Cyrius Fuel Subsystem Setup and Operation Guide

Model DDC-CFS-101

Version 7

March 20,2024

Developed by Transportation Laboratories

Version History

Version	Date	Revision Description
1	9/26/2015	Initial publication
2	2/10/2016	Added descriptions of operating modes to Section 11.2 Descriptions of Modes. Listed Ethernet port number provided with the CFS in Section 2.3.1 Provided with the CFS
3	3/21/2016	Added AK command to set the filter factor for instantaneous fuel rate in Section 13.2.2 Setting Commands Added the following to Section 13.2.3 Inquiry Commands: • Added state of the system value for system not enabled • Added AK command for system watch dog status
4	5/18/2016	Added statement to enable monitoring of the UPS power level any time the UPS is turned off in Section 3. Safety Labeled and noted the location of USB ports in Section 4.1 Electrical and I/O Revised Section 5.1 Initial Procedure: • Added section name to the existing steps for powering on the CFS • Added a statement to clarify when to use the steps • Updated the desktop screenshot Added Section 5.2 Monitoring the UPS Power Level Revised steps to use `eth1` instead of `eth0` in Section 7. Changing the IP Address Changed description of command from “VFD Fault” to “Power Fault in Section 13.2.3. Inquiry Commands. Revised Section 15.4 Error Messages: • For the message VESSEL TOO HOT, deleted the suggested action to "Verify no VFD fault". • Replaced the message “VFD FAULT” with “POWER FAULT” and revised the associated cause and suggested actions accordingly.
5	8/23/2018	Formatted with SGS brand
6	4/15/2020	Retrofit to new template
7	3/20/2024	Rebrand to TRP Laboratories

Document Conventions

This document uses the following typographic and syntax conventions.

- Commands, command options, file names or any user-entered input appear in Courier type. Variables appear in Courier italic type.

  Example: Select the `cmdapp-`*`relVersion-buildVersion`*`.zip` file….

- User interface elements, such as field names, button names, menus, menu commands, and items in clickable dropdown lists, appear in Arial bold type.

  Example: **Type**: Click **Select Type** to display drop-down menu options.

- Cross-references are designated in Arial italics.

  Example: Refer to *Figure 1*…

- Click intra-document cross-references and page references to display the stated destination.

  Example: Refer to *Section 1 Overview* on page 1.

  The clickable cross-references in the preceding example are *1*, *Overview*, and on page 1.

CyFlex Documentation

CyFlex documentation is available at https://cyflex.com/. View **Help & Docs** topics or use the **Search** facility to find topics of interest.

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1 Overview

This document is a guide for installing, calibrating, and operating the TRP Laboratories Cyrius Fuel Subsystem (CFS), including a brief overview.

The CFS measures fuel consumption and is typically installed inside of a test cell. It conditions fuel temperature at the engine fuel inlet. Configuration options include a mobile cart on wheels and a wall-mounted version. In the mobile configuration, the CFS automation cabinet mounts to a wheeled cart and includes a touch-screen interface. Either configuration may be integrated with a test cell automation system.

Designed with safety as priority, the CFS is usually connected directly to external emergency stop circuitry, or to a facility safety system at the test cell. When external stop circuitry or the CFS-Stop on the front panel removes 24V from the subsystem, the valves, fuel heater and pump are turned off, rendering the system safe.

Everything needed for maintaining the engine fuel inlet temperature and protecting against fuel overflowing in the cabinet is included. The CFS controls fuel temperature for the engine supply and includes an overflow sensor in the fuel weighing bucket.

The DDC-CFS-101 is configured with an Ethernet connection and controlled from a test cell computer. Communication follows the Transmission Control Protocol/Internet Protocol (TCP/IP), over an intranet or extranet. The CFS acts as the server (slave) and the test cell computer as the client (master), with commands and messages using the AK protocol. The user controls the CFS from the test cell PC through a client program provided by the customer.

1.1 Standard Features

Standard features for the Cyrius Fuel Subsystem include:

- Choice of configuration:
  - Wall-mounted unit

    or
  - Mobile cart
- Mass flow calculation:
  - Fuel consumption measurements are direct mass flow rates, not volumetric flow rates
  - The user may select the units of measurement displayed – such as lb./hr., kg/sec, lb./min, or kg/min, among others.

Operator controls are readily available on the front panel as in *Figure 1* on page 2.

Figure 1: DDC-CFS-101 Front Panel

1.2 Measurement Accuracy

The Cyrius Fuel Subsystem obtains accurate readings consistently by utilizing the most effective measuring techniques from two different measurement devices:

- Coriolis mass flow
- Gravimetric mass

Coriolis mass flow measurements are almost instantaneous, and accurate from 100% down to about 5% of full scale, but much less accurate for very low flows.

Gravimetric mass measurement of fuel as it is consumed provides accurate readings for steady state operating conditions, even at very low flows. However, this method is less suitable for fast response measurements (such as for transient test cycles).

The TRP Laboratories “smart” fuel flow measurement software automates conditioning the fuel temperature and measuring flow. Once fuel is flowing, the software chooses the best sensor technology based on the flow rate. Flow measurements use direct mass flow sensors, not volumetric flow sensor readings converted to mass flow measurements using calculated or

Every fuel reading characteristically includes minimal uncertainty, which is calculated by performing a real-time statistical analysis on the measurement devices being used. In certain modes of operation, the user can specify that a fuel reading stop when a specified uncertainty is achieved. This guarantees the quickest reading for a specified uncertainty. If the fuel reading exceeds ten minutes or the fuel bucket reaches the minimum weight, the reading terminates before achieving the specified uncertainty.

Table 1 shows specifications for a standard CFS subsystem.

Table 1: CFS Subsystem Specifications

Sensors	Coriolis plus Load Cell Sensors	Details
Measurement Range	0 – 200.0 lb./hr. 0 – 1.52 kg/min	Wider or narrower ranges are available.
Accuracy	Coriolis makeup fuel sensor	200 – 12 lb./hr. = 0.1% of reading 12 – 1 lb./hr. = 0.1% - 1% of reading (i.e. constant 0.05 lb./hr. accuracy) 1 – 0 lb./hr. = not recommended (0.05% of reading over 30:1 turndown sensor is optional)
	Load cell fuel bucket weight sensor Calibration weights supplied	Overall: 0.0375% full scale (RMS) Linearity: 0.03% FSO Hysteresis: 0.02% FSO Repeatability: 0.01% FSO Thermal: 0.0028% FSO/^{O}C (RMS) Zero: 0.002% FSO/^{O}C Span: 0.002% FSO/^{O}C
Engine Supply Line Temperature Control	+/- 0.5^{O}F (+/- 0.28^{O}C) @ 104^{O}F (40^{O}C)	10 ft. S.S. over-braid insulated engine supply and return lines are included
Heater Size	1.875 kW	---
Engine Supply Line Pressure	< 3 psi	Optional: regulated supply 0 - 15 psi
Engine Return Line Pressure	< 1 psi	---

2 Installation Prerequisites

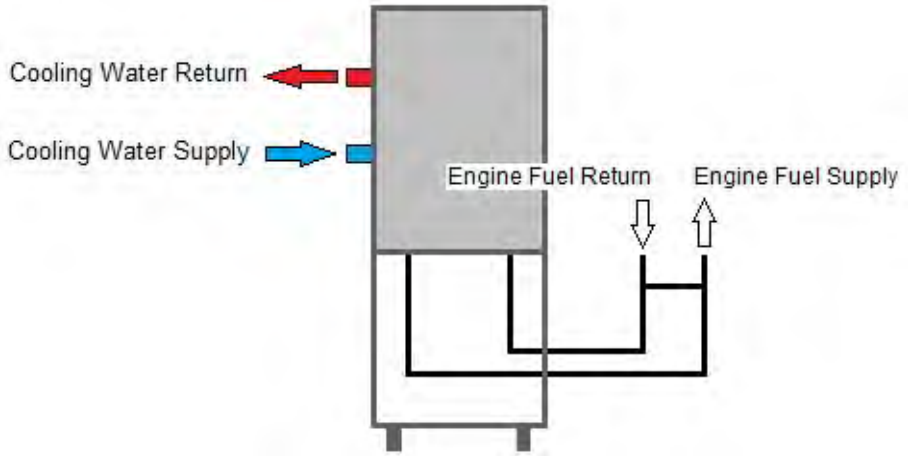
Comply with the instructions in the following sub-sections to ensure the facility is set up to accommodate the installation.

2.1 Connections

2.1.1 Mechanical Connections

Figure 2 illustrates the required water and fuel supply configuration.

Figure 2: Water and Fuel Supply Connections



Ensure the following mechanical connections are in place:

- Cooling water supply and return:
  - 1/2” Female NPT
  - Temperature <= 85 deg F; >= 65 deg F
  - Pressure >= 35 psig

  Note:

  If chilled cooling water is used, adjust the cooling water pressure regulator down to approximately 10 psig in order to increase the control valve range and avoid over cooling the fuel.
- Fuel supply:
  - 1/2” Female NPT
  - Pressure >= 45 psig
  - Flow rate >= 1 GPM
- Engine fuel supply:
  - 3/8” Female NPT
- Engine fuel return:
  - 3/4” Female NPT

2.1.2 Electrical Connections

Refer to *Section 4.1 Electrical and I/O on page 7*.

2.2 Customer-Supplied Hardware, Fittings, and Hoses

The following are not supplied with the Cyrius Fuel Subsystem and should be on hand for the installation:

- Hoses and fittings to connect the engine fuel supply and engine fuel return to the CFS hoses stand
- Keyboard and mouse

2.3 Requirements to Operate the CFS from a Client Computer

2.3.1 TRP Laboratories-Provided Requirements

TRP Laboratories provides the following with this configuration of the CFS:

- Fuel subsystem with onboard computer:
  - Ethernet (command) port
  - Ethernet port number 7600
- AK server program
- AK protocol specification files:
  - AK command
  - AK event response

2.3.2 Customer-Provided Requirements

The customer provides the following:

- Test cell computer (client)
- Network

  Note:

  This is typically a Local Area Network (LAN) connected to a number of test cell devices.

- Ethernet connection to the network

  Important:

  The IP address of the CFS (slave) should be specified by the customer at time of order. The default value is 10.0.1.10.

- AK client program

  Note:

  The client (test cell computer) requires a program to communicate with the server (CFS).

- Test sequence program

3 Safety

Important:

Always follow the safety practices and instructions at your facility when working with potentially dangerous materials and/or electricity.

Adhere to the following warnings:

- Make sure power is disconnected at the source before making electrical connections to the CFS.
- The CFS displays a fault code (code 4, VESSEL TOO HOT) if fuel in the bucket reaches 54 deg C. Avoid running the system with the fuel (in the bucket) at or above this temperature. If the fault code occurs with any regularity, contact TRP Laboratories.
- Follow the process described in this document for powering on the CFS, after initial installation or moving it to a new test cell. Otherwise, components may be damaged.

Adhere to the following cautions:

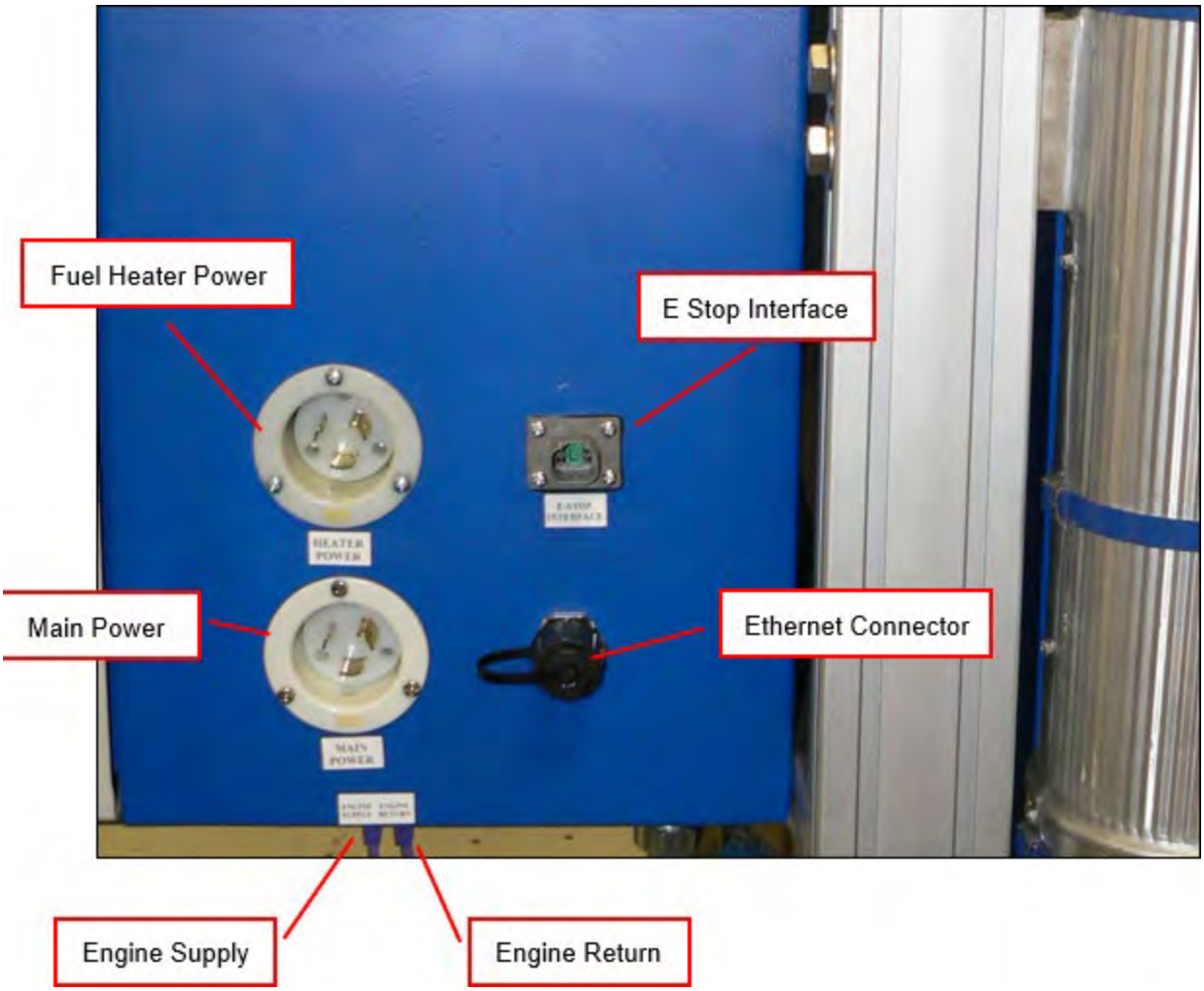
- Empty and clean the fuel bucket before moving the CFS.
- The CFS has an internal “watchdog” function. This means that if the onboard computer stops working for any reason, the CFS shuts down the pump, heater and fill valve. The CFS stops responding to user commands. As a result, the engine could run out of fuel.
- If this happens, immediately shut down the engine following facility procedures, before the bucket runs out of fuel. Then investigate the reason for the problem.
- If the Uninterruptible Power Supply (UPS) is not working properly, a power outage or surge can cause the onboard computer to lock up or shut down. Check the UPS daily to confirm it is functional.
- If the UPS is turned off for any reason, monitoring of the UPS power level is disabled. This includes an extended power outage if the UPS power level drops below about 30%.
- Activate UPS monitoring according to the steps described in *Section 5.2 Monitoring the UPS Power Level* on page 18.
- Before using the system, poll the CFS to verify it is activated and responding to commands. Thereafter while operating the CFS, poll it periodically to verify there are no faults.

