TABLE OF CONTENTS

1. SYSTEM OVERVIEW

Automated drum handling system will consist of an arrangement for remote evacuation or filling of fluid (heavy water) from/to SS drum. The drum will move on a motorized conveyor having input station, handling station and output station. The drum will be loaded on input station and directed towards the handling station for fluid transfer. At handling station, drum should be rigidly clamped using pneumatic arrangement. The drum cap will then be removed and suitable fluid handling attachment (evacuation or filling based on HMI input) shall be tightly fitted to the drum port for leak-proof fluid transfer. Remote handling of drum cap and attachments will be done by gripper mounted on an articulated arm. Identification of cap position and orientation on the drum will be done through a vision based sensor whose data will be transformed to the workspace coordinates of the articulated arm for motion actuation. After completion of evacuation or filling process, the fluid handling attachment is then removed and original cap will be refitted on the drum. The drum will be released from the clamp and then moved to output station for retrieval. All fluid handling attachments and drum cap should rest on the tool stand adjacent to conveyor and articulated robot. All the motions will be initiated remotely through a PC based GUI and precisely controlled through closed loop systems. The motions will be limited within safe limits by use of firmware programs and hardware sensors. Conceptual design of the system is shown in Figure 1.

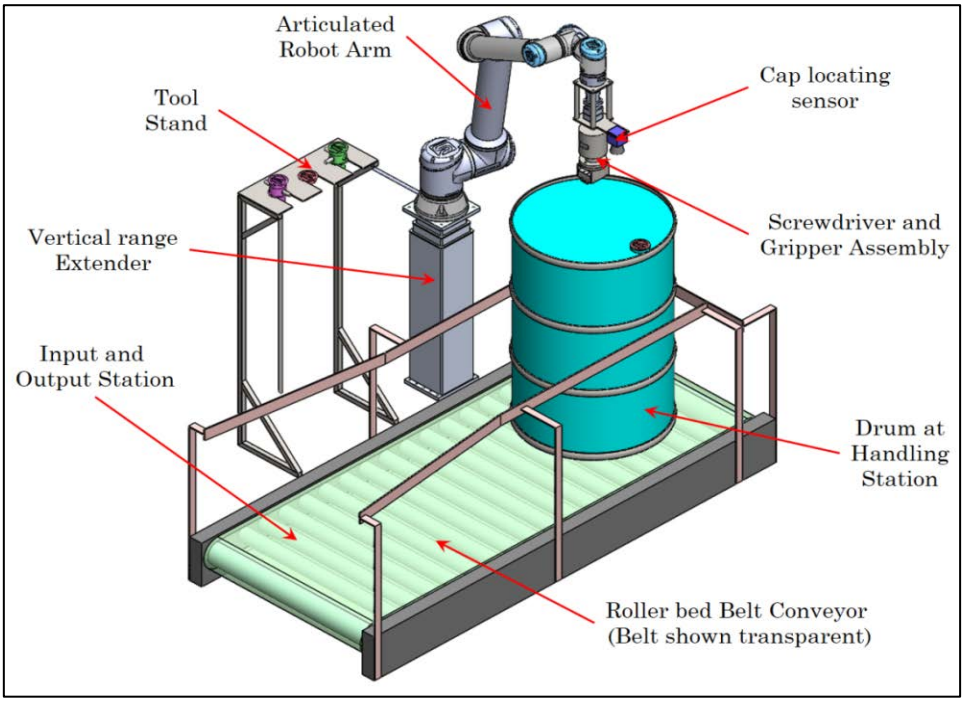

Figure 1: Conceptual design of Automated drum handling system showing drum at handling station and robot above the drum. (For reference only.)

2. SCOPE OF WORK

The scope of work includes detailing of conceptual design provided by BARC, development, preparation of component level/sub-assembly level/assembly level drawings, component selection of electrical sub-systems, routing diagrams for various electrical/electronic subsystems, selection/ procurement of raw material including bought out components, manufacturing, integration, testing, safe delivery, installation and demonstration of Automated Drum Handling System (01 No.). The detailed scope of work is as follows:

A. Design detailing of Automated Drum Handling System based on preliminary design furnished by BARC.
B. Preparation of General Arrangement (GA) layouts, component level, sub-assembly level & assembly level drawings and obtaining approval from BARC.
C. Development, component selection and preparation of routing diagrams of electrical sub-systems.
D. Identification of raw material including bought out components to be used in various subassemblies & assemblies of the equipment.
E. The job should be executed in following phases:
    i. **Phase 1: Preliminary design review**: Vendor should submit preliminary designs including general drawings for user's approval.
    ii. **Phase 2: Detailed design review**: Vendor should submit detailed designs with 3D models and detailed drawings for user's approval.
    iii. **Phase 3: Manufacturing**.
    iv. **Phase 4: Integration** with software suite and testing at vendor's site.
    v. **Phase 5: Pre-Dispatch inspection** and Factory acceptance test at vendor's site.
    vi. **Phase 6: Installation**, demonstration and mock-up trials at BARC premises.
F. The vendor must incorporate minor changes (within 5% of total cost) in the design as required at the time of execution of work at no extra cost.
G. Packing, safe transportation, installation and demonstration of ordered equipment at User's premises.
H. Supply of GA layouts, as-built assembly, sub-assembly & component level drawings including routing diagrams in soft copy along with two sets of hard copies of above drawings, operation/maintenance manuals and parts catalogue.
I. Final motion control software and GUI development shall not be in the scope of vendor. However, the vendor must develop control programs to independently carry out component level and integration tests for demonstration of system operation for pre-dispatch inspection and final acceptance testing. The vendor should also provide support from OEMs for development of control software.

3. SYSTEM REQUIREMENTS

3.1. FUNCTIONAL REQUIREMENTS

A. The system should execute in the following **operational sequence**: (i) Manual loading of drum onto conveyor using drum lifter, (ii) closing of safety gate at loading station, (iii) conveyorized drum motion to handling station, (iv) vision based 3D pose identification of drum cap, (v) robotic decapping operation, (vi) robotic insertion of refilling/evacuation lid, (vii) robotic removal of refilling/evacuation lid, (viii) robotic capping operation for securing back the original drum cap (with requisite tightening torque) , (ix) conveyorized drum motion to output station, (x) Removal of safety gate at output station, (xi) Manual unloading of drum using drum lifter.
Detailed technical specifications of sub-systems is mentioned in Section 4.
B. During operation, all the motions should be smooth and noise free. Occurrences of axis over travel beyond end limit switches should be nil.

