Capstone Turbine Corporation • 21211 Nordhoff Street • Chatsworth • CA 91311 • USA
Telephone: (818) 734-5300 • Facsimile: (818) 734-5320 • Website: www.microturbine.com

Technical Reference

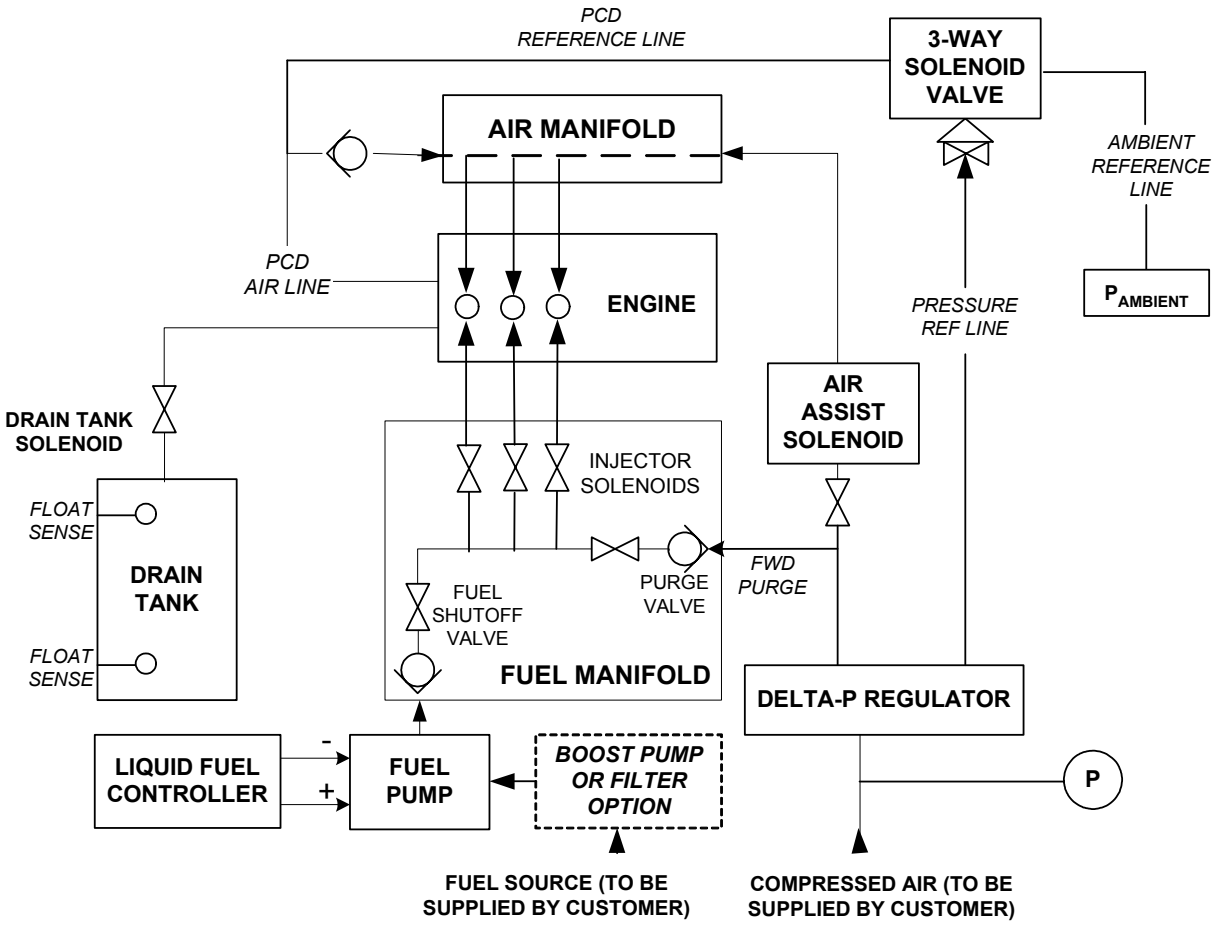
Liquid Fuel System Technical Information – Hybrid Electric Vehicle (HEV)

Introduction

This document provides technical information for Capstone Turbine Corporation® Hybrid Electric Vehicles (HEV) Model C30 MicroTurbine systems operating on kerosene and low-grade diesel fuels. HEV systems are used to supply primary power generation for hybrid electric buses, trolleys and other transit vehicles.

