Annexure I

Lab Modification

(High pressure test facility to test Gas-turbine combustors)

An experimental test rig to test gas turbine combustors is being developed at NCCRD, IIT Madras. The test facility envisages to test the combustors at high pressure and temperature conditions. This includes the development of an air supply line, fuel line, water supply line, instrumentation and control systems. Experiments will be conducted to measure emissions, operability and sub-atmospheric performance.

The test facility consists of a high pressure test rig and an ejector unit. The air and fuel supply lines are to be connected to the rig. The hot combustor gases are to be cooled down using a water flow circuit.

The following items come under the scope of the present tender. Fabrication and erection of the

1. Air supply line
2. Fuel supply line
3. Water supply line
4. Hydrogen flow and ignition circuit
5. Instrumentation and control panel

The below sections explain each of the above mentioned items.

1. Air Supply Line

A high pressure air supply line is needed to be developed to take high pressure hot air to the test rig. Further, the air supply line also has to supply air to the ejector. A brief layout of the air supply line is given in Figure 1. Major parts include

1. Pressure regulating valve (PRV)
2. Air flow meter (FM)
3. Ball valves (BV)
4. Flow control valves (FCV)
5. Critical flow venturi nozzle (CFVN)

During the hot air tests/ emission tests, the air from the main line pass is controlled by the pressure regulating valve (PRV) and then it is metered by the air flow meter (FM). The cold air will be sent to an electric air heater installed on the terrace of the building and the hot air enters back to the inside lab through another pipe line. At the exit of the rig, a high pressure exhaust valve is positioned to control the airflow rate and to maintain the pressure. The required mass flow rate and pressure can be maintained in the rig by simultaneously controlling the PRV and exhaust valve (BV6).

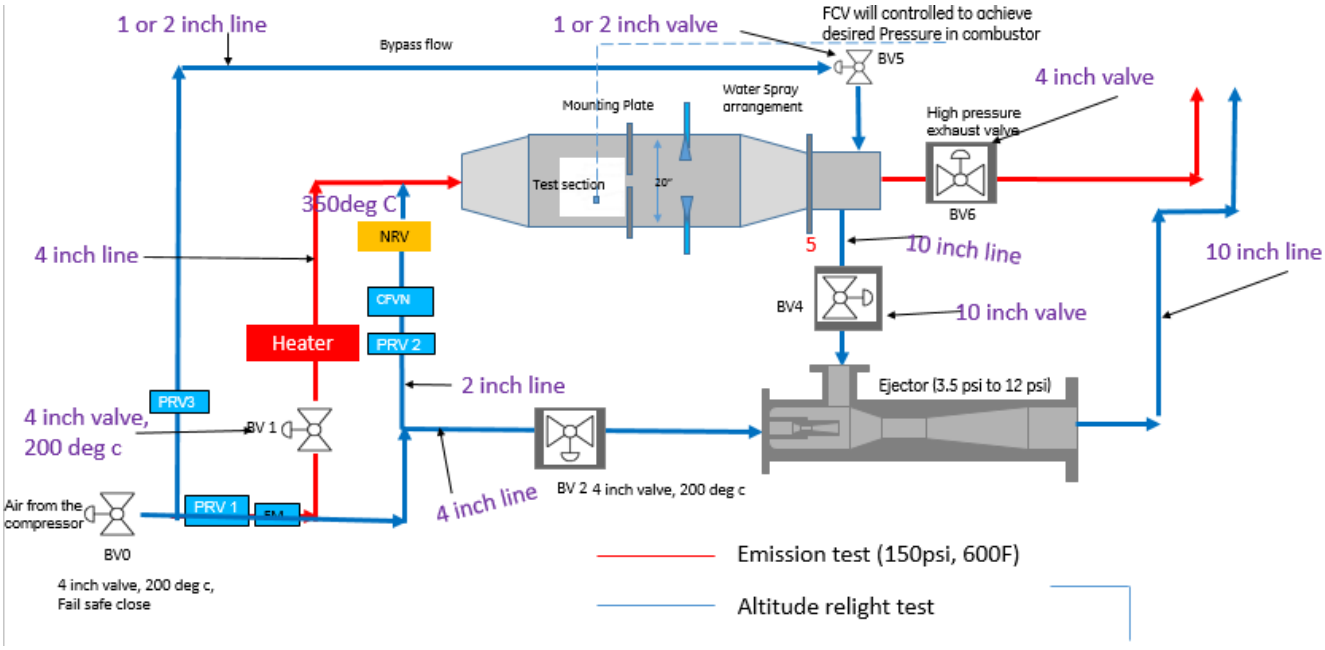


Figure 1. Layout of the test rig.

The sub-atmospheric conditions are simulated in the rig by operating the ejector. During this test, the hot air line is kept closed. Cold air after PRV1 and flow meter (FM) enters to the ejector through BV2. Suction will be created inside the rig and air flow to the rig is monitored and controlled by PRV2 and sonic nozzle/ CFVN. The NRV/Check valve and BV4 is to be opened to allow the flow through the rig. BV6/ high pressure exhaust valve is to be closed during the sub-atmospheric tests. A bypass flow line is also to be installed to supply the additional air required during the ejector operation. This additional air is to be controlled by PRV3 and BV5. Experiments will be conducted 5- 6 hours continuously for each test cases.

Operation sequence:

High pressure experiments: High pressure-hot air to the rig- max operation 2.5 Kg/s, 350 Deg.C, 10 bar

Open: Main gate valve or BV0, PRV1, BV1, BV6

Close: PRV3, BV2, PRV2, NRV/check valve, BV5, BV4

Control: PRV1, BV6

Subatmospheric tests:

3 air supply lines- 1, air flow to the ejector to simulate the vacuum; 2, air flow to the combustor; 3. Bypass air flow to supply additional air to the combustor exit.

Open: BV0, PRV1, BV2, PRV2, PRV3, BV4, BV5

Close: BV1, BV6

Control: PRV1, PRV2, PRV3, BV5

A CAD model showing the entire assembly is given in Figure 2 and 3.