C. Motion limits should be accompanied with hard stopper functionality for safe system operation. When a motion stage hits the hard stopper, the corresponding motor driver should automatically trip and restored back to normalcy after power recycling. Hard stopper hit should not result in damage/toppling of drum or other system components.
D. Repeatability of the robot while gripping the drum cap, evacuation attachment and filling attachment should match the specifications of robot arm. This should be tested during trials.
E. Cap position on the drum should be identified in a single programmed scan by robot arm. Accuracy of cap localization and robot reach at different drum orientations should be tested rigorously during trials.
F. For each correct pair of cap and drum, accurate localization of cap and drum opening followed by capping/de-capping should be achieved in single attempt with zero failure rates. In case of a wrong pair or damaged cap/drum opening, the robot should gracefully halt the operation and report component failure.
G. The insertion of evacuation and filling attachments into the drum opening should be precise and achieved in single attempt with zero failure rate.
H. The inflatable rubber seal of evacuation and filling attachments should create perfect seal between the drum opening and caps within the specified tolerance levels. No leakage of any kind should be present during evacuation/filling operations. Also, damage of any kind in the rubber seal should not be present after multiple trials.
I. During clamping of drum at drum handling station, drum should not be displaced from its halted position. After clamping the drum at drum handling station, no drum motion should be present while performing capping/de-capping operations.
J. No scratch, dent or damage of any kind should occur on cap, drum and any of the robot handling tools even after multiple de-capping and capping operations.
K. After setting of the maximum operating torque in screwdriver actuator obtained by empirical means, the capping and de-capping operations should be successful in all trials with zero failure rates. The operations should be successful within set torque limit and no dent or damage of any kind should be present in the threading of cap and drum opening.
L. Spillage or overflow of liquid should not occur during drum transfer, evacuation and filling operations.
M. After the drum gets filled up to level of 60mm below the drum cap opening, the solenoid valve should automatically close using the range information provided by level sensor.
N. No leakage should be present when evacuation attachment and filling attachment are inserted into drum opening.
O. Conveyor motion should be smooth and no slippage or damage of any kind should be present during drum motion.

3.2. MECHANICAL SUBSYSTEM

A. The design and construction shall be such that the motions are smooth (low friction), jerk free and noise free.
B. The motion should not result in spillage of liquid from the drum while drum movement, liquid evacuation or liquid filling.
C. Liquid carrying pipes should be coated with suitable hydrophobic material to prevent liquid droplets from leaking outside during motion between drum and tool stand.

D. The gears to be used for various drives shall have minimum backlash. Due to maintenance issues, belts and chains for motion transmission should be avoided unless there are no alternate means feasible by design.
E. Roller chain, belts or gears to be used for various drives shall have long life by selecting proper material of construction & surface treatment.
F. Material of belts, chain or gears, if used, shall be corrosion resistant metal only Belts/chain/gears made of polymer or any organic material is not acceptable.
G. All the parts used in the system should be corrosion-free and preferably SS304. For good aesthetics, SS parts used in the system should be of mirror finish. Mild steel, if used for any of the structural components should be plated to prevent corrosion for lifetime.
H. Design and drawings shall be reviewed by BARC for all components, sub-assemblies and complete assembly. The vendor should start fabrication only after obtaining drawings approval from BARC
I. Standardization of fasteners shall be adopted in the design.
J. Fit between mating parts shall be ensured for smooth functioning of the system.
K. Components/parts shall be machined within the tolerances as per the approved fabrication drawings. Use of shims, washers etc. for achieving a fit must be avoided.
L. Compressed air supply at 6 bar will be available for the system. Suitable fittings should be used wherever required.

3.3. ELECTRICAL SUBSYSTEM

A. As each motion subsystem of the equipment is operated independently, related interlocks/logics shall be properly designed for easy approach & rectification.
B. Electrical actuators may be implemented with position sensing and tracking. AC servo-motors with resolver or encoder feedback should be used.
C. Each motor shall have matched driver & low backlash gearbox. The gearbox should be industrial grade with low loss and smooth construction.
D. The actuators shall be of power and torque capacity rated strictly within limits to avoid damage to system.
E. Power supply to the system shall be 1Φ, 230V, 50Hz or 3Φ, 400V (Line-to-line), 50Hz AC supply. Suitable AC to DC converters should be used wherever required.
F. Motion controller/PLC shall comply with IEC 61131.3 standards and must be supplied with its licensed IDE.
G. Rugged duty industrial grade sensors (Micro-switches, proximity switches, optical switches, reed switches) shall be employed for independent (& simultaneous) limit sensing and initialization of motions, wherever necessary.
H. Suitable level shifters or buffer circuits should be used to ensure voltage compatibility between various electronics devices viz. PLC, sensors, encoders, drivers, etc.
I. Electrical control panel shall be suitably sized and must be as compact as possible accommodating all the required features. Suitable arrangement for heat dissipation must be incorporated.
J. All power & control cables shall be suitably selected to meet system requirements.
K. All major components used must be procured from reputed manufacturers only after obtaining approval from BARC.

4. TECHNICAL SPECIFICATIONS

4.1. GENERAL SPECIFICATIONS OF OVERALL SYSTEM

a.	Operating supply	:	1Φ, 230V, 50Hz or 3Φ, 400V (Line-to-line), 50Hz AC
b.	Operational rate	:	Up to 15 drum per hour (Excluding the time taken for transfer of liquid to or from drum.)
c.	Drum movement	:	Roller bed Belt conveyor based. Conveyor shall have two stations, i.e. Input/Output station and Drum handling station
d.	Drum movement speed	:	$0.5 m.s^{-1}$ (maximum). Should be user programmable
e.	Motion actuation	:	Closed loop control using AC servo-motors with encoders
f.	Robot arm type	:	6-DOF articulated arm with safety features supporting collaborative operations. Robot arm to be mounted on a vertical range extender
g.	Cap handling tool	:	Pneumatically operated mounted on electric screwdriver/nut runner. Routing of compressed air and sensor signals through rotary joint
h.	Attachment coupling	:	On drum port. Sealing by means of compressed air actuated pneumatic rubber seal
i.	System safety	:	All the motions should have individual initialization and end-of-limit sensors in addition to mechanical stoppers. The torque ratings or limits of electromechanical actuators and robot should be set to avoid any damage to drum or system itself
j.	Control panel	:	Consists of (robot controller) programmable logic controller, motor drivers, AC-DC converters and auxiliary electronic cards. Suitable arrangement for heat dissipation must be provided
k.	Communication	:	Wired communication between coordinating processor and peripheral devices (PLC, robot controller, cap locating sensor) on 802.3 protocol
l.	Material of construction	:	Structural parts can be made of corrosion resistant Aluminium alloy profiles of suitable strength to reduce overall system weight. For conveyor, stainless steel (SS304) should be used. OEM equipment should not have plastics as structural material.
m.	Operating conditions	:	10°C to 50°C, 90% Relative Humidity
n.	System footprint	:	Approximately 2.5metre × 1.5metre. (Will be finalized during preliminary design review.)

