## List of Abbreviation used in this document

| | |
|---|---|
| **BDS** | **: Beam Diagnostic System** |
| **BM** | **: Bending Magnet** |
| **BTS** | **: Beam Transport System** |
| **NPCT** | **: New Parametric current transformer** |
| **ECRIS** | **: Electron Cyclotron Resonance Ion Source** |
| **FC** | **: Faraday Cup** |
| **FIM** | **: Free Issue of Material** |
| **HVD** | **: High Voltage Deck** |
| **HVPS** | **: High Voltage Power Supply** |
| **IPR** | **: Institute for Plasma Research** |
| **LEBT** | **: Low Energy Beam Transport System** |
| **MEBT** | **: Medium Energy Beam Transport System** |
| **NG** | **: Neutron Generator** |
| **QM** | **: Quadrupole Magnet** |
| **QMD** | **: Quadrupole Magnet Doublet** |
| **QMT** | **: Quadrupole Magnet Triplet** |
| **SM** | **: Switching Magnet** |

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## I. Introduction of Accelerator based 14-MeV neutron Generator

In order to study the neutronics of fusion reactor blankets, a program is underway at the IPR using 14-MeV neutron source. The neutrons are generated using the T(d, n) $^{4}$He reaction. An accelerator based neutron generator is under development in which 20 mA deuterium beam will be accelerated up to 340 keV energy. It will then impinge on a 200 Curie tritium target producing nearly isotropic 14-MeV neutrons. The expected neutron yield is $10^{12}$ n/s. The 14-MeV neutron generator will be used to measure the nuclear responses, such as tritium breeding, neutron heating, shielding effect, etc. in blanket assemblies and compare them with the calculated values.

The Accelerator based 14-MeV neutron generator is consists of high current ECRIS operating at 2.45 GHz, 300 keV Electrostatic Acceleration, BDS and BTS. This consists of LEBT) from ECR to acceleration system and Medium Energy Matching section from acceleration system to Target assembly. The ECRIS, LEBT, vacuum system of LEBT, water cooling of LEBT and its power supplies are kept on a high voltage deck, which is at 300 kV floating with respect to the ground potential. The input electric power to the entire power supply unit is provided through an isolation transformer. The MEBT, SM, vacuum system of MEBT and the target are at ground potential. Schematics diagram and 3D view of 14-MeV Neutron generator is shown in Fig-1 and Fig-2.

## II. Description of major sub-systems of Neutron Generator.

Table-1 lists the sub systems of the Neutron Generator with their brief descriptions. Some of the sub-systems/components already exist in IPR; rest are to be fabricated. All these sub-systems are to be assembled and integrated together to make the neutron generator.

The sub-systems/components existing in IPR are:

1. ECR ion source bench
2. Acceleration Column
3. 300 kV HVPS
4. NPCT
5. Faraday Cup
6. Isolation Transformer

The sub-systems/components need to be designed and fabricated by the vendor are:

1. 8 Nos. QM with their correction coils, power supplies and vacuum chamber
2. 1 Nos. 90 degree bending magnet with its power supply and vacuum chamber
3. 1 Nos. of Switching magnet
4. 2 Nos. x-y slits,
5. 2 Nos. beam profile monitors,
6. 1 Nos. 300kV HV Deck.
7. 1 Nos. 1.8 meter long drift tube
8. 2 Nos. Vacuum chamber for BDS
9. Vacuum system (Optional)
10. Command and Control System for integrated system
11. Support structure for LEBT & MEBT
12. All Cable and connectors, vacuum connector, flanges, vacuum transition, vacuum bellows, support structure etc.

**Table-1: List of Subsystem of Neutron Generator**

| Sr. No | Subsystem | Status | Description of System |
|---|---|---|---|
| 1. | ECRIS bench with control and command system | Existing at IPR | ECR ion source bench able to produce 20/30mA deuterium/Hydrogen beam. It consists of RF system, Magnet System, Plasma Chamber, Extraction system, Magnetic lens and command and control system.<br>Detail Specification of ECRIS is given in Annexure-1 |
| 2. | LEBT: | | LEBT system is to transport the 40keV beam from ECRIS to the Entrance of the acceleration column. It will consist of one set of QMD, 90 Degree BM, one set of QMT and BDS. |

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| | I. Quadrupole Doublet with Power supplies and vacuum chamber | To be designed, fabricated and installed by vendor with technical Specifications. | To focus the beam in entrance of the 90 degree bending magnet. Detail technical specification is given in Section V(1) |
| | II. 90 degree bending magnet with Power Supplies and vacuum chamber | | BM is used to analyse the deuterium beam and separate the D+ ion beam from the other ions spices. Detail technical specification is given in Section V(2 &6) |
| | III. Quadrupole Triplet with Power Supplies and vacuum chamber | | QMT is used to focus the pure D+ ion beam in entrance of the acceleration column. Detail technical specification is given in Section V(3 & 6) |
| | IV. X-Y Slit | | X-Y slit of LEBT is used to control the size of the beam and also used to measure the emittance. Technical specification is given in Section V(8) |
| | V. Beam Profile Monitor | | BPM is used to monitor the beam profile of ion beam for beam diagnostics. Detail specification is given in Section V(8) |
| | VI. BDS Vacuum chamber | | BDS vacuum chamber used to mount all three diagnostic equipment i.e X-Y slit, BPM and FC. |
| | VII. Faraday Cup | Existing at IPR(FIM) | FC is used to measure the ion beam current. Ref: Annexure-2 |
| 3 | 300kV High Voltage deck | To be designed, fabricated and installed by vendor with technical Specifications. | The ECRIS, LEBT, vacuum system of MEBT, water cooling of LEBT and its power supply are kept on a high voltage deck, which is at 300 KV floating with respect to the ground potential. Ref: Section V(9) |
| 4 | 300 kV,50mA HVPS | Existing at IPR(FIM) | To supply the high 300kV high voltage for acceleration. Ref: Annexure-3 |
| 5 | 300 kV Acceleration Column | Existing at IPR(FIM) | To accelerated the ion beam up to 300 keV. It is an electrostatic acceleration tube consists of four sections of vacuum extensions with shaped electrodes fitted inside. They are designed for ultrahigh vacuum and each section of the accelerating column is rated for 75 kV in air and 200 kV in $SF_6$. A multiple series of resistor string in air is used to distribute the electrostatic potential uniformly |