4 Identifying System Components

Refer to the sub-sections below to identify the major components of the Cyrius Fuel Subsystem (CFS) and wiring.

4.1 Electrical and I/O

Figure 3: CFS Electrical and Input/Output Connections



Electrical and Input/Output connections for the CFS installation are described below:

- (2) 120 VAC 20 A circuits (fuel heater, main) with NEMA L5-20 twist-lock plugs
- Test Cell E-Stop interface; set of dry contacts from the test cell E-Stop circuit to the CFS panel
- Ethernet connector for AK communication

Figure 4 on page 8 through *Figure 7* on page 11 identify additional components in the CFS cabinet.

Figure 4: Internal CFS Components

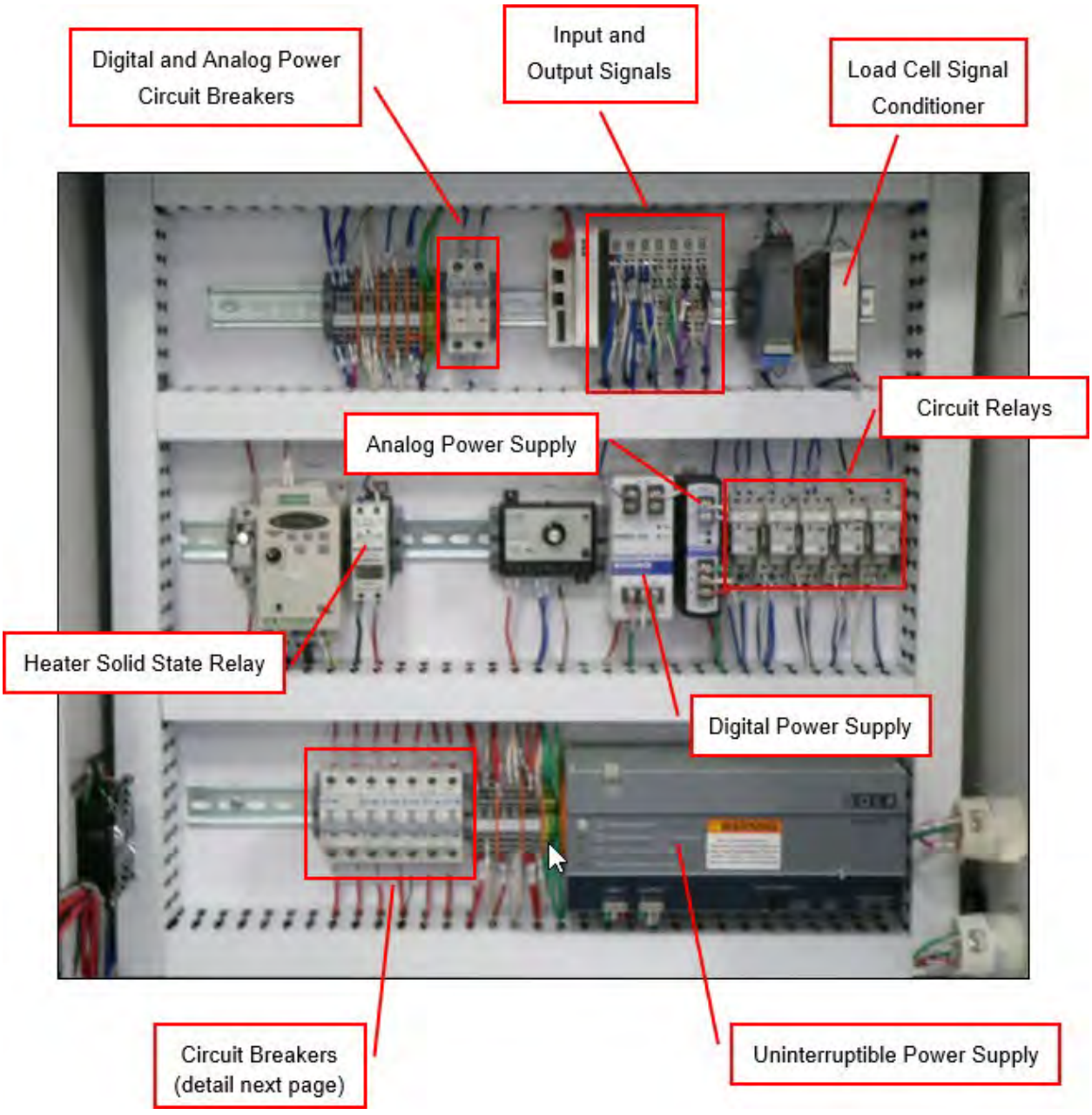
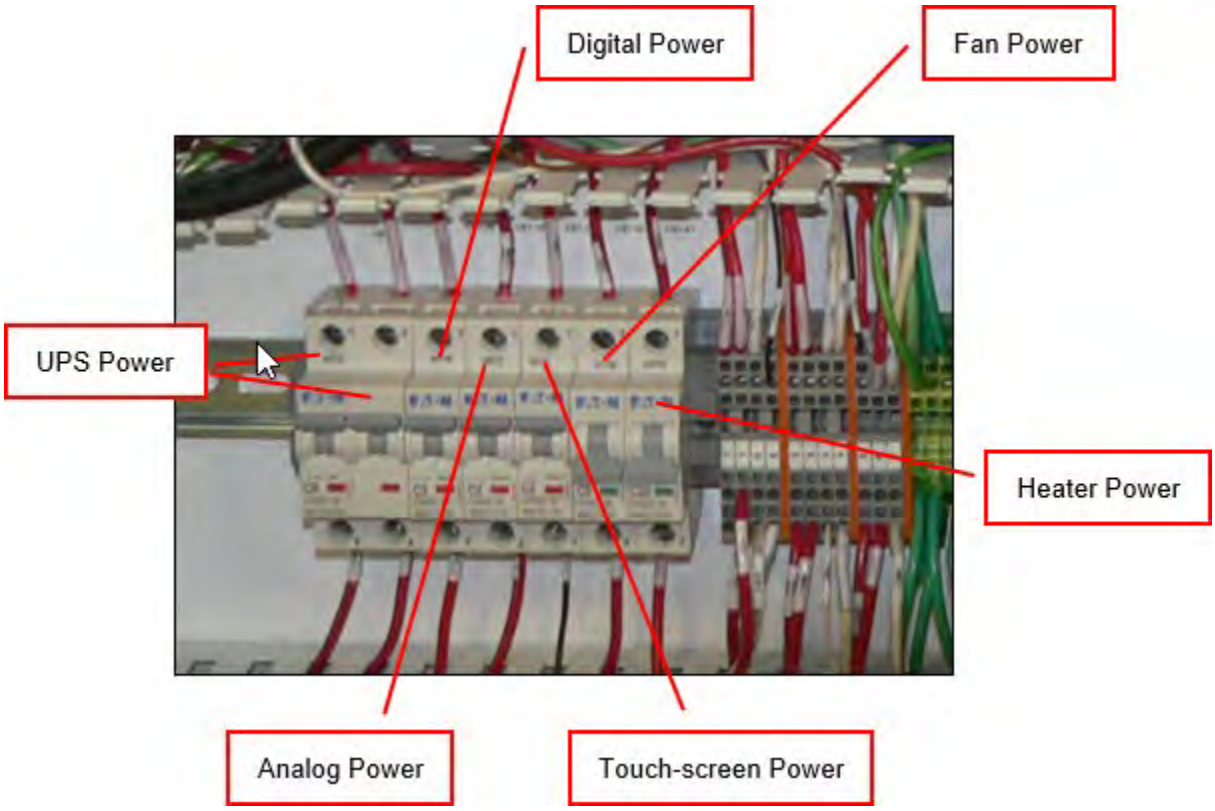


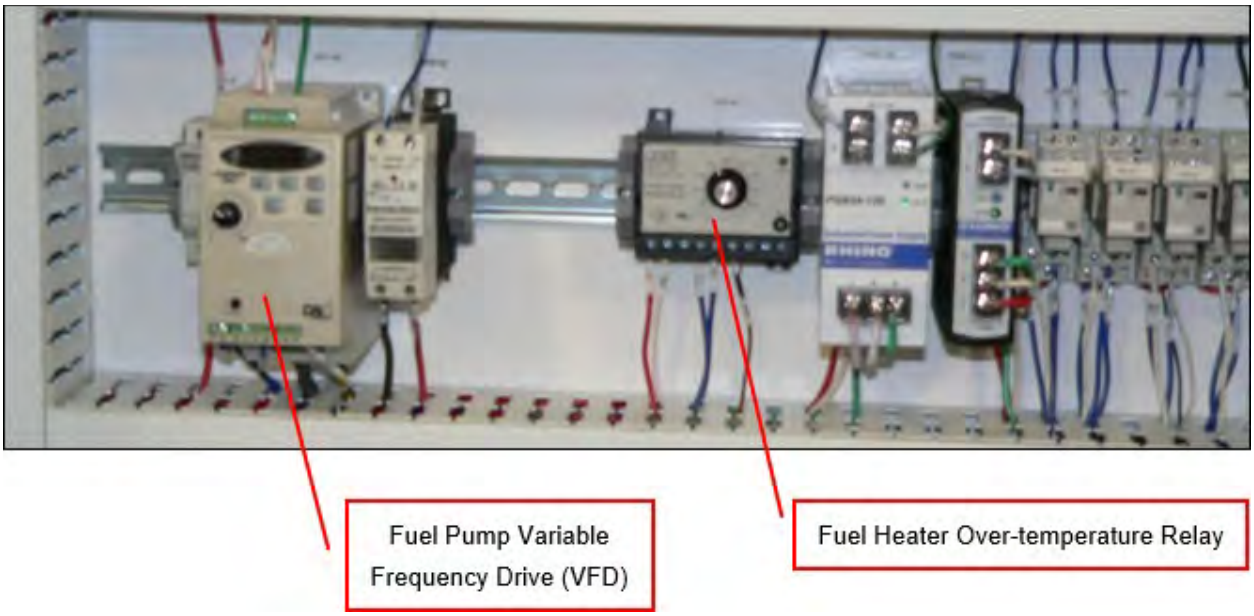
Figure 5:Circuit Breakers – Bottom Rack



Note:

The input and output circuit breaker is located on the top rack as shown in *Figure 4* on page 8.

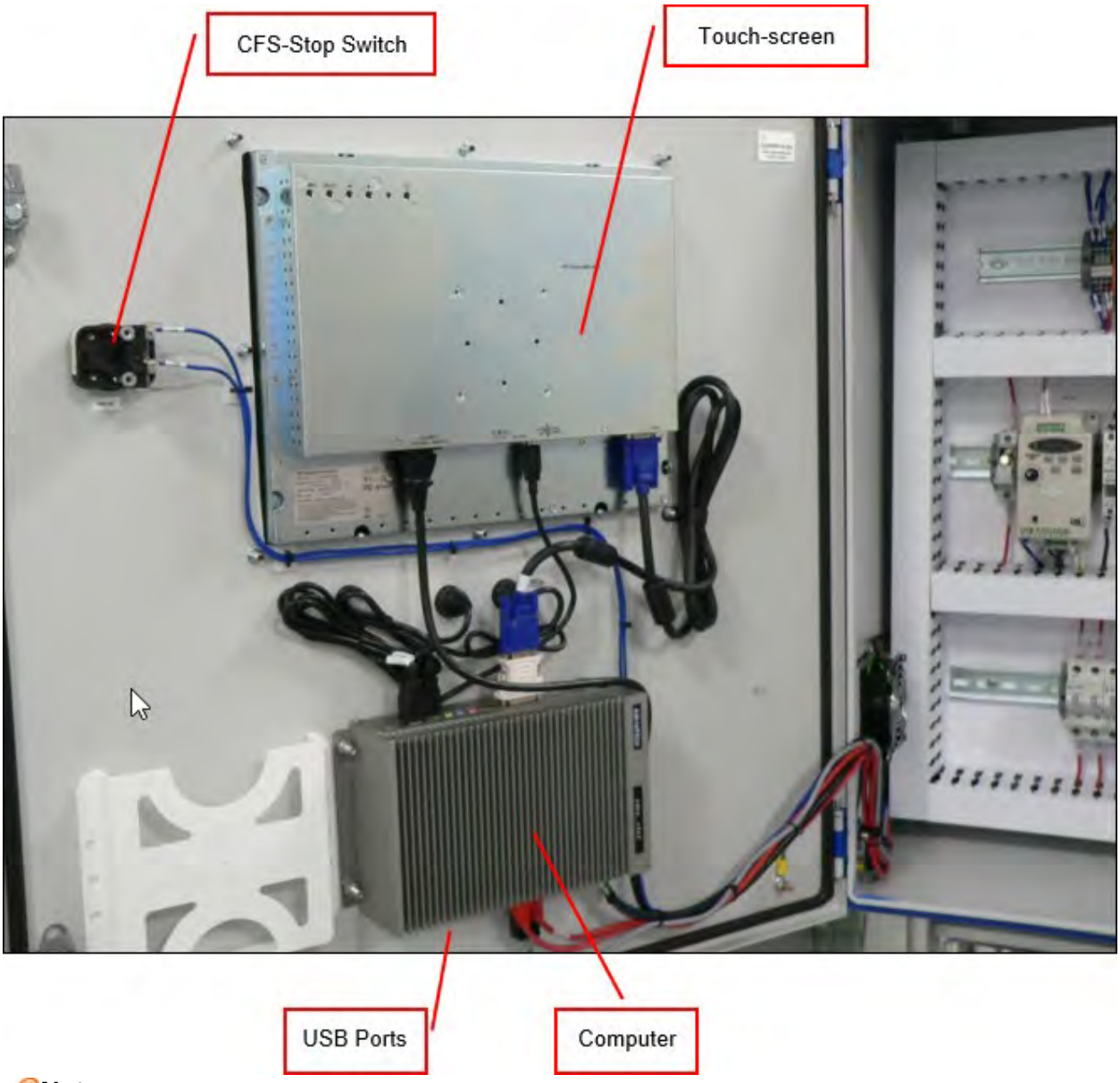
Figure 6: Adjustable Controls - Middle Rack



Note:

The variable frequency drive is controlled by the potentiometer on the VFD. The default setting is 34 Hz.

Figure 7: I/O Cabinet Rear Door



Note:

Depending on the configuration, USB ports may be located on the left side of the computer.

4.2 Fuel

This section describes components that make up the fuel flow measurement and fuel conditioning systems. Fuel temperature is controlled using an electric heater and a water-cooled heat exchanger.

