop button, use these steps to restart the unit:

1 Verify that the condition requiring the emergency stop has been corrected.

2 If the PowerWorks unit has been shut down for more than 2 hours, perform the pre-start check on page 57.

3 Pull out the emergency stop button that initiated the shutdown (emergency stop button on the control panel or a remote emergency stop button).

4 Press the Reset key on the control panel (Figure 33).

5 Continue with the steps in “Normal Startup” on page 58.

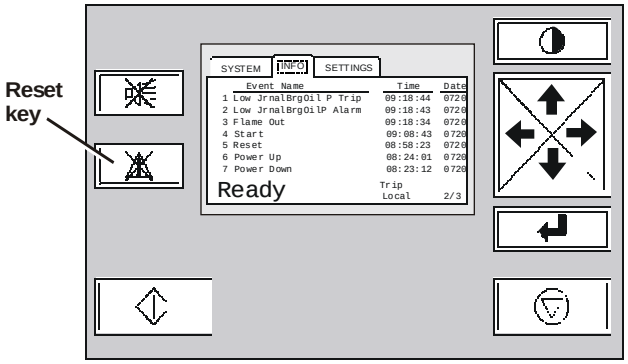


Figure 33. Reset key on control panel

Restart After Protective Shutdown

If the PowerWorks unit has shut down automatically because of a fault condition (protective shutdown), use these steps to restart it:

1. Determine and correct the cause of the protective shutdown. If necessary, refer to the operational symptom troubleshooting table (page 81) and the fault condition troubleshooting table (page 84).
2. If the PowerWorks unit has been shut down for more than 2 hours, perform the pre-start check on page 57.
3. Press the Reset key on the control panel (Figure 33 on page 59).
4. Continue with the steps in "Normal Startup" on page 58.

Normal Shutdown

To shut down the PowerWorks unit:

1. Press the Stop key (Figure 34).
2. Wait for "Ready" to appear on the status bar of the control panel display, indicating that normal shutdown has been completed.

Note "Not Ready" or "Coasting" may appear briefly before "Ready" appears. The coolant pump and cooling fans may continue to run for up to 3 hours after shutdown.

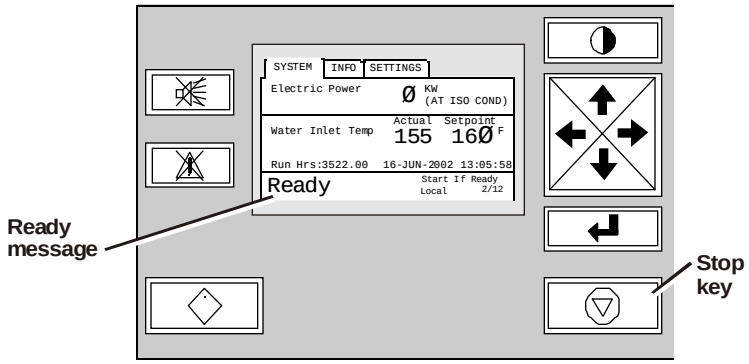


Figure 34. Stop key on control panel

Emergency Stop

Pressing the Emergency Stop button on the control panel (Figure 35) or a remote emergency stop button (usually located near exits from the room) initiates an immediate shutdown of the PowerWorks unit. After shutting down with the Emergency Stop, the event log appears on the display with the message “E-Stop Trip” as the most recent event. The message “Trip” also appears on the control panel status bar.

Because an emergency stop abruptly cuts off the fuel supply instead of gradually reducing it as it does during a normal stop, the PowerWorks unit may emit a brief, sharp noise caused by engine surge.

Note

The coolant pump and cooling fans may continue to run for up to 3 hours after an emergency stop.

To restart after an emergency stop, refer to page 59.

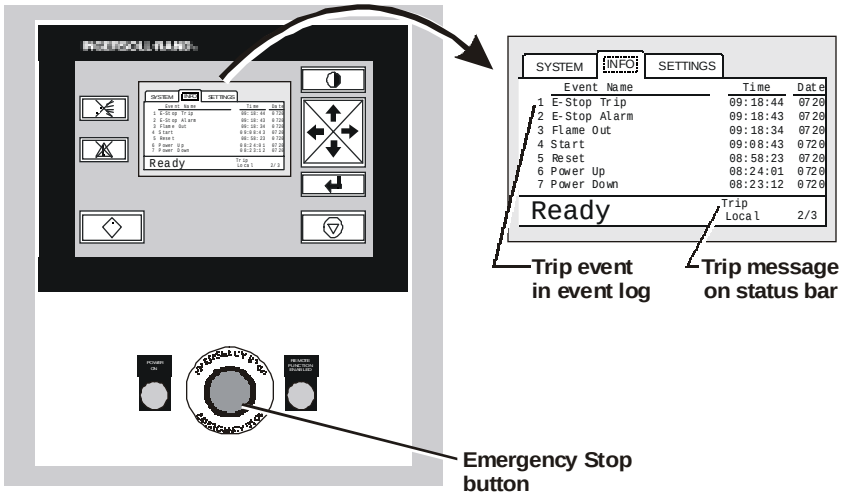


Figure 35. Emergency stop button on control panel

Acknowledging an Alarm

When an alarm message appears on the status bar of the graphic display, pressing the Acknowledge key (Figure 36) removes the alarm message from the status bar and records "Acknowledge (local)" in the event log. If the conditions that caused the alarm reoccur, the message does not reappear.

To allow the alarm message to reappear if the condition causing it reoccurs, press the Reset key instead (see the following section).

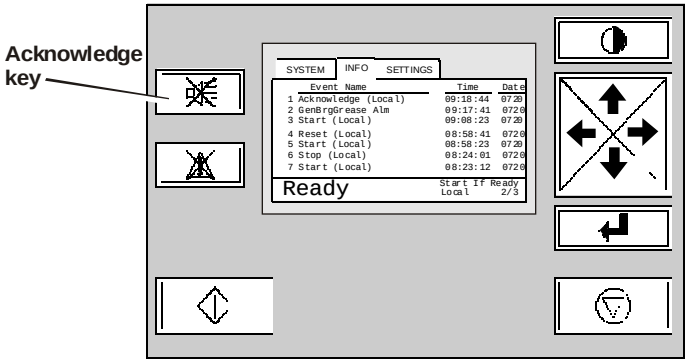


Figure 36. Acknowledge key

Resetting the Unit

When the PowerWorks unit has been shut down with any procedure other than a normal shutdown, the unit must be reset prior to restarting. To reset, press the Reset key on the control panel (Figure 37).

When an alarm message appears on the status bar of the graphic display, pressing the Reset key removes the alarm message from the status bar (if the condition that caused the alarm has been corrected) and records "Reset (local)" in the event log. If the conditions that caused the alarm reoccur, the alarm message also reappears.

To prevent the alarm message from reappearing if the condition causing it reoccurs, press the Acknowledge key instead (see the previous section).

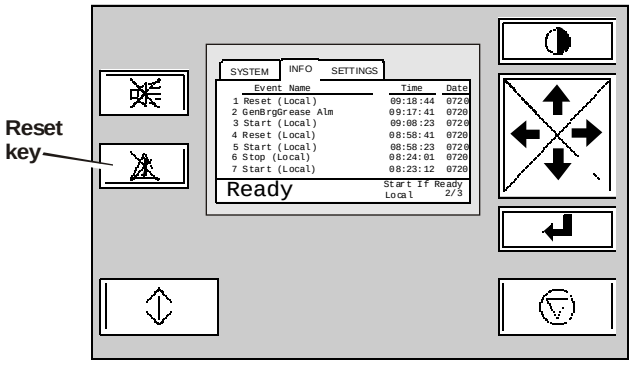


Figure 37. Reset key

8 Keeping Operating Records

Ingersoll-Rand Energy Systems recommends checking and recording operating parameters daily. These records are valuable for troubleshooting in the event of a problem. They are also useful for determining if maintenance is necessary sooner than the normal interval because of unusual operating requirements or environments.

The parameters recommended for recording are shown on the sample logsheet in Figure 38 on page 64. Instructions for viewing operating parameters on the graphic display are on page 47.

For copies of the operating logsheet in Figure 38, contact Customer Service at Ingersoll-Rand Energy Systems (page 19).

