LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY
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Hanford EPICS Vacuum Controls Cryogenic Pump Test Specifications

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Hanford CDS, Operators, Vacuum and PSI

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Hanford EPICS Vacuum Controls Test Specifications

SYSTEM TESTED: _____

SOFTWARE TESTED: _____

HARDWARE CONFIGURATION:

Equipment List	Date	Revision	Serial Number

TESTED BY:

Name	Title	Date

TESTS COMPLETED:

Test Name	Sign Off	Date

APPROVED BY:

Signature	Date

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1 Introduction

The Cryogenic Pump is used as a high capacity, high vacuum pump in all of the Hanford Vacuum Areas. The CPs are fed with liquid nitrogen (LN2) from large capacity dewars located immediately outside of the building.

Each CP can be isolated from the rest of the vacuum system with two Gate Valves, also known as isolation valves.

During normal pumping operations, CPs are kept full of LN2. The boil off LN2 rate is matched with a fill rate, keeping the CPs at LN2 temperatures and therefore pumping on the vacuum system.

Cryogenic pumps need to be regenerated after a period of running time. To regenerate a pump, it is first isolated from the rest of the vacuum system. The LN2 supply is stopped, and the CP is allowed to warm up to room temperature. It is then heated above room temperature by sending heated gaseous Nitrogen through the pump. Regeneration continues until all of the trapped molecules are released from the pump's surface. The pump is returned to normal conditions by allowing it to cool, and then bringing it down to LN2 temperatures by opening the LN2 supply value.

Each cryopump supplies four analog and two digital signals. The analog signals are:

- Cryopump LN2 Level (4 - 20 mA representing 0 - 100 % Full)
- Regeneration Heater Temperature (4 - 20 mA representing 0 - 250 Deg. C)
- Discharge Line Pressure (4 - 20 mA representing 0 - 25 PSIG)
- Dewar LN2 Level (4 - 20 mA representing 0 - 100 % Full)

The digital signals are:

- Cryopump Level Control Valve Closed (high represents Valve Closed state)
- Cryopump Regeneration Heater Overtemp Alarm (high represents OK, low represents Overtemp state)

The control system sends two analog and one digital signal to each cryopump. These signals are:

- Cryopump Level Control Valve (4 - 20 mA represents 0 - 100 % Open)
- Cryopump Regeneration Heater Control Temperature (4 - 20 mA represents 0 - 200 Deg. C)
- Cryopump Level Control Valve Enable (0V = Closed, 24V = Open)

1.1. Purpose

This document is the test specification for the EPICS controls of this device. With the EPICS system running in simulation mode, this test spec. allows the user to fully test the control system functionality with no impact on PSI. In non-simulation mode, both the EPICS controls, the PSI interface and the Cryopump itself can be tested.

1.2. Test Description

The Cryopump database will be tested in three phases:

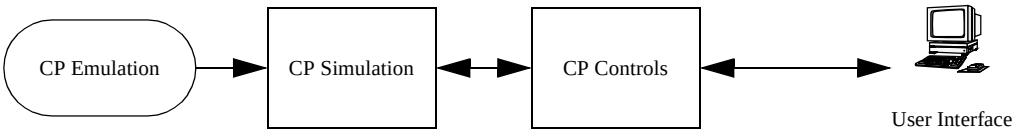
- Simulation mode.
- Non-simulation mode, not connected to PSI wiring.
- Non-simulation mode, fully connected to PSI wiring.

THE TEST MAY ONLY BE RUN FULLY CONNECTED TO PSI WIRING WHEN PSI AND CALTECH VACUUM MANAGEMENT HAVE GIVEN EXPRESS PERMISSION TO DO SO. Ignoring this warning may cause damage to the Cryopump and the Vacuum System. **Remember, the cryopump contains potentially lethal cryogenic liquids.**

In simulation mode the user can only test the basics of database execution. In non-simulation mode the user will inject voltages to emulate the PSI wiring. Output voltages and/or currents will be measured.

When running directly to the PSI vacuum system, the actual operation of the cryopump will be tested. These tests will be performed with the Hanford Vacuum team and PSI.

In simulation mode, all input and output from/to hardware are simulated by an additional EPICS database. Also, the consumption of LN2 from the Dewar is emulated by an additional sequencer which drives the simulation records in such a manner as to emulate LN2 consumption over a period of time.



This document will show testing of the Right Mid Station Cryopump 5. Replace this name with the name of the pump you are testing.

1.3. Test Initialization

The user must have booted the IOC with the correct EPICS databases for the system to be tested. It is assumed throughout this document that the user is familiar with EPICS configuration and operation.

The cryopump uses the sequencer object code, HVE_MX_CP5LNRATE.o, to calculate the consumption rate of LN2 in the dewar. The emulation system uses HVE_MX_CP5ELNE.o to emulate the flow of the LN2 from the dewar to the cryopump over a selected period of time and dependent on the percent open of the control valve. The cryopump database also contains a subroutine record whose procedure is defined in VE_CP_LVLCNTRL.o. This object provides code to automatically control the LN2 level in the cryopump by adjusting the control valve percent open/close.

1.3.1. Simulation Mode

The following database files must be loaded and initialised:

HVE-MX:CP5.db

HVE-MX:CP5S.db

HVE-MX:CP5E.db

HVE-MX:X1S.db

HVE-MX:X2S.db

HVE-MX:X3S.db

HVE-MX:GV13.db

HVE-MX:GV13S.db

HVE-MX:GV14.db

HVE-MX:GV14S.db

The following sequencers must be loaded and running:

HVE_MX_CP5LNRATE.st

HVE_MX_CP5ELNE.st

HVE_MX_GV13OPEN.st

HVE_MX_GV13GVEE.st

HVE_MX_GV14OPEN.st

HVE_MX_GV14GVEE.st

The following MEDM screens must be running. All widgets must be connected to the database:

HVE-MX:CP5.adl

HVE-MX:CP5S.adl

HVE-MX:CP5EE.adl

HVE-MX:GV13.adl

HVE-MX:GV13E.adl

HVE-MX:GV14.adl

HVE-MX:GV14E.adl

HVE-MX:X1S.adl

HVE-MX:X2S.adl

HVE-MX:X3S.adl

The following Alarm Handler file must be running:

Vac.alhConfig

1.3.2. Non-Simulation Mode, Not Connected to PSI Wiring

Ensure all signals are disconnected to PSI. The user is required to inject constant current into the Cryopump controls (4 - 20mA range), emulate relay contact closures and measure output voltages in the 0 - 24V range and measure output current from 4-20 mA.

