WHEN YOU NEED TO BE SURE

Dust-in-Fuel Rig Reference

Model DDC-CFS-101

Version 3

April 15, 2020

Developed by SGS North America, Inc.

Version History

Version	Date	Revision Description
1	2/10/2016	Initial publication
2	8/23/2018	Format with SGS brand
3	4/15/2020	Retrofit to new template

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

The Dust-In-Fuel (DIF) rig is a standalone system that adds a measured amount of dust to diesel fuel, within industry standards, for testing the performance of fuel filtration and injection systems. The dust rig was built to meet the requirements of the Cummins Seymour Technical Center. Those requirements are covered in a separate document available from SGS.

All data variables are available with the standard CyFlex node-link and push-link servers.

There are several settings and empirical values that are used in the Dust-In-Fuel (DIF) rig:

- The final concentration of 4-micron dust particles should be between 10,000 and 20,000 particles/milliliter to meet the ISO standard.
- The target concentration is set at 14,400 part/ml.
- From empirical data, 4 mg of dust per liter are required to produce 14,400 part/ml. This can also be expressed as 0.000004 gm/ml and is represented with the label “K1” in the computed expressions.
- The particle counter used to measure the concentration of dust in the mixing tank samples fuel at a rate of 25 ml/minute and outputs a value every minute.
- If the target concentration is set at 14,400 part/ml, then the output of the counter at the desired concentration would be 360,000 particles/minute.

There are also a number of important measurements:

- The inside diameter of all three tanks is the same and the volume per inch of fuel is 8953 ml/inch. This value is represented with the label “K2” in the computed expressions.
- The volume in the angled portion of the return tank, which is not measured by the level indicator, is approximately 5.1 gallons or 19306 ml.

2 Safety

Important:

Always follow the safety practices and instructions at your facility when working with potentially dangerous materials and/or electricity. Safety is the sole responsibility of the customer.

Adhere to the following warning:

- Make sure power is disconnected at the source before making electrical connections to the dust rig. Otherwise, injury to personnel or damage to equipment can occur.

Adhere to the following cautions:

- Follow the steps described in this document for powering on the dust rig and powering off. Refer to the following:
  - *Section 3 Powering On the Dust Rig* on page 4
  - *Section 10 Powering Off the Dust Rig* on page 13
- The dust rig has an internal “watchdog” function. This means that if the onboard computer stops working for any reason, the dust rig shuts down. The dust rig 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 vessel 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.

Perform the following before moving the dust rig to a different test cell, or changing to a different fuel:

- Power off the dust rig as described in *Section 10 Powering Off the Dust Rig* on page 13.
- Follow facility safety protocol and “Lock-Tag-Out” procedures to ensure that electrical power and fuel are off, and instrument air is discharged.
- Close all input and output valves to articles (engine, test bench, etc.).
- Pump fuel out of the tank to an appropriate drain location, using hoses, hardware and an external container approved for fuel.
- Wipe any remaining fuel from equipment and the drain pan container.
- Follow approved procedures at your facility when disposing of fuel.
- Close all drain ball valves.
- Disconnect the fuel line that goes from the rig to the remote particle counter stand.
- Wipe down the particle stand and its equipment.
- Roll-up the communication and power cables, protecting the MIL connector end.
- Wrap-up the fuel lines from the particle counter to the fuel rig and lay them in a designated area where they will not be tripped over.
- At the remote particle counter stand, on the counter manifold, cap off the fitting ends used to attach the fuel hoses.

- At the dust hopper, recover dust intended for future use and vacuum out any remains. This prevents moisture from collecting, which causes dust to clump.
- Wipe out any residual dust to prevent collection of contaminates.
- Close and lock the dust rig lid, ensuring proper sealing.
- Close and lock all electrical cabinets.

3 Powering On the Dust Rig

Execute the following steps to apply power to the dust rig:

1. Check all mechanical connections.
2. Turn on main power.
3. After the main power is on, open the 120VAC panel and turn on the UPS.
4. Inside the control cabinet, start the computer by pressing the small white button on the back of the computer.
5. The computer should automatically login.
6. At the command line, enter:
   ```
   $ go
   ```
7. When ready, enable the system from the touch screen.

4 Dust Addition Calculations

By knowing the volume of the mixing tank at the full level, the total amount of dust that should be present in the fuel is calculated as:

Target dust mass (gm) = Total volume (ml) * 0.000004 gm/ml

OR

Target dust mass (gm) = Total volume (ml) * K1

The fuel in the mixing tank is made up of three components:

- The fuel left in the bottom of the tank from the previous batch.
- The fuel that is returned from the engine and is held in the return tank
- Fresh fuel that will be added to bring the level to full

Therefore, the amount of dust that must be added can be expressed as:

Added dust = Target dust mass –

Dust remaining in the tank from the previous batch –

Dust in the return fuel –

Dust in the fresh makeup fuel

In order to know how much dust must be added to the tank for any given batch, the dust concentrations for each of the constituents must be well known. However, only one of the dust concentrations on the right-hand side of the calculation is actually measured. That is the concentration in the fuel remaining from the previous batch. Therefore, certain assumptions about the concentrations in the other constituents must be made.

The dust concentration after the secondary engine filter is known as well as the concentration of dust in the injector return line. While these are not direct measurements from the primary fuel return, they can be used to make a reasonable estimate.

There are indications that a wide variety of dust levels exist in any given batch of fresh fuel so it is critical that the fuel supplied to the rig be heavily filtered or that a measure of the concentration be provided to the rig computer if a narrow band of concentration at the engine is required.

The actual amount of dust (gm) in any of the constituents is calculated as:

Dust mass = measured concentration (part/25ml) / 360000 (part/25ml) *

0.000004 gm/ml * volume of fuel (ml)

5 Computed Expressions

All calculations for the dust rig can be found in the specification file `/specs/gen_labels.DIF`. The file is listed in *Appendix A. Specification File* on page 14. Of note are the expressions that determine the state of the three fuel tanks. These states can be:

- `Empty' if the fuel level is at or below the lower level threshold
- `Full' if the fuel level is at or above the upper level threshold
- `Normal' if the fuel level is between empty and full

The state string values are converted to integers and an overall state integer value is calculated for use as an index into the state variable table.

6 Test Procedures

Test Procedure files are shown in *Appendix B. Test Procedure Files* on page 27.

6.1 Descriptions

Several general-purpose test procedures and files control the dust rig, including:

- `gp_header_DIF`

  This is the typical Test Manager (`gp_test`) header file used when launching `gp_test`.

- `gp_DIF_master`

  This is the main test procedure to be used with the new test (`nt`) command.

- `DIF_initial_fill`

  This is a sub procedure called by gp_DIF_master.

  If all tanks are empty and the user presses the initial fill button on the GUI (`DIF_test.ui`), then a batch of fuel will be mixed and transferred to the day tank, and a second batch of fuel will be prepared and will remain in the mixing tank.

