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Title: NSLS-II Beamline Cryocooler Operations – Suzuki Shokan			Technical

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VERSION HISTORY LOG

VERSION	DESCRIPTION	DATE
1	First Issue.	16Mar2016

ACRONYMS

ESH	Environment, Safety and Health	ODH	Oxygen Deficiency Hazard
LN_2	Liquid Nitrogen	PPE	Personal Protective Equipment
NSLS–II	National Synchrotron Light Source II	SBMS	Standards Based Management System

1 PURPOSE AND SCOPE

The purpose of this procedure is to set forth the requirements for operation of the Suzuki Shokan Beamline Cryocooler. The scope of this procedure includes the following:

- System Startup (Pre-operations)
- System Operation
- System Shutdown
- Troubleshooting (in automated modes)
- Emergency Shutdown and Restart

This procedure does not apply to the FMB Oxford Cryocooler, Bruker-ASC Cryocooler or Research Instruments Cryocooler, which are operated in accordance with their specific NSLS-II procedures.

This procedure also does not apply to troubleshooting and repair that includes "hardware hacking" (e.g., breaking hoses, venting, etc.). Troubleshooting and repair beyond the automated modes shall be performed by or at the direction of System Experts and/or Suzuki Shokan Staff, and shall be planned in accordance with PS-ESH-PRM-1.3.6, *Work Planning and Control Procedure*.

This procedure is performed in accordance with the Suzuki Shokan Co., Ltd., *Operation and Instruction Guide* (referred to herein as the *Suzuki Shokan User Manual*), which is included as Attachment A.

2 DEFINITIONS

2.1 System Expert: Staff members(s) appointed by the Lead Beamline Scientist.

3 RESPONSIBILITIES

3.1 Authorized Beamline Staff

3.1.1 Perform system startup, operation, shutdown, and emergency shutdown of the Suzuki Shokan Cryocooler in accordance with this procedure.

3.1.2 Perform troubleshooting of the Suzuki Shokan Cryocooler within the limitations of this procedure.

3.2 System Experts and Suzuki Shokan Staff

3.2.1 Perform troubleshooting and repair of the Suzuki Shokan Cryocooler as needed.

3.3 ESH Manager

3.3.1 Permits restart of the cryocooler system after the system has been stopped for an emergency using the Emergency Stop feature.

4 PREREQUISITES

4.1 Authorized Beamline Staff have read the *Suzuki Shokan User Manual* (Attachment A) and are familiar with the following:

- Location of emergency stop button
- Warnings and Alarms
- Overview schematic
- Location and description of valves and temperature sensors

4.2 The compressed air supply that is used to operate the control valves on the cryocooler is properly connected and operating.

4.3 The nitrogen gas supply (i.e., site supplied, compressed gas cylinder or Dewar) is properly connected and operating.

4.4 All pressure relief valves and exhaust venting valves are free of ice.

4.5 The high pressure lines to the beamline optical chamber are properly labeled "Liquid Nitrogen" with an arrow indicating the direction of flow and properly connected to the cryocooler ports.

4.6 The fill lines are connected to an NSLS-II LN_2 supply drop.

4.7 The fill line is equipped with a relief valve to prevent overpressure caused by trapped LN_2.

4.8 Authorized Beamline Staff have verified (in the following order) that the cryocooler may be safely started, specifically:

a. All LN_2 drops and taps along the beamline are in a safe configuration as directed by the System Expert.

b. The LN_2 beamline supply valve may be safely opened and/or closed when directed by the System Expert.

c. The beamline optical component may be cooled AND the optical chamber is under vacuum.

4.9 The cryocooler is properly grounded.

4.10 The control system is properly connected to the cryocooler AND correctly powered.

4.11 Authorized Beamline Staff have completed training for Cryogen Safety (HP-OSH-025) and Compressed Gas Safety (TQ-COMPGAS1).

4.12 The system is in the proper configuration, as shown in the Flow Diagram in Figure 4-1, from section 9 of Attachment A, *Suzuki Shokan User Manual*.

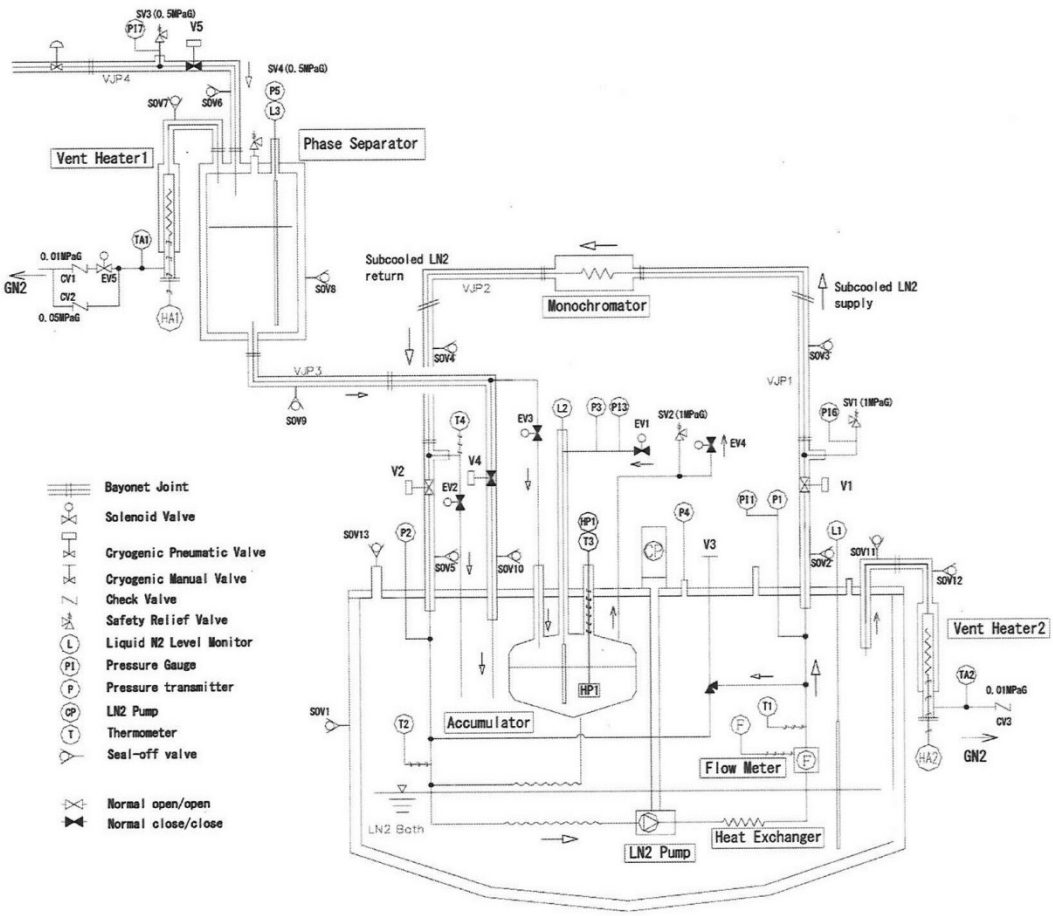

Figure 4-1: Flow Diagram

5 PRECAUTIONS AND LIMITATIONS

5.1 Authorized Beamline Staff shall only operate and troubleshoot the system by the automated modes as described in this procedure. All troubleshooting and repair that includes "hardware hacking" (e.g., breaking hoses, venting, etc.) shall be performed by or at the direction of System Experts and/or Suzuki Shokan Staff, and shall be planned in accordance with PS-ESH-PRM-1.3.6, *Work Planning and Control Procedure*.

5.2 Proper PPE, in accordance with the SBMS Subject Area, *Cryogenics Safety*, shall be worn to prevent personnel injury. Direct contact with LN_2 or exposed surfaces that are cooled by LN_2 may cause a burn. The required minimum PPE for handling cryogenic liquids includes long pants, lab coat or apron, long sleeved shirt, eye protection, and insulated gloves.