(QT) Tests marked with this symbol and are underlined define a Quick Test. Quick Tests allow the user to just test the hardware interface to the EPICS controls, and not test the control logic itself.

1.3.3. Non-Simulation Mode, Full Connection to PSI Wiring

These tests will be performed with Hanford Operators, Hanford Vacuum management and PSI. They will be fully coordinated with these teams and will only proceed with the express permission of all parties. Full lock and tag procedures will be followed.

THIS TEST WILL ONLY PROCEED WHEN IT IS DEEMED SAFE TO DO SO.

All PSI wiring will be attached to the PSI interface wiring block.

THESE TEST SPECS ARE TO BE DETERMINED.

1.3.4. Data Tables

Attached to this Test Spec are two data tables:

Table 1: PSI Signal Matrix for Hanford Cryogenic Pumps. This specifies the PSI interface connectors used by all the Cryopumps at the Hanford site.

Table 2: Signal Data Matrix for Hanford Cryogenic Pumps. This specifies the cryopump input and output signal limits, units, engineering conversions and alarm limits.

	PASS	FAIL	COMMENTS

2 Testing in Simulation Mode

2.1. Test Setup

2.1.1. Run the Alarm Handler with the alarm configuration file appropriate for the Cryopump being tested.

- Acknowledge all outstanding alarms (e.g. Interlocks or out of range inputs). Refer to Table 2: Signal Data Matrix for Hanford Cryogenic Pumps for a list of all signal levels.

2.1.2. On all the simulation screens, switch the databases into simulation mode by pushing the Sim On button.

- Verify the simulation is on and the simulated signals have entered the SIMULATION alarm state (foreground colours set to YELLOW and a MINOR alarm on the alarmhandler).

2.1.3. On the gate valve screens set the cold cathode gauges to ON.

2.1.3.0.a On the gauge pair simulation screens set the Pirani voltages to 0.39 and the Cold Cathode voltages to 5.0.

- Confirm that the gauge pair interlocks, on the gate valve main screens are in their "Good" (green) state.

2.1.3.0.b Iconize the gate valve and gauge pair screens.

2.1.4. On the cryopump simulation screen, enter 90 into the Dewar LN2 Level.

2.2. Test Cryopump Initial Fill

2.2.1. Test Discharge Line Pressure and Alarms

In the following tests the user will simulate the cryogenic pump Discharge Line Pressure input from PSI. The user will check that the interlocks and alarms operate according to their stated ranges and that the Control Valve between the Dewar and the cryopump can't be opened in an alarm state.

The Discharge Line Pressure has a range from 0 to 25 PSIG. MAJOR alarms are set for a low PSIG of 2.0 and below and a high PSIG of 12.0 and greater. MINOR alarms which will prevent the Control Valve from being opened are set between 10.0 and 12.0.

2.2.1.1 Simulate invalid Discharge Line Pressure (below valid range).

2.2.1.1.a You will check the following during this test:

- Verify the Discharge Line Pressure on the main screen changes to the value entered.
- Verify both of the Initial Fill interlocks on the main screen are red.
- Verify the Valve Open Enable on the simulation screen reads Closed.
- Verify on the main screen and the alarm handler this signal goes into a MAJOR alarm state.

	PASS	FAIL	COMMENTS

2.2.1.1.b Enter 0.0 PSIG on the simulation screen, then press the Valve Open Request button on the main screen.

2.2.1.2. Simulate invalid Discharge Line Pressure (MINOR alarm).

2.2.1.2.a You will check the following during this test:

- Verify the Discharge Line Pressure on the main screen changes to the value entered.
- Verify both of the Initial Fill interlocks on the main screen are red.
- Verify the Valve Open Enable on the simulation screen reads Closed.
- Verify on the main screen and the alarm handler this signal stays in a SIMULATION alarm state.

2.2.1.2.b Enter 10.0 PSIG on the simulation screen, then press the Valve Open Request button on the main screen.

2.2.1.3. Simulate invalid Discharge Line Pressure (MAJOR alarm).

2.2.1.3.a You will check the following during this test:

- Verify the Discharge Line Pressure on the main screen changes to the value entered.
- Verify both of the Initial Fill interlocks are red.
- Verify the Valve Open Enable widget on the simulation screen reads Closed.
- Verify on the main screen and the alarm handler this signal goes into a MAJOR alarm state.

2.2.1.3.b Enter 12.0 PSIG on the simulation screen, then press the Valve Open Request button on the main screen.

2.2.1.4. Simulate valid Discharge Line Pressure (middle of valid range).

2.2.1.4.a You will check the following during this test:

- Verify the Discharge Line Pressure on the main screen changes to the value entered.
- Verify both of the Initial Fill interlocks on the main screen are green.
- Verify the Valve Open Enable on the simulation screen reads Open.
- Verify on the main screen and the alarm handler this signal goes into a SIMULATION alarm state.

2.2.1.4.b Enter 4.0 PSIG on the simulation screen, then press the Valve Open Request button on the main screen.

2.2.2. Test Valve Open/Close Request.

Reset the PSIG value on the simulation screen to 4.0. Press the Valve Open Request button on the main screen. The Valve Open Enable on the simulation screen should read Open.

2.2.2.1. Test Valve Close Request.

2.2.2.1.a You will check the following during this test:

	PASS	FAIL	COMMENTS

- Verify that the Valve Open Interlock on the main screen changes to red.
- Verify that the Valve Open Enable on the simulation screen reads Closed.