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| | | | along the tube. The holding voltage of tube is 300 kV in air acceleration column<br>Ref: Annexure-4 |
| 6 | MEBT | | MEBT system is to transport the 340 keV beam from acceleration column to the target assembly. It will consist of one set of QMT, BDS, SM, drift tube and target assembly. |
| | I. Quadrupole Triplet magnet with power supplies | To be designed, fabricated and installed by vendor with technical Specifications. | QMT is used to focus the pure D+ ion beam in to the target assembly. Detail technical specification is given in Section V(4 & 6) |
| | II. Switching Magnet with power supplies | | SM is used to switch the beam in to three different beam line. $0^0$, $-45^0$ and $+45^0$. Each beam line will be used for different purposes. $0^0$ beam line will be used for production of 14-MeV neutron, $-45^0$ beam line will be used for ion beam irradiation and $+45^0$ beam line for 2.5MeV neutron generation. Ref: Section V(5 & 6) |
| | III. 2 m long drift tube | | Ref: Section V(8) |
| | IV. BDS Vacuum Chamber | | BDS vacuum chamber used to mount all three diagnostic equipment i.e X-Y slit, BPM and FC Ref: Section V(8) |
| | V. X-Y slit system | | X-Y slit of MEBT is used to control the size of the beam and also used to measure the emittance Ref: Section V(8) |
| | VI. Beam Profile Monitor | | BPM is used to monitor the beam profile of ion beam as beam diagnostics. Ref: Section V(8) |
| | VII. NPCT | Existing at IPR (FIM) | Ref: Annexure-2 |
| 7 | Vacuum System | | Ref: Section V(10) |
| 8 | Command and control system | To be designed, fabricated and installed by vendor | Central command and control system to remotely control the entire accelerator.<br>Ref: Section V(12) |
| 9 | Cooling system | To be designed, fabricated and installed by vendor | Two separate cooling system required for LEBT and MEBT. |

## III. Scope of work

The detailed scope of work of the Vendor has been listed in the following Table 2.

Table – 2: Scope of work by Vendor

| Sr. No | Sub-System | Vendor's Scope of work |
|---|---|---|
| 1. | Beam transport system | 1. Preliminary beam optics design guidelines will be given by IPR for reference to qualified vendor. According to that vendors should do the final beam optics of the beam line and hardware design as per the input and output beam parameters given below:<br>➢ Input deuteron beam parameters at the first magnetic elements (Quadrupole doublet):<br>• Beam current (Deuteron): 20 mA<br>• Energy: 40 keV,<br>• Beam diameter: 15 mm,<br>• RMS emittance: 0.2 pi.mm.mrad<br>➢ Required output deuteron beam parameters at the end of the beam line:<br>• Pure D+ Beam current: 20 mA,<br>• Energy: 340 keV,<br>• Beam diameter: less than 20 mm,<br>• RMS emittance: 0.2 pi.mm.mrad.<br>• Expected beam axis height is 2.5 m (±0.1) from the floor.<br>2. The vendor shall produce and submit a Preliminary Design Report to IPR for approval. A preliminary design review meeting could be scheduled after receipt of the Preliminary Design Report. Preliminary design report should include:<br>➢ Beam optics calculation and simulation<br>➢ Detail technical specification of subsystem as per Table-1<br>3. The vendor shall prepare and submit a Final Design Report to IPR as per the agreed design. This final design report should include:<br>➢ All detailed design report and/or drawings for each item supplied,<br>➢ The Quality Assurance Plan,<br>➢ The Control plan describing all tests that will be carried out on each supplied items, including the templates of Control Records/Reports.<br>➢ The detailed manufacturing schedule<br>4. A final design review meeting could be scheduled after receipt of the final design report. The vendor shall not start manufacturing before IPR approved the final design report. |

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|---|---|---|
| 2. | Quadrupole Magnets, Bending Magnet and Switching Magnet for LEBT & MEBT | ➢ The vendor shall perform the electro-magnetic design and the mechanical design of all necessary magnets for the beam line.<br>➢ Submit the Design report of the magnets to IPR for the approval.<br>➢ Once design is approved by IPR, the Vendor shall manufacture and test all the magnets.<br>➢ The Vendor shall provide a Magnetic Measurement Specification that describes all measurements necessary for the full qualification of the magnet in terms of field strength and field quality as agreed during the design phase.<br>➢ Adjustable support stands for all magnets must be supplied by the vendor.<br>➢ Vendor shall perform all the test mentioned in section VI<br>➢ Installation of support structure and magnet at IPR<br>➢ Alignment of magnet with the beam axis at IPR |
| 3 | Power supplies for Magnets | ➢ The vendor shall manufacture/procure (standard power supplies) all the power supplies necessary for the magnets, with adequate stability, regulation and remote control as per given specifications in section V (6)<br>➢ Vendor shall perform all the test mentioned in section VI |
| 4 | BDS for LEBT & MEBT | ➢ The vendor shall provide beam diagnostics systems for LEBT and MEBT with necessary vacuum tank, support stand, actuators and electronics as per given specification in section V (8)<br>➢ Vendor shall perform all the test mentioned in section VI |
| 5 | 300 kV high Voltage Deck | ➢ The vendor shall design and fabricate the 300 kV Deck, to accommodate all necessary equipments like ECRIS bench, LEBT, vacuum system of LEBT, water cooling of LEBT and its power supplies. The total weight of all these equipments will be approximately 7 ton. Vendor shall submit the design report of 300 kV HV Deck to IPR for approval.<br>➢ Once design is approved by IPR, the Vendor shall fabricate 300 kV HV Deck.<br>➢ Vendor shall perform all the tests mentioned in section VI |
| 6 | Command and Control cabinet | ➢ The vendor shall supply all necessary command and control equipment for all the items supplied by vendor.<br>➢ The vendor shall be responsible to integrate the existing control system of ECR ion source bench, Faraday cup, 300kV-50mA HVPS, NPCT and any other equipment (if required) with beam line control system and provide a central control system.<br>➢ Vendor shall perform all the tests mentioned in section VI |

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| 7 | Cooling System | ➢ The vendor shall provide the cooling system for the equipment on 300 kV deck, as well as distribution panel for the equipments kept at ground potential. |
| 8 | Vacuum System | ➢ The vendor shall provide the vacuum system for entire beam line.<br>➢ Vendor shall perform all the test mentioned in section VI |
| 9 | Installation and Alignment | ➢ The vendor should do the installation of all the equipment supplied at IPR site and integrate the full beam line with existing ECR ion source bench and 300 kV acceleration column.<br>➢ Alignment of all magnets and diagnostics must be carried out by vendor. An alignment report must be submitted to IPR. |
| 10 | ECRIS bench and it's command and control cabinet | ➢ ECRIS bench is to be uninstalled from existing place at IPR and install on the 300 kV HV deck in the proposed FNL at IPR.<br>➢ Integration with vendor supplies equipments. |
| 11 | 300kV acceleration Column | ➢ Acceleration column is to be uninstalled from existing place at IPR and install in to the beam line in the proposed FNL at IPR.<br>➢ Integration with vendor supplies equipments. |

## IV. Technical specifications/requirement of fabrication work

### IV.1 Quadrupole Magnet between ECRIS to Bending Magnet:

The list of quadrupoles and their specifications are given in the following Table-3.

