



Technical Reference

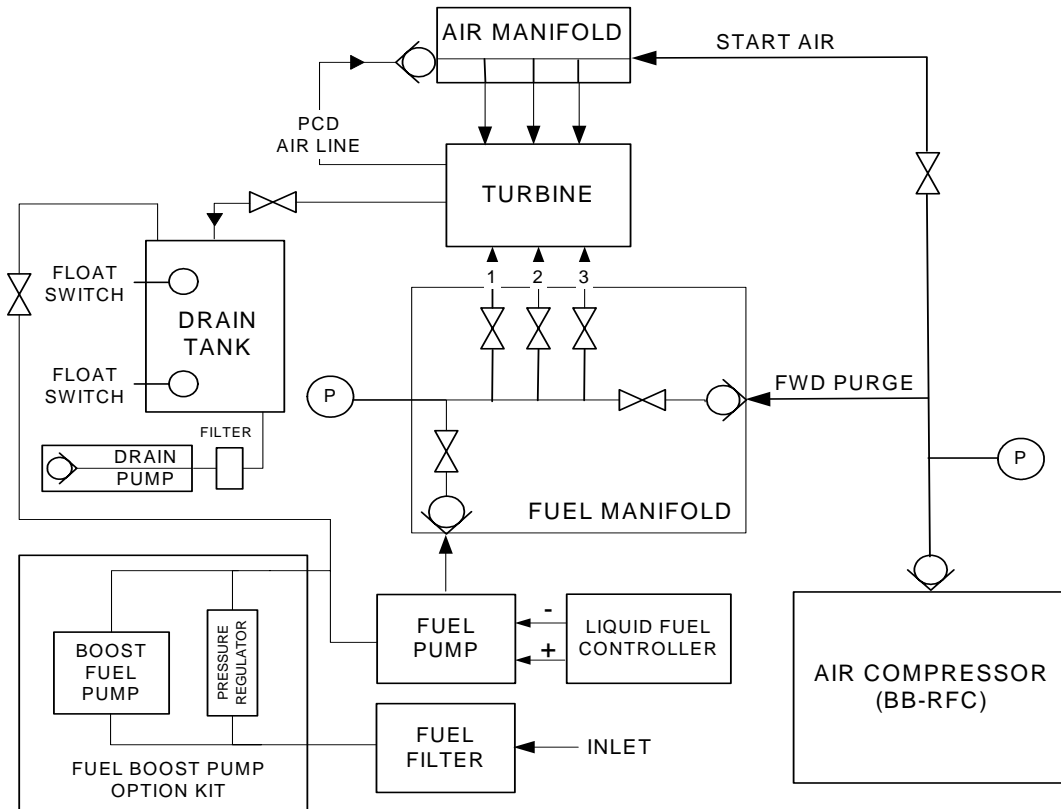
Liquid Fuel System Technical Information – Model C30 MicroTurbine

Introduction

This document provides technical information for Capstone Turbine Corporation® Model C30 MicroTurbine systems operating on kerosene and low-grade diesel fuels. Liquid fuel systems have multiple applications in remote locations where grid power may be unavailable, such as offshore oil, or stand alone heating applications. Refer to the MicroTurbine Fuel Requirements Technical Reference (410002) for additional information on fuel requirements.

Liquid Fuel System injector modifications and software design have resulted in increased combustion stability, allowing operation at levels as low as 0 kW. This lower operating level allows the MicroTurbine to recharge the battery in Stand Alone mode. In addition, the software-driven auto-priming linefill sequence improves start reliability by eliminating the undesirable presence of excess air in fuel system components and fuel lines connecting to the MicroTurbine. This extends the service life of the components such as the fuel pump (increased lubrication) and the igniter (reduced failed starts).

