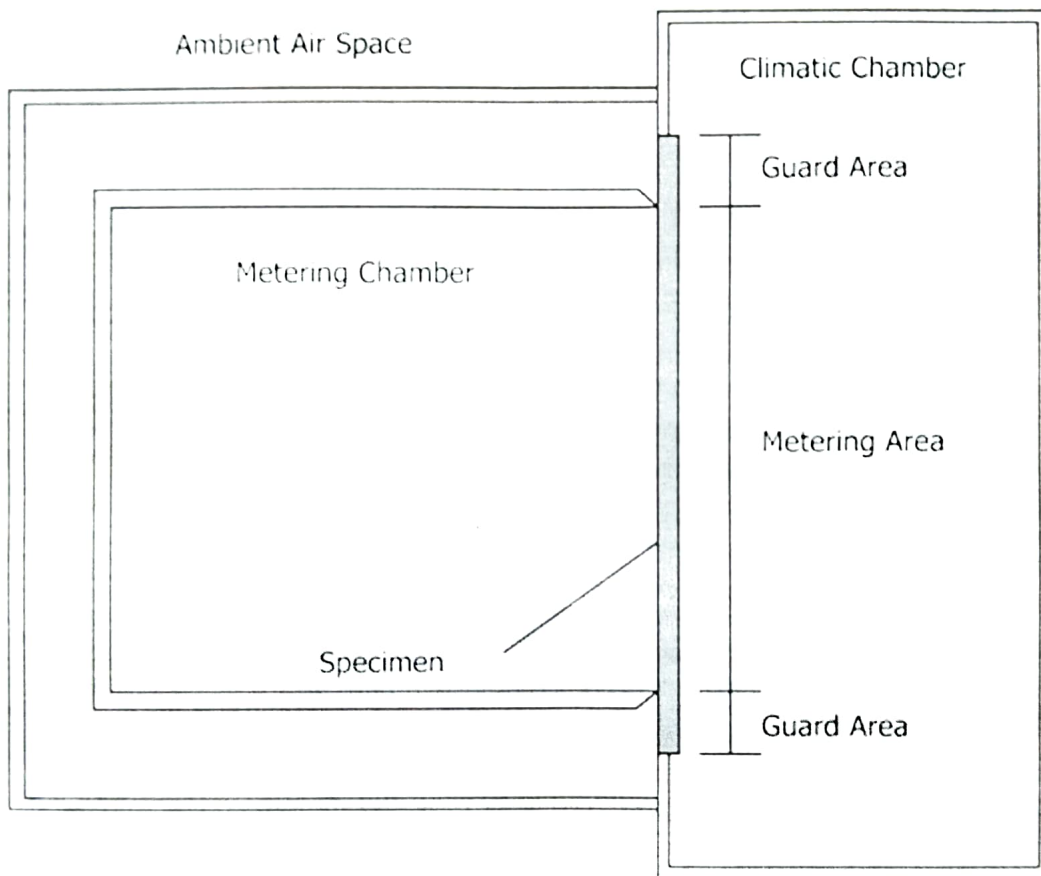


## Annexure II

### TECHNICAL SPECIFICATIONS OF OVERALL HEAT TRANSFER COEFFICIENT (U-VALUE) APPARATUS FOR FULL SCALE BUILDING COMPONENT TESTING

Guarded Hot Box type Overall Heat Transfer Coefficient (U Value) Apparatus for Measurement of U value of Building materials. The apparatus shall be a HotBox Test Chamber with Guarded Hotbox as shown in figure 1 and shall strictly meet all the requirements of international standard ASTM C1363-19 and similar such standards such as IS 9403:1980, DIN EN ISO 8990, having the general specifications as follows



**Figure 1: Typical Guarded Hot Box apparatus for measurement of U Value**

The apparatus shall consist mainly three chambers defined in figure 2 and given below