Table-3: General specifications of QMD

| Magnetic Quadrupole | Effective Length (mm) | Half Aperture (mm) | Max. Field Gradient (T/m) | Numbers |
|---|---|---|---|---|
| Q1 | 160 | 42 ±0.1 (Plus chamber thickness) | 2 | 1 |
| Q2 | 160 | 42 ±0.1 (Plus chamber thickness) | 2 | 1 |

1. **Gap between Quadrupole**: 100mm ±5%
2. **Field Quality:** Total Harmonic contents for each quadrupole: ≤ 1% over 80% of aperture diameter.
3. **Pole Material:** Low carbon Solid or laminated steel should be used. The steel must be tested for, and documentation provided for the following:
   - Chemical composition
   - Magnetic properties
   - Porosity (ultra-sonic testing)
4. **Yoke Material:** Steel AISI-1010 or St.37, Max. C 0.15%
5. **Coil Data:**
   - All quadrupoles coils should be either air cooled if possible or water cooled if necessary. Coils to be made of Oxygen free copper (OFC) material.
   - All Quadrupoles coils must have correction coils. For each quadrupoles two correction coils will be powered at the same time and current should be 10A maximum. Separate power supplies for each correction coil should be provided.
   - Cooling water (if used):
     - Inlet temperature: ~$25^0$C
     - $\Delta T = 20^0$C
     - $\Delta P = 5$ bar
6. **Others:**
   - Overall length of quadrupoles to be matched with the gap between them and adequate space is required between them for servicing. Overall length of the quadrupoles must be mentioned in the specifications.
   - Chamber for Q1 & Q2, Suitable bellows in between dipole magnet and quadrupole chamber to be provided.
   - Chamber material to be used: AISI 304/304L
   - Alignment marks to be indicated on top of the quadrupoles
   - Support stand to be provided (Height ~**1500 mm)** from HV Deck floor to beam axis)
   - Gas injecting system should be provided for space charge compensation after solenoid or magnetic lens. It should be remotely controlled.

## IV.2 Specification of 90 degree Bending Magnet

Bending Magnet: .The specifications for the bending magnet are given in following table-4.

Table-4: Specifications of 90 degree Bending Magnet

| **Parameters of Bending Magnet (B1) with vacuum chamber** | |
|---|---|
| **Magnet Type** | H-Shaped |
| **Pole Gap** | 80 mm |
| **Entrance and Exit Angles** | 30 deg., 30 deg. (±0.5deg.) |
| **Bending Angle** | 90 deg. |
| **Bending Radius** | 300 mm |
| **Maximum Magnetic rigidity** | 0.06T.m |
| **Homogeneity** | $\leq 10^{-3}$ over ±30mm of central trajectory in radial plane |
| **Pole & Yoke material (Solid)** | Low carbon steel |
| **Gap inside the vacuum chamber** | ~76mm |
| **Extension of vacuum chamber outside the Physical magnet** | 50 to 100mm |
| **Chamber material** | AISI 304 |
| **Flange type** | CF 100 |
| **Leak rate** | $10^{-8}$ std leak |
| **Conductor type** | Hollow type |
| **View port** | CF type |
| **Alignment marks to be provided** | Four Alignment marks on top of the magnet |
| **Cooling type** | Low conductivity water |
| **Inlet water temperature ,Pressure** | 25 C, 5 bar |
| **Power supplies** | Individual matching power supplies for bending magnet, |

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| **Support Stand for bending magnet** | X-Y-Z movement ±20mm |
| **Provision for Inserting Hall probe** | To be provided |
| **Height of Mid plane** | 1500mm from HV deck floor to beam axis |
| **Alignment port** | Dia: 40mm OD, CF63 |
| **Power supply of banding magnet have reverse current option.** | |

1. **Pole Material:** As per section IV.1
2. **Yoke Material:** As per section IV.1
3. **Coil Data:**
   BM coils are water cooled. Coils to be made of Oxygen free copper (OFC).
   Cooling water):
   - Inlet temperature.~$25^0$C
   - $\Delta$T=$20^0$C
   - $\Delta$P = 5bar
4. **Others:**
   - Overall length of BM to be matched with the gap between them and adequate space is required between them for servicing. Overall length of the BM must be mentioned in the specifications.
   - Chamber material AISI 304/304L
   - Alignment marks on top of BM
   - Support stand to be provided (Height (~**1500mm)** from HV Deck floor to beam axis)
   - Matching power supply for BM to be provided

**IV.3 Quadrupole Triplet Magnet between Bending Magnet to Acceleration Column:**

The list of quadrupoles and their specifications are given in the following Table-5.

Table-5: General specifications of QMT-1.

| **Magnetic quadrupole** | **Effective Length (mm)** | **Half Aperture (mm)** | **Max. Field Gradient (T/m)** | **Numbers** |
|---|---|---|---|---|
| Q3 | 160 | 42 ±0.1 (Plus chamber thickness) | 2 | 1 |
| Q4 | 160 | 42 ±0.1 (Plus chamber thickness) | 2 | 1 |
| Q5 | 160 | 42 ±0.1 (Plus chamber thickness) | 2 | 1 |

1. **Gap between Quadrupole:** 100mm ±5%

2. **Field Quality:** Total Harmonic contents for each quadrupole: ≤ 1% over 80% of aperture diameter.
3. **Pole Material:** As per section IV.1
4. **Yoke Material:** As per section IV.1

5. **Coil Data:** As per section IV.1
6. **Others:**

- Overall length of the quadrupoles to be matched with the gap between them and adequate space is required between them for servicing. Overall length of the quadrupoles must be mentioned in the specifications.
- Common chamber for Q3, Q4, and Q5 with Bellows on both side are to be provided.
- Chamber material: AISI 304 / AISI 304L
- Alignment marks to be indicated on top of the quadrupole.
- Support stand to be provided Height (~**1500 mm)** from HV Deck floor to beam axis.
- Matching power supply for each quadrupole to be provided.