- `DIF_dust_meter`

  This sub procedure is called by both `gp_DIF_master` and `DIF_initial_fill`.

  The procedure adds the appropriate amount of dust, dumps the fuel from the return tank into the mixing tank, and adds fresh fuel to bring the mixing tank to the full level.

- `DIF_state_vrbls`

  This is a variable file that specifies the various digital outputs as a function of the state of the three fuel tanks.

  The index into this table is the overall state of the system.

- `gpEmergency_DIF`

  This sub-procedure sets the digital outputs in case of an emergency. At this time, all error conditions result in an E-stop which is passed along to the test cell computer.

- `gpIdle_DIF`

  This sub-procedure sets the digital outputs in case an idle command is issued.

- `gpShutdown_DIF`

  This sub-procedure sets the digital outputs for shutting down the system.

- `TRACE`

  This file contains the trace information from the various test procedures.

6.2 Master Test Procedure

The master test procedure (`gp_DIF_master`) takes care of all of the important operations by monitoring the overall state of the system.

If the state indicates that the mixing tank is empty, the `DIF_dust_meter` sub-procedure is called. This causes dust to be metered and mixed, the return tank to be emptied into the mixing tank, and fresh fuel to start flowing into the mixing tank. The fresh fuel continues to flow until the mixing tank reaches the full threshold.

The transfer pump is turned on if the state indicates that the day tank is empty and is turned off when the mixing tank reaches the empty threshold.

As long as the system is enabled, the mixing paddles will be moving whether fuel is being used by the engine or not. This prevents dust from settling to the bottom of tank.

It should be noted that dust may settle out in the line from the day tank to the engine if the engine is shut off for an extended period of time. There is nothing that can be done for this. The readings from engine supply particle counter should be ignored until the fuel supply line has been purged and refilled with fuel from the day tank.

7 Trace File

The standard `gp_test` TRACE file captures standard CyFlex test mode information during the test. The trace is disabled any time that the test procedures go into a normal loop waiting for a particular condition to be met. This prevents unwanted, repeated information from cluttering the file.

8 Mechanical Settings and Procedures

8.1 Required Settings

The following mechanical and control settings must be maintained for the system to operate correctly.

Table 1: Required Mechanical and Control Settings

Line Item	Medium	Device	Setting			Units
			Nom	Min	Max	
A	Instrument Air	Main Regulator	85	80	90	PSIG
B	Instrument Air	Vibrator Regulator	60	55	65	PSIG
C	Instrument Air	Solenoid Regulator	80	75	85	PSIG
D	Instrument Air	Vibrator Lubricator	(1 Drip per 20 Secs)			
E	Sand	Auger Speed (0-10 Dial)	3.5	3.5	3.5	Units
F	Fuel	Mixing Pump VFDs	60	60	60	Hz

Note:

VFD = Variable Frequency Drive. The speed of the day tank mixer varies with the level of the fuel in the tank. For this reason, the speed can be 40, 50 or 100% of 60 Hz.

The vibrator lubricator (attached to the vibrator regulator) maintains a 1 – drip per 20 second rate when the vibrator is on. The recommended oil is Fuch's Air Lube 10PAO.

Caution: A lack of lubricant can damage the vibrator. Every 24 hours of operating the dust rig, inspect the oil level in the lubricator reservoir. Before adding oil to the fill line, shut off air and discharge.

8.2 Priming the Transfer Pump

Before powering on the dust rig, execute the steps below to prime the transfer pump.

Always follow the protocols explained in *Section 2 Safety* on page 2.

1. Make sure there are 2-3 gallons of fuel in the day tank.
2. Ensure the ball valve located between the day tank and pump is closed.
3. Bleed air and fuel from the pump, by loosening the pump's bleed nut counter-clock wise one-quarter (1/4) turn.
4. Note: An approximately 1/16" hole in the bleed nut assembly allows air and fuel to escape from the pump cavity. The bleed nut is located on the upper surface of the pump. (If needed, refer to the manufacturer's service manual.)
5. Open the ball valve located between the day tank and pump.
6. Let air and fuel purge from the system. Once only fuel is coming out, wait 3-5 seconds and then close the bleed nut.

The pump is ready for use.

Power-on the dust rig as described in *Section 3 Powering On the Dust Rig* on page 4.

8.3 Filling and Priming the Dust Auger

If the dust auger is disassembled for cleaning, execute the following steps to fill and prime it after reassembly.

1. Add dust to the dust line marked on the hopper. Do not over-fill, since extra dust collects moisture.
2. Put a container under the discharge hose to catch any dust.
3. Turn on the auger and wait 3-5 minutes until 100-200 grams of dust collect in the container.
4. Turn off the auger.
5. Empty the container and return the discharge hose to the container.
6. Turn on the auger for 30 seconds.
7. Place the collected dust on a white piece of paper.
8. Collect five different samples and compare the volumes.
9. If the dust volume is approximately the same for each sample, priming is complete and the dust auger is ready. If not, repeat the steps above until the samples produce roughly the same volumes.

9 Final Adjustments

There are a few final adjustments that must be made to the system to ensure that it works correctly.

- Set the target concentration which is initially set to 14,400 particles/ml by changing the value of the CyFlex variable `TargetDust`. Add permanent changes to `/specs/gen_labels.DIF`.
- There is constant (K3) that determines how long the dust metering system runs in order to provide a given mass of dust. These values are set during the final commissioning of the system and should not need to be changed. They are listed for reference only.
    - It is recommended to have the metering system run for at least 10 seconds to provide good resolution to the metered quantity.
    - The value of K3 will be determined on final commissioning and will be stored in `/specs/gen_labels.DIF`.
    - There is also a potentiometer in the control cabinet that adjusts the speed of the metering auger and it is set to 3.6 on delivery of the system. If the speed is set too high, then the on-time will be very short and resolution will be compromised.

10 Powering Off the Dust Rig

Execute the following steps to shut down the dust rig:

1. Disable the system from the touch screen on the control cabinet.
2. “Slay” all of the CyFlex programs, either at the front panel or through a remote login.
3. Shut down the computer using standard Linux OS procedures.
4. Remove main power from the system.
5. After the main power is off, open the 120VAC panel and turn off the UPS.