1. Climatic Chamber (Outdoor Chamber)
2. Guard Chamber (Indoor Chamber)
3. Metering Chamber

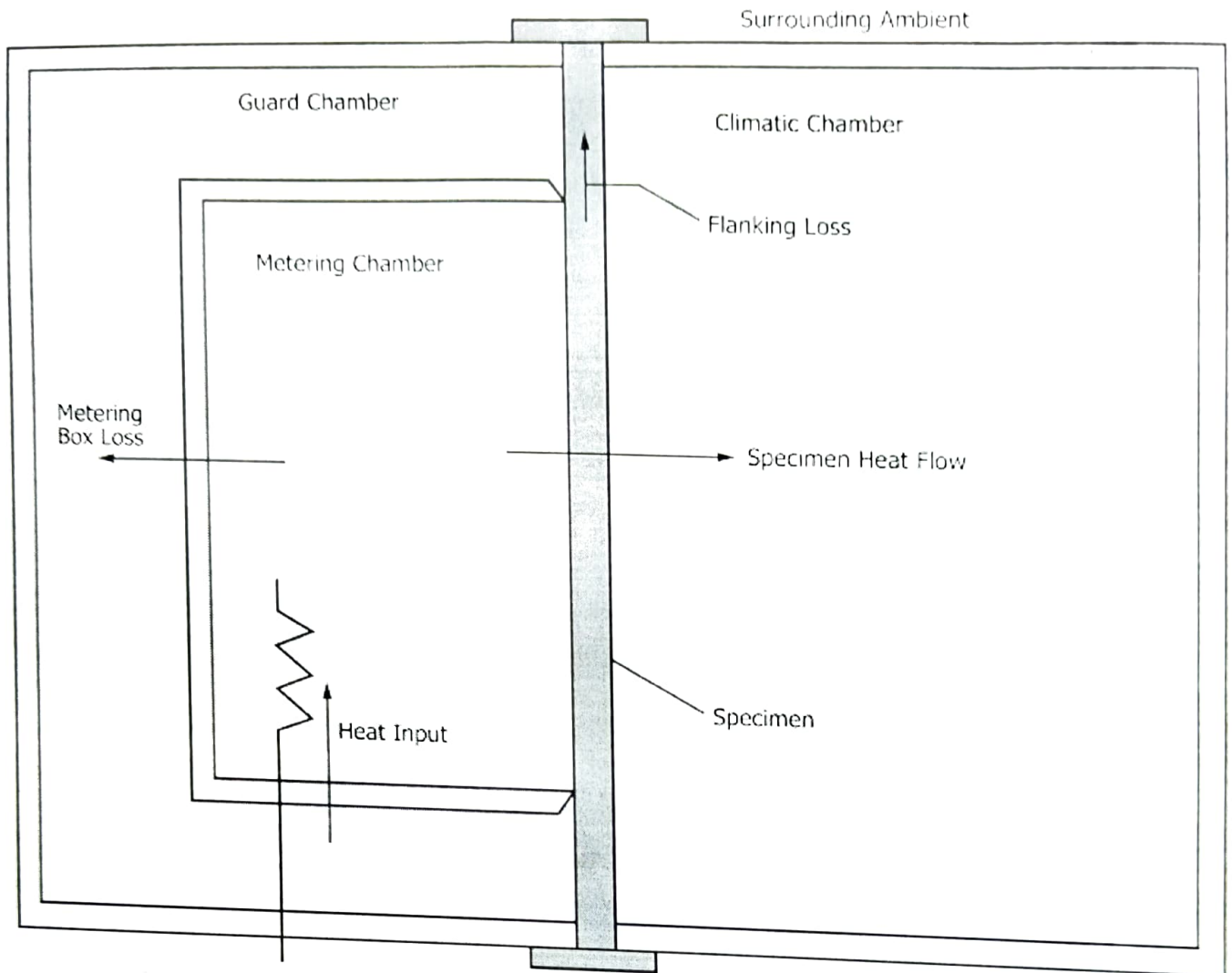


Figure 2: Typical Guarded Hot Box Apparatus

### General Specifications of Guarded Hot Box type U value measurement Apparatus

The dimensions of Guarded hot box type apparatus are given in figure 3.

1. Closed Apparatus maximum Dimensions in mm (H X W X D) : 2800 X 3300 X 6300
2. Open Apparatus maximum Dimensions in mm (H X W X D) : 2800 X 3300 X 7300
3. Base Frame : Extruded Aluminum Hollow with Double walled insulation thermal break profile
4. Connecting Frame : Aluminum Frame/SS Frame

#### Lateral wall and Ceiling specifications

1. Wall panel construction: 150 mm thick closed cell monolithic uniform insulation foam with Stainless Steel facing material type prefabricated panels. The core material shall be specially molded at the joints to ensure perfect continuity of insulation. The joint is guaranteed by interlocking system made with composite and non-deformable materials.
2. Insulation Foam material: Extruded Polystyrene Foam or Poly Urethane Foam, self-extinguishing, CFC and HCFC free.
3. Thermal Conductivity (K value) of insulation material used  $\leq 0.035$  W/m/K at 25 deg. Mean temperature

4. Facing material : stainless steel material having thickness  $\geq 0.8$  mm on both sides of the insulation foam wall
5. Panel Design: Panels shall be interlocked with thermal break profile and no thermal bridges. The chamber wall panels shall be uninterrupted by any highly conducting structural members, and by eliminating any localized hot or cold sources from adjoining space. Thermal bridges, structural cracks, insulation voids, air leaks and localized hot or cold spots from the air conditioning equipment inside the chamber wall panels shall be avoided.
6. Total Hemispherical Emittance of wall panel :  $\geq 0.9$
7. Insulation Material Density  $\geq 40$  Kg/m<sup>3</sup>