## IV.4 Quadrupole Triplet between Acceleration columns to switching magnet:

The list of quadrupoles and their specifications are given in the following Table-6.

Table-6: General specifications of QMT-2.

| **Magnetic quadrupole** | **Effective Length (mm)** | **Half Aperture (mm)** | **Max. Field Gradient (T/m)** | **Numbers** |
|---|---|---|---|---|
| Q6 | 160 | 42±0.1 (Plus chamber thickness) | 2 | 1 |
| Q7 | 160 | 42±0.1 (Plus chamber thickness) | 5 | 1 |
| Q8 | 160 | 42±0.1 (Plus chamber thickness) | 2 | 1 |

1. **Gap between Quadrupole:** 100mm ±5%
2. **Field Quality:** Total Harmonic contents for each quadrupole: ≤ 1% over 80% of aperture diameter.
3. **Pole Material:** As per section IV.1
4. **Yoke Material:** As per section IV.1
5. **Coil Data:** As per section IV.1
6. **Others:**

- Overall length of quadrupoles to be matched with the gap between them and adequate space is required between them for servicing. Overall length of the quadrupoles must be mentioned in the specifications.
- Common chamber for Q6, Q7, and Q8 with Bellows on both side are to be provided.
- Chamber material AISI 304
- Alignment marks on top of quadrupole
- Support stand to be provided Height (1500 mm + HV Deck ) from floor to beam axis)

- Matching power supply for each quadrupole to be provided

## IV.5 Switching Magnet

1. **Switching magnet able to deliver beam to 3 different trajectories**: +45°, 0°, -45°.
2. **Beam parameters:** Deuteron 340 keV
3. **Semicircle Radius:** 345 ± 3% mm
4. **Magnet Gap height:** 80 mm
5. **Maximum magnetic rigidity Brho**: 0.16 Tm
6. **Required field homogeneity dB/B:** ± 5x10-4 or better
7. **Pole Material: As per section IV.1**
8. **Yoke Material: As per section IV.1**
9. **Coil Data:** SM coils are water cooled. Coils to be made of Oxygen free copper (OFC).
10. **Other:**
    - A three ports vacuum chamber and support stand to be delivered with the magnet.
    - Chamber material AISI 304
    - Alignment marks on top of quadrupole
    - Support stand to be provided Height (1500 mm + HV Deck ) from floor to beam axis)
    - Matching bipolar power supply with polarity reversal switch should be provided

## IV.6 Magnet Power Supplies

### IV.6.1 General Specifications for power supplies used for the quadrupole magnets and correction coils:

- Output Voltage and Current : Unipolar To be matched with individual quadrupoles and bending magnets
- Input AC Power : 3-Phase, 50Hz, 420Volt ±10% or 1-Phase,50Hz, 230V±10%
- Stability ≤ 10ppm over 8hrs ( DCCT regulation)
- Load Regulation : ≤10ppm for 10% load variation
- Line Regulation: ≤10ppm for 10% line voltage variation
- Local control panel to be provided
- Inlet water temperature = $25^0$C, $\Delta T = 10^0$C, $\Delta P$ = 3-5bars
- All power supplies should be air cooled if possible and water cooled if necessary.
- Water flow meter and flow switch, flow interlock to be provided if water cooled.
- Major interlocks viz. over current, transistor failure, etc. should be provided.
- Remote control should be provided.
- Quantity: For each low gradient quadrupole1 power supply for main coils and one power supply for correction coils.

### IV.6.2 General Specifications for power supplies used for the Bending magnet and Switching magnet:

- Output Voltage and Current: Unipolar to be matched with bending magnets and bipolar to be matched with switching magnet.
- Input AC Power : 3-Phase, 50 Hz, 420 Volt ±10% or 1-Phase,50 Hz, 230 V±10%
- Stability ≤ 10ppm over 8hrs ( DCCT regulation)
- Load Regulation : ≤10ppm for 10% load variation
- Line Regulation: ≤10ppm for 10% line voltage variation
- Local control panel to be provided
- Inlet water temperature = $25^0$C, ΔT = $10^0$C, ΔP = 3-5bars
- All power supplies should be air cooled if possible and water cooled if necessary.
- Water flow meter, flow switch flow interlock to be provided if the power supply is water cooled.
- Major interlocks viz. over current, transistor failure, etc. should be provided.
- Remote control should be provided.
- Switching magnet power supply should have remote controlled polarity reversal switch.

  **Quantity**:
- For bending magnet: 1 Power supply with reverse current option
- For switching magnet: 1 power supply with polarity reversal switch.
- For high gradient quadrupole: 8 Power supplies and separate power supplies for correction coil of each quadrupole

## IV.7 Digital Teslameter along with Hall probe:

- Maximum Field: 3 Tesla
- Precision: 0.01%
- Resolution : 0.1 T
- Temperature Stability: 3ppm/$^0$C
- Digital Display
- Remote output: Analog and RS 232/ IEEE-488
- AC input power: 220V, 50Hz
- Hall probes : Transverse type Probe head size: ~14x14x2.5 mm
- Quantity : 3

## IV.8 Beam Diagnostic system:

- ✓ **General:** The beam diagnostic equipment is fully designed in order to provide full beam profile.
- ✓ **Purposes:**
  - Beam profile measurement.
  - Current measurements.
  - Emittance Measurements

There should be two diagnostic systems. One is located on the 300 kV high voltage deck and one is located in MEBT at ground potential. The position of the beam diagnostic systems is defined according to beam optic simulations.

### IV.8.1 On 300kV deck – designed for a 1.5 kW, beam diagnostics configuration

- Slit system, consisting of
    - 1 pair of independent slits in the horizontal plan X for 1.5 kW beam
    - 1 pair of independent slits in the vertical plan Y for 1.5 kW beam
    - 1 XY beam profile monitor for 1.5 kW beam.
- 1 Faraday cup (Provided by IPR): corresponds to the Faraday cup which already exists with the ion source bench. It should be removed from its existing position and adapt to the diagnostic vacuum tank. Detail specification of the faraday cup is provided by IPR during design.
- 1 vacuum tank designed for the assembly of the diagnostic system and including vacuum ports for the connection of a TMP pump and a vacuum pressure gauge.