4.2. DRUM DETAILS

a.	Drum size	:	Height: 900~925mm, Diameter: 585~590mm
b.	Drum capacity	:	200 litres
c.	Drum weight	:	Empty: 40 kg; Full: 300 kg
d.	Drum inlet opening	:	58mm diameter (Approximate)
e.	Cap size	:	Upper groove: 70mm, Threaded region: 56~60mm
f.	Cap thread details	:	Around 6 threads at approximate 9TPI

g.	Cap construction	:	Having external threads mating with internal threads on drum port. Hollow top surface with ridge for holding. (Typical cap shown in Figure 2.)	 Figure 2: Typical drum cap construction
h.	Material of construction	:	Stainless steel (SS304) (For both Drum and cap)	

4.3. DRUM MOVEMENT SUBSYSTEM

4.3.1. GENERAL REQUIREMENTS

a.	Purpose	:	Movement of drums (as per section 4.2) from input station to handling station and output station thereafter
b.	Construction	:	**Roller bed Belt conveyor** supported on alloy aluminium frame
c.	Conveyor size	:	**Approximate length 2.5 metres and width 0.8 metre**. (Exact details will be finalized during preliminary design review)
d.	Conveyor height	:	**150mm from the ground** for enabling loading/unloading of drums by means of drum lifter
e.	Material of construction	:	Stainless steel (SS304)
f.	Actuation	:	All the motions to be actuated by AC servo-motors (Details in section 4.3.2) or Geared AC motors. In case geared AC motors are used, auxiliary sensing arrangements must be present to ensure precise stopping of drum at required location.
g.	Conveyor speed	:	$0.5 m.s^{-1}$ (maximum). The motion should be jerk free to avoid spillage of liquid while the drum is in motion.
h.	**Drum clamping mechanism**	:	To be present at handling station. Actuated by means of pneumatically operated linear cylinders. Suitable contact material to be selected and force should be limited to avoid damage to drums. Any uncertainty in drum's lateral position must be accommodated in the design without causing drum displacement.
i.	Safety	:	(i) Drum should be supported using spring loaded guide bars to restrict lateral movement/wobbling. Spring tension should be sufficient to hold the drums without creating unnecessary friction at the point of contact. (ii) Sensors should be used for sensing of drum received at input station, drum reached at handling station and drum reached at output station. (iii) **Mechanical Safety bars** should be present on either sides of the conveyor to prevent drum from toppling onto floor in case of sensor/actuator malfunction. The entrance side of the conveyor should have hinged bar to facilitate drum loading/unloading

4.3.2. ELECTROMECHANICAL ACTUATORS

4.3.2.1. AC servo-motor and gearbox

a.	Motor type	:	AC servo-motor
b.	Output power, speed and torque ratings	:	To be determined by vendor based on requirements
c.	Position feedback	:	Encoder for precise position sensing having >2500ppr resolution
d.	Electrical connections	:	Lead wire with suitable standard connectors
e.	Motor voltage, current and frequency	:	Compatible with AC servo-driver mentioned in section 4.3.2.2
f.	Holding brake	:	Electromagnetic type actuated by 24V DC supply. Brake engaged in absence of power.
g.	Gearbox type	:	Planetary gearhead (Single/Multi stage)
h.	Gearbox ratings	:	Compatible with AC servo-motor and as per load requirements
i.	Backlash	:	Less than 10arc-min
j.	Efficiency	:	Greater than 90%
k.	Protection class	:	IP65. Oil seal should be present on all bearings.
l.	Operating conditions	:	0°C to 50°C, 90% Relative Humidity

4.3.2.2. AC servo-driver

a.	Operating modes	:	Position control, speed control, full closed control
b.	Features	:	Mode switching, auto gain tuning, console option for monitoring and setting parameters, internal velocity command, 7-segment display
c.	Encoder compatibility	:	Absolute/incremental encoder having >2500ppr resolution
d.	Input commands	:	For position control: Pulse train (500kHz) interface. For speed control: Analog voltage ±10V (12-bit resolution)
e.	Input signals	:	Servo-on, alarm clear, deviation clear, control mode switching, command pulse inhibition, torque limit
f.	Output signals	:	Digital: Position complete, zero-speed detection, servo-ready, servo-alarm, torque in-limit, brake release Analog: Torque monitor and speed monitor Position feedback: Differential encoder channels with index output
g.	Communication	:	USB, RS232 and RS485 with suitable software for connecting with PC and setting of parameters
h.	Protection	:	Over-current protection, over-voltage protection, over-load protection, over-speed protection, under-voltage trip, control power supply under-voltage trip
i.	Control method	:	IGBT PWM sinusoidal wave drive
j.	Input power supply	:	1Φ, 230V, 50Hz or 3Φ, 400V (Line-to-line), 50Hz AC
k.	Output power rating	:	Compatible with AC servo-motor mentioned in section 4.3.2.1
l.	Operating conditions	:	0°C to 50°C, 90% Relative Humidity

m.	Accessories	:	Motor power cables, encoder feedback cables, brake cables (Approx. 25 meter each, Actual length to be finalized during preliminary design review), control interface cables and serial communication cables with suitable connectors of industrial grade