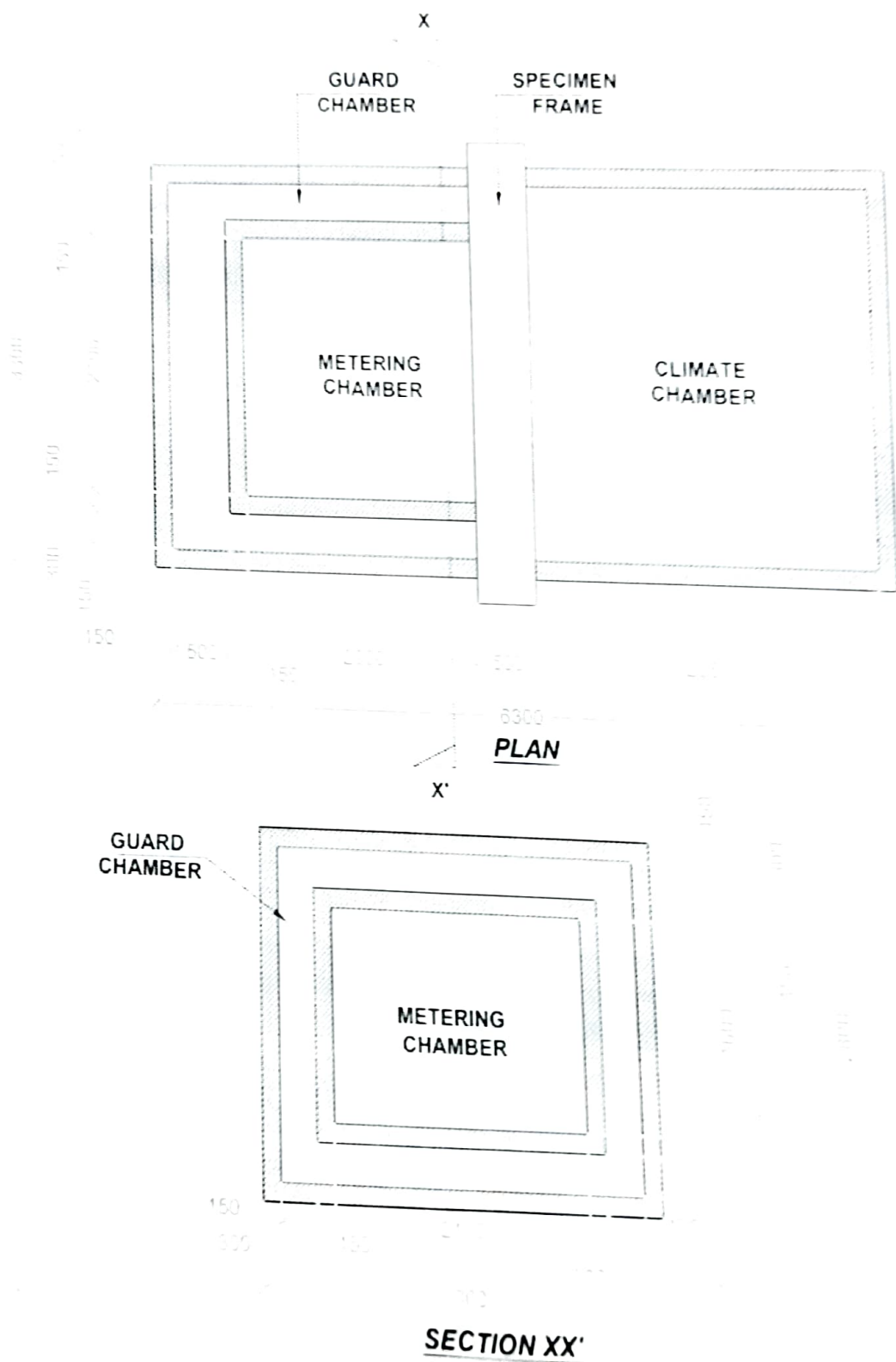
**Floor Specifications:** The floor shall be made of prefabricated panels, AISI304 Stainless steel interior and Galvanized Steel exterior. The floor is completely flat without any slope. The reinforcement shall be installed inside the floor panels to reach the required load capacity of 3000Kg/m<sup>2</sup>

**Door Specifications:** One door shall be installed for each chamber i.e. Guard chamber and climatic chamber. The door shall be manual single wing door with inner clearance dimensions in mm (W X H) as 900X1900. It shall have opening system by interior, double silicon seals, SS interior finish and SS painted Steel exterior. Each door shall be equipped with 1 inspection window of size in mm (W X H) 450 X 550, having multi-pane toughened glass with built-in heaters to prevent condensation on the glass.

**Chamber movement and sealing mechanism specifications:** Stainless Steel Guide Rails shall be provided for Guard chamber and Climatic chamber with a translation length of  $\geq 3$ m. Provision shall be made to easily move the guard chamber manually in-order to place the sample specimen while the climatic chamber shall be fixed. The movement is allowed by manual system on Stainless Steel Guide Rails embedded on the floor. The Guard chamber is also provided with electric motor for moving the Guard chamber electrically. The sealing between the climatic chamber (fix room) and the Guard chamber (mobile room) will be ensured by dedicated gaskets that are pressed by manual mechanical clamps with a minimum of 12 point locking system. The opening and closing activities are done by pneumatic pistons controlled by micro-switches

**Drainage provision specification:** A draining system shall be provided in order to evacuate the condensation water if any on the chamber walls during transition phase

**Sound Attenuation Specifications:** The hot box apparatus shall be completely sound proof and the total decibel output from the any source of sound producing device associated with this system shall be  $\leq 70$ db at 1m distance and shall be  $\leq 60$ db at 3m distance.



**Figure 3: Guarded Hot Box type Apparatus dimensions (in mm)**

**Specifications of Metering Chamber:**

1. \*Internal Dimensions in mm (H X W X D) : 1600 X 2100 X 2000
2. External Dimension in mm (H X W X D) : 1900 X 2400 X 2150
3. Range of Temperature to be maintained inside Metering Chamber: +5°C to 60°C

4. Temperature Uniformity: The temperature variation inside metering chamber shall not be more than  $\pm 1$  °C at any two locations within the chamber.
5. Temperature Resolution :  $\leq \pm 1$  °C
6. Temperature Accuracy :  $\leq \pm 0.1$  °C during steady state conditions
7. Average Temperature Rates : 0.5 °C/min heating up  
: 0.5 °C/min cooling down
8. Air flow rate : 0.1 to 10 m/s
9. Thermal Resistance of metering chamber walls  $\geq 1.0$  m<sup>2</sup>K/W
10. The metering chamber shall be independent of the Guard chamber and a provision shall be made to easily remove the metering chamber from the Guard chamber when the machine is operated in calibrated hot box mode which enables measurement of U value for large scale building components

*\*Note: The depth of the metering chamber shall be kept as minimum as possible enough to place all the necessary metering chamber equipment, which will reduce the heat loss of the chamber*

**Metering chamber sealing specification:** at point of contact between the metering chamber walls and the sample specimen, an airtight seal shall be provided. The cross section of the contact surface of the metering chamber with the specimen shall be narrowed to the minimum width necessary to hold the seal but in any case the contact width of the seal should not exceed 13mm

**Metering chamber equipment:** The metering chamber shall consist of heaters, fans, air flow baffles to generate air curtain (i.e. air flow parallel to the sample specimen) and cooling coils and any other equipment necessary to meet the temperature and air flow conditions required to be maintained inside the chamber. All These equipment shall be shielded or placed behind an air baffle to maintain the uniformity of surface temperature radiating to the surface of the specimen.