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



System Components

Major liquid fuel system components are identified below:



Part Number	Liquid Fuel Major Components
513684 -1XX	Liquid Fuel Pressure Sensor
514401 -1XX	Drain Tank Assembly
513620 -1XX	Boost Pump and Filter Assembly (sold as one unit)
513769-0XX	Boost Pump (sold separately)
513770-0XX	Filter -2-micron (sold separately)
513692-0XX	Priming Solenoid (sold separately)
510921-0XX	Electric Fuel Pump
513778-1XX	Drain Return Pump/Filter
513684-1XX	Liquid Fuel Pressure Sensor
513692-XXX	Priming Solenoid
508593-1XX	Liquid Fuel Controller Board

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). 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 as the internal generator brings the MicroTurbine to ignition speed, and engine firing on the No. 1 injector occurs at the beginning of each sequence. 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 RFC is turned on.
2. The air-assist solenoid opens to provide air to the air-assist manifold from the RFC - until an ISO-corrected generator power level of approximately 7 kW.
3. The fuel shutoff solenoid and injector 1 solenoid open to allow fuel through injector 1. If air pressure feedback from the RFC does not reach commanded pressure at start-up, a “3029 RFC AIR ASSIST” fault is declared.

The drain system includes a drain tank fuel-level float sensor to detect the amount of fuel present in the tank at all times and collects excess fuel during a “6006 FAIL TO LIGHT” fault. The tank is equipped with a float sensor to provide feedback to the operator as 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. The drain tank return pump returns excess fuel from the tank to an external fuel waste container during auto-prime, shutdown, and line filling operations (as a result of multiple fail-to-lights).

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.

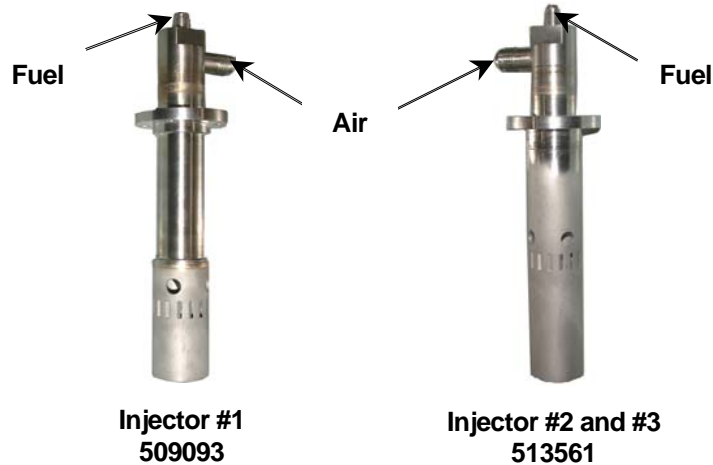
Steady State

The system is considered to be in “steady” state if it operates continuously at a power level greater than 0 kW, using at least a single injector. When the MicroTurbine reaches ambient-corrected generator power of 7kW, the system transitions from one injector 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.

In addition, air assist pressure/flow is utilized during steady state operation to atomize the fuel for combustion and to purge the fuel lines during system shutdown. Air is supplied from the BB-RFC through the air-assist solenoid during a start (and below 7 kW), and through engine compressor discharge pressure (PCD) during operation above the 7 kW power level.

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 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.

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 opportunity for coking to occur inside the injectors after the unit is turned off.