### IV.8.1.1 Detailed specification, Slit System

**Quantity: One for 1.5 kW beam**

- The slit system aperture should be 25 mm in the vertical direction and 25 mm in the horizontal direction.
- Each blade of the slit system should be motorized and should provide the possibility to translate a 25 mm vertical and horizontal opening by at least ± 25 mm.
- Each blade must be carefully aligned so that operation with <0.1 mm accuracy should be maintained over the blade travelling range.
- The accuracy and reproducibility of the blade movements should be 0.1mm or better.
- Each blade should be water cooled and withstand a heat load of 60 W/mm2 (minimum)
- The motors driving the blade should be two-phased bi-polar precision stepper motors.
- Limit switches, normally closed, should be included in each blade actuator.
- The UHV chamber must have marks for alignment on the outside of the vessel. The marks must relate to the beam center within the slit apertures.
- Each blade must be equipped with drain current measurement for beam position monitoring, and thermocouples for temperature measurement. Connection to the sensors should be provided on the outside of the UHV chamber.
- Flange type : CF
- The flange is equipped with special vacuum feed through for water circulation.
- Slit stroke: 50 mm (+/- 25 mm with respect to the beam axis)
- Water cooling up to 1.5 kW: 3 bars, 3 l/min, resistivity > 2µSiemens or better
- Electronics hardware as well as software to operate the slits and measurement of beam emittance should be provided.

### IV.8.1.2. Detailed specification, Beam Profile Monitoring system:

**Quantity: One for 1.5 kW beam**

- Beam profile monitor for up to 15 W/mm² beam
- X and Y plan beam profile are available with one device.
- Connection flange: CF type

- Insertion distance: 11 to 12 cm
- Beam aperture: 40 to 50 mm
- Beam power: 15 W/mm² or better
- This item includes all electronics hardware consisting of a preamplifier unit and a controller which gives a complete autonomous system.

**IV.8.1.3 Faraday cup (Provided by IPR):**

**Quantity: One for 1.5 kW beam, provided by IPR.**

It should be removed from its existing position in the ECRIS bench and adapt to the diagnostic vacuum tank. Detail specification of the faraday cup is given in Annexure-I.

**IV.8.2 At MEBT (ground potential) designed for a 10 kW, beam diagnostics configuration**

- Slit system, consisting of
  - 1 pair of independent slits in the horizontal plan X for 10 kW beam
  - 1 pair of independent slits in the vertical plan Y for 10 kW beam
  - 1 XY beam profile monitor for 10 kW beam
- 1 NPCT(Provided by IPR)
- 1 vacuum tank designed for the assembly of the diagnostic system and including vacuum ports for the connection of a TMP pump and a vacuum pressure gauge.

**IV.8.2.1 Detailed specification, Slit System**

**Quantity: One for 10 kW**

- The slit system aperture should be 25 mm in the vertical direction and 25 mm in horizontal direction.
- Each blade of the slit system should be motorized and should provide the possibility to translate a 25 mm vertical and horizontal opening by at least ± 25 mm.
- Each blade must be carefully aligned so that operation with <0.1 mm accuracy should be maintained over the blade travelling range.
- The accuracy and reproducibility of the blade movements should be 0.1 mm or better.
- Each blade should be water cooled and withstand a heat load of 130 W/mm$^2$
- The motors driving the blade should be two-phased bi-polar precision stepper motors.
- Limit switches, normally closed, should be included in each blade actuator.
- The UHV chamber must have marks for alignment on the outside of the vessel. The marks must relate to the beam center within the slit apertures.
- Each blade must be equipped with drain current measurement for beam position monitoring, and thermocouples for temperature measurement. Connection to the sensors should be provided on the outside of the UHV chamber.
- Flange type : CF
- The flange is equipped with special vacuum feed through for water circulation.
- Slit stroke: 50 mm (+/- 25 mm with respect to the beam axis)
- Water cooling up to 10 kW: 6 bars, 4,5 l/min, resistivity > 2 µSiemens or better
- Electronics hardware as well as software to operate the slits should be provided.

### IV.8.2.2 Detailed specification, Beam Profile monitoring system:

**Quantity: One for 10 kW**

- Beam profile monitor for up to 100 W/mm² beam
- X and Y plan beam profile are available with one device.
- Connection flange: CF type
- Insertion distance: 11 to 12 cm
- Beam aperture: 40 to 50 mm
- Beam power: 100 W/mm² or better
- This item includes all electronics hardware consisting of a preamplifier unit and a controller which gives a complete autonomous system.

### IV.8.2.3 NPCT (Provided by IPR):

**Quantity: One NPCT, provided by IPR.**

It should be adapted to the diagnostic vacuum tank. Detail specification of NPCT is given in Annexure-II.

## IV.9 Specification of 300kV High Voltage Deck.

- The support structure, hereafter referred as Deck, should be an assembled structure. The details of the components to be used in the structure are given in table-7 below:

| Sr. No | Description | Approximate Size | QTY | Material |
|---|---|---|---|---|
| 1 | Pipe Structure | Pipe: 6inch OD wt=2 mm<br>Structure maximum Size: 4500 mm x 4500 mm x2000 mm | As per Design | SS304 |
| 2 | MS Frame | Channel: 150 mm x 100 mm x6.3 mm, round corners<br>Over all maximum Frame Size: 4000 mm x 4000 mm | | IS 2062 MS from reputed manufactures |
| 3 | Aluminium Alloy Plate size | 1000 mm x 1000 mm x 20 mm | | 7076-T6 or equivalent |
| 4 | MS round Plates | Φ280 x-20 mm | | M.S |
| 5 | Ceramic Post Insulator | 300 kV solid Post Insulator | | Ceramic |

- Following electrical Connection should be provided on the HV deck

  2 Nos 3-phase, 64 A,420 VAC

  3 Nos 1-phase, 32 A, 230 VAC

The Deck will consist of mainly;

- A welded MS frame made from rectangular section [150 mm x 100 mm x 6.3 mm] with round corners

- A modular piped structure hereafter referred as toroid [made of SS304, 6" OD pipe, wt=2 mm]
- 300 kV DC solid post insulator.
- The frame sits on insulators placed and bolted under all the joints of the frame. Aluminium Plates should be bolted on the top surface of the frame. The frame should be flat (±1.0 mm flatness) from top and bottom surface [Critical for assembly] therefore welding has to be done very carefully.
- There should be no dents or scratches on the pipe surface. Buffing/polishing of the piped structure should be done only after inspection of welded structure by IPR personnel.
- The MS frame should be grit blasted before painting. It should be enamel painted [colour would be intimated later] following proper painting process. There should not be any sharp edge or burr, anywhere, in the structure.
- The reference design of HV deck is given in the Fig-3.
- The total load on the HV Deck is approximately 5000 kg excluding frame structure and toroid
- The bidder may in his quotation offer an alternative design for the HV deck, as long as this is appropriate for the application and lead to the same or improved performance.