5.3 System over pressurization caused by the expansion of nitrogen gas and pressure build-up is possible. All LN_2 lines that can be closed at both ends shall have a relief valve to prevent over pressurization.

5.4 If the system is not functioning in accordance with this procedure or the *Suzuki Shokan User Manual* (Attachment A), the System Expert shall be notified.

5.5 Standing in or near nitrogen gas vapor clouds may cause hypothermia. Personnel shall take precautions to avoid standing in or near vapor clouds.

5.6 The system may become hot during operation and cause burns. Personnel shall avoid hot surfaces and take precautions, including the use of signs or barricades as necessary, to prevent injury.

5.7 Purge gas shall be <u>high purity</u> gaseous nitrogen from one of the following:

- Site-supplied gaseous nitrogen (preferred if available)

  <u>OR</u>

- A compressed gas cylinder of 99.999% purity nitrogen

  <u>OR</u>

- The gas output (boil-off) of an LN_2 Dewar

5.8 The purge gas system shall be pressure regulated below the cryocooler manufacturer's set point <u>OR</u> a pressure relief valve shall be used to prevent over pressurization.

5.9 The cryocooler shall be positioned and set up such that it is protected from incidental damage from equipment and personnel in the area. If the cryocooler is on wheels, the wheels shall be locked or chocked, or equivalent.

5.10 A large amount of nitrogen exhaust gas will be generated during cool-down. The nitrogen exhaust gas shall be ducted to a safe location to avoid risk of asphyxiation from the accumulated gas.

5.11 All cryocooler alarms that occur during normal cryocooler operations shall be immediately acted upon. False alarms from the cryocooler are not expected during normal operations.

5.12 Personnel shall follow the requirements of PS-C-XFD-PRC-006, *Beamline Enclosures and Cryogen Fill Station ODH Monitoring System Alarm Response Procedure* for response to all alarms related to the PureAire Air Check O_2 Oxygen Deficiency Monitors.

5.13 Only Authorized Beamline Staff and System Experts shall be inside the hutch during any of the steps of System Startup (purge, cool-down and fill), and the hutch door shall remain open. The opening to the hutch shall be posted, indicating that no personnel are permitted and that purge/cool-down/fill is in progress. Once System Startup (purge, cool-down and fill) is complete and the system is in routine operation, the entry door may be closed and personnel may enter the hutch; however, personnel are never permitted to be inside the hutch with the door closed.

5.14 Warm-up shall be performed prior to each time the monochrometer is accessed.

6 PROCEDURE

6.1 System Startup (Pre-Operations)

6.1.1 Perform system startup in accordance with the *Suzuki Shokan User Manual* (Attachment A), including:

a. Connection Check (section 3.2)

b. Drying Process (section 3.3)

c. Filling and Precooling Process (section 3.4)

d. Steady Operations Process (section 3.5)

6.2 System Operation

6.2.1 Operate the system in accordance with the *Suzuki Shokan User Manual* (Attachment A).

6.3 System Shutdown

6.3.1 Shut down the system in accordance with the *Suzuki Shokan User Manual* (Attachment A), including:

a. Shutdown and Warming Up (section 5)

6.4 Troubleshooting

6.4.1 Perform system troubleshooting in accordance with the *Suzuki Shokan User Manual* (Attachment A).

6.5 Emergency Shutdown and Restart

Note: The following step should be followed if there is an emergency (e.g., LN_2 leak, ODH alarm, other safety issues, etc.) or the cryocooler appears to be heading towards an unsafe condition.

6.5.1 **Emergency Stop:**

a. Press the "Stop" button.

Note: The ready signal for the beamline interlock is now disabled.

6.5.2 **Restart after Emergensy Stop was depressed:**

a. IF the Emergency Stop was pressed due to a safety emergency, THEN request permission from the ESH Manager prior to restarting the cryocooler.

b. Restart the cryocooler in accordance with the *Suzuki Shokan User Manual* (Attachment A).

7 REFERENCES

7.1 PS-C-XFD-PRC-006, *Beamline Enclosures and Cryogen Fill Station ODH Monitoring System Alarm Response Procedure*

7.2 SBMS Subject Area, *Cryogenics Safety*

7.3 PS-ESH-PRM-1.3.6, *Work Planning and Control Procedure*

8 ATTACHMENTS

Attachment A, *Suzuki Shokan User Manual*

9 DOCUMENTATION

None.

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Attachment A – Suzuki Shokan User Manual

Suzuki Shokan Co., Ltd.

Operation and Instruction Guide

Model name: LN2 Cryocooler SCLL-2500

Manual No.: 84084-MA08-02

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1. Preparation

1.1. Connections

The cryocooler (below: CCL) and the control rack (below: CRK) should be connected with the appropriate cables.

The phase separator (below: PS) and the LN2 drop available at the customer's premises should be connected with the vacuum-jacketed pipe (below: VJP) 4. The measurement lines between the CRK and both level meter L3 and pressure gauge P5, located on the PS, should be connected as well. The air tube between the cryogenic valve V5 of the VJP4 should also be connected to the gas port present on the electrical box of the CCL.

The PS and the vent heater (below: VH) 1 should be connected with the VJP 5. The VH1 should be electrically connected to the CRK as well

The CCL and the PS should be connected with the VJP3.

The CCL and the customer's monochromator (below: MNC) should be connected through VJP 1 for the supply of cryogen and VJP2 for its return.

The CCL and the VH2 should be connected. The VH2 should be electrically connected to the CRK as well.

The N2 gas line necessary to the purge of the equipment in the early steps of its operation should be connected to the solenoid valve EV1

The compressed air line necessary to the operation of the cryogenic valves should be connected to the gas port present on the electrical box of the CCL.

The CRK should be connected to the local 208 V power.

The PLC should be connected to the UPS.

1.2. Electrical check and start-up

When the CCL is not in use, the circuit breakers present in the CRK should all be in the OFF position.

Confirm that the 208 V line is connected to the premises power source by checking that the 200 V lamp on the front of the CRK is lit. If it is unlit, please check the premises power source.

Turn ON the circuit breakers in the following order: NFB1, NFB2, ELB1 to ELB5, NFB11 and NFB12.

The three level meters integrated in the CRK should display values from 0% to 15% (range due to the fact that level meters are calibrated for liquid nitrogen temperature).

The five digital pressure gauges P1 to P5 installed on the CCL should display near-0 values.

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The touch panel should display the program's main menu.
Clicking on the "Monitor Screen" button, all the temperatures, pressures and levels should be correctly displayed.

In the case the Emergency Stop button is pressed, the power supply also stops for the solenoid valves.

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2. Touch panel explanation

2.1. Items abbreviation list

Item	Description	Unit	Remarks
T1	LN2 supply temperature	K	
T2	LN2 return temperature	K	
T3	HP1 heater temperature	K	
T4	LN2 exhaust temperature	K	For precooling
L1	LN2 bath level	%	
L2	Accumulator level	%	
L3	PS level	%	
EV1	N2 gas input solenoid valve		
EV2	LN2 exit solenoid valve		For precooling
EV3	Accumulator input solenoid valve		
EV4	Depressurization solenoid valve		
EV5	PS pressurization solenoid valve		
V1	LN2 supply valve		Pneumatic
V2	LN2 return valve		Pneumatic
V3	LN2 bypass valve		Manual
V4	LN2 bath fill valve		Pneumatic
V5	PS fill valve		Pneumatic
SV1	Circulation line safety valve		Set at 1 MPa
SV2	Accumulator safety valve		Set at 1 MPa
SV3	LN2 input safety valve		Set at 0.5 MPa
HP1	Pressurization heater		
HA1	Vent heater 1		
HA2	Vent heater 2		
P1	LN2 supply pressure	kPa	
P2	LN2 return pressure	kPa	
P3	Accumulator pressure	kPa	
P4	LN2 bath pressure	kPa	
P5	PS pressure	kPa	
F	Flow	L/min	
LNP	LN2 pump		