2.2.2.1.b On the main screen press the Valve Close Request button.

2.2.2.2. Test Valve Open Request.

2.2.2.2.a You will check the following during this test:

- Verify that the Valve Open Interlock on the main screen changes to green.
- Verify that the Valve Open Enable on the simulation screen reads Open.

2.2.2.2.b On the main screen press the Valve Open Request button.

2.2.2.3. Test Valve Open and Gauge Pair Interlock (faulted).

2.2.2.3.a You will check the following during this test:

- Verify that the Valve Open Interlock, on the cryopump main screen changes to red.
- Verify that the Valve Open Enable on the simulation screen reads Closed.

2.2.2.3.b Bring up the X2S screen. On the X2S screen, set the Cold Cathode voltage to 7.0.

2.2.2.4. Test Valve Open and Gauge Pair Interlock (valid).

2.2.2.4.a You will check the following during this test:

- Verify that the interlock on the cryopump screen returns to green.
- Verify that the Valve Open Enable on the simulation screen reads Open.

2.2.2.4.b Reset the X2S Cold Cathode voltage to 5.0. On the cryopump main screen press the Valve Open Request button.

2.2.2.4.c Iconize the X2S screen.

2.2.2.5. Test Valve Open and Dewar Low Level Interlocks (below valid range).

The Level Control Valve cannot be opened and MAJOR alarms are set when the Dewar level is below 10.0 % Full.

2.2.2.5.a You will check the following during this test:

- Verify that the Dewar Low Level Interlock on the main screen changes to red.
- Verify that the Valve Open Interlock on the main screen changes to red.
- Verify that the Valve Open Enable on the simulation screen reads Closed.
- Verify that the Dewar LN2 Level on the main screen and on the alarm handler goes into a MAJOR alarm state.

2.2.2.5.b On the cryopump simulation screen, enter 5.0 into the Dewar LN2 Level.

2.2.2.6. Test Valve Open and Dewar Low Level Interlocks (valid range).

2.2.2.6.a You will check the following during this test:

- Verify that the Dewar Low Level Interlock on the main screen changes to

	PASS	FAIL	COMMENTS

green.

- Verify that the Valve Open Interlock on the main screen changes to green.
- Verify that the Valve Open Enable on the simulation screen reads Open.
- Verify that the Dewar LN2 Level on the main cryopump screen and on the alarm handler returns to a SIMULATION alarm state.

2.2.2.6.b On the cryopump simulation screen, enter 11.0 into the Dewar LN2 Level. Press the Valve Open Request button on the main screen.

2.3. Test Normal Operation

2.3.1. Test Pump LN2 Level and Alarms.

Set the Dewar LN2 Level on the simulation screen to 100% Full.

The LN2 level in the Cryopump has a MAJOR alarm set for a high of 99.0 % Full and greater and a low of 83.0 % Full and less. MINOR alarms are set at 98.0 % and 84.0 %.

The user will simulate changes in the LN2 level and will test the alarm limits. The manual and automatic control of the Dewar Valve % Open will be tested with the emulation software.

2.3.1.1 Simulate invalid Pump LN2 Level (below valid range).

2.3.1.1.a You will check the following during this test:

- Verify that the Pump LN2 Level on the main screen is 83.0.
- Verify that this signal on the main screen and on the alarm handler goes into a MAJOR alarm state.

2.3.1.1.b On the simulation screen, enter 83.0 into the Pump LN2 Level.

2.3.1.2. Simulate invalid Pump LN2 Level (above valid range).

2.3.1.2.a You will check the following during this test:

- Verify that the Pump LN2 Level widget on the main screen changes to 99.0.
- Verify that this signal on the main screen and on the alarm handler goes into a MAJOR alarm state.

2.3.1.2.b On the simulation screen, enter 99.0 into the Pump LN2 Level.

2.3.1.3. Simulate valid Pump LN2 Level.

2.3.1.3.a You will check the following during this test:

- Verify that the Pump LN2 Level widget on the main screen changes to 90.0.
- Verify that this signal on the main screen and on the alarm handler goes into a SIMULATION alarm state.

2.3.1.3.b On the simulation screen, enter 90.0 into the Pump LN2 Level.

	PASS	FAIL	COMMENTS

2.3.2. Test Level Control Auto/Manual Selection.

2.3.2.1. Simulate output of LN2 Level Control (Manual).

2.3.2.1.a You will check the following during this test:

- Verify that the Level Cntrl Output Select on the main screen changes to 30.0.
- Verify that the LN2 Level Control Output on the simulation screen changes to 30.0.

2.3.2.1.b Press Manual on the Level Control Auto/Manual Selection button. On the main screen enter 30.0 into the Manual Level Control Valve Set.

2.3.2.2. Simulate output of LN2 Level Control (Auto).

The Auto Control subroutine will automatically change the Auto Level Control Valve from 40 % Open when the Pump LN2 Level drops to 84 % Full and to 10 % Open when the Pump LN2 Level climbs back up to 96 % Full.

On the simulation screen reset the Pump LN2 Level to 96.0 and the Dewar LN2 Level to 100.0 %.

2.3.2.2.a You will check the following during this test:

- Verify that the Auto Level Control Valve Set and Level Cntrl Output Select on the main screen is at 10.0.
- Verify the LN2 Level Control Output on the simulation screen is 10.0.
- As the emulation runs verify that the Pump LN2 Level on the main screen decreases until it reaches 84.0 %.
- At 84.0 % verify that the Auto Level Control Valve Set and Level Cntrl Output Select on the main screen change to 40.0.
- Verify the LN2 Level Control Output on the simulation screen changes to 40.0.
- Verify that the Pump LN2 Level on the main screen then increases until it reaches 96.0 %.
- Verify that the Auto Level Control Valve Set and Level Cntrl Output Select on the main screen is again 10.0.
- Verify the LN2 Level Control Output on the simulation screen is 10.0.

2.3.2.2.b Press Auto on the Level Control Auto/Manual Selection button. On the emulation screen, set the % increase to 20.0, the % decrease to 5.0, the time to run the emulation to 10 seconds, and press Go.