Appendices

Appendix A. Specification File

/specs/gen_labels.DIF

```
##  SPEC_FILE_VERSION
VERSION_2  (do not remove this line)

@REG_NAME
   GL_DIF

#  This file contains the labels, units, and format information for
#  the GENERAL_USAGE rdata, ldata, and idata arrays.  The rdata array
is an
#  array of REAL_VARIABLES, the ldata array is an array of
INTEGER_VARIABLEs,
#  and the ldata array is an array of LOGICAL_VARIABLES.
#
#   The following table is used to initialize the labels, units, and
format
#   strings of the rdata array in GENERAL_USAGE

##########################################################################
#
#  These variables represent fixed values used in formulas or for
plotting
#
##########################################################################

# Target dust value part/ml (this should be between 10-20,000)
#label         units    format initial_value interval/event  hst_flag
tolerance
TargDust       none     2      14400         -               OFF
1
-

# Target value for dust concentration - from 25 * 14400
#label         units   format initial_value interval/event  hst_flag
tolerance
TargDustConc   none    2      -             -               OFF
1
25[none] * TargDust

# Conversion factor to go from dust concentration to grams
# of dust at 4ug - from STC
#label         units   format initial_value interval/event  hst_flag
tolerance
K1             none    7      0.0000040     -               OFF
1
-
```

```
# Conversion factor to go from level in inches to ml
#label         units   format initial_value interval/event  hst_flag
tolerance
K2             none    4      8953.12       -               OFF
1
-

# Conversion factor to go from required dust mass to on-time
#label         units   format initial_value interval/event  hst_flag
tolerance
K3             none    4      0.050         -               OFF
1
-

## Estimated particle count (part/25ml) in the makeup fuel from the
facility
#label         units   format initial_value interval/event  hst_flag
tolerance
ClnDustConc    none    2      5000          -               OFF
1
-

# Convert concentration read to part/ml - this value is used for
plotting only
#label         units    format initial_value interval/event  hst_flag
tolerance
SupDust        none     2      -             SLO             OFF
1
SupDustConc / 25[none]

# Convert concentration read to part/ml - this value is used for
plotting only
#label         units    format initial_value interval/event  hst_flag
tolerance
RetDust        none     2      -             SLO             OFF
1
RetDustConc / 25[none]

# Convert concentration read to part/ml - this value is used for
plotting only
#label         units    format initial_value interval/event  hst_flag
tolerance
MixDust        none     2      -             SLO             OFF
1
MixDustConc / 25[none]

# Maximum dust for ISO21 - this value is used for plotting only
#label         units    format initial_value interval/event  hst_flag
tolerance
```

```
MaxDust         none     2      20000          -               OFF
1
-

# Minimum dust for ISO21 - this value is used for plotting only
#label          units    format initial_value interval/event  hst_flag
tolerance
MinDust         none     2      10000          -               OFF
1
-

# This value is the speed of the day tank mixer at high levels
#label          units    format initial_value interval/event  hst_flag
tolerance
DTankHiSpd      %        1      100            -               OFF
1
-

#label          units    format initial_value interval/event  hst_flag
tolerance
DTankLowSpd     %        1      50             -               OFF
1
-

# This value is the speed of the day tank mixer at VERY low levels
#label          units    format initial_value interval/event  hst_flag
tolerance
DTankVLowSpd    %        1      40             -               OFF
1
-

# Volume of fuel in angled part of return tank - not
# counted by level indicator
#label          units   format initial_value interval/event  hst_flag
tolerance
RetAngleVol     ml      1      19306          -               OFF
1
-

# Fuel level in the mixing tank considered the desired low level -
there must be
# enough fuel to cover the sample lines for the particle counter
#label          units   format initial_value interval/event  hst_flag
tolerance
MTankEmptyThresh IN     2      7.50           -               OFF
1
-

# Fuel level in the mixing tank considered the full level
```

```
#label         units   format initial_value interval/event  hst_flag
tolerance
###### change to 23 after testing
# Testing MTankFullThresh IN     2      23.0          -
OFF       1
MTankFullThresh IN     2      16.0          -               OFF
1
-

# Fuel level in the return tank considered the empty level (this is
also
# the minimum reading from the level sensor)
#label         units   format initial_value interval/event  hst_flag
tolerance
RTankEmptyThresh IN    2      0.75           -               OFF
1
-

# Fuel level in the return tank considered the full level
# This value is calculated as the maximum mixing tank level -
# min mixing tank level - 2" to account for the angled part of the
# return tank which holds 5.1 gallons or ~2"
#label         units   format initial_value interval/event  hst_flag
tolerance
RTankFullThresh IN     2      15.0          -               OFF
1
-

# On time that does not produce dust
#label         units   format initial_value interval/event  hst_flag
tolerance
LostOnTime     sec     2      0.0           -               OFF
1
-

# Target temperature in the return tank
#label         units   format initial_value interval/event  hst_flag
tolerance
RetnTempTR     deg_f   1      104           -               OFF
1
-

# Maximum swing in return fuel temperature out of HX
#label         units   format initial_value interval/event  hst_flag
tolerance
RetnTempDT     dt_f    1      4             -               OFF
1
-

# Fuel level in the day tank considered the low level
```

```
#label         units   format initial_value interval/event  hst_flag
tolerance
DTankEmptyThresh IN    2      4.0           -               OFF
1
-

# Fuel level in the day tank considered the full level
#label         units   format initial_value interval/event  hst_flag
tolerance
DTankFullThresh IN     2      22.0          -               OFF
1
-

# Fuel level in the day tank to lower the mixing speed to avoid
aeration