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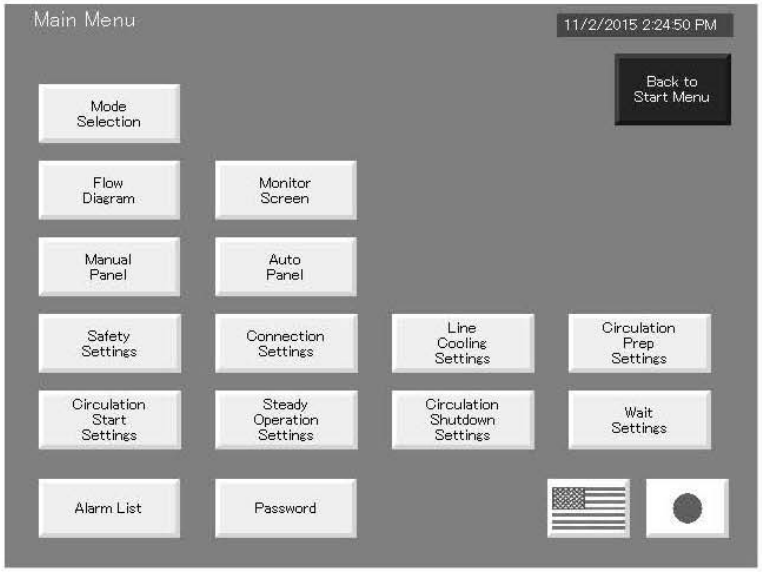
2.2. Main Menu screen explanation



Button	Description
Back to Start Menu	Leave the program
Mode Selection	Switch between auto and manual
Flow Diagram	Check operation visually
Monitor Screen	Check operation from values
Manual Panel	Configure manual parameters
Auto Panel	Configure auto parameters
Safety Settings	As named
Connection Settings	As named
Line Cooling Settings	As named
Circulation Prep Settings	As named
Circulation Start Settings	As named
Steady Operation Settings	As named
Circulation Shutdown Settings	As named
Wait Settings	As named
Alarm List	Display the alarm log
Password	Insert password to allow changes
USA Flag	Change language to English
Japan Flag	Change language to Japanese

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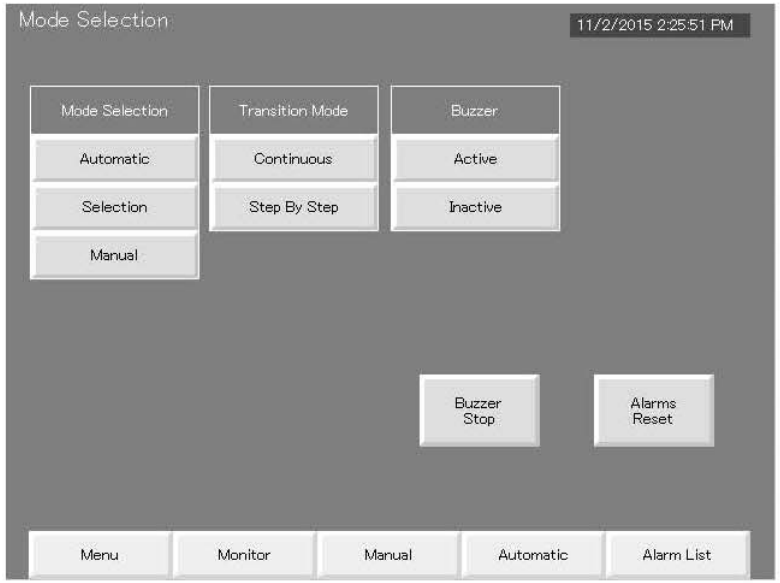
2.3. Mode Selection screen explanation



Button	Description
Automatic	Perform processes successively
Selection	Perform one process at a time
Manual	Give manual control to the user
Continuous	Perform steps successively
Step By Step	Perform one step at a time
Buzzer Active	Activate the buzzer
Buzzer Inactive	Deactivate the buzzer
Priority to PS filling	As named
Buzzer Stop	As named
Alarms Reset	As named
Shortcut Bar	Access various menus directly

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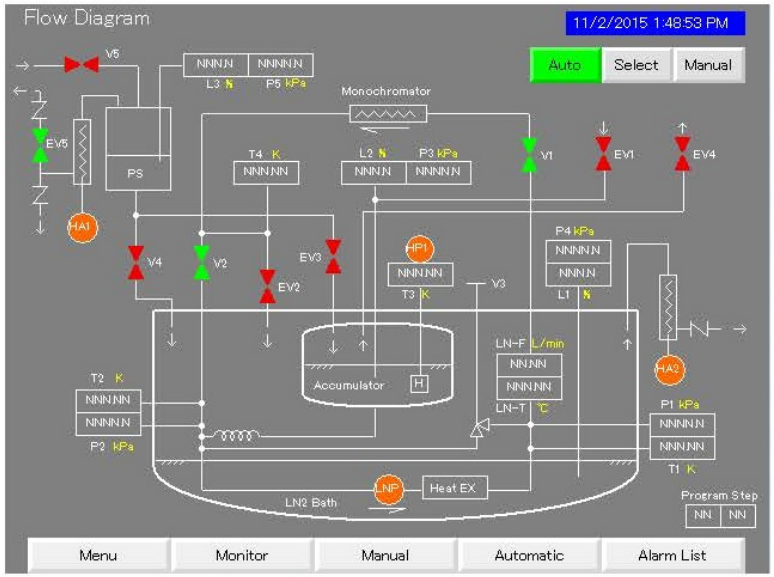
2.4. Flow Diagram screen explanation



Open Close

OFF ON

Label	Description
T1	LN2 supply temperature
T2	LN2 return temperature
T3	HP1 heater temperature
T4	LN2 exhaust temperature
HP1	Pressurization heater
L1	LN2 bath level
L2	Accumulator level
L3	PS level
P1	LN2 supply pressure
P2	LN2 return pressure
P3	Accumulator pressure
P4	LN2 bath pressure
P5	PS pressure
LN-F	Flow
LN-T	Flowmeter temperature

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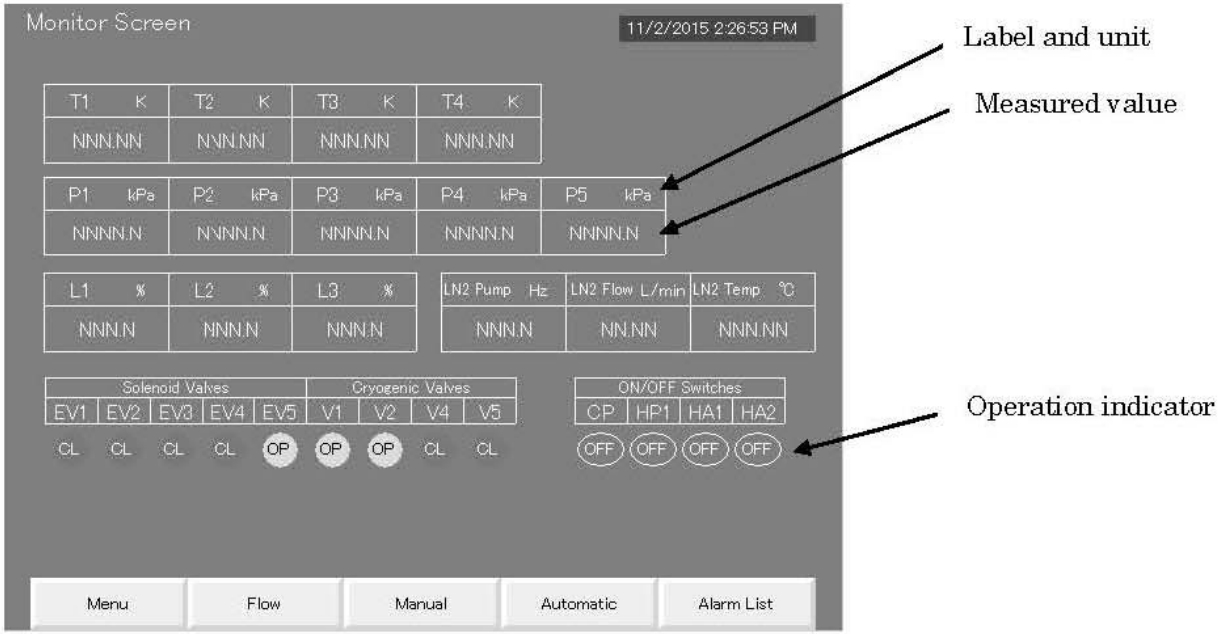
2.5. Monitor Screen explanation



