Design, Manufacturing, Validation, and Supply of Spray Test Rig

1. Introduction

A spray characterization test rig is required at NCCRD, IITM and IPRC, Mahendragiri, to capture the spray formation from fuel injectors. This spray test rig is designed to use along with several laser-based optical diagnostic tools to visualize and capture the ensuing spray features. The system shall be a compact-sized spray test rig comprising around 8 x 10 ft in size. Within this space, the spray test rig, Laser and camera tables, control panels, computer, etc., can be placed.

2. Description of Test Rig

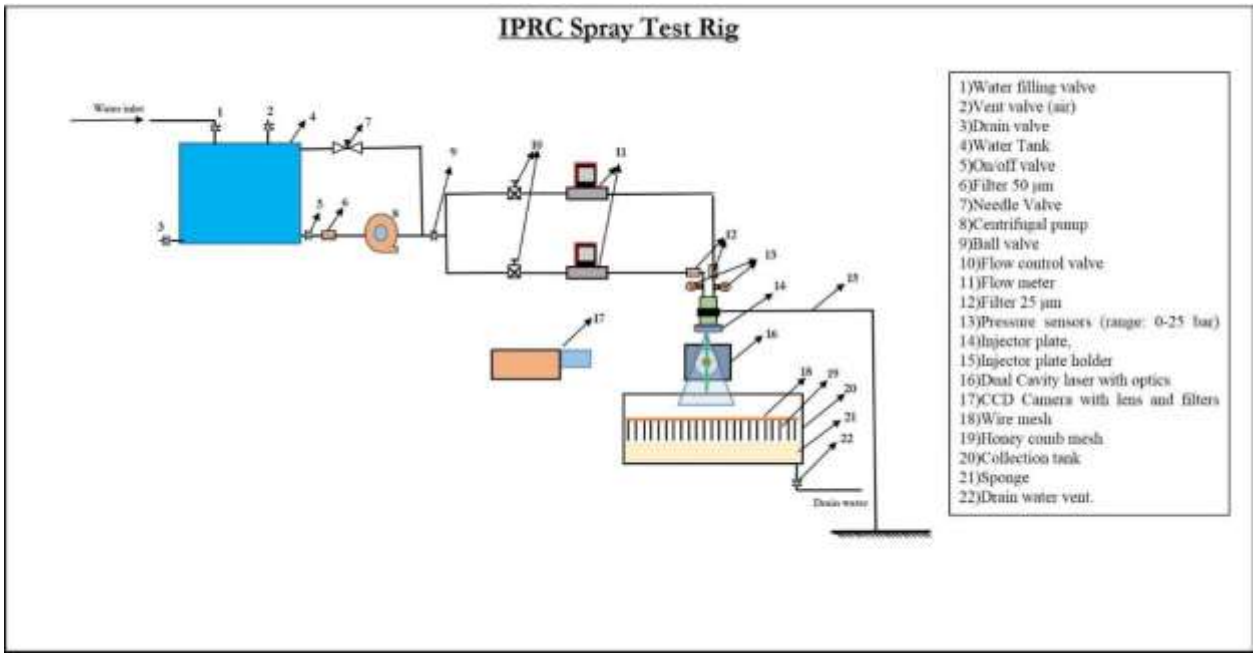

Fig 1 – Schematic of the spray test facility.

The primary part of the facility is an injector to which water is supplied via two separate lines. The injector is to be mounted on a specially designed nozzle holder, which allows different degrees of motion to the injector assembly. The holder is to be mounted vertically, and the ensuing spray is collected in a collection tank. A brief schematic of the test rig is shown in Figure 1.