The HEV liquid fuel system utilizes a fuel-on-plate (FOP) design for easy fuel and air inlet access. The minimum set of HEV system components also enables users to supply their own boost pump, filter and drain tank and locate them according to space requirements.

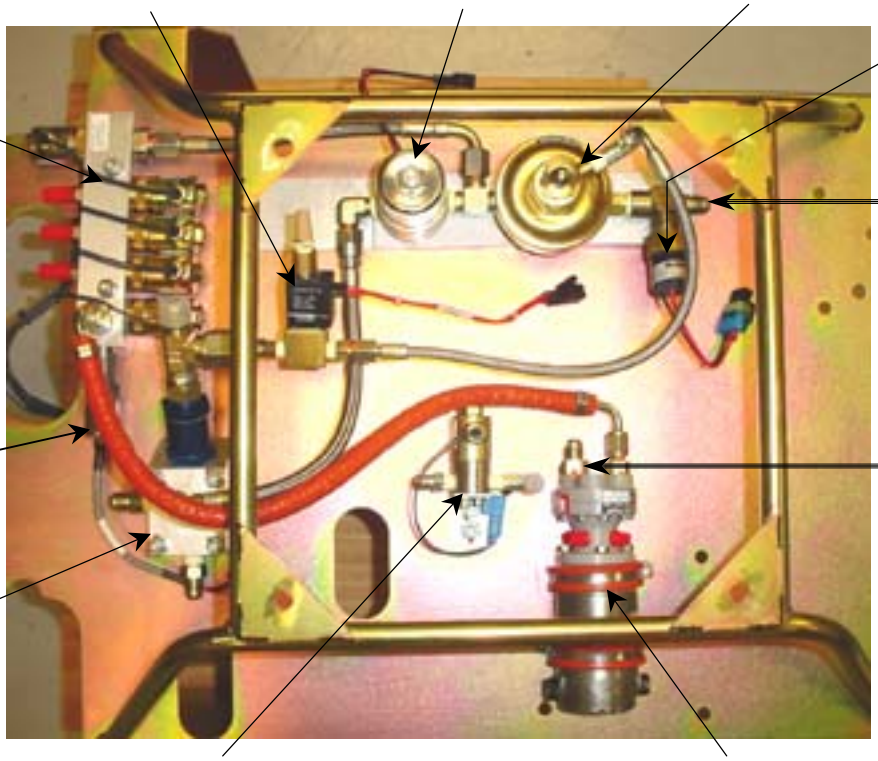
Major components of the liquid fuel system are shown in the block diagram below.



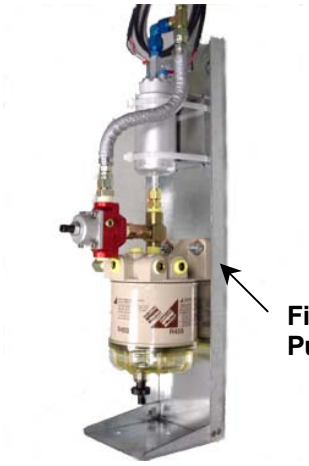
System Components

NOTE	Component descriptions are provided in the Components Description Technical Reference Manual (410012).

Typical Configuration:



Options:



Filter and Boost Pump Assembly (514080)

Filter Assembly (513770)

Drain Tank Assembly (recommended option) (514428)

System Operation

Engine Start-up

The MicroTurbine initiates a fuel line fill cycle at the beginning of the start sequence. Fuel supplied by the customer is cycled into the fuel lines from the fuel pump (and optional boost pump). At the end of each injector's line fill sequence, the system performs a check to detect a clogged injector. The Liquid Fuel Controller (LFC) supplies voltage and current to the fuel pump. As individual injector lines fill, the manifold pressure rise-over-time is monitored to determine if the fuel line is full to the injector. If the pressure rate requirements are not satisfied, the unit issues a "16004 LF FAIL LINFIL" pressure-related fault.

Fuel is introduced into the combustion chamber through injector #1 after the MicroTurbine reaches ignition speed. When the Turbine Exit Temperature (TET) sensor reports an increase in temperature, the system is declared lit, and the MicroTurbine accelerates to full load.