Label and unit

Measured value

Operation indicator

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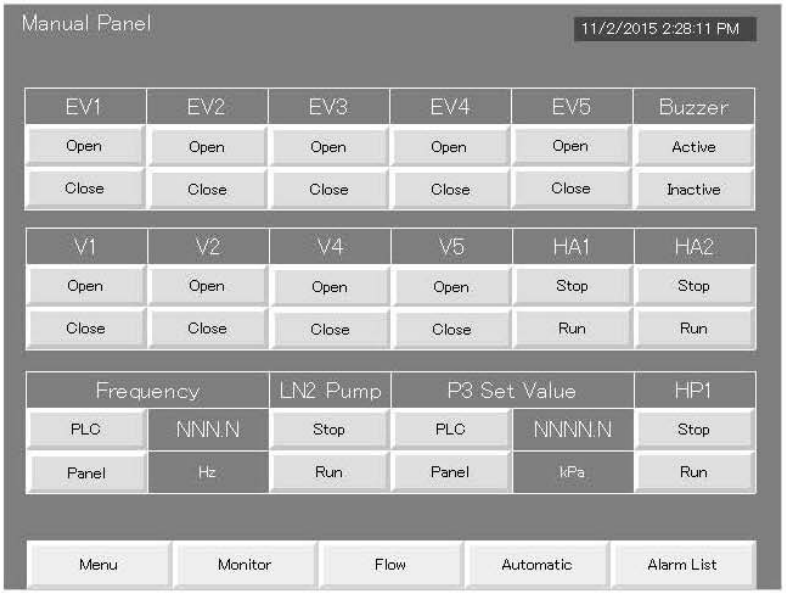
2.6. Manual Panel screen explanation



Frequency

PLC: the frequency set is the one entered through the HMI

Panel: the frequency set is the one entered directly through the inverter

LN2 Pump

Stop: switch off the inverter

Run: switch on the inverter

P3 Set Value

PLC: the accumulator pressure set is entered through the HMI

Panel: the accumulator pressure set is entered through the HP1 controller

HP1

Stop: stop the pressurization heater HP1

Run: start the pressurization heater HP1

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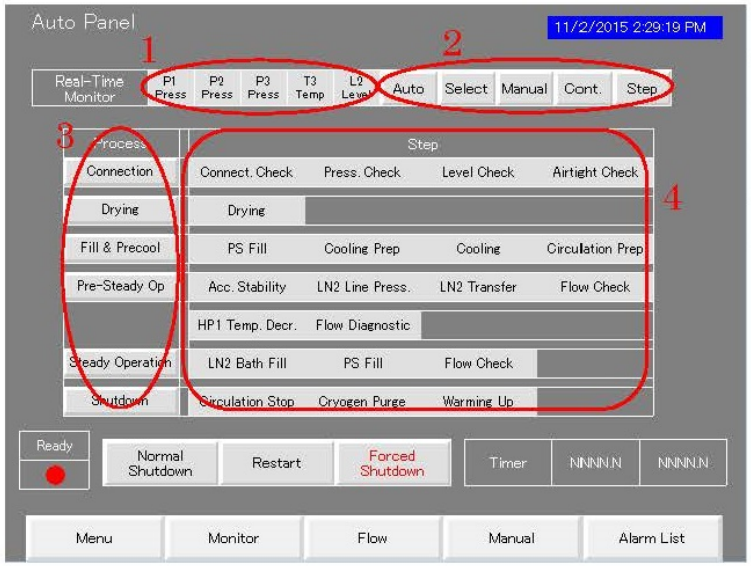
2.7. Auto Panel screen explanation



Button	Description
Real-Time Monitor	Lit in case of anomaly
Mode Display	Current operation mode
Auto Process Buttons	Push to start process in auto mode
Step Display	Display the current step
Normal Shutdown	Trigger normal shutdown
Restart	Go to the next step in Step by Step
Forced Shutdown	Trigger forced shutdown
Timer	Display the current step timer

Process

Connection: do the necessary verifications after connecting the pipes

Drying: dry the moisture inside the system

Fill & Precool: charge the PS and precool the SCL

Pre-Steady Op: prepare the system to stable LN2 circulation

Steady Operation: circulate LN2 into the user's system

Shutdown: trigger normal shutdown

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2.8. Alarm List screen explanation

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3. Automatic start-up

3.1. Getting started

Make sure the Main Menu is displayed or go back to Main Menu.
Go to Flow Diagram.
Check that the valves, heaters and pump are in their unexcited state. In the case one is excited, go to Main Menu, Mode Selection and select Manual in the Mode Selection table, to be able to act freely on the valves, heaters and pump. Go to Main Menu, Flow Diagram and click the items you want to set to the unexcited state.
Go to Main Menu, Mode Selection and select Automatic in the Mode Selection table and Continuous in the Transition Mode table. The Step By Step mode is used when a particular sequence of the automatic start-up is needed.
Go to Main Menu, Auto Panel to choose then follow the automatic start-up progress.

To stop the process in progress, go to Auto Panel and push Forced Shutdown. Restarting from the desired process is possible by pushing the corresponding button in the Process column, but it can only restart from the first step of this process.

3.2. Starting from the connection check

When it is the first time the program is run after connecting the pipes and measurement lines or when there is a doubt with the airtightness of the assembly, then the start-up should be actuated by pushing Connection.
If a problem is detected or if one parameter displays an abnormal value, the Alarm List pops up. After verification of the alarm, it is possible to go back to the Main Menu by pressing Menu. Once the cause of the error is solved, restart the process by pushing Connection again.
If Continuous was selected in Mode Selection, then the program will automatically proceed to the drying process.

3.3. Starting from the drying process

When the circulation line has experienced an inner pressure below atmospheric pressure during the machine's halt period, if there is a doubt with the presence of water in the line or if the machine has been halted for more than a week, then it is recommended to start from the drying process by pushing Drying.

3.4. Starting from the filling and precooling process

When the line is supposed to be clean but that there is no LN2 available for circulation and that the user's heat load has not reached low temperatures yet, then the process should be started by pushing Fill & Precool.

3.5. Starting from the steady operation process

When the circulation line is cold and that levels are sufficient, for example when the steady operation was stopped for a short period in order to change parameters, then the process should be started by pushing Steady Operation.

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4. Manual start-up

When a particular cooling pattern is required, then it may be useful to start the cooldown manually. Please remember than auto-refill and interlock functions are off in manual mode. Be sure to push back Automatic in the Mode Selection menu then one of the processes in the Auto Panel before leaving the area (see the explanation of the different processes in paragraph 3).

The following paragraph should allow the user to reproduce the behavior taken by the cryocooler in automatic mode, while offering the possibility to vary parameters.

4.1. Connection check

Previous connection check
For safety, verify the presence of pressurized GN2 inside the high-pressure loop.
If P1>50 kPa, open EV4 until P1<50 kPa.

Pressurizing check
Verify the availability of GN2 at the premises.
Open EV1 until P1>100 kPa.