- Coriolis meter
- Fuel bucket with a baffle system for removing air bubbles from the fuel
- Fuel filter
- Fuel flow control valve
- Fuel pump
- Fuel pressure regulator
- Fuel on/off valve
- Heat exchanger
- Load cell
- Water flow control valve

Figure 8: Coriolis Meter and Fuel Filter

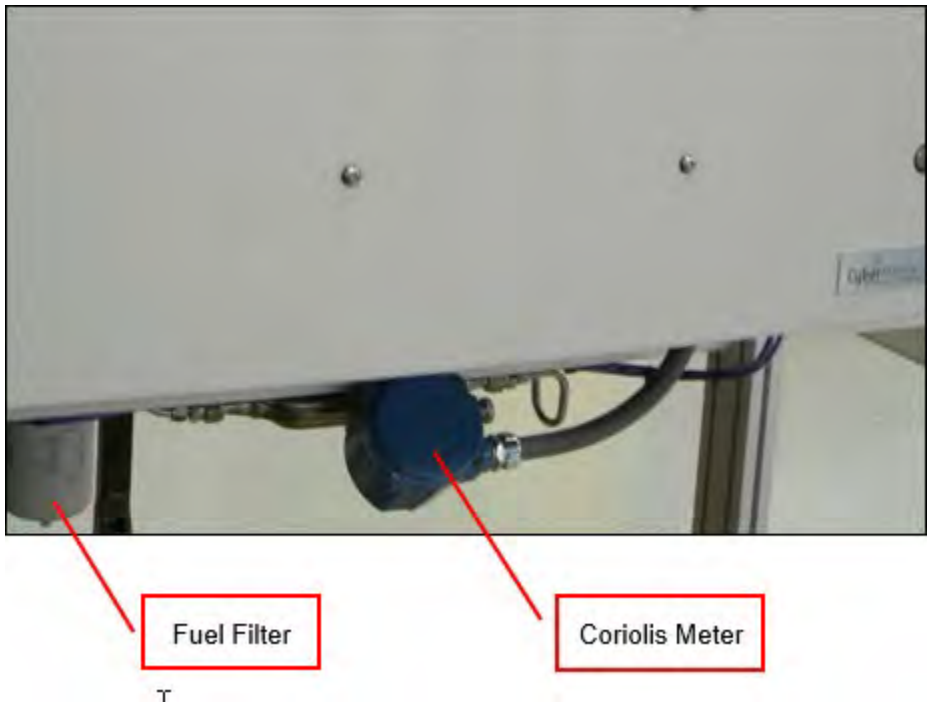
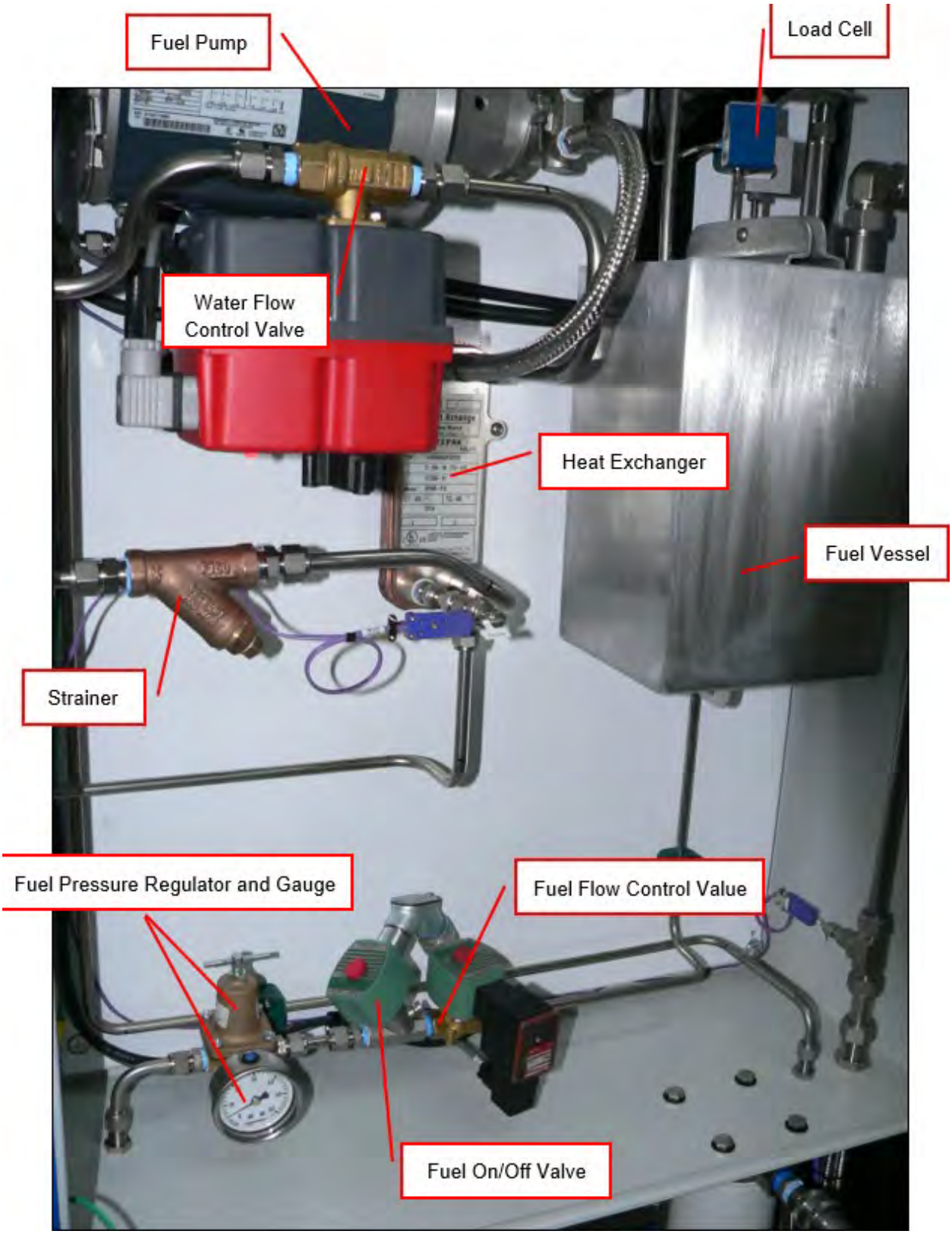


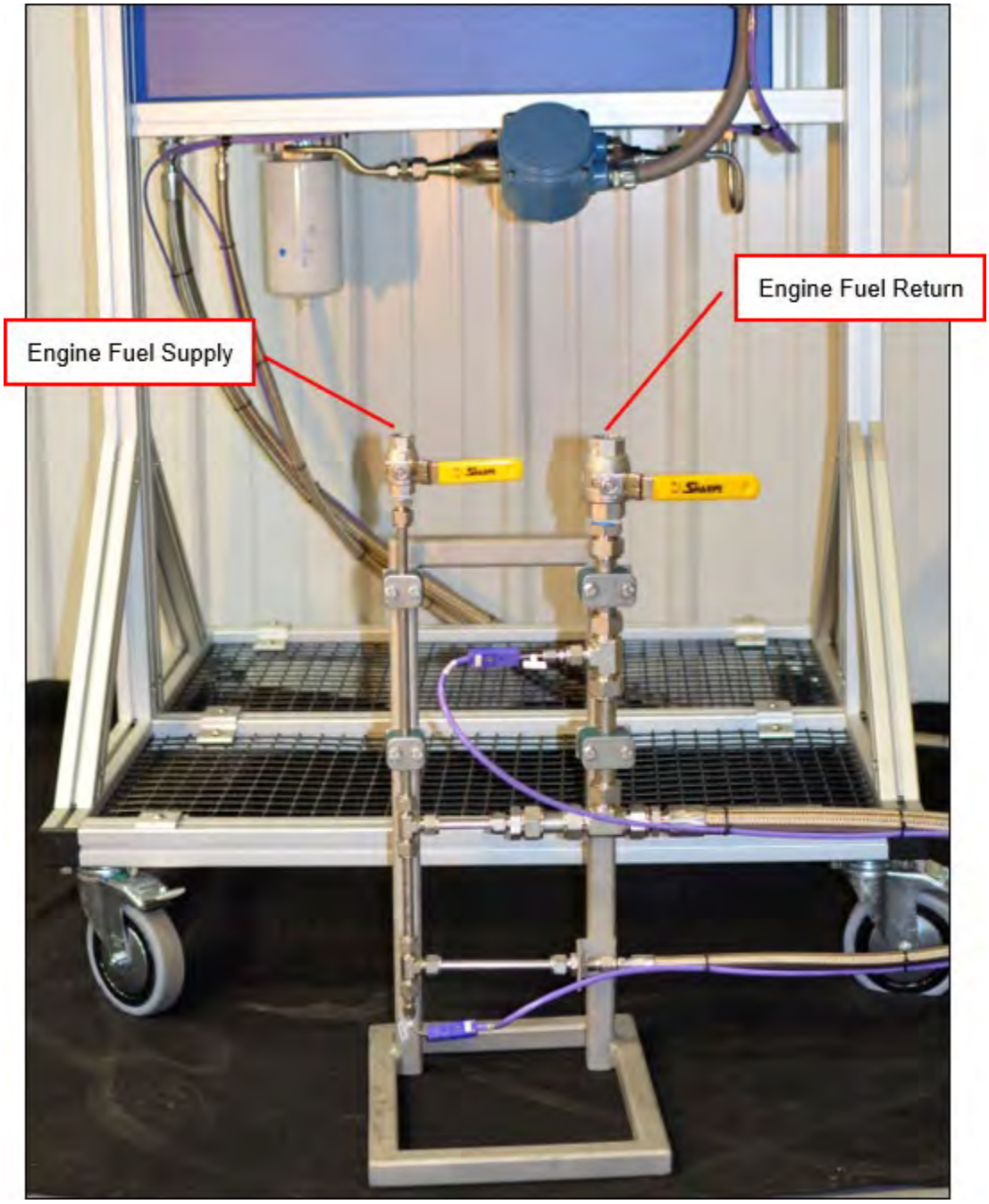
Figure 9: Fuel Flow Measurement and Fuel Conditioning Components



Connect the engine fuel supply and return lines at the CFS stand provided with the CFS.

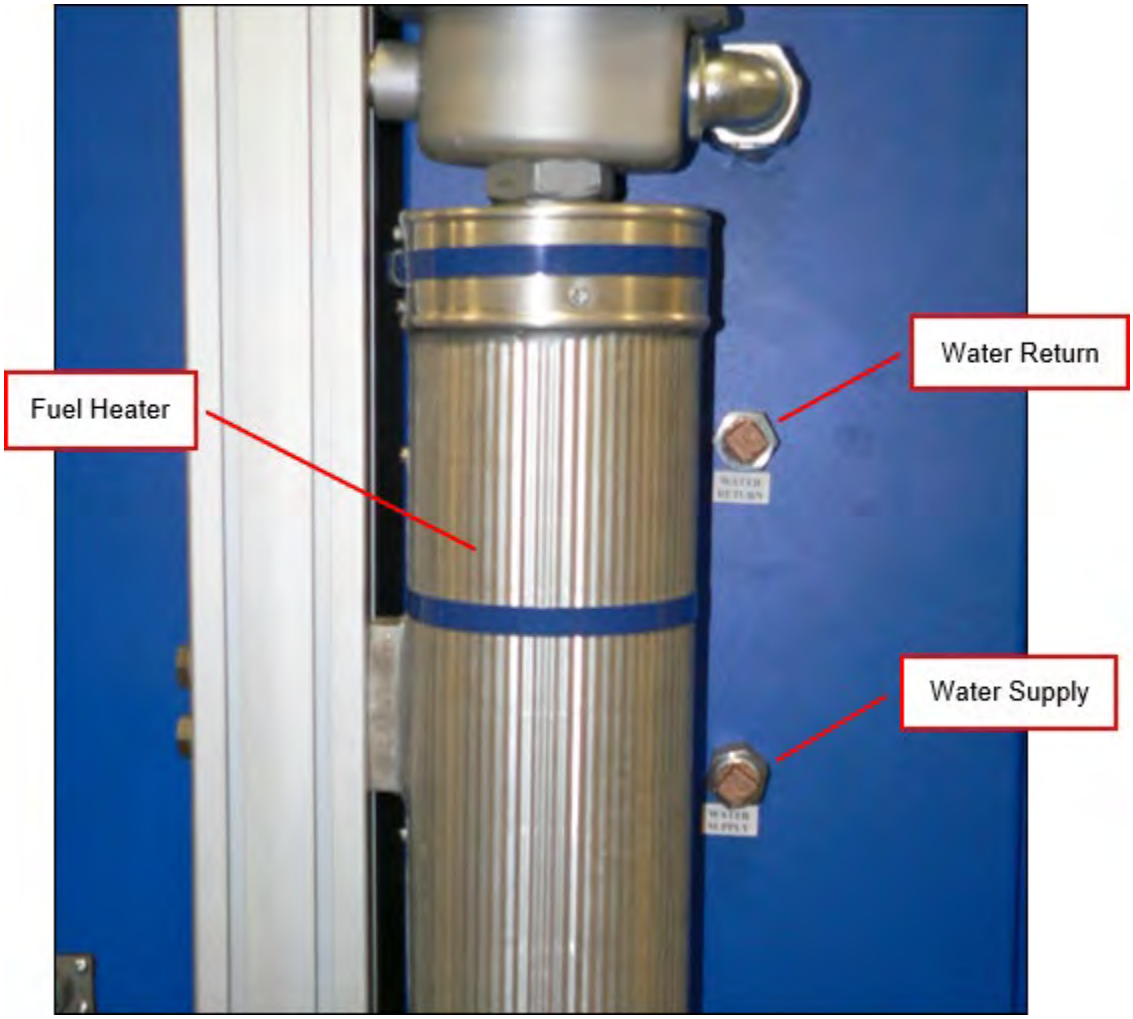
Place the CFS stand as close to the engine fuel inlet and return fittings as is practical (typically on the floor close to the engine); so that the interconnecting fuel lines are as short as practical for the best engine fuel inlet temperature control.

