Table of Contents

List of Figures and Tables

ABBREVIATIONS

MPTTF	Mono-Propellant Thruster Test Facility
GN2	Gaseous Nitrogen
GHe	Gaseous Helium
HAT	High Altitude Test
SLT	Sea-Level Test
POU	Point Of Use (Panel)
ASME	American Society for Mechanical Engineers
ASTM	American Society for Testing and Materials
SOV	Shut-Off Valve
CV	Check Valve
NV	Needle Valve
BV	Ball Valve
SV	Solenoid Valve
EP	Electro-pneumatic
EPR	Electronic Pressure regulator
PR	Manually operated Pressure Regulator
FPI	Fluorescent Penetrant Inspection
PF	Propellant Feed Line
LP	Leak Test/Purging Line
MEOP	Maximum Expected Operating Pressure

PART–A: TECHNICAL SPECIFICATION

Preamble

This document provides scope of work and specifications for design, fabrication, supply, installation, testing, commissioning and demonstration of gas distribution system, propellant feed system and PLC based control system with utilities for Monopropellant Thruster Test Facility (MPTTF) in LPSC, Tumakuru campus. Detailed scope of work in provided in Chapter 1.

A Monopropellant Thruster Test Facility (MPTTF) is being established to test monopropellant hydrazine thrusters at LPSC, Tumakuru campus. Towards this, gas distribution system, liquid propellant feed system along with utilities, needs to be installed in the facility to supply gases and propellant from sources to the user points.

The gas distribution system shall supply pressurised gaseous nitrogen, helium and compressed air from gas cylinder bank in gas distribution room to the user points in different facilities of MPTTF to cater for the requirements during testing of mono-propellant thrusters. Figure 1 shows schematic of gas distribution system. The gas distribution system consists of Gas distribution panels (2 Nos.), Compressed air distribution panel (1 No.), Point-of-Use (POU) panels (9 Nos.), controls panels (2 Nos.) and SS304L tubes & valves connecting all these panels. The panels shall be installed at different locations; overall layout of the system is shown inFigure 2. Detailed technical description of the system is in Chapter 2.

The propellant feed system shall deliver pressurised hydrazine (a liquid propellant) in a safe manner from tanks (located in Run tank room) to thruster testing location (inside vacuum chamber& test stand in sea-level test facility)through SS 304L feed lines. Schematic and overall layout of the system is shown in Figure 3&Figure 4respectively. Fluid circuits are shown in Figure 10 & 11. The run tanks are pressurized by control panels which are part of gas distribution system. Detailed description of propellant feed system is in Chapter 3.

Chapter 4 contains details of utilities to be supplied, integrated and tested along with above described gas distribution and propellant feed system.

(Note: LPSC will supply Nitrogen & Helium gas cylinders, air compressors, propellant tanks, vacuum chamber, test stand etc. Hence the supply of these items is not part of this scope of work. Where ever details provided related to these items are only for information).

Chapter 1: Scope of Work

1.1 Detailed Scope of Work

The scope of work includes design, fabrication, supply, installation, testing, commissioning and satisfactory demonstration of gas distribution system, propellant feed system and PLC based control system at MPTTF in LPSC, Tumakuru campus.

1.1.1 Gas Distribution System: The overall scope of work includes **design, fabrication, supply, installation, testing, commissioning and satisfactory demonstration of gas distribution system** for supply of gases (GN2, GHe and compressed air) including gas distribution panels, point-of-use (POU) panels, control panels, SS304L tubes for interconnecting all the panels at MPTTF facility in LPSC, Tumakuru campus as per detailed specifications and bill of materials provided in chapter 2. Schematic of the gas distribution system in shown in Figure 1.

a) The gas distribution system shall supply pure gaseous Nitrogen, Helium and compressed air from gas distribution room to the user points.
b) 2 Nos. of gas distribution panels (1 each for GN2 & GHe) and 1 No. of compressed air distribution panel shall be provided in gas distribution room.
c) At user points, different types of panels such as POU panels (9 Nos.), Control panels (2 Nos.) shall be provided as per layout shown in figure 2.
d) Electronic Pressure Regulators (EPR) shall be provided in control panels. The EPRs shall be tuned properly to meet required functionality and to achieve required accuracy in pressure.
e) The gas supply tubing for nitrogen, helium and compressed air from the gas distribution panels to the user points shall be made of SS304Ltube with 1/2“OD as per layout shown in figure 2. Approximate length of tubing is 1000meters.
f) The gas supply tubing shall have intermediate isolation valve at locations marked in figure 2.
g) Structure of all panels (gas distribution, POU and control) shall be made up of stainless-steel (SS 304) sheets and frames. The structures shall be buffed to mirror finish for elegant look.
h) The panels shall be grouted/ fixed rigidly on the ground using appropriate anchor.
i) The fluid circuit shall be constructed with high quality orbital TIG welding with 100% fusion except for component interfaces. The component interfaces shall be connected with standard double compression ferrule fittings. All the welded joints must be Fluorescent Penetrant (FP) tested.

j) Vendor shall submit the design and layout of the panels to LPSC and approval shall be obtained for the detailed design and layout prior to commencement of fabrication/assembly of individual panels and of the entire system.
k) The system shall be realized as per approved layout by LPSC. Any deviation from the approved layout shall be intimated to LPSC before implementation.
l) All the SS304L tubes used in the realization of system shall be pre-cleaned and passivated.
m) Entire tubing for gas supply shall be routed through trenches/walls appropriately and shall be covered with PVC casing. Wherever tubes are required to be routed across the wall, holes shall be drilled through the wall. The entire tubing shall be securely anchored with suitable anchors/supports.
n) All the gas supply lines shall be provided with appropriate colour coding as per relevant standard for clear identification.
o) All the panels shall be provided with schematic drawing of the fluid circuits on the front side of the panel and with clear identification of components at their respective location. Also, the valve operating positions like open/close shall be marked by means of good quality stickers.
p) The certificate of conformance for materials, functionality, calibration certificate for pressure gauges and pressure transmitters shall be submitted. Details of required documents are mentioned in section 5.3.
q) The gas distribution system shall be integrated with PLC based control system.
r) Quantity of spare components is mentioned in bill of materials of each panel. Spare components shall be supplied together with the panels.
s) Installation, integration, testing, commissioning and demonstration of the entire system shall be carried out “On Site” in LPSC, Tumakuru campus.

1.1.2 <u>Propellant feed system:</u> The overall scope of work includes **design, fabrication, supply, installation, testing, commissioning and satisfactory demonstration of propellant feed system** as per the schematic and bill of materials including flow meter panels, propellant feed valve panels and SS304Ltubing etc. for MPTTF Facility at LPSC, Tumakuru as per detailed specifications and bill of materials provided in chapter 3. The schematic is shown in Figure 3.

a) The liquid propellant feed system shall supply hydrazine propellant from propellant source tanks (called **Run Tanks**) to the test facilities.
b) Flow meter panels shall be provided in Run Tank Room and Propellant feed valve panels shall be located in engine assembly area (adjacent to vacuum chamber) and sea-level test facility each. The locations are shown in layout (refer Figure 4).

c) Structure of flow meter panels and propellant feed valve panel shall be made up of stainless-steel (SS 304) sheets and frames. The structure shall be buffed with mirror finish for elegant look.
d) The panels shall be grouted/ fixed rigidly on the ground using appropriate anchor.
e) The fluid circuit shall be constructed with high quality orbital TIG welding with 100% fusion except for component interfaces. The component interfaces shall be connected with standard double compression ferrule fittings. All the welded joints must be Fluorescent Penetrant (FP) tested.
f) Vendor shall submit the design and layout of the panels to LPSC and approval shall be obtained for the detailed design and layout prior to commencement of fabrication/assembly of individual panels and of the entire system.
g) The system shall be realized as per approved layout by LPSC. Any deviation with respect to the approved layout shall be intimated to LPSC before implementation.
h) All the stainless-steel tubes used in the realization of system shall be pre-cleaned and passivated.
i) Installation, commissioning, integration, testing and demonstration of the entire system shall be carried out “On Site” in LPSC, Tumakuru campus.
j) Entire tubing shall be routed (laid) through trenches/walls appropriately subjected for easy maintenance purpose and shall be covered with a suitable PVC casing. Wherever tubes are required to be routed across the wall, suitable holes shall be drilled through the wall. The entire tubing shall be securely anchored with suitable anchoring mechanism.
k) Necessary tube routing shall be done inside vacuum chamber for supplying propellant inside the chamber.
l) All the vent line tubing, Relief valve outlet tubing, propellant drain line tubing shall be taken out from the facility to effluent pit(Note: effluent pit is not in scope of vendor).
m) SS 304L tubing for compressed air shall be routed for operation of Electro-pneumatic valves.
n) All the panels shall be provided with schematic drawing of the fluid circuits on the front side of the panel and with clear identification of components at their respective location. Also, the valve operating positions like open/close shall be marked by means of good quality stickers.
o) Quantity of spare components is mentioned in bill of materials of each panel. Spare components shall be supplied together with the panels.
p) The certificate of conformance for materials, functionality& calibration certificate for pressure gauges & pressure transmitters, calibration certificate for mass flow meters shall be submitted.

1.2 Scope of LPSC

a) To provide buildings and civil construction, trench as per the layout.
b) Review and approve the design drawings, specifications, layout of the entire gas distribution and propellant feed system after placement of PO.
c) Participation in factory acceptance tests to provide pre-dispatch clearance. (refer section 5.1)
d) Final acceptance of the systems based on site acceptance test data analysis and clearance. (refer section 5.2)
e) Electricity, gases (GHe, GN2, Compressed Air), IPA, particle counters etc. for site acceptance tests will be provided.

Chapter 2: Gas Distribution System

The gas distribution system shall supply gaseous nitrogen, helium and compressed air from gas distribution room to different user point locations. The overall schematic and layout of the system is shown in Figure 1 & Figure 2 respectively. The gas distribution room shall have GN2, GHe and compressed air distribution panels. The GN2 and GHe distribution panels are separate units but have identical fluid circuits (Refer Figure 5). Fluid circuit of compressed air distribution panel is shown in Figure 6.The gases shall be supplied to Point-Of-Use (POU) panels (9 Nos.) and Control panels (1 each for HAT and SLT) through 1/2" SS tubes with Isolation Valves at necessary locations.

The major components of gas distribution system are as follows.

Table 1: Major components of Gas Distribution System

S. No.	Items	Quantity	Remarks
1	Gas distribution panel	2 Nos.	1 each for GN2 &GHe.
2	Compressed air distribution panel	1 No.	To supply compressed air to POU panels.
3	Point-of-Use panel	9 Nos.	For general usage of gases.
4	Control panel-HAT	1 No.	To pressurize run tank for High Altitude Test (HAT) of thrusters.
5	Control panel-SLT	1 No.	To pressurize run tank for Sea-Level Test (SLT) of thrusters.
6	1/2"x0.049” SS304L Tubes	1000 m	For supplying gas from distribution panels to POU and control panels.

2.1 Gas Distribution Panel:

The gas distribution panels are located inside the Gas Distribution Room. There are two separate panels meant for GN2 and GHe distribution. The panels for both the gases have identical fluid circuit and specifications. Fluid circuit is shown in Figure 5.

2.1.1 Technical Description

a) Operating pressure of fluid circuit is 150 bar.
b) The panels shall be provided with two branches of gas cylinders with 4 cylinders each in each branch.
c) Each cylinder shall be connected with SS316 bull nose connecter, SS braided flexible hose, check valve and isolation valves.
d) The cylinders shall be supported by fabricated stainless-steel structure/frame with proper anchoring and belts to ensure safety.
e) The panel structure shall be made of SS304 sheets and frame. The structure shall be buffed with mirror finish for elegant look

f) The panels shall be of leg-mounted pedestal type. Stability of panels shall be ensured and it shall be properly anchored to the ground.
g) The panels shall be realized as per fluid circuit shown in Figure 5.
h) Table 2provides bill of materials including spares for realizing gas distribution panels.
i) The fluid circuit shall be realized with 1/2" OD seamless SS304L tubes.
j) All the pressure gauges, pressure display, regulators, valves shall be assembled on the front panel aesthetically.
k) Vendor shall optimally design the panel sizes while considering future maintenance activities. Vendor shall submit the design to LPSC and approval shall be obtained prior to commencement of fabrication/assembly.
l) All tube joints shall be welded by orbital TIG welding with 100% fusion construction except component interfaces, which shall be provided with double compression ferrule type tube fittings. All the welded joints must be Fluorescent Penetrant (FP) tested.
m) The fluid circuit shall be proof pressure tested at 225 bar (1.5 times of 150 bar) and leak tested (Bubble leak method with helium) at operating pressure 150 bar.
n) Schematic drawing of the fluid circuit shall be provided on front side with clear identification of components at their respective location. Also, the valve operating positions like open/close shall be marked by means of good quality stickers.

Table 2: Bill of materials for gas distribution panel

Gas Distribution Panel
Location: Gas Distribution Room
Operating Pressure: 150Bar
Qty: 2Panels (1 each for GN2 and GHe)
Panel structure material:SS304
Fluid Circuit: Refer Figure 5

S No	Specifications of components	Qty (Nos. Per Panel)	Total Qty (For 2 Panels)	Spares (Nos.)	Make
1	**SOV-1 to SOV-15** **Shut-Off Valve** Type: Ball valve Pressure Rating: 300 bar Material: SS316 Interface: 1/2"	15	30	8	Swagelok/Hamlet/ Dk-lok/ Fitok/Parker
2	**CV-1 to CV-8** **Check Valve** Type: Spring-poppet Pressure Rating: 300 bar Material: SS316 Interface: 1/2"	8	16	4	Swagelok/Hamlet/ Dk-lok/ Fitok/Parker

3	**SS braided flexible hoses** Pressure Rating: 240-300 bar Core: SS 304/316 Braid: SS 304/316 Internal Dia: 1/2" Length: 2 meters	8	16	4	Titeflex/Swagelok/ Hamlet/ Dk-lok/ Fitok/Parker
4	**PG-1 & PG-2** **Bourdon tube pressure gauge** Bourdon tube material: SS316 Range: 0-300 bar Resolution: 1 bar Accuracy: ±1% FSO Dial size: 6”	2	4	1	Mass/ Wika/Ashcroft/
5	**PG-3** **Bourdon tube pressure gauge** Bourdon tube material: SS316 Range: 0-100 bar Resolution: 1 bar Accuracy: ±1% FSO Dial size: 6”	1	2	1	Mass/ Wika/Ashcroft
6	**PT-1** **Pressure transmitter & display** Range: 0-300 bar Accuracy: ≤± 0.25% FSO Excitation voltage: 24 VDC Output: 4-20 mA, 2 wire config. Wetted material: SS316	1	2	1	Druck/Mass/ Wika/Ashcroft/ Keller
7	**PT-2** **Pressure transmitter & display** Range: 0-100 bar Accuracy: ≤± 0.25% FSO Excitation voltage: 24 VDC Output: 4-20 mA, 2 wire config. Wetted material: SS316	1	2	1	Druck/Mass/ Wika/Ashcroft/Keller
8	**F-1 & F-2** **Gas Filter** Type: Pleated Wire Mesh Filter Range: 20µ absolute Pressure Rating: 300 bar Body material: SS316 Mesh material: SS316 Interface: 1/2"	2	4	1	Swagelok/Norman/ Classic
9	**F-3& F-4** **Gas Filter** Type: Pleated Wire Mesh Filter Range: 10µ absolute Pressure Rating: 300 bar Body material: SS316 Mesh material: SS316 Interface: 1/2"	2	4	1	Swagelok/Norman/ Classic

10	**RV-1 & RV-2** **Relief valve** Pressure Rating: 300 bar Body material: SS 316 Interface size: 1/2 “interface Fully open orifice size: 6.4 mm Set Pressure Range: 52 to 70 bar	2	4	1	Swagelok/Hamlet/ Dk-lok/ Fitok/ Parker
11	**TV-1 &TV-2** **3 Way Valve** Type: Ball valve Pressure Rating: 300 bar Material: SS316 Interface: 1/2"	2	4	1	Swagelok/Hamlet/ Dk-lok/ Fitok/Parker
12	**PR-1 & PR-2** **Pressure Reducing Regulator** Type: Spring loaded regulator Venting: Self Venting Inlet pressure: 300 bar Outlet Pressure: 0 to 60 bar Cv: 2 Body material: SS 316 Interface: 1/2"	2	4	1	Tescom/GCE/ Draster/Dutch/IMF/ Swagelok
13	**Seamless Tubes:** Tube OD: 1/2" x 0.065” wall thickness Standard: ASTM A269 Material: SS304L Pressure rating: 300 bar	As per fluid circuit	-	-	Sandvik/ Swagelok/ Dk-lok/Fitok/Parker/Valex
14	**Fittings:** Union, elbow, tee, reducers, cross, plugs, caps, bulk heads etc. Pressure rating:300 bar Material: SS316 Size: as deemed necessary in order to suit the components interface.	As per fluid circuit	-	-	Swagelok/Hamlet/ Dk-lok/ Fitok/ Parker
15	**Gas cylinder connector (Bull nose& Adpater)** Material: SS316 as per IS 3224	8	16	10	Standard make
16	**Belt for gas cylinders (safety purpose)** Cylinder size: Ø 230 x 1400 mm height nominal	8	16	6	Standard make
17	**Structure to support 4 cylinders along the wall** Cylinder size: Ø 230 x 1400mmheightnominal	2 sets	4 sets	-	Standard make

2.2 Compressed Air Distribution Panel

The compressed air distribution panel is located inside Gas Distribution Room (Refer Figure 2). It is connected to two air compressors (**Note: Air compressor supply is not in vendor's scope of work**) as shown in fluid circuit Figure 6. The panel shall supply compressed air to all 9 Nos. of POU panels through 1/2" SS 304L tubes. Bill of materials is provided in Table 3. The panel shall be realized as defined below.

2.2.1 Technical Description

a) The operating pressure for the compressed air distribution panel fluid circuit is 15 bar.
b) The panel shall be connected to two air compressors through isolation valves and SS braided flexible hoses in each line.
c) The panel structure shall be made of SS304 sheets and frame. The structure shall be buffed with mirror finish for elegant look.
d) The panel shall be of leg-mounted pedestal type. Stability of panel shall be ensured and it shall be properly anchored to the ground.
e) The panel shall house the flow components as per fluid circuit shown in Figure 6.
f) Table 3 provides bill of materials including spares for realizing compressed air distribution panel.
g) The fluid circuit shall be realized with 1/2" OD seamless SS304L tubes, suitable fittings and flow components as per details provided in Table 3.
h) All the valves, pressure gauge, pressure display shall be assembled on the front side aesthetically.
i) Vendor shall optimally design the panel sizes while considering future maintenance activities. Vendor shall submit the design to LPSC and approval shall be obtained prior to commencement of fabrication/assembly.
j) All tube joints shall be welded by orbital TIG welding with 100% fusion construction except component interfaces, which shall be provided with double compression ferrule type tube fittings. All the welded joints to be Fluorescent Penetrant (FP) tested.
k) The fluid circuit shall be proof pressure tested at 22 bar (1.5 times of 15 bar) and leak tested (Bubble leak method with helium) at operating pressure 15 bar.
l) Schematic drawing of the fluid circuit shall be provided on front side with clear identification of components at their respective location. Also, the valve operating positions like open/close shall be marked by means of good quality stickers.

Table 3: Bill of materials for compressed air distribution panel

Compressed Air Distribution Panel
Location: Gas Distribution Room
Operating Pressure: 15 Bar
Qty: 1 No.
Panel structure material: SS304
Fluid Circuit: Figure 6

S. No.	Specifications of components	Qty (Nos.)	Spares (Nos.)	Make
1	**SOV-1 to SOV-6** **Shut-Off Valve** Type: Ball valve Pressure Rating: 60 bar Material: SS316 Interface: 1/2"	6	2	Swagelok/Hamlet/ Dk-lok/ Fitok/ Parker
2	**SS braided flexible hoses** Pressure Rating: 60 bar Core: PTFE Braiding: SS304/316 Internal Dia: 1/2" Length: 2 meters	2	1	Titeflex/Swagelok/Hamlet/Dk-lok/Fitok/Parker
3	**PG** **Bourdon tube pressure gauge** Bourdon tube material: SS316 Range: 0-30 bar Resolution: 0.5 bar Accuracy: ±1% FSO Dial size: 6”	1	-	Mass/ Wika/Ashcroft
4	**PT** **Pressure transmitter & display** Range: 0-30 bar Accuracy: ≤ ± 0.25% FS Excitation voltage: 24 VDC Output: 4-20 mA, 2 wireconfig. Wetted material: SS316	1	-	Druck/Mass/Wika/ Ashcroft/Keller
5	**RV** **Relief valve** Pressure Rating: 60 bar Body material: SS 316 Interface size: 1/2 “interface Set Pressure Range: 5 to 15bar	1	1	Swagelok/Hamlet/ Dk-lok/ Fitok/Parker
6	**CV-1, CV-2** **Check Valve** Type: Spring-poppet Pressure Rating: 60 bar Material: SS316 Interface: 1/2"	2	1	Swagelok/Hamlet/Dk-lok/ Fitok/ Parker
7	**Seamless Tubes** Tube OD: 1/2" x 0.065” wall thickness	As per fluid circuit	-	Sandvik/ Swagelok/ Dk-lok/Fitok/ Parker/Valex

	Standard: ASTM A269 Material: SS304L			
8	**Fittings:** Union, elbow, tee, reducers, cross, plugs, caps, bulk heads etc. Pressure rating: 60 bar Material: SS316 Size: as deemed necessary in order to suit the components interface.	As per fluid circuit	-	Swagelok/Hamlet/ Dk-lok/ Fitok/Parker

2.3 Point of Use (POU) Panel

The POU panels shall be located at 9 locations in the campus; the locations are shown in layout (refer Figure 3). Each panel has to be supplied with GN2, GHe and compressed air. The panels have3 modules for each mentioned gas as per the fluid circuit shown in Figure 7. Bill of materials is as per Table 4. The panel shall be realized as per following points.