2.4. Test Dewar Monitor

2.4.1. Test Dewar Conversion of % Full to Gallons for large dewar.

2.4.1.0.a You will check the following during this test:

- Verify the Dewar LN2 Level changes to 100.0 and the Convert % Full to Gallons changes to 17260.0.

2.4.1.0.b On the simulation screen enter 100.0 in the Dewar LN2 Level.

	PASS	FAIL	COMMENTS

On the main screen, type 17260.0 in the Total capacity of dewar.

2.4.2. Test Dewar Conversion of % Full to Gallons for smaller dewar.

2.4.2.0.a You will check the following during this test:

- Verify the Convert % Full to Gallons changes to 14400.0.

2.4.2.0.b On the main screen, type in 14400.0 in the Total capacity of dewar.

2.4.2.1. Test Dewar Conversion of % Full to Gallons, Consumption Rate and Days to Tank Empty for smaller dewar at 90 %.

You will need a stopwatch for these tests.

2.4.2.1.a You will check the following during this test:

- On the main screen, verify the Dewar LN2 Level changes to 90.0 and the Convert % Full to Gallons is 12960.0.
- Verify the LN2 Consumption Rate reads 1440.0, within 5 seconds.
- Verify the Dewar Days to Tank Empty reads 5.21e-04, within 5 seconds.

2.4.2.1.b On simulation screen type in 90.0 in the Dewar LN2 Level.

2.4.2.2. Test Dewar Conversion of % Full to Gallons, Consumption Rate and Days to Tank Empty for smaller dewar at 50 %.

2.4.2.2.a You will check the following during this test:

- On the main screen, verify the Dewar LN2 Level changes to 50.0 and the Convert % Full to Gallons is 7200.0.
- Verify the LN2 Consumption Rate reads 5760.0, within 5 seconds.
- Verify the Dewar Days to Tank Empty reads 7.23e-05, within 5 seconds.

2.4.2.2.b On simulation screen type in 50.0 in the Dewar LN2 Level.

2.4.2.3. Test Dewar Conversion of % Full to Gallons, Consumption Rate and Days to Tank Empty for smaller dewar at 20 %.

2.4.2.3.a You will check the following during this test:

- On the main screen, verify the Dewar LN2 Level changes to 20.0 and the Convert % Full to Gallons is 2880.0.
- Verify the LN2 Consumption Rate reads 4320.0, within 5 seconds.
- Verify the Dewar Days to Tank Empty reads 3.86e-05, within 5 seconds.

2.4.2.3.b On simulation screen type in 20.0 in the Dewar LN2 Level.

2.4.2.4. Emulate Dewar LN2 consumption from 100 % to 20 % Full at a 20 % decrease every 5 seconds.

2.4.2.4.a You will check the following during this test:

- As the emulation runs, verify the Convert % Full to Gallons transitions from 14400.0 to 2880.0.
- Verify the LN2 Consumption Rate reads 2880.0 after 5 seconds.

	PASS	FAIL	COMMENTS

- Verify the Dewar Days to Tank Empty reads 2.20e-04 after 5 seconds

2.4.2.4.b On the simulation screen, enter 96.0 into the Pump LN2 Level and 100.0 into the Dewar LN2 Level. On the main screen Press Manual and enter 50.0 into the Manual Level Control Valve Set. On the emulation screen, set the % increase to 8.0, the % decrease to 4.0, the time to run the emulation to 20 seconds, and press Go.

2.5. Test Regen Control

2.5.1. Test Regen Loop Overtemp Alarm, Valve Closed, Regen Heater Interlock and Regen Start/Stop.

The Regen Loop Overtemp Alarm = OK when set high (1) and Overtemp when low (0). The Valve Closed relay is Closed when high (1) and open when low (0).

2.5.1.1. Simulate Regen Loop Overtemp Alarm and Valve Closed (low = 0).

2.5.1.1.a You will check the following during this test:

- Verify that the Valve Closed widget, on the main screen, reads "Open".
- Verify that the Regen Heater Interlock on the main screen is red.
- Verify that the Regen Heater Setpoint Filter on the main screen and the Regen Heater Control Output on the simulation screen are zero.
- Verify that the Regen Loop Overtemp Alarm signal on the main cryopump screen and on the alarm handler is in a MAJOR alarm state.

2.5.1.1.b Set both the Regen Loop Overtemp Alarm and Valve Closed widget on the simulation screen to zero.

2.5.1.2. Test Regen Heater Control Output with Overtemp Alarm and Valve Open

2.5.1.2.a You will check the following during this test:

- Verify that Regen Heater Setpoint Filter on the main screen and the Regen Heater Control Output on the simulation screen remain zero.

2.5.1.2.b Set the Regen Heater Setpoint on the main screen to 150. Press the Regen Heater Start button on the main screen.

2.5.1.3. Simulate Regen Loop Overtemp Alarm and Valve Closed (high=1)

2.5.1.3.a You will check the following during this test:

- Verify that the Overtemp Alarm on the main screen reads "Normal".
- Verify that the Valve Closed widget on the main screen reads"Closed".
- Verify that the Regen Heater Interlock on the main screen is green.
- Verify that Regen Heater Setpoint Filter on the main screen and the Regen Heater Control Output on the simulation screen both change to 150.0.

2.5.1.3.b Set both the Regen Loop Overtemp Alarm and Valve Closed widgets on the simulation screen to one. Press the Regen Heater Start button on the main screen.

2.5.1.4. Test Regen Heater Start/Stop.

	PASS	FAIL	COMMENTS

2.5.1.4.a You will check the following during this test:

- Verify that Regen Heater Setpoint Filter on the main screen and the Regen Heater Control Output on the simulation screen return to 0.0.

2.5.1.4.b On the main screen, press the Regen Heater Stop button.