Figure 10: Fuel Supply and Fuel Return Assembly



Mount the fuel heater to the frame of the mobile CFS next to the water supply and return fittings as in *Figure 11*:

Figure 11: Mounted Fuel Heater

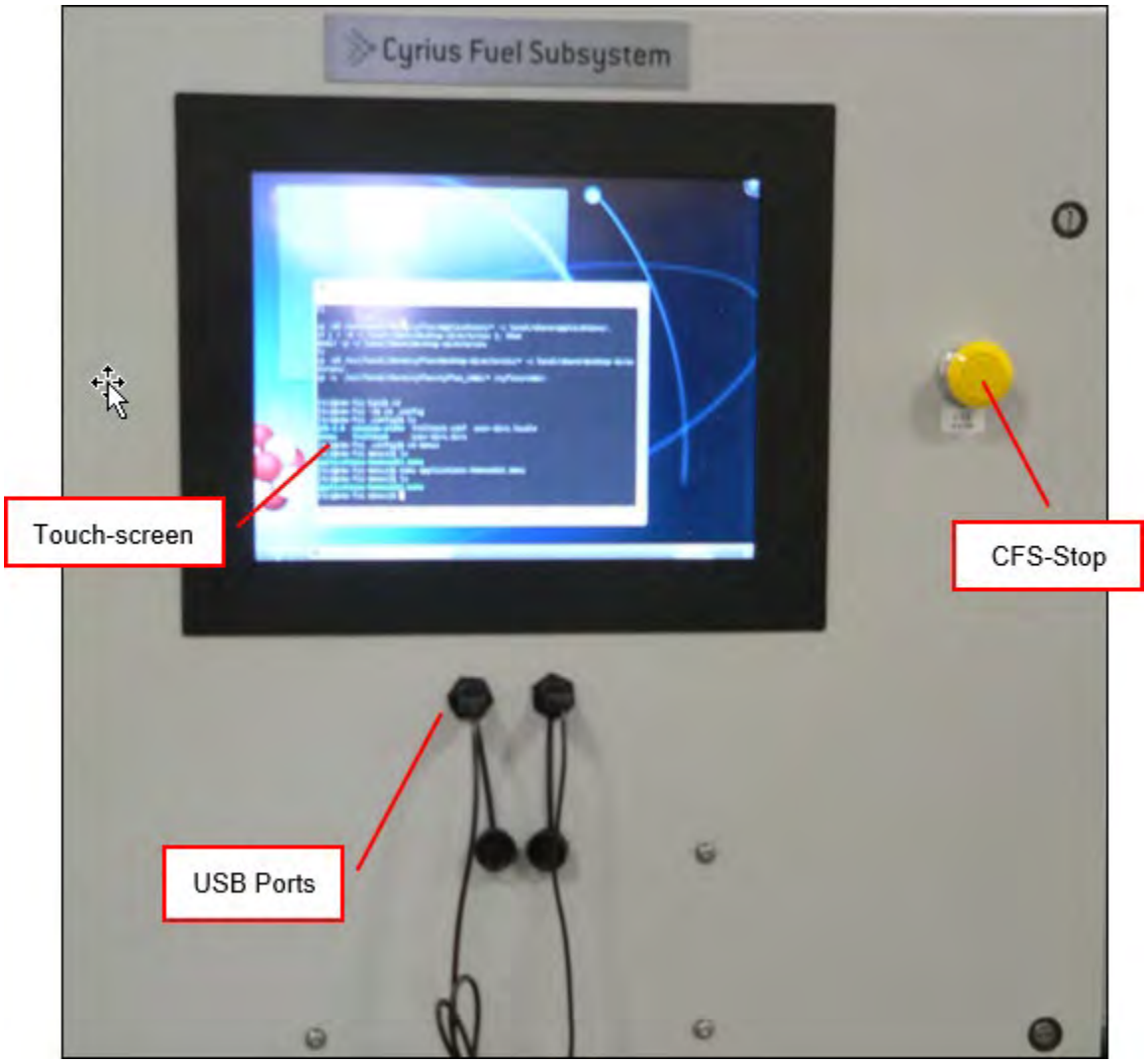


4.3 Operator Controls

Operator controls include:

- Touch-screen (Human-Machine Interface)
- CyFlex® (pre-installed system automation software)
- CFS-Stop
- Universal Serial Bus (USB) Ports
- Mouse and keyboard

Figure 12: Operator Touch Screen, CFS Stop Button, USB Ports Location



A user supplied mouse and keyboard may be connected to the USB ports for navigating screens.

5 Powering On and Monitoring the CFS

5.1 Powering On the CFS

Execute the following steps to power-on the CFS:

1. Check all mechanical connections.
2. Ensure all of the circuit breakers inside of the CFS I/O cabinet are turned OFF.
3. Plug the two power cords into the CFS.
4. Plug the power cords into two 120 VAC outlets of sufficient amperage capacity (20 A each, minimum).
5. Turn on the two UPS power circuit breakers by flipping the switches upward. Refer to *Figure 5* on page 9.
6. Turn on the UPS by pressing the button on its front. A yellow light illuminates followed by a green light. If the green light does not come on, the UPS has failed or there is a problem with incoming power.
7. Switch on (in any order) the other five circuit breakers located in the bottom rack of the cabinet. Refer to *Figure 5* on page 9.
8. Switch on the two circuit breakers located in the top rack. Refer to *Figure 4* on page 8.
9. Press the power button on the bottom of the CFS onboard computer to switch it on.

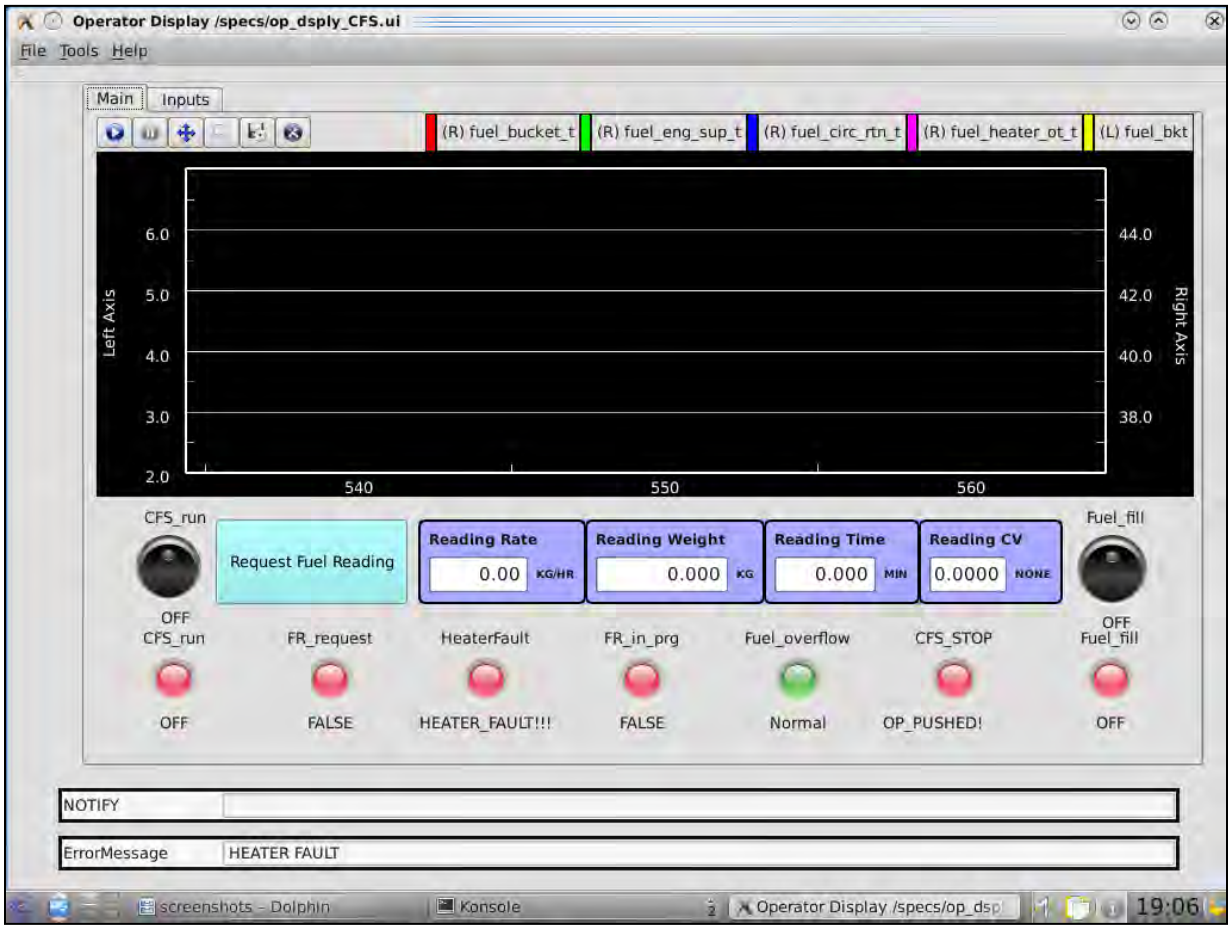
   The AK server program automatically runs after the operating system boots, The desktop appears briefly followed by the operator display as in *Figure 13*..

Note:

After powering off the CFS, the CFS may thereafter be powered on using only the UPS power circuit breakers. Refer to the following:

- *Figure* 5 on page 9
- *Section 14 Powering Off the CFS* on page 48

Figure 13: Start-up Operator Display



Navigate the screen using the touch-screen, or a mouse and keyboard connected to the cabinet's USB ports. Refer to *Figure 12* on page 16 for the USB ports location.

Note:

The operator display may be started from the desktop using the **Launch Operator Display** icon, or the bottom menu bar.

5.2 Monitoring the UPS Power Level

The CFS monitors the power level of the UPS. This allows the CFS to systematically shut down if the UPS power level drops below about 30%.

UPS monitoring is disabled any time the UPS is turned off, including an automatic system shutdown in the event of an extended power outage.

If the UPS was off, execute the following steps to reactivate UPS monitoring:

1. Power on the CFS.
2. Once the computer is fully powered on (the desktop appears), unplug the USB cable at the computer; refer to *Figure 7* on page 11. The cable that goes to the UPS is labeled.

Important:

The cable terminates at the UPS in a serial connection, which should not be removed.

3. Leave the USB cable unplugged for at least 5 seconds and then plug it in again.
4. At the computer desktop, launch the **Restart UPS Monitoring** (icon).

Note:

Ignore error messages for failed parameters.

6 The Client Computer

The test cell computer acts as the client and controls the CFS (server/slave) using AK protocol commands. Refer to *Section 13 AK Protocol* on page 39.

1. If not already on, switch on the client computer.
2. Typically, users add the client program to a startup script for automatically launching the program at startup. Otherwise, start the client program.
3. Operate the CFS from the test cell.

Note:

If it is necessary to change the IP address of the CFS (for example, if the customer did not specify an IP address when ordering the system), configure the address as described in *Section 7 Changing the IP Address* on page 21.

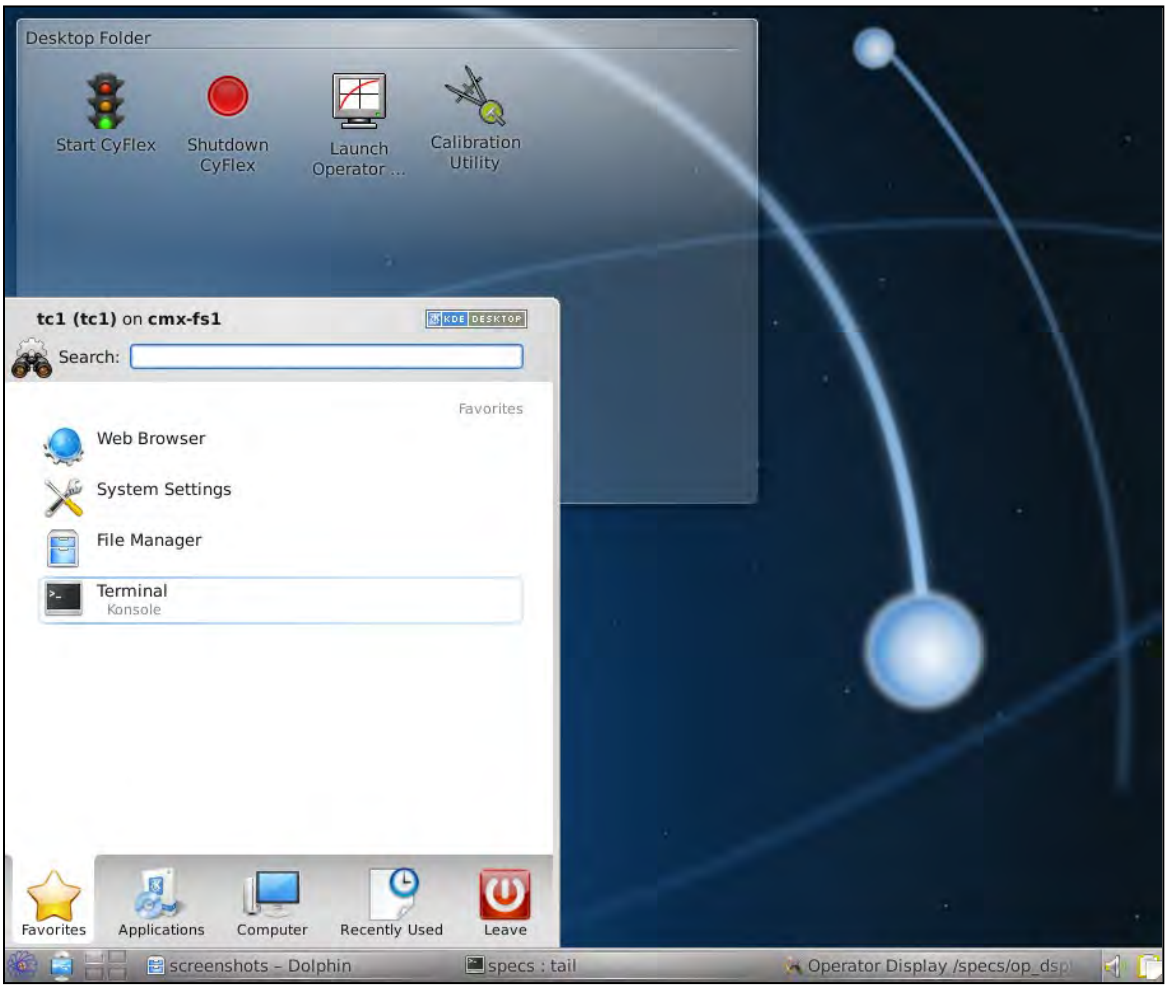
7 Changing the IP Address

If it is necessary to change the IP address of the CFS (server/slave), work with your network administrator or another person familiar with setting up device connections on your network.

Execute the following steps:

1. Connect a keyboard (and mouse if preferred) to the USB port(s) on the CFS.
2. Open a terminal shell window as in *Figure 14*.