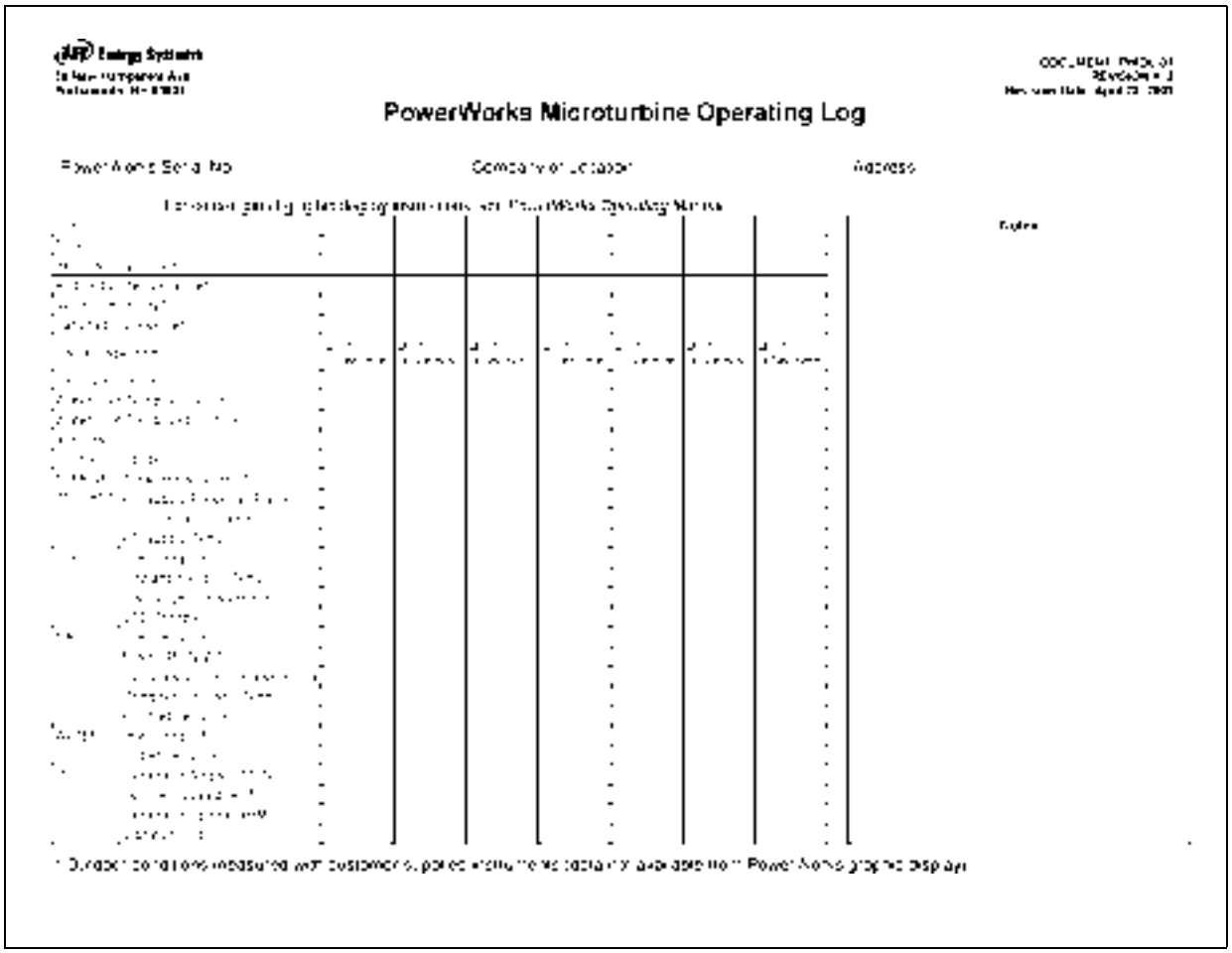


Figure 38. Sample operating logsheet

9 Maintenance

Maintenance Requirements

Routine maintenance requirements for the PowerWorks microturbine are specified in Table 5

Table 5. PowerWorks Microturbine Maintenance Requirements

Procedure	*Weekly*	*Yearly*	*As Needed*	*More Information*
Check turbine coolant level	■			Page 70
Check fuel booster coolant level	■			72
Keep maintenance log	■	■	■	79
Replace inlet air filter		■	■	77
Replace control panel air filters		■	■	78
Clean interior spaces		■		*PowerWorks Owner Maintenance Manual*
Inspect hoses, rubber parts, insulation		■		
Inspect compressor duct o-rings		■		
Inspect turbine coolant fittings		■		
Inspect coolant and starter pump couplings		■		
Inspect electrical contacts		■		
Test ground fault circuit interrupter (GFCI)		■		
Replace air inlet hose		■		
Replace ignitor		■		
Service coalescer		■		
Flush heat recovery heat exchangers		■		
Inspect heat exchanger positioning mechanism		■		
Replace generator lubrication cartridge		■		
Change power turbine coolant and filters		■		

(continued on following page)

Table 5. PowerWorks Microturbine Maintenance Requirements (continued)				
Procedure	**Weekly**	**Yearly**	**As Needed**	**More Information**
Change fuel booster coolant, separator element and filter		■		*PowerWorks Owner Maintenance Manual*
Inspect turbine-coolant-to-air heat exchanger		■		
Inspect fuel booster coolant heat exchanger		■		
Test coolant backup system		■		
Check for coolant leaks		■		
Inspect safety labels		■		
Inspect cable connections		■		
Test protective relay		■		
Inspect ventilation, inlet and exhaust ducts		■		
Check balance of plant (BOP)		■		

Weekly Maintenance Requirements

Under normal operating conditions, turbine coolant and fuel booster coolant levels should be checked weekly (see pages 70 and 72 for procedures). While the enclosure panels are removed for checking coolant levels, the interior of the unit should be inspected visually for coolant leaks, discoloration or any other signs of potential problems.

No other routine maintenance is normally required until 1 year or 8000 hours of running time has elapsed.

Yearly Maintenance Requirements

Every year or every 8000 hours of running time (which ever occurs first), the yearly maintenance procedures in Table 5 should be performed. Harsh environments (high levels of dust or dirt, temperature extremes, frequent startup and shutdown, etc.) may require more frequent maintenance. If necessary, contact Customer Service (page 19) for further guidance.

Instructions for yearly maintenance procedures are in *PowerWorks Owner Maintenance Manual*.

Non-Scheduled Maintenance

In some environments, replacing the air inlet filter and the control panel air filters may be required between 1-year maintenance intervals.

The air inlet filter should be replaced when the message “High Filt DP Alarm” (high filter differential pressure alarm) appears in the event log of the graphic display. See page 48 for more information about the event log.

Air inlet filter replacement instructions are on page 77. When replacing the air inlet filter, also replace the control panel air filters. Instructions for replacing these filters are on page 78.

Service Contracts

Ingersoll-Rand Energy Systems offers a variety of contracts for PowerWorks microturbine service, including periodic maintenance and repairs. Contact Customer Service (page 19) for more information.

Obtaining Maintenance Supplies and Parts

The typical supplies and parts required for the maintenance procedures in this chapter are listed in Table 6. Parts and supplies for 1-year maintenance are in *PowerWorks Owner Maintenance Manual*.

The maintenance items in Table 6 are available from Customer Service at Ingersoll-Rand Energy Systems (see page 19). Before calling Customer Service, obtain the serial number from the nameplate (see page 16) for reference when ordering.

Table 6. Selected Maintenance Supplies and Parts

Item	*Quantity*
MegaCool™ power turbine coolant	5 gal
BoosterCool™ booster coolant	1 gal
Air inlet filter element	1
Control panel air filter	2

Maintenance Safety Precautions

Before starting any procedure described in this chapter, read and follow these safety precautions:

Ensure that all maintenance personnel are adequately trained, competent and have read these instructions.

Read and understand the important safety instructions in Chapter 1 (page 5).

Before performing any work inside the PowerWorks unit, open, lock and tag the external fused disconnect module.

The PowerWorks microturbine contains a variable frequency drive. When it is switched off and the motor is stopped, the internal capacitors store a potentially lethal high voltage electric charge which gradually falls to zero over time. After switching off the machine at the external fused disconnect module, WAIT AT LEAST 5 MINUTES for the capacitors to fully discharge before performing any work within the PowerWorks unit.

Use suitable equipment for lifting heavy items and ensure loose components are adequately supported to eliminate risk of dropping.

Before opening or removing panels or covers to work inside the machine, ensure that:

- Anyone entering the machine is aware of the reduced level of protection and the additional hazards, including hot surfaces and intermittently moving parts.
- The machine cannot be started accidentally or otherwise, by posting warning signs and/or fitting appropriate anti-start devices.

Upon completion of maintenance tasks and prior to returning the machine to service, ensure that:

- The machine is suitably tested.
- All guards and safety protection devices are refitted.
- All panels are replaced and all doors are closed.
- Hazardous materials are effectively contained and disposed of.

Removing Enclosure Panels

To remove the enclosure panels for maintenance access:

1 If you are performing maintenance other than checking coolant levels, perform the maintenance shutdown procedure on page 73 to shut down the PowerWorks unit, disconnect it from electric power, and disable the coolant backup system before continuing.

If you are checking coolant levels only, skip to step 3. (Shutdown is not necessary if panels are being removed to check coolant levels.)

2 Before continuing to step 3, wait at least 5 minutes.

A variable frequency drive within the PowerWorks unit contains internal capacitors that store a potentially lethal high voltage electric charge. This charge gradually falls to zero after the PowerWorks unit is disconnected from 480-volt power. After switching off the external fused disconnect module as described in step 4 on page 74, WAIT AT LEAST 5 MINUTES for the capacitors to discharge fully before removing the enclosure panels.

3 Using the enclosure key, open the two locks at the top of the left rear enclosure panel and remove the panel (Figure 39).

If the PowerWorks unit is running, do not touch any interior components or reach into the unit. Surfaces may be hot and may cause severe injury.

Figure 39. Removing the left rear enclosure panel

4 Open the two locks at the top of the right rear enclosure panel and remove the panel (Figure 40).

WARNING

If the PowerWorks unit is running, do not touch any interior components or reach into the unit. Surfaces may be hot and may cause severe injury.

Figure 40. Removing the right rear enclosure panel

Checking Turbine Coolant Level

Power turbine coolant level should be checked at least weekly under normal operating conditions.