The engine start-up sequence is as follows:

1. The air-assist solenoid opens to provide air to the air-assist manifold.
2. The 3-way solenoid is set to reference PCD, resulting in an air-assist pressure of PCD + 10 psig
3. The fuel shutoff and injector #1 solenoid open to allow fuel flow through injector #1. If the customer supplied air-assist pressure is less than 40 psig at start-up, the air-assist solenoid is shut off and a "16009 LF STRTAIR SOL" fault will occur.

The drain tank is used to collect excess fuel during an engine 6006 Fail to Light fault. The tank is equipped with a float sensor to provide feedback to the operator related to the level of fuel in the tank. There are two levels: 1) Lower level (30% full) which triggers a warning fault if actuated, and 2) High level (80% full) which triggers a shutdown fault if actuated.

Idle Operation

The system is considered in "idle" state if the power level is 0 kW. During idle operation, the unit operates on only one injector. If the engine experiences a combustion flame-out/stability issue, the controller will use auto-relight logic to select the most stable injector for idle operation.

Steady State

The system is considered to be in "steady" state if it is operating continuously at a power level greater than 0 kW. When the MicroTurbine reaches an ambient-corrected generator power of 7kW, the system will transition to three-injector engine operation. The injector switch point varies with ambient conditions. When off-loading, the engine will switch back from three injector to single injector operation.

Engine Shutdown

When the unit is issued a shutdown command, or experiences a severity level 3 (or greater) fault other than a flameout, the unit performs a fuel purge of all injector fuel lines. A fuel purge is required to eliminate the possibility of coking inside the injectors after the unit is turned off.

There may be a slight over-temperature in the TET due to excess fuel entering the combustor during this time (software masks TET reading for 10 seconds to avoid over-temperature faults). This over-temperature is normal for a shutdown, and will vary depending on the shutdown power level. No purge is performed if the run state was not reached.

The engine shutdown sequence is as follows:

1. The fuel pump is turned off.
2. The air-assist solenoid is turned off.
3. The fuel purge valve on the manifold opens.

During shutdown, the air-assist solenoid and 3-way switch are activated if the generator power is above 3kW to minimize over-temperature during purge. This generator power set point varies with ambient conditions and shutdown conditions.

Air-assist Function

Air-assist pressure/flow is utilized during normal engine operation to atomize fuel for combustion and to purge the fuel lines during system shutdown. Air may be supplied to the injectors through the air-assist solenoid or through engine compressor discharge pressure (PCD) – see table below. PCD assists combustion fuel atomization during steady state operating conditions, excluding idle. Two other air-assist levels are achieved by using the pressure regulator and 3-way solenoid valve.

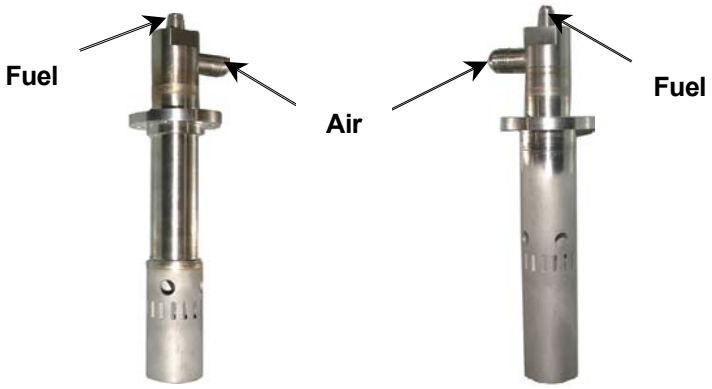
Air-assist operation is summarized below (using iso-corrected power levels).

Air Assist Operation				
Air Assist Level	**Function**	**3-Way Valve Position**	**Air Assist Valve**	**Customer Air Supply Used**
10 psig + PCD	Start-Up	PCD reference (energized)	ON	YES
	Fuel Shutdown Purge if Gen Pwr > 3kW[1]	PCD reference (energized)	OFF	YES
10 psig + ambient	Gen Pwr levels < **"X"** kW[2] including Idle	Ambient reference (not-energized)	ON	YES
	Fuel Shutdown Purge if Gen Pwr < 3kW[1]	Ambient reference (not-energized)	OFF	YES
PCD	Gen Pwr levels > **"X"** kW[2]	N/A	OFF	NO

NOTES: [1]Generator power level may vary with ambient conditions and shutdown conditions.
[2]If engine is going: up in speed - "**X**" = 10kW; down in speed "**X**" = 8kW.