### IV.10 Vacuum System (Optional)

Two set of TMPs with Oil free scroll pump should be provided. One is located at 300 kV deck potential and remaining one is located at ground with necessary gauges, valves and controller.

### IV.10.1 Specification of turbo molecular pump with all controller and accessories

- Pumping speed: 550 liter/sec or better (for H2)
- Base pressure: $1 \times 10^{-10}$ mbar
- Compression ratio: Better than $1 \times 10^{5}$ (for H2)
- Inlet flange: DN 160 CF
- Outlet flange: KF Type
- Power supply: 230 ± 5% V, 50 Hz, 1-PH
- Cooling system: Air cooling
- Type: Magnetically levitated Turbo Molecular Pump

  Accessories:
- Splinter shield
- Electrical venting Valves
- Air Cooling Kit
- Heating jacket
- Quantity : 02

### IV.10.2 Technical Specification of Oil Free scroll vacuum pump

- Pumping Speed: 15 $m^3/h$
- Attainable ultimate pressure: ≤ 0.016 mbar
- Leak rate: 1 X $10^{-6}$ mbar*l/sec
- Maximum inlet pressure: Atmosphere
- Ambient Temperature: 5 to 40 $^0$C
- Inlet flange: 25 DN
- Exhaust flange: 15 DN
- Cooling : Air cooling
- Power supply : 230 ± 10% VAC , 50Hz±5%
- Quantity : 02

## IV.11 Power provision and distribution

This item corresponds to the Power and Command & Control rack located on the deck. Input line is the 420 VAC (3-Ph) /220 VAC (1-Ph) coming from the 350 kV isolation transformer. It should be designed to provide individual power lines to power supplies, pumping system, cooling system with adequate protections like breakers.
Detail information of Power distribution should be provided at the time of design

## IV.12 Control & Command System

### IV.12.1 Command & Control function

- Command and control system should be designed for remote operation as a stand-alone system, controlling the vendor supplied components and equipment.
- IPR supplied components and equipment (ion source with power supplies, Solenoid with power supplies, Acceleration tube with HV power supply, Faraday Cup, NPCT), will be controlled from the IPR provided control system.
- Vendor should do Interface between the two control systems, e.g. interlocks or simple signals, to be specified and agreed upon in the design phase of the project.

### IV.12.2. Control system with vendor supplies control software

- All the vendor supplied equipment related to the beam line should be remotely controlled.
- All the component on the HV deck should control via PLC system or better.
- All the component on the ground potential should control through PXIe or better.
- The cabinet, including interlock of the HV and grounding system, control the security/safety of the whole beam line.
- The software as well as the PC for controlling the whole system should operate via lab view GUI (graphical user interface).
- Vendor should provide the real time monitoring and data storage system for all the beam diagnostic.
- Vendor should provide all the safety/security interlocks.
- Vendor should provide minimum 50 numbers of spare Analog & Digital Input & Output in to command and control system for future expansion.

## V. General conditions/guidelines, procedural rules to be adhered by the Vendor for NG system integration work at IPR and factory site.

1. Vendor should take all precautions and utmost care to avoid breakage, damage, loss etc. while erection and commissioning of the scope of supply items. If damage, breakage or loss occurs to Purchaser's property while doing the above work and damage to adjacent components, contractor will be responsible for making compensation to the purchaser. The typical value of the Components/ parts/ equipments/ systems are listed in Table-7. Vendor shall take insurance for the listed values of the systems/components as they may get damaged due to accident.
2. Working hours are defined as 09:00 hrs to 17:30 hrs, Saturday and Sunday will be closed for work.
3. Ensure human and component safety during assembly and erection Works.
4. Ensure proper planning and routing of components in hall to avoid potential conflicts with other activities in parallel.
5. Instant correction of any deviations as they occur, no accumulation.
6. Contractor/Sub contractor shall carry out the tasks as per the predefined assembly sequence, following prescribed quality assurance plan.
7. Price list of components for insurance
   Please note that during assembly of NG components/systems, extreme care shall be taken by vendor and his man power. The price/cost of the existing components/systems in the IPR is as listed below. If the components/systems get damaged due to accident/improper handling or negligence of the deployed man power, the cost of the damaged system(s) will be deducted or paid by the insurance company to IPR. Hence, comprehensive insurance shall be taken for the following components/systems and for the deployed man power by the vendor till the completion of the job.

   Table-7 : List of FIM

| Sr.No | Component/System | Quantity | Unit Price In Lacs (Rs) | Total Price in lacs (Rs) |
|---|---|---|---|---|
| 1 | ECR ion source bench with command and control cabinet | 01 | 265 | 265 |
| 2 | Faraday Cup | 01 | 35 | 35 |
| 3 | NPCT | 01 | 35 | 35 |
| 4 | 300kV,50mA HVPS | 01 | 150 | 150 |
| 5 | Acceleration column | 04 | 05 | 20 |
| | | | Total | 505 lacs |

## VI. Acceptance Test Plans (ATP) and QA/QC.

### VI.1. Acceptance tests at vendor's site

Tests have to be carried out at vendor's factory before shipment. IPR representative/ representatives may inspect the tests at manufacturer works. Measuring equipment of adequate accuracy class and having valid calibration certificates shall be used in all measurements. All main calibration certificate copies shall be enclosed in FAT report.

Visit of IPR persons to vendor's site:

- One/two weeks to finalize the primary design of beam line.
- One/two weeks to finalize the final design of beam line.
- Three to four weeks for testing of the magnets, power supplies, beam diagnostics system, high voltage deck and as well as full integrated beam line.

#### VI.1.1 Magnets

All the magnets should undergo hydraulic, mechanical and electrical testing

I. Mechanical :
   1. Dimensional check with respect to approved design and drawing.
   2. The conductor cross section should not change during manufacturing of coil. It should be demonstrated on conductor sample.

II. Hydraulic :
   1. Leak test for the water cooled conductor to be performed as a water pressure test, 30 bar for 2 hours.