To check power turbine coolant level:

1 If you have not already done so, remove the left rear enclosure panel (page 69).

WARNING

Do not touch any interior components or reach into the unit. Surfaces may be hot and may cause severe injury.

2 Observe the turbine coolant tank sight glass (Figure 41) and record the coolant level in the maintenance log. (See “Keeping a Maintenance Log” on page 79.)

3 If the coolant level is below the minimum level indicated on the tank, contact Customer Service at Ingersoll-Rand Energy Systems (page 19) or follow instructions on page 74 to add power turbine coolant.

CAUTION

The coolant tank is pressurized and coolant may be hot. To prevent hot coolant from escaping and causing injury, never attempt to add coolant while the unit is running.

Note

If the coolant level falls more than 1/2 inch (13 mm) during a 1-week period of operation, shut down the PowerWorks unit and contact Customer Service.

4 Visually inspect the interior of the PowerWorks unit for coolant leaks, discoloration of shields or insulation, or any other indications of potential problems. If necessary, contact Customer Service at Ingersoll-Rand Energy Systems (page 19).

5 Reinstall the enclosure panel.

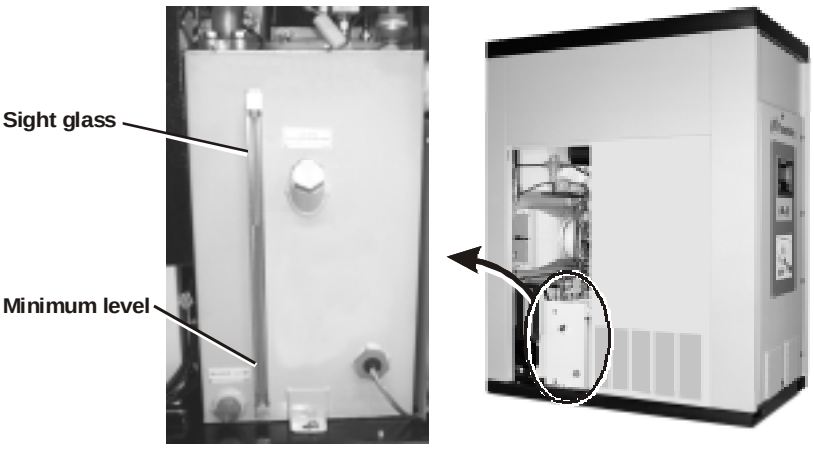


Figure 41. Turbine coolant sight glass

Checking Fuel Booster Coolant Level

Fuel booster coolant level should be checked at least weekly under normal operating conditions.

To check fuel booster coolant level:

1. If you have not already done so, remove the right rear enclosure panel (page 69).

WARNING

Do not touch any interior components or reach into the unit. Surfaces may be hot and may cause severe injury.

2. Observe the separator tank sight glass (Figure 42) and record the coolant level in the maintenance log. (See "Keeping a Maintenance Log" on page 79.)

3. If the sight glass indicates low coolant level (concentric rings visible), contact Customer Service at Ingersoll-Rand Energy Systems (page 19) or follow instructions on page 75 to add booster coolant.

CAUTION

The separator tank is pressurized and coolant may be hot. To prevent hot coolant from escaping and causing injury, never attempt to add coolant while the unit is running.

Note

If the coolant level falls below the sight glass twice during a 2-week period of operation, shut down the PowerWorks unit and contact Customer Service.

4. Visually inspect the interior of the PowerWorks unit for coolant leaks, discoloration of shields or insulation, or any other indications of potential problems. If necessary, contact Customer Service at Ingersoll-Rand Energy Systems (page 19).

5. Reinstall the enclosure panel.

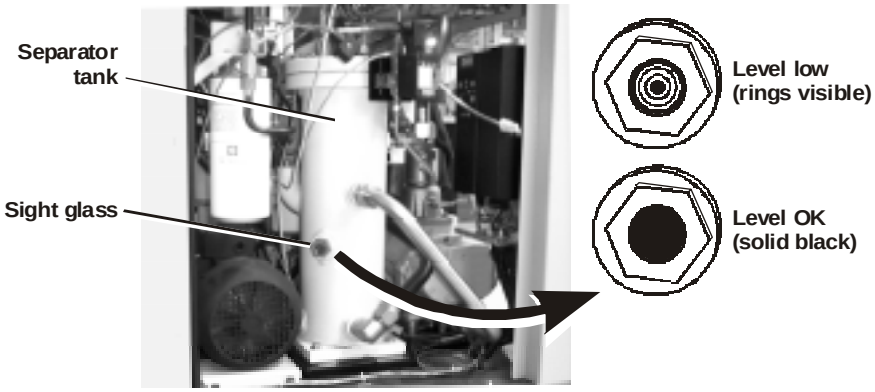


Figure 42. Separator tank sight glass

Maintenance Shutdown

Before removing enclosure panels for any of the maintenance procedures later in this chapter, shut down the PowerWorks unit and disconnect it from electric power as described below.

Note

This shutdown procedure is not necessary when checking coolant levels, but it is required before adding coolant or performing the other maintenance procedures in this chapter.

When maintenance has been completed, restart the PowerWorks unit according to instructions on page 79.

WARNING

Failure to perform the shutdown steps, especially disconnecting from 480-volt power, may result in serious injury, death, or damage to the PowerWorks unit during maintenance procedures later in this chapter.

1. Shut down the PowerWorks unit by pressing the Stop key (Figure 43).
2. Wait for "Ready" to appear on the status bar of the control panel display, indicating that the normal shutdown sequence has been completed.

Note

"Not Ready" or "Coasting" may appear briefly before "Ready" appears.

3. Wait until the turbine coolant pump stops.

Note

The pump may continue to run for up to 3 hours after shutdown. (If necessary, determine whether the pump is off by viewing the turbine coolant pump status on page 10 in the SYSTEM folder on the control panel graphic display. See "Using the Graphic Display" on page 47 for more information.)

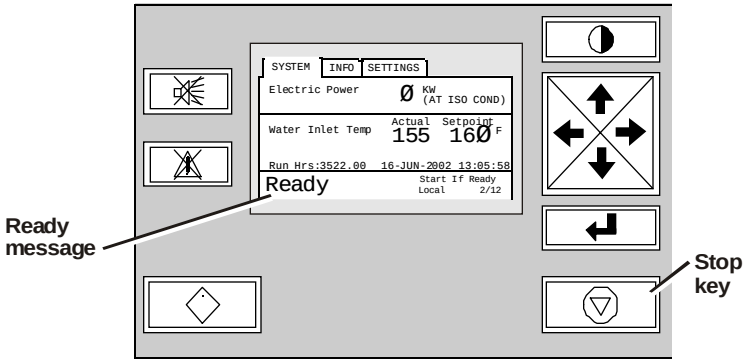


Figure 43. Stop key on control panel

4 Disconnect the PowerWorks unit from 480-volt power by turning off and locking the external power disconnect module.

The external power disconnect module is usually wall-mounted within sight of the PowerWorks unit. If you are unsure of the disconnect module location, consult your supervisor or facility engineer.

5 Using the enclosure key, unlock and open the control panel door (Figure 44). Turn the coolant backup control switch to DISABLE. Then close and lock the control panel door.

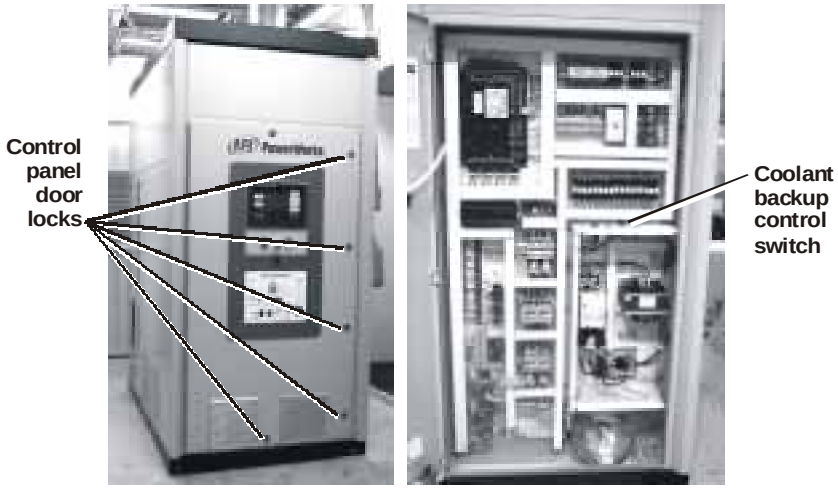


Figure 44. Disabling the coolant backup system

Adding Turbine Coolant

Use the steps below to add turbine coolant if the level falls below the minimum indicated on the turbine coolant tank.

1 If you have not already done so, perform the maintenance shutdown procedure (page 73) to shut down the PowerWorks unit, disconnect it from electric power, and disable the coolant backup system.

Do not continue this procedure without performing the maintenance shutdown on page 73. Hot surfaces, high voltage and rotating machinery within the PowerWorks unit can cause serious injury or death.

2 If you have not already done so, remove the left rear enclosure panel (page 69).

3 Add power turbine coolant through the fill port (Figure 45) until the level reaches the Nominal mark on the sight glass.

Note

Use only Ingersoll-Rand MegaCool power turbine coolant to prevent damage to the PowerWorks unit. See "Obtaining Maintenance Supplies and Parts" on page 67 for more information.