The test facility includes 3 parts:

1. Liquid pressurization unit
2. Injector mounting rig , nozzle holder and Collection tank
3. Controls and instrumentation

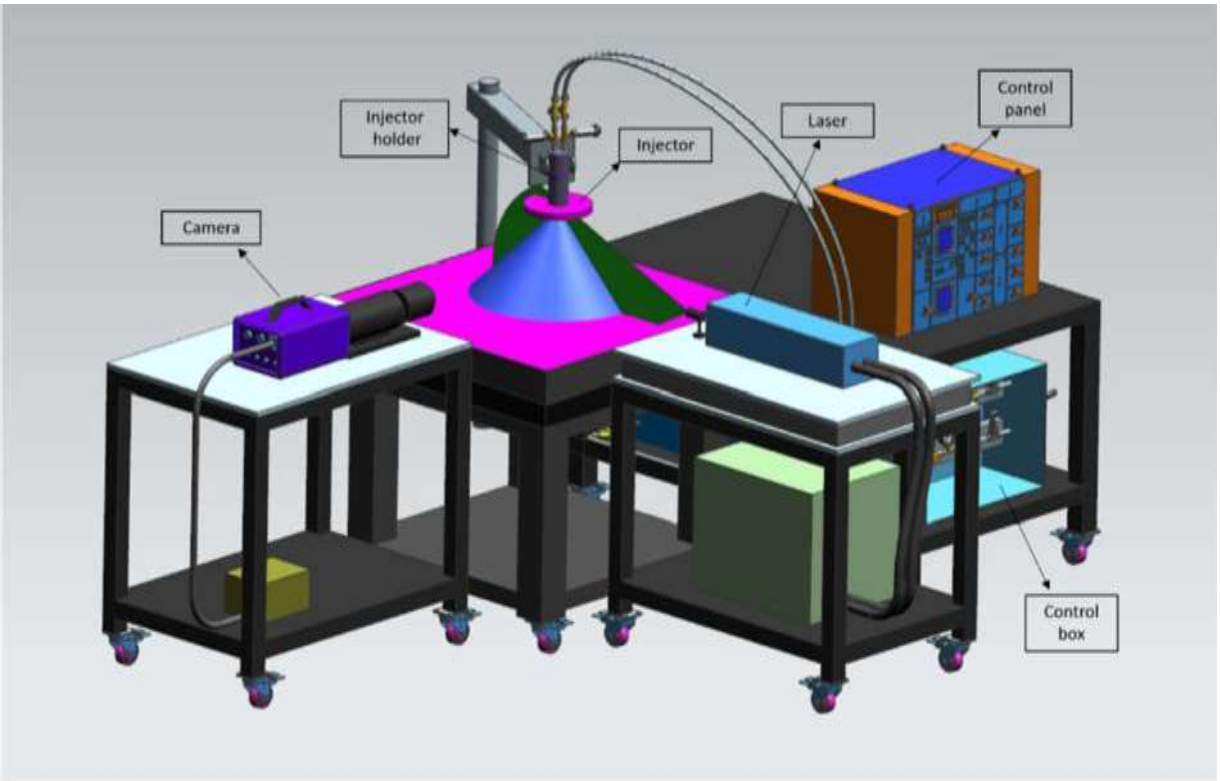

Fig 2 - Layout of the experimental facility and optical arrangement

1. Liquid pressurization unit:

A pump-fed pressurization system is adopted to supply water at the required pressure and flow. Distilled water is used as the test fluid, and it is pressurized using a centrifugal pump. Operating flow rates and pressures are listed in table 1.

Table 1. Operating flow rates and pressure of the centrifugal pump.

Operating pressure	Flow rate
0-25 bar	0 – 1 kg/s

A stainless steel water storage tank of 120 Lit capacity feeds the pump. After the pump, a bypass line is included to take away additional water back to the tank. Since the present experiment required low flow rates at higher pressures, part of the water from the centrifugal pump needs to be sent back to the tank. A needle valve control arrangement is provided to achieve the necessary flow control. Subsequently, this feed-line is bifurcated into two lines. The water flow to each liquid lines should be controlled using individual flow control valves and measured using separate Coriolis flowmeters. The injection pressure should be measured using strain gauge type pressure sensors attached to each liquid line just upstream of the injector plate assembly. Additional filters of 25 µm shall be installed upstream of the pressure sensors to remove any dirt/ rust particles in the liquid lines. Liquid lines are connected to the individual inlets of the main injector plate, which is positioned on a nozzle holder. A list of individual components along with detailed specifications is given in Table 2.