2.3.1 Technical Description

a) The panel has modules for GN2, GHe and compressed air each. Operating pressure is 50 bar for GN2, GHe module and 15 bar for compressed air module.
b) Inlet of each module shall be connected to respective gas supply lines.
c) The panel structure shall be made of SS304 sheets and frame. The structure shall be buffed with mirror finish for elegant look.
d) The panel shall be of leg-mounted pedestal type while ensuring stability and it shall be properly anchored to the ground.
e) The panel shall be realized as per fluid circuit shown in Figure 7.
f) Table 4 provides bill of material including spares for realizing POU panel.
g) Tubing for GN2 and GHe module shall be 1/4" OD seamless SS304L tubes. Compressed air module shall be realized with 1/2" OD seamless SS304Ltubes.
h) All the pressure gauges, regulator, valves shall be assembled on the front side aesthetically.
i) Vendor shall optimally design the panel sizes while considering future maintenance activities. Vendor shall submit the design to LPSC and approval shall be obtained prior to commencement of fabrication/assembly.
j) All tube joints shall be welded by orbital TIG welding with 100% fusion construction except component interfaces, which shall be provided with double compression ferrule type tube fittings. All the welded joints to be Fluorescent Penetrant (FP) tested.

k) The fluid circuit (GN2 & GHe module) shall be proof pressure tested at 75 bar (1.5 times of 50 bar) and leak tested (Bubble leak method with helium) at operating pressure 50 bar.
l) For compressed air module, proof pressure test shall be done at 22 bar followed by leak test at 15 bar operating pressure.
m) Schematic drawing of the fluid circuit shall be provided on front side with clear identification of components at their respective location. Also, the valve operating positions like open/close shall be marked by means of good quality stickers.

Table 4: Bill of materials for Point-of-Use (POU) Panel

POU Panel
Location: Vacuum pump room (2 nos.), Engine assembly area (1 no.), Run tank room (1 No.), Sea-level test facility (1 No.), chemical lab (1 No.), Hydrazine storage room (1 No.), Compatibility test lab (1 No.), Storage and maintenance room (1 No.)
Operating Pressure: 50 Bar for GN2, GHe module, 15 bar for compressed air module.
Qty: 9 Panels
Panel structure material: SS304
Fluid Circuit: Figure 7

S. No	Specifications of components	Qty per panel (Nos.)	Total Qty (for 9 panels)	Spares (Nos.)	Make
For GN2, GHe Module					
1	**SOV-1 to SOV-4** **Shut-Off Valve** Type: Ball valve Pressure Rating: 200 bar Material: SS316 Interface: 1/4"	4	36	7	Swagelok/Hamlet/ Dk-lok/Fitok/ Parker
2	**NV-1 to NV-2** **Needle Valve** Pressure Rating: 200 bar Material: SS316 Interface: 1/4"	2	18	4	Swagelok/Hamlet/ Dk-lok/ Fitok/ Parker
3	**PG-1, PG-3** **Bourdon tube pressure gauge** Bourdon tube material: SS316 Range: 0-100 bar Resolution: 1 bar Accuracy: ±1% FSO Dial size: 6”	2	18	4	Mass/ Wika/Ashcroft
4	**PG-2 & PG-4** **Bourdon tube pressure gauge** Bourdon tube material: SS316 Range: 0-60 bar Resolution: 0.5 bar Accuracy: Better than ±1% FSO Dial size: 6”	2	18	4	Mass/ Wika/Ashcroft
5	**F-1 & F-3**	2	18	4	Swagelok/Norman/Clas

	Gas Filter Type: Pleated Wire Mesh Filter Range: 20µ absolute Pressure Rating: 200 bar Body material: SS316 Mesh material: SS316 Interface: 1/4"				sic
6	**F-2, F-4** **Gas Filter** Type: Pleated Wire Mesh Filter Range:10µ absolute Pressure Rating: 200 bar Body material: SS316 Mesh material: SS316 Interface: 1/4"	2	18	4	Swagelok/Norman/Clas sic
7	**RV-1 & RV-2** **Relief valve** Pressure Rating: 200 bar Body material: SS 316 Interface size: 1/4“interface Set Pressure Range: 24 to 50 bar	2	18	4	Swagelok/Hamlet/ Dk-lok/ Fitok/ Parker
8	**PR-1 & PR-2** **Pressure Reducing Regulator** Type: Spring loaded Venting: Self Venting Inlet pressure: 200 bar Outlet Pressure: 0 to 50 bar Cv: 0.06 – 0.15 Body material: SS 316	2	18	4	Tescom/GCE/Draster/ Dutch/IMF/Swagelok
9	**Seamless Tubes** Tube OD: 1/4" x 0.035” wall thickness Standard: ASTM A269 Material: SS304L Pressure rating: 200 bar	As per fluid circuit	-	-	Sandvik/ Swagelok/Dk-lok/Fitok/Parker/Valex
10	**Fittings:** Union, elbow, tee, reducers, cross, plugs, caps, bulk heads etc. Pressure rating: 200 bar Material: SS316 Size: as deemed necessary in order to suit the components interface.	As per fluid circuit	-	-	Swagelok/Hamlet/ Dk-lok/ Fitok/Parker
For Compressed Air Module					
11	**SOV-5 to SOV-7** **Shut-Off Valve** Type: Ball valve Pressure Rating: 60bar Material: SS316 Interface: 1/2"	3	27	5	Swagelok/Hamlet/ Dk-lok/ Fitok/ Parker

12	**PG-5, PG-6** **Bourdon tube pressure gauge** Bourdon tube material: SS316 Range: 0-20 bar Resolution: 0.5 bar Accuracy: ±1% FSO Dial size: 6”	2	18	4	Mass/ Wika/ Ashcroft
13	**F-5** **Gas Filter** Type: Pleated Wire Mesh Filter Range: 20µ absolute Pressure Rating: 60bar Body material: SS316 Mesh material: SS316 Interface: 1/2"	1	9	2	Swagelok/Norman//Classic
14	**F-6** **Gas Filter** Type: Pleated Wire Mesh Filter Range: 10µ absolute Pressure Rating: 60 bar Body material: SS316 Mesh material: SS316 Interface: 1/2"	1	9	2	Swagelok/Norman/Classic
15	**PR-3** **Pressure Reducing Regulator** Type: Spring loaded Venting: Self Venting Inlet pressure: 60 bar Outlet Pressure: 0 to 10 bar Cv: 0.3 Body material: SS 316	1	9	2	Tescom/GCE/Draster/ Dutch/IMF/ Swagelok
16	**RV-3** **Relief valve** Pressure Rating: 60 bar Body material: SS 316 Interface size: 1/2“interface Set Pressure Range:10 to 20bar	1	9	2	Swagelok/Hamlet/ Dk-lok/ Fitok/ Parker
17	**Seamless Tube:** Tube OD: 1/2" x 0.065” wall thickness Standard: ASTM A269 Material: SS304L Pressure rating: 60 bar	As per fluid circuit	-	-	Sandvik/ Swagelok/Dklok/Fitok/ Parker/Valex
18	**Fittings:** Union, elbow, tee, reducers, cross, plugs, caps, bulk heads etc. Pressure rating: 60 bar Material: SS316 Size: as deemed necessary in order to suit the components interface.	As per fluid circuit	-	-	Swagelok/Hamlet/ Dk-lok/ Fitok/ Parker

2.4 Control Panel-HAT& Control Panel-SLT

Control panel for High Altitude Test Facility (HAT)and Control Panel for Sea-Level Test Facility (SLT) are located in Engine Assembly Area as shown in the layout (Figure 2). The panels are used for pressurizing the run tank for High Altitude Testing and Sea-Level Testing of thrusters. Each panel has two modules, GN2 and GHe module. The respective modules shall be connected with GN2 and GHe lines emerging from gas distribution panels. Fluid circuit of control panel-HAT and Control Panel-SLT is shown in Figure 8&Figure 9 respectively. The fluid circuit of the panels is identical. Bill of materials including spares are provided in Table 5 for Control Panel-HAT and in Table 6 for Control Panel-SLT. The Control Panels shall be designed, fabricated, assembled, tested and supplied as per the following points.

2.4.1 Technical Description

(a) The operating pressure of fluid circuit for both the panels is 40 bar.
(b) The panel has modules for GN2 and GHe each.
(c) Inlet of each module shall be connected to respective gas supply line incoming from distribution panels.
(d) The panel structure shall be made of SS304 sheets and frame. The structure shall be buffed with mirror finish for elegant look.
(e) The panel shall be of leg-mounted pedestal type while ensuring stability and it shall be properly anchored to the ground.
(f) The panels shall be realized as per fluid circuit shown in Figure 8&Figure 9.
(g) Table 5 & Table 6 provide bill of materials including spares for Control Panel-HAT and SLT respectively.
(h) The fluid circuit shall be realized with 3/8" OD seamless SS304L tubes.
(i) All the pressure gauges, pressure transmitter display, regulators, valves shall be assembled on the front side aesthetically.
(j) Vendor shall optimally design the panel sizes while considering future maintenance activities. Vendor shall submit the design to LPSC and approval shall be obtained prior to commencement of fabrication/assembly.
(k) All tube joints shall be welded by orbital TIG welding with 100% fusion construction except component interfaces, which shall be provided with double compression ferrule type tube fittings. All the welded joints should be Fluorescent Penetrant (FP) tested.
(l) The fluid circuit shall be proof pressure tested at 60 bar (1.5 times of 40 bar) and leak tested (Bubble leak method with helium) at operating pressure 40 bar.
(m) Schematic drawing of the fluid circuit shall be provided on front side with clear identification of components at their respective location. Also, the valve operating positions like open/close shall be marked by means of good quality stickers.
(n) Electronic Pressure Regulator (EPR-1 & 2) are used for maintaining required constant pressure (Range 1 bar to 30barControl band ± 0.05 bar) in run tank during thruster firing. (Refer chapter 3 for more details on propellant feed system)

(o) Tescom make ER5000 series electro-pneumatic PID Controller and compatible air/dome loaded regulator combination shall be used as EPR.
(p) EPR shall be tuned properly to obtain require accuracy of± 0.05 bar over the full pressure range 1-30 bar.
(q) The pressure sensor PT-1, PT-2 in control panels and PFPT-1 on run tank (refer chapter 3) shall be properly chosen to ensure compatibility with PID controller and to achieve required accuracy of pressure.
(r) Graphic User Interface software shall be provided to command EPR. It shall have provision for pressurization up to input value of pressure, maintaining constant pressure and depressurization.
(s) These panels are the interface between gas distribution system and propellant feed system. Detailed description of propellant feed system is provided in chapter-3.

Table 5: Bill of materials for Control Panel-HAT

Control Panel (HAT)
Location: Engine Assembly Area
Operating Pressure: 40 Bar
Qty: 1Panel
Panel structure material: SS304
Fluid Circuit: Figure 8

S. No	Specifications of components	Qty (Nos.)	Spares (Nos.)	Make
1	**SOV-1 to SOV-10** **Shut-Off Valve** Type: Ball valve Pressure Rating: 200 bar Material: SS316 Interface: 3/8"	10	2	Swagelok/Hamlet/ Dk-lok/ Fitok/ Parker
2	**NV-1 to NV-6** **Needle Valve** Pressure Rating: 200 bar Material: SS316 Interface: 3/8"	6	2	Swagelok/Hamlet/ Dk-lok/ Fitok/ Parker
3	**CV-1 & CV-2** **Check Valve** Type: Spring poppet Pressure Rating: 200 bar Material: SS316 Interface: 3/8" Cracking pressure: 1/3 psi	2	1	Swagelok/Hamlet/Dk-lok/ Fitok/ Parker
4	**PG-1 & PG-3** **Bourdon tube pressure gauge** Bourdon tube material: SS316 Range: 0-100 bar Resolution: 1 bar	2	1	Mass/ Wika/ Ashcroft

	Accuracy: ±1% FSO Dial size: 6”			
5	**PG-2 & PG-4** **Bourdon tube pressure gauge** Bourdon tube material: SS316 Range: 0-40 bar Resolution: 0.1 bar Accuracy: Better than ±0.2% FSO Dial size: 6”	2	1	Heise/Mass/ Wika/Ashcroft
6	**PT-1 & PT-2** **Pressure transmitter & display** Range: 0-40 bar Accuracy: <± 0.1% FSO Excitation voltage: 24 VDC Wetted material: SS316 Output: 4-20 mA, 2 wire config.	2	1	Druck/Mass/ Wika/ Ashcroft/Keller
7	**F-1 & F-4** **Gas Filter** Type: Pleated Wire Mesh Filter Range: 10µ absolute Pressure Rating: 200 bar Body material: SS316 Mesh material: SS316 Interface: 3/8"	2	1	Swagelok/Norman/Classic
8	**F-2, F-3, F-5 & F-6** **Gas Filter** Type: Pleated Wire Mesh Filter Range:10µ absolute Pressure Rating: 200 bar Body material: SS316 Mesh material: SS316 Interface: 3/8"	4	1	Swagelok/Norman/Classic
9	**RV-1 & RV-2** **Relief valve** Pressure Rating: 200 bar Body material: SS 316 Interface size: 3/8 “interface Set Pressure Range: 24 to 50 bar	2	1	Swagelok/Hamlet/ Dk-lok/ Fitok/ Parker
10	**SV-1 to SV-6** **Solenoid Valve** Type: 2 way, normally closed Pressure Rating: 100 bar Operating voltage: 24-30 VDC Material: SS 316 Interface: 3/8” Orifice size: 6mm or larger Seat, Seal: PTFE, PCTFE	6	2	Burkert/Parker/Honeywell/ Asco
11	**EPR-1 & EPR-2** **Electronic Pressure Regulator** **(a) Electro-pneumatic PID**	2 sets	1 set	Tescom

	Controller Tescom ER5000 series controller **(b) Pressure reducing regulator** Type: Air/dome loaded regulator Self venting Inlet pressure: 200 bar Outlet Pressure: 0 to 40 bar Cv: 0.06 - 0.15 Body material: SS 316			
12	**PR-1 & PR-2** **Pressure Reducing Regulator**(manual operation) Type: Spring loaded Venting: Self Venting Inlet pressure: 200 bar Outlet Pressure: 0 to 40 bar Cv: 0.06 Body material: SS 316	2	1	Tescom/GCE/Draster/ Dutch/IMF/Swagelok
13	**Seamless Tubes** Tube OD: 3/8" x 0.035” wall thickness. Standard: ASTM A269 Material: SS304L Pressure rating: 200 bar	As per fluid circuit	-	Sandvik/ Swagelok/Dk-Lok/Fitok/ Parker/Valex
14	**Fittings** Union, elbow, tee, reducers, cross, plugs, caps, bulk heads etc. Pressure rating: 200 bar Material: SS316 Size: as deemed necessary in order to suit the components interface.	As per fluid circuit	-	Swagelok/Hamlet/ Dk-lok/ Fitok/ Parker

Table 6: Bill of materials for Control Panel-SLT

Control Panel-SLT
Location: Engine Assembly Area
Operating Pressure: 40 Bar
Qty: 1 Panel
Panel structure material: SS304
Fluid Circuit: Figure 9

S. No	Specifications of components	Qty (Nos.)	Spares (Nos.)	Make
1	**SOV-1 to SOV-10** **Shut-Off Valve** Type: Ball valve Pressure Rating: 200 bar Material: SS316 Interface: 3/8"	10	2	Swagelok/Hamlet/ Dk-lok/ Fitok/ Parker
2	**NV-1 to NV-6** **Needle Valve** Pressure Rating: 200 bar Material: SS316 Interface: 3/8"	6	1	Swagelok/Hamlet/ Dk-lok/ Fitok/ Parker
3	**CV-1 & CV-2** **Check Valve** Type: Spring poppet Pressure Rating: 200 bar Material: SS316 Interface: 3/8" Cracking pressure: 1/3 psi	2	1	Swagelok/Hamlet/Dk-lok/ Fitok/ Parker
4	**PG-1 & PG-3** **Bourdon tube pressure gauge** Bourdon tube material: SS316 Range: 0-100 bar Resolution: 1 bar Accuracy: ±1% FSO Dial size: 6”	2	1	Mass/ Wika/ Ashcroft
5	**PG-2 & PG-4** **Bourdon tube pressure gauge** Bourdon tube material: SS316 Range: 0-40 bar Resolution: 0.1 bar Accuracy: Better than ±0.2% FSO Dial size: 6”	2	-	Heise/Mass/ Wika/Ashcroft
6	**PT-1 & PT-2** **Pressure transmitter & display** Range: 0-40 bar Accuracy: <± 0.1% FSO Excitation voltage: 24 VDC Output: 4 – 20 mA, 2 wire config. Wetted material: SS316	2	-	Druck/Mass/Wika/ Ashcroft/Keller
7	**F-1 & F-4** **Gas Filter**	2	-	Swagelok/Norman/Classic

	Type: Pleated Mesh Wire Filter Range: 10µ absolute Pressure Rating: 200 bar Body material: SS316 Mesh material: SS316 Interface: 3/8"			
8	**F-2, F-3, F-5 & F-6** **Gas Filter** Type: Pleated Mesh Wire Filter Range: 10µ absolute Pressure Rating: 200 bar Body material: SS316 Mesh material: SS316 Interface: 3/8"	4	1	Swagelok/Norman/Classic
9	**RV-1 & RV-2** **Relief valve** Pressure Rating: 200 bar Body material: SS 316 Interface size: 3/8 “interface Set Pressure Range: 24 to 50 bar	2	1	Swagelok/Hamlet/ Dk-lok/ Fitok/ Parker
10	**SV-1 to SV-6** **Solenoid Valve** Type: 2 way, Normally closed Pressure Rating: 100 bar Operating voltage: 24-30 VDC Material: SS 316 Interface: 3/8” Orifice size: 6mm or larger Seat, Seal: PTFE, PCTFE	6	2	Burkert/Parker/ Honeywell/Asco
11	**EPR-1 & EPR-2** **Electronic Pressure Regulator** Electro-pneumatic Controller with regulator **(a) Electro-pneumatic PID Controller** Tescom ER5000 series **(b) Pressure reducing regulator** Type: Air/dome loaded regulator, Self-venting Inlet pressure: 200 bar Outlet Pressure: 0 to 40 bar Cv: 0.06 -0.15 Body material: SS 316	2 sets	-	Tescom
12	**PR-1 & PR-2** **Pressure Reducing Regulator** (manual operation) Type: Spring loaded, Self-Venting Inlet pressure: 200 bar Outlet Pressure: 0 to 40 bar Cv: 0.15 Body material: SS 316	2	1	Tescom/GCE/Draster/ Dutch/IMF/Swagelok

13	**Seamless Tube** Tube OD: 3/8" x 0.035" wall thickness. Standard: ASTM A269 Material: SS304L Pressure rating: 200 bar	As per fluid circuit	-	Sandvik/ Swagelok/Dk lok/Fitok/Parker/Valex
14	**Fittings:** Union, elbow, tee, reducers, cross, plugs, caps, bulk heads etc. Pressure rating: 200 bar Material: SS316 Size: as deemed necessary in order to suit the components interface.	As per fluid circuit	-	Swagelok/Hamlet/ Dk-lok/ Fitok/Parker

Table 7: Bill of materials for SS tubes, fittings and Isolation valves used for inter-connecting the panels of gas distribution system.