Levels check
Verify the condition of the level meters.
It is not abnormal that a level meter displays more than 0 even if no LN2 is present inside the system, but a display of 100% should warn the user that there is a wiring or sensor problem.

Airtightness check
Remove hard impurities by opening EV1 and EV2 and closing V2 for 1 minute.
Close EV2 and open V2. P1 should increase. Close EV1 when P1>150 kPa.
Wait 10 minutes for stabilization. Then check P1 for the next 30 minutes. If P1 decreases by more than 3 kPa then the system is not perfectly tight and the connections need to be rechecked.

4.2. Drying

The circulation line is purged with GN2 to evacuate all humidity. With EV1 still open, open EV2 and close V2. Wait for 12 hours. To save on GN2, the user may want to use the regulator placed at EV1 to lower the pressure and decrease the flow rate.

4.3. Filling and precooling

Phase separator filling
Charge the phase separator with the LN2 from the premises.
Activate the HA1 vent heater.
Open EV5 if it is closed and open V5 until L3>80%, then close V5. Close EV5 if necessary.

Cooling
Caution: at any time during this step, if L3<30% then bring the valves back to their normal position and redo the phase separator filling step.
Fill the bath with LN2 by opening V4 until L1>50%, then close V4.

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Meanwhile, open EV3, EV2 and close V2 to flow LN2 from the phase separator into the accumulator and high-pressure line. Close EV5 to increase the pressure of the gaseous phase in the phase separator and thus increase the flow of LN2 pushed into the accumulator. Check the return temperature T4 and the DCM temperature to evaluate the cooling speed. Proceed until T4<200 K. If the cooling speed is too fast or too slow, then go to the next step anyway.
Close EV3, EV2 and open V2 to return the system in its previous state.

Circulation preparation
The goal is to accumulate LN2 in the accumulator and use the heater HP1 to pressurize it and flow it into the high-pressure line.
Refill the phase separator until L3>80%.
With EV5 still closed, open EV4 and EV3 until L2>75%.
Close EV3 and EV4. Activate the pressurization heater HP1. SP should be set to 100 kPa. When the pressure is reached, shut down HP1 and open EV2 to flow LN2 from the accumulator to the DCM. Open and close EV2 at the wanted rhythm to control the cooling speed.
When L2<30%, open EV4 and EV3 until L2>75%.
When T4<90 K, it means the line is cold and that the program should be set back to automatic mode for the pump to start running.

To do so, choose Automatic in the Mode Selection menu and click Fill and Precool in the Auto Panel.

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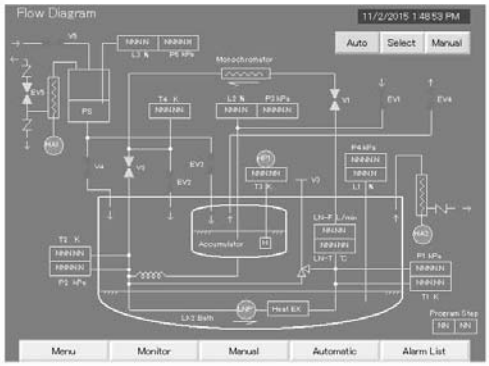
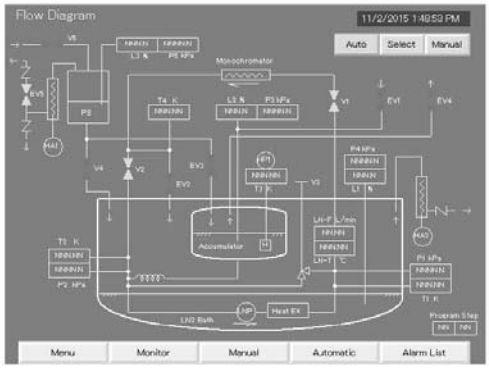
5. Shutdown

During Steady Operation, operation can be stopped and warming up initiated by pushing Normal Shutdown on the Auto Panel.



This is the screen which should be displayed during the Steady Operation of the cryocooler.

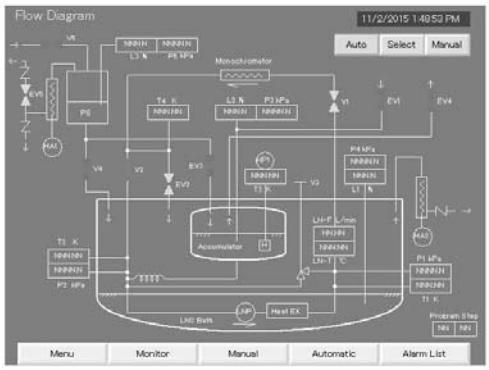
Three steps are part of the Shutdown process: Circulation Stop, Cryogen Purge and Warming Up.



Circulation Stop

Pump speed is brought to 0 Hz and inverter shut down. Heaters HA1, HA2 and HP2 are shut down.

There is a 30 s wait time before moving to the next step.



Cryogen Purge

V2 is closed and EV2 opened, so that the pressurized gas still in the accumulator pushes out the liquid of the circulation line into the bath.

In case P3 is too low, HP1 is switched on so that P3 is at least 50 kPa (rare).

This step stops when L2 reaches 10%.

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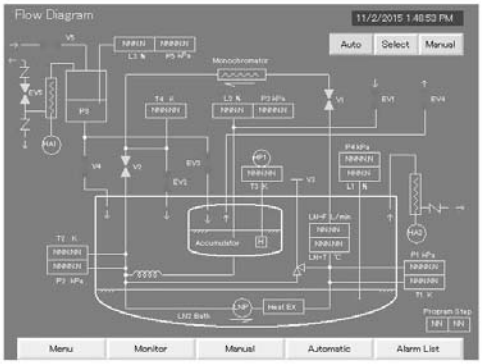
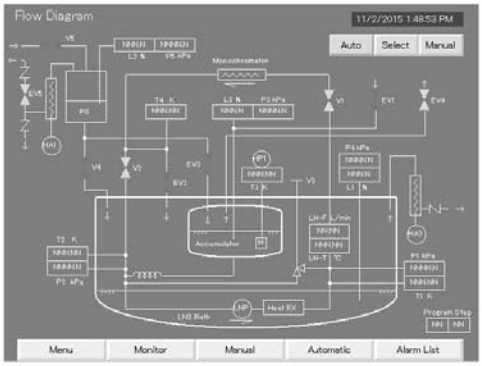


Warming Up

EV2 closes, V2 opens again and the rest of the liquid of the circulation line naturally vaporizes.



When the pressure measured at P1, P2 or P3 reaches 100 kPa, EV4 opens automatically to vent the circulation line until it reaches 50 kPa.

The cryocooler can be kept safely in this state until it is totally warm.

To restart the cryocooler after having shut it down once, but while one is sure of the quality of the mechanical connections and of the absence of water inside the system, push Forced Shutdown on the Auto Panel to stop the Shutdown process and then Fill & Precool on this same panel to restart the cooling process. The Steady Operation process should be reached within one or two hours.

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6. To change the steady operation parameters

Depending on the needs of the user's heat load, one may want to change the flow and pressure parameters of the circulating LN2. To do so while in steady operation mode, please follow the procedure below.

The program should still be running in automatic mode. Thus start by pushing Manual on the Mode Selection to switch to manual mode.

To change the LN2 flow, go to Manual Panel and look for the Frequency item. The flow of LN2 is proportional to the frequency the pump is run at.

To insert a value through the HMI, tap PLC below Frequency and enter a value in Hz in the dedicated space on the right.

To insert a value through the inverter display equipping the CRK, tap Panel and follow the instructions of the inverter's manual to do so.

To change the pressure of the fluid in the circulation line, go to Manual Panel and look for the P3 Set Value item.

To insert a value through the HMI, tap PLC below P3 Set Value and enter a value in kPa in the dedicated space on the right.

To insert a value through the pressure controller display equipping the CRK, tap Panel and follow the instructions of the pressure controller's manual to do so.