Figure 14: Terminal Shell



3. Enter the following at the command line to launch the `system-config-network` utility.

   ```
   $ sudo system-config-network
   ```

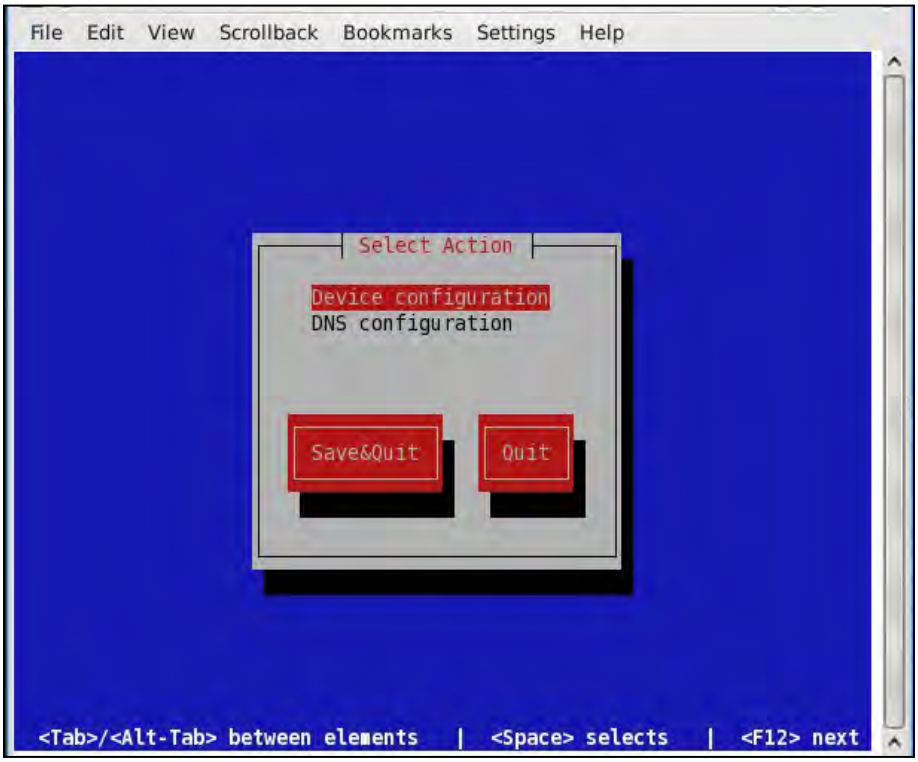
Figure 15: Launch system-config-network

4. Enter the password as prompted. The password is `celluser`.

Figure 16: system-config-network Password Prompt

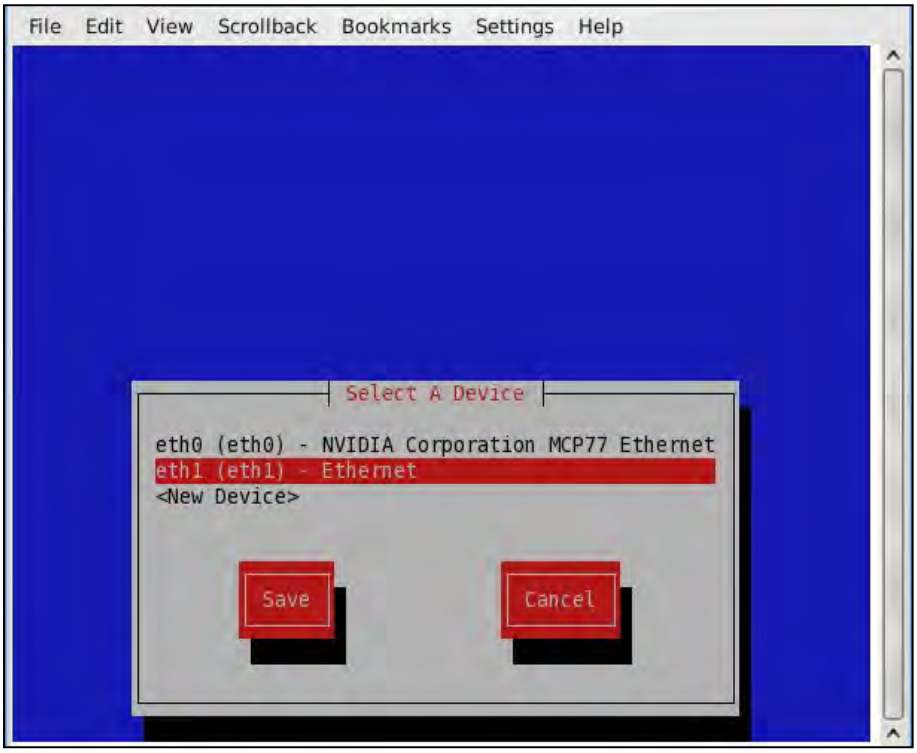
5. Select **Device Configuration** as in *Figure 17*.

Figure 17: Device Configuration Action



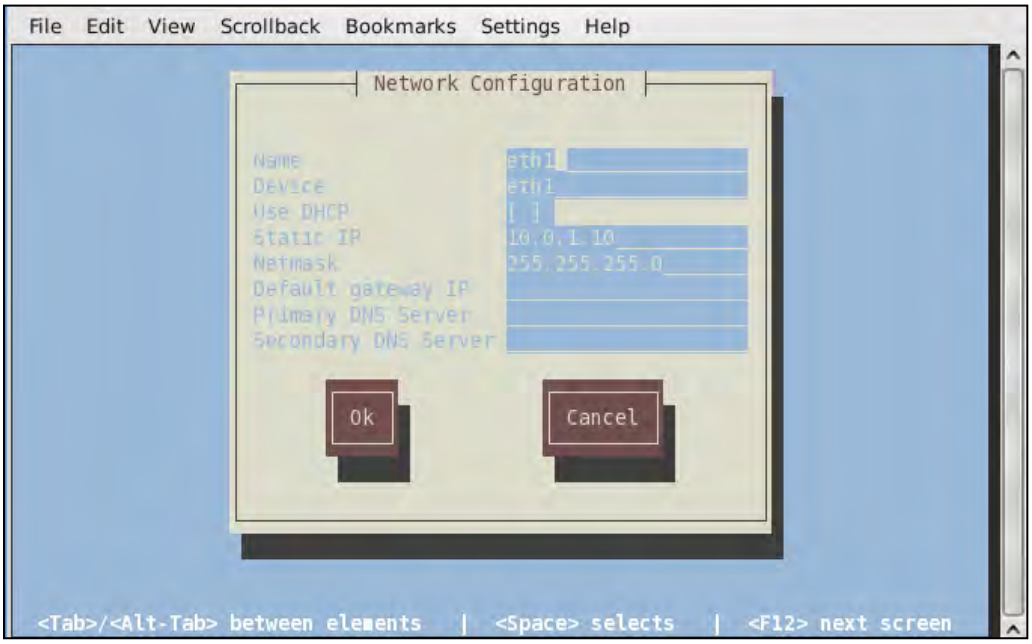
6. Select the **eth1** device as in *Figure 18*.

Figure 18: Select a Device



7. Complete the fields on the resulting **Network Configuration** screen.

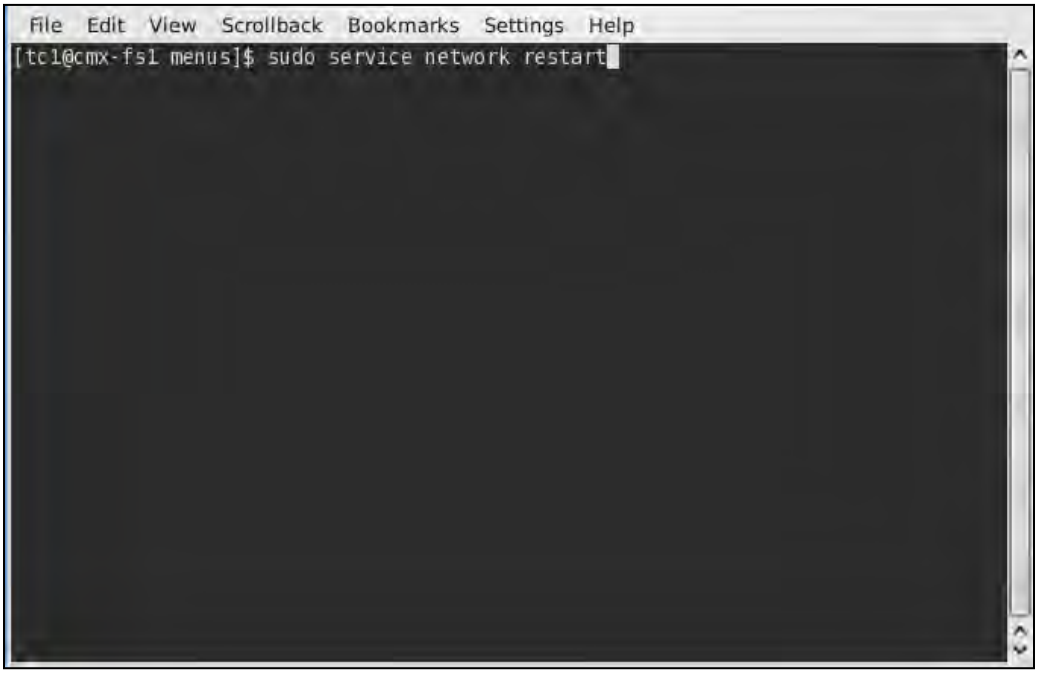
Figure 19: Network Configuration Settings



8. Select **ok** to save changes.
9. Enter the following at the command line to restart the CFS network or computer:

```
$ sudo service network restart
```

Figure 20: Network Restart Command

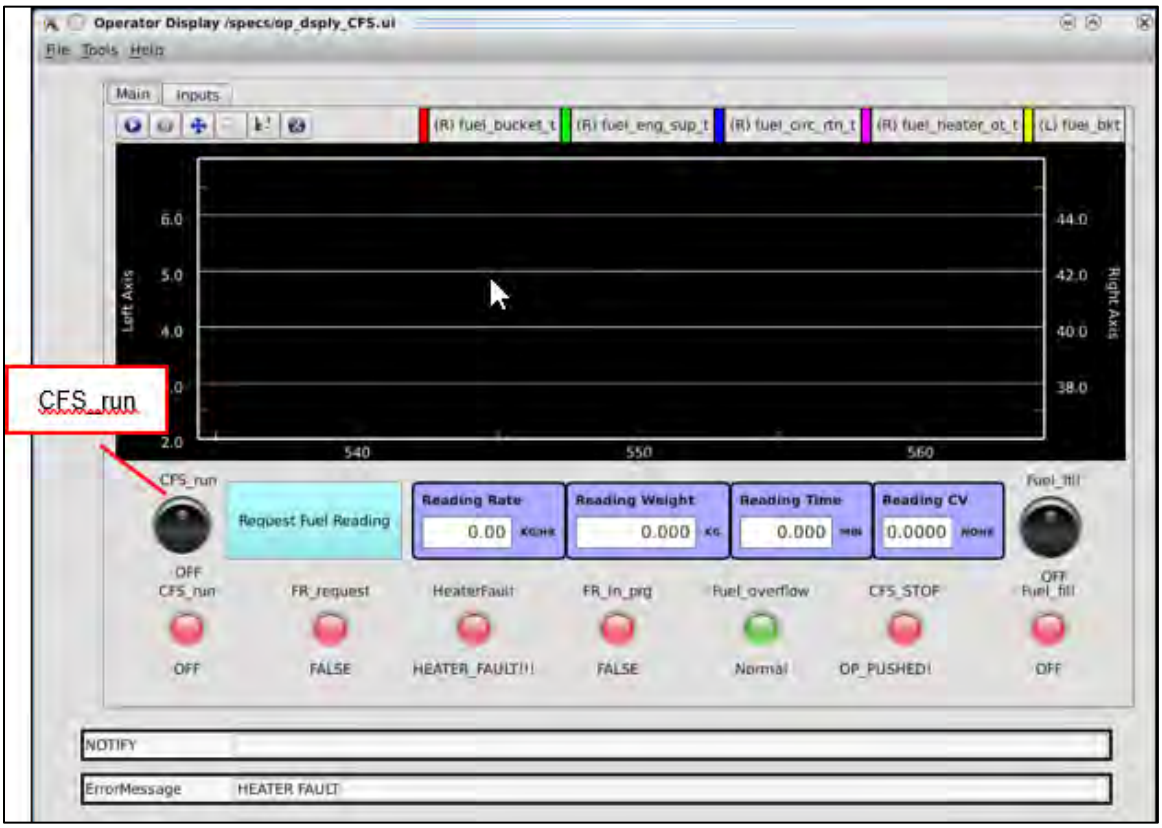


8 Calibrating the Load Cell

The load cell is an electronic weighing system and requires periodic calibration. The American Society for Testing and Materials (ASTM) recommends calibrating load cells annually "or more often… where heavy usage or possible damage has occurred." Follow this practice and calibrate the CFS if moved to another cell.

1. Connect a keyboard and mouse to the cabinet's USB ports.
2. From the operator display, select the **Main** tab.
3. Make sure the CFS is not running. The **CFS_run** button on the display should be **OFF**.
4. If the **CFS_run** button is **ON**, press the button to turn it **OFF** as in *Figure 21*.

Figure 21: Operator Display CFS-run OFF

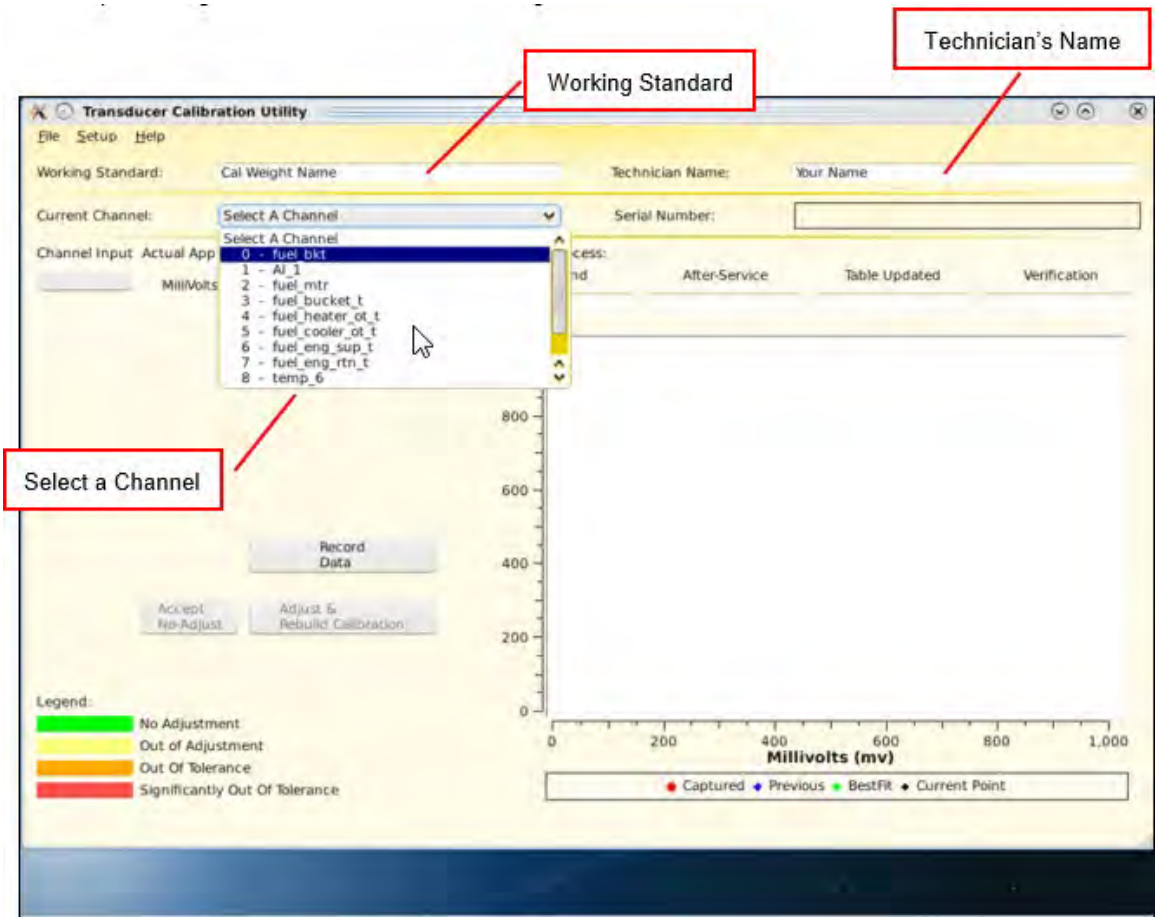


5. Close the engine fuel supply and engine return ball valves.
6. Remove the fuel bucket from the load cell.

   Caution: Avoid exerting excess compressive or tensile force on the load cell to prevent permanent damage.
7. Remove all fuel from the fuel bucket.
8. Clean the bucket with a paper towel or microfiber cloth.
9. Re-hang the bucket from the load cell.
10. Exit or minimize the operator display.