S. No.	Specifications of components	Qty	Spares	Make
1	**SS Seamless Tubes** Tube OD: 1/2" x 0.049" wall thickness Standard: ASTM A269 Material: SS304L Pressure rating: 200 bar	Approx. 1000 m	-	Sandvik/ Swagelok/ Dk-lok/Fitok/ Parker/Valex
2	**Isolation Valves** Type: Ball valve Pressure Rating: 200 bar Material: SS316 Interface: 1/2"	15 Nos.	3 Nos.	Swagelok/Hamlet/ Dk-lok/ Fitok/ Parker
3	**Fittings** Union, elbow, tee, reducers, cross, plugs, caps etc. Pressure rating: 200 bar Material: SS316 Size: as deemed necessary in order to suit the components interface.	As per fluid circuit	-	Swagelok/Hamlet/ Dk-lok/ Fitok/ Parker

Chapter 3: Propellant Feed System

Propellant feed system shall supply pressurised liquid propellant from run tanks located in Run Tank Room to the desired location inside vacuum chamber and at sea-level test stand. The propellant feed system includes mass flow meters, pneumatically operated valves; manual valves etc. All the components shall be interconnected by SS304L tubes. Major components of propellant feed system are shown in schematicFigure 3.

The fluid circuit of propellant feed system for High Altitude Tests (HAT) and Sea-Level Testing (SLT) is shown in Figure 10&Figure 11 respectively. The propellant which is stored in run tank shall be pressurized to required pressure through control panel. When the valves are opened, the propellant shall flow through mass flow meters to the thruster mounted inside vacuum chamber for HAT. Similar operation would take place for SLT also. Whole propellant feed system for HAT shall be realized with 1/4" OD SS304L seamless tubes. For SLT, 3/8” OD SS304L seamless tubes shall be used.

As shown in the Figure 10&Figure 11, the feed system for each HAT and SLT has two panels, Flow meter panel and propellant feed valve panel. Overall layout of propellant feed system for Both HAT and SLT is shown in **Figure 4**. Both the flow meter panels (HAT & SLT) shall be located in Run Tank Room. The Propellant Feed Valve Panel-HAT shall be placed in engine assembly area (near vacuum chamber) while the Propellant Feed Valve Panel-SLT shall be placed in sea-level test facility (Near test stand).The flow meter panels and propellant feed valve panels shall be connected to nearby POU panels for supply of compressed air to operate Electro-pneumatic valve.

3.1 Propellant Feed System for HAT

Propellant feed system for HAT mainly consists of Flow Meter Panel-HAT, Propellant Feed Valve Panel-HAT. The fluid circuit is shown in Figure 10. The flow meter panel shall be located in run tank room (adjacent to run tank) and to be connected to Control panel-HAT (Described in Section2.4), POU panel (located in Engine Assembly Area), propellant feed valve panel-HAT and Effluent pit. The panels shall be interconnected by SS 304L seamless tubes.

3.1.1 Technical description:

a) Operating Pressure of the system is 27 bar.
b) The panels’ structure shall be made of SS304 sheets and frame. The structure shall be buffed with mirror finish for elegant look.
c) The panels shall be of pedestal type. Stability of panels shall be ensured & it shall be properly anchored to the ground.
d) The panels shall be realized as per fluid circuit shown in Figure 12&Figure 14.

e) Table 8 provides bill of materials including spares for propellant feed system-HAT.
f) As the pressure in run tank (**Run tank is not in vendor's scope**) would be controlled by Control Panel-HAT. Outlet of the Control panel (i.e. GN2 Outlet-2 and GHeOutlet-2) shall be connected to Gas Pressurization (GP) line of Flow Meter Panel by 3/8" OD SS304L seamless tubes.
g) The fluid circuit of Flow Meter Panel-HAT shall be realized with 1/4" OD SS304L seamless tubes and GP line with 3/8" OD SS304L seamless tubes.
h) Pneumatically operated bellow sealed valve (SS-4BG-3C) shall be used in Propellant Feed (PF) line.
i) The pneumatically operated valve shall be operated by 3 way solenoid valve. Both shall be supplied as a set.
j) Regulated compressed air supply shall be provided to solenoid valves from POU panel placed in Engine Assembly Area (Refer Figure 4 & Figure 10) by means of SS304L tubes.
k) Flow meter panel shall be connected to run tank by means of SS braided flexible hoses.
l) 2 Nos. of Coriolis mass flow meters (Micro Motion make CMFS007M with transmitters) shall be incorporated in propellant feed line for propellant flow measurement during tests.
m) Flow meter panel shall be connected to propellant feed valve panel-HAT through 1/4" OD, SS304L seamless tube.
n) To conduct leak test and purging of thruster, GN2 Outlet-1 and GHe Outlet-1 of Control Panel-HAT shall be connected to Leak Test/Purging (LP) line of Propellant Feed Valve Panel-HAT by 1/4" OD, SS304L seamless tubes.
o) The fluid circuit of Propellant Feed Valve Panel-HAT shall be realized with 1/4" OD SS304L seamless tubes.
p) All the valves, pressure & flow transmitter display shall be assembled on the front side of panels aesthetically.
q) Propellant feed line shall be routed into the vacuum chamber till the thruster mounting point **(Vacuum Chamber& thruster are not in vendor's scope).**
r) Components inside the vacuum chamber shall be anchored properly on brackets and supports.
s) Considering the hazardous nature of propellant, all the electrical components used in propellant feed system must be **ATEX certified**.
t) Pressure in the run tank shall be maintained by Electronic Pressure Regulators (EPR1 & 2) of Control Panel-HAT.
u) EPR shall be tuned properly to maintain required pressure within accuracy in run tank during propellant flow (Pressure Range: 1-30 bar ± 0.05 bar)
v) All the stainless-steel tubes used shall be pre-cleaned and passivated.
w) All tube joints shall be welded by orbital TIG welding with 100% fusion construction except component interfaces, which shall be provided with

double compression ferrule type tube fittings. All the welded joints should be Fluorescent Penetrant (FP) tested

x) The system shall be proof pressure tested at 40 bar (1.5 times of 27 bar) and leak tested (Bubble leak method with helium) at operating pressure 27 bar.

y) Pressure hold test for 8 hours shall be conducted at operating pressure of 27 bar.

z) Vendor shall optimally design the panel sizes while considering future maintenance activities. Vendor shall submit the design to LPSC and approval shall be obtained prior to commencement of fabrication/assembly.

aa) Schematic drawing of the fluid circuit shall be provided on front side with clear identification of components at their respective location. Also, the valve operating positions like open/close shall be marked by means of good quality stickers

bb) Spare items mentioned in Table 8 shall be supplied along with panels.

Table 8: Bill of materials for propellant feed system HAT

Location: Flow meter panel-HAT in Run tank room, Propellant feed valve panel-HAT in Engine Assembly Area (adjacent to Vacuum Chamber) and remaining components as per fluid circuit.
Operating Pressure: 27 Bar
Panel structure material:SS304
Fluid Circuit: Refer Figure 10

S. No.	Specifications of components	Qty (Nos.)	Spares (Nos.)	Make
1	**PFBV-1 to PFBV-8, LPBV-1 to LPBV-3** **Shut-Off Valve** Type: Ball valve Pressure Rating: 100 bar Material of construction: SS316 Packing: PTFE Other wetted material: SS316 Interface: 1/4"	11	3	Swagelok/Hamlet / Dk-lok/ Fitok/ Parker
2	**GPBV-1 & 2** **Shut-Off Valve** Type: Ball valve Pressure Rating: 100 bar Material of construction: SS316 Packing: PTFE Other wetted material: SS316 Interface: 3/8"	2	1	Swagelok/Hamlet / Dk-lok/ Fitok/ Parker
3	**PFNV-1** **Needle Valve** Pressure Rating: 100 bar Material of construction: SS316 Other wetted material: SS316 Interface: 1/4"	1	1	Swagelok/Hamlet / Dk-lok/ Fitok/ Parker
4	**PFCV-1, LPCV-1** **Check Valve**	2	1	Swagelok/Hamlet /Dk-lok/ Fitok/

	Type: Spring poppet Pressure Rating: 100 bar Material: SS316 Interface: 1/4" Cracking pressure: 1/3 psi O ring: PTFE, EPDM			Parker
5	**GPCV-1** **Check Valve** Type: Spring poppet Pressure Rating: 100 bar Material: SS316 Interface: 3/8" Cracking pressure: 1/3 psi O ring: PTFE, EPDM	1	1	Swagelok/Hamlet /Dk-lok/ Fitok/ Parker
6	**PFPT-1, PFPT-2** **Pressure transmitter & display** Range: 0-30 bar Accuracy: <± 0.1% FSO Excitation voltage: 24 VDC Output: 4 – 20 mA, 2 wire config. Wetted material: SS316 **Protection**: ATEX Exia II C T4	2	1	Druck/Mass/ Wika/Ashcroft/Keller
7	**PFF-1, PFF-2** **Liquid Propellant Filter** Type: Pleated Wire Mesh Filter Range: 10µ absolute Pressure Rating: 100 bar Body material: SS316 Mesh material: SS316 Interface: 1/4"	2	1	Swagelok/Norman/Classic
8	**LPF-1** **Gas Filter** Type: Pleated Wire Mesh Filter Range: 10µ absolute Pressure Rating: 100 bar Body material: SS316 Mesh material: SS316 Interface: 1/4"	1	1	Swagelok/Norman/Classic
9	**GPF-1** **Gas Filter** Type: Pleated Wire Mesh Filter Range: 10µ absolute Pressure Rating: 100 bar Body material: SS316 Mesh material: SS316 Interface: 3/8"	1	1	Swagelok/Norman/Classic
10	**PFRV-1** **Relief valve** Pressure Rating: 100 bar Body material: SS 316 Interface size: 1/4“ Set Pressure Range: 24 to 50 bar	1	1	Swagelok/Hamlet / Dk-lok/ Fitok/ Parker

	O ring: PTFE, EPDM			
11	**PFEP-1 to PFEP-4, LPEP-1** **Electro-Pneumatic Valve** **a) Pneumatically Operated Valve** **Swagelok SS-4BG-3C** Type: Bellow sealed valve Actuator: Pneumatic, Normally closed spring return Valve pressure rating: 69 bar Valve Interface: 1/4" **b) Solenoid valve** (to control pneumatic valve operation) Type: 3 way, normally closed Pressure rating: 20 bar Operating voltage: 24-30 VDC Material: SS316 Interface: 1/4" **Protection**: ATEX certified	5 sets	2 sets	**Pneumatically Operated valve:** Swagelok **Solenoid valve:** Burkert/Parker/Honeywell/Asco
12	**PFMF-1 & PFMF-2** **Coriolis Mass flow meter** **Model No: Micro Motion CMFS007M with transmitter** Range: 0-10 g/s Accuracy: ±0.10% of rate Protection: ATEX Zone1 (or better) II C T4 Interface: 1/4" Output: 4-20 mA, RS485 Pressure Rating: 100 bar **Flow Transmitter:** **Model No: 5700** Protection: ATEX Zone 1 II C T4	2	2	Micro motion
13	**PFHose-1, PFHose-2** **SS braided flexible hose** Interface: 1/4" Internal dia: 1/4" Inner core: SS304L corrugated Braiding: SS304/316 Pressure rating: 100 bar Length: 2 m	2	2	Titeflex/Swagelok/Hamlet/Dk-lok/Fitok/Parker
14	**GPHose-1** **SS braided flexible hose** Interface: 3/8" Internal dia: 3/8" Inner core: SS304L corrugated Braiding: SS304/316 Pressure Rating: 100 bar Length: 2 m	1	1	Titeflex/Swagelok/Hamlet/Dk-lok/Fitok/Parker
15	**PFHose-3** **SS braided flexible hose** Interface: 1/4" Internal Dia: 1/4"	1	1	Titeflex/Swagelok/Hamlet/Dk-lok/Fitok/Parker

	Inner core: SS304L corrugated Braiding: SS304/316 Pressure Rating: 100 bar Length: 1 m			
16	**SS Tubing for Flow meter panel-HAT and Propellant feed valve panel-HAT** **Seamless tube** Tube OD: 1/4" x 0.035" wall thickness Standard: ASTM A269 Material: **SS304L** Pressure rating: 100 bar	As per fluid circuit	-	Sandvik/ Swagelok/ Dk-lok/Fitok/Parker/Valex
17	**SS Tubes for interconnection between Control panel-HAT & Flow meter panel-HAT [for GN2, GHe]** **Seamless Tube** Tube OD: 3/8" x 0.035" wall thickness Standard: ASTM A269 Material: **SS304L** Pressure rating: 100 bar	60 meters	-	Sandvik/ Swagelok/ Dk-lok/Fitok/Parker/Valex
18	**SS Tubes for interconnection between Control panel-HAT & Propellant feed valve panel-HAT[for GN2, GHe gas supply]** **Seamless Tube** Tube OD: 1/4" x 0.035" wall thickness Standard: ASTM A269 Material: **SS304L** Pressure rating: 100 bar	70 meters	-	Sandvik/ Swagelok/ Dk-lok/Fitok/Parker/Valex
19	**SS Tubes for interconnection between flow meter panel-HAT, Propellant Feed Valve panel-HAT & Vacuum Chamber [for Propellant]** **Seamless Tube** Tube OD: 1/4" x 0.035" wall thickness Standard: ASTM A269 Material: **SS304L** Pressure rating: 100 bar	50 meters	-	Sandvik/ Swagelok/ Dk-lok/Fitok/Parker/Valex
20	**SS Tubes line from flow meter panel-HAT & Propellant Feed Valve panel-HAT to Effluent pit [For Propellant]** **Seamless Tube** Tube OD: 1/4" x 0.035" wall thickness Standard: ASTM A269 Material: **SS304L**	70 meters	-	Sandvik/ Swagelok/ Dk-lok/Fitok/Parker/Valex
21	**SS tubes for compressed air from POU panel (in Engine assembly area) to Flow meter panel-HAT & Propellant Feed Valve panel-HAT** **[For pneumatic valve operation]** Tube OD: 1/4" x 0.035" wall thickness Standard: ASTM A269 Material: **SS304L**	70 meters	-	Sandvik/ Swagelok/ Dk-lok/Fitok/Parker/Valex
22	**SS Fittings for propellant feed system-HAT**	As per	-	Swagelok/Hamlet

	Union, elbow, tee, reducers, cross, plugs, caps, bulk heads etc. Pressure rating: 100 bar Material: SS316 Size: as deemed necessary in order to suit the components interface.	fluid circuit		/ Dk-lok/ Fitok/Parker

3.2 Propellant Feed System for Sea-Level Test

Propellant feed system for SLT mainly consists of Flow Meter Panel-SLT, Propellant Feed Valve Panel-SLT. The whole fluid circuit is shown in Figure 11. The flow meter panel shall be located in run tank room (adjacent to run tank) and to be connected to Control panel-SLT (Described in Section2.4), POU panel (located in Sea-Level Test Facility), propellant feed valve panel-SLT and Effluent pit. The panels shall be interconnected by SS 304L seamless tubes. Bill of materials is as per Table 9.

3.2.1 Technical description:

a) Operating Pressure of the system is 27 bar.
b) The panel structures shall be made of 304 sheets and frame. The structure shall be buffed with mirror finish for elegant look.
c) The panels shall be of pedestal type. Stability of panels shall be ensured & it shall be properly anchored to the ground.
d) The panels shall be realized as per fluid circuit shown in Figure 13&Figure 15.
e) Table 9provides bill of materials including spares for propellant feed system-SLT.
f) As the pressure in run tank (**Run tank is not in vendor's scope**) would be controlled by Control Panel-SLT. Outlet of the Control panel-SLT (i.e. GN2 Outlet-2 and GHe Outlet-2) shall be connected to Gas Pressurization (GP) line of Flow Meter Panel by 3/8" OD SS304L seamless tubes.
g) The fluid circuit of Flow Meter Panel-SLT shall be realized with 3/8" OD SS304L seamless tubes.
h) Pneumatically operated bellow sealed valve (SS-6BG-3C) shall be used in Propellant Feed (PF).
i) The pneumatically operated valve shall be operated by 3-way solenoid valve. Both shall be supplied as a set.
j) Regulated compressed air supply shall be provided to solenoid valves from POU panel placed in sea-level test facility (Refer Figure **4** & Figure 11) by means of SS304L tubes.
k) Flow meter panel shall be connected to run tank by means of SS braided flexible hoses.
l) 2 Nos. of Coriolis mass flow meters (Micro Motion make CMF025M with transmitters) are incorporated in propellant feed line for propellant flow measurement during tests.

m) Flow meter panel shall be connected to propellant feed valve panel-SLT through 3/8" OD SS304L seamless tube.
n) To conduct leak test and purging of thruster, GN2 Outlet-1 and GHe Outlet-1 of Control Panel-SLT shall be connected to Leak Test/Purging (LP) line of Propellant Feed Valve Panel-SLT by 3/8” OD SS304L seamless tubes.
o) The fluid circuit of Propellant Feed Valve Panel-SLT shall be realized with 3/8" OD SS304L seamless tubes.
p) All the valves, pressure & flow transmitter display shall be assembled on the front side of panels aesthetically.
q) Propellant feed line shall be routed to the test stand till the thruster mounting point (**Test stand & thruster are not in vendor’s scope**).
r) Components near the test stand shall be anchored properly on brackets and supports.
s) Considering the hazardous nature of propellant, all the electrical components used in propellant feed system must be **ATEX certified**.
t) Pressure in the run tank shall be maintained by Electronic Pressure Regulators (EPR1 & 2) of Control Panel-SLT.
u) EPR shall be tuned properly to maintain required pressure within accuracy in run tank during propellant flow (Pressure Range: 1-30 bar Control band ± 0.05 bar)
v) All the stainless-steel tubes used shall be pre-cleaned and passivated.
w) All tube joints shall be welded by orbital TIG welding with 100% fusion construction except component interfaces, which shall be provided with double compression ferrule type tube fittings. All the welded joints should be Fluorescent Penetrant (FP) tested.
x) The system shall be proof pressure tested at 40 bar (1.5 times of 27 bar) and leak tested (Bubble leak method with helium) at operating pressure 27 bar.
y) Pressure hold test for 8 hours shall be conducted.
z) Vendor shall optimally design the panel sizes while considering future maintenance activities. Vendor shall submit the design to LPSC and approval shall be obtained prior to commencement of fabrication/assembly.
aa) Schematic drawing of the fluid circuit shall be provided on front side with clear identification of components at their respective location. Also, the valve operating positions like open/close shall be marked by means of good quality sticker.
bb) Spare items mentioned in Table 9shall be supplied along with panels.