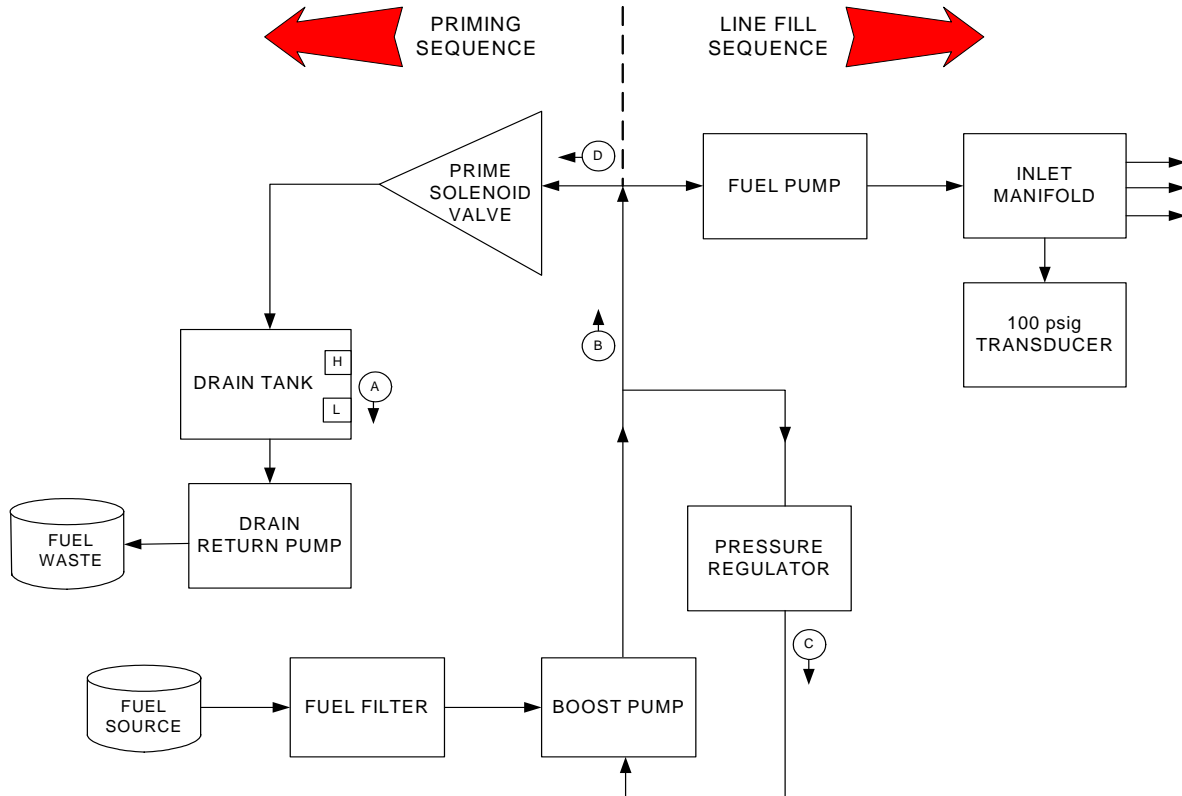
There may be an over-temperature in the TET due to excess fuel entering the combustor during this time (software masks TET reading for 10 seconds to avoid over-temperature faults). This over-temperature is normal for a shutdown, and will vary depending on the shutdown power level. No purge is performed 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 opens.
4. Injector solenoids cycle to purge fuel.
5. High-pressure air is blown through injector lines to purge remaining fuel.
6. The RFC is turned off.

Initial Priming Sequence

The initial priming sequence shown below is required upon initial commissioning or if the fuel source is ever completely drained.



- (A) **Purge the Tank** – The priming sequence begins initially by purging residual drain tank fuel through the tank discharge line. When MicroTurbine power is turned on, the drain pump is activated. High and low sensors located inside the drain tank detect the existing fuel level. If the fuel level is above the low sensor, the drain pump drains the tank until the low level sensor indicates that the fuel level is below its level. The drain pump will run for 30 seconds (max) to ensure that fuel is completely purged. A “16005 FAIL TO DRAIN” fault is set if the drain pump cannot drain the fuel below the low-level sensor after 2 minutes.
- (B) **Fuel Line Fill** – The boost pump is turned on, and fuel begins filling the lines. At this point, the prime solenoid valve is opened and the path through the electric fuel pump has closed. The direction of fuel flow is from the fuel source through the boost pump and the prime solenoid valve, into the drain tank.
- (C) **Return Line Prime** - Fuel is cycled in a closed-loop path through the boost pump to remove any air pockets remaining in the system. During this time, the boost pump remains on while the prime solenoid valve pulses three times (3 seconds open, 1 second closed).
- (D) **Drain Tank Fill** - Fuel flows through the lines to the drain tank through an open prime solenoid valve and activated boost pump. The solenoid valve is kept open for 10 seconds after the first float triggers. The drain tank continues to fill during this time. If the drain tank fuel level reaches the high sensor, a “16003 LF DRNTNK FULL” fault is triggered.

Commissioning the System

Fuel Pressure Requirements

Inlet fuel pressure requirements are: -34 kPa (-5 psig) to 34 kPa (+5 psig). This range of inlet pressures accommodates differences in fuel tank placement (e.g. above ground, below ground, and distance of separation). Supply pressure must remain stable within $\pm 2\%$ of the nominal pressure (within the specified minimum-to-maximum pressure range) for the entire load range operation of the MicroTurbine system.