**Metering chamber Instrumentation:** All the walls of the metering chamber shall be provided with heat flux meter or differential thermocouples. A minimum of 10 heat flux meters or differential thermocouple pairs per each sq.m of metering box shall be used. The thermocouple junctions shall be located directly opposite each other on both sides of the panel and located symmetrically at the centers of approximately equal areas. All the thermocouple wires and junctions shall be affixed with foils having the surface emittance matching the remainder of the box walls for atleast 100mm distance from the thermocouple junction. The thermocouple wires being used for measurement of heatflux shall have an option to be connected in series to form a thermopile junction to give single voltage output.

### Specifications of Guard Chamber

1. Internal Dimensions in mm(H X W X D) : 2500 X 3000 X 2650
2. External Dimension in mm (H X W X D) : 2800 X 3300 X 2800
3. Range of Temperature to be maintained inside Gaurd Chamber (Indoor Chamber) : +5°C to 60°C
4. Temperature Uniformity : The temperature variation inside Gaurd chamber shall not be more than  $\pm 1$  °C at any two locations within the chamber.
5. Temperature Resolution :  $\leq \pm 1$  °C
6. Temperature Accuracy :  $\leq \pm 0.1$  °C during steady state conditions
7. Average Temperature Rates : 0.5 °C/min heating up  
: 0.5 °C/min cooling down
8. Air flow rate : 0.1 to 10 m/s

**Guard Chamber Temperature mode:** The guard chamber temperature control shall have both auto mode and manual mode of control and during auto mode setting the chamber control system shall follow the metering chamber temperature with a feedback control circuit with the allowable maximum temperature difference limit of  $\leq \pm 1^\circ\text{C}$

**Guard chamber equipment:** The Guard chamber shall consist of heaters, fans, air flow baffles to generate air curtain (i.e. air flow parallel to the sample specimen), cooling coils and any other equipment necessary to meet the temperature and air flow conditions required to be maintained inside the chamber. All These equipment shall be shielded or placed behind an air baffle to maintain the uniformity of surface temperature radiating to the surface of the specimen.

### Specifications of Climatic Chamber:

Internal Dimensions (H X W X D): 2.5m X 3m X 3m

External Dimension (H X W X D): 2.8m X 3.3m X 3.15m

Range of Temperature to be maintained inside Climatic Chamber (Outdoor Chamber) :  $-40^\circ\text{C}$  to  $+40^\circ\text{C}$

Temperature Uniformity: The temperature variation inside Climatic chamber shall not be more than  $\pm 1^\circ\text{C}$  at any two locations within the chamber.

Temperature Resolution :  $\leq \pm 1^\circ\text{C}$

Temperature Accuracy :  $\leq \pm 0.1^\circ\text{C}$  during steady state conditions

Average Temperature Rates :  $0.5^\circ\text{C}/\text{min}$  heating up

:  $0.5^\circ\text{C}/\text{min}$  cooling down

Relative humidity range : from 40% to 80% in the temperature range of  $+20^\circ\text{C}$  to  $+40^\circ\text{C}$

Air flow rate : 0.1 to 10 m/s

**Climatic Chamber Equipment:** The climatic chamber shall consist of heaters, fans, air flow baffles to generate air curtain (i.e. air flow parallel to the sample specimen) and cooling coils and any other equipment necessary to meet the temperature and air flow conditions required to be maintained inside the chamber. All These equipment shall be shielded or placed behind an air baffle to maintain the uniformity of surface temperature radiating to the surface of the specimen.

### Specifications of Measuring Specimen and Specimen Frame

1. Measuring Specimen types : Doors, windows, building Components, Building Sections etc
2. U Value Measuring range : 0.1 to  $8.0 \text{ W}/(\text{m}^2\cdot\text{K})$
3. U Value Measurement Accuracy :  $\pm 0.1 \text{ W}/(\text{m}^2\cdot\text{K})$
4. U Value Measurement Resolution :  $0.1 \text{ W}/(\text{m}^2\cdot\text{K})$
5. Maximum Specimen Dimension (W X H): 3.0 m X 2.5 m
6. Maximum specimen thickness : 0.50 m
7. Maximum Specimen Area :  $\geq 7.50 \text{ m}^2$
8. Perimeter insulation :  $\geq 150 \text{ mm}$  on all sides of sample
9. Specimen Frame: SS or Aluminum Frame to support and position the specimen and to provide the perimeter insulation. The frame opening shall be atleast the maximum specimen area of  $7.50 \text{ m}^2$ . The construction of specimen frame shall ensure that there shall not be any conductive plates, fasteners or any type of structural members which shall conduct heat in the flanking path which could increase the flanking heat loss.
10. Specimen Frame Thickness  $\geq 500\text{mm}$  with adjustable inner grooves, which can hold specimen sample thickness in the range of 10mm to 500 mm
11. Thermocouples to be placed on specimen minimum 5nos. / $\text{m}^2$  per each side of the sample

12. 2 nos. of 2 Ton Hydraulic Forklift to be provided for lifting and placing the sample specimen for testing.