Table 9: Bill of materials for propellant feed system-SLT

Location: Flow meter panel-SLT in Run tank room, Propellant feed valve panel-SLT in Sea-level test facility.
Operating Pressure: 27 Bar
Panel structure material:SS304
Fluid Circuit: Figure 11

S. No	Specifications of components	Qty (Nos.)	Spares (Nos.)	Make
1	**PFBV-1 to PFBV-8, GPBV-1 & 2, LPBV-1 to LPBV-3** **Shut-Off Valve** Type: Ball valve Pressure Rating: 100 bar Material of construction: SS316 Packing: PTFE Other wetted material: SS316 Interface: 3/8"	13	4	Swagelok/Hamlet / Dk-lok/ Fitok/Parker
2	**PFNV-1** **Needle Valve** Pressure Rating: 100 bar Material of construction: SS316 Other wetted material: SS316 Interface: 3/8"	1	1	Swagelok/Hamlet / Dk-lok/ Fitok/Parker
3	**GPCV-1, PFCV-1, LPCV-1** **Check Valve** Type: Spring poppet Pressure Rating: 100 bar Material: SS316 Interface: 3/8" Cracking pressure: 1/3 psi O ring: PTFE, EPDM	3	1	Swagelok/Hamlet /Dk-lok/ Fitok/Parker
4	**PFPT-1, PFPT-2** **Pressure transmitter & display** Range: 0-30 bar Accuracy: <± 0.1% FSO Excitation voltage: 24 VDC Output: 4 – 20 mA, 2 wire config. Wetted Material: SS316 **Protection**: ATEX Exia II C T4 or equivalent	2	1	Druck/Mass/ Wika/Ashcroft/Keller
5	**PFF-1, PFF-2** **Liquid Propellant Filter** Type: Pleated Mesh Wire Filter Range: 10µ absolute Pressure Rating: 100 bar Body material: SS316 Mesh material: SS316 Interface: 3/8"	2	1	Swagelok/Norman/Classic
6	**GPF-1, LPF-1** **Gas Filter** Type: Pleated Mesh Wire Filter Range: 10µ absolute	2	1	Swagelok/Norman/Classic

	Pressure Rating: 100 bar Body material: SS316 Mesh material: SS316 Interface: 3/8"			
7	**PFRV-1** **Relief valve** Pressure Rating: 100 bar Body material: SS 316 Interface size: 3/8“ Set Pressure Range: 24 to 50 bar O ring: PTFE, EPDM	1	1	Swagelok/Hamlet / Dk-lok/ Fitok/Parker
8	**PFEP-1 to PFEP-4, LPEP-1** **Electro-Pneumatic Valve** **a) Pneumatically Operated Valve** **Swagelok SS-6BG-3C** Type: Bellow sealed valve Actuator: Pneumatic, normally closed spring return Valve pressure rating: 69 bar Valve Interface: 3/8" **b) Solenoid valve** (For control pneumatic valve operation) Type: 3 way, normally closed Pressure rating: 20 bar Operating voltage: 24-30 VDC Material: SS316 Interface: 1/4" **Protection**: ATEX Certified	5 sets	2 sets	Pneumatically Operated valve: Swagelok Solenoid valve: Burkert/Parker/Honeywell/Asco
9	**PFMF-1 & PFMF-2** **Coriolis Mass flow meter** **Model No: Micro Motion CMF025M with transmitter** Range: 0-300 g/s Accuracy: ±0.10% of rate Protection: ATEX Zone1 (or better) II C T4 Interface: 3/8" Output: 4-20 mA, RS485 Pressure Rating: 100 bar **Flow Transmitter:** **Model No: 5700** Protection: ATEX Zone1 II C T4	2	-	Micro motion
10	**PFHose-1, PFHose-2, GPHose-1** **SS braided flexible hose** Interface: 3/8" Internal Dia: 3/8" Inner core: SS304L corrugated Braiding: SS304/316 Length: 2 m Pressure Rating: 100 bar	3	3	Titeflex/Swagelok /Hamlet/Dk-lok/Fitok/Parker

11	**PFHose-3** **SS braided flexible hose** Interface: 3/8" Internal Dia: 3/8" Inner core: SS304L corrugated Braiding: SS304/316 Length: 1 m Pressure Rating: 100 bar	1	1	Titeflex/Swagelok /Hamlet/Dk-lok/Fitok/Parker
12	**SS Tubing for panels** **Seamless tube** Tube OD: 3/8" x 0.035” wall thickness Standard: ASTM A269 Material: **SS304L** Pressure rating: 100 bar	As per fluid circuit	-	Sandvik/ Swagelok/ Dk-lok/Fitok/Parker/Valex
13	**SS Tubes for interconnection between Control panel-SLT, Flow meter panel-SLT, Propellant Feed Valve panel-SLT** **Seamless Tube** Tube OD: 3/8" x 0.035” wall thickness Standard: ASTM A269 Material: **SS304L** Pressure rating: 100 bar	200 meters	-	Sandvik/ Swagelok/ Dk-lok/Fitok/ Parker/Valex
14	**SS Tubes lines from Flow meter panel-SLT & Propellant Feed Valve panel-SLT to Effluent pit.** **Seamless Tube** Tube OD: 1/4" x 0.035” wall thickness Standard: ASTM A269 Material: **SS304L** Pressure rating: 100 bar	80 meters	-	Sandvik/ Swagelok/ Dk-lok/Fitok/ Parker/Valex
15	**SS tubes for compressed air from POU panel (in Sea-level test facility) to Flow meter panel-SLT & Propellant Feed Valve panel-SLT.** **[For pneumatic valve operation]** Tube OD: 1/4" x 0.035” wall thickness Standard: ASTM A269 Material: **SS304L**	50meters	-	Sandvik/ Swagelok/ Dk-lok/Fitok/ Parker/Valex
16	**SS Fittings for propellant feed system-SLT** Union, elbow, tee, reducers, cross, plugs, caps, bulk heads etc. Pressure rating: 100 bar Material: SS316 Size: as deemed necessary in order to suit the components and tube interface.	As per fluid circuit	-	Swagelok/Hamlet / Dk-lok/ Fitok/Parker

Chapter 4: PLC Based Control System & Flushing Cart

The gas distribution system and propellant feed system shall have capability of remote operation and monitoring of major parameters, therefore a PLC based control system which shall be operated through Industrial PC shall be supplied, integrated, tested and demonstrated along with the gas distribution and propellant feed systems. Also, a flushing cart shall be fabricated, assembled, supplied tested and installed as per the description and specifications. The list of utilities is following.

Table 10: List of utilities to be provided

S. No.	Items	Quantity	Purpose & Remarks
1	PLC based control system with Industrial PC	1 No.	To command/operate solenoid valves. To command electronic pressure regulators (EPR). To monitor pressure transmitter reading.
2	Rack	1 No.	To house PLC and other relevant components
3	Printer	1 No.	-
4	Flushing cart	1 No.	For flushing the thruster with IPA and hot DM water and later purging with GN2.

4.1 PLC based Control System with Industrial PC

For remote operation of the gas distribution system and propellant feed system, a Programmable Logic Controller (PLC) based control system shall be supplied along with an Industrial PC (IPC)& printer. Software shall be provided in IPC to operate the systems. The control system shall be realized as per following requirements and functionality as per the above mentioned requirement to be demonstrated.

4.1.1 Technical description:

a) The interface between PLC& IPC shall be SCADA based platform.
b) The software provided in IPC shall have provision to operate solenoid valves of control panel-HAT, Control Panel-SLT and electro-pneumatic valves of propellant feed system-HAT & SLT.
c) Safety interlocks for valve operations and valve emergency shutdown option.
d) Open/close indication of solenoid valves and electro-pneumatic valves.
e) Provision to set pressure values and pressure profile in EPRs.
f) Display pressure transmitter readings in numerical and graphical form. Pressure transmitters are provided in gas distribution panels, compressed air distribution panels, control panel-HAT& SLT, propellant feed system HAT & SLT etc.
g) Display mass flow meter readings in numerical and graphical form.

h) Data logging option for pressure transmitter readings and mass flow meter reading.
i) Electrical wiring between IPC, PLC, instruments (pressure transmitters and flow meters), EPRs and valves shall be done considering the above mentioned requirements.

Table 11: Specification of PLC, Industrial PC and printer

1	PLC Make	Siemens/Allen bradly/Schneider
2	Rack make	Rittal/APW
IPC details		
3	IPC Make	Siemens/Prolific/Proface
4	Screen	24-inch FHD
5	Processor	Intel Core i7 12th gen or better, base speed of 3.3 GHz or higher, 64 bit processor
6	RAM memory	16 GB, 3200 MHz DDR4
7	Hard disk	1TB SSD
8	Operating system	Window 11, 64 bit with perpetual licence
9	Interfaces	Ethernet: 2 X 1000Mbps, USB: 2 X USB 3.0, 4 X USB 2.0.
10	Graphical interface	NVIDIA GeForce (latest) 4 GB
11	Display port	1 X DVI-D, 1 X Display Port, 2 X HDMI
12	Power supply	230VAC/24 VDC
13	Operating temperature	10 to 40 °C
14	Degree of protection/ EMC	IP65 in accordance with IEC 60529/ EN 61000-6-4
15	Keyboard	Wired keyboard with USB Interface
16	Mouse	Wired mouse with USB Interface with Mouse Pad
17	Printer	Heavy duty, A4 size colour laser printer cum scanner, with 2 sets of ink refill.
18	Printer make	Epson/HP/Canon

4.2 Flushing cart

a) The flushing cart is configured for liquid flushing and gas purging application. It shall be realized with 1/4” OD size stainless tubes with necessary filters, pressure regulator, isolation valves, check valves, pressure vessels and safety relief valve as per fluid circuit shown inFigure 16. A typical cart is shown in Figure 17with tentative dimensions.
b) All the pressure gauges, regulator, valves, temperature display shall be assembled on the front panel aesthetically.
c) The cart shall be fitted with necessary nos. of good quality swivel PTFE wheels with locking provision.
d) Two SS304L tanks of 15 litres capacity shall be supplied for storing IPA and DM water, MEOP of tanks is 5 bar.

e) The tanks shall be designed as per ASME BPVC Sec VIII Div 1. Radiography and testing shall be as per ASME standards.
f) Tank design calculations, detailed drawings, material composition certificate shall be submitted to LPSC for approval prior fabrication. Test certificates of tanks shall also be submitted to LPSC.
g) A support structure shall be provided at the bottom of tanks for stability, the tanks shall be properly anchored to the cart structure.
h) The water tank shall be fitted with a heater and removable type temperature sensor.
i) The resistance wire heating element should be screw-in thread type and corrosion resistant. Material should be SS304L. Leak proof and electrical shock resistant connection must be ensured at the interface of heater and tank wall. (Refer Figure 18).
j) It must the ensured that the heater is shock resistant and highly reliable insulation shall be used for the same.
k) Temperature controller for water tank as shown in Figure 19 shall be provided. A temperature display (in °C) shall be visible on the front panel.
l) The cart shall have doors on the front side for easy removal of tanks and maintenance purpose.
m) Fluid collection tray as shown in the Figure 17shall be detachable type.
n) A compartment shall be provided to house the power supplies. All the switches and DPMs shall be assembled on front panel aesthetically.
o) Handles to be provided on both sides of cart for easy handling while movement.
p) Vendor can optimize the layout while ensuring enough space for maintenance of feed lines and easy removal of tanks for filling and draining.
q) Schematic drawing of the fluid circuit shall be provided on front side with clear identification of components at their respective location. Also, the valve operating positions like open/close shall be marked by means of good quality sticker.
r) The fluid circuit shall be tested at the vendors premises before delivery and also after installation and commissioning at our site as per following:
    - Proof pressure test: 1.5 x MEOP (With GN_2).
    - Leak test at MEOP with snoop solution.
    - Pressure hold test at MEOP for 2 hour duration.

s) Final drawings proposed by the vendor with all the components shall be submitted to LPSC for approval before implementation.
t) The certificate of conformance for materials & functionality and calibration certificate for pressure gauges and pressure transmitter shall be submitted.
u) The supporting frame and sheets used in fabricating the flushing cart and pressurization panel shall be made of stainless steel.

v) The fluid circuit shall be of all welded construction except the component interface.
w) The SS 304L tubes used for interconnection between the components shall be pre-cleaned and passivated.
x) The spare items shall be supplied along with the cart.
y) Weld Joints: All the SS welding shall be done using High quality argon arc TIG welding with 100% fusion. The weld joints shall be tested by FP test.
z) Schematic drawing of the fluid circuit shall be provided on front side with clear identification of components at their respective location. Also, the valve operating positions like open/close shall be marked by means of good quality stickers.

Table 12: Bill of materials for flushing cart

S. No.	ID	Specification	Qty in cart (Nos.)	Spare (Nos.)	Total Qty (Nos.)	Make
1	**SOV-1 to SOV-4, V-1 to V-3 Valves for Tanks**	**Ball Valve** Material : SS 316 Pressure rating : 200 bar Interface : 1/4"	13	4	17	Swagelok/ Hamlet / Dk-lok/Fitok/Parker
2	**NV-1 to NV-3**	**Needle Valve** Material : SS 316 Pressure rating : 200 bar Interface : 1/4"	3	1	4	Swagelok/ Hamlet / Dk-lok/Fitok/Parker
3	**CV-1 to CV-3**	**Check Valve** Material : SS 316 Pressure rating : 200 bar Type: Spring-poppet Cracking pressure: 1/3 psi Interface : 1/4"	3	1	4	Swagelok/ Hamlet / Dk-lok /Fitok/Parker
4	**PR-1**	**Pressure Regulator** Type: Self Venting Inlet Pressure: 200 bar Outlet Pressure: 0 to 7 bar Body Material: SS 316 Cv: 0.06	1	1	2	Tescom / Dutch / GCE / Drastar/IMF/ Swagelok
5	**PG-1**	**Pressure Gauge** Bourdon tube material : SS 316 Pressure range : 0-100 bar Resolution: 1 bar Accuracy: 1% FS Dial size : 6”	1	-	1	Mass / Wika/ Ashcroft
6	**PG-2**	**Pressure Gauge** Bourdon tube material: SS 316 Pressure range: 0-10 bar Resolution: 0.1 bar,	1	-	1	Mass / Wika/ Ashcroft

		Accuracy: 1% FS Dial size: 6”				
7	**F-1**	**Gas Filter** Type: Pleated Mesh Wire Material : SS 316 Pressure Rating : 200 bar Range : 10µ absolute Interface : 1/4"	1	-	1	Swagelok/Norman /Classic
8	**F-2**	**Liquid Filter** Type: Pleated Mesh Wire Material : SS 316 Pressure Rating : 200 bar Range : 10µ absolute, Interface : 1/4"	1	1	2	Swagelok/Norman /Classic
9	**F3**	**Gas Filter** Type: Pleated Mesh Wire Material : SS 316 Pressure Rating : 200 bar Range : 10µ absolute, Interface : 1/4"	1	-	1	Swagelok/Norman /Classic
10	**RV-1 to RV-3**	**Relief Valve** Material : SS 316, Pressure Rating : 200 Bar Interface : 1/4” Set pressure range: 3-10 bar Set pressure: 4 bar	3	1	4	Swagelok/ Hamlet / Dk-lok /Fitok/Parker
11	**Tank-1**	**Water Tank** Material: SS 304L Operating Pressure: 5 bar a Operating Temperature: 70°C Volume: 15 Litres O-ring: PTFE (3 Nos.)	1	-	1	Reputed make
12	**Tank-2**	**IPA Tank** Material: SS 304L Operating Pressure: 5 bar a Operating Temperature: 40°C Volume: 15 Litres O-ring: PTFE (3 nos.)	1	-	1	Reputed make
13	**Tubes**	Seamless Tubes Material : SS 304L Pressure rating: 200 bar Tube: OD 1/4” (as per schematic) Standard: ASTM A 269	-	-	-	Swagelok/ Dk-lok /Fitok/Sandvik/Parker/ Valex
14	**Fittings**	Fittings Material : SS 316 Pressure rating: 200 bar Size : 1/4” (as per schematic)				Swagelok/Hamlet/Dk-Lok/Fitok/ Parker
Electrical Components						
15	**Variable Power**	I/P Voltage: 230VAC, 50Hz O/PVoltage:0-80VDC Variable	2	-	2	GW Instek/aplab/

	supply 80V/2A	No. of o/p:single Output Current: 2A Line Regulation :0.1% ±2mV Load Regulation:0.1% ±2mV Ripple& Noise :<10mV rms Protection: Overload and Short circuit protection Voltage & current display :3 digits DPM				Lambda
16	**DPDT switches**	Voltage rating: 250 V Current Rating: 15 A	1	1	2	Reputed make
17	**Temperature controller**	Suitable for the application.	1	-	1	Reputed make
18	**Temperature Sensor and Display**	Range: 0 to 100 deg C	1	-	1	Reputed make
19	**Water Tank Heater**	Power: 1.5 kW Voltage Rating: 230V Wetted material: Stainless steel	1	1	2	Reputed make

Chapter 5: Acceptance Criteria & Other Relevant Information

Final acceptance will based on installation at our site in LPSC, Tumakuru campus and successful functional testing and satisfactory performance demonstration of all the components and subsystems of gas distribution system and propellant feed system to satisfactory level in the presence of LPSC engineers as per following.

5.1 Pre-Delivery Inspection (Factory Acceptance Test – FAT)

a) Physical verification for all components and subsystems for the facility as per bill of materials.
b) Verification of the material & equipment test certificates.
c) Visual inspection & Dimensional inspection of panels.
d) Proof pressure test of all panels (at 1.5 times of operating pressure)
e) Leak test (by snoop solution) of all panels at operating pressure.
f) Completeness of all deliverables.

5.2 Final Acceptance Testing (Site Acceptance testing – SAT)

System shall be transported, installed, commissioned at the premises of LPSC, Tumakuru campus and the following tests shall be carried out in the presence of LPSC engineers.

a) Visual inspection of all panels, equipments, flushing cart etc.
b) Physical verification all components and sub-systems as per bill of materials and completeness verification of installed systems.
c) Leak test (with helium) of complete gas distribution and propellant feed systems including panels at MEOP. (bubble leak test with snoop solution)
d) Proof pressure test of complete gas distribution and propellant feed systems including panels at 1.5 times MEOP. Followed by leak test again at MEOP by snoop solution method.
e) Pressures hold test (For 8 Hour duration) and estimation of leak rates.
f) Verification of PLC based control system by operating valves, EPRs etc. through IPC.
g) Contamination to be checked at necessary location of gas distribution system by gas contamination particle counter provided by LPSC. The gas cleanliness verification criteria provided in Table 13must be met.
h) Filtered IPA (Provided by LPSC) shall be flushed through propellant feed system and particle count of samples shall be taken to check contamination by particle counter (Provided by LPSC). Liquid cleanliness verification criteria provided in Table 14must be met.
i) The functioning and accuracy of Electronic Pressure Regulators (EPRs) of control panels shall be tested. IPA (provided by LPSC) shall be filled inside

run tanks; the tanks to be pressurized using EPRs and IPA shall be drained at outlet (Thruster location inside vacuum chamber and sea-level test stand) at different flow rates and set pressure of run tank. The run tank pressure shall be maintained between control band ± 0.05 bar of set pressure by EPR and it shall be monitored to check the accuracy. The flow meter readings shall be monitored to test their functionality and accuracy. Flow rates and test durations are provided in Table 15&Table 16.

Table 13: Cleanliness verification criteria for gases (in 1 Cu Feet)

S. No	Particle Size	No. of Particles allowed
1	<5µ	No limit
2	5µ to 10µ	13
3	10µ to 20µ	5
4	Above 20µ	Nil

Table 14: Cleanliness verification criteria for liquids (in 100 mL)

S. No	Particle Size	No. of Particles allowed
1	<5µ	No limit
2	5µ to 15µ	960
3	15µ to 25µ	80
4	25µ to 50 µ	24
5	50µ & above	0

Table 15: Test Matrix for EPR performance demonstration by IPA flow through propellant feed system HAT.

S. No.	Set Pressure (Bar)	IPA Flow Rate (g/s)	Duration (s)
1	5	0.2	100
2	5	1.0	100
3	8	0.2	200
4	8	1.5	200
5	8	3.0	200
6	16	0.4	300
7	16	3.0	300
8	16	5.0	300
9	24	0.5	900
10	26	4	900
11	26	8	900

Table 16: Test Matrix for EPR performance demonstration by IPA flow through propellant feed system SLT.

S. No.	Set Pressure (Bar)	IPA Flow Rate (g/s)	Duration (s)
1	5	0.5	20
2	5	1.0	20
3	8	1.0	30
4	8	2.5	30
5	8	25	30
6	16	2.5	50
7	16	25	50
8	16	50	50
9	24	4.0	100
10	26	40	100
11	26	80	100

5.3 Documents Requirement

a) Drawings of all the panels.
b) Complete gas distribution system and propellant feed system layout drawings.
c) Datasheets and details of all components i.e. valves, pressure transducers & gauges, pressure regulators, filters, flow meters, tubes and fittings, PLC etc.
d) Calibration certificates of all measurement instruments such as flow meters, pressure transducers & gauges etc. for period of one year.
e) Three sets of detailed operation and maintenance manuals along with necessary drawings in hard and soft copy.
f) Certificate of FP test carried out on welds.
g) Complete parameters details for EPRs.
h) All other relevant documents.

5.4 Warranty

a) The entire gas distribution system, propellant feed system and other utilities shall be warranted for total performance and failure-free operation for a minimum period of 12 months from date of final acceptance of system by LPSC. A warranty certificate stating the same shall be provided.

5.5 General Conditions

a) LPSC will supply the gas cylinders for Nitrogen, Helium, air compressors (with Receiver Tank), IPA etc. Hence the supplies of these items are not part of the scope of work.
b) Third Party inspection certificate for the raw material procurement shall be provided.

c) Fabrication, assembly of all the panels and flushing cart shall be done based on approval from LPSC.
d) The drawings and layouts of gas distribution system and propellant feed system shall be approved and cleared by LPSC before the start of realization.
e) Spare items mentioned in bill of materials shall be supplied along with delivery of other items.
f) All the tubes and fittings used for realization of gas distribution, propellant feed system and flushing cart shall be pre-cleaned and passivated.
g) All the tubes and fittings to be procured as per ASTM standards and material test certificates shall be provided to LPSC.
h) Use of standard/recommended fabrication and assembly procedures and construction practices shall be adopted.
i) High quality workmanship using well trained, well qualified certified personnel and well supervisory manpower shall be employed.
j) Detailed technical specification including make, model no., part number shall be provided by party for all the equipment/components.
k) Calibration certificates of all measuring instruments, such as pressure gauges, pressure transmitters, mass flow meters etc. shall be provided.
l) During execution of work, changes (which lead to improvements) suggested by the party or LPSC shall be implemented with mutual agreement.
m) The party shall arrange necessary support equipment, tools, machines, accessories etc. LPSC would not provide any such items.
n) All necessary safety precautions shall be taken by party during execution of work and also party is responsible for personal safety of the work force engaged by party for this project.
o) Parties shall visit the site in Tumakuru campus and existing Monopropellant Thruster Test Facility (MTTF) in LPSC-Bengaluru before submitting the offer.
p) Subcontracting if any, shall be intimated in advance to LPSC and prior permission shall be obtained.