CAUTION

The coolant tank is pressurized and coolant may be hot. To prevent hot coolant from escaping and causing injury, never attempt to add coolant while the unit is running. Reinstall and tighten the fill port cap before restarting.

4 Record the date and amount of coolant added in the maintenance log. (See "Keeping a Maintenance Log" on page 79.)

5 Reinstall the enclosure panel.

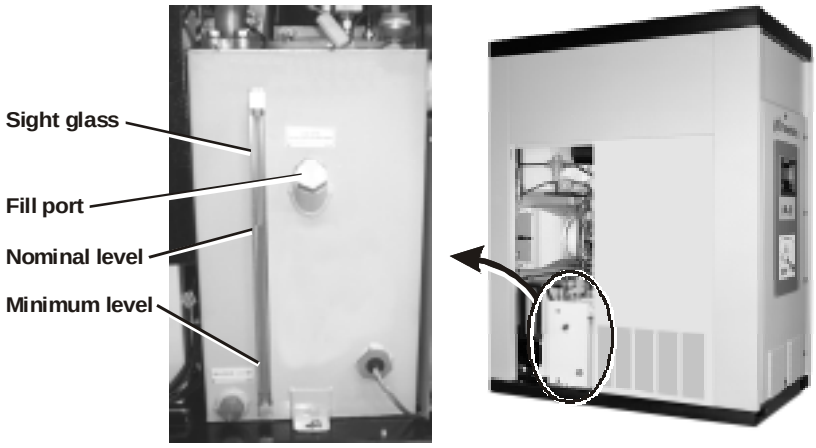


Figure 45. Turbine coolant fill port

Adding Fuel Booster Coolant

Use the steps below to add fuel booster coolant if the level falls below the sight glass on the separator tank.

1 If you have not already done so, perform the maintenance shutdown procedure (page 73) to shut down the PowerWorks unit, disconnect it from electric power, and disable the coolant backup system.

WARNING

Do not continue this procedure without performing the maintenance shutdown on page 73. Hot surfaces, high voltage and rotating machinery within the PowerWorks unit can cause serious injury or death.

2 If you have not already done so, remove the right rear enclosure panel (page 69).

3 Add fuel booster coolant through the fill port (Figure 46) until the level reaches the sight glass.

WARNING

Never open the fill port when the PowerWorks unit is running. Hot fuel and coolant escaping from the pressurized separator tank can cause severe injury or death. Reinstall and tighten the fill port cap before restarting.

Note

Use only Ingersoll-Rand BoosterCool coolant to prevent damage to the PowerWorks unit. See "Obtaining Maintenance Supplies and Parts" on page 67 for more information.

4 Record the date and amount of coolant added in the maintenance log. (See "Keeping a Maintenance Log" on page 79.)

5 Reinstall the enclosure panel.

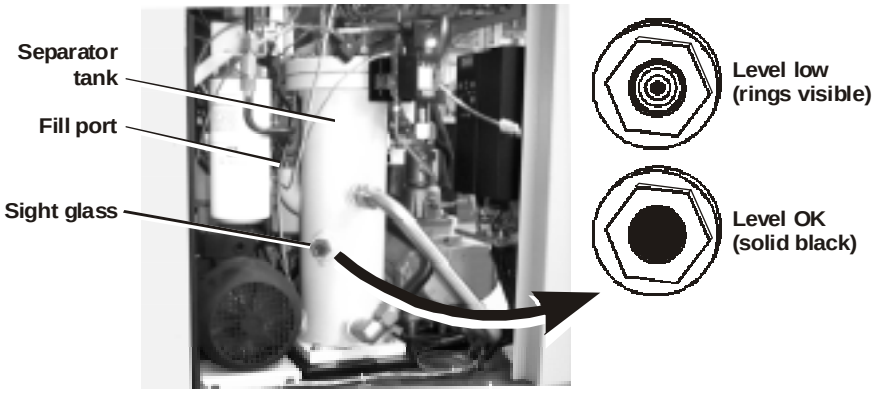


Figure 46. Separator tank fill port

Replacing the Inlet Air Filter

1 If you have not already done so, perform the maintenance shutdown procedure (page 73) to shut down the PowerWorks unit, disconnect it from electric power, and disable the coolant backup system.

WARNING

Do not remove the enclosure panels without performing the maintenance shutdown on page 73. Hot surfaces, high voltage and rotating machinery can cause serious injury or death.

2 If you have not already done so, remove the left rear and right rear enclosure panels (page 69).

3 Disconnect the inlet air temperature sensor cable and the pressure differential sensor tubing (Figure 47).

4 While supporting the inlet hose adapter and hose, release the left and right filter latches.

5 Remove the filter element and insert a new one. See page 67 for information about ordering replacement parts.

Note

Make sure the flow direction arrows on the filter point toward the inlet hose adapter.

6 Reposition the inlet hose adapter on the filter and lock the left and right filter latches.

7 Reconnect the inlet air temperature sensor cable and the pressure differential sensor tubing.

8 Reinstall the enclosure panels.

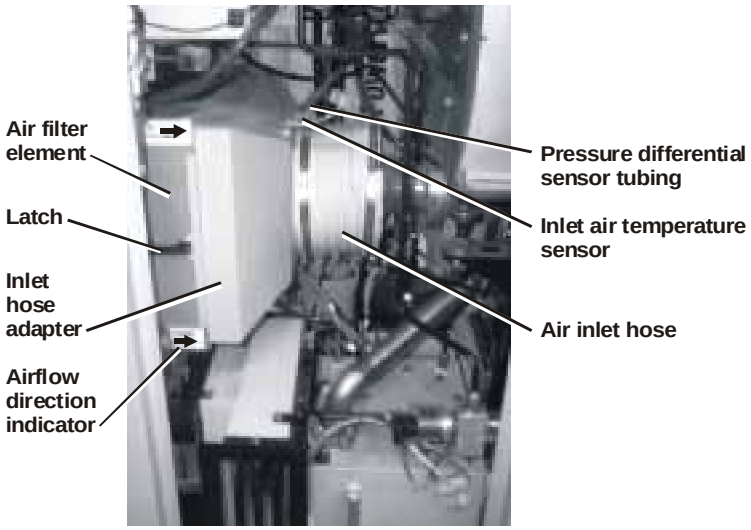


Figure 47. Replacing the air inlet filter

Replacing Control Panel Air Filters

When replacing the inlet air filter (see the previous section), also replace the two control panel air filters (Figure 49).

To replace the filters:

1. Remove the filter covers by gently pulling out the bottom edges (Figure 49).
2. Remove the filters.
3. Install new filters (see page 67 for information about ordering replacement parts) and reinstall the filter covers.

Figure 48. Control panel air filter locations

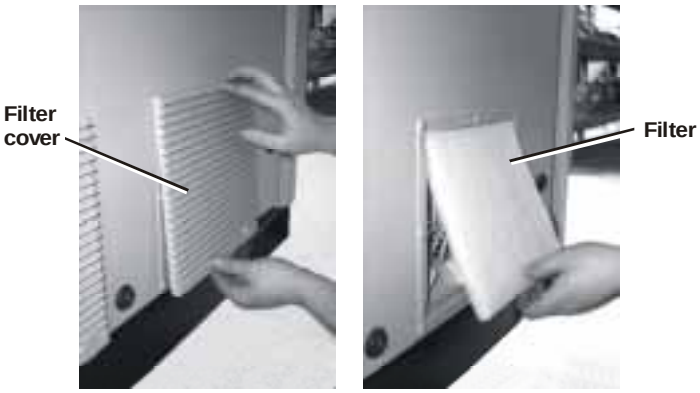


Figure 49. Removing the control panel air filters

Restarting After Maintenance

Use the steps below to start the PowerWorks unit after performing maintenance.

The interior of the PowerWorks unit contains high-voltage components and connectors that can cause serious injury or death. Do not start this procedure unless the PowerWorks unit is disconnected from 480 V power.

1. Install all enclosure panels.
2. Using the enclosure key, unlock and open the control panel door. Turn the coolant backup control switch to ENABLE (see Figure 44 on page 74). Then close and lock the control panel door.
3. Reconnect the PowerWorks unit to 480-volt power by unlocking and turning on the external power disconnect module.
4. Perform the normal startup (page 58).

Keeping a Maintenance Log

A written record of all maintenance and any necessary repairs should be maintained on a maintenance checklist and log (Figure 50 on page 80) or other appropriate document.

For copies of the maintenance checklist and log in Figure 50, contact Customer Service at Ingersoll-Rand Energy Systems (page 19).