#label         units   format initial_value interval/event  hst_flag
tolerance
DTankLoMixThresh IN     2     10.5          -               OFF
1
-

# Fuel level in the day tank to raise the mixing speed (provides
hysteresis)
#label         units   format initial_value interval/event  hst_flag
tolerance
DTankHiMixThresh IN     2     11.5          -               OFF
1
-

# Amount of time to mix the dust at the DesiredMixLevel
# before adding the return fuel
#label         units   format initial_value interval/event  hst_flag
tolerance
PreMixTime     sec     0      30.0          -               OFF
1
-

##############################################################################
#
#  End - variables represent fixed values used in formulas or for
plotting
#
##############################################################################
```

```
## Particle count measured in the mixing tank
#label         units    format initial_value interval/event  hst_flag
tolerance
MixDustConc    none     1      -             SLO             OFF
1
pamas5_4_count

## Particle count measured in the fuel arriving at the
## engine filter inlet
#label         units    format initial_value interval/event  hst_flag
tolerance
SupDustConc    none     1      -             SLO             OFF
1
Pamas1_4_count

## Particle count measured in the fuel leaving the engine filters and
## most likely in the return tank
#label         units    format initial_value interval/event  hst_flag
tolerance
RetDustConc    none     1      -             SLO             OFF
1
pamas2_4_count

# Instantaneous mix tank volume
#label         units   format initial_value interval/event  hst_flag
tolerance
MixTankVolume  ml      1      -             MED             OFF
1
{MixTankLevel.AV * K2}

# Volume of mixing tank at the full level
#label         units   format initial_value interval/event  hst_flag
tolerance
MixTankFullVol ml      1      -             MED             OFF
1
{MTankFullThresh * K2}

# Amount of dust at the target level in the mixing tank
#label         units   format initial_value interval/event  hst_flag
tolerance
TargMixDust    gm      3      -             -               OFF
1
{MixTankFullVol * K1}

# Amount of dust at the bottom of the mixing tank
#label         units   format initial_value interval/event  hst_flag
tolerance
StrtMixDust    gm      3      -             MED             OFF
1
{if MixDustConc.AV > 0[none] then \
```

```
   MixTankVolume * MixDustConc.AV / TargDustConc * K1 else \
      MixTankVolume * MixDustConc / TargDustConc * K1 }

# Instantaneous return tank volume
#label         units   format initial_value interval/event  hst_flag
tolerance
RetTankVolume  ml      1      -             MED             OFF
1
{if RetTankLevel.AV < RTankEmptyThresh then 0[ml] else \
RetTankLevel.AV * K2 + RetAngleVol}

# Amount of dust in the return tank
#label         units   format initial_value interval/event  hst_flag
tolerance
RetTankDust    gm      3      -             MED             OFF
1
{RetTankVolume * RetDustConc / TargDustConc * K1}

# Amount of dust in fresh fuel that will be added
#label         units   format initial_value interval/event  hst_flag
tolerance
FreshFuelDust  gm      3      -             MED             OFF
1
{if(MixTankFullVol - RetTankVolume - MixTankVolume) <= 0[ml] then
0[gm] else \
  (MixTankFullVol - RetTankVolume - MixTankVolume) * \
     ClnDustConc / TargDustConc * K1}

# Amount of dust that needs to be added
#label         units   format initial_value interval/event  hst_flag
tolerance
AddedDustMass  gm      3      -             MED             OFF
1
TargMixDust - StrtMixDust - RetTankDust - FreshFuelDust

# Calculated on-time for the dust metering based on measured values
#label         units   format initial_value interval/event  hst_flag
tolerance
OnTime         sec     1      -             MED             OFF
1
{AddedDustMass / K3 + LostOnTime}

# Calculated on-time for the dust metering based on measured values -
this is
# used as a mode time out in a gp_test procedure so we can't allow a
value of 0.0
#label         units   format initial_value interval/event  hst_flag
tolerance
on_time        sec     2      -             MED             OFF
1
```

```
if OnTime <= LostOnTime then -1[sec] else OnTime
-

# Fuel level in the mixing tank in percent
#label         units   format initial_value interval/event  hst_flag
tolerance
MTankLevelPct   %      0      -             SLO             OFF
1
if (MixTankLevel.AV < MTankEmptyThresh) then 0[%] else \
   (MixTankLevel.AV - MTankEmptyThresh) / \
   (MTankFullThresh - MTankEmptyThresh ) * 100[%]

# Fuel level in the day tank in percent
#label         units   format initial_value interval/event  hst_flag
tolerance
DTankLevelPct   %      0      -             SLO             OFF
1
if (DayTankLevel.AV < DTankEmptyThresh) then 0[%] else \
   (DayTankLevel.AV - DTankEmptyThresh) / \
   (DTankFullThresh - DTankEmptyThresh ) * 100[%]

# Fuel level in the return tank in percent
#label         units   format initial_value interval/event  hst_flag
tolerance
RTankLevelPct   %      0      -             SLO             OFF
1
if (RetTankLevel.AV < RTankEmptyThresh) then 0[%] else \
   (RetTankLevel.AV - RTankEmptyThresh) / \
   (RTankFullThresh - RTankEmptyThresh ) * 100[%]

# Fuel level in the mixing tank where initial dust mixing is started
#label         units   format initial_value interval/event  hst_flag
tolerance
DesiredMixLevel IN     1      -             MED             OFF
1
MTankEmptyThresh - 0.50[in]

# Last level in the mixing tank with noise removed
#label         units   format initial_value interval/event  hst_flag
tolerance
LastMTankLevel IN      1      -             SLO             OFF
1
if( @fabs( MixTankLevel - LastMTankLevel ) > 0.15[IN] ) then
MixTankLevel \
   else LastMTankLevel

# Last level in the day tank with noise removed
#label         units   format initial_value interval/event  hst_flag
tolerance
```

```
LastDTankLevel IN      1      -             SLO             OFF
1
if( @fabs( DayTankLevel - LastDTankLevel ) > 0.15[IN] ) then
DayTankLevel \
   else LastDTankLevel

# Last level in the return tank with noise removed
#label         units   format initial_value interval/event  hst_flag
tolerance
LastRTankLevel IN      1      -             SLO             OFF
1
if( @fabs( RetTankLevel - LastRTankLevel ) > 0.15[IN] ) then