Injector Operation

There are two different injectors used on liquid fuel systems – one for injector 1 and another for injectors 2 and 3. Each injector delivers fuel from two points of entry – fuel and air.



Injector #1
509093

Injector #2 and #3
513561

Injector operation changes at different power levels (ISO corrected generator power). Below 3.5 kW, the MicroTurbine operates with a single pilot injector. When MicroTurbine power reaches between 3.5 to 7kW, the system transitions from one injector to three-injector engine operation. The injector switch point varies with ambient conditions.

Commissioning the System

WARNING	Be careful not to introduce any dirt, debris or contaminants into the fuel system. Introducing contaminants may cause clogged fuel system injectors, leading to system failures.

Fuel Pressure and Air Assist Requirements

The HEV system requires a minimum inlet fuel pressure of 34 kPa (5 psig) to 69 kPa (10 psig) and maximum fuel flow of 18 lph to the fuel pump. If using the Capstone-supplied boost pump assembly, the pressure requirement into this pump is -34 kPa (-5 psig) to 34 kPa (5 psig) psig. Capstone also offers a combination of the boost pump and 2-micron filter as an assembled unit.

In addition, the following air-assist requirements are required:

- Start/Cooling mode: 80 slpm @ 427.8 min/861.8 max kPa (62 min/125 max psig) @140° F (60° C) max.
- Idle mode 60 slpm @ 427.8 min/861.8 max kPa (62 psig min/125 max) @140° F (60° C) max.

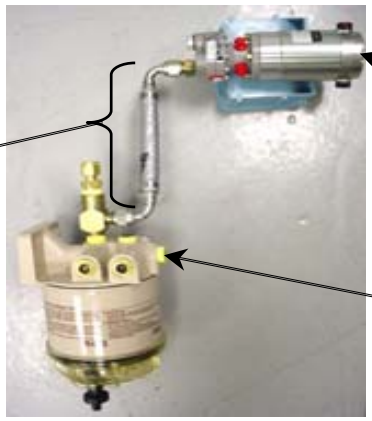
Priming Valve Installation

A priming valve should be installed between the boost pump (if installed) and the fuel pump inlet to ensure that no air pockets exist before fuel enters the fuel system. This valve can be manual or solenoid driven – depending on the level of automation desired, and should be located less than 0.3 meter from the fuel pump inlet.

NOTE	Priming will ensure system start reliability. The system must be primed before initial operation or if the customer fuel supply has been depleted.

Perform the following steps to complete the installation:

1. Connect priming valve to container to catch fuel during priming process.
2. Install site glass to view condition of fuel exiting the priming valve for system quality.



Perform the following steps to manually prime the system:

1. Open the priming valve.
2. Turn the boost pump ON (Capstone boost pump or customer-provided).
3. Wait for fuel to exit the priming valve.
4. Cycle (open/close) the priming valve several times to purge remaining air from the lines between the fuel tank and the fuel pump inlet.

Drain Tank Installation

If the (optional) Capstone drain tank is purchased, the drain tank mounting location must be installed below the height of the recuperator and at a distance no more than 10 feet (max.) from drain valve. In addition, the customer must supply attaching fuel lines and fittings. Recommended hose and fitting size parameters are:

- Inlet and outlet fittings – 1/4-inch male SAE, 37° flare
- Recommended hose size – 3/8-inch diameter

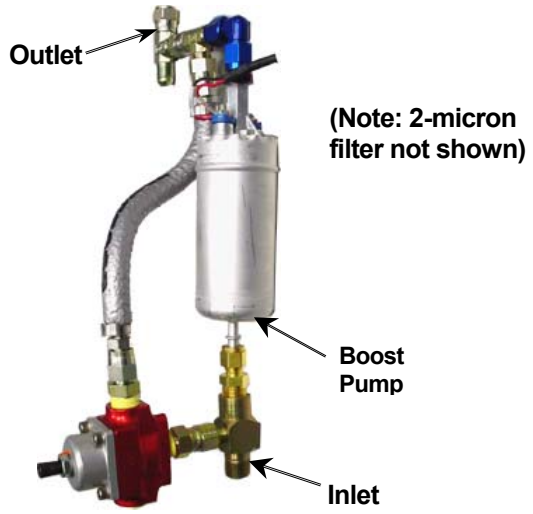
Boost Pump and Filter Installation Requirements