5.6 Delivery Schedule

a) The delivery schedule for supply, installation and commissioning of gas distribution and propellant feed system along with utilities shall be **9 months from the placement of Purchase Order.**

T_0 is date of Purchase Order placement.

S. No	Description	Time period (Months)
1	Approval of panel and layout Drawings	T_0+1

2	Procurement of all major items, fabrication of panels	T_0+6
3	Pre-despatch inspection by LPSC & FAT, Delivery and transportation to LPSC	T_0+7
4	Installation, commissioning & Acceptance at LPSC	T_0+9

- Total time for completion = **9 months**

b) The gas distribution system, propellant feed system along with utilities shall be supplied, installed and commissioned at Monopropellant Thruster Test Facility (MPTTF) in Tumakuru, Karnataka.

ANNEXURE-1

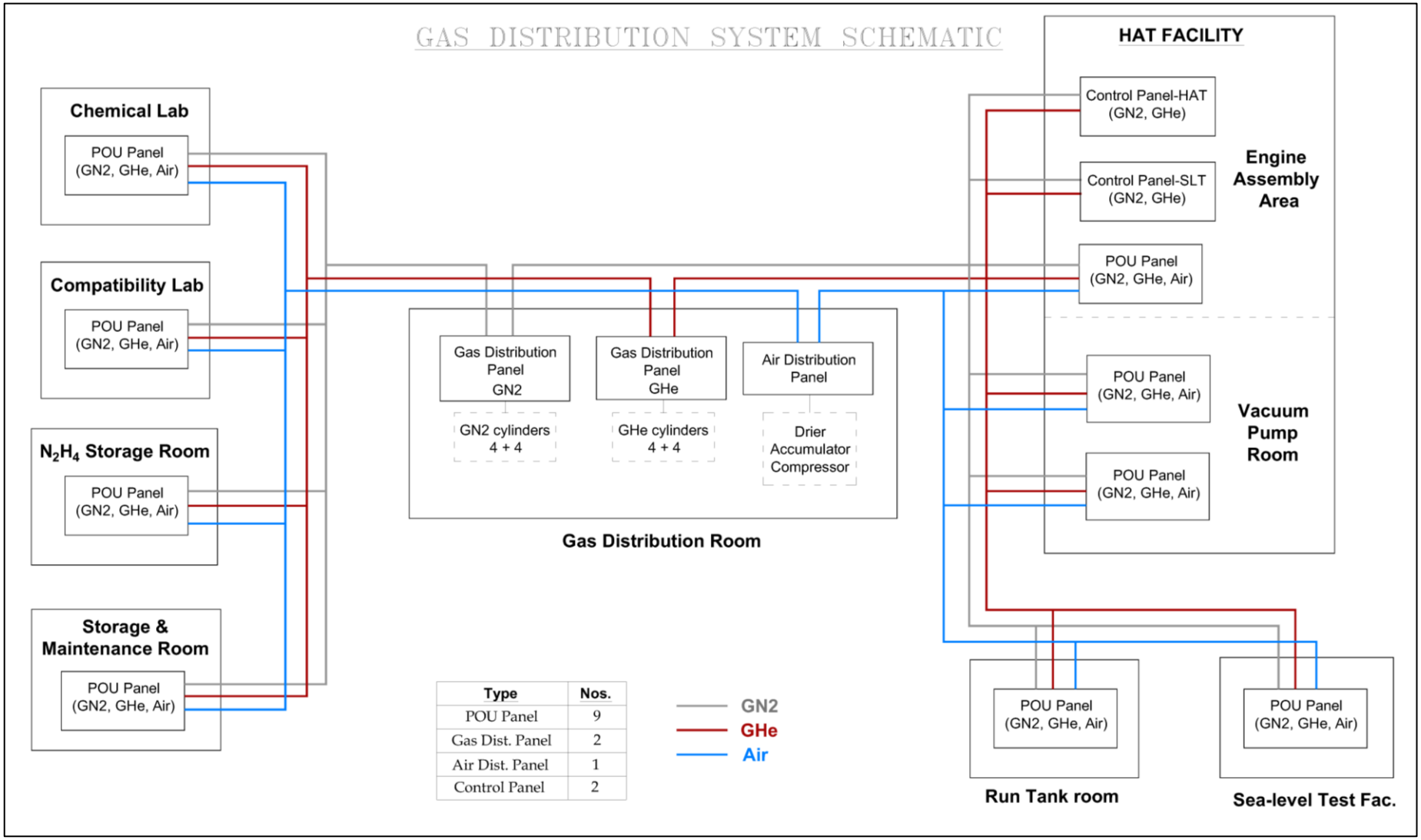


Figure 1: Schematic of Gas Distribution System.

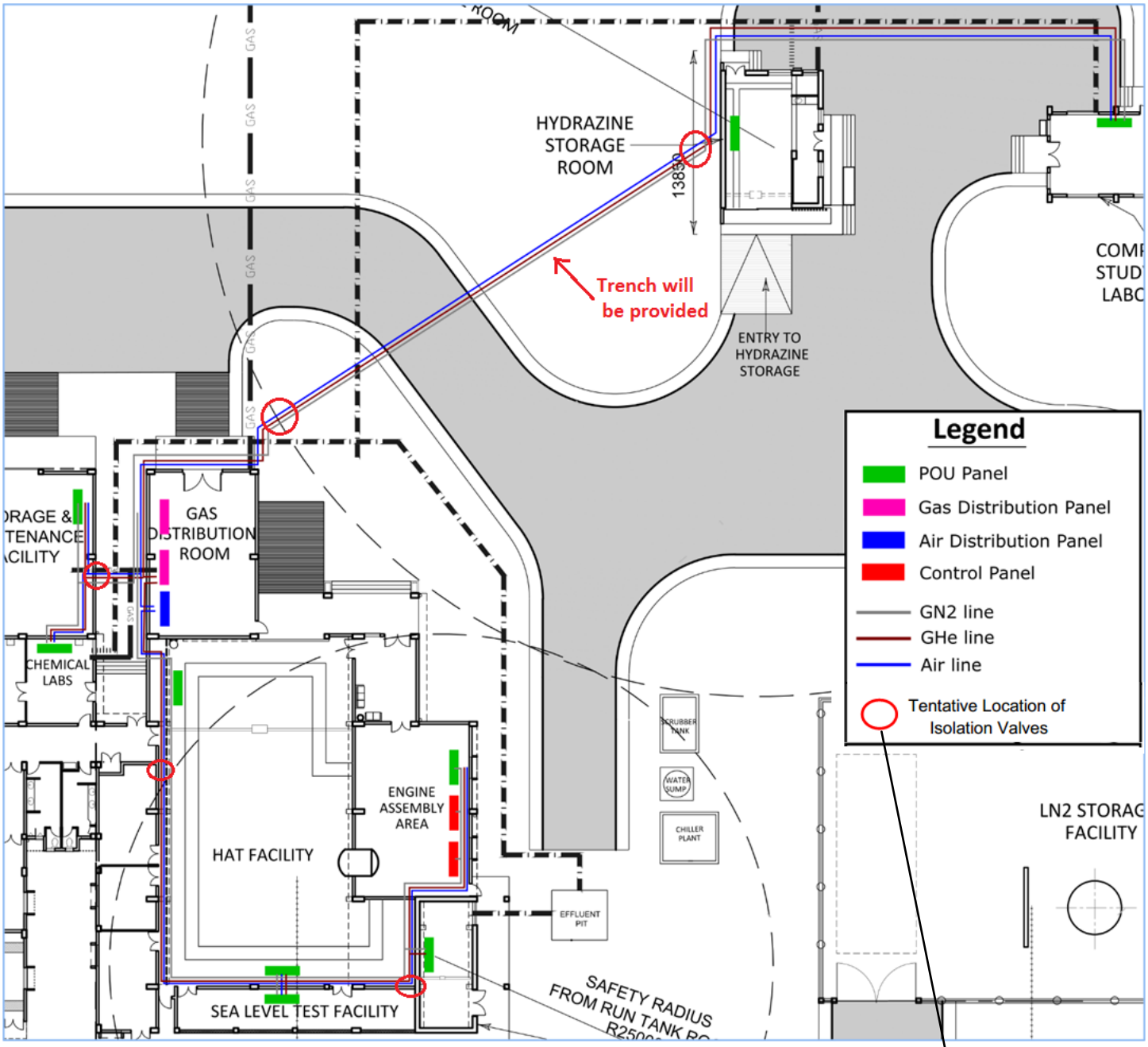
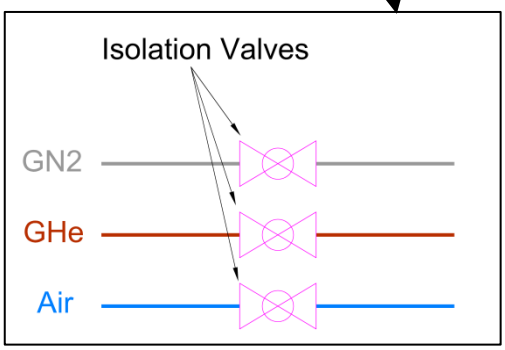


Figure 2: Overall layout of gas distribution system



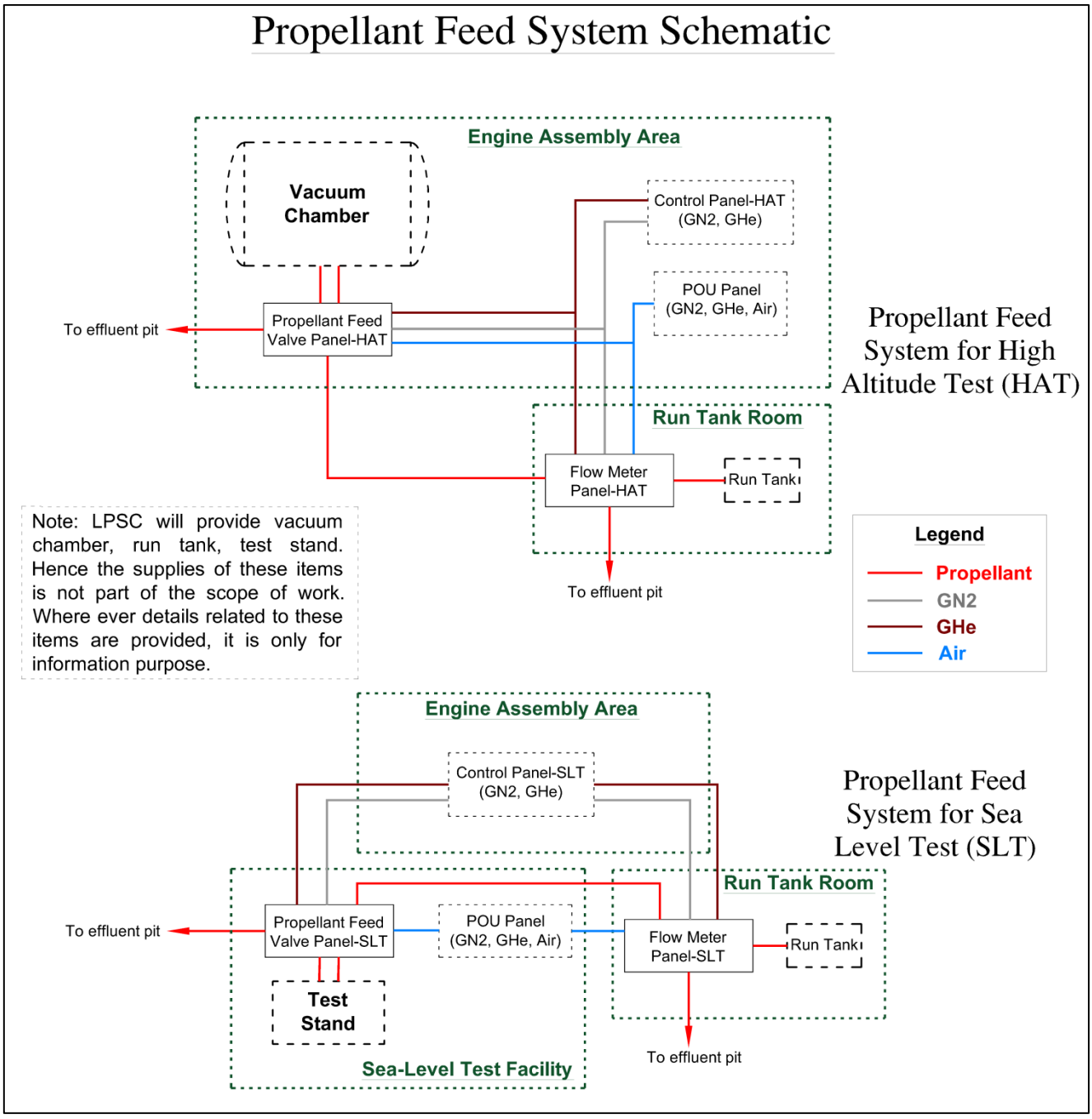


Figure 3: Schematic of Propellant Feed System for High Altitude and Sea-Level Tests.

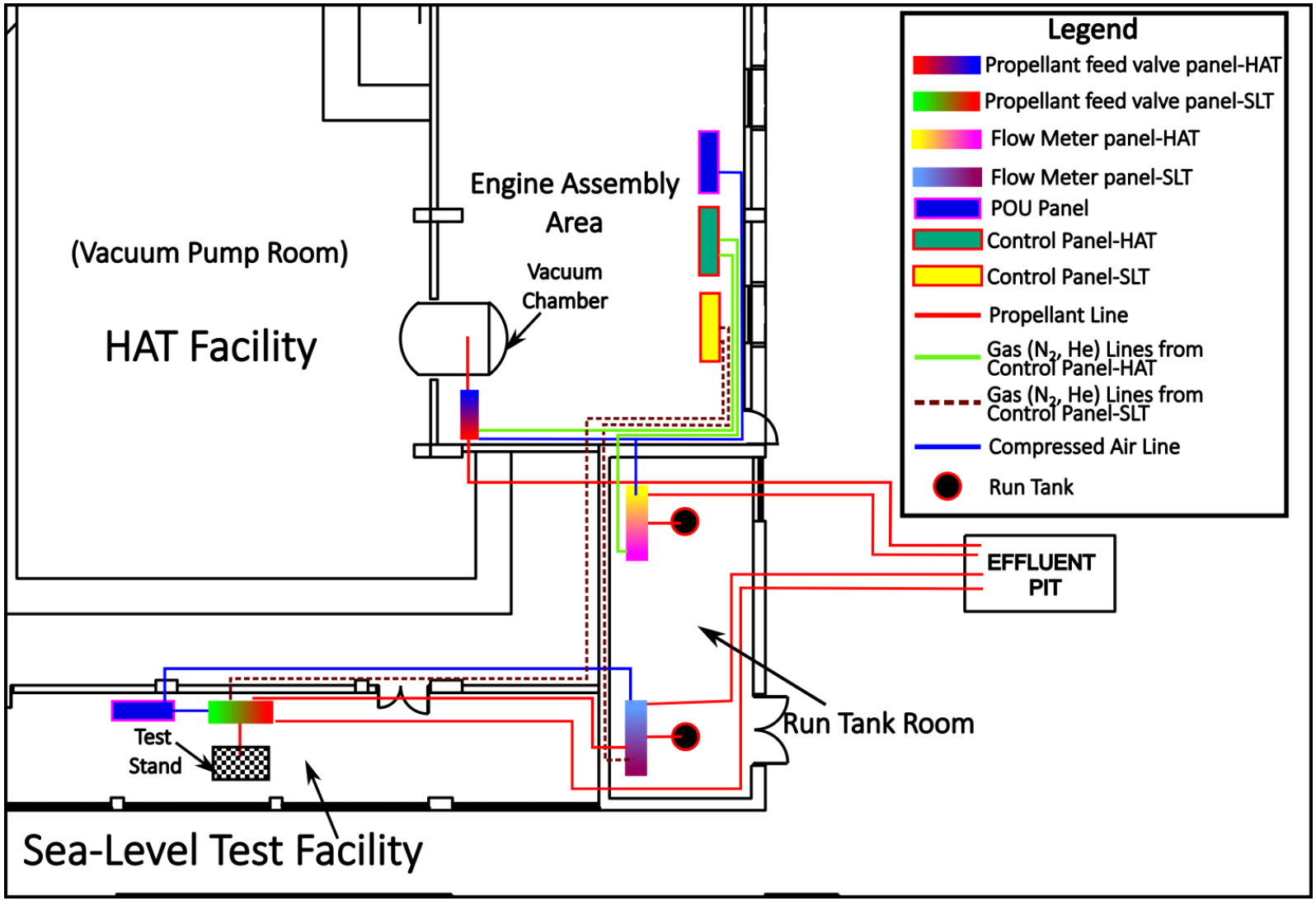


Figure 4: Overall layout of propellant feed System

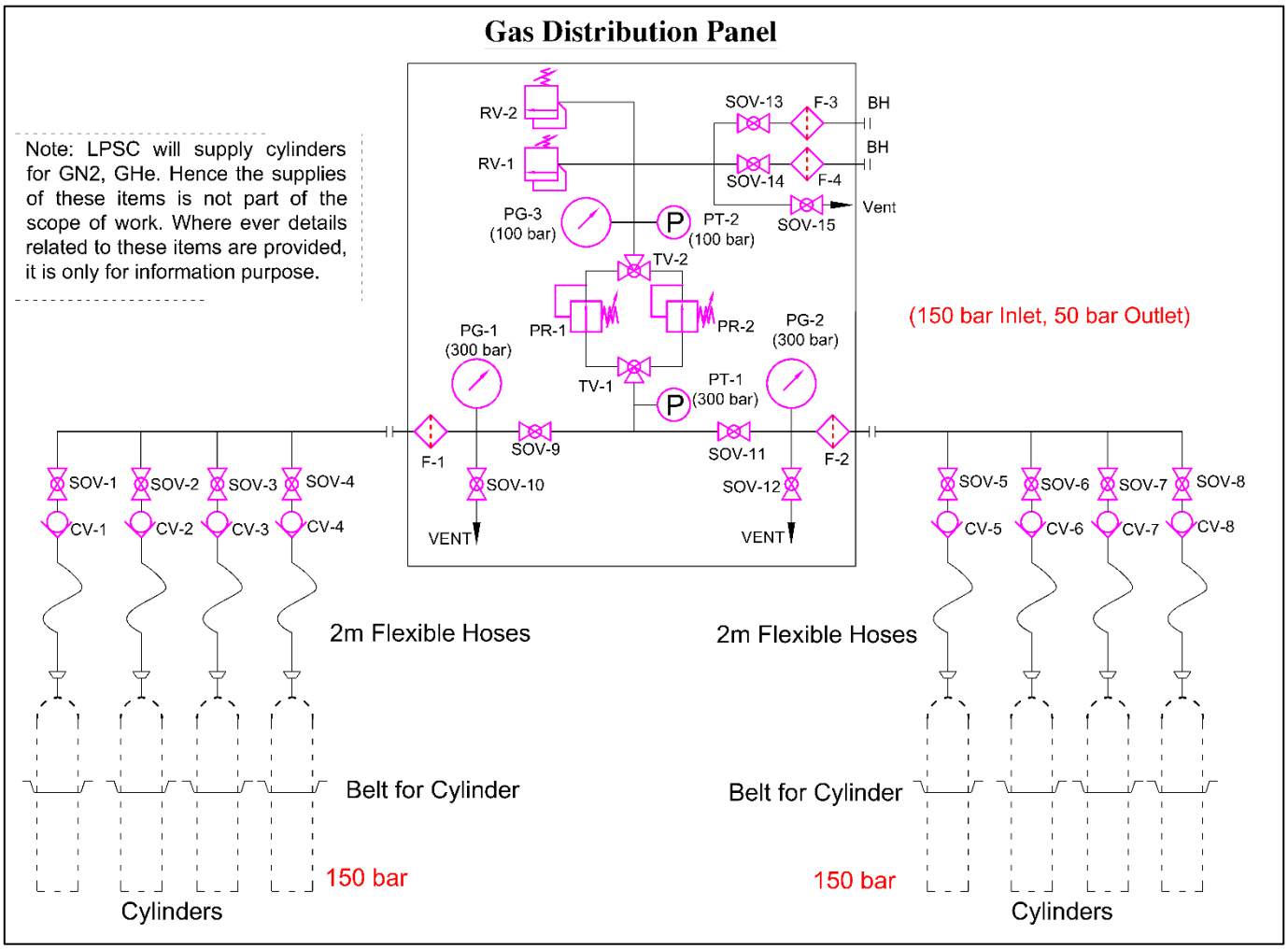


Figure 5: Fluid circuit of Gas Distribution Panel for GN2 & GHe each (Total 2Nos.)