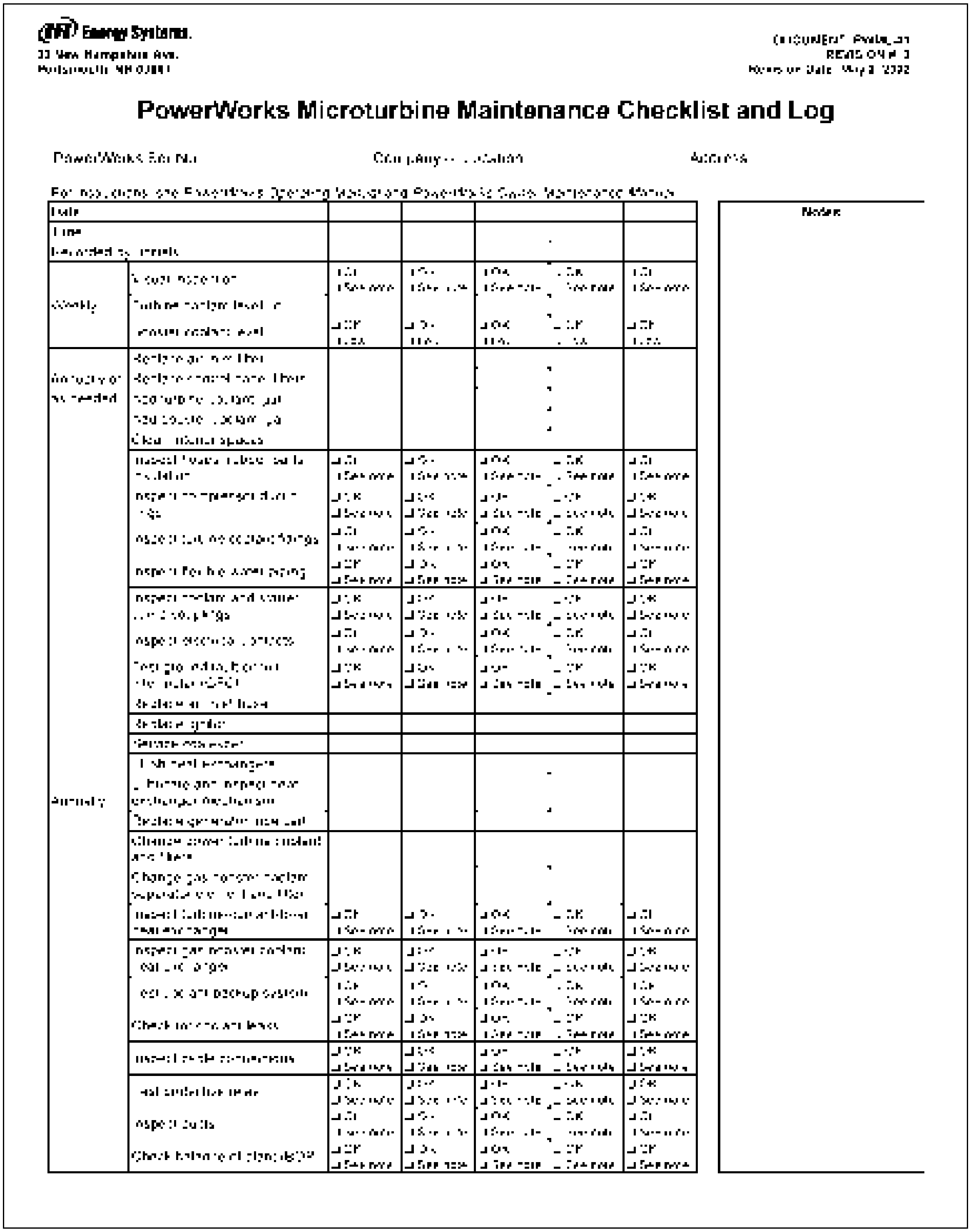


Figure 50. Sample maintenance checklist and log

10 Troubleshooting

Recommended Approach to Troubleshooting

When operational problem arise, review the operational symptoms in the following section for possible simple causes that may not require a service call. If the problem is accompanied by a fault condition indicated on the control panel display, refer to the fault condition troubleshooting table on page 84 for possible solutions.

Operating Symptom Troubleshooting Table

The operating symptom troubleshooting table (Table 7) lists common operating problems, along with possible causes and solutions for each. Locate the description of your problem in the table, then check each cause in the order given.

If the solutions listed do not solve the problem or if your problem is not listed, contact Customer Service at Ingersoll-Rand Energy Systems (see page 19).

Table 7. Operating Symptom Troubleshooting

Operating Symptom	*Possible Cause*	*Corrective Action*
PowerWorks unit fails to respond in any way when Start key pressed; Power On indicator on control panel **not** lighted	Fused disconnect module switch open	Close switch.
	Grid power failure	Contact electric utility company.
	Open PowerWorks unit breaker on facility distribution panel	Close breaker.
	Faulty fuse in fused disconnect module	Replace fuse.
	Control panel GFCI tripped (on units equipped with GFCIs)	Reset GFCI (page 83).

Table 7. Operating Symptom Troubleshooting (continued)		
Operating Symptom	***Possible Cause***	***Corrective Action***
PowerWorks unit fails to respond in any way when Start key pressed; Power On indicator lighted on control panel	Earlier fault requires reset before startup	Press Reset key on control panel (page 62), then press Start key.
	Coolant backup system disabled	Re-enable the coolant backup system (see “Restart After Maintenance” on page 79).
	Fault requires action before restart	View the event log (page 48) and take action recommended in Table 8 (page 84).
PowerWorks unit shuts down unexpectedly; Power On indicator on control panel **not** lighted	Fused disconnect module switch open	Close switch.
	Faulty fuse in fused disconnect module	Replace fuse.
	Open PowerWorks unit breaker on facility distribution panel	Close breaker.
	Control panel GFCI trip (on units equipped with GFCIs)	Reset GFCI (page 83).
	Grid power failure	Contact electric utility company.
PowerWorks unit shuts down unexpectedly; Power On indicator lighted on control panel	Fault condition detected by sensors within PowerWorks unit	View the event log (page 48) and take action recommended in Table 8 (page 84).

Resetting the GFCI

Use the following steps to reset the ground fault circuit interrupter when indicated in the troubleshooting table on page 81.

Note Some PowerWorks units do not have a GFCI.

1. Disconnect the PowerWorks unit from 480-volt power by turning off and locking the external power disconnect module.

   The external power disconnect module is usually wall-mounted within sight of the PowerWorks unit. If you are unsure of the disconnect module location, consult your supervisor or facility engineer.

2. Using the enclosure key, unlock and open the control panel door (Figure 51).

WARNING **Do not open the control panel door without disconnecting and locking out 480-volt power at the power disconnect module as described in step 1 above. The control panel interior contains hazardous voltages that can cause severe injury or death.**

3. If the GFCI is present as shown in Figure 51, press the Reset button on the front of the GFCI.

   If the GFCI is not visible, the PowerWorks unit does not have one. Close and lock the control panel door and discontinue this procedure.

4. Close and lock the control panel door.

5. Unlock and turn on the external power disconnect module.

6. Restart the PowerWorks unit according to “Restart After Protective Shutdown” on page 60.

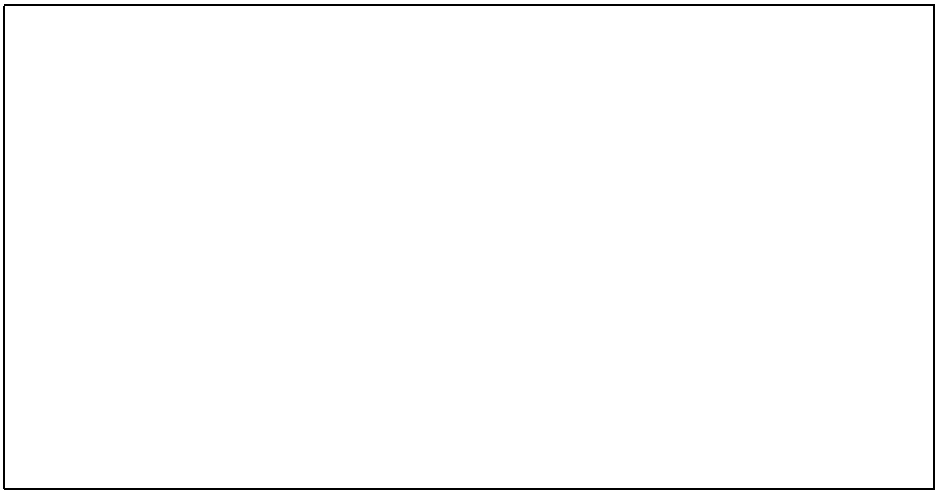


Figure 51. Ground fault circuit interrupter (some PowerWorks units)

Fault Condition Troubleshooting Table

The fault condition troubleshooting table (Table 8) lists fault conditions that can appear in the event log of the graphic display, along with possible causes and solutions for each.

When a fault condition occurs, the event log automatically appears on the graphic display. To display the event log manually, see page 48.

Locate the displayed fault condition in the table, then check each cause in the order given.

If the solutions listed do not resolve the fault condition, contact Customer Service at Ingersoll-Rand Energy Systems (see page 19).

Table 8. Fault Condition Troubleshooting

Fault or Message in Event Log	*Cause*	*Corrective Action*
Acknowledge (Local)	Acknowledge key pressed to acknowledge alarm condition	Informational message. No action necessary.
All TOT Sensors Fail	Power turbine coolant below minimum operating temperature	Wait for tank heater to raise coolant temperature.
	All power turbine outlet temperature sensors failed	Shut down PowerWorks unit. Contact Customer Service at Ingersoll-Rand Energy Systems.
Comp in Tmp Sens Fail	Compressor inlet temperature sensor failed	Contact Customer Service at Ingersoll-Rand Energy Systems.
ComprOutPres Sens Fail	Compressor outlet temperature sensor failed	Contact Customer Service at Ingersoll-Rand Energy Systems.
CoolTankPres Sens Fail	Power turbine coolant tank pressure sensor failed	Shut down PowerWorks unit. Contact Customer Service at Ingersoll-Rand Energy Systems.