Filter and Boost Pump Assembly (514080):

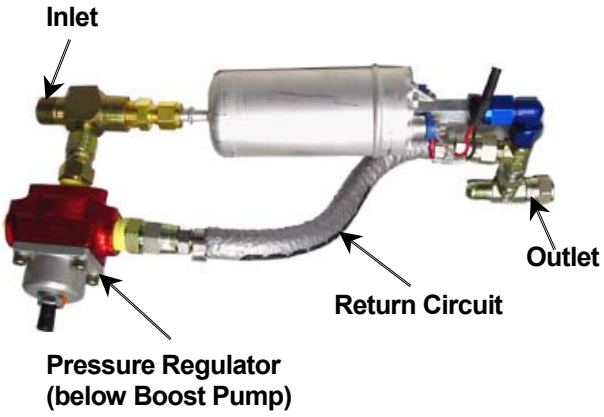
NOTE	If a boost pump is installed, a 12V (2A @nominal, 9A @ startup) power supply and cable must be provided.

1. Hose and fitting size parameters:
   - Inlet and outlet fittings – 3/8-inch diameter male SAE, 37° flare
   - Recommended hose size and length – 3/8-inch diameter, 20 feet max. between filter/boost pump assembly to fuel pump on engine
2. Recommended boost pump cable terminal connections:
   - #10 ins, 22-16 awg for pump (-)
   - # 8 ins, 22-16 awg for pump (+)
3. Recommended boost pump cable wire size:
   - 16 awg

The boost pump/pressure regulator assembly should be mounted vertically with the boost pump outlet upright, or horizontally with the pressure regulator below the boost pump.



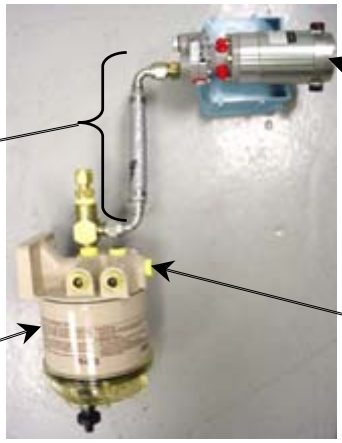
Boost Pump/Regulator Installation (Vertical Orientation)



Boost Pump/Regulator Installation (Horizontal Orientation)

4. Priming Valve requirement:

If using the Capstone filter/boost pump kit, a priming valve must be installed within 0.3 meters (1 ft) of the fuel pump inlet. The priming valve will be utilized during initial engine operation to bleed the air out of the fuel lines between the fuel tank and fuel pump inlet.



Filter Assembly only (513770):

Hose and fitting size parameters:

- Inlet and outlet fittings – 3/8-inch female NPT
- Recommended hose diameter – 3/8-inch

1. Fuel filter orientation - The filter must be mounted in a vertical position to ensure proper air removal. Filter bowl should be facing down.

2. Priming valve requirement:

A priming valve must be included between the filter and fuel pump within 0.3 meters (1 ft) of the fuel pump inlet. The priming valve is utilized during initial engine operation to bleed air out of the fuel lines between the fuel tank and fuel pump inlet.

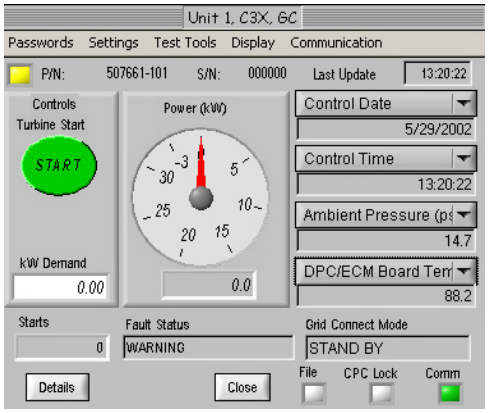
Operating the MicroTurbine

The MicroTurbine may be operated using one of two interfaces: CRMS, or the display panel. CRMS has two modes of operation: 1) Control Panel or 2) Command line.

NOTE	A 6006 FAIL TO LIGHT fault may occur on the first start while air is initially pumped through the fuel system. If this occurs, performing another start command should allow the system operate normally.

Method 1 – CRMS Control Panel

At the initial MicroTurbine Control Panel screen, click on the **<START>** button to initiate the MicroTurbine operation.