11. From the desktop window, double-click the **Calibration Utility** icon.
12. On the resulting **Transducer Calibration Utility** window, enter the **Technician Name** of the technician performing the calibration and the **Working Standard** as in *Figure 22*.

Figure 22: Working Standard and Technician Name



Notes:

The **Working Standard** is a name or number used to track calibration weights. Typically, the facility has a list of working standards for calibration weights. If calibration was done previously, the screen displays the prior used value.

13. Click on the **Select A Channel** drop-down menu and select **0 – fuel_bkt** as in *Figure 22.*

14. As in *Figure 23*, suspend the hanger on the fuel bucket which has an attachment point on its base.

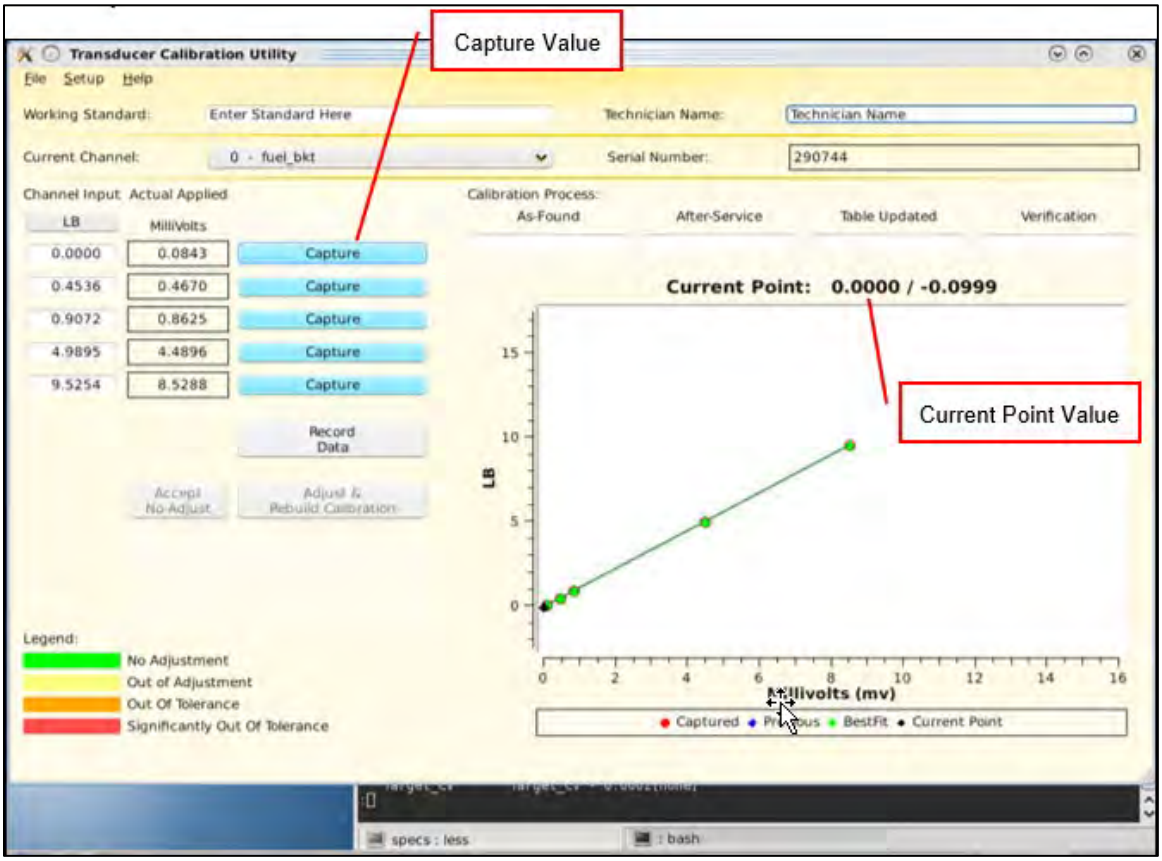
Note:

The hanger weighs 1 pound.

Figure 23: Fuel Bucket Hanger

15. Once the value for the bucket stabilizes, click the **Capture** button located to the right of the **1.0001 LB** value as in *Figure 24*.

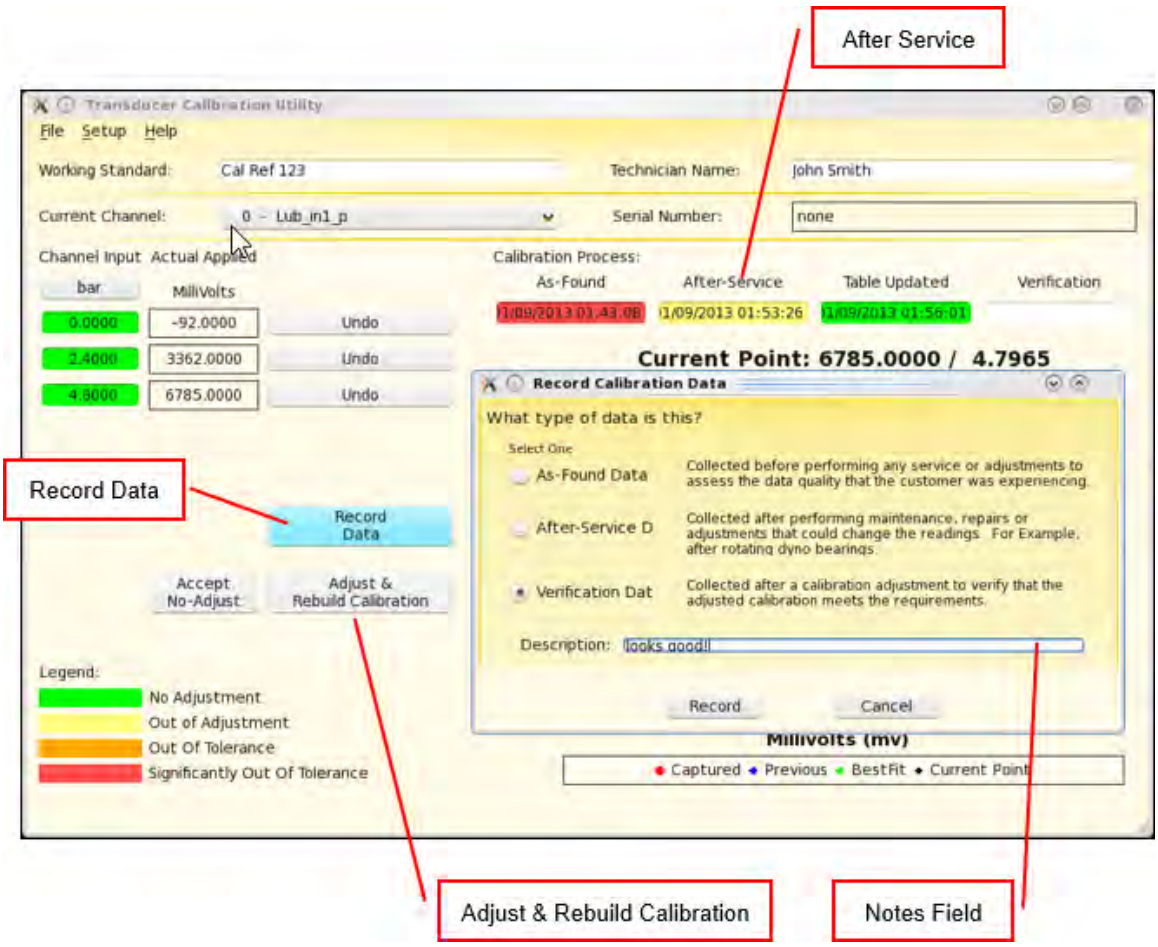
Figure 24: Capture Selection



16. Attach (1) 5 lb. weight to the hanger.
17. When the value next to Current Point stabilizes, click on the Capture button next to the value that corresponds to 6.0007 lbs.
18. Remove the weights from the hanger.
19. Place (1) 10 lb. weight on the hanger.
20. Once the current value stabilizes, capture this point as 11.011 pounds by clicking on Capture.
21. Remove the weights from the hanger.
22. Place (1) 10 lb. weight on the hanger and (1) 5 lb. weight on the 10 lb. weight.
23. Capture this point as 16.0017 pounds.
24. Remove the weights from the hanger.
25. Hang (1) 10 lb. weight, (1) 5 lb. weight and (1) 2 lb. on the hanger.
26. Capture this point as 18.0020 pounds.
27. Click the **Record Data** button.

28. Select **After Service** as in *Figure 25*.

Figure 25: Add a Service



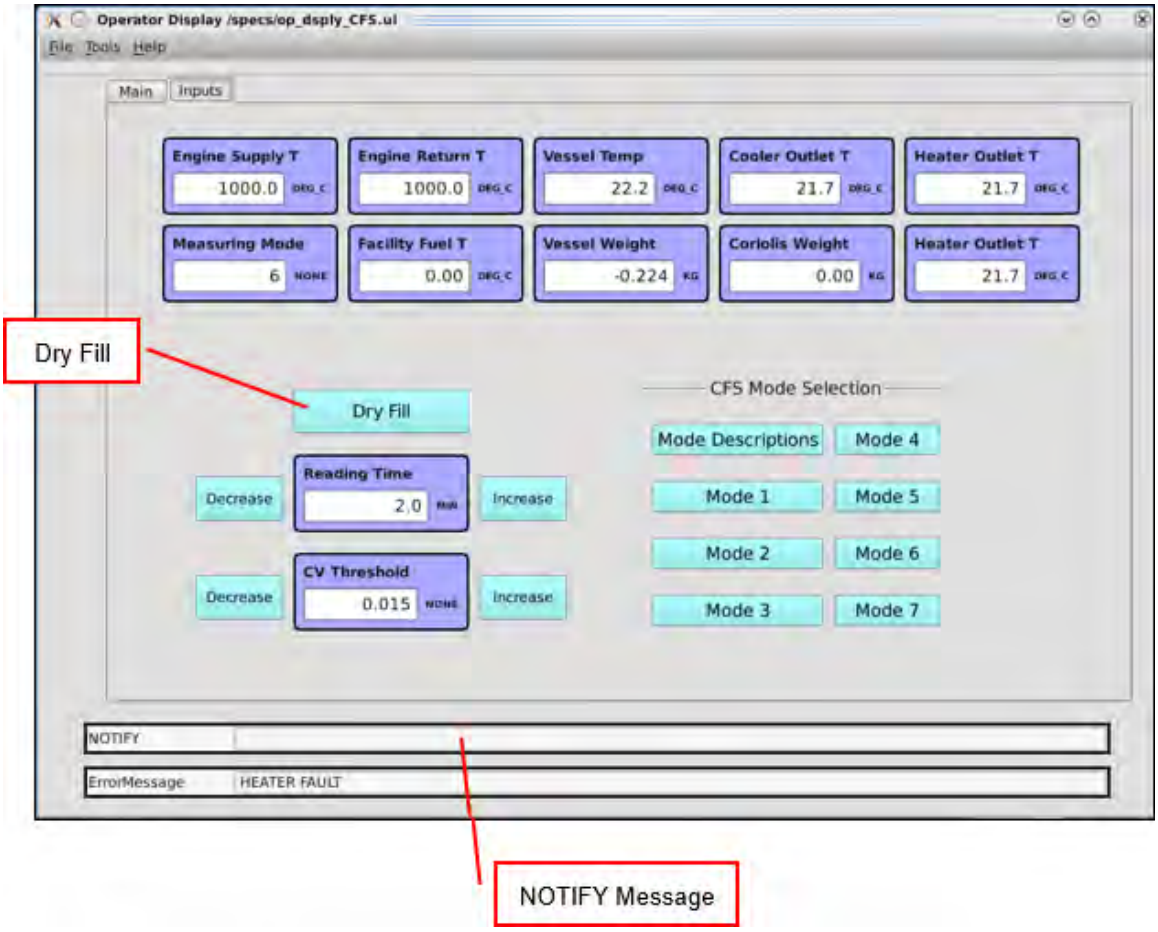
29. Enter any notes into the **Description** field as in *Figure 25.*
30. When finished, click the **Record Data** button as in *Figure 25.*
31. Click the **Adjust & Rebuild Calibration** button as in *Figure 25*.
32. Close the calibration utility.

9 Filling the Fuel Bucket

Execute the following steps to fill the fuel bucket when it is dry:

1. Make sure the CFS-stop is not depressed (not activated).
2. Confirm that a pressurized fuel supply line is connected to the CFS.
3. From the operator display, select the **Inputs** tab as in *Figure 26*.

Figure 26: Inputs Tab Selection



4. Click **Dry Fill** as in *Figure 26.*

   The **NOTIFY** message at the bottom of the display should state **Bucket filling!** The fuel bucket fills to the specified value. The default weight limit is 6.2 kg. Refer to *Section 15.3* NOTIFY Messages *on page 50.*

   When the fuel bucket finishes filling, the **NOTIFY** message changes to **Bucket has filled. CFS ready to start**. Refer to *Section 10 Running the CFS* on page 31.

10 Running the CFS

Before starting the CFS, fill the fuel bucket as described in *Section 9 Filling the Fuel Bucket* on page 30.

Execute the following steps to start the fuel pump and begin heating the fuel:

1. Open the **Main** tab on the operator display.
2. Press the **CFS_run** button on the display. This turns on the pump and begins heating the fuel to its temperature set point (40 deg C).

Note:

The fuel over-temperature relay monitors the temperature of the heating elements, not the fuel itself. Avoid requesting a fuel supply temperature that will cause the fuel in the open vessel to exceed 122 deg F / 50 deg C.

Recommendation: Change the fuel filter every 250-500 hours of normal use depending on the facility supply fuel cleanness.