III. Electrical
   1. Insulation between ground and coil should correspond to DC current 1 micro amp at 5kV. Inter layer insulation testing for the coils should be done.
   2. Magnetic measurement for all the magnets will be for 50% and 100% current and the magnet parameters should be calculated and compared with the specifications.
   3. Dipole magnet and switching magnet should be measured for: homogeneity $\leq 10^{-3}$ over ±30mm of central trajectory in radial plane.
   4. All quadrupole magnets should undergo harmonic contents measurement, effective length & angle, deviation between magnetic center and mechanical center
   5. Total Harmonic contents for each quadrupole: ≤ 1% over 80% of aperture diameter.
   6. Temperature rise of the magnets should be noted for eight hours constant operation at 100% current. It should not be more than $80^0$ C

### VI.1.2. Power Supplies

1. Stability ≤ 10ppm over 8hrs ( DCCT regulation)
2. Load Regulation : ≤10ppm for 10% load variation
3. Line Regulation: ≤10ppm for 10% line voltage variation

### VI.1.3. Beam diagnostics systems

1. Leak test of beam diagnostic system < 1 x $10^{-8}$ mbar l/s (individual joint)
2. Calibration of all the beam diagnostics system, which can be done without beam. Which include to calibrate the slit position, accuracy and reproducibility of the blade movements should be 0.1mm
3. Leak test with water is performed at a line pressure of 10 bar (Approx.)
4. Operational tests as per specifications.

### VI.1.4. 300 kV High voltage deck

1. The vendor should assemble the high voltage deck and check the all dimension as per design.

### VI.1.5. Integrated system:

1. Alignment with laser beam
2. Leak test of integrated system < 1 x $10^{-7}$mbar l/s.
3. Magnetic measurement for all the magnets will be for 50% and 100% current and the magnet parameters should be calculated and compared with the specifications.

### VI.1.6. Vacuum Chamber

1. Dimensional check and surface finish of all the components as per the approved drawings tolerance range. If any deviation in dimensional and surface finish check occurs, vendor shall correct the same to meet the drawing specifications.
2. Hydrostatic pressure test (Pressure test) of cooling water headers and branch lines/pipes and welded joints in fully assembled condition as per ASME guidelines.
3. Helium leak rate test (Vacuum leak test) will be carried out for the welded joints with leak tightness of 1x$10^{-8}$ mbar-lit/sec of all parts/components/systems that have been welded for use in the Vacuum applications.

## VI.2. Acceptance test at IPR

Upon installation the supplied equipment should be tested by Vendor at IPR in collaboration with IPR representative for final acceptance tests.
The following tests shall be conducted in the beam line:

1. Calibration of beam diagnostics elements, which must be done with deuteron beam
2. Measurement of ion beam current with energy of 40 keV before acceleration and 340 keV after acceleration
3. Measurement of ion beam emittance with current range from 5 to 20 mA and beam emittance should be < 0.2 pi.mm.mrad
4. Measurement of beam profile, beam diameter should be < 20mm and beam profile should be Gaussian.
5. Stability test of full beam diagnostic system with 20 mA beam current for 2 hr operation and it should be < ±5%
6. The whole structure on insulators should be tested at 300 kV DC.
7. Stability test of full integrated system with 20mA beam current for 8hr operation and it should be < ±5%

**VI.3. Quality Assurance/Quality control (QA/QC):**

1. The Vendor should prepare and submit a detailed plan for QA/QC before commencing fabrication work and assembly work at IPR site and at vendor's own site/sub-contractor site.
2. The test plans should comply with test requirements stated in above **VI_I** and **VI_II**.
3. Vendor shall discuss the quality assurance and quality control time to time and get it approved from IPR before execution of work in order to avoid re-work.

## I. Applicable codes & standards/specifications

The material, fabrication, testing shall comply with all currently available statues, regulations and safety code in the locality where system is fabricated and installed. ASME (or Equivalent) code shall be followed at the various stages of fabrication, inspection and testing of the core Assembly, wherever applicable. The equipment shall also conform to the latest applicable codes and standards of practice. The vendor shall refer to the following standards.

- ASME Section—VIII Division 1 and 2 for design and fabrication.
- ASME Section—II Part A- for Materials
- Inspection and testing should be done as per ASME Section—V
- ASME B & PV Code Section VIII Div.2 Part 5 for allowable stress limits and Analysis procedures and load combinations
- ASME B & PV code Section IX– Welding and Brazing qualifications
- ASME B & PV codes Section II – Part C- Specification for welding rods, Electrodes and filler Metals
- ASME B31.6 for Flanges for process equipment
- Relevant IS/ISO standards applicable to various ports etc. for vacuum flanges and vacuum seals etc.
- ASME B31.3 for process piping
- ASME B16.5 for Pipe flanges and flanged fitting
- IEC standard applicable to manufacturing and testing all power supplies, electrical and electronics items

## II. List of documents to be submitted while offering the bid (mandatory):

Technical:

- Compliance table for all the specification as in tender/ enquiry
- Lay-out of the beam line system
- Technical description of the offer
- Proposed project organization diagram for the IPR Beamline project, with project members CV's.
- Provisional project schedule
- Description of in-house coil manufacturing facility
- Description of in-house magnet testing equipment and power supplies
- Description of in-house design capabilities, facilities and design tools

Commercial:

- Company profile
- Reference list covering delivery of similar high performance beam line systems to reputed accelerator laboratory in India or abroad, including customers contact information
- Reference list covering delivery of similar accelerator magnets to reputed accelerator laboratory in India or abroad, including customers contact information
- Reference list covering delivery of similar magnet power supplies to reputed accelerator laboratory in India or abroad, including customers contact information
- Previous client list to be submitted along with the offer.

## III. Eligibility Criteria

1. The vendor should have at least ten years of experience in beam line design, installation and alignment.
    - The vendor should submit proof of supply and installation of beam line (300keV or higher) to reputed Institute and organizations in global market and copy of purchase order before February, 2006 and its completion certificate issued by end-user.
2. Manufacturer must have the quality management system adopted as per ISO 9001-2008.
    - The vendor should submit valid ISO 9001-2008 Certificate
3. The vendor should have minimum Rupees 70000000=00 (Seventy Million Rupees or Equivalent Dollar/Euro) single work order for similar kind of work in to global market in last five year.
    - The vendor should submit the copy of purchase order and work completion certificate of same purchase order issued by end-user.
4. Vendor must have in-house experience and facilities for Magnetic field measurement for performance tests of the magnets, its cover electromechanical, hydraulic and magnetic tests such as excitation curve, homogeneity plots and magnetic length and angle.
    - The vendor should submit relevant document/list of instruments for the above mentioned test.
5. Vendor should have minimum 250000000=00(Two hundred fifty million Rupees or Equivalent Dollar/Euro) annual turnover in last three years.
    - The vendor should submit the annual turnover statements of last three years.

## IV. Drawings and Figures

The drawings of various components and assemblies for the scope of work information are given in Fig-1. 3D view of NG systems has been attached herewith for information/understanding to the vendor in Fig-2.