To return to steady operation, tap Automatic in Mode Selection and then Steady Operation in the Auto Panel. Take a few minutes to verify that the parameters newly input present the awaited results.

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7. Reference data

Basic values
Atmospheric pressure: 101.3 kPaA
Saturation pressure of LN2 at 80 K: 136.7 kPaA
Saturation pressure of LN2 at 86 K: 251.2 kPaA

Symbol	Description	PLC Tag	Unit	Remarks
L1	LN2 bath level	DM100	%	0 – 100
L2	Accumulator level	DM101	%	0 – 100
L3	PS level	DM102	%	0 – 100
T1	LN2 supply temperature	DM120	K	0 – 400
T2	LN2 return temperature	DM121	K	0 – 400
T3	HP1 heater temperature	DM122	K	0 – 400
T4	LN2 exhaust temperature	DM123	K	0 – 400
LN-F	LN2 flow	DM126	L/min	0 – 30
LN-T	LN2 flowmeter temperature	DM127	°C	-273 – 100
P1	LN2 supply pressure	DM110	kPa	0 – 1,000
P2	LN2 return pressure	DM111	kPa	0 – 1,000
P3	Accumulator pressure	DM112	kPa	0 – 1,000
P4	LN2 bath pressure	DM113	kPa	0 – 1,000
P5	PS pressure	DM114	kPa	0 – 1,000
V1	OPen/CLose status	R38006		OP: 0, CL: 1
V2	OPen/CLose status	R38007		OP: 0, CL: 1
V4	OPen/CLose status	R38009		CL: 0, OP: 1
V5	OPen/CLose status	R38010		CL: 0, OP: 1
EV1	OPen/CLose status	R38011		CL: 0, OP: 1
EV2	OPen/CLose status	R38012		CL: 0, OP: 1
EV3	OPen/CLose status	R38013		CL: 0, OP: 1
EV4	OPen/CLose status	R38014		CL: 0, OP: 1
EV5	OPen/CLose status	R38015		OP: 0, CL: 1
LNP	Pump inverter status	R38002		OFF: 0, ON: 1
LNP	Pump rotation speed	DM200	Hz	0 – 100
HP	Pressurization heater	R38003		OFF: 0, ON: 1
	Auto mode	R21004		OFF: 0, ON: 1
	Manual mode	R21006		OFF: 0, ON: 1
	Operation status	R500		OK: 0, NOK: ≠0

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	Decision timer	DM300	ds	0 – 10,000
	Current process	DM8000		2: Wait, 3: Connection, 4: Drying, 5: Fill and Precool, 6: Pre-Steady Op., 7: Steady Operation, 8: Shutdown

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8. Alarm list

No.	Message	Possible cause	Countermeasure
000	Emergency Stop Button	The emergency button was pushed	Reset the emergency button
001	LN2 Pump Inverter Malfunction	Max torque of the pump exceeded Presence of water in the loop	Check the pump's resistance Dry the circulation line
002	P1 Press Rise Default (at Press Rise Check)	No gas supplied Malfunction of the supply valves	Check the GN2 supply pressure and flow Check the valves behavior
003	L1, 2, 3 Level Default (at Level Check)	Too much LN2 supplied Display malfunction Bad cable connection	Supply less than 100% of LN2 Repair the display Check the cables
004	P1 Leak Default (at Airtight Check)	Airtightness trouble	Identify the leak and repair it
005	L3 Level Default (at PS Charge)		
006	L3 Charge Malfunction (at PS Charge)	Too much LN2 supplied Display malfunction Bad cable connection	Supply less than 100% of LN2 Repair the display Check the cables
007	L3 Charge Malfunction (at Circulation Prep)	Too much LN2 supplied Display malfunction Bad cable connection	Supply less than 100% of LN2 Repair the display Check the cables
008	L3 Charge Malfunction (at Steady Operation)	Too much LN2 supplied Display malfunction Valve malfunction Bad cable connection	Supply less than 100% of LN2 Repair the display Check the air supply of the valve Check the cables
009	FL Flow Default (at Steady Operation)	Flow below the limit Dysfunction of the flowmeter	Redo the precooling process Check for water in the piping Check the flowmeter's connections
010	Remote Stop Signal On		

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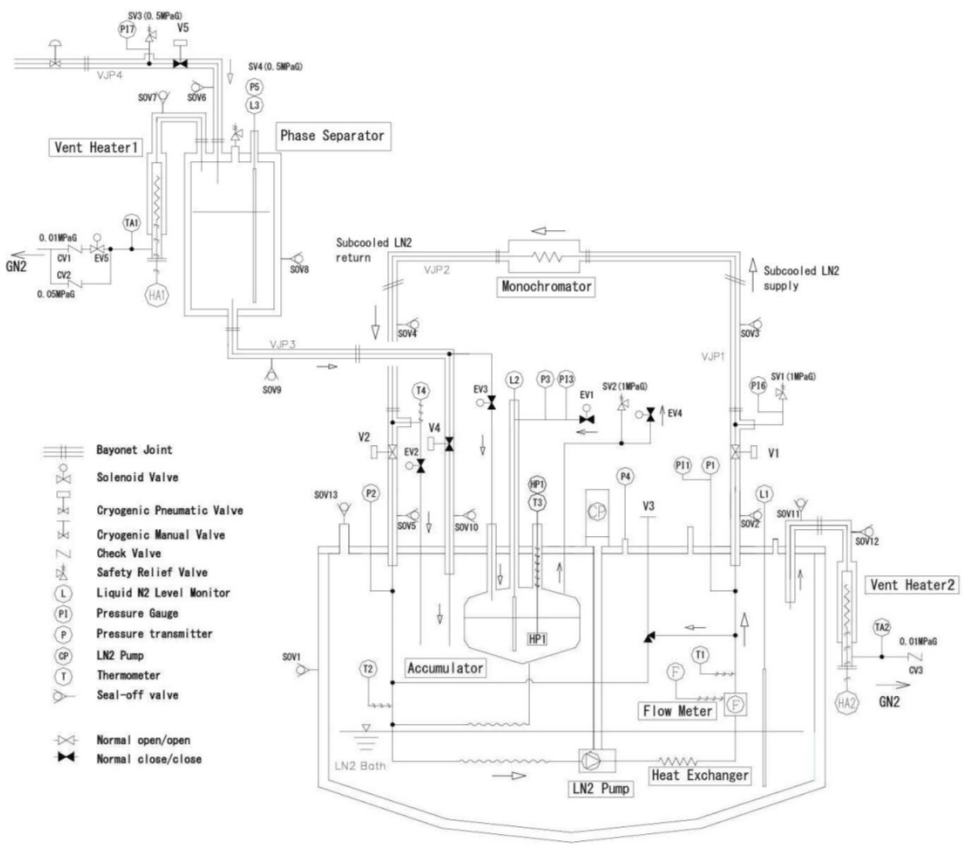
9. Flow diagrams