RetTankLevel \
   else LastRTankLevel


$  end of REAL_VARIABLE section - start of INTEGER_VARIABLES


# INTEGER_VARIABLE specifications for GENERAL_USAGE

# Convert mixing tank state from a string to an integer value
#label          units    initial_value interval hst_flag
transition_event
MTankStateI     none     -             MED      OFF      -
if @strcmp_lbl_lit( MixTankState, 'Empty' ) then 0[none] else \
  if @strcmp_lbl_lit( MixTankState, 'Normal' ) then 1[none] else \
    if @strcmp_lbl_lit( MixTankState, 'Full' ) then 2[none] else \
      3[none]

# Convert day tank state from a string to an integer value
#label          units    initial_value interval hst_flag
transition_event
DTankStateI     none     -             MED      OFF      -
if @strcmp_lbl_lit( DayTankState, 'Empty' ) then 0[none] else \
  if @strcmp_lbl_lit( DayTankState, 'Normal' ) then 1[none] else \
    if @strcmp_lbl_lit( DayTankState, 'Full' ) then 2[none] else \
      3[none]

# Convert return tank state from a string to an integer value
#label          units    initial_value interval hst_flag
transition_event
RTankStateI     none     -             MED      OFF      -
if @strcmp_lbl_lit( RetTankState, 'Empty' ) then 0[none] else \
  if @strcmp_lbl_lit( RetTankState, 'Normal' ) then 1[none] else \
    if @strcmp_lbl_lit( RetTankState, 'Full' ) then 2[none] else \
      3[none]

# Overall system state
```

```
#label          units    initial_value interval hst_flag
transition_event
SystemState     none     -             MED      OFF      -
MTankStateI * 100[none] + DTankStateI * 10[none] + RTankStateI

# Value used in the state transition variable table
#label          units    initial_value interval hst_flag
transition_event
Next            none     -             -        OFF      -
-

$  end of INTEGER_VARIABLE section - start of LOGICAL_VARIABLES

# LOGICAL_VARIABLE specifications for GENERAL_USAGE


# System enable variable set by the user
#label     true_evnt  false_evnt  true_desc   false_desc   interval
hst_flag
Enable     DIF_enable DIF_disable ON          OFF          -       OFF
-

# Initial fill request set by the user - this only works if all
# tanks are empty
#label     true_evnt  false_evnt  true_desc   false_desc   interval
hst_flag
InitialFill -         -           ON          OFF          -       OFF
-

$  end of LOGICAL_VARIABLE section - start of pre-existing

#This section is for computed expression to be applied to pre-existing
variables

# Analog output value used to set the speed of the mixing tank mixer
# label             process_interval or event_name
# computed expression
AO_CH_0             SLO
100[%]

# Analog output value used to set the speed of the day tank mixer
AO_CH_1             SLO
if(DayTankLevel.AV < DTankEmptyThresh + 3[in]) then DTankVLowSpd else
\
   if(DayTankLevel.AV < DTankLoMixThresh) then DTankLowSpd else \
      if(DayTankLevel.AV > DTankHiMixThresh) then DTankHiSpd \
         else AO_CH_1

# Make sure the transfer pump is off when the mixing tank is empty
TransferPump        MED
```

```
if MixTankLevel < MTankEmptyThresh - 1.0[in] then OFF \
   else TransferPump

# Decide when to turn on the fuel cooling water flow
FuelCooling         SLO
if !Enable then OFF else \
   if( FuelOtHxTemp > (RetnTempTR + RetnTempDT) ) \
      then ON else \
         if( FuelOtHxTemp < (RetnTempTR - RetnTempDT) ) \
            then OFF else FuelCooling

# Decide when to turn on the FuelFill OFF
FuelFill            MED
if !Enable then OFF else \
   if( MixTankLevel.AV > MTankFullThresh + 0.10[in] ) then OFF \
      else FuelFill


$  end of pre-existing variables - start of STRING_VARIABLES

# Logic for the state of the mixing tank
#   label         initial_value           interval          HST flag
MixTankState      ""                      MED               OFF
if( MixTankLevel.AV <= MTankEmptyThresh ) then 'Empty' else \
  if( MixTankLevel.AV >= MTankFullThresh ) then 'Full' else \
    'Normal'

# Logic for the state of the day tank
#   label         initial_value           interval          HST flag
DayTankState      ""                      MED               OFF
if( DayTankLevel.AV <= DTankEmptyThresh ) then 'Empty' else \
  if( DayTankLevel.AV >= DTankFullThresh ) then 'Full' else \
    'Normal'

# Logic for the state of the return tank
#   label         initial_value           interval          HST flag
RetTankState      ""                      MED               OFF
if( RetTankLevel.AV <= RTankEmptyThresh ) then 'Empty' else \
  if( RetTankLevel.AV >= RTankFullThresh ) then 'Full' else \
    'Normal'

# Message to be displayed on the user console
#   label         initial_value           interval          HST flag
SystemMsg         ""                      -                 OFF
-

$     end of STRING_VARIABLE section - start of display variables

############################################################
#
```

```
# section for computing the display status of pre-existing variables
#  the result of the expression must be one of the following:
#
#     NORMAL            use normal display color
#     BLINK             blink the normal display color
#     COLOR             use the 'exception' color
#     COLOR_BLINK       blink the exception color
#     BLUE
#     GREEN
#     CYAN
#     RED
#     MAGENTA
#     YELLOW
#     WHITE
#     BLINK_BLUE
#     BLINK_GREEN
#     BLINK_CYAN
#     BLINK_RED
#     BLINK_MAGENTA
#     BLINK_YELLOW
#     BLINK_WHITE
#
#####################################################################

#   numerical equivalents of color values are listing below
#   use this for testing expressions which set display status
#
#   "NORMAL"             0
#   "BLINK"              1
#   "COLOR"              2
#   "COLOR_BLINK"        3
#   "BLUE"             256
#   "GREEN"            512
#   "CYAN"             768
#   "RED"             1024
#   "MAGENTA"         1280
#   "YELLOW"          1536
#   "WHITE"           1792
#   "BLINK_BLUE"       257
#   "BLINK_GREEN"      513
#   "BLINK_CYAN"       769
#   "BLINK_RED"       1025
#   "BLINK_MAGENTA"   1281
#   "BLINK_YELLOW"    1527
#   "BLINK_WHITE"     1793
# there may be up to 1000 specifications - combined with all other
# computed expressions defined in gen_labels.XXX files

#label         interval/event
#expression
```

```
$  end of computations of display status - start of events
$  END of events
$
```