4.4. DRUM CAP HANDLING SUBSYSTEM

4.4.1. ARTICULATED ROBOT ARM

a.	Purpose	:	To carry out operations including drum capping, de-capping and fitting of fluid handling attachments for fluid transfer
b.	Arm type	:	**Collaborative type articulated arm**
c.	Degrees of freedom (DOF)	:	6 (Base, shoulder, elbow, 3 in wrist). Robot arms which have less than 6 DOF (such as SCARA type) should not be used as they do not have arbitrary orientation capability.
d.	Payload	:	≥ 14 kg
e.	Reach	:	≥ 900mm
f.	Joint ranges	:	±160° or more for all joints. Robot tool mount should reach all points in spherical workspace having radius as robot reach.
g.	Maximum joint speeds	:	±120°s^{-1} or more for all joints
h.	Maximum tool speed	:	1m.s^{-1}
i.	Repeatability	:	±0.1mm or better
j.	Force-torque sensor	:	Built-in
k.	Force-torque sensor characteristics	:	Range (Maximum): 100N, 10N-m; Resolution: Better than 2.0N, 0.02 N-m
l.	Operating power	:	650W (Maximum)
m.	Tool I/O ports	:	Digital in: 02 No.s; Digital out: 02 No.s; Analog in: 01 No.s
n.	Tool power supply	:	24V 600mA
o.	Base support	:	Mounted on vertical range extender (Details in section 4.4.3)
p.	Protection class	:	IP54
q.	Operating conditions	:	0°C to 50°C, 90% Relative Humidity
r.	Footprint	:	Not more than 210mm diameter
s.	Weight	:	Not more than 35kg
t.	Robot control	:	Through compatible controller mentioned in section 4.4.2

4.4.2. ROBOT ARM CONTROLLER

a.	Programming mode	:	Graphical user interface on Interactive display
b.	Display size	:	12” touchscreen with 1280×800 pixels resolution
c.	I/O ports	:	Digital in: 16 No.s; Digital out: 16 No.s; Analog in: 02 No.s; Analog out: 01 No.s
d.	I/O power supply	:	24V 1.5A
e.	Communication ports	:	Ethernet port (TCP/IP, MODBUS, EtherNet/IP), USB 2.0, USB 3.0
f.	Collaborative safety	:	Inputs: Emergency stop, Safeguard stop; Limits: Joint position,

	functions		Joint speed, Orientation limit & safety boundaries, Tool & elbow speed, Tool force, Momentum, Power, Stopping time, Stopping distance; Outputs: Emergency stop, Robot moving, Robot not stopping, Robot reduced mode, Robot not reduced mode; Position: Safe home position
g.	Certifications	:	EN ISO 13849-1 Cat. 3 and EN ISO 10218-1
h.	Operating supply	:	1Φ, 230V, 50Hz AC Supply
i.	Operating power	:	650W (Maximum)
j.	Cable length	:	Controller to Robot: 6m; Controller to Interactive Display: 4.5m
k.	Protection class	:	IP32 or better
l.	Operating conditions	:	0°C to 50°C, 85% Relative Humidity
m.	Size	:	Not more than 500mm×450mm×300mm
n.	Weight	:	Not more than 15kg

4.4.3. FORCE-TORQUE SENSOR

a.	Purpose	:	Continuous monitoring of wrist torques and forces while performing cap handling and fluid attachment handling
b.	Measuring range	:	Force (F_x, F_y, F_z): ±300 N; Torque (T_x, T_y, T_z): ±30 N-m
c.	Overload capacity	:	500% (Combined load on all axes)
d.	Minimum threshold for detection	:	F_x, F_y, F_z: 1 N; T_x, T_y:0.02 N-m; T_z: 0.01 N-m
e.	Signal noise	:	F_x, F_y, F_z: 0.1 N; T_x, T_y:0.005 N-m; T_z: 0.003 N-m
f.	Data output	:	100 Hz
g.	Communication protocol	:	Data stream (RS-485)
h.	Power supply	:	24V DC
i.	Operating power	:	2W
j.	Protection class	:	IP40
k.	Operating conditions	:	5°C to 40°C, 80% Relative Humidity
l.	Size	:	Not more than Φ80mm×40mm
m.	Weight	:	Not more than 350g
n	Accessories	:	Signal cable, robot software plugin, robot attachment plate and robot interface cable (USB-to-RS485 converter cable)

4.4.4. VERTICAL RANGE EXTENDER FOR ROBOT ARM

a.	Purpose	:	To extend vertical reach of robot arm (in section 4.4.1)
b.	Motion range	:	900mm (vertical)
c.	Payload	:	75kg
d.	Speed	:	80mm.s^{-1}
e.	Positioning repeatability	:	±1mm
f.	Alignment	:	Perpendicular to conveyor belt (90°±0.5°). Should be verified at the time of testing at vendor premises and installation at BARC
g.	Retracted length	:	Not more than 1000mm

h.	Frame cross section	:	Not more than 300mm×300mm
i.	Robot compatibility	:	Mounting compatible with robot arm (section 4.4.1)
j.	Power supply	:	1Φ, 230V, 50Hz AC Supply; Maximum current: 4.0A
k.	Safety	:	End of limit signals, Emergency stop connection to robot arm safety I/O.
l.	Features	:	Speed and position control, position feedback, soft start and stop, cable management attachments
m.	Protection class	:	IP40 or better
n.	Operating conditions	:	10°C to 40°C
o	Accessories	:	Power supply and controller box, cables, instruction manual, bottom mounting plate, robot attachment plate

4.4.5. CAP HANDLING TOOLING ARRANGEMENT

4.4.5.1. Electric screwdriver

a.	Purpose	:	For continuous tool rotation of robot gripper for capping and de-capping operations
b.	Torque rating	:	50N-m (Continuous)
c.	Rotation speed	:	60rpm (maximum). Should be controllable and user settable
d.	Rotation direction	:	Bidirectional (Clockwise and counter clockwise)
e.	Torque limiting feature	:	Programmable maximum continuous torque rating
f.	Type of construction	:	Either commercial-off-the-shelf type or Custom made using AC servo-motor and gearbox combinations (For AC servo-motor, gearbox and servo-driver, specifications similar to section 4.3.2 should be used).
g.	Weight	:	Not more than 3kg
h.	Operating supply	:	Operable from controller (in section 4.4.5.2)