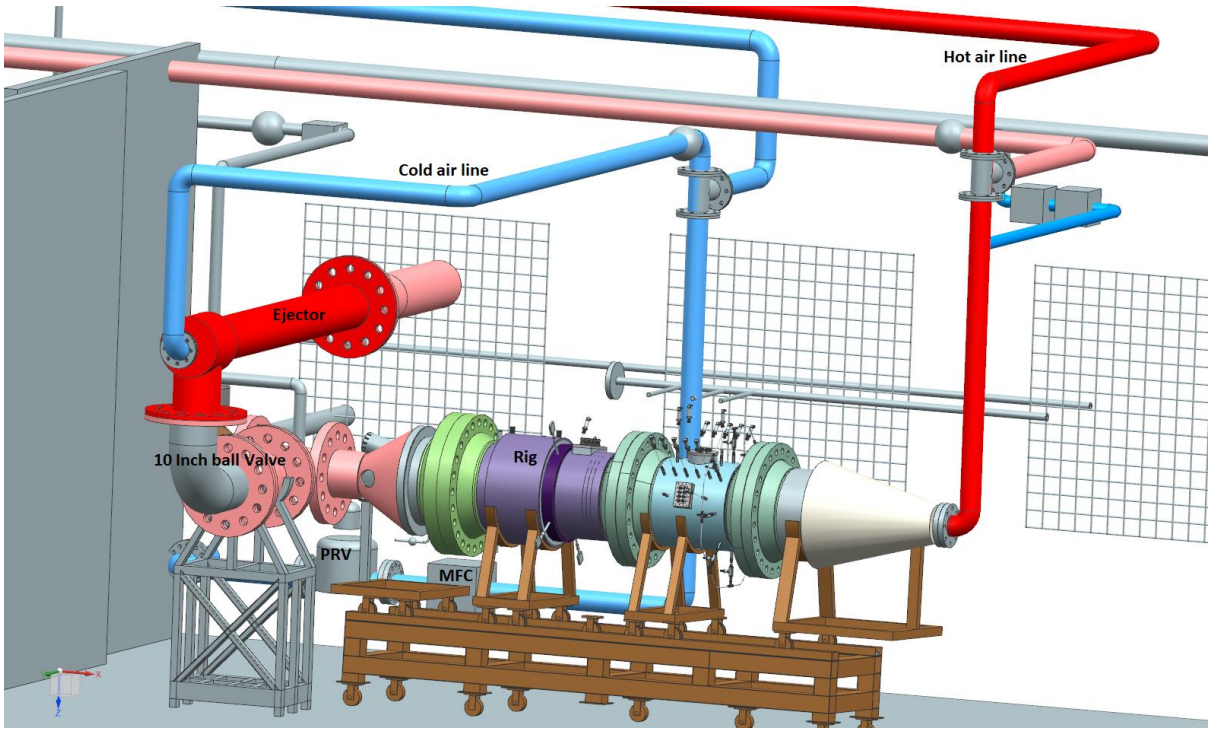


Figure 2: CAD mode of the test rig.

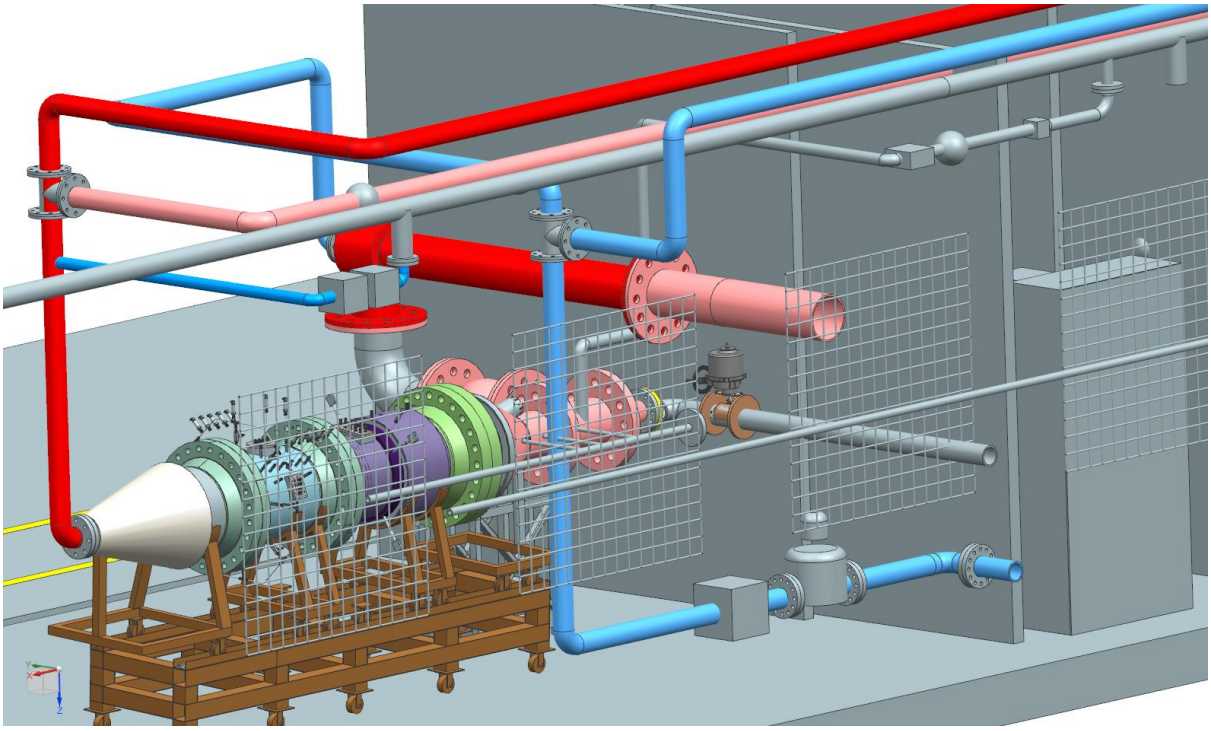


Figure 3: CAD mode of the test rig view 2.

Detailed specs of each components related to the air supply line are listed below.

1. Air flow meter (FM)

1. Operating flow range: 0-2.5 Kg/s
2. Operating pressure range: 1-12 bar
3. Maximum pressure: 14 bar
4. Maximum flow rate: 3 Kg/s
5. Operating temperature – ~30 Deg. C
6. Measurement principle (Preferred): Coriolis
7. Accuracy: $\pm$2 % of actual value
8. Resolution: 1 % FS
9. Line size: 4”
10. Material of construction: SS or cast steel
11. Preferred makes: Micromotion, Bronkhorst
12. Calibration: certificates needs to be produced by the vendor based on reputed 3rd party as per the relevant ASME standards

2. Pressure regulating valve; PRV1

1. Input pressure: 15 bar working Max: 40 bar, Failsafe close with-in 2 sec.
2. Output pressure: 0-12 bar
3. Flow rate: 0- 2.5 Kg/s
4. Max flow rate: 3 Kg/s
5. Line size: 4”
6. Class 300
7. Operating temperature – ~30 Deg. C
8. Material of construction: Body: ASTM-A216 Gr. WCB (Standard), CF8, CF8M,
   Diaphragm casing: Casting Steel or Stainless Steel
   Disc and diaphragm: Nitrile (Standard), Neoprene, EPDM, Silicon, PTFE, Fluoropolymer
9. Control : Electrical, remotely operated, integrated to control panel
10. Preferred makes: R.K.Control, Nirmal or equivalent

3. Pressure regulating valve: PRV2

1. Input pressure: 15 bar
2. Output pressure: 1-5 bar
3. Flow rate: 0- 0.6 Kg/s
4. Max flow rate: 1 Kg/s
5. Line size: 2”
6. # 300
7. Operating temperature – ~30 Deg. C
8. Material of construction: Body: SS 316 Diaphragm casing: Casting Steel or Stainless Steel
   Disc and diaphragm: Nitrile (Standard), Neoprene, EPDM, Silicon, PTFE, Fluoropolymer

9. Preferred makes: Virgo, micro finish, Sankey
10. Control: Electrical, remotely operated, integrated to control panel

4. Pressure regulating valve: PRV3

1. Input pressure: 15 bar, working Max: 40 bar
2. Output pressure: 1-5 bar
3. Flow rate: 0- 0.6 Kg/s
4. Max flow rate: 1 Kg/s
5. Line size: 1 ”
6. Operating temperature – ~30 Deg. C
7. Material of construction: Body: SS 316 Diaphragm casing: Casting Steel or Stainless Steel
   Disc and diaphragm: Nitrile (Standard), Neoprene, EPDM, Silicon, PTFE, Fluoropolymer

8. Preferred makes: Virgo, micro finish, Sankey
9. Control: electro- pneumatic fine controlled
10. CLASS 300

5. Ball valves BV1 and BV0

1. Method of operation: Electro Pneumatic; Failsafe close with-in 2 sec. BV0 only need to be failsafe close
2. Line size: 4 inch
3. No of valves required – 1
4. Max. operating pressure – 12 bar

b. Operating temperature – ~30 Deg. C

1. Max flow rate 3 Kg/s
2. Preferred makes: Virgo, micro finish, Sankey
3. Material of construction: SS 316 body
4. Actuator type, spring return, sizing done at 6 bar
5. 3/2 single coil 24 V DC solenoid valve
6. Limit switch box, 2 SPDT micro switches for open/close feedback