Components	Detailed Specifications	Quantity
Strainers	0-50 microns and 0-25 microns meshes, fixed in a Stainless Steel Y element strainer, Strainer size- 0.5", operating pressure- 25 bar Make: AG filters, Ultrafilters, Marck Engineer	0-50 micron = 2 nos, 4 spare mesh pieces 0-25 micron = 2 nos, 4 spare mesh pieces
Mass flowmeters	Type: Coriolis type, Flowrate range: 0.01 – 60 lpm Repeatability: ≤0.1 % Rd ±≤ 0.4 ml/min, Refresh cycle rate: ≤ 10 msec, Max operating pressure- 25 bar. Flow accuracy ± 0.2 % of reading or ± 0.05 % of full scale, whichever is higher. Proposed make: Bronkhorst, Alicat	2 nos
Water pump	Flow rates: 0 -1 Kg/s, Max oper pressure: 14 bar, Max temp: 60° C, the materials for the casing is grey cast iron and impeller should be SS304; Type centrifugal. Proposed make: Grundfos, Wilo Mather and Platt	1 no
Pressure sensors	Type: Stain gage type, with digital display and DAQ connectivity Operating range: 0-25 bar, Accuracy: ±0.25 %, Sealed Gage Max overload pressure: 70 bar Output voltage: 0.5 - 4.5 V, Supply voltage: 5 V Make: Honeywell, Vika	2 nos
Tubes, hoses, fittings	SS 316 single ferrule fitting tubes, Swagelok(or)Parker fittings, hoses, Swagelok (or) Parker make,– working pressure rating 100 bar, hose size: ½", hose end fittings size: ½", hose material: Teflon inner core R3/R2, steel braided rubber hydraulic hose, elbows, and T joints (all hydraulic fitting in standard SS material) size: ½".	As required
Valves	Valves: As shown in the schematic, spec list: Size: a half-inch, material: SS, thread size: ½", pressure rating: 100 bar, valve mechanism: manual operation, proposed makes: Swagelok or L&T, equivalent,	As required
Anti-vibration tables	Anti-vibration Table 90 x 90 x 150 cm (L x B x H) with adjustable height ((± 75 mm about the mean). Make: Holmarc, Thorlabs	3 nos
Breadboard	Standard breadboards, dimensions :90 x 90 x 10 cm (L x B x H) Make: Holmarc, Thorlabs	3 nos
Storage tank	Capacity: 120 L, material: SS, thickness: 5 mm	1 no
Collection tank	dimensions(90 x 90 x 100 cm) material: SS304, thickness: 3 mm	1 no

Honeycomb	dimensions(90 x 90 cm), tube size(dia : ½"), length: 100 mm , thickness:2 mm, material: SS	1 no
Wire meshes	dimensions(90 x 90 cm), material: SS, size: 1 mm and 5 mm	2 nos
Sponge	dimensions(90 x 90 x 5 cm), material: foam	1 no

Table 2: List of components in the liquid pressurization system

The injector plate consists of 10 pairs of injector holes. Experiments will be conducted in two phases. In the first phase, spray from the individual injector pairs will be characterized one after the other, blocking the unwanted holes for each test. In the second phase, the spray from the entire injector plate (10 pairs of holes) is to be tested. Flow rate and pressure requirements for both liquid lines at each phase are listed in table 3. Therefore, the facility should be able to deliver the flow rates (low and high) at required flow rates and pressure with the desired accuracy as listed in table 2.

Table 3: Flow rate and pressure requirement in injector pair and entire injector plate

	ΔP (bar)	**Q flow rate per injector pair (lpm)**	**Q flow rate in entire injector (lpm)**
Liquid line 1	1	3.072	30.72
Liquid line 2	1	1.206	12.06

The spray from the injector plate is collected using a stainless steel collection tank of size is 90 x 90 x 100 cm. This collection tank consists of a sponge, honeycomb, and wire meshes to ensure that the ejected water spray from the nozzle is completely absorbed. Any mist generated during this process of splashback or spillage shall not be recirculating back to the interrogation area. A 3D model of the test facility with all sub-components is shown in Fig. 2.