Table 8. Fault Condition Troubleshooting (continued)		
Fault or Message in Event Log	***Cause***	***Corrective Action***
Customer Fault Trip	External device (such as a fire alarm system) initiated PowerWorks unit shutdown	**1** Correct problem causing external device to shut down PowerWorks unit. **2** Reset external device (if necessary) **3** Press Reset key on control panel. **4** Press Start key on control panel.
E-Stop Pressed	Emergency stop button pressed	See "E-Stop Trip" below.
E-Stop Trip	PowerWorks unit shut down; Emergency Stop button pressed	**1** Resolve the condition requiring the emergency stop. **2** Pull out the Emergency Stop button. **3** Press the Reset key on the control panel. **4** Press the Start key.
Filt DP Sens Fail	Inlet air filter differential pressure sensor failed	Contact Customer Service at Ingersoll-Rand Energy Systems.
Flame Failed to Light	External fuel valve closed	Open fuel valve, press Reset key on the control panel, and reattempt startup.
	Low fuel line pressure	Contact fuel utility to verify adequate supply pressure.
	Internal fault within PowerWorks unit	Contact Customer Service at Ingersoll-Rand Energy Systems.
Flame Out Trip	Dirty turbine air inlet filter	Replace filter (page 77).
	Internal fault within PowerWorks unit	Contact Customer Service at Ingersoll-Rand Energy Systems.
Fueling Sequence T	Internal error in startup sequence	Contact Customer Service at Ingersoll-Rand Energy Systems.

Table 8. Fault Condition Troubleshooting (continued)		
Fault or Message in Event Log	***Cause***	***Corrective Action***
FuelOrifPres Sens Fail	Fuel orifice pressure sensor failed	Contact Customer Service at Ingersoll-Rand Energy Systems.
FuelPumpCoolIn T Fail	Fuel booster coolant temperature sensor failed	Contact Customer Service at Ingersoll-Rand Energy Systems.
Gas Gen Fault	Gas generator failed to reach adequate speed during startup	Contact Customer Service at Ingersoll-Rand Energy Systems.
Gen. Connect Missed T	Generator failed to connect to grid during startup	Contact Customer Service at Ingersoll-Rand Energy Systems.
GenBrgGrease Alrm	Low generator bearing grease supply	Contact Customer Service at Ingersoll-Rand Energy Systems.
GenBrgGrease Trip	PowerWorks unit shut down; low generator bearing grease supply	Contact Customer Service at Ingersoll-Rand Energy Systems.
Generator Low Speed T	PowerWorks unit shut down; low generator speed	Contact Customer Service at Ingersoll-Rand Energy Systems.
Generator O/L Trip	PowerWorks unit shut down because of momentary phase loss PowerWorks unit shut down; generator overload	Press Reset key on control panel and restart. Contact Customer Service at Ingersoll-Rand Energy Systems.
Grid Connect Loss Trip	PowerWorks unit shut down; fused disconnect opened (disconnecting PowerWorks unit from grid)	**1** Close the fused disconnect. **2** Press the Reset key on the control panel. **3** Press the Start key.

Table 8. Fault Condition Troubleshooting (continued)		
Fault or Message in Event Log	***Cause***	***Corrective Action***
Heat Detection Trip	PowerWorks unit shut down; high temperature within enclosure	If enclosure panels are removed, reinstall them. Verify that all enclosure vents and openings are clear. Verify that room ventilation is operating normally; correct if necessary.
HEX Fan Temp Sens Fail	Coolant-to-air heat exchanger fan control sensor failed	Contact Customer Service at Ingersoll-Rand Energy Systems.
High CompDischTempAlrm	High gas generator compressor discharge temperature	Shut down PowerWorks unit and contact Customer Service at Ingersoll-Rand Energy Systems.
High CompDischTempTrip	PowerWorks unit shut down; high gas generator compressor discharge temperature	Contact Customer Service at Ingersoll-Rand Energy Systems.
High CooTankPress Alrm	High power turbine coolant tank pressure	Shut down PowerWorks unit and contact Customer Service at Ingersoll-Rand Energy Systems.
High Filt DP Alarm	Dirty or blocked turbine air inlet filter	Replace filter (page 77).
High Fuel/CooOutT Trip	PowerWorks unit shut down; high fuel booster outlet temperature	Contact Customer Service at Ingersoll-Rand Energy Systems.
High FuelCooSep DP Al	PowerWorks unit shut down; high separator differential pressure	Contact Customer Service at Ingersoll-Rand Energy Systems.
High GasGen Speed Trip	PowerWorks unit shut down; high gas generator speed	Contact Customer Service at Ingersoll-Rand Energy Systems.

Table 8. Fault Condition Troubleshooting (continued)		
Fault or Message in Event Log	***Cause***	***Corrective Action***
High Gen. Speed Trip	PowerWorks unit shut down; high electric generator speed	Contact Customer Service at Ingersoll-Rand Energy Systems.
High Kilowatts Alarm	High power output	Shut down PowerWorks unit and contact Customer Service at Ingersoll-Rand Energy Systems.
High Kilowatts Trip	PowerWorks unit shut down; high power output	Contact Customer Service at Ingersoll-Rand Energy Systems.
High PwrTrbCooIn T Alrm	High power turbine coolant inlet temperature	Shut down PowerWorks unit and contact Customer Service at Ingersoll-Rand Energy Systems.
High PwrTrbCooIn T Trip	PowerWorks unit shut down; high power turbine coolant inlet temperature	Contact Customer Service at Ingersoll-Rand Energy Systems.
High RecupInlt T Alrm	High temperature at recuperator inlet (power turbine exhaust)	Shut down PowerWorks unit and contact Customer Service at Ingersoll-Rand Energy Systems.
High RecupInlt T Trip	PowerWorks unit shut down; high temperature at recuperator inlet (power turbine exhaust)	Contact Customer Service at Ingersoll-Rand Energy Systems.
High TurbOut Temp Trip	PowerWorks unit shut down; high gas generator turbine outlet temperature	Contact Customer Service at Ingersoll-Rand Energy Systems.
High Vibration Alarm	Vibration in power turbine	Shut down PowerWorks unit and contact Customer Service at Ingersoll-Rand Energy Systems.
High Vibration Trip	PowerWorks unit shut down; vibration in power turbine	Contact Customer Service at Ingersoll-Rand Energy Systems.

Table 8. Fault Condition Troubleshooting (continued)		
Fault or Message in Event Log	***Cause***	***Corrective Action***
High Water Out T Alarm	High heat recovery water outlet temperature	Check circulating pump and other external heat recovery system components to verify normal water flow. If flow is normal, shut down PowerWorks unit and contact Customer Service at Ingersoll-Rand Energy Systems.
High Water Out T Trip	PowerWorks unit shut down; high heat recovery water outlet temperature	Check circulating pump and other external heat recovery system components to verify normal water flow. If flow is normal, contact Customer Service at Ingersoll-Rand Energy Systems.
HighFuelOutletPrs Alrm	High fuel orifice pressure	Shut down PowerWorks unit and contact Customer Service at Ingersoll-Rand Energy Systems.
HighFuelOutletPrs Trip	PowerWorks unit shut down; high fuel orifice pressure	Contact Customer Service at Ingersoll-Rand Energy Systems.
Inlet Air T Sens Fail	Compressor inlet temperature sensor failed	Contact Customer Service at Ingersoll-Rand Energy Systems.
Inlet Gas T Sens Fail	Fuel inlet temperature sensor failed	Contact Customer Service at Ingersoll-Rand Energy Systems.
Lighting Sequence T	Internal error in startup sequence	Contact Customer Service at Ingersoll-Rand Energy Systems.
Loading Sequence T	Internal error in startup sequence	Contact Customer Service at Ingersoll-Rand Energy Systems.
Low CompDischPres Trip	PowerWorks unit shut down; low compressor discharge pressure	Contact Customer Service at Ingersoll-Rand Energy Systems.

Table 8. Fault Condition Troubleshooting (continued)		
Fault or Message in Event Log	***Cause***	***Corrective Action***
Low Coo Level Alarm	Low level in power turbine coolant tank	Shut down PowerWorks unit and contact Customer Service at Ingersoll-Rand Energy Systems.
Low Fuel Inlet Pr Trip	PowerWorks unit shut down; low fuel inlet pressure	Verify that external fuel valves are fully open. Contact fuel utility to verify adequate supply pressure. If valves are open and fuel pressure is adequate, contact Customer Service at Ingersoll-Rand Energy Systems.
Low Kilowatts Alarm	Low net electric power output	Shut down PowerWorks unit and contact Customer Service at Ingersoll-Rand Energy Systems.
Low KW (Reverse Power)	PowerWorks unit shut down; reverse power condition	Shut down PowerWorks unit and contact Customer Service at Ingersoll-Rand Energy Systems.
Low PwrTrbCooInP Alarm	Low power turbine coolant pressure	Shut down PowerWorks unit and contact Customer Service at Ingersoll-Rand Energy Systems.
Low PwrTrbCooInP Trip	PowerWorks unit shut down; low power turbine coolant pressure	Contact Customer Service at Ingersoll-Rand Energy Systems.
Low PwrTrbCooInT Alrm	Low power turbine coolant temperature	Wait for tank heater to raise coolant temperature.
Low Water Out T Trip	PowerWorks unit shut down; low heat recovery water outlet temperature	Verify that external heat recovery water circulating system is supplying inlet water at the correct temperature. If inlet water is at design temperature, contact Customer Service at Ingersoll-Rand Energy Systems.