2.5.1.5. Test Regen Heater Interlock (Gate Valve Open).

2.5.1.5.a You will check the following during this test:

- Verify that the Regen Heater Interlock on the main cryopump screen changes to red.
- Verify that the Regen Heater Setpoint Filter on the main screen and the Regen Heater Control Output on the simulation screen are zero.

2.5.1.5.b Bring up the GV13 main screen. On the GV13 screen, open the gate valve.

2.5.1.6. Test Regen Heater Interlock (Gate Valve Closed).

2.5.1.6.a You will check the following during this test:

- Verify that the Regen Heater Interlock on the main screen is green.
- Verify that Regen Heater Setpoint Filter on the main screen and the Regen Heater Control Output on the simulation screen both change to 150.0.

2.5.1.6.b On the GVI3 screen, close the gate valve. On the main cryopump screen, press the Regen Heater Start button.

2.5.1.6.c Iconize the GV13 screen.

2.5.2. Test Regen Loop Temperature and Alarms.

The Regen Loop Temperature has a range from 0 to 250 degrees C. Major alarms are set for 200 degrees and Minor alarms for 195 degrees. The Regen Heater Control Output record has a DRVH field set at 200 to prevent the output from going above 200 degrees.

2.5.2.1. Test Regen Loop Temperature Minor Alarm state.

2.5.2.1.a You will check the following during this test:

- Verify that the Regen Heater Interlock on the main screen changes to red.

2.5.2.1.b On the simulation screen enter a Regen Loop Temperature of 195.

2.5.2.2. Test Regen Loop Temperature Major Alarm state.

2.5.2.2.a You will check the following during this test:

- Verify that the Regen Heater Interlock on the main screen stays red.
- Verify the Regen Loop Temperature signal on the main cryopump screen and on the alarm handler is in a MAJOR alarm state.

2.5.2.2.b On the simulation screen enter a Regen Loop Temperature of 200.

2.5.2.3. Test valid Regen Loop Temperature.

	PASS	FAIL	COMMENTS

2.5.2.3.a You will check the following during this test:

- Verify that the Regen Heater Interlock on the main screen changes to green.

2.5.2.3.b On the simulation screen enter a Regen Loop Temperature of 150.

2.5.2.4. Test Regen Heater Setpoint and DRVH field (invalid).

2.5.2.4.a You will check the following during this test:

- Verify that the Regen Heater Setpoint Filter on the main screen changes to 300.
- Verify the Regen Heater Control Output on the simulation screen stays at 200.

2.5.2.4.b On the main screen, enter 300 into the Regen Heater Setpoint, then press the Regen Heater Start button.

2.5.2.5. Test Regen Heater Setpoint and DRVH field (valid).

2.5.2.5.a You will check the following during this test:

- Verify that the Regen Heater Setpoint Filter on the main screen and the Regen Heater Control Output on the simulation screen change to 150.

2.5.2.5.b On the main screen, enter 150 into the Regen Heater Setpoint, then press the Regen Heater Start button.

	PASS	FAIL	COMMENTS

3 Testing in Non-simulation Mode, Not Connected to PSI

3.1. Test Setup

3.1.1. Items needed to perform these tests:

3 sources of constant current ranging from 4-20 mA

1 DVM

cables necessary to connect to PSI DIN-rail connectors

shorting cables

Refer to Table 1: PSI Signal Matrix for Hanford Cryogenic Pump System for the PSI DIN-rail connector numbers for each signal.

3.1.2. Complete test setup requires:

one current source connected to the PSI connectors for the Dewar LN2 Level

one current source connected to the PSI connectors for the Pump LN2 Level

one current source connected to the PSI connectors for the Discharge Line Pressure

two shorting connectors will be needed to short the Regen Loop Overtemp Alarm and Valve Closed solenoid

connect the DVM first to the Valve Open Enable lines at the PSI interface, then to the Pump LN2 Level Out lines, and later to the Regen Heater Out lines.

3.1.3. Ensure Gate Valves and Gauge Pairs have been set up for simulation mode testing.

3.1.4. Inject 20 mA into the PSI Connectors for the Dewar LN2 Level, so that the level is 100 % Full (+/- 2%).

3.1.5. Short the WDT between 1 and 2.

3.2. Test Cryopump Initial Fill

For this test you need a DVM to be used on the DC Voltage 0 - 24V range, connected to the Valve Open Enable lines at the PSI interface.

In the following tests the user will emulate the cryogenic pump Discharge Line Pressure input voltage from PSI. The user will check that the interlocks and alarms operate according to their stated ranges and that the Control Valve between the Dewar and the cryopump can't be opened in an alarm state.

The Discharge Line Pressure has a range from 0 to 25 PSIG. MAJOR alarms are set for a low PSIG of 2.0 and below and a high PSIG of 12.0 and greater. MINOR alarms which will prevent the Control Valve from being opened are set between 10.0 and 12.0.

	PASS	FAIL	COMMENTS

3.2.1. Test Discharge Line Pressure and Alarms.

3.2.1.1. Emulate invalid Discharge Line Pressure (Major alarm, above valid range).

3.2.1.1.a You will check the following during this test:

- Verify the Discharge Line Pressure on the main screen is 25.0 (+/- 1.0) PSIG.
- Verify that both of the Initial Fill interlocks are red.
- Verify that this signal on the main screen and on the alarm handler goes into a MAJOR alarm state.
- Verify the DVM connected to the Valve Open Enable line at the PSI interface is reading 0V.

3.2.1.1.b Inject 20 mA into the PSI Connector for the Discharge Line Pressure, then press the Valve Open Request button on the main screen.

3.2.1.2. Emulate invalid Discharge Line Pressure (Minor alarm, above valid range).

3.2.1.2.a You will check the following during this test:

- Verify the Discharge Line Pressure on the main screen is 10.6 (+/- 0.2) PSIG.
- Verify that both of the Initial Fill interlocks are red.
- Verify that this signal on the main screen and on the alarm handler is in a MINOR alarm state.
- Verify the DVM connected to the Valve Open Enable line at the PSI interface is reading 0V.

3.2.1.2.b Inject 10.8 mA into the PSI Connector for the Discharge Line Pressure, then press the Valve Open Request button on the main screen.