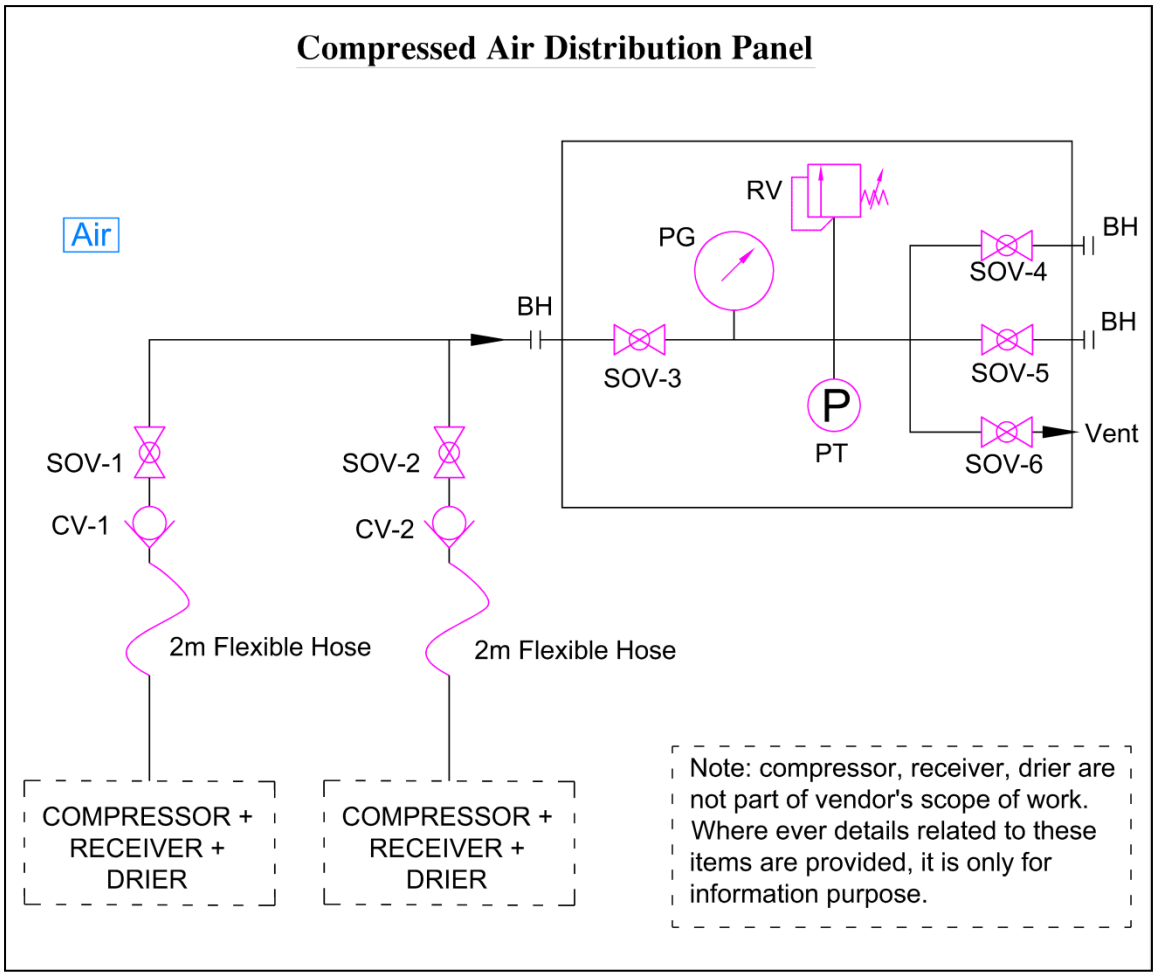


Figure 6: Fluid circuit of Compressed Air Distribution Panel (1 No.)

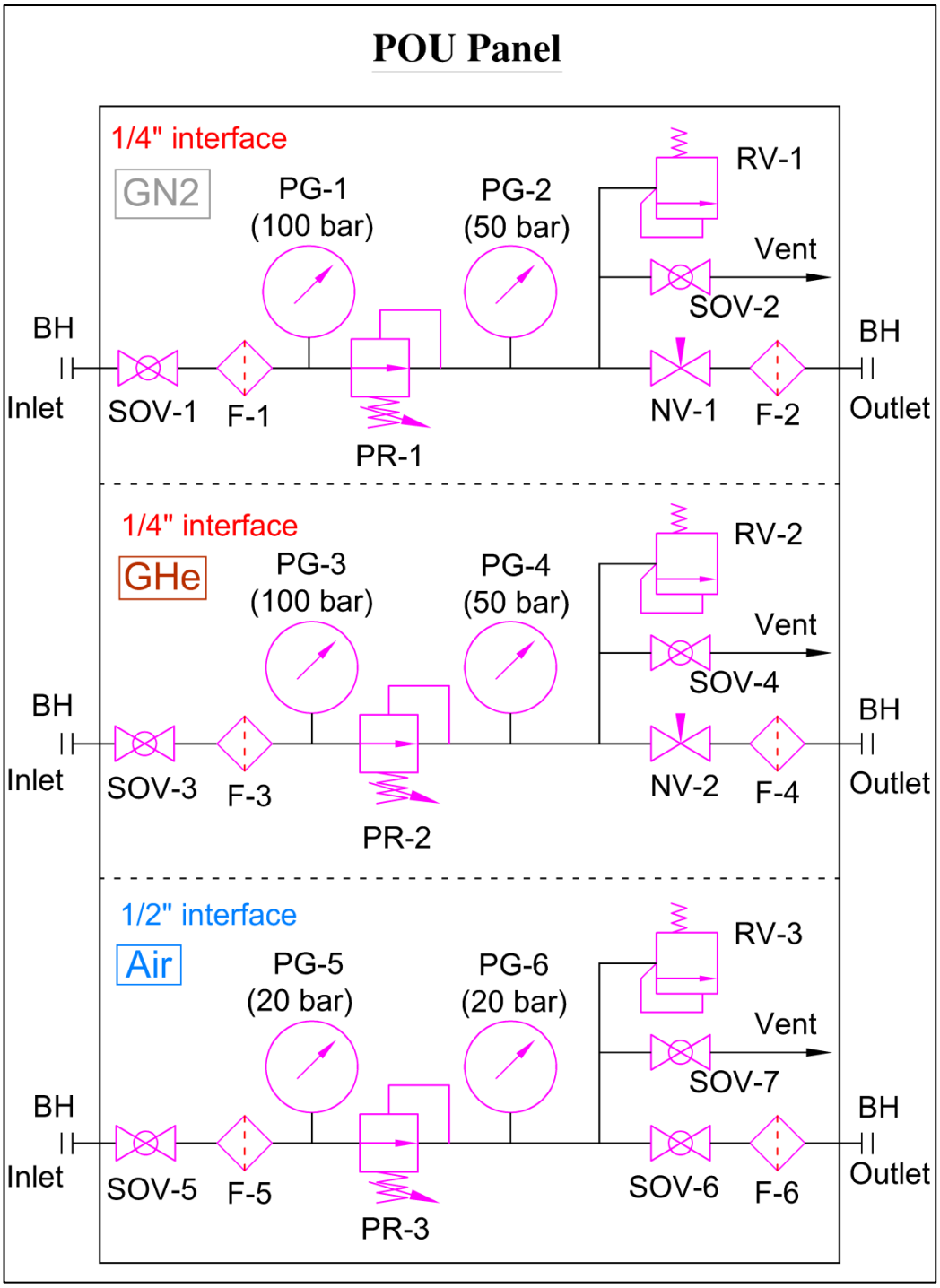


Figure 7: Fluid circuit of Point-of-Use (POU) Panel

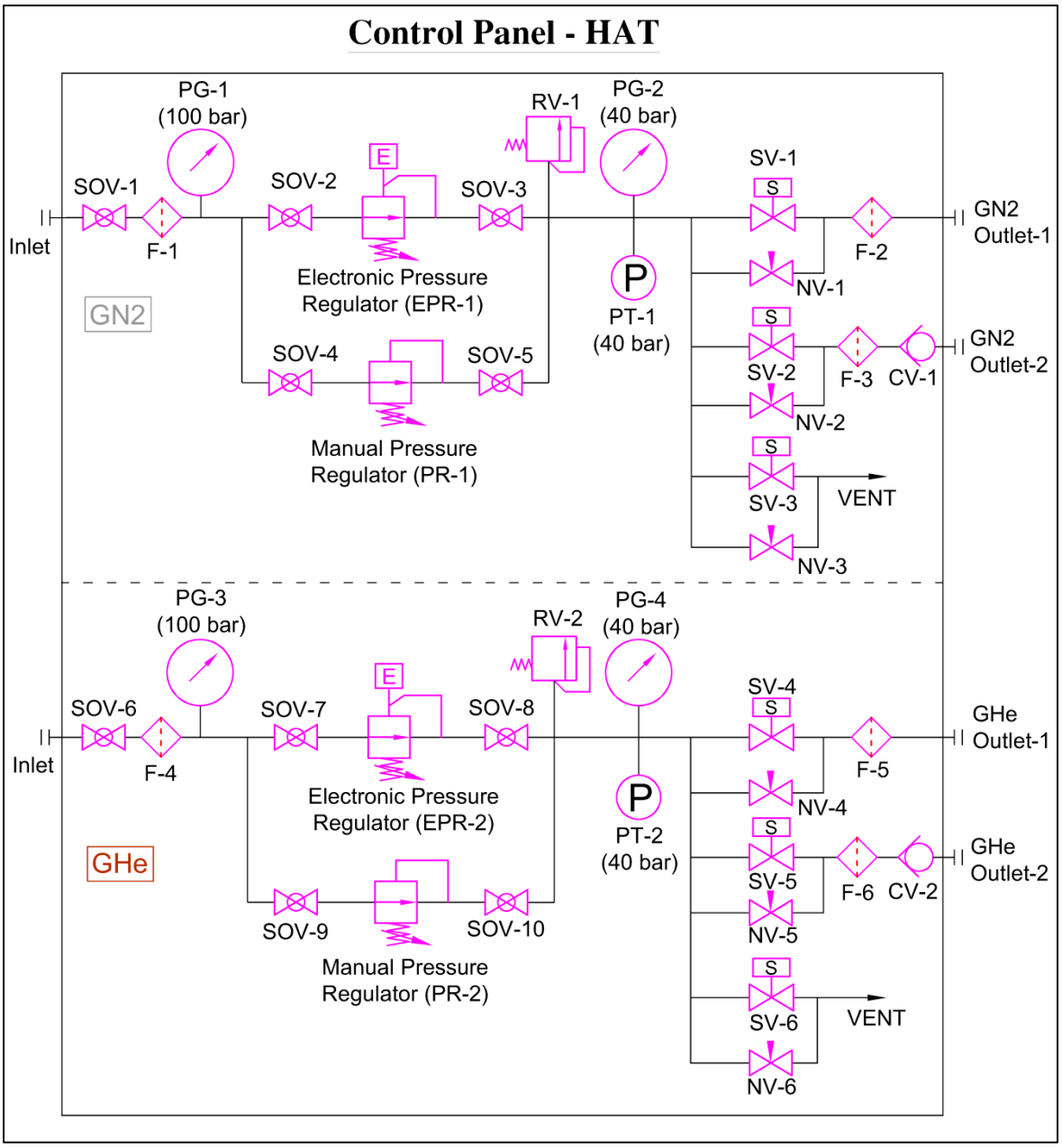


Figure 8: Fluid circuit of Control Panel-HAT (1 No.)

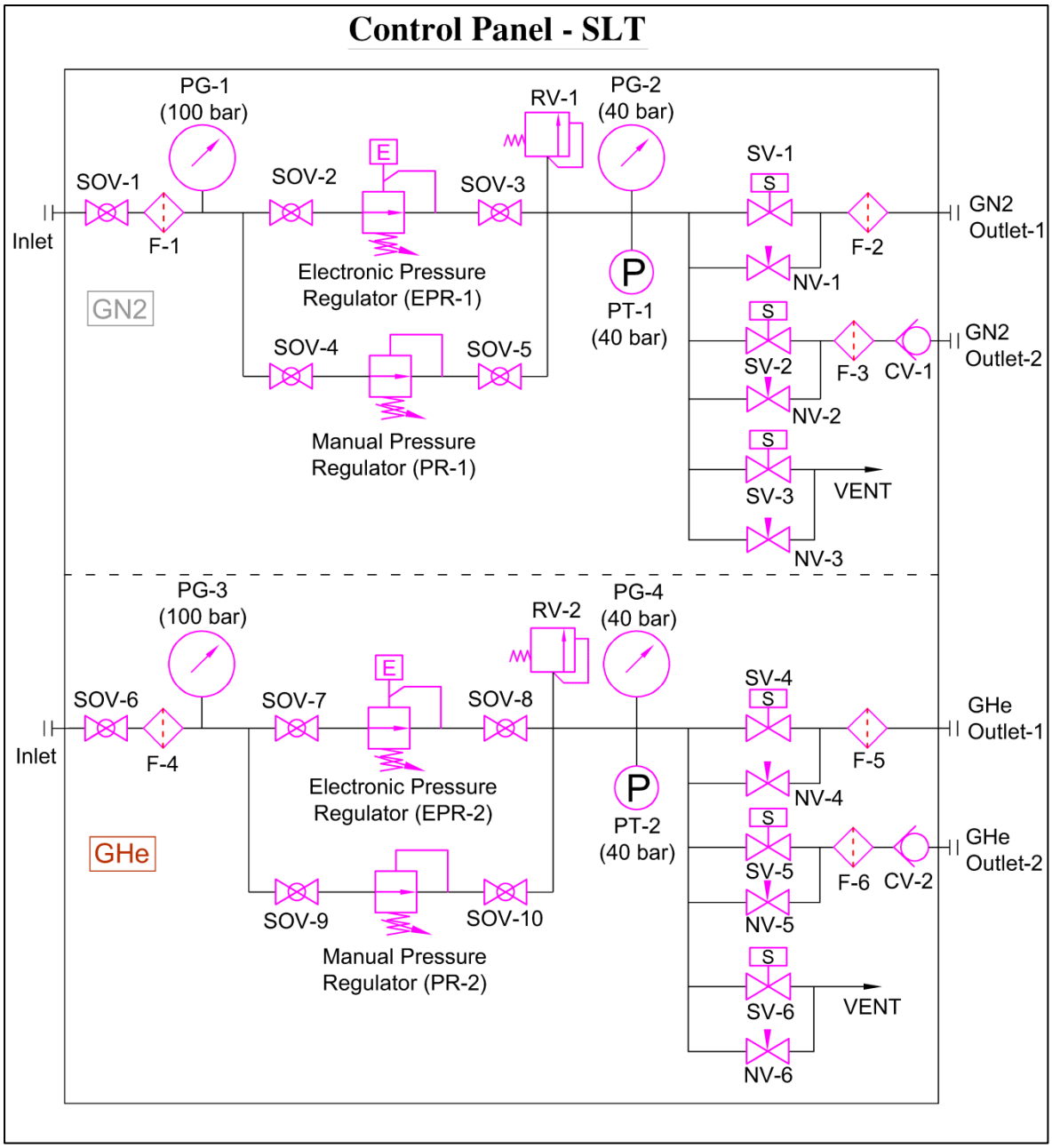


Figure 9: Fluid circuit of Control Panel-SLT (1 No.)

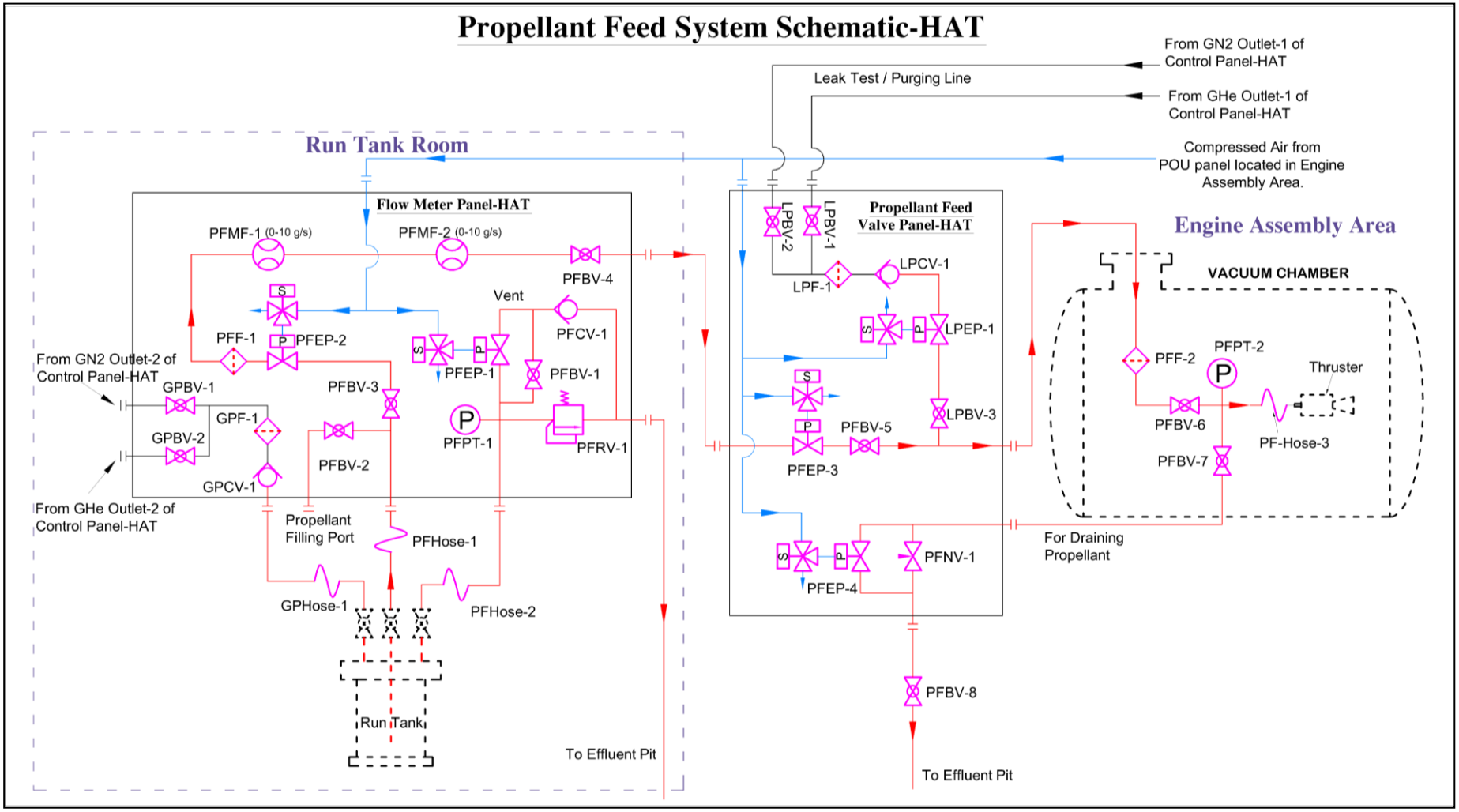


Figure 10: Fluid circuit of propellant feed system for High Altitude Tests (HAT)