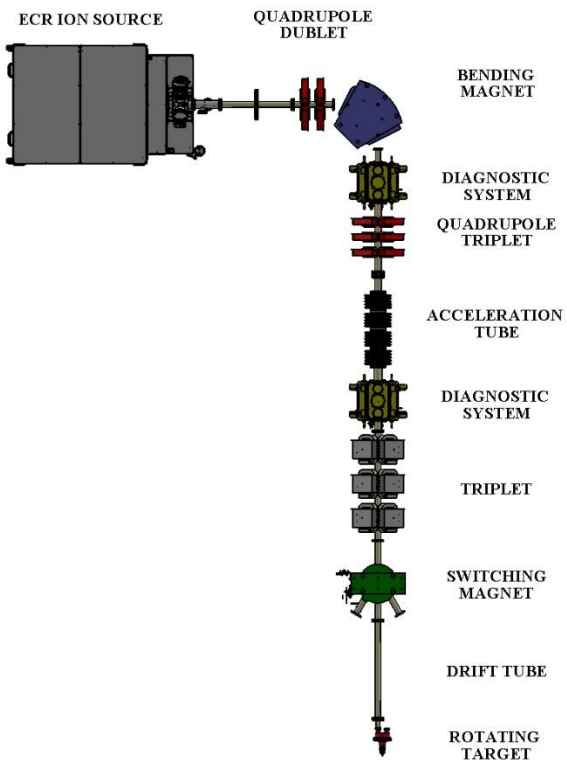


Fig: 1 Beam line diagram

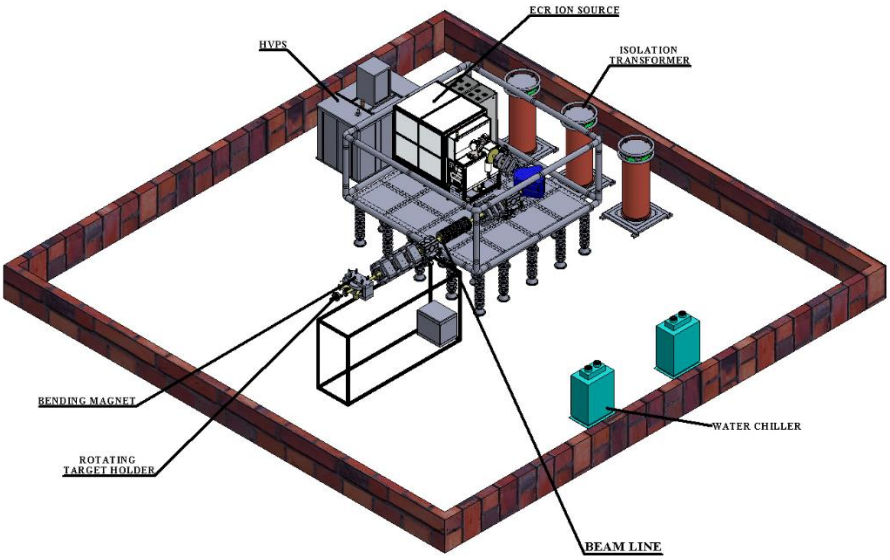


Fig-2 3D view of beam line

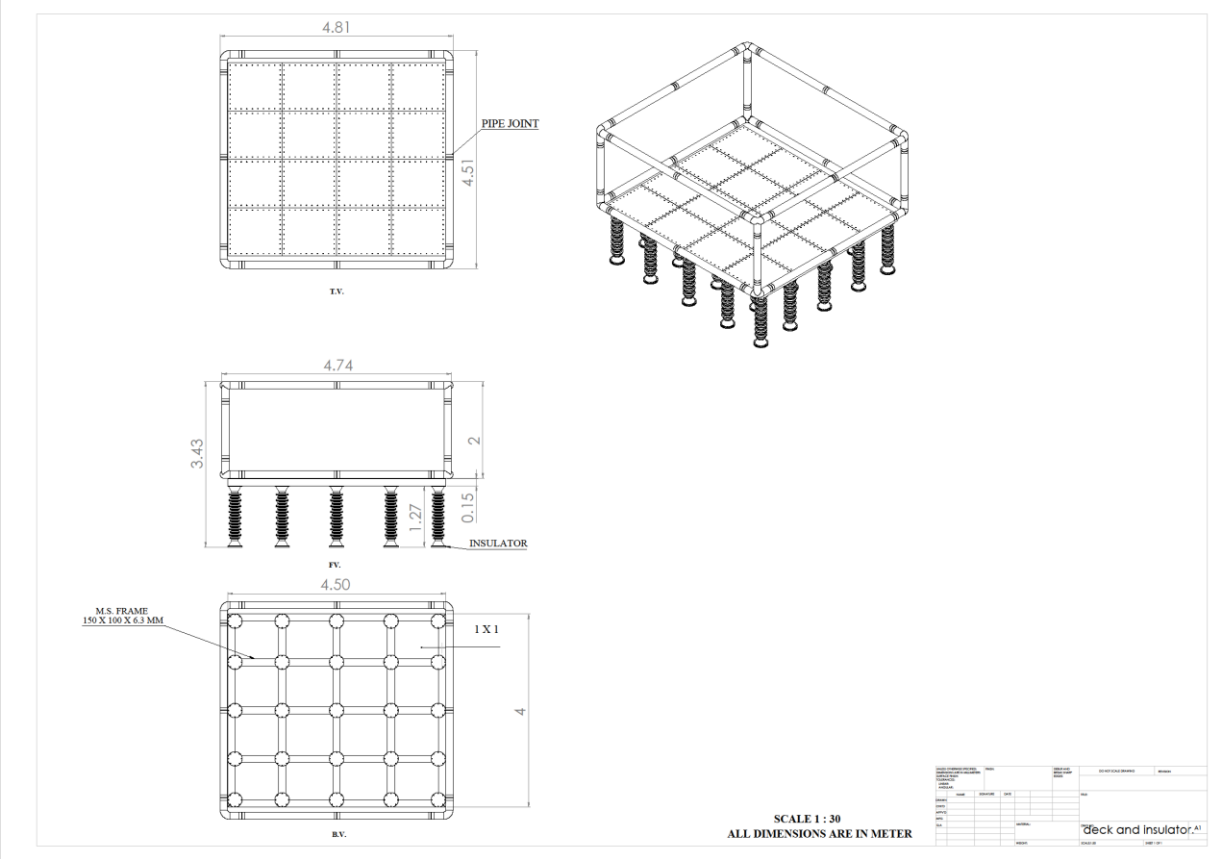


Fig-3 High Voltage Deck drawing