Table 8. Fault Condition Troubleshooting (continued)		
Fault or Message in Event Log	***Cause***	***Corrective Action***
Main Breaker Trip	PowerWorks unit shut down; external protection module detected power fault	**1** Diagnose and correct the fault that caused the shutdown. **2** Reset the external protection module (see instructions for the module). **3** Press the Reset key on the control panel. **4** Press the Start key.
One TOT Sensor Fail	One power turbine inlet temperature sensor failed	Contact Customer Service at Ingersoll-Rand Energy Systems. Continue to run PowerWorks unit.
Package Fan Stopped	PowerWorks unit shut down; enclosure cooling fan failed	Contact Customer Service at Ingersoll-Rand Energy Systems.
Power Down	PowerWorks unit executing power-down sequence	Informational message. No action required.
Power Up	PowerWorks unit executing power-up sequence	Informational message. No action required.
Prestart Purge Seq T	PowerWorks unit shut down; internal sequence error	Contact Customer Service at Ingersoll-Rand Energy Systems.
Reset (Comm)	PowerWorks unit reset via remote serial communications command	Informational message. No action required.
Reset (Local)	PowerWorks unit reset via control panel key	Informational message. No action required.
Start (Comm)	PowerWorks unit started via remote serial communications command	Informational message. No action required.

Table 8. Fault Condition Troubleshooting (continued)		
Fault or Message in Event Log	***Cause***	***Corrective Action***
Start (Local)	PowerWorks unit started via control panel key	Informational message. No action required.
Start (Wire)	PowerWorks unit started via hard-wired remote start/stop circuit	Informational message. No action required.
State Machine Fault T	PowerWorks unit shut down; failure to recognize state	Attempt restart. If message reoccurs, contact Customer Service at Ingersoll-Rand Energy Systems.
Stop (Comm)	PowerWorks unit stopped via remote serial communications	Informational message. No action required.
Stop (Local)	PowerWorks unit stopped via control panel key	Informational message. No action required.
Stop (Wire)	PowerWorks unit stopped via hard-wired remote start/stop circuit	Informational message. No action required.
Turb Coo T Sens Fail	Power turbine coolant temperature sensor failed	Contact Customer Service at Ingersoll-Rand Energy Systems.
Turb Cool Bkup Trip	PowerWorks unit shut down; coolant backup system disabled via switch in control panel Coolant backup battery low or disconnected	Re-enable the coolant backup system (see “Restart After Maintenance” on page 79). Contact Customer Service at Ingersoll-Rand Energy Systems.
Turb Coolant Too Cold	Power turbine coolant below minimum operating temperature	Wait for tank heater to raise coolant temperature.
TurbCoolPres Sens Fail	Power turbine coolant pressure sensor failed	Contact Customer Service at Ingersoll-Rand Energy Systems.
Two TOT Sensors Fail	Two power turbine inlet temperature sensors failed	Contact Customer Service at Ingersoll-Rand Energy Systems. Continue to run.

Table 8. Fault Condition Troubleshooting (continued)		
Fault or Message in Event Log	***Cause***	***Corrective Action***
VFD Fault Trip	PowerWorks unit shut down; fuel booster drive fault	Contact Customer Service at Ingersoll-Rand Energy Systems.
Vibration Sens Fail	Power turbine vibration sensor failed	Contact Customer Service at Ingersoll-Rand Energy Systems.
WaterInTemp Sens Fail	Heat recovery water inlet temperature sensor failed	Contact Customer Service at Ingersoll-Rand Energy Systems.
WaterOutTemp Sens Fail	Heat recovery water outlet temperature sensor failed	Contact Customer Service at Ingersoll-Rand Energy Systems.

Appendix:
Graphic Display Data Listing

PowerWorks unit information on the control panel graphic display is organized in folders and pages as described in the figure below and in the table beginning on page 96. Descriptions of the messages visible on the graphic display status bar begin on page 103.

Instructions for viewing the data and changing operating settings are in Chapter 6 (page 47).

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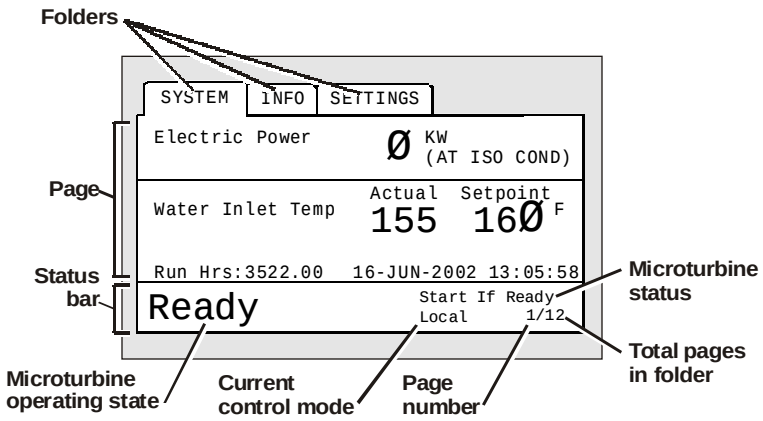
Note

Parameters displayed and their organization are subject to change because of software updates and variations in PowerWorks unit configurations.



Control panel graphic display

Graphic Display Data List				
Folder	**Folder Page**	**Data or Setting**	**Description**	**Typical Value**
System	1	Electric Power	Approximate electric power output	35-98 kW
		Water Inlet Temp, Actual	Temperature of water entering the PowerWorks unit	35-180°F
		Water Inlet Temp, Setpoint	When water entering the heat recovery system reaches this temperature, the air-to-water and coolant-to-water heat exchangers disengage; setpoint is specified on the Settings tab (see "Water Inlet Temp Setpoint," page 102)	As set
		Run Hrs	Total hours of running time to date; for determining service requirements	NA
		Date and Time	Current date and time; value used for annotating event log	Current date, time
	2	Turbine Coolant - Tank Pressure	Turbine coolant tank pressure	0-1.7 psig
		Turbine Coolant - PT Supply Pressure	Coolant pressure at power turbine	40-80 psig
		Turbine Coolant - Cool/Air Hex In Temp	Turbine coolant temperature at air-to-coolant heat exchanger inlet	35-205°F
		Turbine Coolant - PT Supply Temp	Turbine coolant temperature at power turbine	35-155°F
	3	FUEL - Inlet Temp	Fuel temperature at fuel booster inlet	33-115°F
		FUEL - Coolant Injection Temp	Fuel booster coolant temperature at booster inlet	35-200°F
		FUEL - Discharge Pressure	Fuel pressure at separator tank outlet	3-65 psig
		FUEL - VFD Throttle	Fuel booster speed	0-70%

Graphic Display Data List (continued)				
Folder	**Folder Page**	**Data or Setting**	**Description**	**Typical Value**
System (continued)	4	AIR - Inlet Temp	Air temperature at inlet of gas generator compressor	Amb. temp.
		AIR - Filter DP	Differential pressure at air inlet filter	0-1.75 in. WC
		AIR - Compressor Disch Press	Pressure at gas generator compressor discharge	0-60 psig
		AIR - Compressor Disch Temp	Temperature at gas generator compressor discharge	35-400°F
		AIR - PT Inlet Temp	Temperature at power turbine inlet	35-1575°F
	5	WATER - Inlet Temp	Temperature of water entering the PowerWorks unit	35-180°F
		WATER - Outlet Temp	Temperature of water discharged from the PowerWorks unit	35-190°F
		MISC - Generator Amps	Approximate electric current measured at the generator	26-135 A
		MISC - Gas Gen Speed	Speed of gas generator	0-83,000 rpm
		MISC - Generator Speed	Speed of the electric generator	0-3660 rpm
		MISC - Vibration	Vibration measured at gearbox housing	0-0.5 ips
	6	Digital Inputs - E-Stop Pressed	“X” indicates emergency stop button depressed	Blank
		Digital Inputs - Remote Start	“X” indicates remote start/stop activated	Blank or X
		Digital Inputs - Coolant Tank Level Okay	“X” indicates adequate coolant level in turbine coolant tank	X
		Digital Inputs - Heat Detection Fault	“X” indicates temperature limit inside enclosure has been exceeded	Blank

Graphic Display Data List (continued)				
Folder	***Folder Page***	***Data or Setting***	***Description***	***Typical Value***
System (continued)	6 (cont.)	Digital Inputs - No Remote Fault	"X" indicates no remote fault detected	X
		Digital Inputs - Generator Contactor Closed	"X" indicates generator contactor (4G) closed	X
	7	Digital Inputs - VFD Okay	"X" indicates no fuel booster variable frequency drive fault	X
		Digital Inputs - Coolant Tank Cold	"X" indicates power turbine coolant below minimum running temperature	Blank
		Digital Inputs - Gas Booster Temp Okay	"X" indicates satisfactory fuel booster temperature	X
		Digital Inputs - Inlet Fuel Press Okay	"X" indicates satisfactory fuel inlet pressure	X
		Digital Inputs - Generator Overload Okay	"X" indicates no generator overload detected	X
	8	Digital Inputs - Generator Lube Feedback	"X" indicates automatic generator lubrication system currently dispensing lubricant	Blank
		Digital Inputs - Package Cool Fan On	"X" indicates enclosure ventilation fan on	Blank or X
		Digital Inputs - Backup Pump System Failure	"X" indicates backup coolant system battery disconnected or battery voltage low	Blank
		Digital Inputs - Heat Exchanger On	"X" indicates external switch closed, enabling heat recovery to operate	X
	9	Digital Outputs - Fuel Inlet + Vent + Bypass Valves	"X" indicates BCM issued command to energize fuel inlet, fuel vent and bypass valves	X
		Digital Outputs - Starting Fuel Enable	"X" indicates BCM issued command to initiate fueling stage	Blank
		Digital Outputs - Main Fuel	"X" indicates BCM issued command to open main fuel valve	X
		Digital Outputs - Pilot Fuel	"X" indicates BCM issued command to open pilot fuel valve	Blank