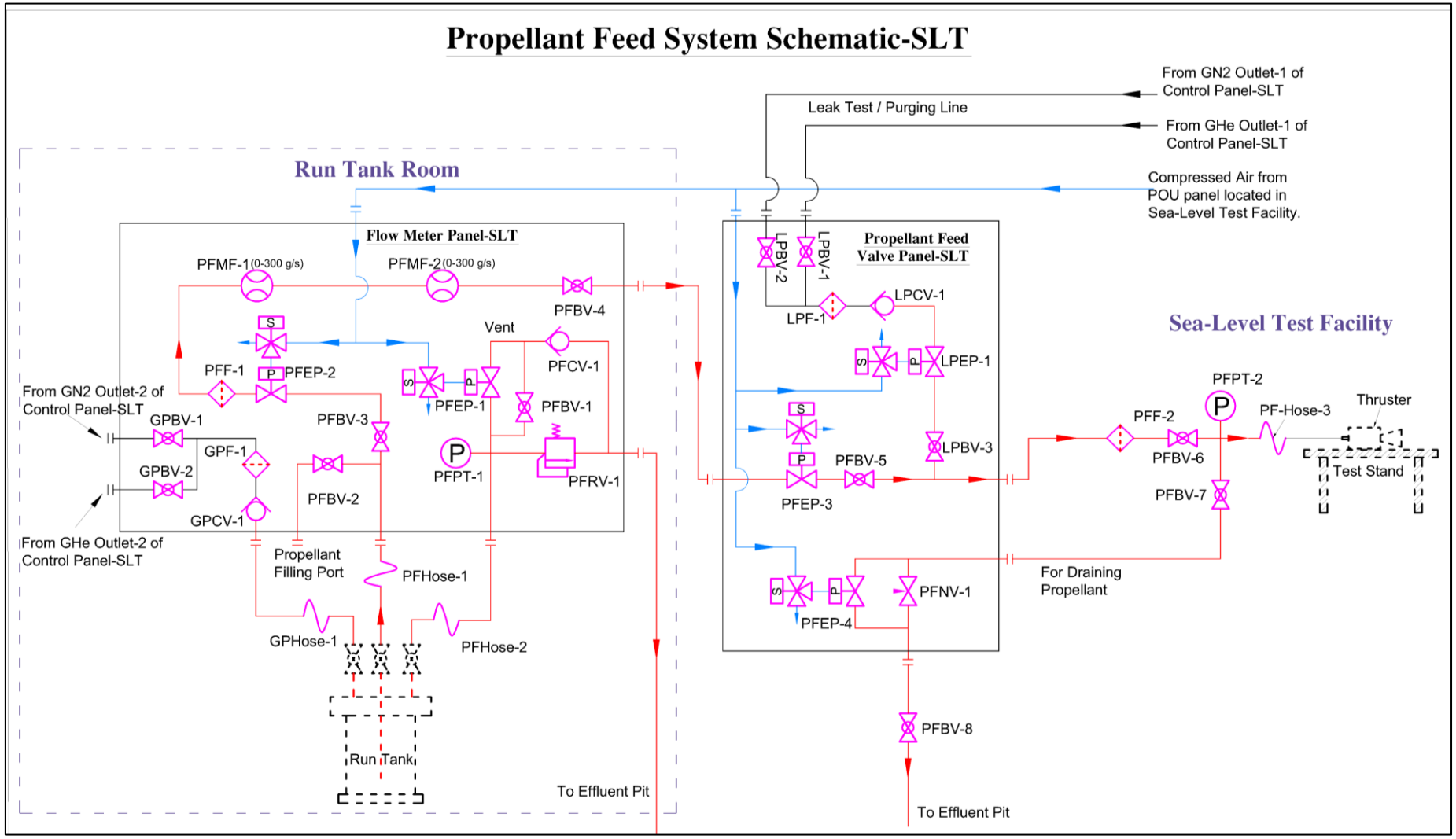


Figure 11: Fluid circuit of propellant feed system for Sea-Level Tests (SLT)

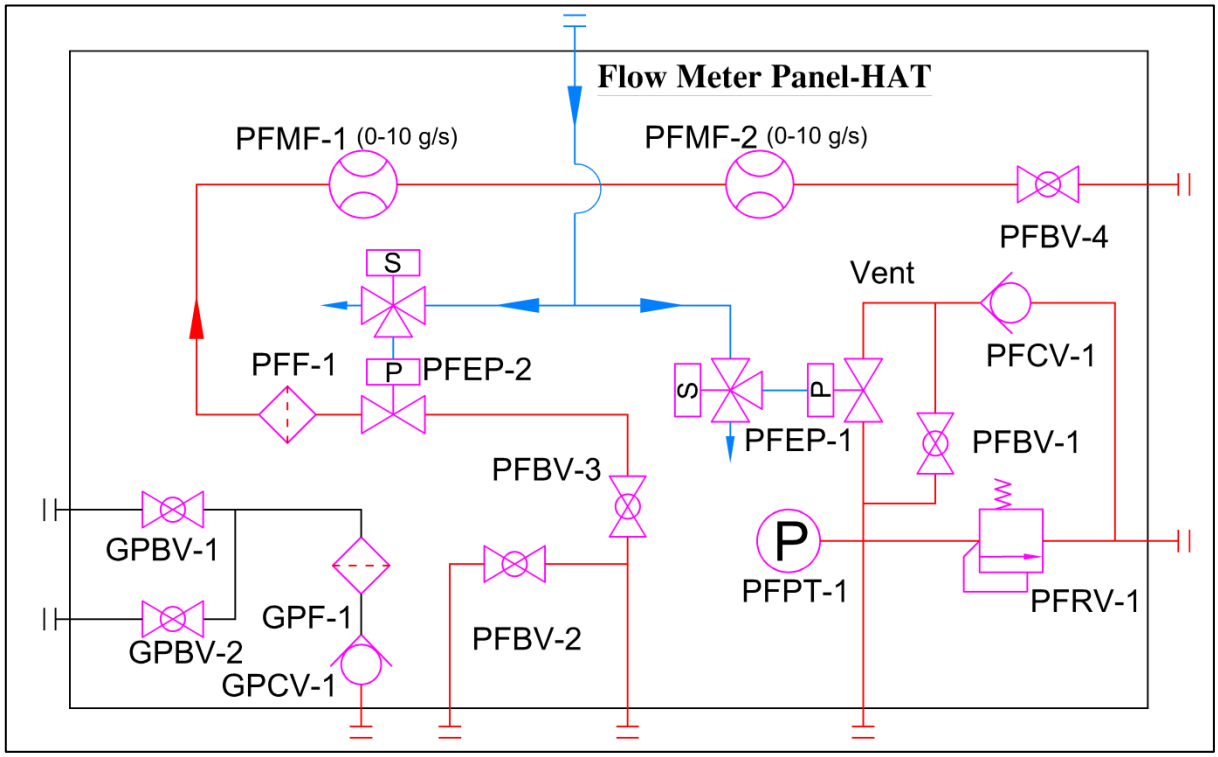


Figure 12: Fluid circuit of flow meter panel-HAT

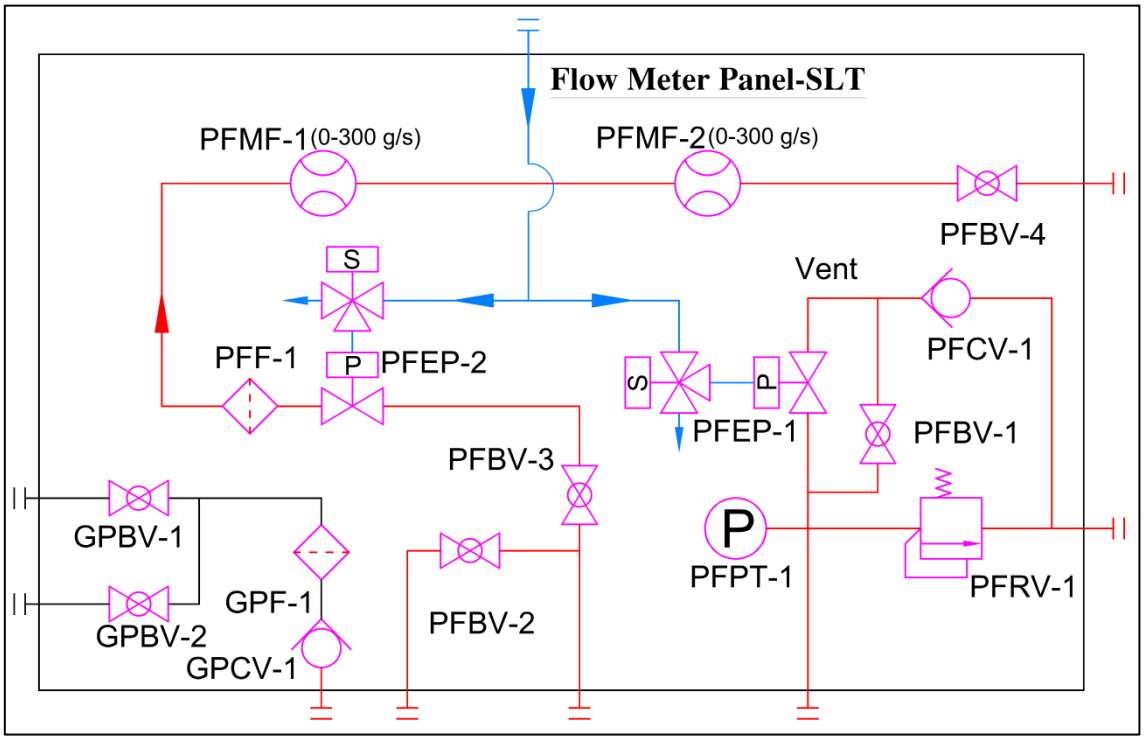


Figure 13: Fluid circuit of flow meter panel-SLT

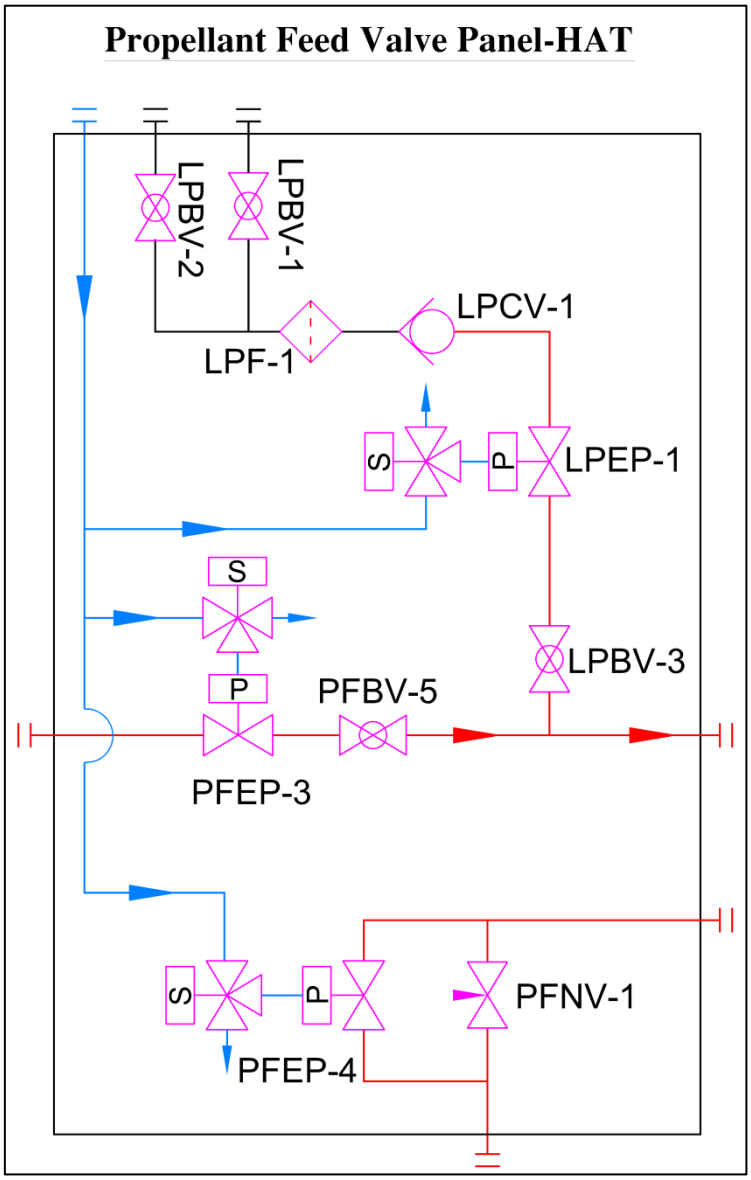


Figure 14: Fluid Circuit of Propellant Feed Valve Panel-HAT

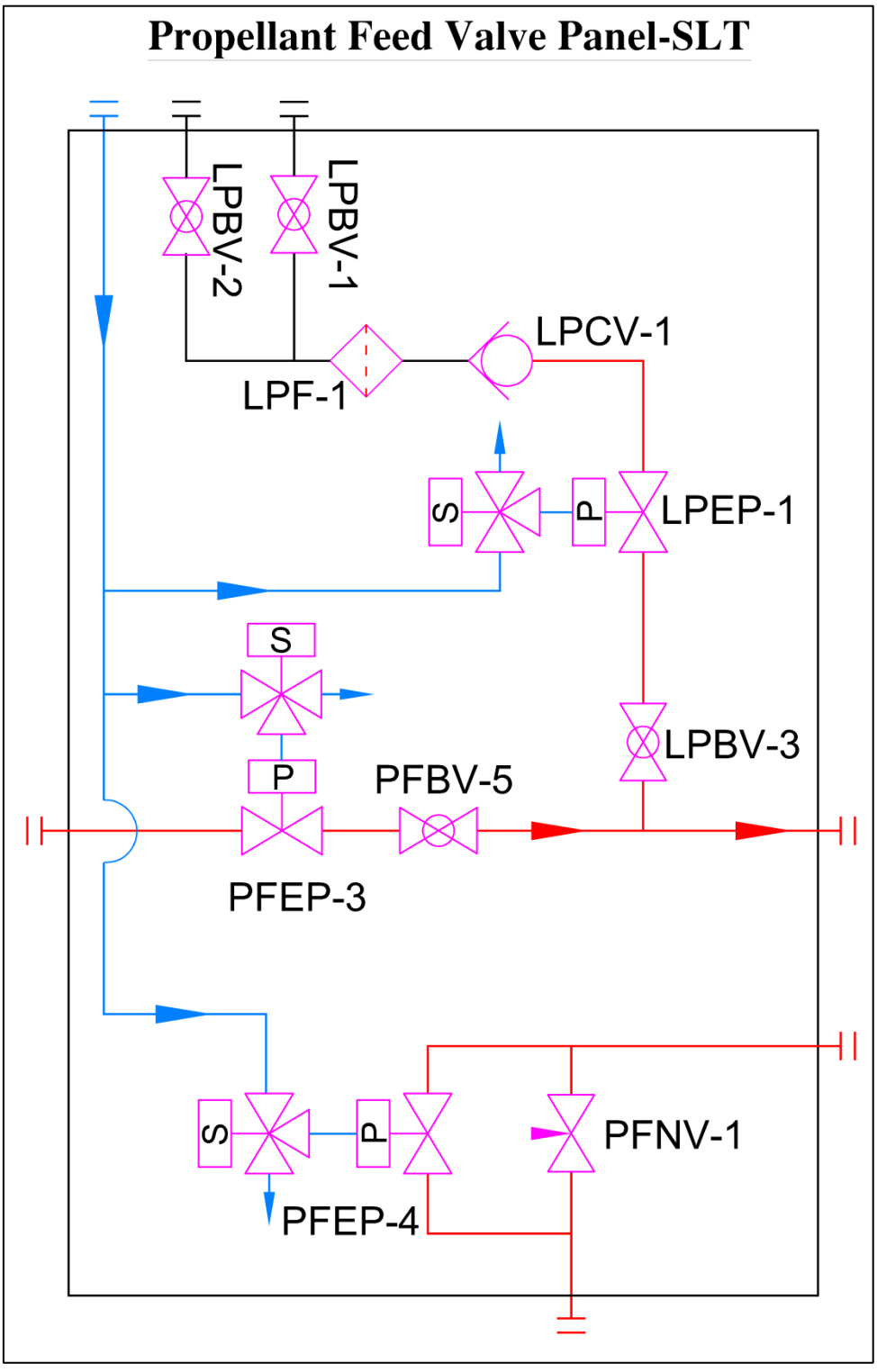


Figure 15: Fluid Circuit of Propellant Feed Valve Panel-Sea Level Testing

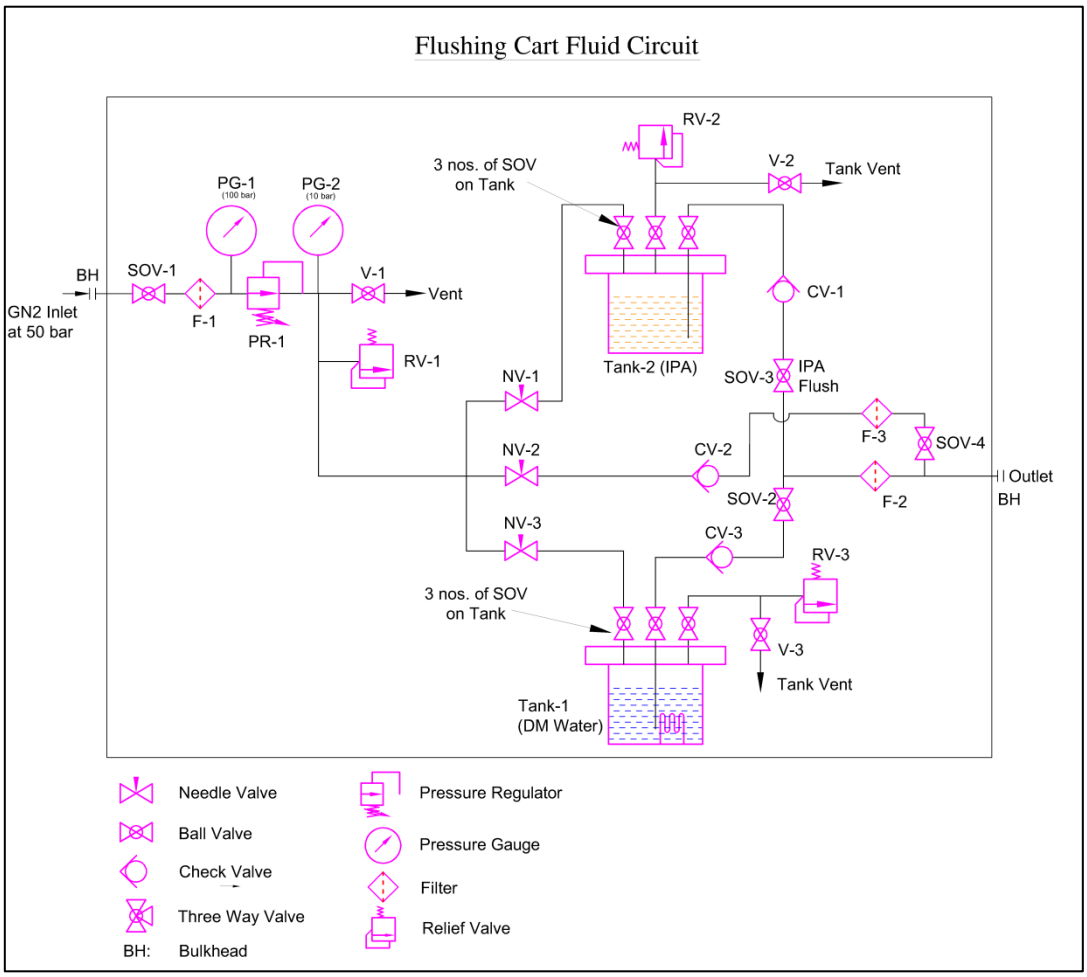


Figure 16: Flushing cart fluid circuit

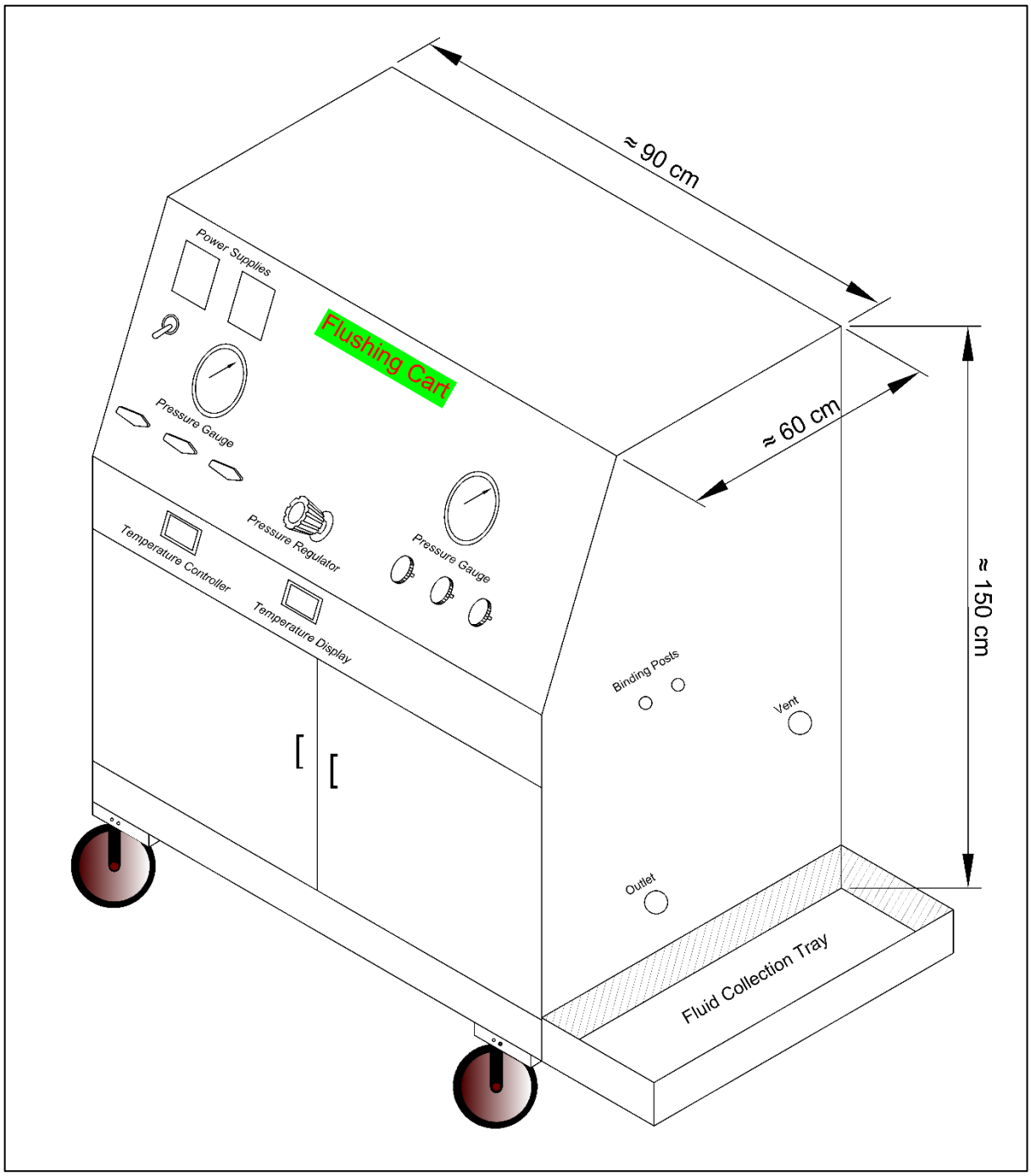


Figure 17: Representation of flushing cart structure with tentative dimensions.