6. Ball valves BV2

1. Method of operation: Electro Pneumatic
2. Line size: 4 inch
3. No of valves required – 1
4. Operating temperature – ~30 Deg. C
5. Max. operating pressure – 12 bar
6. Max flow rate 2.5 Kg/s
7. Preferred makes: Virgo, micro finish, Sankey
8. Material of construction: SS 316
9. Actuator type, double acting, sizing done at 6 bar

10. 5/2 single coil 24 V DC solenoid valve
11. Limit switch box, 2 SPDT micro switches for open/close feedback

7. High temperature Ball valve: BV4

1. Line size: 10 inch
2. Line pressure: 12 bar maximum
3. Max temp: 800 Deg.C
4. Working temp: 650 deg.C max
5. Leakage class: Class 4
6. Fluid: Combustion hot gas and steam/ water mixture
7. Flow rate: 3 kg/s max
8. Class: 300#
9. Method of operation: Hand wheel operated worm gear box
10. Material of construction: SS 316

8. Ball valves: BV5

1. Method of operation: electro pneumatic fine control application
2. Line size: 1 inch
3. No of valves required – 1 no.s
4. Max. operating pressure – 12 bar
5. Max flow rate: 0.5 Kg/s
6. Material of construction: SS316
7. Preferred makes: Virgo, micro finish, Sankey
8. Operating max temperature – 600 deg.C
9. Fluid : air , one end steam-gas mixture in closed position

9. High pressure flow control exhaust valve: BV6

1. Line pressure: 12 bar max
2. Line size 4”
3. Line pressure operation: 0-10 bar
4. Fluid: Combustion hot gas and steam mixture
5. Line temperature: 650 deg. C max, max temp 800 deg C
6. Duration of operation: 6-8 hours continuous
7. Material of construction: SS 316/310
8. Method of operation: Electro Pneumatically controlled with a positioner globe valve
9. Flow rate: 5 Kg/s max.
10. Preferred makes: R.K.Control, Emmersion
11. Class 300
12. Leakage class - 4

10. CFVN / Sonic nozzle

1. Air flow rate : operating flow rate 0.01 to .6 kg/s
2. Line pressure: 12 bar max,
3. Max available upstream pressure for CFVN- 10 bar
4. Upstream pressure measurement: P0 stagnation, pitot probe based
5. Upstream temperature measurement: Thermocouple
6. Accuracy: 1 %
7. Resolution: 1 % of FS
8. Calibration: certificate to be provided by FCRI
9. Material of construction: SS 316
10. Pressure measurement: strain gauge type
11. Line size: 2" flanged ends, #300
12. Design and fabrication should be as per relevant ASME standards. Third party calibration certificate (preferably FCRI) needs to be provided

11.Check valve/ NRV

1. Line size 2 inch
2. No of valves required – 1 no.s
3. Max. operating pressure – 12 bar
4. Max flow rate 1 Kg/s
5. Material of construction : SS316
1. Preferred makes: Virgo, micro finish, Sankey
6. Line temp: 350 Deg.C

12. Electro pneumatic vent valve

1. Line pressure: 12 bar max
2. Line pressure operation: 0-10 bar
3. Fluid: hot air
4. Line temperature: 350 deg. C max
5. Duration of operation: 6-8 hours continuous
6. Material of construction: SS 316/310
7. Method of operation: Electro Pneumatically controlled with a positioner globe valve
8. Flow rate: 3 Kg/s max.
9. Preferred makes: R.K.Control, Emmersion
10. Class 300
11. Size 2 "

All valves should have feedback and controls that is connected to the main control panel. All valves and component should be rated for 6- 8 hours of continuous operation.

List of pipe line work needs to be done. Flanges, bolts and gaskets need to be accounted separately.

Table 1: List of materials for piping work

Works to be done	Bill of materials	Specs	Total no
High pressure hot air line	4 " seamless pipe	WP; 12 bar	15 m
	4" bends		6 no.s
Ejector line	10 " seamless pipe	12 bar working pressure	2 m
	10" bends		2 no.s
	2" line		5m
	2" bends		2 no.s
	1" seamless pipe		8 m
	1" bends		5 no.s

Pipe Class: Schedule 80 MS pipe line from heater to combustor.

Every components and piping should be hydrotested as per the ASME standards, min 1.5 times of the maximum working pressure.

All components design and manufacturing and piping should comply with the relevant ASME and ASTM standards

Sensing elements:

1. Line pressure and temperature
2. PRV – output pressure
3. Air mass flow rate
4. P0 and T0 values from the CFVN
5. CFVN flow rate
6. Skin temperature and inlet air temperature of the rig
7. Exhaust gas temperature just before the exhaust valve
8. Chimney exhaust pressure and temperature
9. Rig inlet and outlet pressure
10. Rig outlet pressure
11. Ejector inlet pressure

All pressure sensors should be strain gauge type with a max pressure of 16 bar G and K type TC should be used for the temperature measurement

Tentative operation protocols & safety procedures

High pressure tests

1. Close BV2,3,4,7
2. Open the gate valve
3. Control the PRV1 opening as needed
4. Open BV1
5. Start the electric heater
6. Sense the heater temperature, inlet pressure, skin temperature.
7. Maintain the required air pressure and flow rate by controlling PRV1 and exhaust valve BV6

Sub-atmospheric pressure tests

1. Close BV1, high pressure exhaust valve
2. Open the gate valve
3. Control the PRV1 opening as needed
4. open BV2, 4
5. Start the ejector
6. Adjust the PRV2, BV5 Flow control valve
7. Sense the ejector pressure, inlet pressure, skin temperature.
8. Maintain the required air pressure and flow rate by controlling PRV2 and flow control valves, measure the flow rate using CFVN

2. Fuel Supply Line

Objective of the fuel line is to supply JetA (aviation) fuel from the terrace of NCCRD building to the test facility inside the lab (4th floor which is top floor of NCCRD building). The line pressure from terrace to the rig is about 40 bar and 250 kg/hr flow rate. The pressure and flow rate need to be metered and control from the common control panel. The pipe material should be SS316 and able to handle the JetA fuel at above mentioned pressure condition. The length of the piping work and other instrumentation required are described below.

As JetA is working fuel, safety is a major concern inside the lab. Therefore, all the connections and instrumentation that are going to be installed should meet the ZONE1 (flame proof zone) criteria.