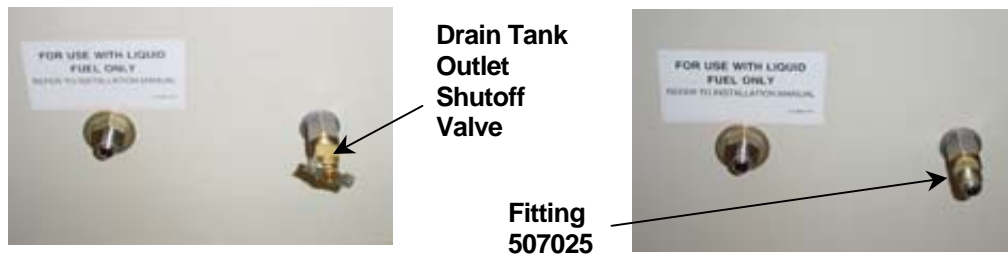
Hardware Preparation

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.
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Perform the following hardware checks in preparation for MicroTurbine priming:

1. The drain tank outlet shutoff valve (510575) on the package outlet should be replaced with a fitting (507025) to attach a drain line, if fuel will be returned to an external tank.

NOTE	Fuel may leak through the adjustment screw shaft of the drain tank outlet shutoff valve during tank draining if the fitting is not installed.
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2. Verify that any external fuel shutoff is open, and the fuel source is securely attached before initiating the start sequence on the MicroTurbine.
3. Initiate a start command to begin system operation and enter a 30 kW Demand to verify system operation. Note the system power level for future reference.

NOTE	A “16004 FAIL TO LINEFILL” or “6006 FAIL TO LIGHT” fault may occur on the initial start sequence while air is initially pumped through the fuel system. If this occurs, perform another start command.
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Priming Sequence

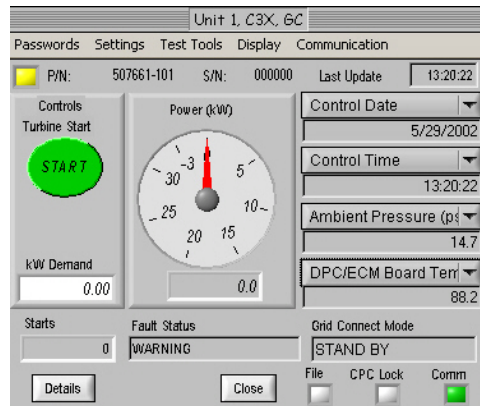
The priming sequence may be performed manually, if required, using the following interfaces:

- Method 1 - CRMS user interface
- Method 2 - CRMS command line
- Method 3 - Display Panel

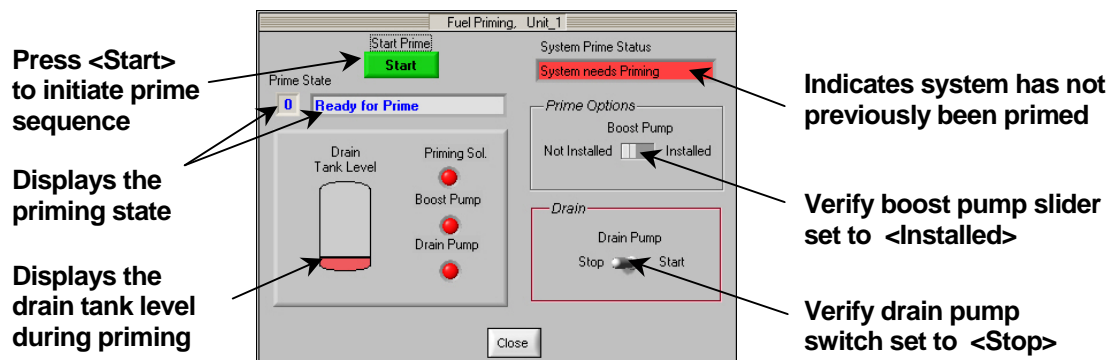
Method 1 – CRMS Control Panel

NOTE	Detailed explanation of CMRS user interface is available in the CRMS Maintenance Edition Technical Reference (410014).
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1. At the initial MicroTurbine Control Panel screen, view the Liquid Fuel Priming Panel by selecting **[Settings][Liquid Fuel System Priming]**.



2. Set the **Boost Pump** slider to **<Installed>** and toggle the **Drain Pump** switch to **<Stop>**. Click on the **Start Prime <Start>** button to initiate the priming sequence.