4.4.5.2. Electric screwdriver controller

a.	Interface	:	Keypad containing hot keys, function keys, numeric keys and navigation keys. VGA backlit colour flat panel display
b.	Communication	:	Ethernet/IP, Modbus-TCP, Ethernet and Serial
c.	Inputs/Outputs	:	8 digital inputs, 8 digital outputs
d.	Torque measurement	:	Accuracy: ±0.2% of full scale; Resolution: ±0.025% of full scale
e.	Torque filter	:	User selectable 75Hz to 750 Hz (Discrete steps)
f.	Features	:	Torque control, speed control, angle control, direction control, start mode selection, tool operation selection, configuration store and mode selection
g.	Report generation	:	Cycle log, parameter dump, diagnostics, event log and tightening curves
h.	Protection class	:	IP52
i.	Operating conditions	:	0°C to 50°C, 90% Relative Humidity
j.	Size	:	Not more than 160mm×200mm×240mm
k.	Weight	:	Not more than 6kg

l.	Operating supply	:	1Φ, 230V, 50Hz AC Supply

4.4.5.3. Gripper

a.	Purpose	:	For holding/gripping drum cap and fluid handling attachments
b.	Stroke	:	20mm
c.	Gripper actuation	:	Pneumatic
d.	Air pressure	:	6 bar
e.	Gripping force	:	Not less than 275N
f.	Cycle time	:	Not more than 1s
g.	Sensors	:	Gripper close, Gripper open
h.	Sensor type	:	Solid state switch (3 wire, NPN, 24V DC) with indication
i.	Attachment features	:	Mounting holes for attaching custom fingers
j.	Size	:	Not more than 90mm×70mm×50mm (Without fingers)
k.	Weight	:	Not more than 0.7kg (Without fingers)

4.4.5.4. Rotary joint

a.	Purpose	:	To connect stationary supply (air) and electrical signals to/from rotating pneumatic gripper (in section 4.4.5.3)
b.	Media	:	**Air, Electric signal**
c.	Rotational speed	:	60rpm
d.	Maximum torque	:	45 N-m
e.	Starting torque	:	Less than 5 N-m
f.	Pressure	:	8 bar (Maximum)
g.	Number of passages	:	03 (Three)
h.	Port size	:	M5
i.	Electrical parameter	:	Voltage: 24V DC; Current: 1A (Maximum)
j.	Number of channels	:	06 (Six)
k.	Sealing material	:	Rubber
l.	Mounting attachment	:	Flange on rotor
m.	Protection class	:	IP65
n.	Operating conditions	:	5°C to 60°C, 85% Relative Humidity
o.	Size	:	Not more than Φ60mm×70mm
p.	Weight	:	Not more than 1.2kg

4.5. DRUM CAP LOCATING SENSOR

4.5.1. VISION CAMERA

a.	Purpose	:	To determine drum cap position in robot workspace
b.	Camera topology	:	**Eye-in-Hand**
c.	Measurement distance	:	100mm ~ 300mm
d.	Field of view (FOV)	:	Aspect ratio: 4:3; Better than 120mm (diagonal) at 100mm and 350mm (diagonal) at 300mm
e.	Resolution	:	2 M pixels or better
f.	Communication port	:	Ethernet

g.	Software compatibility	:	Browser-based GUI for visualization on PC
h.	Power supply	:	12V DC
i.	Protection class	:	IP54 or better
m.	Operating conditions	:	0°C to 50°C, 90% Relative Humidity
n.	Size and weight	:	Compatible with robot arm

4.5.2. 3D LASER LINE PROFILER

a.	Purpose	:	To determine 3D profile of drum cap in robot workspace
b.	Measurement range	:	190mm ~ 400mm
c.	Field of view (FOV)	:	96mm ~ 194mm
d.	Data points	:	640 points in FOV
e.	Resolution	:	Better than 0.04mm in depth and 0.4mm in FOV
f.	Linearity	:	±0.01% of measurement range
g.	Laser wavelength	:	660nm
h.	Laser safety class	:	Class 2, 3R, 3B
i.	Scan rate	:	More than 1000Hz
k.	Communication port	:	Gigabit Ethernet
l.	Inputs	:	Laser safety enable, trigger
m.	Software compatibility	:	Browser-based GUI and open source SDK for configuration and real-time 3D visualization. Open source SDK, native drivers and industrial protocols for integration with user applications.
n.	Power supply	:	24V DC, 13W (Nominal)
o.	Protection class	:	IP67
p.	Operating conditions	:	0°C to 50°C
q.	Size	:	Not more than 200mm×80mm×55mm
r.	Weight	:	Not more than 1kg

4.6. FLUID HANDLING ATTACHMENTS

4.6.1. GENERAL REQUIREMENTS

a.	Purpose	:	(i) Evacuation of liquid from drum (Section 4.6.2) (ii) Filling of liquid into empty drum (Section 4.6.3)
b.	Scope of supply	:	Both the evacuation and filling attachments with proper sealing arrangement for drum opening should be designed and fabricated as per details given in sections 4.6.2 & 4.6.3. Suitable hoses with quick release connectors along with compatible adapters should be provided for connecting these attachments to the existing process equipment to enable fluid transfer
c.	Attachment to drum	:	On the cap opening
d.	Drum coupling seal	:	**Compressed air actuated pneumatic rubber seal**
e.	Tube material	:	Stainless steel (SS304)
f.	Connectors	:	Quick lock/release connectors with seals
g.	Special precautions	:	**Hydrophobic coating to be applied on tubes to avoid liquid adhering to the tube surfaces**

4.6.2. EVACUATION ATTACHMENT

a.	Purpose	:	Lid type arrangement connected to process piping for leak-proof evacuation of liquid from drum
b.	Evacuation principle	:	Pressure difference between drum and storage tank
c.	Attachment ports	:	Three ports. (i) Liquid exit port (ii) High pressure air inlet port (iii) Pressure sensor port. Details shown in Figure 3.
d.	Liquid exit tube	:	Length: 900mm with spring adjustment of ±50mm. Tube OD: 10mm
e.	Air inlet tube	:	Length: 50mm. Tube OD: 6mm
f.	Pressure sensor port	:	Tube OD: 6mm
g.	Flow On/Off control	:	By using industrial grade solenoid valve (Specifications in section 4.6.4.1)
h.	Flexible tubing for liquid transfer	:	Industrial grade braided metal hose of suitable length. (Specifications in section 4.6.4.2)

4.6.3. FILLING ATTACHMENT

a.	Purpose	:	Lid type arrangement connected to process piping for leak-proof filling of liquid to drum
b.	Attachment to drum	:	On the cap opening. Sealed using compressed air actuated pneumatic rubber seal.
c.	Attachment ports	:	Three ports. (i) Liquid entry port (ii) Air exit port (iii) Liquid level sensor port. Details shown in Figure 4.
d.	Liquid entry tube	:	Length: 50mm. Tube OD: 10mm
e.	Air exit tube	:	Length: 30mm. Tube OD: 6mm
f.	Liquid level sensor port	:	Port diameter: 20mm (Maximum)
g.	**Level sensor** type	:	**Non-contact (Ultrasonic distance measuring based)**
h.	Level sensor range	:	50mm to 500mm
i.	Flow On/Off control	:	By using industrial grade solenoid valve (Specifications in section 4.6.4.1)
j.	Flexible tubing for liquid transfer	:	Industrial grade braided metal hose of suitable length. (Specifications in section 4.6.4.2)