11 Operating Modes

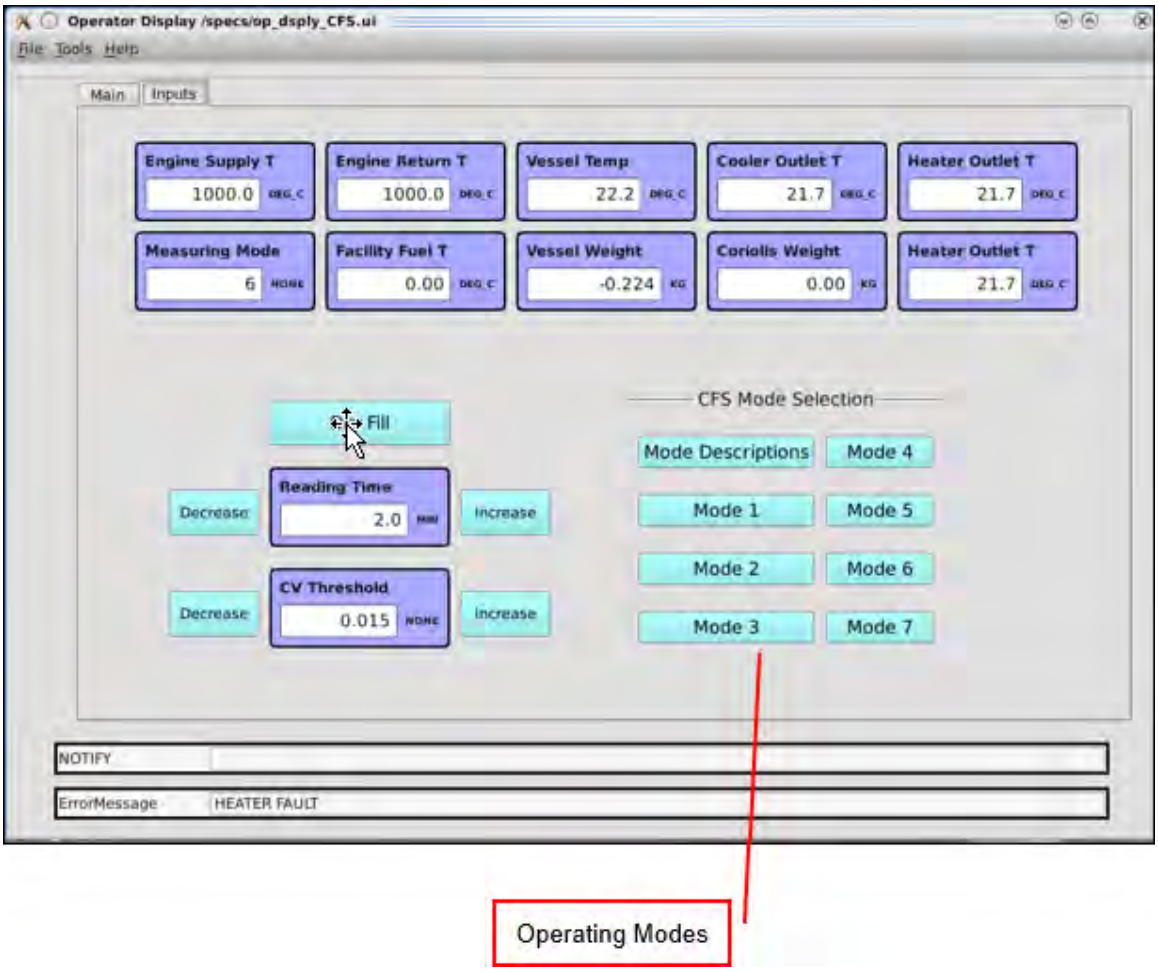
This section describes CFS user-selectable operating modes.

11.1 Setting the Operating Mode

Execute the following steps to set the operating mode of the fuel measurement subsystem:

1. From the operator display, open the **Inputs** tab as in *Figure 27*.
2. Determine which operating mode to use, based on the mode descriptions displayed by pressing the **Mode Descriptions** button.
3. Press the appropriate operating mode button as in *Figure 27*.

Figure 27: Operating Modes



11.2 Operating Mode Descriptions

Table 2 describes the operating modes.

Table 2: Operating Mode Descriptions

Mode	Description	Control of Fuel Bucket Weight		Fuel Measurement Method
		No Fuel Reading In Progress	Fuel Reading In Progress	
1	Default mode – a fuel reading cannot be taken.	Maintains constant weight using proportional valve	Proportional valve maintains constant vessel weight	N/A
2	Gravimetric timed fuel reading – a solenoid valve maintains vessel weight when no reading is taking place.	Keeps vessel mostly full by toggling a solenoid valve on and off	Fill valve is closed and fuel vessel empties during a fuel reading	Gravimetric with load cell
3	Continuous fuel readings with external events used to start (SINT command in AK communications) and stop (SMIS command) a fuel measurement over an arbitrary length of time. This mode is recommended for transient tests.	Proportional valve maintains constant vessel weight	Proportional valve maintains constant vessel weight	This is a continuous fuel reading using the Coriolis meter as the primary measurement device. Adjustments are made for fluctuations in vessel weight using the load cell.
4	Gravimetric timed fuel readings – a proportional valve maintains vessel weight when no reading is in progress.	Proportional valve maintains constant vessel weight	Fill valve is closed and vessel empties during a fuel reading	Gravimetric with load cell

Mode	Description	Control of Fuel Bucket Weight		Fuel Measurement Method
		No Fuel Reading In Progress	Fuel Reading In Progress	
5	Continuous timed fuel readings – this mode is recommended for timed readings during transient tests.	Proportional valve maintains constant vessel weight	Proportional valve maintains constant vessel weight	This is a continuous fuel reading using the Coriolis meter as the primary measurement device. Adjustments are made for fluctuations in vessel weight using the load cell.
6	This mode uses continuous timed fuel readings at higher fuel consumption rates, and gravimetric timed fuel readings at lower fuel consumption rates. This mode is recommended for all steady state fuel readings because it selects the most accurate measurement method given the fuel consumption rate at the beginning of the reading.	Proportional valve maintains constant vessel weight	If the fuel rate is above the Coriolis meter's accuracy cutoff point when the reading is requested, a proportional valve maintains a constant vessel weight. If the fuel rate is below the Coriolis meter's accuracy cutoff point when the reading is requested, a fill valve is closed and the vessel empties during the fuel reading.	If the fuel rate is above the Coriolis meter's accuracy cutoff point when the reading is requested, this mode uses continuous fuel readings with the Coriolis meter as the primary measurement device. If the fuel rate is below the Coriolis meter's accuracy cutoff point when the reading is requested, this mode uses a gravimetric fuel reading with the load cell as the only measurement device.

Mode	Description	Control of Fuel Bucket Weight		Fuel Measurement Method
		No Fuel Reading In Progress	Fuel Reading In Progress	
7	This mode uses continuous fuel readings at higher consumption rates, and gravimetric timed fuel readings at lower consumption rates. The coefficient of variation (CV) is continuously updated and the reading terminated when the CV value goes below a user-specified target (ECVT command in AK communications). If the CV fails to fall below this value and the minimum weight limit is reached or a specified maximum time limit is reached (EMXT command in AK communications), the reading is terminated.	Proportional valve maintains constant vessel weight	Same as for mode 6	Same as for mode 6

12 Setting the Fuel Measurement Variables

Fuel measurement variables must be set before taking a reading. Once configured for a specific test, the variable values do not require setting again for subsequent, identical tests.

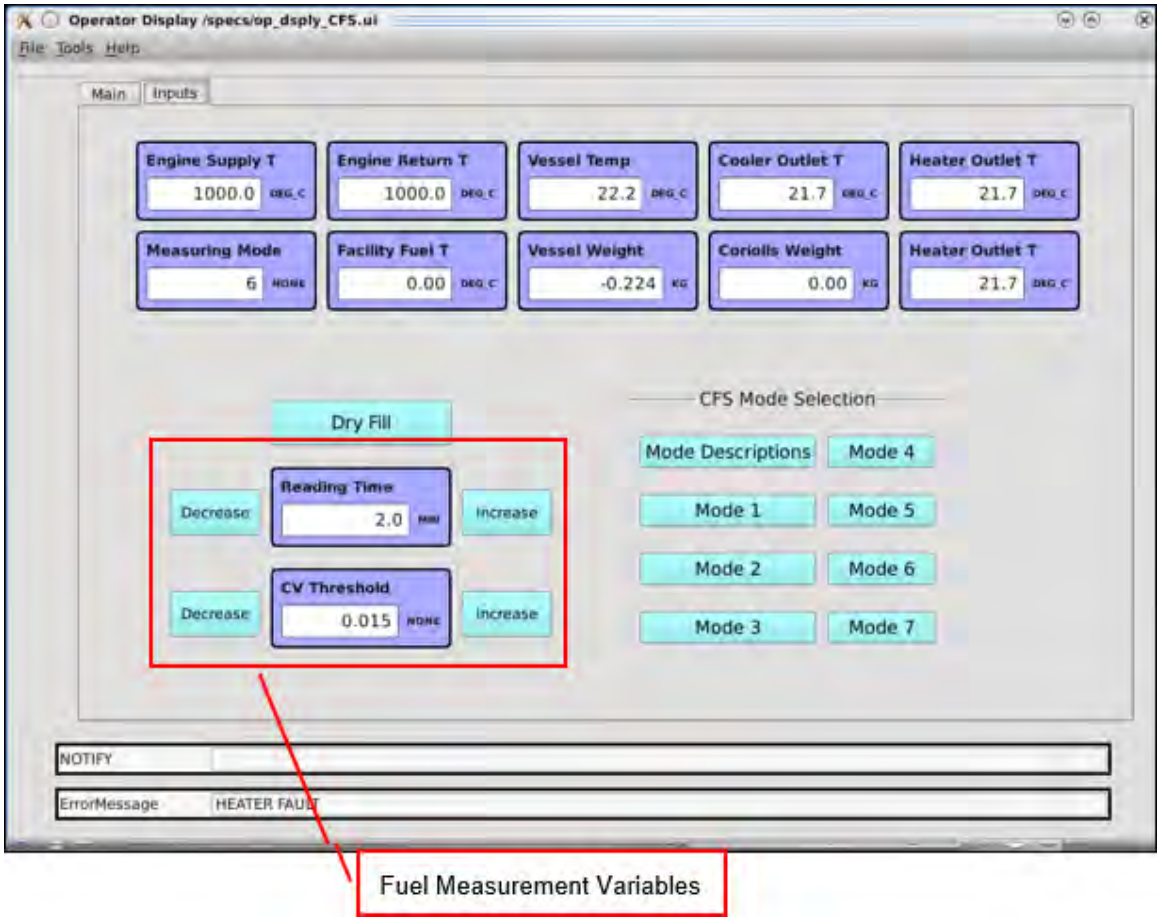
The following variables are user-adjustable at the operator display:

- **Fuel Reading Time**
- **CV Threshold**
- **Maximum Fuel Rate**

Execute the following steps to set fuel measurement variables:

1. From the operator display, click the **Inputs** tab. The values of variables may be changed and saved using the buttons shown in *Figure 28*.

Figure 28: Fuel Measurement Variables



2. Select the **Increase** and **Decrease** buttons to change the variable values as in shown in *Figure 28*.

Refer to *CyFlex Variables, Units, Computed Expressions* for more about variable types.

Table 3 lists Fuel measurement variables used in the CFS.

Table 3: CFS Fuel Measurement Variables

Variable Name	Type	Description
`CFS_run`	Logical	CFS on or off
`CFS_STOP`	Logical	CFS-Stop button depressed (circuit opens) This message also occurs if the CFS-Stop is connected to test cell E-stop dry contacts that open.
`Cooler Outlet T`	Real	Temperature of fuel after passing through the heat exchanger If both fuel and water are going through the heat exchanger and fuel is not cooled enough, check whether the water strainer is clogged.
`Coriolis Weight`	Real	Indicates how much fuel has flowed through the Coriolis meter Note: Value resets upon restarting the CFS per the default configuration
`CV Threshold`	Real	Coefficient of variation (CV) threshold
`Engine Return T (fuel_eng_rtn_t)`	Real	Temperature of fuel returning from the engine
`Engine Supply T (fuel_eng_sup_t)`	Real	Temperature of fuel supplied to the engine
`Facility Fuel T`	Real	Temperature of fuel entering the CFS
`FR_in_prg`	Logical	Fuel reading in progress or not “TRUE” = in progress “FALSE” = not in progress
`FR_request`	Logical	Fuel reading requested or not Once a fuel reading is requested and all stabilization requirements are met, a fuel reading begins. `FR_in_prg` changes to `TRUE` and `FR_request` changes to `FALSE`.
`fuel_circ_rtn_t`	Real	Temperature of the fuel in the circulation loop returning from the CFS stand to the bucket
`Fuel_fill`	Logical	State of solenoid valve for fuel supply to bucket – on/off solenoid valve open (`FILLING`) or closed (`OFF`)
`Fuel_overflow`	Logical	State of fuel bucket safety float switch – normal or overflow
`Heater Outlet T (fuel_heater_ot_t)`	Real	Temperature of fuel after it leaves the heater
`HeaterFault`	Logical	Status of heater temperature – switch is in normal state (`Normal`) or fault state (`HEATER_FAULT!!!`)

Variable Name	Type	Description
Measuring Mode	Integer	Current CFS operating mode
NOTIFY	String	Text message located at the bottom of the screen, notifying the user about the system or a fuel measurement.
Reading CV	Real	Actual coefficient of variation (CV) The CFS takes regular samples from the Coriolis meter, and adjusts the values with changes in the weight of the fuel bucket. While the Coriolis meter is relatively free from noise, vibrations may be present in the test cell – passing those to the load cell, while it is measuring the weight of the fuel bucket. Over time, these variations tend to average, so that a longer reading becomes more accurate than a shorter reading. If a fixed length of time is used for the fuel reading, it must be long enough to sufficiently deal with vibrations from the test cell. An optional operating mode allows a reading to continue until a “quality” measurement is achieved. This allows shorter readings when vibrations are minimal and longer ones when they impact the measurement. In this optional mode, the fuel rate is calculated each time a sample is taken. When the coefficient of variation (CV) of these samples goes below the user-selected threshold, the reading is terminated. The coefficient of variation is the standard deviation of fuel measurement samples divided by the mean value. Basically, it shows the extent of variability in relation to the average reading. When using this mode, a maximum time value is set also, so the reading doesn’t go on indefinitely.
Reading Rate	Real	The fuel rate of the previous fuel reading
Reading Time	Real	Time elapsed during the previous fuel reading
Reading Weight	Real	Fuel weight (mass) used in the previous fuel reading
Vessel Temp (fuel_bucket_t)	Real	Temperature of fuel coming from the bucket while the CFS is on Note: The thermocouple measuring this temperature is not located inside of the bucket and represents the temperature inside of the bucket only when the pump is running.
Vessel Weight (fuel_bkt)	Real	Weight of the fuel in the bucket

13 AK Protocol

The CFS installation includes AK server program and specification files ready for communication using the AK protocol. The customer provides the client program which resides on the test cell PC and is required to communicate with the AK server program on the CFS.

13.1 Protocol Frame

All messages and data are transferred in ASCII format. Command and acknowledge messages are defined as four-digit function codes, as shown in the following tables.

The CFS responds to each command with an acknowledge message.

The first characters of the command message must be <STX> so the CFS can recognize the command as AK protocol. If the first characters are not <STX>, the CFS cannot interpret the command as AK and ignores it.

The rest of the message following the <STX > prefix depends on the command type as described below.

13.1.1 Special Definitions

- Channel information in the command message may be omitted.
- The don't care byte is not evaluated.