## Air circulation specifications

The hot box apparatus shall have air flow apparatus to guide the movement of air on both directions of the sample as follows

- Parallel (Up or down) direction with reference to surface of specimen sample
- Perpendicular to the surface of specimen sample as shown in figure 4

### Parallel Direction

The air circulation system in parallel direction shall be operated to provide both natural convection mode of air transport and forced mode of air transport parallel to the specimen surface by employing air curtains with uniform air velocity

In natural convection mode of testing, the air movement shall be 'down' direction with respect to specimen sample in metering chamber and in 'up' direction in climatic chamber which is achieved by providing air baffles

1. Air velocity to be maintained for natural convection mode  $\leq 0.5$  m/s
2. Air velocity range to be maintained for forced convection mode : 0.5 to 5 m/s
3. Air velocity setting resolution : 0.1 m/s
4. Air velocity measurement accuracy :  $\pm 0.1$  m/s

**Air baffles :** For parallel flow, a baffle, parallel to the specimen surface, shall be used independently in all the three chambers (i.e. guard, metering and climatic chambers) to confine the air to a uniform channel, thus aiding in maintaining an air curtain with uniform velocities. The air baffle setup shall be movable and the spacing should be variable in the range of 140 to 200 mm from the sample specimen surface.

**Air velocity uniformity:** Uniform air flow profile across the specimen width, perpendicular to the air flow direction must be achieved by use of multiple fans or blowers or by use of inlet distribution header across one edge of the baffle and an outlet slot across the opposite side. The inlet header shall incorporate adjustable slots or louvers to aid in obtaining uniform distribution of air velocity. The velocity measured at any two locations across the air delivery cross-section of the air curtain shall be within 5% of the mean air velocity of the air delivery of air curtain. Multiple nos. of velocity Sensors shall be suitably placed in the air curtain to ensure the requirements of air velocity uniformity are met.

1. Air baffle thermal resistance  $\geq 1.0$  m<sup>2</sup>K/W
2. Temperature uniformity of air baffle  $\leq 0.5$  °C/m
3. Air Baffle to sample specimen spacing: the spacing should be variable in the range of 140 to 200 mm from the sample specimen surface
4. Total Hemispherical emittance of air baffle  $\geq 0.9$

### Perpendicular Direction:

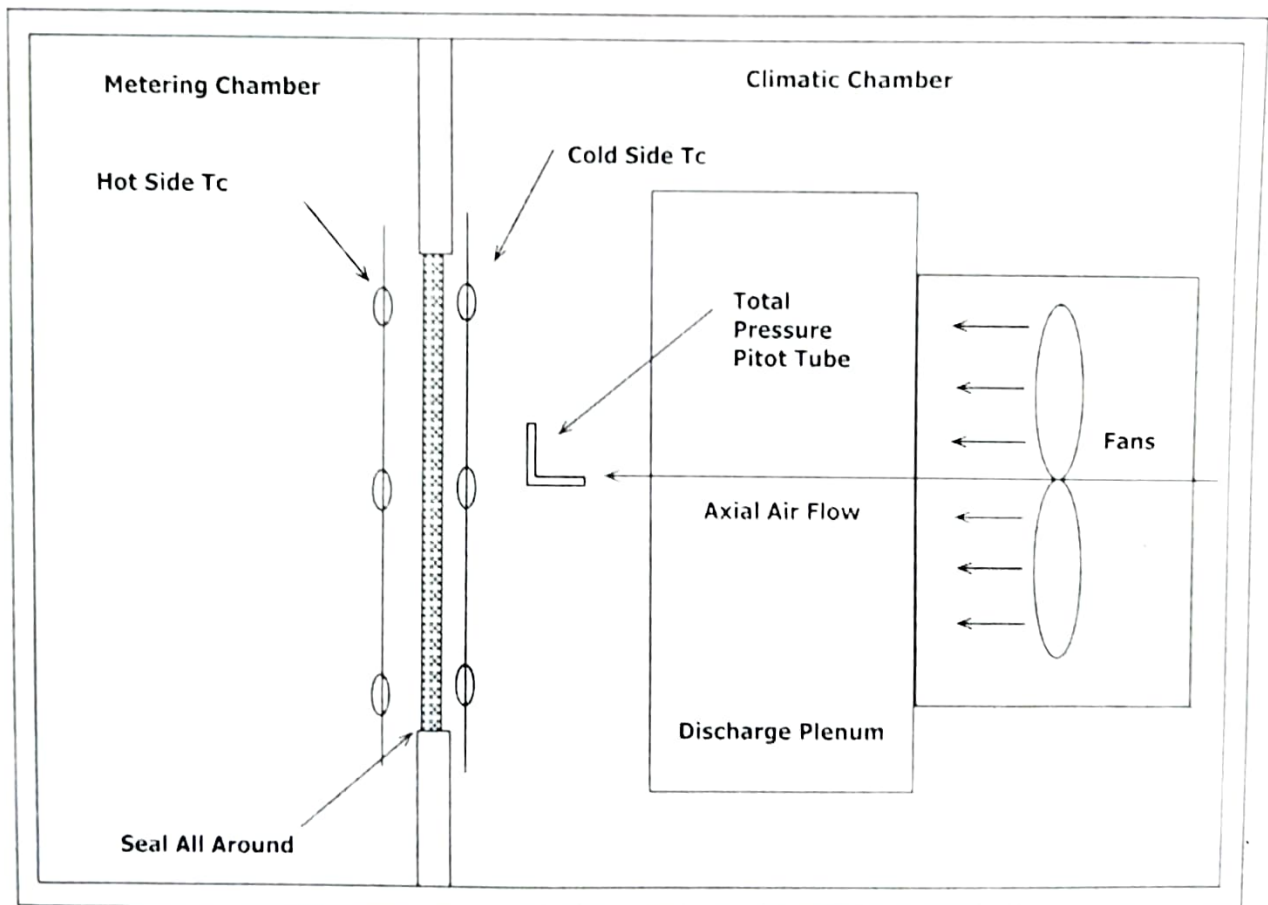
1. Fans or blowers shall be provided to achieve uniform air flow in the direction perpendicular to the specimen sample as shown in figure 4
2. Air velocity range to be maintained for forced convection mode : 0 to 10 m/s
3. Air velocity setting resolution : 0.1 m/s
4. Air velocity measurement accuracy :  $\pm 0.1$  m/s

**Air velocity uniformity:** All velocity measurements at any two locations within the guard chamber, metering chamber and climatic chamber shall be within 5% of the mean air velocity with in their respective chambers.