4.6.4. FLUID HANDLING INTERFACES

4.6.4.1. Solenoid valves

a.	Type	:	Normally closed 2 port solenoid valve
b.	Fluid	:	Water
c.	Port connection	:	1/2” NPT
d.	Flow pattern	:	Straight (2-way)
e.	Material of construction	:	Body, internals: SS316; Guide assembly: SS304; Shadow ring: Copper; Plunger insert: SS430; Spring: SS302; Seat, seal: EPDM
f.	Operating supply	:	24V DC
g.	Certification	:	Exd IIC T6

4.6.4.2. Flexible tubing

a.	Type	:	Braided metal hose
b.	Fluid	:	Water
c.	Nominal size	:	1/2”
d.	Port connection	:	1/2” NPT (M), Both ends (Welded)
e.	Flow pattern	:	Straight (2-way)Length: 50mm. Tube OD: 10mm
f.	Material of construction	:	Braid, core: SS316L; End connections: SS316
g.	Overall active length	:	111cm

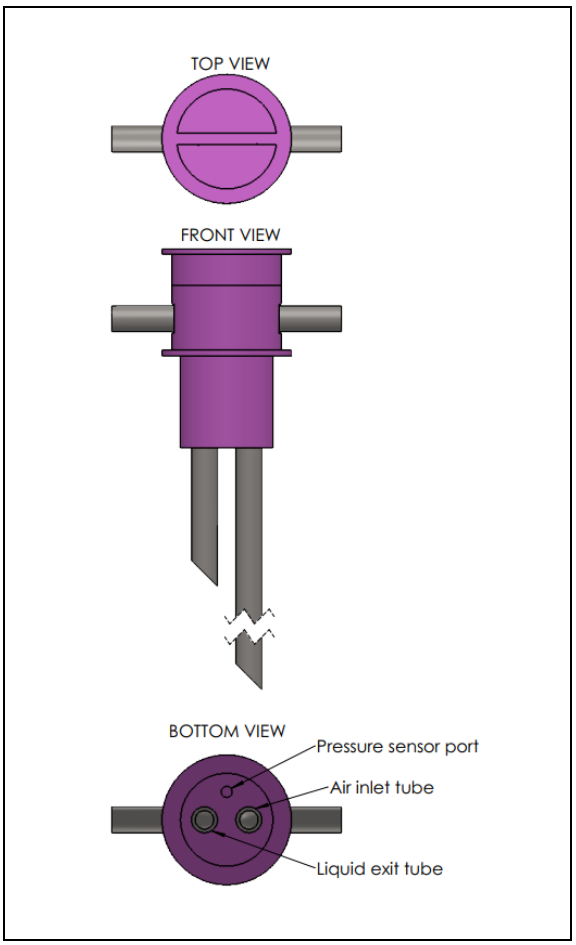

Figure 3: Evacuation attachment

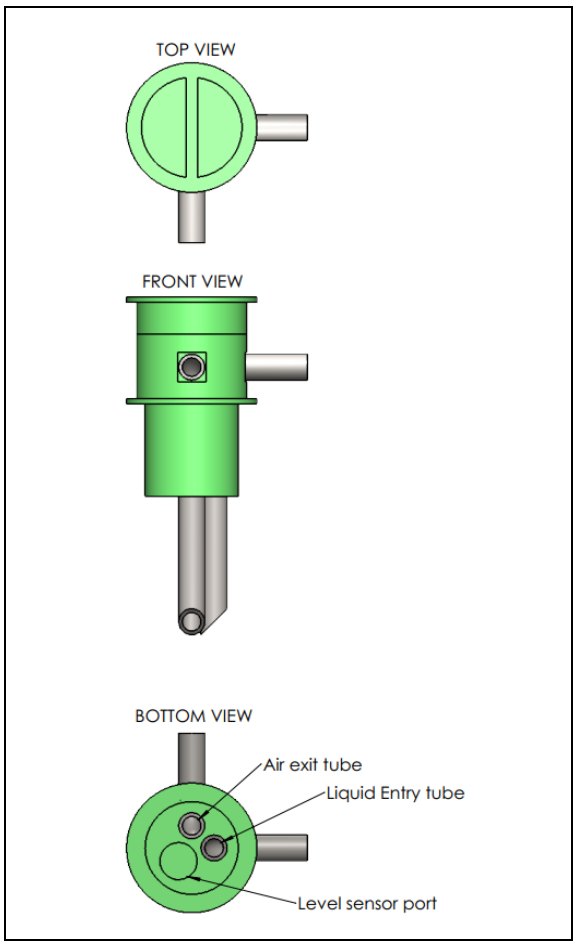

Figure 4: Filling attachment

4.7. CONTROL ELECTRONICS

4.7.1. PLC

a.	Processor type	:	16/32 bit embedded processor with I/O processing capability and embedded monitor/programmable loop for in-situ programming of I/O scanning sequences.
b.	Timer resource	:	0.1ms resolution
c.	Pulse train output	:	4 channels: Pulse rate 200×10^3 Hz in form of Pulse-Sign, Quadrature (A/B) or U/D to operate the servo-motor in position control mode.
d.	Shaft position sensor/ encoder interface	:	4 channels: Pulse rate 200×10^3 pulse/sec of pulse-direction or quadrature phase pulse train. Full scale integration range: $\pm2^{31}$

			counts.
e.	Digital input/output	:	At least 36 digital inputs and 24 digital outputs
f.	Analog input/output	:	At least 12 analog inputs and 12 analog outputs with 0 to ±10V range and 12 bit resolution
g.	Additional peripheral communication modules	:	100 base T Ethernet board, 1 port CANopen board, RS232 and RS485 modules
h.	Additional features	:	Asynchronous interrupts, digital velocity tracking, PID control loops, difference/derivative estimation, ASIC based high speed counters and pulse train output.
i.	Programming support and data export	:	IEEE 61131-3 based control software development environment hosted on WINDOWS compatible desktop type PCs through RS232/Ethernet link. Communication protocol must be documented completely. Licensed software for programming (full version) should be provided for development on two or more PCs.
j.	Auxiliary control and programming option	:	Control and programming support on interactive touch screen based HMI as mentioned in section 4.7.1.1