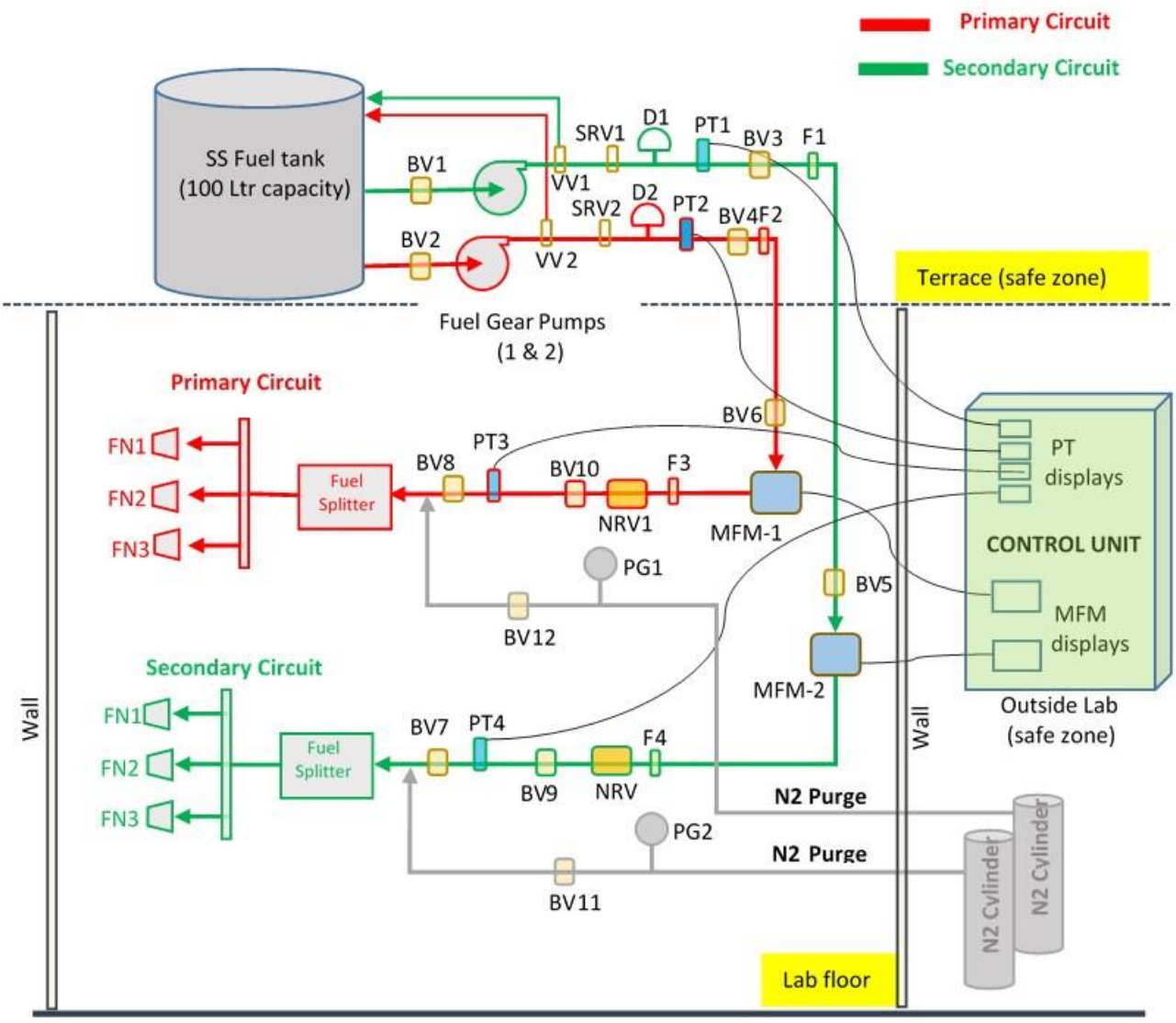
Description and operation of the fuel flow facility is provided below with P&ID. The detailed specs of each components that are going to be used are also provided.
Please refer to the schematic and the details of the specifications for the fuel flow facility.

1. Description of fuel system P&ID:

1) There are two SS barrels requirement at the ground floor to store JetA fuel. The capacity of each barrel is of 200 liters. Vendor has to supply these empty barrels. Both of them will be kept outside the NCCRD building for safety reasons.

2) At the terrace, the fuel tank SS304 of 100 liters capacity will be kept inside the shade (shelter). Vendor has to provide this fuel tank, while the shade is already available at the NCCRD terrace. The maximum height of shade is 1.2 m and width 1 m. Therefore, the dimensions of fuel tank (length and diameter) should sufficient to accommodate the fuel tank inside the shade.

3) Outlet of the terrace fuel tank (100 liters) will be connected to two Fuel Gear Pumps. As shown a ball valve is used between tank and inlet of each of gear pumps (BV1 and BV2). The purpose of two fuel pumps is to provide JetA to the primary and secondary fuel circuits, as shown by red and green color lines respectively in Fig. 2. Both the pump should be provided with variable frequency drive (VFD).



BV1 and BV2 – Ball Valve Type-1
BV3 to BV8 – Ball Valve Type-2
BV9 TO BV12 – EPV Ball Valve Type-2
NRV – Non Return Valve
SRV – Safety Relief Valve
VV – Vent Valve
F1 to F2 - Filters

PT – Pressure/Temperature measuring sensors
D – Damper
PG – Pressure Gauge
MFM – Mass Flow Meter
N2 – Nitrogen
FN – Fuel Nozzle

Figure 2. Fuel System P&ID

4) After each fuel pump, vent valve (VV1 and VV2), safety relief valve (SRV1 and SRV2) and damper (D1 and D2) have to be installed. The purpose of the vent valve is to keep the excess fuel back to the fuel tank back. The dampers are of about 5 liters capacity and this will serve to settle disturbances from the pump action.

5) After the dampers pressure and temperature measuring sensors (PT1 and PT2), BV3 and BV4 and filters (F1 & F2) of 20 microns will be fitted. Both pressures transducers and thermocouples should be connected to main control panel for monitoring pressure and temperature.

6) Fuel from terrace pass through the BV5 and BV6 and finally enters into the mass flow meters (Fig.2).

7) The purpose of the Mass Flow Meter (MFM) is to monitor the fuel coming from the fuel pump. There are two mass flow meters (MFM1 and MFM2) whose reading are displayed at the control panel. The accuracy of MFM should be high (+/- 0.2% of the reading). It is required that the MFM should be connected with pump as a feedback system that provide the provision to allow require fuel mass flow.

8) From the mass flow meter, fuel is supplied to the fuel splitter. Before that, fuel must pass through filter (F3 & F4 of 10 microns), non-return valve (NRV1 and NRV2) and ball valve (BV7-8 and BV9-10). The arrangement is shown in Fig 2. The filters, valve and NRVs should meet the high accuracy and standards mentioned in following table.

9) The fuel pressure and temperature at the injection to the fuel splitter is measured with use of pressure and temperature sensors (PT3 and PT4). As mentioned above both the elements will be connected to display provided at the control panel.

10) Both the fuel splitters will be provided by us. While the fuel piping arrangement up to inlet of fuel splitter will be provided by the vendor.

11) There is a nitrogen line separate for primary circuit and secondary circuit. The purpose is for nitrogen purging. The nitrogen cylinders will be provided by us. The nitrogen line from the cylinder to the inlet of fuel splitter should be provided by the vendor. The line contains ball valve (BV11 and BV12). The line pressure should be measured by providing pressure gauge (PG1 and PG2).

2. Scope of work for the vendor:

Vendor has to carry out the above mentioned piping works at site. Some places erection and assembly work also require, which is under vendor's scope. All installation should meet the requirement as per the standard. Regarding safety, vendor has to verify and check the instruments are flame proof before installation inside the lab. Wherever require, vendor should provide the calibration certificate for particular equipment.

Major component that vendor has to provide are listed below, while the description is given next.

1. Fuel flow meter
2. Gear pumps
3. Ball valves (on/off)
4. Electro Pneumatic Valves
5. Check valves/ NRVs
6. Vent valves
7. Pump Pulsating dampers

8. Fuel filters
9. Safety relief valve
10. Thermocouples
11. Fuel barrels (200 Ltr capacity)
12. Fuel tank (100 Ltr capacity)
153. Pipe or tube fittings

Each of the items shown in Fig. 2 with the specification are given below in tables.