**Air velocity measurement method:** Air velocity shall be measured by both the following methods

1. Volumetric airflow method by measuring the air flow in the ducts to the inlet distribution header by using calibrated orifice or similar flow measuring device
2. Direct measurement of velocity by locating velocity sensors at various locations of the room and also directly in the air curtains. The air velocity sensors shall be located at a distance of 75 to 150mm (away from boundary layer or wakes) out from the test specimen surface and at the near geometrical center of the sample specimen.

**Pressure Difference:** Differential pressure transmitters shall be located in both the chambers on both sides of the sample specimen to measure the air pressure differential between the faces of the test specimen (such as windows etc.) with pressure difference measurement accuracy of  $\pm 1$  Pa or better. Also Differential pressure transmitters are located at various locations of the room.



**Figure 4: Hot Box Arrangement for perpendicular air flow**

#### **Air Handling Unit (AHU) Specifications:**

Individual AHU units shall be installed for each of the three chambers i.e. Guard Chamber, metering chamber and Climatic chamber. The AHU shall consist of cooling system, heating system, humidification system and air treatment systems and any other component as deemed necessary to meet the temperature, humidity and air flow conditions of each of the chambers.



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**Cooling system :** There shall be an individual cooling system for Indoor and Outdoor chambers. All the components of the cooling system except the evaporator and ducting shall be placed outside the chamber. The cooling system shall be adequate to meet the air flow conditions required (i.e. temperature, relative humidity and air flow) in each of these chambers separately. The cooling system shall be an Indirect system or cascade system where in there shall exist an intermediate heat exchanger for precise control of temperature and humidity by the circulation of an intermediate fluid or secondary refrigerant fluid by means of a special pump able to work in the indicated temperature range of the respective chambers and shall be placed inside the machine unit. The cooling is realized through the evaporation of the refrigerant that reduces the heat to the secondary fluid inside the intermediate heat exchanger.

**Heating System :** There shall be an individual heating system for Indoor and Outdoor chambers. The heating system shall be adequate to meet the air flow conditions required (i.e. temperature, relative humidity and air flow) in each of these chambers separately.

**Humidification System :** There shall be an individual heating system for Indoor and Outdoor chambers. The air humidification system shall be adequate to meet the air flow conditions required (i.e. temperature, relative humidity and air flow) in each of these chambers separately. The humidification system shall be direct humidification type such as an electrical vapour humidifier which provides the dry steam and shall avoid the formation of any condensation on the specimens

**Air treatment system :** There shall be an individual air treatment system for Indoor and Outdoor chambers. The air treatment system shall be adequate to meet the air flow conditions required (i.e. temperature, relative humidity and air flow) in each of these chambers separately. The air treatment system shall preferably be placed on the back wall of the chamber and shall consist of the following elements

1. Heat exchanger for cooling: This shall be the evaporator unit in case of direct cooling system or shall be a fan coil unit in case of water chiller type indirect cooling system
2. Heat exchanger for de-humidification: The de-humidification system shall be refrigerant based de-humidification where an additional de-humidification coil shall be placed inside the cooling system to meet the required temperature and humidity conditions of each chamber
3. Heating system : The heating system shall be of resistive electric heater type, protected by double adjustable fail-safe thermostats that disconnects the electrical power.
4. Humidification System : The humidification system shall be electric vapour generation type humidifier where the vapour flows through a orifice arranged in the airflow after the recirculation fan. The system shall be made of copper or Stainless Steel with small perforations for homogeneous distribution and uniform mixing of vapour with air.
5. Air circulation fans : All the air circulation fans shall be installed at the exit of air treatment. The fans shall be made of corrosion free materials and shall be engineered to meet temperature, humidity and air flow requirements of each chamber and also meet the sound attenuation specifications.

## **Instrumentation**

All signal conditioning and data logging instruments shall be located outside the apparatus. There shall be a centralized instrumentation panel where all the sensors shall be connected to the data acquisition system. The electrical and HVAC parameter measuring devices, also shall be located in the centralized instrumentation panel. The display and control of the entire hot box apparatus shall be controlled from the centralized instrumentation panel.

1. Minimum no. of temperature sensors (Thermocouples) to be installed : 500
2. Minimum no. of velocity sensors(probes) to be installed : 20
3. Minimum no. of differential pressure transmitters to be installed : 20
4. Minimum no. of Absolute humidity and Relative Humidity sensors to be installed: 20
5. Minimum no. of Power Analyzer : 2 nos. (1 no. to be installed in Instrumentation panel and 1 portable unit)
6. Minimum no. of HVAC measurement System : 1 nos. (1 portable unit)
7. Temperature shall be readable to  $\leq \pm 0.05$  K and be accurate within  $\leq \pm 0.1$  K
8. Heat flux transducer calibration accuracy :  $\pm 1\%$  or better
9. Air velocity measurement accuracy:  $\pm 0.1$  m/s or better and shall be hot wire anemometer type.
10. Pressure difference measurement accuracy :  $\pm 1$  Pa or better
11. Power measurement accuracy : 0.5% of the Full Scale reading under conditions of use.
12. Energy measurement accuracy : 0.5% of the Full Scale reading under conditions of use.
13. All the power supplies used shall be voltage stabilized power supplies
14. Temperature controllers for steady-state tests shall be capable of controlling temperatures to within  $\pm 0.25$ K

**Temperature Sensor / Thermocouple Specifications:** For measuring surface temperature, Thermocouples or other temperature sensors shall be typically located opposite each other on the two faces of the specimen and walls. The indicated temperature shall be within  $\pm 0.2$ K of the temperature that would exist if the sensor is not applied.