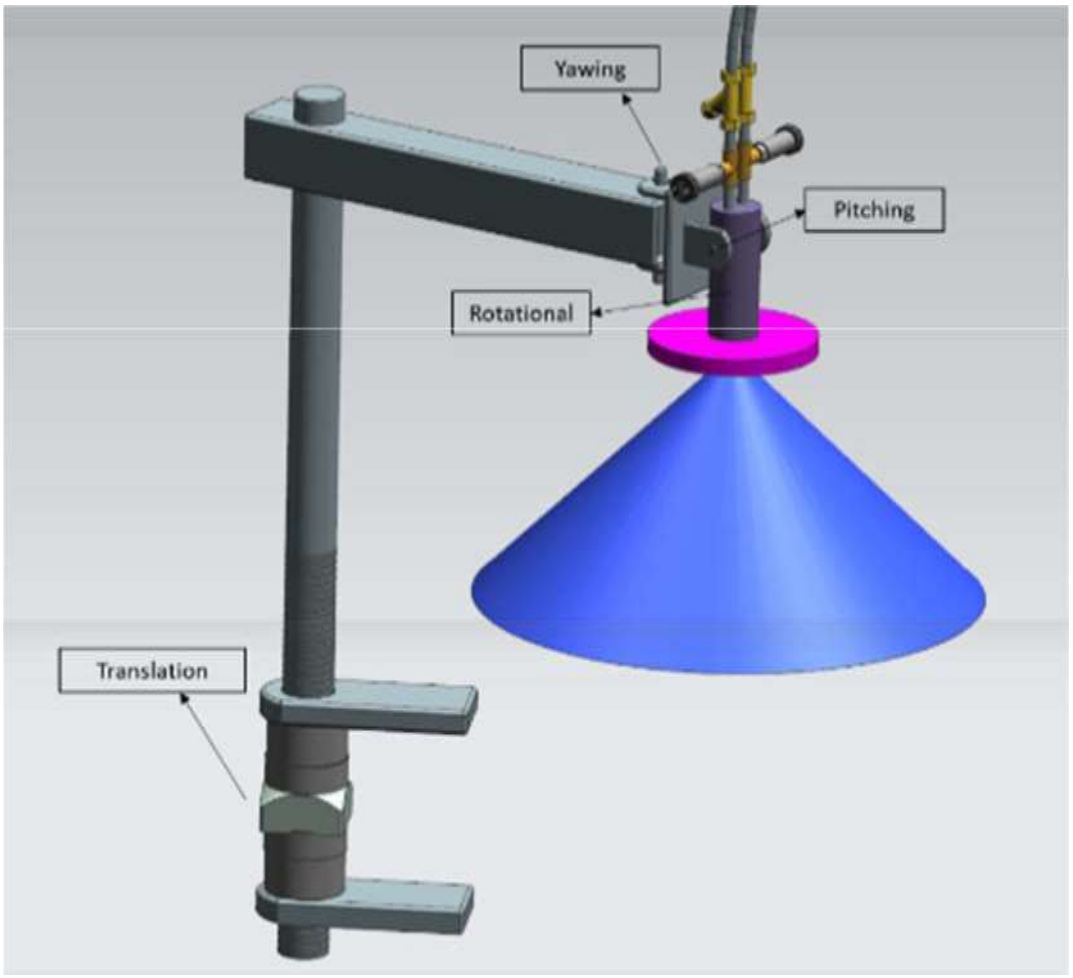

Fig 3. Nozzle holder with pitching, yawing, translation, and rotation motions.

2. Spray rig and nozzle holder

The injector plate needs to be mounted on a specially designed injector holder. The holder is designed such that the laser and camera arrangements can be fixed once aligned, and the injector plate can be moved based on the measurement parameters. The holder to have provisions for moving axially, radially, and to rotate about its axis. Furthermore, a provision to tilt the injector plate to view the inside region is also provided. The height of the injector can be adjusted using a lead screw mechanism. A closeup view of the injector frame holder is provided in Fig. 3. The mainframe, injector holder and collection tank are to be fabricated, a 3 D model of the mainframe is shown in Fig. 5.