Appendix B. Test Procedure Files

/specs/gp/gp_DIF_master

```
#*********************************************************************
#
#  gp_DIF_master
#
#  This test procedure reads the state variable file and makes
decisions on
#  how to proceed
#
#
#  11/18/15 DAR - Begin development
#
#
#*********************************************************************

#start_mode ( mode where the test begins )

   500

#*********************************************************************

@MODE
   #mode_number       timeout                  next_mode
   500                -1.0[sec]                502
   #mode_description
   Turn the TRACE on

@PARAMETERS
   #start_type       label             value
   AT_START          TRACE             ON


#*********************************************************************

@MODE
   #mode_number       timeout                  next_mode
   502                -1.0[sec]                510
   #mode_description
   Check Enable and Estop

@IF_TRUE
   Enable
   EstopSense

@ELSE_MODE
   503

@PARAMETERS
```

```
   #start_type       label             value
   AT_START          TRACE             ON

#*********************************************************************

@MODE
   #mode_number       timeout                  next_mode
   503                1.0[sec]                 502
   #mode_description
   Waiting for Enable and/or Estop

@PARAMETERS
   #start_type       label             value
   AT_START          TRACE             OFF

#*********************************************************************

@MODE
   #mode_number   timeout        next_mode
   510            -1.0[sec]      512
   #mode_description
   Is initial fill required?

@IF_TRUE
   "@strcmp_lbl_lit( MixTankState, 'Empty' )"
   "@strcmp_lbl_lit( DayTankState, 'Empty' )"
   "@strcmp_lbl_lit( RetTankState, 'Empty' )"

@ELSE_MODE
   520

#*********************************************************************

@MODE
   #mode_number   timeout        next_mode
   512            -1.0[sec]      515
   #mode_description
   Is InitialFill requested

@IF_TRUE
   InitialFill

@ELSE_MODE
   513

@PARAMETERS
   #start_type       label             value
   AT_START          TRACE             ON
```

```
#*********************************************************************

@MODE
   #mode_number   timeout        next_mode
   513            1.0[sec]       512
   #mode_description
   Waiting for InitialFill request

@PARAMETERS
   #start_type       label             value
   AT_START          TRACE             OFF

#*********************************************************************

@MODE
   #mode_number   timeout        next_mode
   515            0.0[sec]       520
   #mode_description
   Perform initial fill

@PROCEDURE
   # pathname
   /specs/gp/DIF_initial_fill

#*********************************************************************

@MODE
   #mode_number   timeout        next_mode
   520            -1.0[sec]      540
   #mode_description
   Add other initialization here

@PARAMETERS
   #start_type       label             value
   AT_START          InitialFill       OFF

#*********************************************************************

@MODE
   #mode_number     timeout         next_mode
   540              0[sec]          545
   #mode_description
   Read the state variable table

@AUXILIARY_TASK
   #start_type        stop_type           failure action
   AT_START           MODE_TERMINATE      900

   /cyflex/bin/vrbl_to_file  "/specs/gp/DIF_state_vrbls READ_ONCE
SystemState"
```

```
#*********************************************************************

@MODE
   #mode_number     timeout         next_mode
   545              1[sec]          540
   #mode_description
   Was a NEXT state specified

@SWITCH
   #switch variable
   Next
   #case             path

   # Continue
   10                546

   # Abort
   400               800

   # Refill mixing tank
   450               550

   # Refill day tank
   460               600

   # Initial fill
   480               475

#*********************************************************************

@MODE
   #mode_number     timeout         next_mode
   546              1[sec]          540
   #mode_description
   Nothing to be done

@PARAMETERS
   #start_type       label             value
   AT_END            TRACE             OFF

#*********************************************************************

@MODE
   #mode_number     timeout         next_mode
   475              1[sec]          480
   #mode_description
   Turn the TRACE ON

@PARAMETERS
```

```
   #start_type       label             value
   AT_END            TRACE             ON

#*********************************************************************

@MODE
   #mode_number     timeout         next_mode
   480              -1[sec]         515
   #mode_description
   Has initial fill been requested

@IF_TRUE
   InitialFill

@ELSE_MODE
   540

#*********************************************************************

@MODE
   #mode_number     timeout         next_mode
   550              -1[sec]         560
   #mode_description
   Turn the TRACE ON

@PARAMETERS
   #start_type       label             value
   AT_START          TRACE             ON

#*********************************************************************

@MODE
   #mode_number       timeout                  next_mode
   560                0[sec]                   540
   #mode_description
   Call the sub-procedure to fill the mixing tank and add dust

@PROCEDURE
   # pathname
   /specs/gp/DIF_dust_meter

#*********************************************************************

@MODE
   #mode_number     timeout         next_mode
   600              -1[sec]         610
   #mode_description
   Turn the TRACE ON

@PARAMETERS
```

```
   #start_type       label             value
   AT_START          TRACE             ON

## remove later
   AT_START          LastMixConc       pamas5_4_count

#*********************************************************************

@MODE
   #mode_number     timeout         next_mode
   610              1[sec]          620
   #mode_description
   Turn the transfer pump ON

@PARAMETERS
   #start_type       label             value
   AT_START          TransferPump       ON

#*********************************************************************

@MODE
   #mode_number     timeout         next_mode
   620              -1[sec]         540
   #mode_description
   Wait for the mixing tank to empty

# TransferPump turns off automatically
@IF_FALSE
   TransferPump

@ELSE_MODE
   630

@PARAMETERS
   #start_type       label             value
   AT_START          TransferPump       ON

#*********************************************************************

@MODE
   #mode_number     timeout         next_mode
   630              0.5[sec]        620
   #mode_description
   Wait for the mixing tank to empty

@PARAMETERS
   #start_type       label             value
   AT_END            TRACE              OFF

#*********************************************************************
```

```
@MODE
   #mode_number     timeout         next_mode
   800              -1[sec]         810
   #mode_description
   Turn the TRACE ON

@PARAMETERS
   #start_type       label             value
   AT_START          TRACE             ON

#*********************************************************************

@MODE
   #mode_number       timeout                  next_mode
   810                0[sec]                   540
   #mode_description
   Abort mode - ADV when problem has been fixed

@PARAMETERS
   #start_type       label             value
   AT_START          FuelFill          OFF
   AT_START          DustMeter         OFF
   AT_START          TransferPump      OFF
   AT_START          EstopOut          OFF

#*********************************************************************

@MODE
   #mode_number       timeout                  next_mode
   900                -1[sec]                  905
   #mode_description
   Turn the TRACE ON

@PARAMETERS
   #start_type       label             value
   AT_START          TRACE             ON
#*********************************************************************

@MODE
   #mode_number       timeout                  next_mode
   905                2[sec]                   540
   #mode_description
   Failure reading state table - pause and try again

#*********************************************************************
```

```
/specs/gp/DIF_dust_meter
#*********************************************************************
#
#  DIF_dust_meter
#
#  This test procedure adds dust, dumps the return tank, and
#  fills the mixing tank with fresh fuel
#
#
#  11/18/15 DAR - Begin development
#
#
#*********************************************************************

#start_mode ( mode where the test begins )

   500


#*********************************************************************

@MODE
   #mode_number       timeout                    next_mode
   500                -1.0[sec]                  502
   #mode_description
   Turn the TRACE on

@PARAMETERS
   #start_type       label             value
   AT_START          TRACE             ON

#*********************************************************************

@MODE
   #mode_number       timeout                    next_mode
   502                -1.0[sec]                  505
   #mode_description
   Check Enable and Estop

@IF_TRUE
   Enable
   EstopSense

@ELSE_MODE
   503

@PARAMETERS
   #start_type       label             value
   AT_START          TRACE             ON
```

```
#*********************************************************************

@MODE
   #mode_number       timeout                    next_mode
   503                1.0[sec]                   502
   #mode_description
   Waiting for Enable and/or Estop

@PARAMETERS
   #start_type       label             value