3.2.1.3. Emulate invalid Discharge Line Pressure (invalid signal, MAJOR alarm).

3.2.1.3.a You will check the following during this test:

- Verify the Discharge Line Pressure on the main screen is 0.0 (+/- 0.2) PSIG.
- Verify that both of the Initial Fill interlocks are red.
- Verify that this signal on the main screen and on the alarm handler is in a MAJOR alarm state.
- Verify the DVM connected to the Valve Open Enable line at the PSI interface is reading 0V

3.2.1.3.b Inject 4.0 mA into the PSI Connector for the Discharge Line Pressure, then press the Valve Open Request button on the main screen.

3.2.1.4. Emulate Discharge Line Pressure (valid range).

QT

3.2.1.4.a You will check the following during this test:

- Verify the Discharge Line Pressure on the main screen is 6.0 (+/- 1.0)

	PASS	FAIL	COMMENTS

PSIG.

- Verify that both of the Initial Fill interlocks are green.
- Verify that this signal on the main screen and on the alarm handler shows no alarms.
- (QT) Verify the DVM connected to the Valve Open Enable line at the PSI interface is reading 24V.

3.2.1.4.b Inject 8 mA into the PSI Connector for the Discharge Line Pressure, then press the Valve Open Request button on the main screen.

3.2.2. Test Valve Open/Close Request

3.2.2.1. Test Valve Close Request.

3.2.2.1.a You will check the following during this test:

- Verify that the Valve Open Interlock on the main screen changes to red.
- Verify the DVM connected to the Valve Open Enable line at the PSI interface is reading 0V.

3.2.2.1.b On the main screen press the Valve Close Request button.

3.2.2.2. Test Valve Open Request.

3.2.2.2.a You will check the following during this test:

- Verify that the Valve Open Interlock on the main screen changes to green.
- Verify the DVM connected to the Valve Open Enable line at the PSI interface is reading 24V.

3.2.2.2.b On the main screen press the Valve Open Request button.

3.2.2.3. Test Valve Open and Gauge Pair Interlock (faulted).

3.2.2.3.a You will check the following during this test:

- Verify that the Valve Open Interlock, on the cryopump main screen changes to red.
- Verify that the DVM connected to the Valve Open Enable line at the PSI interface is reading 0V.

3.2.2.3.b Bring up the X2S screen. On the X2S screen, set the Cold Cathode voltage to 7.0.

3.2.2.4. Test Valve Open and Gauge Pair Interlock (valid).

3.2.2.4.a You will check the following during this test:

- Verify that the interlock on the cryopump screen returns to green.
- Verify that the DVM connected to the Valve Open Enable line at the PSI interface is reading 24V.

3.2.2.4.b On the X2S screen, set the Cold Cathode voltage to 5.0. Press the Valve Open Request button on the cryopump main screen.

3.2.2.4.c Iconize the X2S screen.

3.2.2.5. Test Valve Open and Dewar Low Level Interlocks (below valid

	PASS	FAIL	COMMENTS

range).

3.2.2.5.a You will check the following during this test:

- Verify that the Dewar Low Level Interlock and the Valve Open Interlock, on the cryopump main screen change to red.
- Verify that the Dewar LN2 Level signal on the main cryopump screen and on the alarm handler goes into a MAJOR alarm state.
- Verify that the DVM connected to the Valve Open Enable line at the PSI interface is reading 0V.

3.2.2.5.b Inject 5 mA into the PSI Connectors for the Dewar LN2 Level, so that the level is below 10 % Full.

3.2.2.6. Test Valve Open and Dewar Low Level Interlocks (valid range).

3.2.2.6.a You will check the following during this test:

- Verify that the Dewar Low Level Interlock and the Valve Open Interlock, on the cryopump main screen change to green.
- Verify that the Dewar LN2 Level signal on the main cryopump screen and on the alarm handler shows no alarms.
- Verify that the DVM connected to the Valve Open Enable line at the PSI interface is reading 24V.

3.2.2.6.b Inject 12 mA into the PSI Connectors for the Dewar LN2 Level, so that the level is 50 % Full. Press the Valve Open Request button, on the cryopump screen.

3.3. Test Normal Operation

3.3.1. Test Pump LN2 Level and Alarms.

3.3.1.1. Emulate invalid Pump LN2 Level (below valid range).

3.3.1.1.a You will check the following during this test:

- Verify that the Pump LN2 Level, on the main screen, is 0.0 (+/- 2.0).
- Verify that the Pump LN2 Level signal on the main cryopump screen and on the alarm handler goes into a MAJOR alarm state.

3.3.1.1.b Press Manual on the Level Control Auto/Manual Selection button, on the cryopump main screen. Inject 4 mA, so that the Pump LN2 Level is 0 % Full, into the PSI Connectors for the Pump LN2 Level.

3.3.1.2. Emulate invalid Pump LN2 Level (above valid range).

3.3.1.2.a You will check the following during this test:

- Verify that the Pump LN2 Level, on the main screen, changes to 100.0 (+/- 1.0).
- Verify that the Pump LN2 Level signal on the main cryopump screen and on the alarm handler goes into a MAJOR alarm state.

3.3.1.2.b Inject 20 mA, so that the Pump LN2 Level is 100 % Full, into the PSI Connectors for the Pump LN2 Level.

	PASS	FAIL	COMMENTS

3.3.1.3. Emulate Pump LN2 Level (valid range).

3.3.1.3.a You will check the following during this test:

QT
- Verify that the Pump LN2 Level, on the main screen, changes to 90.0 (+/- 1.0).
- Verify that the Pump LN2 Level signal on the main cryopump screen and on the alarm handler shows no alarms.

3.3.1.3.b Inject 19 mA, so that the Pump LN2 Level is 90 % Full, into the PSI Connectors for the Pump LN2 Level.

3.3.2. Test Level Control Auto/Manual Selection.

This test requires a DVM to be used on the constant current 4-20 mA range. Connect the DVM to the Pump LN2 Level Control Output line at the PSI interface.