1. Type and classification of Thermocouple : T type with classification TT-T-30-SLE
2. Wire diameter of Thermocouple  $\leq 0.25$  mm
3. Thermocouple Junction diameter  $\leq 0.50$  mm
4. The thermocouple junction shall be welded or soldered
5. Adjoining wire length to be taped  $\geq 100$  mm
6. Total hemispherical Emittance of taping material or cementing or bonding material on the surface of sample specimen  $\leq \pm 0.05$
7. Temperature shall be readable to  $\leq \pm 0.05$  K and be accurate within  $\leq \pm 0.1$  K

**Velocity Sensor(probe) Specifications :**

1. Type : Hot wire anemometer probe
2. Measuring range : 0.01 to 30 m/s
3. Accuracy :  $\leq \pm 0.05$  m/s
4. Resolution :  $\leq 0.01$  m/s
5. Operating Temperature : -40 to +80 °C
6. Signal Output (Configurable): 4 to 20 mA / 0 to 10V
7. Communication : RS232/RS422/RS485 and PLC connectivity should be available.

**Differential Pressure Transmitter Specification:**

1. Parameters of measurement: measurement of absolute and gauge pressure
2. The device shall have two types of pressure sensors : stainless steel sensors and ceramic diaphragm sensor for measurement of process, absolute and hydrostatic pressure
3. Measuring range : 0 - 160 mbar (0 - 64 inchH<sub>2</sub>O) to 0 - 40 bar (0 - 580 psi)
4. Accuracy :  $\leq 0.1$  % or 1 Pa or better
5. Long-Term Stability  $\leq 0.1$  % / 12 months

6. Operating Temperature : -40 °C to +80 °C
7. Signal Output (Configurable) : 4 to 20 mA / 0 to 10V
8. Communication : RS232/RS422/RS485 and PLC connectivity should be available.

**Humidity Sensor Specifications:**

1. Measuring Parameters : Relative Humidity, Absolute Humidity, Temperature
2. Range of Temperature : -40 to +100 °C
3. Range of %RH : 0.0 to 100%
4. Dew Point Range : -90 to +100 °C
5. Temperature measurement Resolution :  $\leq 0.1^{\circ}\text{C}$
6. %RH Resolution :  $\leq 0.1\%$
7. Temperature measurement Accuracy :  $\leq 0.1^{\circ}\text{C}$
8. %RH Resolution Accuracy :  $\leq \pm 1\%$
9. Operating Temperature : -40 °C to +80 °C
10. Signal Output (Configurable) : 4 to 20 mA / 0 to 10V
11. Communication : RS232/RS422/RS485 and PLC connectivity should be available.

**Power Analyzer Specifications:**

1. Measurement Parameters : 3-Phase and 1-Phase electric parameters including Voltage, Current, Power, power factor, Frequency, Harmonics, THD with max 100 ms cycle
2. Measures Both DC & AC parameters
3. Input Channels and probes : 3 Voltage and 3 Current Input channels with all necessary clamps, current and voltage probes for entire range of current and voltage measurement
4. Current range: 0.5 to 20 A
5. Voltage range: 15 to 600 V
6. frequency range: DC and 0.5 Hz to 100 kHz
7. Accuracy for all input ranges : 0.1% reading + 0.05% of range (50) and DC 0.1% reading + 0.2% range.
8. Display Update Rate :  $\leq 100$  ms
9. Data update : up to 10 readings per second
10. Connectivity / Interface : USB, Ethernet
11. The power analyzer shall have following features
  - auto-range function to select or change the ranges of measuring parameters automatically
  - Simultaneous measurement of DC and AC signals
  - Display of numerical values, waveforms and trends
  - Separate integration functions
  - Saving measured data directly to USB memory

**HVAC measurement System Specifications** : The system shall consist high pressure gauges for measurement of refrigerant and compressor parameters, thermo-hygrometers and pressure gauge with following specifications. These devices are directly connectable to smartphone/tablet/laptop etc with dedicated software and necessary clamps and probes for the given measuring range

**Clamp thermometer**

1. Measuring range : -40 to +150 °C
2. Accuracy :  $\leq \pm 1.3^{\circ}\text{C}$  (-20 to +85 °C)
3. Resolution :  $\leq 0.1^{\circ}\text{C}$

**Pressure Gauge**

1. Measuring range : -1 to +60 bar

2. Accuracy :  $\leq \pm 0.5$  % of full scale reading
3. Resolution :  $\leq 0.01$  bar

**Thermo-hygrometer**

1. Measuring range : -20 to +60 °C
2. Accuracy :  $\leq \pm 0.8$  °C (-20 to 0 °C),  $\leq \pm 0.5$  °C (0 to +60 °C)
3. Resolution :  $\leq 0.1$  °C

**Data Acquisition:**

The following data shall be recorded during the testing period during a defined measurement interval with minimum measurement interval setting of 1 sec. The data logger shall record the data continuously and have a capacity to store this data for 120 days at 1 sec interval data frequency.