   AT_START          TRACE             OFF

#*********************************************************************

@MODE
   #mode_number       timeout                    next_mode
   505                -1.0[sec]                  510
   #mode_description
   Add fuel until the particle counter inlet is covered

@IF_TRUE
   "MixTankLevel.AV < DesiredMixLevel"

@ELSE_MODE
   555

@PARAMETERS
   #start_type       label             value
   AT_START          FuelFill          ON

#*********************************************************************

@MODE
   #mode_number       timeout                    next_mode
   510                1.0[sec]                   505
   #mode_description
   Wait for fuel level to rise

@PARAMETERS
   #start_type       label             value
   AT_START          TRACE             OFF

#*********************************************************************

@MODE
   #mode_number       timeout                    next_mode
   555                -1.0[sec]                  560
   #mode_description
   Turn the TRACE ON
```

```
@PARAMETERS
   #start_type       label             value
   AT_START          TRACE             ON

#*********************************************************************

@MODE
   #mode_number       timeout                    next_mode
   560                -1.0[sec]                  570
   #mode_description
   Start the dust metering

@PARAMETERS
   #start_type       label             value
   AT_START          FuelFill          OFF
   AT_END            DustMeter         ON

#*********************************************************************

@MODE
   #mode_number       timeout                    next_mode
   570                on_time                    580
   #mode_description
   Meter dust into the tank

@PARAMETERS
   #start_type       label             value
   AT_END            DustMeter         OFF

#*********************************************************************

@MODE
   #mode_number       timeout                    next_mode
   580                PreMixTime                 585
   #mode_description
   Mix dust in tank and then start to add return fuel

@IF_TRUE
   "RetTankLevel <= ( MTankFullThresh - MixTankLevel )"

@ELSE_MODE
   900

@PARAMETERS
   #start_type       label             value
   AT_END            ReturnValve       ON

#*********************************************************************

@MODE
```

```
   #mode_number       timeout                    next_mode
   585                1[sec]                     590
   #mode_description
   Give some time for return tank to empty

@PARAMETERS
   #start_type       label             value
   AT_END            TRACE             OFF

#*********************************************************************

@MODE
   #mode_number       timeout                    next_mode
   590                5.0[sec]                   600
   #mode_description
   Is return tank empty?

@IF_TRUE
   "@strcmp_lbl_lit( RetTankState, 'Empty' )"

@ELSE_MODE
   585

@PARAMETERS
   #start_type       label             value
   AT_END            ReturnValve       OFF
   AT_END            TRACE             ON

#*********************************************************************

@MODE
   #mode_number       timeout                    next_mode
   600                -1.0[sec]                  610
   #mode_description
   Add fresh fuel if needed

# If the mixing tank is not full
@IF_TRUE
   "MixTankLevel.AV < MTankFullThresh"

# The tank is now full
@ELSE_MODE
   615

@PARAMETERS
   #start_type       label             value
   AT_START          FuelFill          ON

#*********************************************************************
```

```
@MODE
   #mode_number       timeout                    next_mode
   610                1.0[sec]                   600
   #mode_description
   Wait for fill to complete

@PARAMETERS
   #start_type       label             value
   AT_START          TRACE             OFF

#*********************************************************************

@MODE
   #mode_number       timeout                    next_mode
   615                -1.0[sec]                  620
   #mode_description
   Turn TRACE back on

@PARAMETERS
   #start_type       label             value
   AT_START          TRACE             ON

#*********************************************************************

@MODE
   #mode_number       timeout                    next_mode
   620                -1.0[sec]                  630
   #mode_description
   Close fuel fill valve

@PARAMETERS
   #start_type       label             value
   AT_START          FuelFill          OFF

#*********************************************************************

@MODE
   #mode_number       timeout                    next_mode
   630                -1.0[sec]                  RETURN
   #mode_description
   Return from DIF_dust_meter procedure

#*********************************************************************

@MODE
   #mode_number       timeout                    next_mode
   900                3.0[sec]                   /specs/gp/gpShutDn_DIF
   #mode_description
   Return tank is too full to dump into mixing tank
#*********************************************************************
```

```
/specs/gp/DIF_initial_fill
#*********************************************************************
#
#  DIF_initial_fill
#
#  This test procedure adds dust, dumps the return tank, and fills the
mixing
#  tank with fresh fuel.  It then mixes the fuel and pumps it to the
day tank
#  followed by a second fill cycle in the mixing tank.
#
#
#  11/25/15 DAR - Begin development
#
#
#*********************************************************************

#start_mode ( mode where the test begins )

   500


#*********************************************************************

@MODE
   #mode_number       timeout                  next_mode
   500                -1.0[sec]                502
   #mode_description
   Turn the TRACE on

@PARAMETERS
   #start_type       label             value
   AT_START          TRACE             ON

#*********************************************************************

@MODE
   #mode_number       timeout                  next_mode
   502                -1.0[sec]                510
   #mode_description
   Check Enable and Estop

@IF_TRUE
   Enable
   EstopSense

@ELSE_MODE
   503

@PARAMETERS
```

```
   #start_type       label             value
   AT_START          TRACE             ON

#*********************************************************************

@MODE
   #mode_number       timeout                  next_mode
   503                1.0[sec]                 502
   #mode_description
   Waiting for Enable and/or Estop

@PARAMETERS
   #start_type       label             value
   AT_START          TRACE             OFF

#*********************************************************************

@MODE
   #mode_number       timeout                  next_mode
   510                0[sec]                   520
   #mode_description
   Call the sub-procedure to fill the mixing tank and add dust

@PROCEDURE
   # pathname
   /specs/gp/DIF_dust_meter

#*********************************************************************

@MODE
   #mode_number       timeout                  next_mode
   520                10[min]                  525
   #mode_description
   Wait for fuel in the mixing tank to blend

#*********************************************************************

@MODE
   #mode_number       timeout                  next_mode
   525                1[sec]                   530
   #mode_description
   Turn the transfer pump ON

@PARAMETERS
   #start_type       label             value
   AT_START          TransferPump      ON

#*********************************************************************

@MODE
```

```
   #mode_number       timeout                    next_mode
   530                -1.0[sec]                  550
   #mode_description
   Is the transfer to the day tank complete

# The TransferPump turns off automatically
@IF_FALSE
   TransferPump

@ELSE_MODE
   540

@PARAMETERS
   #start_type       label             value
   AT_START          TRACE             ON

#*********************************************************************

@MODE
   #mode_number       timeout                    next_mode
   540                1.0[sec]                   530
   #mode_description
   Wait for mixing tank to empty

@PARAMETERS
   #start_type       label             value
   AT_START          TRACE             OFF

#*********************************************************************

@MODE
   #mode_number       timeout                    next_mode
   550                2[sec]                     560
   #mode_description
   Wait for pump to stop

@PARAMETERS
   #start_type       label             value
   AT_START          TRACE             ON
#*********************************************************************

@MODE
   #mode_number       timeout                    next_mode
   560                0[sec]                     570
   #mode_description
   Call the sub-procedure to fill the mixing tank and add dust

@PROCEDURE
   # pathname
   /specs/gp/DIF_dust_meter
```

```
#*********************************************************************

@MODE
   #mode_number       timeout                  next_mode
   570                -1.0[sec]                580
   #mode_description
   Make sure the TRACE is ON

@PARAMETERS
   #start_type       label             value
   AT_START          TRACE             ON

#*********************************************************************

@MODE
   #mode_number       timeout                  next_mode
   580                -1.0[sec]                RETURN
   #mode_description
   Return from DIF_initial_fill procedure

#*********************************************************************
```