4.7.1.1. HMI

a.	Purpose	:	To carry out system operation, debugging/programming of PLC and creation & management of logs (events, alarms, data)
b.	Software	:	Integrated programming environment having toolboxes (in-built and user-defined), customizable keyboard and resource libraries (Image library, audio library, font library and text library). Script based programming for complex tasks.
c.	Security and safety	:	Password protection for accessing of software and logic programs. Facility to provide multiple users with different access levels and updating of user access control remotely via external storage.
d.	System surveillance	:	Alarm and trend generation, data logging and backup. USB camera support for capturing of system state in case of alarm or errors.
e.	Other features	:	Modbus gateway, FTP server, simulation mode, remote configuration facility, storing of programs into SD cards or USB storage devices
f.	Display	:	Interactive 15" TFT LCD display with 16M colours, 1024×768 resolution and resistive film touch with accuracy of ±2%
g.	Inbuilt processor	:	32 bit RISC cortex 1GHz with 256MB flash, 256MB RAM and built in real-time-clock
h.	Input/output ports	:	Serial port: RS232, RS422, RS485; Ethernet: 10/100Mbps; USB: Type-A, Type mini-B; Micro-SD slot, audio and built-in termination resistors for RS422/485
i.	Operating supply	:	24V DC
j.	Operating power	:	20W (Maximum)

k.	Protection class	:	IP65
l.	Operating conditions	:	0°C to 50°C, 90% Relative Humidity
m.	Certifications	:	CE, UL
n.	Material of construction	:	Aluminium
o.	Size	:	Not more than 375mm×300mm×60mm
p.	Weight	:	Not more than 3kg

4.7.2. AC-DC CONVERTER

a.	Output parameters	:	Voltage and power as per requirement, Voltage ripple and noise: 2% (maximum), Voltage adjustment range: ±10%, Line and load regulation: ±1% each (Maximum)
b.	Input supply	:	1Φ, 230V, 50Hz AC Supply
c.	Protection	:	Short circuit protection, Overload protection: 135% of rated output power, Over voltage protection: 110%~135% of rated voltage, Over temperature protection. Terminals must be covered for protection
d.	Withstand voltage	:	Input-to-Output: 3kVac; Input-to-Frame: 2kVac; Output-to-frame: 0.5kVac
e.	Operating conditions	:	Upto 50°C and 90% relative humidity non-condensing
f.	Dimensions	:	As compact as possible
g.	Power supply type	:	Closed frame with free/forced air circulation cooling

4.7.3. COORDINATING PROCESSOR

a.	Hardware specifications	:	Intel Core i5, 2.4GHz Processor with HD graphics mounted on compatible motherboard with built–in Sound, Gigabit LAN, DVI-D/HDMI/DP/VGA port. 8GB 2133MHz DDR4 RAM, 1TB 7200rpm SATA HDD, 16x DVDRW optical drive, Ports (Front: 1 x USB 3.0, 3 x USB 2.0; Rear: 3 x USB 3.0, 3 x USB 2.0, RJ45 Gigabit Ethernet and Serial port). Operating System: 64-bit Windows 10 professional. Additional Gigabit Ethernet PCI card should be provided. All the components shall be integrated in compact cabinet having SMPS power supply of at least 400W rating.
b.	Display screen	:	68.47cm (27") Ultra HD 4K IPS LED monitor
c.	Accessories	:	USB keyboard and mouse, Mouse pad with palm rest, 8 port Gigabit LAN switch
d.	Power supply	:	Adapter having input 1Φ, 230V, 50Hz AC Supply

4.7.4. CONTROL PANEL

a.	Cabinet type	:	Full tight cabinet with complete power supply and forced air cooling of the internal shelves. Front door should be present for accessing internal modules.
b.	Cabinet size	:	As compact as possible to suit the site conditions
c.	Cabinet material	:	Preferably Powder coated mild steel sheet with thickness at

			least 2mm for adequate strength. (Other suitable material may be suggested by vendor.)
d.	Electronic modules	:	Preferably din-rail mountable
e.	Wire routing within cabinet	:	Wiring channels of suitable width/depth to be provided. Wiring to be done by Vendor.
f.	Cable entry/exit point from cabinet	:	Preferably on the rear side. Suitable connectors to be used for sealed type connections. Cables include: a. Input power supply b. Cables to collaborative articulated arm controller c. Power cable and encoder cable for AC servo-motors d. LAN cable for connection between PC, PLC, Robot controller and cap locating sensor e. Power/signal cable for sensors
g.	Input power supply	:	1Φ, 230V, 50Hz or 3Φ, 400V (Line-to-line), 50Hz AC
h.	Power supply distribution	:	a. AC-DC converters: 1Φ, 230V, 50Hz AC b. AC servo-motor drivers: 1Φ, 230V, 50Hz or 3Φ, 400V (Line-to-line), 50Hz AC c. Collaborative robot arm and vertical extender controller: 1Φ, 230V, 50Hz AC d. Electronic components (PLC, Sensors): DC supply from respective converter e. Adapter for LAN switch: 1Φ, 230V, 50Hz AC
i.	Communication distribution	:	8-port IEEE 802.3 based switch
j.	Additional features	:	Shelves must be present in the cabinet in order to keep spares and tools necessary for maintenance of the system. Cabinet must be portable type with lockable wheels and retractable legs for support.

5. BOUGHT OUT ITEMS

The vendor shall prepare comprehensive list of all bought out items required for Automated drum handling system and get approval from BARC before going ahead with their procurement. Components shall be of best quality from reputed manufacturers to have long mean time between failures. The components procured should be brand new having suitable warranty from OEM.

6. DOCUMENTATION

A. Design Report & Drawing

i. Detailed design report giving the design criteria, features, design calculations considering load & sizing of the components, payload, C.G & all relevant design data concerning each sub-assembly/ component shall be furnished. The design shall be reviewed by BARC & if required changes shall be incorporated.

ii. Two sets of finally approved as built drawings (assembly & part drawings) taking into account changes accorded during manufacturing & testing shall be submitted to BARC in hard copy and in electronic form.