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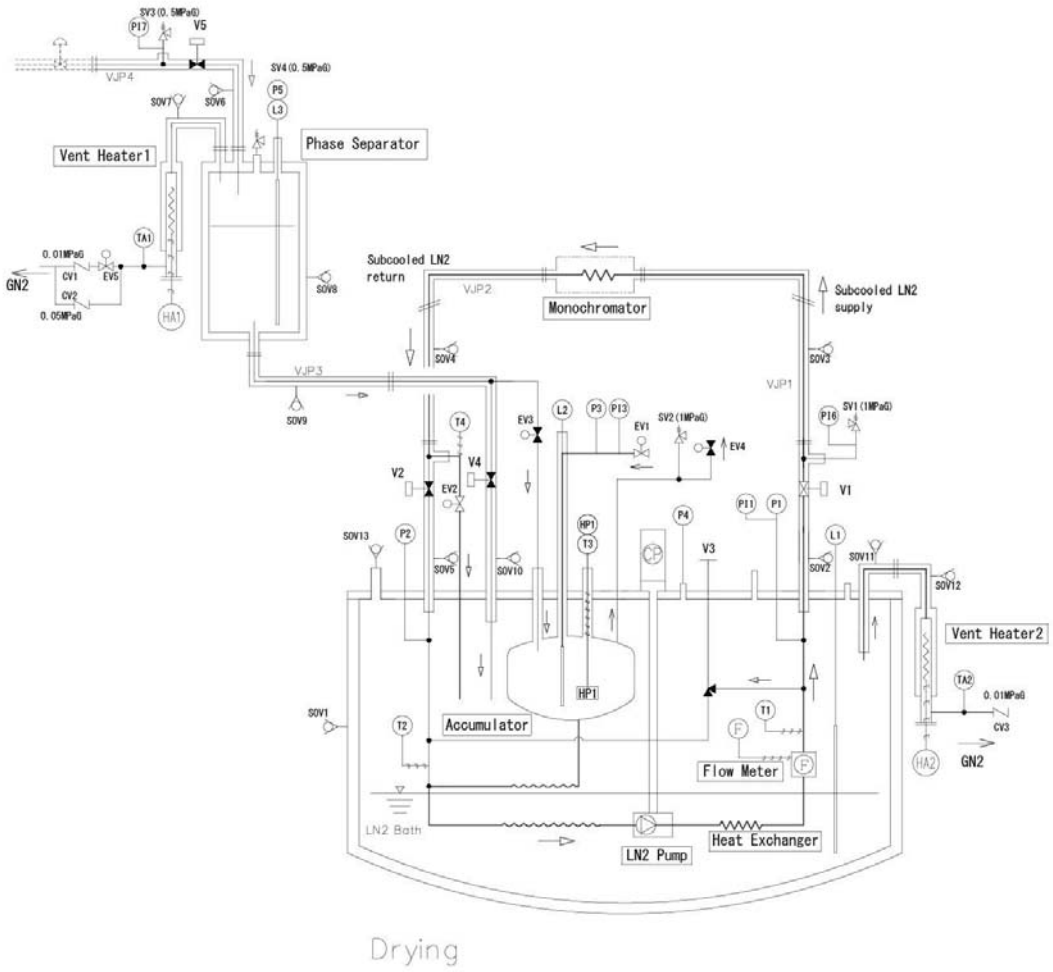

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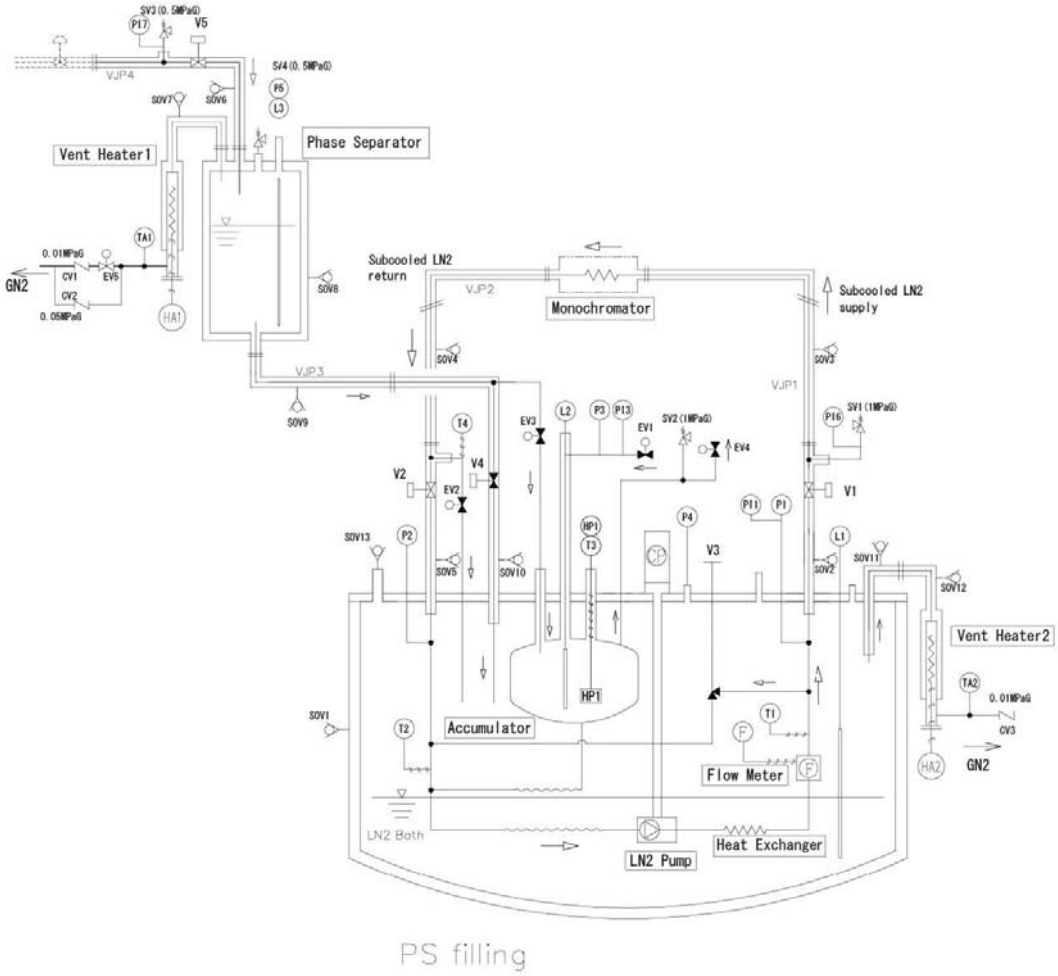

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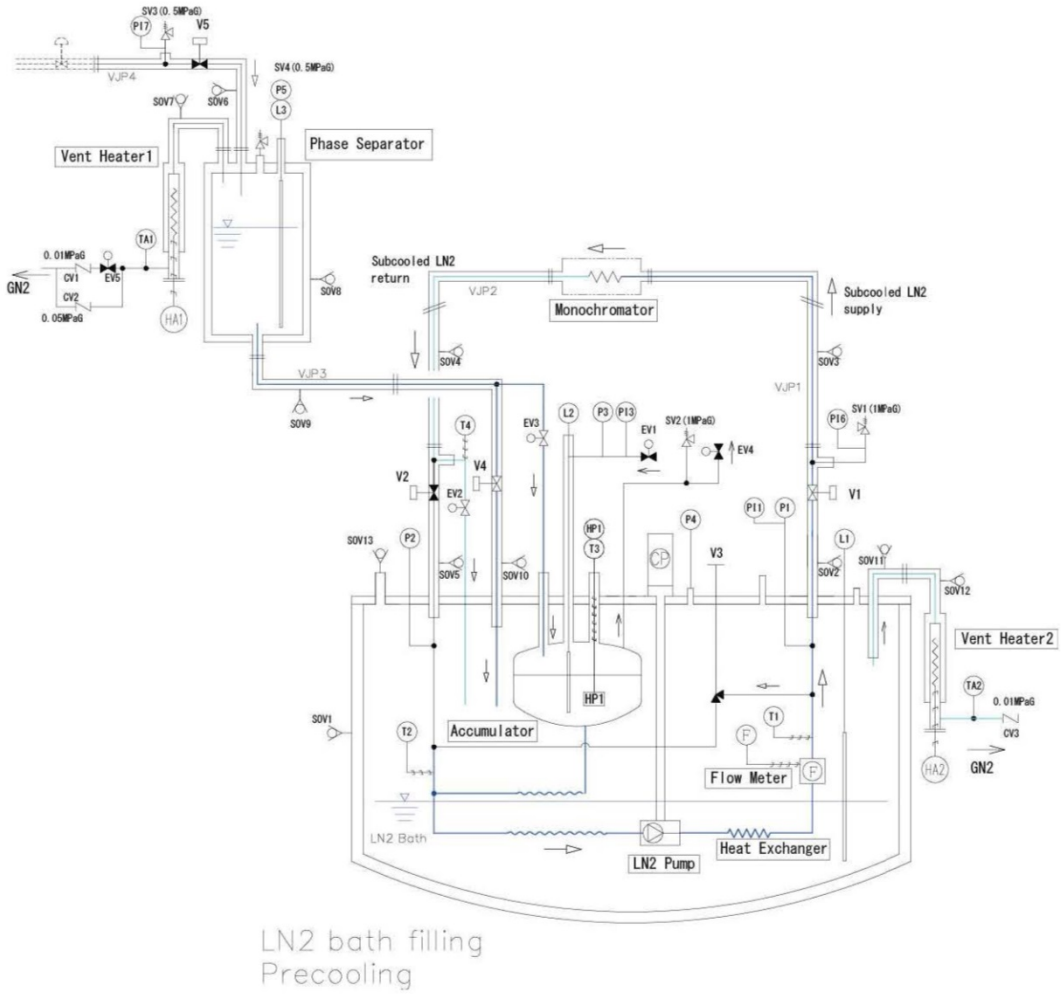