Appendix C. Output Values

/specs/gp/DIF_state_vrbls

```
#
#  DIF_state_vrbls
#
#  This file contains the desired values for all outputs as a
#  function of the SystemState

HORIZONTAL_LABELS

#
# Key to states
#
#                  Tank
#
# State   Mixing   Day      Return
#
#   0     Empty    Empty     Empty
#   1     Empty    Empty    Normal
#   2     Empty    Empty      Full
#
#   10    Empty   Normal     Empty
#   11    Empty   Normal    Normal
#   12    Empty   Normal      Full
#
#   20    Empty     Full     Empty
#   21    Empty     Full    Normal
#   22    Empty     Full      Full
#
#  100   Normal    Empty     Empty
#  101   Normal    Empty    Normal
#  102   Normal    Empty      Full
#
#  110   Normal   Normal     Empty
#  111   Normal   Normal    Normal
#  112   Normal   Normal      Full
#
#  120   Normal     Full     Empty
#  121   Normal     Full    Normal
#  122   Normal     Full      Full
#
#  200     Full    Empty     Empty
#  201     Full    Empty    Normal
#  202     Full    Empty      Full
#
#  210     Full   Normal     Empty
#  211     Full   Normal    Normal
#  212     Full   Normal      Full
#
```

```
#  220     Full     Full     Empty
#  221     Full     Full    Normal
#  222     Full     Full      Full
#

#
       TransferPump MixTankMixer DayTankMixer EngineSupply EstopOut
Next SystemMsg
          none           none         none         none         none
none   none


#SysState    Transfer M_Mix D_Mix Engine Estop  Next   SystemMessage

    0         OFF      OFF  OFF  OFF      ON    480  'Initial state -
wait for initial fill command'
    1         OFF      ON   ON   ON       ON    450  'Meter dust for
new batch'
    2         OFF      OFF  OFF  OFF      ON    400  'Abort - return
tank filled unexectedly'

    10        OFF      ON   ON   ON       ON    450  'Meter dust for
new batch'
    11        OFF      ON   ON   ON       ON    450  'Meter dust for
new batch'
    12        OFF      ON   ON   ON       OFF   400  'Abort - return
tank unexpectedly full'

    20        OFF      ON   ON   ON       ON    450  'Meter dust for
new batch'
    21        OFF      ON   ON   ON       ON    450  'Meter dust for
new batch'
    22        OFF      ON   ON   ON       OFF   400  'Abort - return
tank unexpectedly full'

   100        ON       ON   ON   ON       ON    460  'Refilling day
tank'
   101        ON       ON   ON   ON       ON    460  'Refilling day
tank'
   102        OFF      ON   ON   ON       OFF   400  'Abort - day tank
unexpectedly empty'

   110        OFF      ON   ON   ON       ON    10   'Normal
operation'
   111        OFF      ON   ON   ON       ON    10   'Normal
operation'
   112        OFF      ON   ON   ON       OFF   400  'Abort - return
tank unexpectedly full'
```

```
   120         OFF       ON    ON    ON        ON     10    'Normal
operation'
   121         OFF       ON    ON    ON        ON     10    'Normal
operation'
   122         OFF       ON    ON    ON        OFF    400   'Abort - return
tank unexpectedly full'

   200         ON        ON    ON    ON        ON     460   'Refilling day
tank'
   201         ON        ON    ON    ON        ON     460   'Refilling day
tank'
   202         OFF       ON    ON    ON        OFF    400   'Abort - return
tank unexpectedly full'

   210         OFF       ON    ON    ON        ON     10    'Normal
operation'
   211         OFF       ON    ON    ON        ON     10    'Normal
operation'
   212         OFF       ON    ON    ON        OFF    400   'Abort - return
tank unexpectedly full'

   220         OFF       ON    ON    ON        ON     10    'Normal
operation'
   221         OFF       ON    ON    ON        ON     10    'Normal
operation'
   222         OFF       ON    ON    ON        OFF    400   'Abort - return
tank unexpectedly full'
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Appendix D. List of Electrical and Mechanical Drawings

The drawings listed below are available separately from SGS.

Index	Drawing #	Description
1.0 Pipe & Instrument Diagram (P&ID)		
1.01	SEP-DR-I-101	SEP-PAD8 I6 FUEL CONT RIG P&ID AND CONTROL SEQUENCE
2.0 ELECTRICAL DRAWINGS		
2.01	65-00-000	SEP-PAD8 I6 FUEL CONT RIG 480VAC CABINET SECTION INDEX
2.02	65-00-002	SEP-PAD8 I6 FUEL CONT RIG 480VAC BILL OF MATRIALS
2.03	65-00-005	SEP-PAD8 I6 FUEL CONT RIG 480VAC GENERAL ARRANGEMENT
2.04	65-01-005	SEP-PAD8 I6 FUEL CONT RIG 480VAC AC POWER
2.05	66-00-000	SEP-PAD8 I6 FUEL CONT RIG 120VAC CABINET SECTION INDEX
2.06	66-00-002	SEP-PAD8 I6 FUEL CONT RIG 120VAC BILL OF MATRIALS
2.07	66-00-005	SEP-PAD8 I6 FUEL CONT RIG 120VAC GENERAL ARRANGEMENT
2.08	66-00-010	SEP-PAD8 I6 FUEL CONT RIG 120VAC TERMINAL STRIP DETAIL
2.09	66-01-005	SEP-PAD8 I6 FUEL CONT RIG 120VAC AC POWER
2.10	67-00-000	SEP-PAD8 I6 FUEL CONT RIG CONTROLS CABINET SECTION INDEX
2.11	67-00-002	SEP-PAD8 I6 FUEL CONT RIG CONTROLS CABINET BILL OF MATRIALS (1OF2)
2.12	67-00-003	SEP-PAD8 I6 FUEL CONT RIG CONTROLS CABINET BILL OF MATRIALS (2OF2)
2.13	67-00-005	SEP-PAD8 I6 FUEL CONT RIG CONTROLS CABINET GENERAL ARRANGEMENT
2.14	67-00-007	SEP-PAD8 I6 FUEL CONT RIG CONTROLS CABINET SUBPANEL ARRANGEMENT
2.15	67-00-010	SEP-PAD8 I6 FUEL CONT RIG CONTROLS CABINET TERMINAL STRIP DETAIL
2.16	67-02-005	SEP-PAD8 I6 FUEL CONT RIG CONTROLS CABINET 24VDC POWER
2.17	67-03-005	SEP-PAD8 I6 FUEL CONT RIG CONTROLS SNAP RACK 1
2.18	67-03-010	SEP-PAD8 I6 FUEL CONT RIG CONTROLS SNAP RACK 1; SLOTS 0-3
2.19	67-03-015	SEP-PAD8 I6 FUEL CONT RIG CONTROLS SNAP RACK 1; SLOTS 4-7
2.20	67-03-020	SEP-PAD8 I6 FUEL CONT RIG CONTROLS SNAP RACK 1; SLOTS 8-11
2.21	67-03-025	SEP-PAD8 I6 FUEL CONT RIG CONTROLS SNAP RACK 1; SLOTS 12-15

Index	Drawing #	Description
2.22	67-12-005	SEP-PAD8 I6 FUEL CONT RIG CONTROLS MIXING CONTROLS
2.23	67-12-010	SEP-PAD8 I6 FUEL CONT RIG CONTROLS MIXING VFDs
2.24	67-12-015	SEP-PAD8 I6 FUEL CONT RIG CONTROLS PARTICLE COUNTER COMM
2.25	68-00-000	SEP-PAD8 I6 FUEL CONT RIG REMOTE PARTICLE COUNTER CABINET SECTION INDEX
2.26	68-00-002	SEP-PAD8 I6 FUEL CONT RIG REMOTE PARTICLE COUNTER BILL OF MATERIALS
2.27	68-00-005	SEP-PAD8 I6 FUEL CONT RIG REMOTE PARTICLE COUNTER GENERAL ARRANGEMENT
2.28	68-00-010	SEP-PAD8 I6 FUEL CONT RIG REMOTE PARTICLE COUNTER TERMINAL STRIP DETAIL
3.0 MECHANICAL DRAWINGS		
3.01	14-7305-000	SEP-PAD8 I6 FUEL CONT RIG BILL OF MATERIAL (BOM)
3.02	14-7305-001	SEP-PAD8 I6 FUEL CONT RIG DUST RIG PDF INTERACTIVE 3D MODEL
3.03	14-7305-001	SEP-PAD8 I6 FUEL CONT RIG REMOTE PARTICLE COUNTER PDF INTERACTIVE 3D MODEL