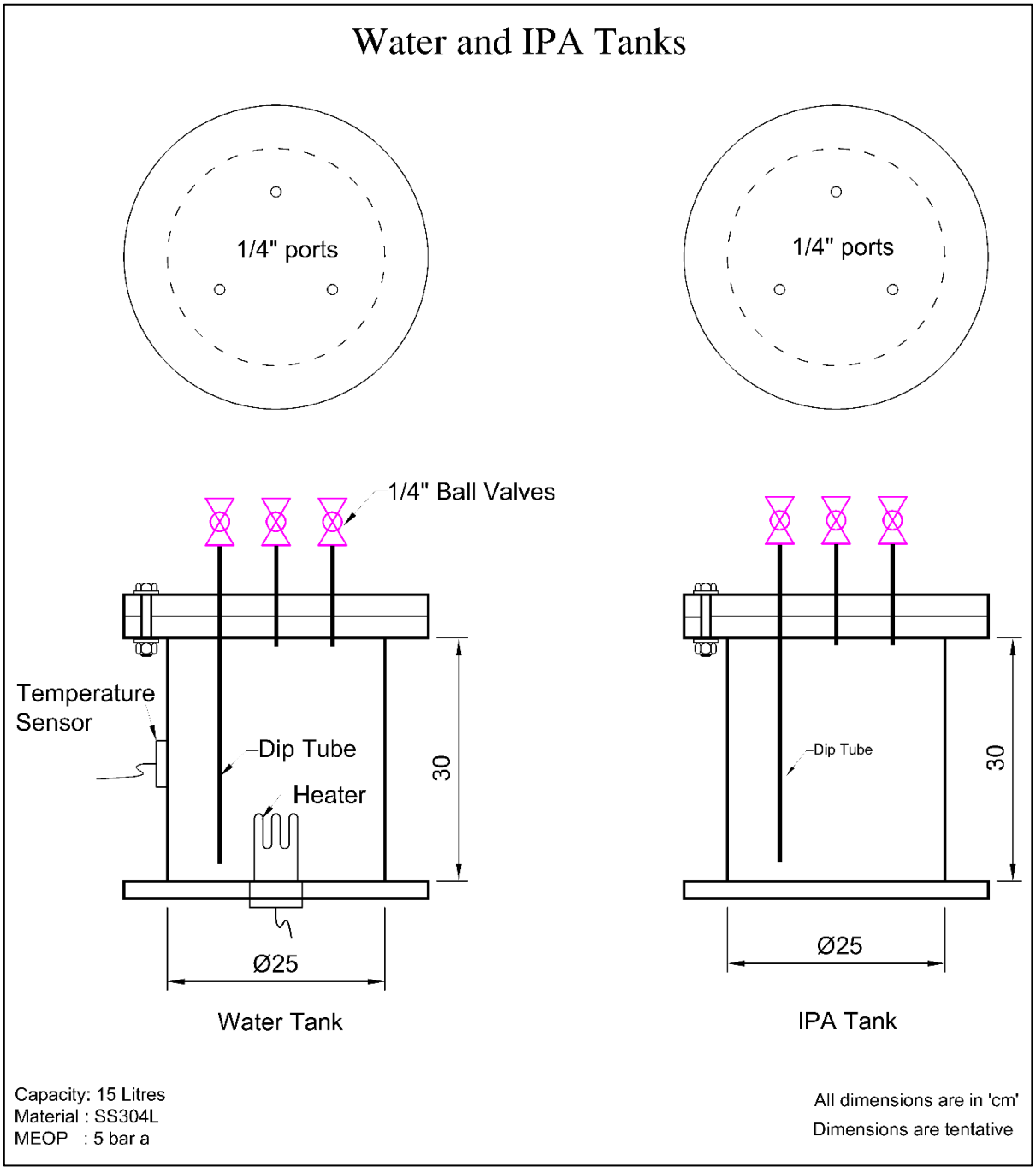
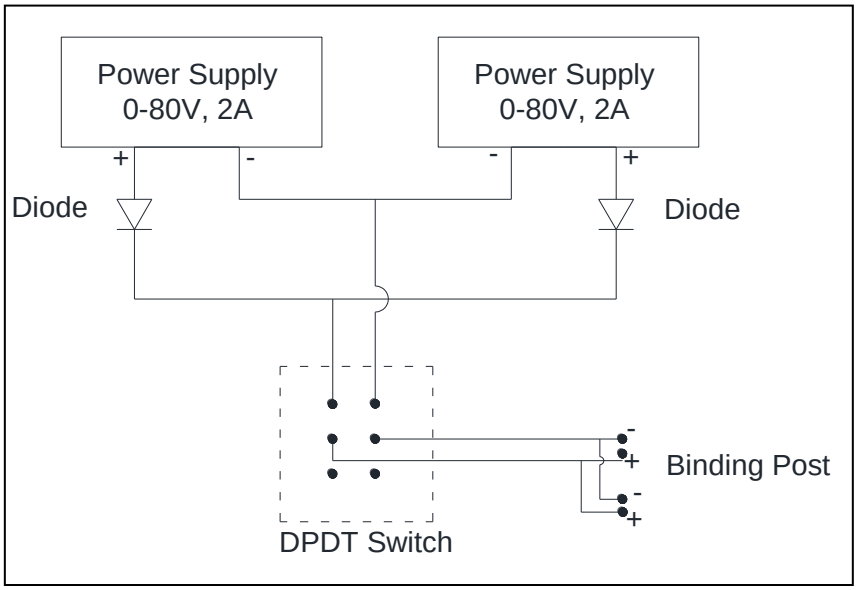


Figure 18: Schematic of water and IPA tanks (Part of flushing cart)



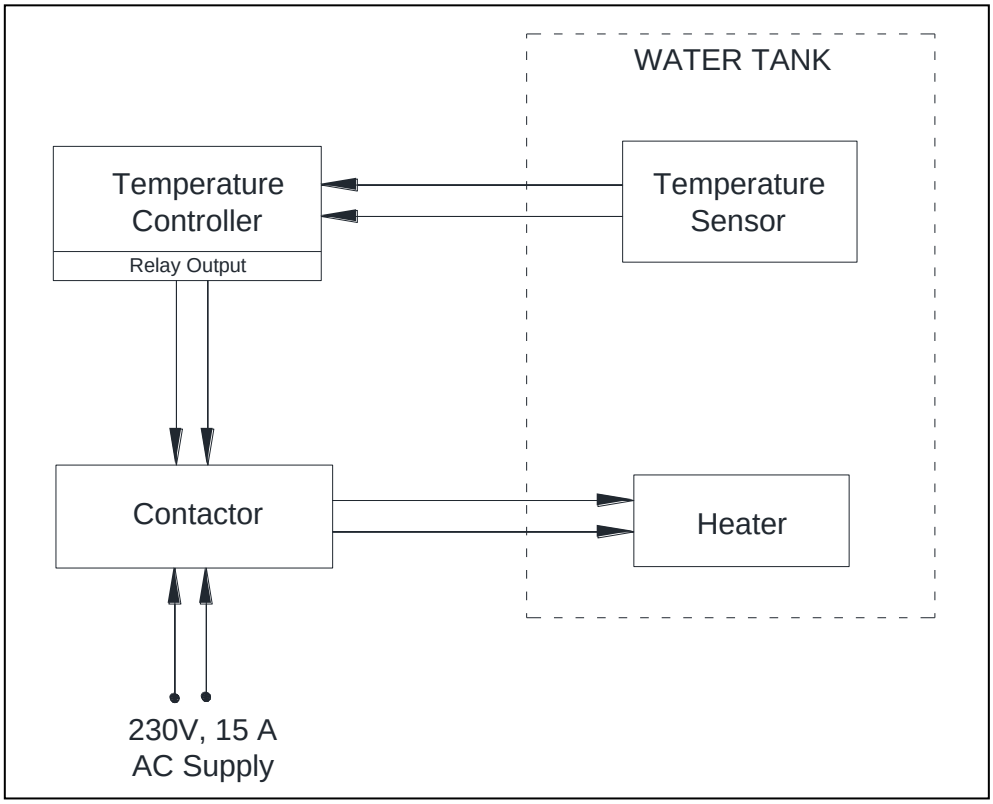


Figure 19: Electronic circuit schematic in Flushing cart

PART-B: COMMERCIAL TERMS & CONDITIONS

1. Price

The prices are FIRM and FIXED. On receipt of Purchase Order, Vendor has to prepare detailed work break-up and delivery schedule chart as per Chapter 5 Section 5.6 and submit to LPSC for our acceptance.

2. Security Deposit

The party shall submit the security deposit for the performance of the contract, equivalent to **3**% of the total order value in the form of bank guarantee or either form of negotiable instrument, issued by a nationalized or scheduled bank in a Rs. 500 non-judicial stamp paper. This Security Deposit will be returned (interest free) after the successful completion of the ordered contract. The security deposit shall have a further claim period of 6 months.

3. Warranty

The total system shall be warranted for total performance and failure-free operation for a period of 12 months from date of final acceptance of system by LPSC/ISRO.

4. Performance Bank Guarantee (PBG)

To cover the warranty period of 12 months, the party shall submit the performance bank guarantee for the performance of the systems, equivalent to **3**% of the total order value in the form of bankguarantee or either form of negotiable instrument issued by a nationalized or scheduled bank in a Rs. 500 non-judicial stamp paper. This PBG (interest free) will be returned after the successful completion of the warranty period. The PBG shall have a further claim period of 6 months.

5. Liquidated Damages

As per the Delivery Schedule mentioned is the essence of the order, in case if you fail to deliver the item within the time specified or any extension thereof. Liquidated Damages at 0.5% (Zero Point Five Percent) of the order value or part thereof of the undelivered item for each calendar week of delay shall be recovered from your bill. However, total LD shall not exceed 10% (Ten Percent of the Order Value).

6. Arbitration

Dispute if any shall be settled mutually, failing which it will be referred to a One Man arbitrator appointed by Director, LPSC in accordance with the Indian Arbitration and Conciliation Act 1996, whose decision shall be final and binding on both the parties. In case of import supply, the Arbitration shall be applicable as per International Chamber of Commerce.

7. Jurisdiction

The Courts in the City of Bangalore alone shall have jurisdiction to deal with and decide any matter or dispute whatsoever arising out of this agreement including those arising under the Arbitration Act.

8. Force Majeure

If at any time during the continuance of the order the performance in whole or in part by either Contractor of any obligation under this order shall be prevented or delayed by reasons of any war, hostility, acts of public enemy, civil commotion, sabotage, fire, floods, epidemic, quarantine restrictions, strikes, go-slow, lockout or acts of God, notice of which is given either Contractor to the other within 21 days from the date of occurrence thereof, neither Contractor shall be reasons of such eventuality be entitled to terminate this order nor shall either Contractor have any claim for damages against the other in respect of such non-performance or delay in performance.

9. Secrecy

The drawings and documents sent along with this tender form part of vital documents and same should be kept on top secret. Under any situations, contractor should not part with or transfer the technology/contents of drawings and documents whatsoever to any 3rd party/agency without our prior consent. If at any time, it is brought to our notice that the secrecy has been transferred by you intentionally or otherwise to any third party /agency, contractor shall be liable to indemnify the loss/ damage to Government of India.

10. Indemnity

Contractor shall warrant and be deemed to have warranted that all the items supplied against this tender are free and clean of any infringement of any patent, copy right or trademark and shall at all times indemnify LPSC against all claims which may be made in respect of the items for infringement of any right protected by patent registration of design or trade mark and shall take all risk of accidents or damage which may cause a failure of the supply from whatsoever cause arising and the entire responsibility for the sufficiency of all the means used for executing the Purchase Order.

11. Delivery

Items shall be supplied and installed and site acceptance tested within **9 months** from the date of receipt of Purchase Order. This delivery schedule is the essence of the order and shall be strictly complied with. Detailed Grant chart shall be provided to prove the same.

12. Payment Terms

100% payment shall be made after receipt of all items and installation, commissioning & satisfactory acceptance at the LPSC site.

13. Validity

The quoted price should be valid for a period of 6 months from the date opening of the technical and commercial quotation.

14. Heritage Clause

Party should have executed similar works at Aerospace industries. Details of similar project execution in ISRO or any Aerospace industries in India and reference of at least 2 installations during last 10 years to be provided. Enclose the completion/appreciation certificates from clients.

15. General Conditions to The Vendors

15.1 Vendor Details

The execution of the complete project is on turnkey basis as per the specifications and requirements deliberated in previous sections. The response to the tender is in the form of two separate offers, one as 'Part-A: Technical-Commercial Offer' and other as 'Part-B: Price Bid'. Both the offers are to be submitted simultaneously in separate sealed covers.

In order to understand the vendors profile for execution of the project, following information shall be provided to LPSC along with the technical offer.

a) Profile of the company clearly bringing out the areas of strengths and weaknesses to supply the system of such nature.
b) Self-assessment of technical and organizational competence to supply the system of this nature and magnitude.
c) List of sub-contractors and major equipment suppliers for this project execution.
d) Local office in India or authorized Indian agents details to be provided for ease of project executions.
e) All necessary electrical and mechanical tools and hardware, material handling equipments etc. which are useful and necessary for assembly and efficient working of system, are under the scope of vendor's supply and the cost of the same shall be deemed to be included in the quote, whether specifically mentioned in the tender document or not.
f) Any material and labour which may be necessary to complete the work in accordance with the intent of the specification shall be furnished by the vendor without any extra cost.
g) Any modifications in the system till installation shall meet the technical specification of the tender document and prior approval to be obtained

from LPSC. Further the modifications made shall be technically equal or superior w.r.t. to the original offer and should not have any additional cost implication.

15.2 Pre-bid Meeting & Visit to Existing Facility

Vendors shall attend pre-bid meeting to obtain necessary clarifications on specified date before submission of quotation. **Vendors who are participating in pre bid meeting are only eligible to quote.**

Vendors shall visit the site in LPSC-Tumakuru campus and existing facility in LPSC-Bengaluru.

15.3 Mode of Quoting

The offers shall be submitted on two-part basis as follows: Technical &commercial (other than price) bid & Price bid. Also the validity of quotation shall be 6 months minimum from the date of quoting. The scope of Purchase Order will cover the turnkey execution of the total system as per terms enlisted in the tender document.

a) The quotation shall be based on fixed and firm price and no price escalation is permitted.
b) During the evaluation of technical bids alternatives/options/suggestions shall be confirmed in technical offer to meet the system specifications. As the contract is for fixed price, no provision for addition/reduction in charges will be entertained after opening the price bid.
c) FIRM DELIVERY PERIOD After receipt of order shall be quoted taking into account of all contingencies.
d) Offer shall be valid for minimum six months from the due date.
e) LPSC/ISRO may incorporate specific provisions and conditions before ordering with mutual consent. These provisions will deal with delivery schedule, specifications, demonstration criteria, financial provision, quality control procedures, specific provisions relating to imported items, penalty clauses, etc.
f) Any information kept vague or not furnished shall be treated as non-compliance with the requirements of the vendor and hence tender are liable for rejection.

15.4 Following Documents Shall Be Submitted By The Vendor Along With Technical Offer (Part-A)

a) Compliance matrix of each specification as given in this document.
b) List and details of non-compliance of specifications by the vendor if any.
c) Confirmation of scope of supply as given in this document by vendor.
d) Overall plan of project execution with details of facilities/capabilities available for timely completion of the project in all respects.

e) Preliminary system layout plan of the proposed gas distribution and propellant feed system.
f) List of imported &indigenous items and source of supply shall be provided.
g) Specification of components, model number, data sheet andsource of supply.
h) Information asked in Section 15.1Vendor Details.
i) List of Indian associates or partners, consultants, subcontractors, major equipment suppliers, proposal to be involved in this project, the past experience, competence and extent of the involvement.
j) Details of utilities to be provided by LPSC/ISRO and time stages at which these are required by the contractor
k) Commercial Terms such as delivery date, taxes, duties payable, place of delivery, payment term, validity, guarantee etc. and scope of supply shall not be covered in this part. Please enclose a copy of the details indicated in price quotation (WITHOUT PRICES OR BY MASKING THE PRICE) mainly to know the items/ specifications for which you have indicated prices in price bid. **This part should not contain prices.**
l) The Technical and commercial part of the offer should be kept in a sealed envelope super scribing the following details:

QUOTATION AGAINST TENDER NO - _____

DUE ON _____

GAS DISTRIBUTION SYSTEM & PROPELLANT FEED SYSTEM ATLPSC, TUMAKURU

PART A – TECHNICAL & COMMERCIAL

15.5 Following Documents Shall Be Submitted Along With Price Bid (Part-B)

a) The vendor responding to this tender, shall submit comprehensive price bid in a separate document meeting all the requirements specified therein.
b) This contract is proposed to be firm and fixed price contract and no price escalation will be permitted during the period of contract.
c) Vendor shall not be allowed to change any item from imported to indigenous or vice-versa without prior approval of LPSC after Purchase Order is placed.
d) The Vendor is chosen on the basis of suitability of techno-commercial merits. The scope of contract will cover the turnkey execution of the total system.
e) Vendor shall furnish all details as called for in this chapter giving due justification. Any information kept vague or not furnished shall be

treated as non-compliance with the requirements of the Vendor and hence tender is liable for rejection

The offer should include the following documents:

f) The total cost of the systems including fabrication, supply, installation, commissioning and testing.
g) Break up of cost for gas distribution system, propellant feed system, PLC based control system, flushing cart etc.
h) Break up cost of imported & indigenous items.
i) Transportation charges, taxes, government levies shall be specified separately.
j) Installation & commissioning charges shall be specified separately.
k) Warranty certificate for the period of 1 year, from the date of acceptance of the total system.
l) Performance bank guarantee for a minimum period of 12 months from the date of acceptance of the total system by LPSC/ISRO from a nationalized Bank.
m) Acceptance to the commercial clauses and conditions.
n) Any other information relevant to this tender.
o) This part should also be kept in a sealed cover super scribing as follows:

QUOTATION AGAINST TENDER NO - _____

DUE ON _____

GAS DISTRIBUTION SYSTEM & PROPELLANT FEED SYSTEM ATLPSC, TUMAKURU

PART B – PRICE BID

16. Special Instructions to Tenderers for Submitting Two Part Tenders

File No:

ITEM: **Gas Distribution System & Propellant Feed System at LPSC, Tumakuru Campus**

Please note the following instructions and submit your offer accordingly.

(a) PART-A: TECHNO–COMMERCIAL

This part shall contain only the technical details and specifications together with technical catalogues. All commercial conditions shall also be indicated in this part. Deviations, if any, to our specifications shall be brought out very clearly. Tenderers shall mention point-wise confirmation with regard to Technical Specification and Commercial Terms & conditions (Techno-Commercial). Price details should not be shown in this part.

This part shall contain the detailed technical specification and commercial terms such as delivery dates, taxes, duties payable, place of delivery, payment term, validity, warranty \guarantee etc. and scope of supply shall be covered in this part. Please enclose a copy of the details indicated in price quotation (without prices or by masking the price). Mainly to know the items/specifications for which you have indicated prices in price bid.

(b) PART-B: PRICE BID

The part shall contain the PRICES details only.

The prices for the item shall be indicated item wise in this part. All the items as per specifications mentioned in the technical part shall be included and prices shall be indicated against each item. The break up for each item of supply and services also shall be indicated

Whenever options are quoted, same shall also be indicated with quantity and unit rate separately. The prices are to be mentioned both in figures and in words.