3.3.2.1. Emulate output of LN2 Level Manual Control (0 % open).

3.3.2.1.a You will check the following during this test:

- Verify that the Level Cntrl Output Select, on the main screen, changes to 0.0.
- Verify that the DVM connected to the Pump LN2 Level Control Output line at the PSI interface is reading 4 mA.

3.3.2.1.b Press Manual on the Level Control Auto[Manual Selection button. Enter 0.0 into the Manual Level Control Valve Set widget.

3.3.2.2. Emulate output of LN2 Level Manual Control (100 % open).

3.3.2.2.a You will check the following during this test:

- Verify that the Level Cntrl Output Select, on the main screen, changes to 100.0.

QT
- Verify that the DVM connected to the Pump LN2 Level Control Output line at the PSI interface is reading 20 mA.

3.3.2.2.b Enter 100.0 into the Manual Level Control Valve Set widget.

3.3.2.3. Emulate output of LN2 Level Auto Control (10 % open).

3.3.2.3.a You will check the following during this test:

- Verify that the Auto Level Control Valve Set and Level Cntrl Output Select, on the main screen, change to 10.0.
- Verify that the DVM connected to the Pump LN2 Level Control Output line at the PSI interface is reading 5.0 (+/- 0.6) mA.

3.3.2.3.b Inject 19.2 mA, so that the Pump LN2 Level is 96 % Full, into the PSI Connectors for the Pump LN2 Level. Press Auto on the Level Control Auto/Manual Selection button.

3.3.2.4. Emulate output of LN2 Level Auto Control (40 % open).

3.3.2.4.a You will check the following during this test:

- Verify that the Auto Level Control Valve Set and Level Cntrl Output Select on the main screen changes to 40.0.

	PASS	FAIL	COMMENTS

- Verify that the DVM connected to the Pump LN2 Level Control Output line at the PSI interface is reading 10.0 (+/- 0.4) mA.

3.3.2.4.b Inject 17.4 mA, so that the Pump LN2 Level is 84 % Full, into the PSI Connectors for the Pump LN2 Level.

3.4. Test Dewar Monitor

3.4.1. Test Dewar Conversion of % Full to Gallons (High range).

3.4.1.0.a You will check the following during this test:

- On the main screen, verify the Dewar LN2 Level changes to 100.0(+/- 3.0) and the Convert % Full to Gallons is 14400.0 (+/- 300.0).

3.4.1.0.b Inject 20 mA, so that the Dewar LN2 Level is 100 % Full, into the PSI Connectors for the Dewar LN2 Level.

3.4.2. Test Dewar Conversion of % Full to Gallons (Low range).

3.4.2.0.a You will check the following during this test:

(QT)

- On the main screen, verify the Dewar LN2 Level changes to 20.0 (+/- 2.0) and the Convert % Full to Gallons is 2880.0 (+/- 200.0).

3.4.2.0.b Inject 7 mA, so that the Dewar LN2 Level is 20 % Full, into the PSI Connectors for the Dewar LN2 Level.

3.5. Test Regen Control

For this test the Regen Loop Temperature Thermocouple must be less than 195 degrees. This test requires a DVM to be used on the constant current 4-20 mA range, connected to the Regen Heater Control Output line at the PSI interface. Short the WDT between 3 and 4.

3.5.1. Test Regen Loop Overtemp Alarm, Valve Closed, Regen Heater Interlock and Regen Start/Stop.

Ensure that the Valve Closed, on the main screen, reads "Open". The Regen Heater Interlock on the main screen is red, and the Regen Loop Overtemp Alarm signal on the main cryopump screen reads Overtemp.

3.5.1.1. Emulate Regen Heater Control Output (interlocks faulted).

3.5.1.1.a You will check the following during this test:

- Verify that the Regen Heater Setpoint Filter on the main screen is zero.
- Verify that the DVM connected to the Regen Heater Control Output line at the PSI interface is reading 4 mA.

3.5.1.1.b Set the Regen Heater Setpoint on the main screen to 150. Press the Regen Heater Start button.

3.5.1.2. Emulate Regen Heater Control Output (interlocks valid, no start command).

3.5.1.2.a You will check the following during this test:

- Verify that the Regen Loop Overtemp Alarm on the main screen reads "Normal".

	PASS	FAIL	COMMENTS

- Verify that the Valve Closed widget on the main screen reads "Closed".
- Verify that the Regen Heater Interlock on the main screen is green.
- Verify that the DVM connected to the Regen Heater Control Output line at the PSI interface is still reading 4 mA.

3.5.1.2.b Short the PSI Connectors for the Regen Loop Overtemp Alarm and for the Valve Closed solenoid.

3.5.1.3. Emulate Regen Heater Control Output (interlocks valid, start command).

- Verify the Regen Heater Setpoint Filter on the main screen changes to 150.0.
- (QT) Verify that the DVM connected to the Regen Heater Control Output line at the PSI interface is reading 16 mA.

3.5.1.3.a Press the Regen Heater Start button on the cryopump main screen.

3.5.1.4. Emulate Regen Heater Control Output (stop command).

- Verify that Regen Heater Setpoint Filter on the main screen changes to 0.0.
- Verify that the DVM connected to the Regen Heater Control Output line at the PSI interface is reading 4 mA.

3.5.1.4.a Press the Regen Heater Stop button.

3.5.1.4.b Press the Regen Heater Start button.

3.5.1.5. Emulate Regen Heater Control Output (gate valve interlock faulted).

- Verify that the Regen Heater Interlock on the main cryopump screen changes to red.
- Verify that the Regen Heater Setpoint Filter on the main screen is zero.
- Verify that the Regen Heater Control Output line at the PSI interface is reading 4 mA.

3.5.1.5.a Bring up the GV13 screen. On the GV13 screen, open the gate valve. On the main cryopump screen, press the Regen Heater Start button.