3. Return to the initial MicroTurbine Control Panel screen and press **<Start>** to initiate the MicroTurbine operation.

Method 2 - CRMS Command Line

The Initial Prime (LFCPRM) command may be manually entered through the CRMS Command Line screen.

1. Select the screen by selecting **[Communication] [Command Line]** at the MicroTurbine control panel screen.
2. Configure the software to recognize the installed boost pump by entering the sequence **BSTPMP =1**. Initiate the Initial Priming sequence by entering **LFCPRM = 1**.

Method 3 - Display Panel

NOTE	Detailed explanation of the display panel is available in the Capstone MicroTurbine Users Manual (400001).
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To perform the priming sequence using the display panel, navigate through the four submenus to configure the MicroTurbine to recognize the boost pump and initiate the Liquid Fuel Priming sequence as follows:

1. Log on with a password (default is **87712370**). All changes to system configuration require a user password.
2. Navigate to the **<System Data>** top-level menu.
3. Navigate on line 2 to the **<Sys Config>** submenu.
4. Navigate on line 3 to the **<LF Boost Pump>** option.
5. Select the **<Installed>** option, and then press the **<Accept>** button.
6. Navigate on line 3 to the **<LF Fuel Prime>** option.
7. Select the **<Start>** option, and then press the **<Accept>** button.

The system is now configured. Verify system operation by initiating a **<Start>** command.

RS-232 Control Commands

This section summarizes the available RS-232 commands. The first three commands may be executed using the CRMS LF Priming Panel, CRMS Command Line or display panel.

BSTPMP

This parameter should be set to “1” to recognize installation of the integrated boost pump.

Display Menu System Data Sys Configuration	Parameter Description	Parameter Value	Default Value
LF Boost Pump	Allows user to set the parameter for an installed Liquid Fuel Boost Pump on the MicroTurbine.	0 = Not Present 1 = Installed	0

LFCPRM

This parameter starts or stops a user-initiated Liquid Fuel Priming sequence.

Display Menu System Data Sys Configuration	Parameter Description	Parameter Value	Default Value
LF Fuel Prime	Allows user to start/stop the Liquid Fuel Priming sequence.	0 = Off 1 = Start	0

LFCDRN

This parameter starts/stops the user-initiated Liquid Fuel Manual Drain Pump sequence. If commanded ON, the DC Bus is energized and the system state transitions to the Liquid Fuel Drain state. The sequence stops prematurely if a severity level 3 (or greater) fault is present.

Display Menu System Data Sys Configuration	Parameter Description	Parameter Value	Default Value
LF Manual Drain	Allows user to start/stop the Liquid Fuel Manual Drain sequence. If the drain tank is full, this command will not run. If the drain tank sensor warning fault appears, then run this command when the system is in the Stand By state.	0 = Off 1 = Start	0

FUELI1

Sets the liquid fuel system index point for diesel and kerosene liquid fuel systems. The default value should be 1.00 (unitless scalar to the W-energy command). **Default values should not be adjusted unless flameout problems arise.**

Display Menu	Parameter Description	Parameter Values	Default Value
Fuel Index 1 (Value)	Sets the liquid fuel system index point	0.10 to 14.00	1.00

FUELI2

Fuel Index 2 (FUELI2) is not currently used on liquid fuel systems. **The default value of 1.00 should not be adjusted.**

Liquid Fuel Diagnostic Faults

The following table summarizes possible liquid fuel system diagnostic faults.

NOTE	Detailed explanation of Liquid Fuel Controller Faults is available in the MicroTurbine Model C30 Troubleshooting Guide (430000).
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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
16000	PMP NOT PRIMED	3	Fuel Fault
16001	FAIL TO PRIME	3	Fuel Fault
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	3	Fuel Warning
16020	LF INJ 3 CLGD	3	Fuel Warning
16021	LF MULT INJ CLGD	3	Fuel Fault

Maintenance Items

Scheduled maintenance intervals for the Enhanced Liquid Fuel System include maintenance of the Fuel Pump and Boost Pump. Details for these component parts are summarized in the Capstone 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
440020	Capstone Liquid Fuel System Retrofit Kit Work Instructions

Capstone Technical Information

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

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