3. Fuel mass flow meter Specifications

Specifications for Mass flow Meter (MFM-1)

S.No.	Description	Specs
1.	Fuel	Jet Fuel A1
2.	Material of construction	SS316L
3.	Pressure Range	0-40 bar @ the exit of MFM
4.	Temperature	Ambient to 45C
5.	Flow rate range	0-250 Kg/h
6.	Accuracy	+/- 0.2% of the reading
7.	Power supply	220 V, single phase
8.	Measuring principle	Coriolis
9.	Make (Preferably)	Emerson, micro motion

Specifications for Mass flow Meter (MFM-2)

S.No.	Description	Specs
1.	Fuel	Jet Fuel A1
2.	Material of construction	SS316L
3.	Pressure Range	0-40 bar @ the exit of ~~MFC (or~~ MFM)
4.	Temperature	Ambient to 45C
5.	Flow rate range	0-50 Kg/h
6.	Accuracy	+/- 0.2% of the reading
7.	Power supply	220V, single phase
8.	Measuring principle	Coriolis
9.	Make (Preferably)	Emerson, micro motion

4. Specifications for other instruments

Sr No	Description	Specs	Qnt
1.	SS fuel barrels	SS304, 200 Ltr, Cylindrical tank with inlet and outlet valves, and with breather valves.	2
2.	Gear pump	Gear Pump SS316 with Exd VFD Pump motor. Makes should be confirm during technical evaluation stage; flow rate 0-250 Kg/h and 0-40 bar pressure range.	2
3.	Fuel tank SS304	SS304 100L, Cylindrical tank with Inlet Valve + Outlet Valve, with level transmitter with 4-20ma O/P	1
4.	Ball valve (type-1) (BV1 and BV2 in Fig.2)	Isolation Valve / Ball valve 15NB BSP(F) or flanged valves SS304 #150 Ball Valve, 2PC/3PC Make: Sankey /Virgo/Microfinish	3
5.	Ball valve (type-2) (BV3 to BV8 in Fig 2)	Tube End instrumentation ball Valve 15NB Tube End SS316 PN100 Ball Valve, 1PC. Make: Parker / Swagelok	6
6.	Ball valve (EPV) (type-2) (BV9 TO BV12 in Fig. 2)	Tube End instrumentation ball Valve 15NB Tube End SS316 PN100 Ball Valve, 1PC, Tube End, + Spring Return Pneumatic actuator + 3/2, Namur Ex-D Solenoid Valve 24Vdc + LSB Ex-D Make: Parker / Swagelok	4
7.	Safety relief valve	Safety relief valve 1/2 inch 55 bar SS316 PN100, Tube End (Double Compression)	3
8.	Vent valve (EPV) (type-2)	Tube End instrumentation ball Valve 15NB Tube End SS316 PN100 Ball Valve, 1PC. Tube End, + Spring Return Pneumatic actuator + 3/2 , Namur Ex-D Solenoid Valve 24Vdc + LSB Ex-D Make: Parker / Swagelok	3
9.	Pump Pulsating dampers	SS304, 5 liters Working Pressure 50 bar	2
10.	Fuel Filters (F1 and F2 in Fig.2)	TEE Cartridge type filter 20microns for 10 lpm 50bar SS316, Pressure Drop 1 bar	3
11.	Pressure transducer	S-10 0-60BAR, 4-20MA Out Pressure Transmitters, Make: Wika / Baumer / Keller	4
12.	Thermocouple	K-Type Tube End Thermocouple Make: Omega /Reputed make	4
13.	Check valve / NRV	Check valve 15NB #1500 SS316 Tube End, Poppet Type Make: Sankey / Parker / Swagelok	2
14.	Fuel filter (F3 and F4 in Fig.2)	TEE Cartridge type filter 10 microns for 10 lpm 50bar SS316, Pressure Drop : 1 bar Make: Sankey / Classic Filters / Norgren / Reputed make	3

15.	Pressure gauge	100mm 0-60bar,1/2 inch BSP (f) Panel Mounted Make: Wika / Baumer / Keller	3
16.	Panel enclosure	MS fabricated as per requirement, all manual valve should be panel mounted , gauge should be panel mounted, junction box for electrical wiring should be ex-D with EX proof glands and connectors	1
17.	Pipe or tube fittings	As required, Pipe should SS316 and Tube fitting should parker /Swagelok make, Pipe Tubing Make: Sandvik	1 as per requirement

* type-1 means low pressure side (atmospheric pressure)
  type-2 means high pressure side (40 bar)

5. Sensing elements

- Thermocouples
- Pressure transducers
- Pressure gages
- Check valve
- Vent Valve

6. Control elements

- Mass Flow Meters
- Pump rpm
- Ball valve on/off
- Electro Pneumatic Valves

All components design and manufacturing and piping should comply with the relevant ASME standards. It is mandatory that all the digital equipment must monitor by providing the displays on the control panel the outside of the lab. The control panel location maybe around 10 meters from the instrumentation. The length of wires to connect may vary.

Note: The fuel line is made up of 1/2 inch SS316 line with Swagelock fittings and Sanvik (or well standard) tubing. API Compliant tank for fuel storage tank.

7. Other Requirements

S.No.	Description
1.	The Mass flow meter/controller shall have software interface and LabView interface (through USB port) to control and monitor the parameters
2.	Data acquisition signal, for 2 flowmeter, 2 pressure transmitter, 2 Thermocouple
3.	Display is required in the mass flow meter – Optional quote
4.	Swagelok (or Parker) Fittings is required, and the line size should be 1/2 inch.
5.	Suitable filter must be supplied.
6.	Add all the necessary spares required
7.	Calibration certificate
8.	Warranty Certificate – 3 years
9.	All the connecting cables shall have a length of 15 meters
10.	Supplier shall install and commission the mass flow meter/controller unit at IIT madras.
11.	The supplier shall check the working of the entire system in their facility and give us inspection report before delivering it to IIT madras.

3. Water Supply Line

There are three purposes of the water flow facility: (1) for the cooling of jacket of combustion chamber, (2) to spray water against the exhaust hot gases to cool down the gas temperature and (3) for the cooling of emission rack. Each of the line will be supplied from the common water pipe line. The line pressure for (2) and (3) is about 220 psi and for (1) is 14.5 psi. The flow rate for each of the above three line is 1 kg/s. The description and P&ID of the water flow requirement are explained below.

Please refer to the schematic and the details of the specifications for the water flow facility.

1. Description of Water supply System

1) The water from 25,000 liters water tank is supplied to the pump system by providing the water pipeline (1 inch or as per the pump inlet) arrangement. We will provide the water tank.

2) Location of the water tank is at the terrace and the pump system inside the lab. Therefore, the water pipeline arrangement would be about 60 meters. The length of the pipeline may vary. The material of the pipe should be SS304.

3) There are four ball valves, one at the outlet of the water tank (BV1) and another at the inlet/outlet of the pump system (BV2 and BV3). The fourth ball valve (BV4) will be provided at the exit of the rig.

4) The water flow rate from the pump system will be monitored by a flow meter.