Graphic Display Data List (continued)				
Folder	**Folder Page**	**Data or Setting**	**Description**	**Typical Value**
System (continued)	9 (cont.)	Digital Outputs - Ignitor	"X" indicates BCM issued command to energize ignitor	Blank
		Digital Outputs - VFD Enable	"X" indicates BCM issued command to enable fuel booster variable frequency drive	X
	10	Digital Outputs - Generator Contactor Closed	"X" indicates BCM issued command to close generator contactor (4G)	X
		Digital Outputs - Turbine Coolant Pump	"X" indicates BCM issued command to energize power turbine coolant pump	X
	11	Digital Outputs - Coolant/Air Heat Exchanger Fast Fan	"X" indicates BCM issued command to run coolant-to-air heat exchanger fan on fast speed	Blank or X
		Digital Outputs - Coolant/Air Heat Exchanger Slow Fan	"X" indicates BCM issued command to run coolant-to-air heat exchanger fan on slow speed	Blank or X
		Digital Outputs - Air/Water Heat Exchanger	"X" indicates BCM issued command to engage air-to-water heat exchanger	Blank or X
		Digital Outputs - Coolant/Water Heat Exchanger	"X" indicates BCM issued command to engage coolant-to-water heat exchanger	Blank or X
		Digital Outputs - Remote Controls Enabled	"X" indicates BCM issued command to enable remote control by dry contact or serial communications (see page 2 of Settings folder)	Blank or X
		Digital Outputs - Alarm + Trip Remote Fault	"X" indicates BCM issued command to display fault condition on external annunciator	Blank
	12	Digital Outputs - Fuel Inlet Valve Open	"X" indicates BCM issued command to open external fuel inlet solenoid valve	X
		Digital Outputs - 88Q-F2B Shorting Contactor On	"X" indicates shorting contactor closed to enable low speed operation of coolant/ air heat exchanger fan	Blank or X

Graphic Display Data List (continued)				
Folder	***Folder Page***	***Data or Setting***	***Description***	***Typical Value***
System (continued)	12 (cont.)	Digital Outputs - Starter Pump On	"X" indicates BCM issued command to energize the starter pump	Blank
		Digital Outputs - Coolant Heater On	"X" indicates BCM issued command to energize the coolant tank heater	Blank
		Digital Outputs - Generator Bearing Lube Power On	"X" indicates BCM issued command to energize the generator bearing lubrication system	X
		Digital Outputs - Fuel/Coolant Heat Exchanger Fan On	"X" indicates BCM issued command to energize the fuel booster coolant heat exchanger fan	Blank or X
Info	1	Control panel key descriptions	Key function descriptions for operator reference	NA
	2	Event Log	Most recent 224 events recorded by controller with time and date of each. See "Viewing the Event Log" on page 48 and "Fault Condition Troubleshooting Table" on page 84 for more information.	NA
	3	Powered Hours	Total time PowerWorks unit has been connected to external electric power	NA
		Running Hours	Total time PowerWorks unit has been generating electric power	NA
		Starts	Total number of times PowerWorks unit has been started	NA
		Cycles	Total number of times PowerWorks unit has been started, remained grid-connected for at least 3 minutes, and shut down	NA
		Connects	Total number of times PowerWorks unit has connected to the power grid	NA
		Start Attempts	Total number of times start sequence has been initiated	NA
		Serial	PowerWorks unit serial number	NA

Graphic Display Data List (continued)				
Folder	***Folder Page***	***Data or Setting***	***Description***	***Typical Value***
Info (continued)	3 (cont.)	SW Ver	PowerWorks unit software version number	NA
		BCM Ver	Base control module version number	NA
Settings	1	Password	Password fields for enabling edit mode displayed as "****"; see "Enabling or Disabling Edit Mode" on page 49 for more information	****
		Setpoint Changes Enabled	"X" indicates controller in Edit mode for changing setpoints; see "Enabling or Disabling Edit Mode" on page 49 for more information	Blank
		English	Display language	NA
		Date	Format of current date displayed in System folder, page 1	NA
		Time	Format of current time displayed in System folder, page 1	NA
	2	Remote Control Mode - Remote functions disabled	Indicates that PowerWorks unit can be started and stopped via local control panel only; see "Changing the Remote Control Mode" on page 51 for more information	Blank or X
		Remote Control Mode - Remote control by dry contact	Indicates that PowerWorks unit can be started and stopped via the hard-wired remote start/stop control or the local control panel; see "Changing the Control Mode" on page 51 for more information	Blank or X
		Remote Control Mode - Remote control by serial comm's	Indicates that PowerWorks unit can be started and stopped with digital commands through the serial port of an external universal communications module (UCM) if installed; see "Changing the Remote Control Mode" on page 51 for more information	Blank or X
		Power Setpoint	Electric power output setting; see "Changing the Power Setpoint" on page 53 for more information	As set

Graphic Display Data List (continued)				
Folder	***Folder Page***	***Data or Setting***	***Description***	***Typical Value***
Settings (continued)	3	Heat Recovery Disabled	"X" indicates that turbine exhaust bypasses the air-to-water heat exchanger and turbine coolant bypasses the coolant-to-water heat exchanger, minimizing output to the heat recovery system; see "Enabling or Disabling Heat Recovery (Cogeneration)" on page 54 for more information	As set
		Water Inlet Temp Setpoint	When water entering the exhaust heat recovery system reaches this temperature, the air-to-water and coolant-to-water heat exchangers disengage; see "Changing the Water Inlet Temperature Setpoint" on page 55 for more information	As set

Graphic Display Status Bar Information (See page 95 for message location)		
Information Type	***Message***	***Description or Meaning***
Operating State	Ready	All internal systems ready for startup
	Prestart	Start sequence initiated, turbine coolant pump on, starter pump on
	Fueling	Fuel inlet solenoid valve open, fuel booster on
	Lighting	Pilot and main fuel valves open, fuel at starting pressure, ignitor on, sensors monitoring for flame
	Ramping	Flame detected in combustor, fuel booster speed increases to accelerate electric generator to generating speed, main breaker closes when correct generator speed detected
	Generating	Generator contact closure confirmed, starter deactivates, heat recovery system starts after 5 minute delay
	Unloading	Stop sequence initiated, fuel booster decelerates, main generator contactor opens, gas generator and power turbine slow down to zero speed, heat recovery heat exchangers disengage
	Waiting	Internal processor booting, clearing registers, etc., when power first applied
	Not Ready	Condition prevents PowerWorks unit from starting. Check event log to determine corrective action (see page 48).
	03HF	Program or firmware being uploaded
Microturbine Status	Alarm	Operating parameter exceeded alarm value but did not reach trip (automatic protective shutdown) value. Check event log to determine corrective action. (If event log does not appear automatically, see page 48 for instructions.)
	Local	PowerWorks unit in Local control mode (see Control Mode information type on page 104)
	Remote	PowerWorks unit in Remote control mode (see Control Mode information type on page 104)
	RMT-Stop	Remote stop button depressed. Pull out button and press Reset key to allow starting

Graphic Display Status Bar Information (continued) ***(See page 95 for message location)***		
Information Type	***Message***	***Description or Meaning***
Microturbine Status (continued)	Running	Turbine running (generator may not be connected to grid)
	Start if Ready	PowerWorks unit can be started if "Ready" appears in operating state field
	Starting	PowerWorks unit in startup sequence (Prestart, Fueling, Lighting or Ramping operating state above)
	Trip	Operating parameter exceeded trip (automatic protective shutdown) value and shut down PowerWorks unit. Check event log to determine corrective action. (If event log does not appear automatically, see page 48 for instructions.)
Control Mode (To change control mode, see page 51.)	Local	Remote Functions Disabled is currently selected as the control mode. PowerWorks unit can be started and stopped via the control panel only. Remote start/stop via the hard-wired remote start/stop control (if connected) and serial communications (if installed) is disabled. Monitoring via hard-wired control circuits (if connected) and serial communications (if installed) remains functional.
	Remote	One of the following control modes selected: **Remote Control by Dry Contact** PowerWorks unit can be started and stopped via the hard-wired remote start/stop control (if connected) and the control panel. Remote start/stop via serial communications (if installed) is disabled, but monitoring via serial communications (if installed) remains functional. **Remote Control by Serial Comm's** PowerWorks unit can be started and stopped via serial communications (if installed) or via the control panel. The hard-wired remote start/stop control (if connected) is disabled, but remote monitoring via hard-wired control circuits (if connected) remains functional. For more detailed descriptions of control modes, see "Control and Monitoring" on page 37. For information about changing the control mode, see page 51.

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