1. Collection tank:

The collection tank should be made with stainless steel,and should be suitability accommodated within a table. The dimensions of this collection tank are 900 x 900 X 1000 mm. A 3D model of the collection tank is shown in Fig. 4. This collection tank should consist of two layers of wire meshes of 1 mm top layer and 5 mm below layer. Below these wire meshes, a Honey comb structure to be placed having a thickness of 100 mm. Each honeycomb mesh should have a diameter around ½" and pitch should be less than 1". Finally, a sponge of dimensions 90 x 90 x 5 cm should be placed towards the bottom of the collection tank.

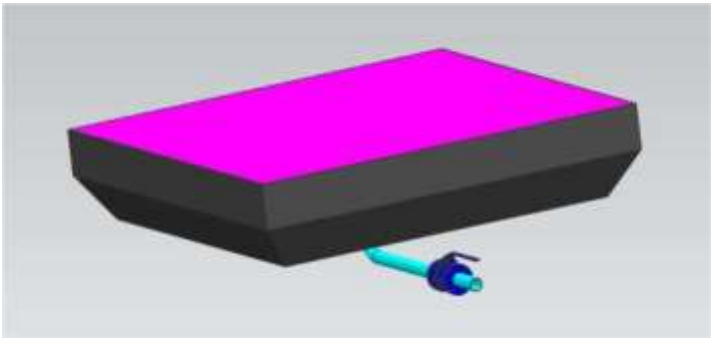

Fig. 4 3D model of the collection tank.

2. Nozzle holder:

The nozzle holder connects with the main rig frame. A series of arrangements have to be incorporated in whilst fabrication, as follows.

(a) This Nozzle holder should have a lead screw arrangement, which can have a translation motion about 100 mm from the mean. This should be capable of rotating atleast 90° such that the complete injector holder arrangement can move away from the collection tank.

(b) A ±30° yawing arrangement should be made.

(c) This is followed by a pitching arrangement of ±30°.

(d) Finally, to rotate the entire injector plate 360° about its axis, it is recommended to introduce a leak free turning joint arrangement, to avoid hose twisting.

It should be noted for both the rotation and pitching arrangement should be having a scale, each with a least count of 0.5° for pitching and 1° for the rotation. The entire arrangement should have 4 degrees of freedom. It is also important to note that all the joints should have provisions to lock at any given position securely. A 3 D model of the nozzle holder is shown in Fig 3. The injector plate is attached to the nozzle holder through bolts and O-rings. The injector is cylindrical with 184 mm dia, height 70 mm and weight around 3 kgs. Details of the mounting arrangement and holder motion will be further explained during the pre-bid meeting based on the queries from the vendors.

3. Mainframe:

The mainframe consists of four tables, two for cameras and one for laser (These three should be placed over standard breadboards) and another table for hosting storage tank, water pump, control valves, mass flow meters, control box, and control panel. All the arrangements should be ergonomically placed such that one can easily operate the valves and also view the pressures/mass flow rate reading on the control panel. This mainframe can be made with mild steel or equivalent, with powder coating for water corrosion protection. A detailed figure of the mainframe is shown in Fig.4. It should be noted that all camera and laser tables and the corresponding breadboards are optional items. Please refer the terms and conditions for more details.