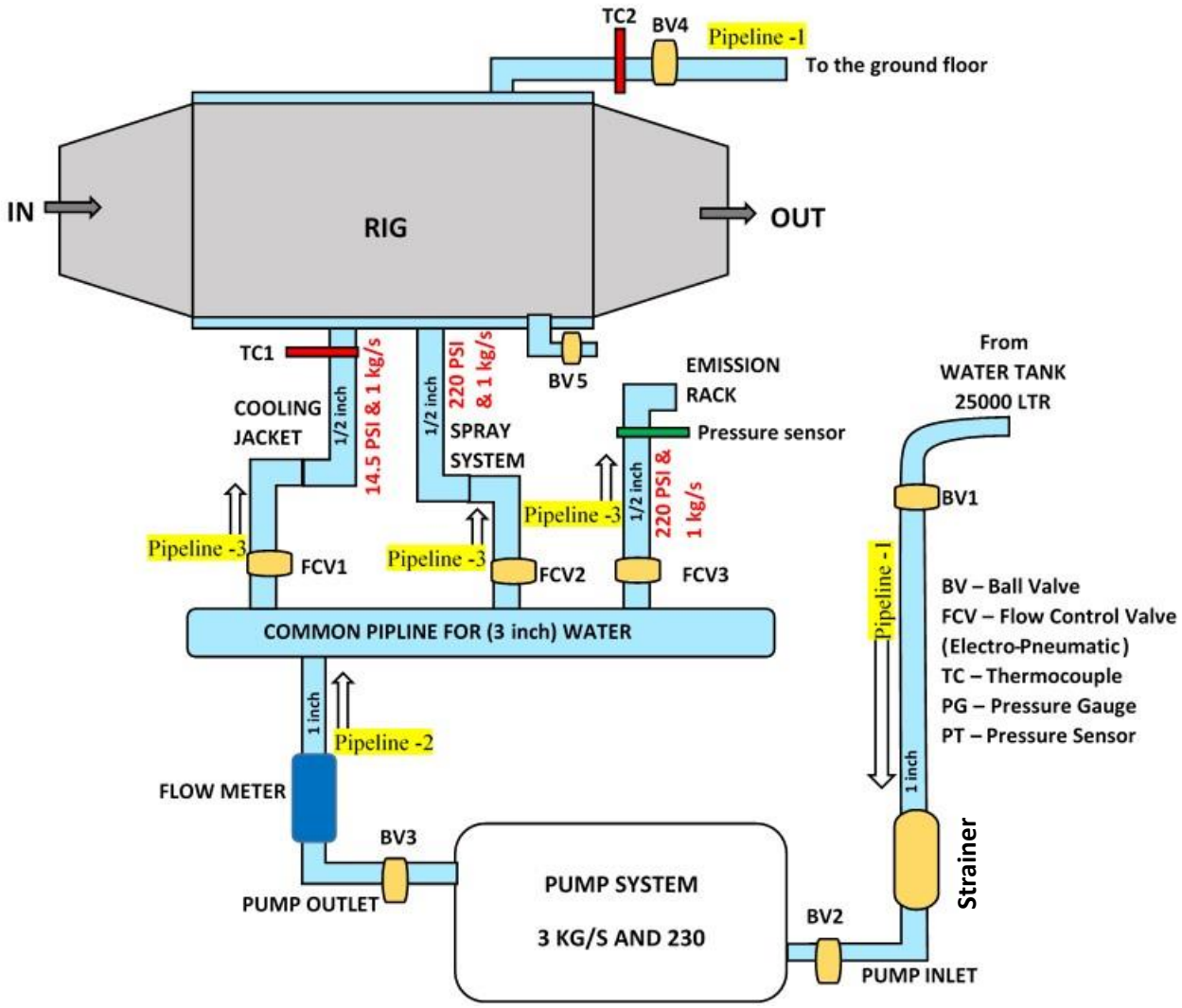


Figure 3. Water Flow System P&ID

5) The pump system should provide a water flow rate of 3 kg/s and at 230 psi. The plunger type pump with motor is preferable here.

6) The outlet of the pump is connected with the common pipe from where three sub-pipelines will supply to three different circuits. (a) first-line will be connected to the water cooling jacket. The cooling jacket will be provided by us. The pressure and flow rate of this line are 14.5 psi and 1 kg/s respectively. (b) The second sub-pipeline is for spray purposes. The pressure and flow rate of this line are 220 psi and 1 kg/s respectively. (c) The third line is connected to the emission rack. The pressure and flow rate of this line are 220 psi and 1 kg/s respectively. The connection of all three lines up to the required locations will be within the lab (about 30 meters of water pipeline). Some places flexible hoses may be needed due to lab space constraints.

7) All the above three lines should be provided with the Flow Control Valve (FCV1, FCV2, FCV3) to monitor the water flow rate.

8) There is a ball valve at the bottom of the rig to drain the condensed water (BV5) in Fig. 3.

9) The spray system line should be installed with a water flow meter of 220 psi and 0-1 kg/s flow capacity. We need to monitor the flow at the main control panel.

10) The emission rack also requires a pressure measuring sensor.

11) At the cooling jacket, we need to measure at inlet and outlet of the water (TC1 and TC2 in Fig.3)

2. Specifications of different parts of the water flow facility

Sr No	Description	Specs	No.
1.	Pump System	Max flow rate = 3 kg/s and Pressure = 230 psi	1
2.	Flow Meter	Turbine flowmeter 0-200lpm, 25bar with display	1
3.	Flow meter (at spray system line in Fig. 3)	Water flow meter for 220 psi and 0-1 kg/s flow rate	1
4.	Pipeline -1	SS304 pipeline installation from terrace to the lab (atm pressure) and from lab to the ground floor. (complete circuit 1 inch pipe dia)	60 meter length
5.	Pipeline -2	Internal arrangement of SS304 pipeline of 1 inch pipe dia. and 230 psi pressure	30 meter length
6.	Pipeline -3	Internal arrangement of SS304 pipeline of 1/2 inch pipe dia. and 230 psi pressure Sch40	30 meter length
7.	Common pipeline	SS pipeline installation of 3 inch pipe dia. and 230 psi pressure	1-2 meter length
8.	Strainer (Type 1)	15NB BSP(F) Strainer SS304 #150 Y Type, Suitable for 50 Micron Mesh Make: Sankey /Virgo/Microfinish	2
9.	Isolation Valve	Isolation valve Ball valve 40NB BSP(F) SS304 (for 1 inch pipe dia. and 230 psi pressure)	2
10.	Isolation Valve	Isolation valve Ball valve 25NB BSP(F) SS304 (for 1 inch pipe dia. and 230 psi pressure)	2
11.	Flow Controls Ball Valve	Electro-Pneumatic Flow Control Valve V-port Ball valve + actuator + Positioner V-60 Deg (To be confirmed later) 1 inch #300, Screwed End Valve for controls application	3
12.	Thermocouple	K-Type Tube End Thermocouple Make: Omega /Reputed make	3

13.	Pressure sensor	A pressure sensor of 0-220 psi range needs to be installed at the inlet of emission rake	1
14.	On-Off Drain /Outlet Ball Valve	Valve 15NB BSP(F) SS316 PN16 Ball Valve, 1PC. Tube End, + Spring Return Pneumatic actuator + 3/2, Namur IP-67 Solenoid Valve 24Vdc + LSB Ip-67 Make: Sankey / Microfinish	2

3. Sequence of operation of the water lines

- Switch on the pump
- Open the FCV as per the required water flow rate
- Monitor the water flow rate from water flow meter
- Measure pressure at inlet of the emission rack
- Measure temperature at inlet and outlet of cooling jacket

4. Sensing elements

- Thermocouples
- Pressure sensors
- Flow meter

5. Control elements

- Flow Control valves

4. Hydrogen Flow and Ignition Circuit

The purpose of the hydrogen line is to provide an ignition source to the fuel air mixture inside the combustor. The mixture will be ignited with the use of hydrogen flame. Once the ignition started, the hydrogen flame will be shut off. The arrangement of piping work will be inside the lab. (See Fig. 4). The hydrogen cylinders will be kept outside the lab.
It is to be noted that we are going to provide the hydrogen cylinders.