B. Operation & maintenance (O & M) Manual

The vendor shall submit two sets of O&M manual in hard copy and in electronic form. The O&M manual shall also contain all the datasheets and user manuals for bought out components which are provided by OEM.

7. DELIVERABLES

A. Automated drum handling system as per Technical Specifications at Sr. No. 4 – 01 (One) No.

B. Documentation as per Sr. No. 6.

8. ACCEPTANCE/REJECTION CRITERIA

A. The work/job/items under the scope of supply shall be subject to surveillance/ inspection by the indenter or his authorized representative during the progress of the work and/or before final delivery.

B. Final acceptance shall be after its interfacing with control software and successful mock-up trials. Although the process side functionality is not in the scope of vendor, however for acceptance testing, the vendor must arrange a setup for demonstrating the drum evacuation and filling process at the vendor site. All the testing and inspection costs at vendor site is to be borne by vendor.

C. The system shall be remotely operated and all the functionalities will be tested. Multiple trials shall be executed at the vendor site demonstrating fully automated sequence starting from drum loading onto conveyor at input station until drum reaches the output station. All the functional requirements in Section 3.1 should be met by the system. Occurrences of system malfunctioning should be nil.

D. Failure in execution of any of the above operation or missing functionalities will lead to rejection.

9. TRAINING

The vendor shall provide adequate training to engineers and operators appointed by BARC. The training will be imparted to 4 persons from BARC. The training shall be given at vendor's works for the following:

A. Familiarization about various components and assemblies used in the system.

B. Maintenance aspect and trouble shooting.

C. Operational and maintenance aspects of OEM components used in the system. For such components, OEM representatives should provide training.

10. PACKAGING & TRANSPORTATION

A. After carrying out the training and demonstration at vendor's works, the item shall be properly packed, suitably crated and protected from damage during transport, transit and storage at site. The packing shall include adequate cushioning, blocking, bracing, anti-skidding, hoisting and tie down provisions.

B. The vendor shall notify the dispatch of the goods well in advance to BARC giving all pertinent details of this packing. This is necessary to avoid delays/damages during unloading of the packages and storages at site.

C. Safety of the items being transported shall be the responsibility of the vendor & hence vendor shall make necessary arrangement to deliver the goods safely in BARC, Trombay. After receipt at BARC, the items will be installed by vendor and tested to meet the functional requirements.

11. DELIVERY SCHEDULE, GUARANTEE & GENERAL INSTRUCTIONS

11.1. DELIVERY PERIOD & DELIVERY SCHEDULE

Automated drum handling system shall be delivered to BARC **within 10 months** from the date of placement of purchase order. The vendor shall submit to the purchaser the detailed time schedule covering various aspects involved in the manufacturing & supply of ordered items such as preparation of drawings, procurement of raw materials & bought out components, fabrication/machining, parts inspection, assembly, testing and safe delivery in the form of Gantt chart or PERT chart. Delivery Period along with delivery schedule for the item shall be clearly mentioned in the offer. Time schedule to be adhered in completion of major milestones is given below:

S.no.	Milestone Activity	Completion time
1	Approval of design & drawings	Within 3 months from date of P.O
2	Procurement of major bought out materials (6-axis arm, FT sensor, nut runner, 3D laser line profiler, pneumatic gripper, rotary joint, vision camera, solenoid valves, PLC)	Within 7 months from date of P.O
3	System Integration & delivery	Within 9 months from date of P.O
4	Installation & Demonstration	Within 10 months from date of P.O

The sub-activities pertaining to each major milestone activity such as preliminary design, system assembly, testing at vendor site, etc is to be worked out by the vendor and submitted in tabular or PERT format.

11.2. GUARANTEE

A. The vendor shall guarantee that the goods furnished by him shall be in full accordance with the requirements of the tender technical specifications.

B. The vendor shall provide the warranty that the goods are new & of high quality and that the goods are free from defects in design, materials or workmanship as applicable. The warranty shall cover for a period of twelve (12) months from the date of final acceptance.

C. If within the expiry of the above stipulated warranty period, the subject goods or a part thereof are found defective because of workmanship or materials, the vendor shall at his own expense repair or furnish a new part of proper workmanship & material duly approved by BARC. The same shall be installed & tested thoroughly. The warranty period for replaced parts or repair works shall be the same as above.

11.3. GENERAL INSTRUCTIONS

A. The vendor should submit details of past works undertaken for BARC or other government organizations in form of work order reference numbers with details and completion certificates.

B. All items shall be of best quality and brand new from reputed manufacturers procured from their authorized agents/principals. Used materials/ recycled items/ repaired items will not be acceptable and will be rejected.

C. The vendor shall be responsible for the part of work that is being sub-contracted.

12. TECHNO-COMMERCIAL QUALIFICATION CRITERIA OF OFFERS

The offers received from the bidders will be evaluated based on the following criteria and hence the bidders are requested to submit the following details along with their techno-commercial offer:

A. The vendor shall submit detailed techno-commercial offer including salient features, components/raw material details and offered list of components with model/make indicating compliance against each item specifications. The offer must include all technical details for proper technical evaluation. Failure to provide technical details will lead to rejection of offer.

B. The firm shall have experience in design, manufacturing & supply of robotic/ automation systems having precise machined components, mechanisms for motion transfer and compact designs which resemble the requirements of robotic work cell.

C. Firm should have successfully executed at least one single order exceeding Rs 50 Lakh in the field of robotic work cell development in the last 5 years. Satisfactory performance certificates shall be provided for the same.

D. The vendor shall provide organizational details including organizational chart, manufacturing facilities, testing and inspection facilities, manpower etc. along with quotation. Considering the complexity of work involved, the organization should be able to allocate a minimum of 2 Mechanical engineers (at least one having above 5 years' experience in industry), 2 Electrical/Electronics engineers (at least one having above 5 years' experience in industry), 1 No. of fitter & 1 No. of electrical technician for this project. The full list of qualified & experienced personnel/staff in the firm should be submitted along with the offer.

E. Suitable QA procedures must be followed by the vendor. The fabrication shop should be accessible to BARC representatives for evaluating the QA procedures followed there on. A general QA document to be followed by the firm for this project should be provided.

F. The firm shall have in-house design facilities for preparation of component level design drawings. These shall be backed up with the help of 3D assembly software to assess the interferences as well as mechanism visualization.

G. The firm shall have clean, well ventilated & dust control area (3m x 3m) with sturdy flooring and material handling facility for assembly and testing of the system.

–x–x–x–x–