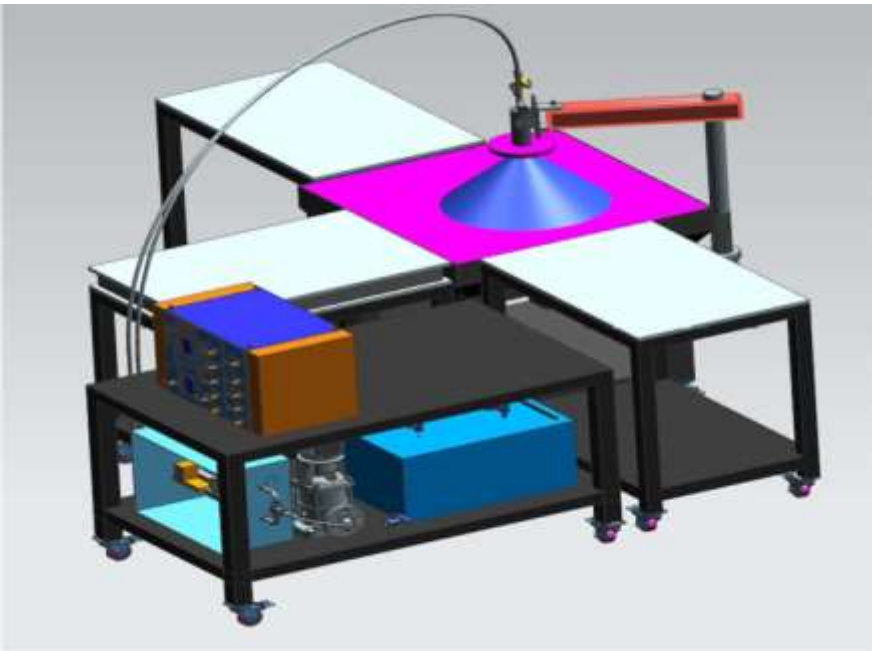

Fig. 5. A 3 D model of the mainframe.

3. Controls and instrumentation

Liquid injection pressures and mass flow rates in the two lines are the main parameters that need to be varied during the experiments. The mass flow rate, pump line pressure, and injection pressures are to be measured and displayed on the control panel. Instrumentation needs to be done appropriately to measure the above parameters. Provision for connecting a DAQ card from the control panel shall be given. Furthermore, an electrical junction box needs to be provided to supply power to the laser, pump, cameras and mass flow meters. The number of power outlets and their corresponding power ratings is enlisted in Table 4. Furthermore, the number of display units and the output signal, which should be connected to the DAQ card, is shown in Table. 5. It should be noted that the output signal can be in the range of 0- 5 V (or) 4 – 16 mA.

Table 4. List of power outlets and their corresponding power ratings

S/No.	Power outlets	Power rating
1	Laser	100 – 240 VAC, 50/60 Hz, single phase, current rating : 15 Amps
2	Cameras (Qty-2)	9-28 VDC (12 VDC optional)
3	Mass flow meters (Qty -2)	9-28 VDC
4	Water pump	415 VAC, 50 Hz, three phase
5	DC voltage supply to 3 pressure transducers	24 VDC
6	Additional Sockets (Qty -2)	240 VAC, 50 Hz, single phase, 5 Amps

Table 5. List of display units and output signal to DAQ card

S/No.	Output signal to the DAQ card
1	Pressure at the outlet of water pump
2	Mass flow rate for liquid line 1
3	Mass flow rate for the f liquid line 2
4	Injection pressure at the liquid line 1
5	Injection pressure for the liquid line 2

OPTIONAL:

One Laser and two Camera bread boards and tables to be quoted separately.

Terms and conditions:

This test rig intended to be purchased is for integration with other equipment to be supplied by IIT Madras to ISRO Propulsion Complex, Mahendragiri, Tirunelveli District, Tamil Nadu.

1. Supply should be made within 6 weeks of release of purchase order
2. Warranty service must be provided on-site at IIT Madras and ISRO Propulsion Complex, Mahendragiri, Tirunelveli District, Tamil Nadu for duration of warranty period.
3. Vendors should provide continuous technical support and maintenance of equipment during warranty period. And testmonials shall be produced in case requested
4. The vendor must have at least 3 years' experience in design and manufacturing similar equipment.
5. Vendors must have sufficient experience in supplying equipment to reputed organisations for research purpose.
6. All equipment must be compatible with Indian electrical standards and codes.
7. Cost breakup for all modules included in the scope of supply is mandatory.
8. Vendors must provide detailed documentation covering drawings, BoMs, operation manual for the equipment.
9. Vendors must provide training to our technical staff for using the equipment, free of cost.
10. Vendor must have permanent service representative stationed in India.
11. Optional item may be considered for finalisation of L1 vendor if the optional items are chosen for purchase.