A Hydrogen line of ¼ inch SS swage lock / parker fittings is required with the ignition systems for piloting the combustion as shown in the P& ID diagram.

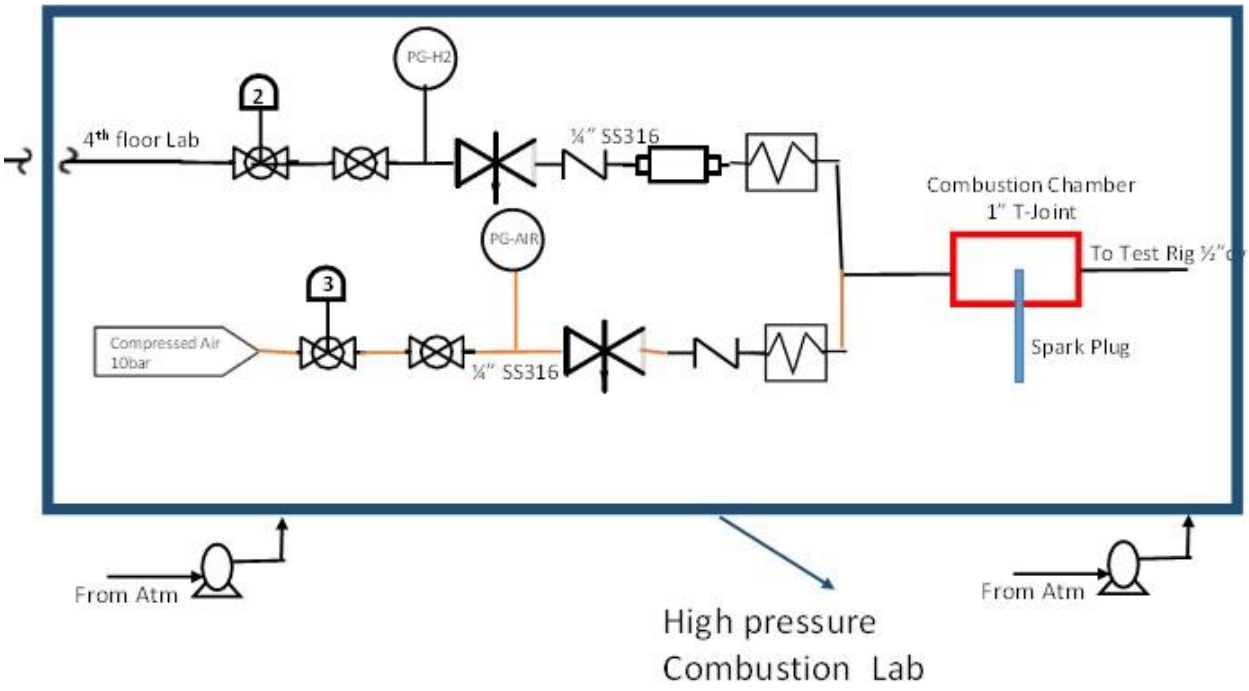
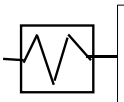
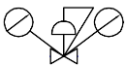


Figure 4. Hydrogen line P&ID

	2-way ball valve with pneumatic actuator 1/4" OD process end connections 316 SS valve body, PTFE seat/ seals Max. pressure 414 bar Requires min. 4 bar pneumatic pressure to operate actuator With Automatic Shut-off. **Valves 1 and 3 will be connected to the safety interlocking system, to shut-off during emergency.**
	Excess flow control valve
	Whittgas flashback arrestor
	Needle Valve
	Non-return Valve
	Water bath – ¼" tube spiralled around (5 turns) and kept inside ~15 cm dia vessel
	Pressure Gauge
	150 bar to 10 bar pressure regulator with pressure gauges
	Ventilation fan suitable for installation in hazardous area zone 1 & 2. Gas group IIC, IP65, PESO certified

1. Specifications of different parts

S.No.	Description	Specs	No.
1.	EPV-1/EPV-2	Tube End instrumentation ball Valve 8Nb Tube End SS316 PN100 Ball Valve, V-port Slot CV, 1PC, Tube End, + Spring Return Pneumatic actuator + E/P Positioner Ex-D + LSB Ex-D Make: Parker / Sankey /Swagelok	2
2.	BV-1/BV-2	Tube End instrumentation ball Valve 8Nb Tube End SS316 PN100 Ball Valve, , 1PC , Make: Parker / Sankey /Swagelok	3
3.	Check valve	Poppet type check valve 8NB #1500 SS316 tube end	2
4.	Flame Arrestor	Make : WITTGAS , SS304 0-15BAR	1
5.	Pressure Gauge	100MM 0-16 BAR,1/2 inch BSP(F) panel mounted	2
6.	Pressure transducer	S-10 0-16 BAR, 4-20MA , Ex-I Pressure	2
7.	Check valve	Poppet type check valve 15NB #1500 SS304 Tube End	2
8.	FBA 1 and 2	SS304 0-15BAR , Whittgas	2
9.	Water bath	SS304 , 1/4 tube as per design	1
10.	Panel enclosure	MS fabricated	1
11.	Hydrogen leak detector	Descriptio is given below*	1
12.	Pipe/tubes & fitting	As required	1

2. Hydrogen leak Detector

The hydrogen leak alarm system is for safety in the lab environment. The hydrogen sensor should be a highly sensitive, selective, and rapid response to low levels of hydrogen in the ambient air. When hydrogen concentration levels are detected within the Lower Flammability Limit (LFL), the system will produce audible and visual alarms with initiating a mechanical relay at 1% and 2% hydrogen in air to prevent further exposure to hydrogen and all hydrogen related accidents.

Hydrogen sensor description

- Quantity: 3 numbers
- Measurement Range of H2 concentration and Scale of 0 to 2000 PPM H2 v/v in Air.
- Max H2 Exposure 100 % Pure H2
- Accuracy of FSD +/- 2 %
- Instantaneous response < 3 seconds
- Specificity and Selectivity H2 Only
- Resolution should be 1 PPM
- Flameproof model and Operating Temperature 32 To 122 Degree
- Highly selective, specific and intelligent response to Hydrogen.
- Buzzer Beeping Proportionate to H2

- No cross-sensitivity, no false alarms.
- No damage to sensor even if exposed to 100% pure Hydrogen.
- LCD display
- Extendable probe
- User-friendly calibration process
- At least 1 Year Manufacturer's warranty
- Makes: Multi Nano Sense Technologies Private Limited; Ambetronics Engineers Private Limited; Acorn Controls Private Limited (or) any Indian make

3. Jet-A/combustible gas/vapour leak detector

A leak detector that can detect Jet A vapour within the lab premises need to be installed and integrated to the control panel. The item should be procured from a reputed manufacturer.

Description

- Quantity: 3 numbers
- No false alarms Infrared NDIR sensor technology
- Highly sensitive to flammable hydrocarbon gases and vapors
- Virtually immune to high humidity/moisture
- No zero drift with changes in ambient conditions
- LCD display
- Not affected by temperature 30 deg. C to 80 deg. C
- Makes: Mil-Ram technology, or any Indian make

4. Sensing elements

- Hydrogen sensor
- Pressure gauges
- Pressure transducer

5. Control element

- Elector pneumatic valves

5. Instrumentation and Control Panel Installation

To monitor and control the specific parameters of ongoing combustor operation, the control panel outside the lab (within 15 meter from the combustor rig) need to be installed. Our requirement is (1) live monitoring of process parameters and (2) controlling (giving input) of input parameters. The description is given as below.