3.5.1.6. Emulate Regen Heater Control Output (gate valve interlock valid).

- Verify that the Regen Heater Interlock on the main screen is green.
- Verify that Regen Heater Setpoint Filter on the main screen changes to 150.0.
- Verify that the Regen Heater Control Output line at the PSI interface is reading 16 mA.

3.5.1.6.a On the GVI3 screen, close the gate valve. On the main cryopump screen, press the Regen Heater Start button.

3.5.1.7. Test Regen Loop Temperature and Alarms.

This test requires a DVM to be used on the constant current 4-20 mA range. Connect the DVM to the Regen Heater Control Output line at the PSI interface.

	PASS	FAIL	COMMENTS

3.5.1.8. Emulate valid Regen Loop Temperature.

- Verify that the Regen Heater Interlock on the main screen changes to green.
- Verify that the Regen Loop Temperature signal on the main cryopump screen and on the alarm handler shows no alarms.

3.5.1.8.a The thermocouple temperature should be below 195 Deg. C, so that the Regen Loop Temperature is less than 195 ' C.

3.5.1.9. Test Regen Heater Setpoint and DRVH field (valid).

3.5.1.9.a You will check the following during this test:

- Verify that the Regen Heater Setpoint Filter changes to 200.
- Verify that the Regen Heater Control Output line at the PSI interface is reading 20 mA.

3.5.1.9.b On the main screen, enter 200 into the Regen Heater Setpoint widget.

3.5.1.10. Test Regen Heater Setpoint and DRVH field (invalid).

3.5.1.10.a You will check the following during this test:

- Verify that the Regen Heater Setpoint Filter on the main screen changes to 300.
- Verify that the Regen Heater Control Output line at the PSI interface is reading 20 mA.

3.5.1.10.b On the main screen, enter 300 into the Regen Heater Setpoint widget.

	PASS	FAIL	COMMENTS

4 Testing in Non-Simulation Mode, Full Connection to PSI Wiring

To Be Determined.

Table 1: PSI Signal Matrix for Hanford Cryogenic Pump System.

Location	ID	INPUT												OUTPUT					
		Pump LN2 Level		Regen Level Control Valve Close		Regen Loop Temp.		Regen Loop Over-temp Alarm		Dis-charge Line Pres-sure		Dewar LN2 Level		LN2 Level Control		Level Control Valve Open Enable		Regen Heater Control	
		+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-
LVEA Y	CP1	032	033	131	132	122	123	133	134	036	037	040	041	051	052	171	173	055	056
LVEA X	CP2	032	033	143	144	122	123	145	146	036	037	040	041	051	052	183	185	055	056
Left Mid Station	CP3	020	021	165	166	136	137	167	168	024	025	028	029	047	048	212	214	051	052
	CP4	032	033	205	206	145	146	207	208	036	037	040	041	059	060	239	241	063	064
Right Mid Station	CP5	020	021	165	166	136	137	167	168	024	025	028	029	047	048	212	214	051	052
	CP6	032	033	205	206	145	146	207	208	036	037	040	041	059	060	239	241	063	064
Left End Station	CP7	014	015	105	106	086	087	107	108	018	019	022	023	029	030	130	132	033	034
Right End Station	CP8	014	015	105	106	086	087	107	108	018	019	022	023	029	030	130	132	033	034

Table 2: Signal Data Matrix for Hanford Cryogenic Pumps

Signal	Type	Signal Value Limits					Engineering Value Limits.				Alarm Limits				
		OFF/ Invalid	Low/ OFF	High/ ON	Tolerance	Units	Low/ OFF	High/ON	Units	Tolerance	Src	LO-LO/ ZSV	LOW/ ZSV	HIGH\ OSV	HIHI/ OSV
Discharge Line Pressure Voltage	ai	<0.0	4	20	+/- XXX	mA	0.0	25	PSIG	+/- 1.0	Eng	1	2	10	12
Valve Open Request	bi						Close	Open							
Discharge Line Pressure Interlock	calc						TRUE	FALSE			Eng				
Valve Open Interlock	calc						TRUE	FALSE			Eng				
Valve Open Command	bo						Closed	Open							
Pump LN2 Level	ai	<0.0	4	20	+/- XXX	mA	0	100	% Full	+/- 1.0	Eng	84	83	98	99
Auto Level Control	sub	<0.0					10	40	% Open		Eng	-100	-50	85	
Manual Level Control	ai	<0.0					0	100	% Open						
Auto/Manual Select	bi						Manual	Auto							
Level Control Output	calc						FALSE	TRUE							
Valve % Open Command	ao		4	20	+/- XXX	mA	0	100	% Open	+/- 1.0					
Dewar LN2 Level	ai	<0.0	4	20	+/- XXX	mA	0	100	% Full	+/- 2.0	Eng	5	10	99	100

Table 2: Signal Data Matrix for Hanford Cryogenic Pumps

Signal	Type	Signal Value Limits					Engineering Value Limits.				Alarm Limits				
		OFF/ Invalid	Low/ OFF	High/ ON	Tolerance	Units	Low/ OFF	High/ON	Units	Tolerance	Src	LO-LO/ ZSV	LOW/ ZSV	HIGH\ OSV	HIHI/ OSV
Dewar Low Interlock	calc						TRUE	FALSE							
Regen Loop Temp	ai	<0.0	4	20	+/- XXX	mA	0	250	Deg. C	+/- XXX	Eng			195	200
Overtemp Alarm	bi						Over-temp	Normal				Major			
Valve Closed limit switch	bi						Open	Closed							
Regen Heater Set-point	ai						0	200	Deg. C	+/- XXX	Eng				
Regen Heater Inter-lock	calc						TRUE	FALSE							
Regen Heater Con-trol	ao						0	200	Deg. C	+/- XXX	Eng				

Hanford LIGO EPICS Test Specification Comments Sheet.

Comment ID: | Sheet | of

Raised By: | Test Spec ID:

Date: | Change Request Raised:

☐ **Hardware related** ☐ **Software related**

☐ **High priority, no work around exists** ☐ **Low priority**

☐ **High priority, work around exists** ☐ **For information only.**