13.1.2 Command Messages

13.1.2.1 *Command Messages - Functions*

Table 4: Command Messages - Functions

Byte	Function	
1	<STX>	
2	Don’t care byte (ignored)	
3 … 6	Function codes: SXXX … Action commands EXXX … Setting commands AXXX … Inquiry commands	
7	Blank	Channel information may be omitted
8	K (identification of channel number)	
9	0 (channel number)	
10	Blank (only if followed by a variable data block)	
11 … n1	Variable data block (only for setting commands)	
n	<ETX> (end of command)	

13.1.2.2 *Command Messages – Other Parameters*

- Variable data block – possible data formats:
  - Identification of device:
    - Freely definable ASCII-string (max. of 80 characters)
  - Numeric values:
    - Floating-point format of variable length
    - For integer numbers, the decimal point can be omitted
    - Only negative numbers can include a sign (-) to identify it as negative or positive
- Blanks must be used to separate individual data

13.1.3 Acknowledge Messages

13.1.3.1 *Acknowledge Messages - Functions*

Table 5: Acknowledge Messages - Functions

Byte	Function
1	<STX>
2	Don't care byte (ignored)
3 … 6	Function codes: SXXX … Action commands EXXX … Setting commands AXXX … Inquiry commands
7	Blank
8	Error status: 0 (no error)
9	Blank (only if followed by a variable data block)
10 … n-1	Variable data block (depending on the function code)
n	<ETX> (end of acknowledgement)

13.1.3.2 *Acknowledge Messages – Other Parameters*

- Error status
  - If the operation of the CFS is trouble-free (no error messages), the error status equals zero.
- If a received command message does not start with <STX> or if the function code is unknown, the following occur:
  - The don't care byte is set to blank
  - The function code is replaced by "????"
  - The variable data block is omitted from the acknowledge message
- Acknowledgement of action commands:
  - If the action command is accepted, the variable data block is omitted

    - All action commands are executed and may overwrite a previous command.
- Acknowledgement of inquiry commands:
    - Requested data is transferred in a variable data block
    - Multiple values are separated by blanks
- Possible data formats:
    - Identification of device
        - Freely defined ASCII-string (max. 80 characters)
    - Numeric values:
        - Floating-point format of variable length
        - For integer numbers, the decimal point can be omitted
        - The sign is only indicated before negative numbers
- Acknowledgement of setting commands:
    - If the setting command is accepted, the variable data block is omitted

13.2 Command Types

Table 6 lists the four-digit function command codes.

Table 6: Command Function Codes

Command Type	Function Code
Action	1st character: S (example: SMES)
Setting	1st character: E (example: ERFT)
Inquiry	1st character: A (example: AKEN)

13.2.1 Action Commands

Table 7 lists action commands and their corresponding output variable names.

Table 7: Action Commands and Corresponding Output Variable Names

Customer Output Variable Name	AK Command	Comments	Prerequisites
Enable system	SNAB	None	Fuel and water supplies should be turned on to the CFS. The fuel temperature should be allowed to stabilize before starting the engine.
Disable system	SDAB	None	Fuel and water supplies should be turned off when the system is not in use.
Begin reading other than SINT and return immediately	SMES	Aborts current reading	System enabled – uses the previously set mode of operation.

Customer Output Variable Name	AK Command	Comments	Prerequisites
Begin reading other than SINT and return when completed	SMEW	None	System enabled – uses the previously set mode of operation.
Begin start/stop reading – generally used for test cycles	SINT	Starts interval measurement (start/stop measurement)	Mode of operation must be set to 3 Vessel should be allowed to fill prior to this command
End start/stop reading	SMIS	Stops interval measurement	Must follow SINT
Reset system to default state	SRES	Sets the CFS to the same state as it was after start-up	Any time
Measurement mode			
Fuel temperature target			
Settling time (gravimetric modes)			
Low fuel level			
Full fuel level			
Fuel rate switch threshold			
CV threshold			
Cooling feed forward gain			
Heating feed forward gain			
Open fill valve	SAVA	Opens fill valve, unless fuel level is already “full” Interrupts or aborts all measurements in progress	The vessel must be below the full level.
Close fill valve	SAVZ	Closes the fill valve	The engine should not be running.
Reset total fuel used	SZRO	This can be done at any time.	None

Customer Output Variable Name	AK Command	Comments	Prerequisites
Fill the deaeration vessel	SFIL	Fills the vessel to the full weight	The fuel supply to the system must be turned on.
Restart all CyFlex software	SRST	Perform if the system fails to respond, or if the watchdog has been tripped.	Determine the reason for the system failure and fix any hardware problems.

13.2.2 Setting Commands

Table 8 lists setting commands and their corresponding output variable names.

Table 8: Setting Commands and Corresponding Output Variable Names

Customer Output Variable Name	Value	AK Command	Comments
Reset system fuel total		ERFT	Useful for fuel usage charge back systems
Set fuel supply temperature target		EFST	Default setting: 40 deg C
Supply floating point value in deg C between (cooling water temp. +3 deg C) and 50 deg C			
Select fuel rate measurement mode (1-7) Note: Set the mode of operation enough in advance of a reading, to allow for stabilization in the new mode.		EMOD	Default setting: mode 6
Instantaneous values only with continuous flow	1		Not often used
Timed gravimetric always	2		Not often used
Continuous flow with user start/stop	3		Normally used for long cycles
Continuous flow switching to timed gravimetric for readings	4		Not often used
Timed continuous flow only	5		Best for temperature control
Timed continuous flow readings switching to timed gravimetric readings at low flows	6		Best accuracy at all times with good temperature control and fixed time

Customer Output Variable Name	Value	AK Command	Comments
Continuous flow readings switching to gravimetric readings at low flow with ending based on CV	7		Best overall accuracy with good temperature control. Readings automatically increase in time at low flows.
Not available	8		
Not available	9		
Not available	10		
Length of fuel reading when time based		EFRT	Default setting: 2 minutes
Floating point number in minutes			
CV threshold for mode 7		ECVT	
Floating point number – requires experimentation between 0.001 and 0.05, depending on the level of vibration in the test cell			Default setting: 0.015
Set rate for switching from continuous flow to gravimetric in modes 6 and 7		ERAT	Default setting: 9 kg/hr.
Floating point number in kg			
Set the full weight of the vessel		EFUL	
Floating point number unit of measurement: kg			Default setting: 6.5 kg
Set the low level of the vessel		EMPT	
Floating point number unit of measurement: kg			Default setting: 3.2 kg
Set the stability time after filling		ESST	
Floating point number unit of measurement: seconds			Default setting: 5 s
Set the maximum reading time when end of reading is CV based		EMXT	Defaults to 10 minutes
Floating point number in minutes			
Set the desired filter factor for instantaneous fuel rate.		ESFF	Values from 0.1 to 0.999 for a recursive filter where 0.1 is low filtering and 0.999 is very high
Floating point number with no units			

13.2.3 Inquiry Commands

Inquiry commands are permitted during any mode. Refer to *Table 9* for AK commands and their descriptions.

Table 9: AK Command Descriptions

Command Description	Value	AK Command
Device identification		AKEN
Response: Text containing model/serial number		
State of the system		ASTZ
Response: Integer number with values:		
Ready	0	
Filling	1	
Reading in progress	2	
Fault	3	
System not enabled	4	
Fault code		ASTF
Response: Integer number with values:		
No error	0	
Deaeration vessel overflow	1	
Deaeration vessel too low	2	
Low water supply (strainer plugged or pressure low)	3	
Deaeration vessel too hot	4	
Thermocouple error	5	
Weight cell values not updating	6	
Power Fault	7	
E-Stop	8	
Fuel heater fault	9	
System temperatures		ASTM
Response: Floating point numbers with values for:		
House fuel supply temperature(deg C)		
Fuel temperatures (Diagnostics only)		AFTM
Response: Floating point numbers with values for:		
Engine fuel supply (deg C)		

Command Description	Value	AK Command
Deaeration vessel (deg C)		
Fuel cooler outlet (deg C)		
Fuel heater outlet (deg C)		
Fuel circulation return (deg C)		
Engine fuel return (deg C)		
System weights		ARFW
Response: Floating point numbers with values for:		
Deaeration vessel (kg)		
Total fuel through Coriolis meter (kg)		
Deaeration vessel controls (Diagnostics only)		ABKT
Response: Floating point numbers with values for:		
Target (kg)		
Command (%)		
Integral term (%)		
Proportional term (%)		
Loop error (kg)		
Loop in tolerance		
Fuel cooling controls (Diagnostics only)		ACLR
Response: Floating point numbers with values for:		
Target (deg C)		
Command (%)		
Integral term (%)		
Proportional term (%)		
Feed forward term (%)		
Loop error (deg C)		
Loop in tolerance		
Fuel heating controls (Diagnostics only)		AHTR
Response: Floating point numbers with values for:		
Target (deg C)		
Command (%)		
Integral term (%)		

Command Description	Value	AK Command
Proportional term (%)		
Feed forward term (%)		
Loop error (deg C)		
Loop in tolerance		
Results after SMES complete*		ABEW
Response: Floating point numbers with values:		
Average fuel rate (kg/hr.)		
Actual length of reading (min)		
Actual coefficient of variation (none)		
Fuel weight consumed (kg)		
* Results are available starting 0.1 seconds after SMES, depending on mode.		
Instantaneous fuel rate		AMES
Response: Floating point number (kg/hr.)		
Interval values since last SINT		AIMG
Response: Floating point numbers with values for:		
Elapsed time (min)		
Fuel weight consumed (kg)		
Reading results after start/stop		AERG
Response: Floating point numbers with values for:		
Average fuel rate (kg/hr.)		
Actual length of reading (min)		
Fuel weight consumed (kg)		
Total fuel used since SZRO		ARST
Response: Floating point number in kg		
System watch dog status		ASWD
Response: Integer number with values:		
Watch dog normal	0	
Watchdog not updating	1	

14 Powering Off the CFS

Execute the following steps to shut down the CFS:

1. Exit CyFlex.

   If CyFlex is running, double-click the **Stop CyFlex** icon on the desktop. CyFlex must be shut down before powering off the computer.

2. Shut down the computer.

3. Switch off the two UPS circuit breakers.

   The UPS circuit breakers are located inside of the CFS cabinet as shown in *Section 4.1* Electrical and I/O on page 7.

Important:

Clean the fuel bucket periodically and leave the cabinet door closed to keep out air-borne dirt, etc.

If moving the CFS to a different test cell or changing to a different fuel, first drain the CFS. Accomplish this by turning the hose stand on its side over a suitable container and opening the ball valves to siphon fuel from the bucket and drain the hoses.

15 Troubleshooting

Warning: The CFS has an internal “watchdog” function. This means that if the onboard computer stops working for any reason, the CFS shuts down the pump, heater and fill valve. The CFS stops responding to user commands. As a result, the engine could run out of fuel.

If this happens, immediately shut down the engine following facility procedures, and investigate the problem.

Problems with a setup may result from any of the following:

- Equipment connections or cables/hoses
- Device error or malfunction
- Application or specification file(s)
- Parameter(s) limits exceeded

Refer to the general information below if the setup does not work properly.

15.1 Equipment Connections

Check all connections, cables, and hoses. A connection may be loose, a hose kinked, etc.

15.2 Linux Diagnostics Command

The Linux `strace` command displays information that may help diagnose a problem.

Enter `strace` at the command line.

The command results display activity, such as communication with devices. This is useful for example, if the application calls a file that does not exist or is in the wrong directory.

Specify which information to view by adding arguments added to the `strace` command. For example, using `strace` can display communication between an application and test device (CFS).

This requires knowing the process ID (PID) of the communication program. To determine the process ID, at the command line enter:

```
sin -P AK_slave
```

where AK_`slave` is the communication program

Once the PID is determined, enter the following `strace` arguments

```
strace -eread,write
```

The results show communication read-from / written-to the program

15.3 NOTIFY Messages

The purpose of the NOTIFY message is to inform of system status such as when the fuel bucket is full or a measurement variable entry is out of range. Messages appear in the text field at the bottom of the screen.

Table 10 lists suggested user actions in response to various NOTIFY messages.

Table 10: NOTIFY Messages and Suggested Responses

NOTIFY Message	Reason for Message	Suggested Action(s)
CFS NOT STARTED!! CHECK CFS-STOP AND FUEL LEVEL	Attempt to turn on the CFS when: • Fuel level is too low, and/or • CFS-Stop is depressed	Check that: • Fuel tank is filled, and • CFS-Stop is not depressed Try starting the CFS again.
BUCKET HAS FILLED. CFS READY TO START	Dry Fill button pressed: • Fuel vessel has filled, and • CFS ready to be started	Run the CFS.
HEAT EXCHANGER NOT COOLING. CHECK STRAINER AND WATER FLOW	• CFS is running, and • Fuel is not being adequately cooled coming out of the heat exchanger	Confirm: • At least 35 psi water pressure at the gauge before the heat exchanger • All water valves in the system are open • Temperature of water flowing through system is <=85 deg F If all of the above are true, then: • The water strainer is clogged and not allowing flow, or • The heat exchanger is due for replacement Note: Clean the strainer to verify flow before replacing the heat exchanger.
CFS_STARTED	Cart has successfully turned on	No action required
CFS HAS BEEN SHUT OFF	Cart has successfully shut off	No action required

NOTIFY Message	Reason for Message	Suggested Action(s)
Bucket Filling!!	User requested a dry fill of the vessel and the supply valves are open, allowing fuel to flow into the vessel	No action required
BUCKET FULL OR CFS_STOP PUSHED, NOT FILLING	User requested a dry fill of the vessel and the vessel is already full, or the CFS_STOP button is depressed	Verify: • Vessel is not already filled • Weights not left hanging from the vessel • CFS_STOP button is not depressed
BUCKET HAS FILLED. CFS READY TO START	• User requested a dry fill and the vessel is already full • CFS ready to be started	No action required

15.4 Error Messages

Error messages can help with troubleshooting. *Table 11* lists suggested user actions in response to the messages.

Table 11: Error Messages and Suggested Responses

Error Message	Reason for Message	Suggested Action(s)
VESSEL OVERFLOW	Overflow switch was triggered	Empty some fuel from the bucket.
VESSEL FUEL LOW	Fuel level dropped below minimum fuel level requirement	Fill the vessel manually or using the dry fill procedure in *Section 9 Filling the Fuel Bucket* on page 30..
WATER FLOW IS LOW – CHECK SCREEN	Not enough cooling water is flowing through the heat exchanger for cooling to the desired temperature	Remove the mesh screen strainer and clean it using water or shop air.
VESSEL TOO HOT	Temperature of fuel in the vessel exceeded 50 deg C	• Ensure the strainer is clean. • Make sure the process water supply is within specified tolerance.
THERMOCOUPLE ERROR	A thermocouple is unplugged	Ensure all thermocouples are plugged-in.
WEIGHT VALUES NOT UPDATING	Software in unable to read value from load cell	• Check that the load cell is not damaged. • Make sure the analog power circuit breakers are on.

Error Message	Reason for Message	Suggested Action(s)
POWER FAULT	The UPS detected a drop in the house power supply.	• If the power stays off for more than a few minutes, shut down the computer as described in *Section 14 Powering Off the CFS* on page 48. • When power returns, restart the system following the steps in *Section 5 Powering On and Monitoring the CFS* on page 17. • Enable monitoring as described in *Section 5.2 Monitoring the UPS Power Level* on page 18.
E_STOP	• CFS-Stop button on the CFS front panel is depressed, or • If external emergency stop circuitry at the site is connected to the CFS, a stop is activated	Deactivate the CFS-Stop button or external circuitry, as applicable.
HEATER FAULT	Heater temperature switch is in fault state	Check whether the red light is illuminated on the temperature switch. If so, reset the switch by depressing it (using a pen or similar). If the switch trips regularly, contact TRP Laboratories.