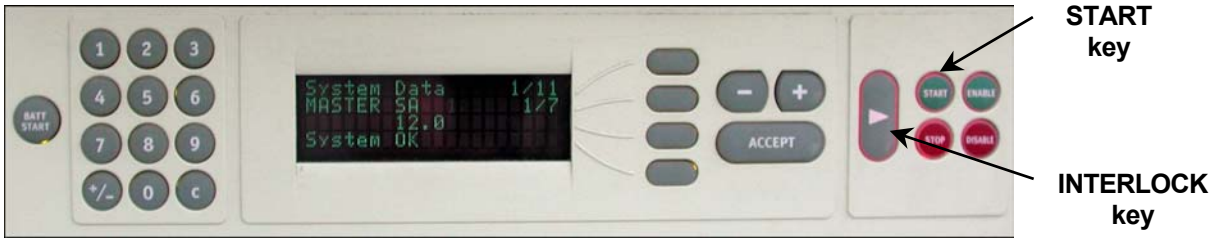


Method 2 - CRMS Command Line

Enter the Start command through the CRMS Command Line screen by selecting **[Communication] [Command Line]** at the MicroTurbine control panel screen. Enter the sequence **STRCMD =1**.

Method 3 - Display Panel

NOTE	Detailed explanation of the display panel is available in the MicroTurbine Users Manual (400001).



Press the keys **<INTERLOCK>** and **<START>** keys simultaneously to begin operation.

Diagnostic Faults

The following table summarizes possible liquid fuel system diagnostic faults.

NOTE	Detailed explanation of all possible diagnostic faults is available in the Capstone MicroTurbine Model C30 Troubleshooting Guide (430000).

Engine Faults			
Fault No.	**Fault Description**	**SSL**	**Isolation Message**
6006	FAIL TO LIGHT	3	Internal Fault
6011	FLAMEOUT START	3	Internal Fault
6012	FLAMEOUT LOAD	3	Internal Fault

Liquid Fuel System Faults			
Fault No.	**Fault Description**	**SSL**	**Isolation Message**
16002	LF DRNTNK LVL	2	Fuel Warning
16003	LF DRNTNK FULL	6	Fuel Fault
16004	LF FAIL LINFIL	3	Fuel Fault
16005	FAIL TO DRAIN	3	Fuel Fault
16006	LF FUEL SOL	3	Fuel Fault
16007	LF DRAIN SOL	3	Fuel Fault
16008	LF PURGE SOL	3	Fuel Fault
16009	LF STRTAIR SOL	3	Fuel Fault
16010	LF BRD OTMP	3	Fuel Fault
16011	LF BRDTMP SENS	3	Fuel Fault
16012	LF COMM TO	3	Fuel Fault
16013	LF XDUCER OP	3	Fuel Fault
16014	LF XDUCER SH	3	Fuel Fault
16018	LF INJ 1 CLGD	3	Fuel Fault
16019	LF INJ 2 CLGD	2	Fuel Warning
16020	LF INJ 3 CLGD	2	Fuel Warning
16021	LF MULT INJ CLGD	3	Fuel Fault

Maintenance Items

Scheduled maintenance intervals for the Liquid Fuel System include maintenance of the fuel pump and boost pump. Details for these component parts are summarized in the MicroTurbine Standard Maintenance Schedule (440000).

Related Documentation

The following table lists applicable Capstone documentation.

Document No.	Document Title
400001	Capstone MicroTurbine Users Manual
410002	Capstone MicroTurbine Fuel Requirements Technical Reference
410013	Capstone Remote Monitoring System (Users Edition) Technical Reference
430000	Capstone Model C30 Troubleshooting Guide
440000	Capstone MicroTurbine Standard Maintenance Schedule
440023	Capstone HEV Enhanced Liquid Fuel System Retrofit Kit Work Instructions

Capstone Technical Information

If questions arise regarding HEV liquid fuel system operation for your Capstone MicroTurbine, please contact Capstone Turbine Technical Support for assistance and information.

Capstone Technical Support
Toll Free Telephone: (877) 282-8966
Service Telephone: (818) 407-3600 • Fax: (818) 734-1080
E-mail: service@capstoneturbine.com

Capstone Technical Support (Japan)
Service Telephone: (818) 407-3700 • Fax: (818) 734-1080
E-mail: servicejapan@capstoneturbine.com

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