LN2 bath filling
Precooling

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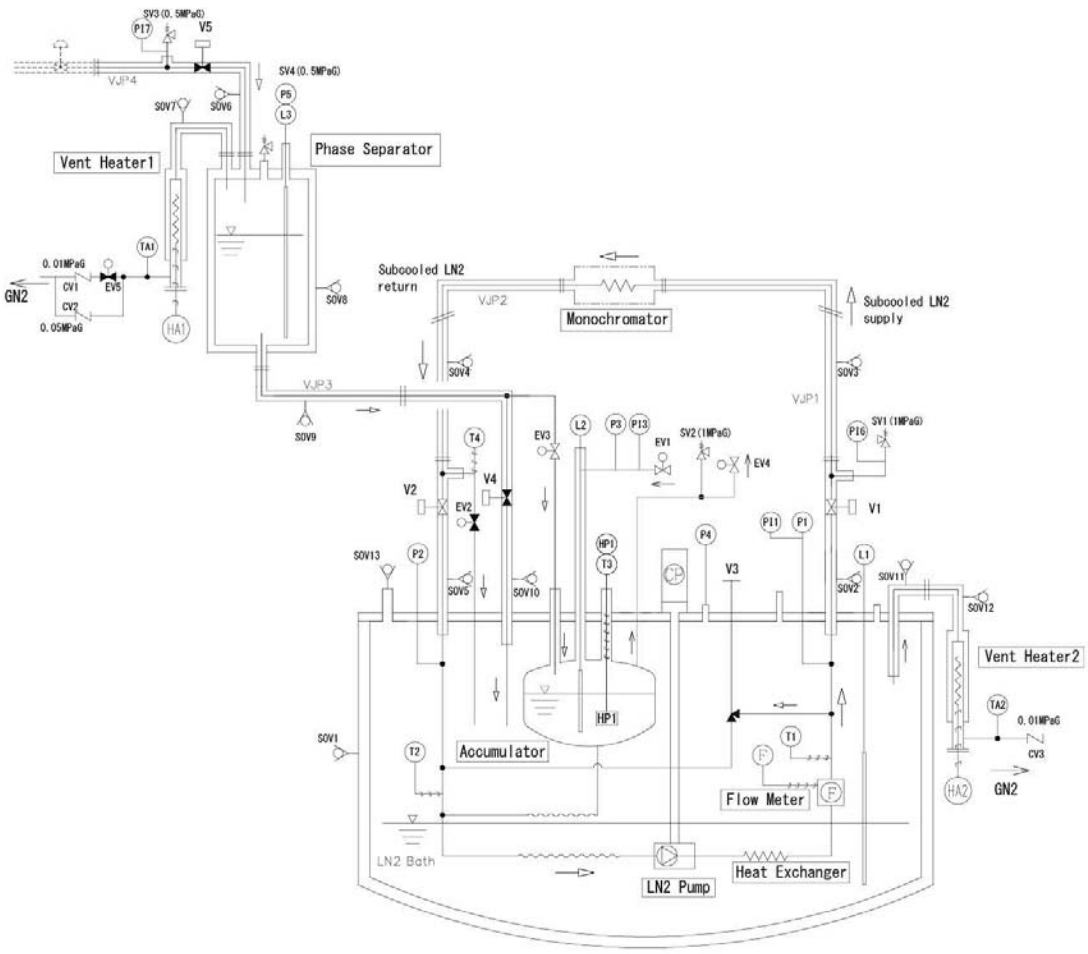

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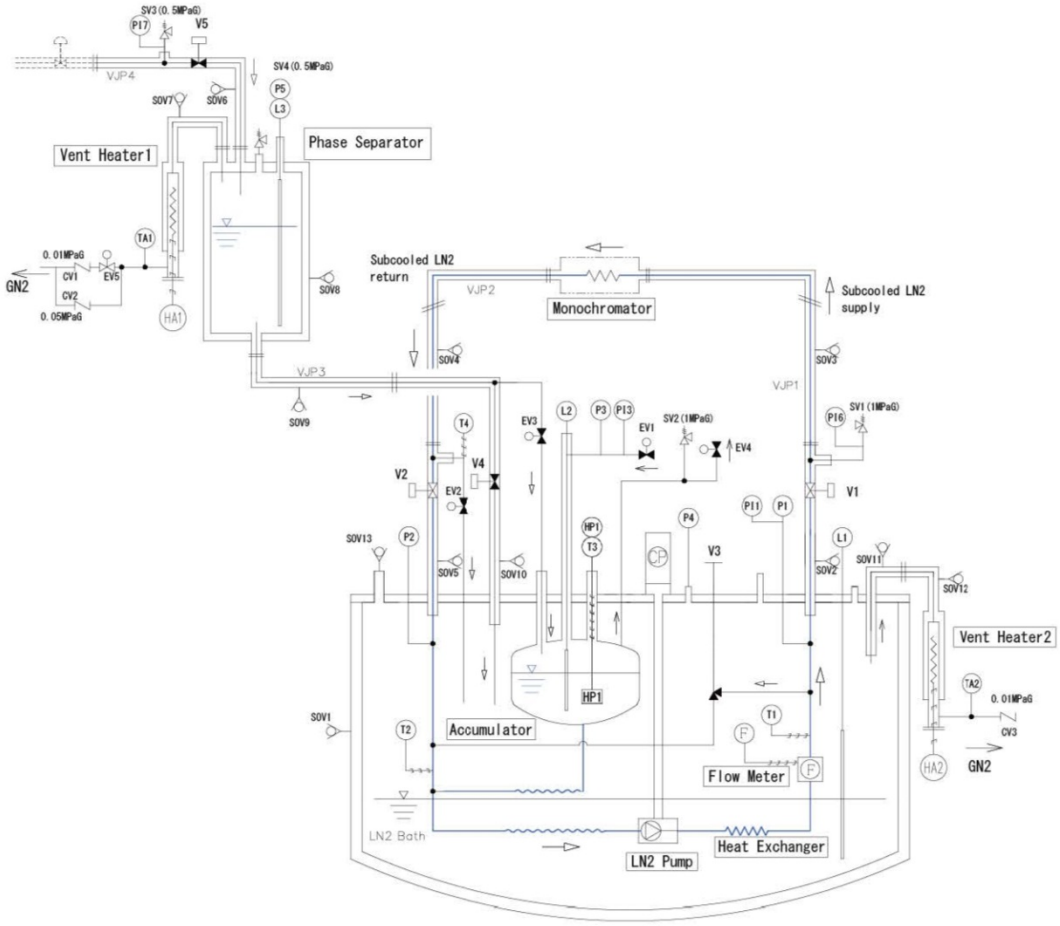

Steady operation

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