1. Monitoring parameters that shown on the control panel display

We need to continuously monitor the following parameters, while experiment is on:

- Air line pressure and temperature
- Fuel line pressure and temperature
- Hydrogen line pressure
- Nitrogen line pressure
- Water line inlet and outlet temperature
- Water line pressure at the inlet of emission rake
- Water flow rate of the water line
- Water flow rate of three individual line (cooling line, spray line and emission line) as shown in Fig. 3.
- Heater temperature
- Exhaust gas temperature
- Lab room temperature

2. Controlling parameters that control from the control panel

The following parameters/instruments can be controlled (by giving input) to the live experiments

- Air flow rate and pressure
- Fuel flow rate
- Water flow rate for each of the three lines (Fig. 3)
- On/Off operations for the EPVs mentioned in the above systems
- Control valves
- Interlocks

3. The total number of input/output signals required

The number of signals required for the complete installation of control panel are given in following table.

Analog Input (AI)	40
Analog Output (AO)	10
Digital Input (DI)	30
Digital Output (DO)	18
Terminal Count (TC)	15

4. Scope of software

The controlling sequence and the shutdown procedures need to be programmed as per user requirements which will be finalized during installation.

The SCADA system is preferable for monitoring and controlling the process parameters and instruments of complete test facility.

Vendor should provide a suitable software module to control the above mentioned processes. Software should be user friendly and should meet all the requirements. A control and monitoring sequence will be designed based on the experimental requirements and the software should be programmed to meet the same. Further, safety cut off sequence based on emergency situations and manual overrides also to be included to the software module.

Data should be able to monitor and store in real time.

5. Scope of vendors

- Vendor has to provide complete wiring of all the instruments
- The installation of control panel will be on site
- The instrument provided should meet the necessary industrial standards
- Sequence flexibility should be there, Duration of line being ON has to adjustable.
- Vendor has to provide the feedback system as per our requirement
- Vendor has to provide a standard software module that meet our requirements

Note: The above scope should meet the following tentative operational/shut down procedure, which may change in terms of control logic, input signals, display.

6. Tentative Operational/Shutdown Procedures

1. Shut Down Procedure

- i) Reduce Fuel flowrate to FAR = 0.005
- ii) Estimate air flow rates and calculate exit f/a ratio
- iii) Shut off fuel circuit and initiate the N2 pulse purge @ 15 psi (continue for 1 minutes/1 flow thru time)
- iv) Close H2 valve
- v) Continue air flow rate till, exhaust temperature equals to ambient temperature.
- vi) Close N2 valve
- vii) Stop Air line
- viii) Continue exhaust water cooling flow, till inlet water temperature equals to outlet temperature
- ix) Wait for couple of hours before allowing person inside

Failure/Issue	**Corrective Action**
High exhaust temperatures	Reduce FAR (fuel air ratio) to Safe Point and initiate shut down procedure if temperatures continue to rise
Failure of air supply line	Initiate the shutdown procedure and purge the fuel line

Rig pressure panel failure (past failure)	Switch to manual control and head to Safe Point (set W3 rather than ΔP/P)
Overheating of Rig	Reduce the fuel rate to a safe point and Check the operation of ventilation fan, check the cooling water flow rate and temperature. If any major problem in ventilation or cooling water system initiate the showdown procedure.
Failure of gate valve	Turn-off the fuel and check the gate Valve position and try to readjust using LabVIEW, if problem persists initiate shut down procedure and check the valve manually
Leakages through various gaps/joints	Turn-off the fuel, do inspection of the rig, apply high temperature at leak spots for temporary fix, if problem persists shutdown the entire system and change the gaskets.
Sudden Power Outage	First close the LPG line, Fuel line and finally air line manually.
Leakage in Fuel line	Close the main fuel supply valve, initiate shut down procedure, remove the leaked fuel
Pressure sensor fault	Check exit temperature & initiate shutdown
Sudden dip in T exit/Dome Pressure	Initiate shutdown and Check or inspect the liner crack through baroscopic inspection (Skin TC near the Outer liner step)
Test hardware breaks away from Rig	Immediate close fuel valve and initiate emergency shut down
Emergency/fire alarm in NCCRD	initiate emergency shutdown procedure

2. Safety protocols:

Possible failure scenarios

1. Hot air Leak inside the lab
2. Air heater malfunction
3. Fire/ fuel line leak in the lab
4. Valve failure, bellow failure
5. Hydrogen leak
6. Explosion

Emergency Shut down procedure

1. Switch on emergency alarms (in the lab and outside)
2. Close hydrogen supply valve (if open)
3. Switch off fuel pump.
4. Vent valve, high pressure exhaust valve open
5. Turn on nitrogen purge for fuel circuit

6. Switch off power source to heater
7. Close air supply valve (BV0)
8. Switch off water pump
9. Shut down all Electrical system
10. Lock the barricade for safety, prohibited reg

ELIGIBILITY CRITERIA:

Vendors with some or most of the following prior experience will be considered eligible:

1. The bidder should be a registered company in India with at least 10 years experience in piping, instrumentation and control systems. Copy of Registration certificate of the company should be submitted.
2. Experience in handling piping, instrumentation and control systems works.
3. Installation of high-pressure (10 bar or higher) piping systems
4. Installation in flameproof zone (zone 1)
5. Experience in handling high-pressure (10 bar or higher) and high temperature (700-1000 deg C) valves and pump systems
6. All fabrication and erection work need to be carried out as per relevant ASME/ASTM standards
7. Capable of providing EPV (electro pneumatic valves) with controlling facility.
8. All components should be of preferred makes and relevant certifications need to be provided.
9. Capable of developing Control Panel and SCADA system for monitoring and controlling the process parameters and instruments of complete test facility
10. Capability of providing service support during and after warranty for efficient running of the supplied systems. Provide service level agreement details.
11. The warranty for the Lab modification work shall be for a period of 12 months form the date of successful commissioning or 18 months from the date of supply.
12. Vendor must provide details of previous installations at reputed organizations with values above 50 lakhs per specific work order, along with their contact details. Details of the works carried out should be filled in a table as indicated below in “DETAILS OF EXPERIENCE IN ACADEMIC INSTITUTION/ GOVERNMENT SECTOR”. Income tax financials and tax returns for the last 5 years should be submitted, attested by a qualified chartered accountant.
13. A pre bid meeting will be conducted and additional inputs will be given during the meeting. Any modifications or detailed spec will be added as an addendum to the present tender document. Participation in pre bid meeting is essential for qualification as vendor.
14. Based on the pre bid meeting additional work/modifications if any will be added as an addendum to the tender.
15. GST Registration certificate.
16. PAN card

Optional:

1. Please quote for 1 year and 2 years extended warranty
2. Please quote for comprehensive and non- comprehensive AMC beyond warranty.

Optional item quotes may be considered for purchase order release along with main work. In that case the selection of L1 vendor will be done taking into consideration of the optional item cost along with the Lab modifications work cost.

DETAILS OF EXPERIENCE IN ACADEMIC INSTITUTION / GOVERNMENTSECTOR

1. **Customer References related to Academic Institution / Govt. Sector that the applicant has been engaged during the last Five years:**

S.No.	Name & Address of the client with contact details(with e-mail Id and contact no:	Date of start Of the work	Date of Completion	Details of work carried out	Value of the Project
1.					
2.					
3.					
4.					
5.					

Note:

Please note that the copies of above mentioned requirement should be furnished with relevant work orders and completion certificate from the customer end self-attested by an authorized signatory of the vendor