1. The total net energy or average power transferred through the metered specimen.
2. Individual energy consumption of the parameters including metering box heating energy, metering box cooling energy, power to fans, blower and any other ventilation equipment, corrections for metering chamber wall energy transfer, flanking loss, corrections for enthalpy of infiltrating air, and any other extraneous energy flows shall be recorded in similar manner for a defined measurement interval
3. All air and surface temperatures
4. Average air velocity on each side of metered specimen and any velocity sensors located
5. Flow rate at each location of air flow from ducts etc.
6. the pressure differential across the metered specimen
7. Infiltration flow rate required to maintain zero differential pressure
8. Effective test specimen dimensions and metered area
9. Hot and cold side surface temperatures
10. metering area of the hot box
11. 10 option for any other conditions specific to the test purpose.

**Test Completion criteria:** After the final test temperature conditions are reached as per initial test setting conditions, five repeated data acquisitions sets shall be obtained. The minimum time interval for obtaining these 5 sets of data is 30 min. The combination of these five data acquisition runs shall constitute a valid test if the datum obtained for each measured variable differs from its mean by no more than the maximum uncertainty of each variable

**Safety Protocol Specifications:**

**The cooling unit shall have the following safety and control specifications**

1. Low Pressure and High pressure switch to control the compressor with in its operator pressure range
2. Hand Shutoff Valve to pump down the total refrigerant gas into the condenser and receiver incase of fault.
3. Liquid Dryer installed in the liquid line of refrigerant for ministration of moisture in the liquid.
4. Moisture indicator by colour change to indicate if the refrigerant system is safely dry or dangerously wet.
5. Electrically operated Solenoid valve to remotely start/stop the flow in the refrigerant circuit.
6. Oil separator of Stainless steel 304 which intercepts the lubricant oil mixed with the refrigerant gas and to return it to the crankcase of the compressor.
7. Suction accumulator to maximize the efficiency of the relief valve.
8. Liquid receiver as per ASME section VIII division 1 for storage of refrigerant

9. Pressure Gauge
10. De-frosting circuit to remove/condense and drain the ice formation on the refrigerant coils

#### **Chamber Electric Safety requirements**

1. Each chamber shall be equipped with internal lighting of minimum 1000 Lumens
2. A lockable master switch
3. Safe thermostats that disconnect overall chamber main power components (such as compressors, fans and heaters) in case of accidental over-temperature.
4. Excess and low temperatures for test compartment by means of digital undertemperature/overtemperature switch with independent probe
5. In case of faulty operations or failures of individual components, the incorporated safety devices will cause shutdown of the system or individual groups to prevent any consequential damage. Detailed fault alarms will be displayed in plain text that will ensure detection of system faults as quickly as possible.

#### **Main safety features to be implemented in electric control panel:**

1. Min-Max Temperature Safety System
2. Emergency push buttons (internal and external)
3. Safety opening system for the door from inside and stopping of fans at door opening
4. Overload protection device for cooler (temperature release)
5. Protection devices for a short-circuit or overheat for motors
6. Protection devices for a short-circuit or overheat of heaters
7. Overload protection device for electrical circuit.
8. Main isolator switch
9. Visual alarm (working in case of alarms and indoor chamber movement)

#### **Control System and User Interface Software**

The Guarded Hot box apparatus shall have a PLC based control system such as Siemens or equivalent PLC programmable control system and software. The PLC system shall have the following specifications

1. Processing time  $\leq 60$  ns per binary instruction
2. Memory  $\geq 1024$  KB high-speed RAM for program sections
3. Program memory  $\geq 8$  MB
4. Input/Output Capability
5. Digital inputs : can connect upto 65,536 digital inputs
6. Digital outputs : can connect upto 65,536 digital outputs
7. Analogue inputs : can connect upto 4,096 digital inputs
8. Analogue outputs : can connect upto 4,096 digital outputs
9. Interface : PROFIBUS/PROFINET interface or equivalent in case of distributed automation configuration or similar standard package
10. Communication: Ethernet TCP/IP Communication port for access and control over internet IP
11. Wifi Connectivity
12. RS232/RS422/RS485 Communication ports

**PLC functionality:** The control system shall manage individual sub systems, sequencing, safety interlocks, user defined programs and operator interfaces such as HMI's. In the case of failure of utilities like power, pneumatic supply, cooling water circulation etc. the built in PLC software shall automatically shutdown the subsystems to ensure the safety of operating personnel, test object and facility equipment.

The control system should also have various essential and safety features such as but not limited to Inspection Window, Safety Thermostats, Automatic Temperature and Humidity Setting, Adjustable Limits, Low water alarm, High and Low pressure refrigerant gas indicator, Over heat indicator for

compressor, Door open protection, Over temperature and under temperature of chamber indicator, Test complete notification, Remaining test time display, Temperature/RH sensor fail notification, SMS alert for all notification, Remote access of computer via LAN, Real time graph, Defragment system status for condensing, Fresh Air setting percentage control, Two chambers operating with single AHU and humidity unit remotely as required, and any customized feature as required by user

**User Interface Software Specifications:** The UI software should be based on SCADA or similar standard packaged software compatible with the PLC and having the whole system display on single screen with live status of all controlled parameters at all locations. All the systems shall be accessible and controllable from the system software. All the data logged in the Data Logger must be fully accessible through provided software. The full version of software should be provided with perpetual license and Free upgradation. The software shall have the following features

1. Manual or automatic measuring procedure at atleast 500 definable measuring locations per measurement
  2. Integrated calibration routines
  3. Display facility of all relevant data, measuring results, intermediate and final results as graphs and Tables
4. Measuring point function test and monitoring with defined limit values
5. Monitoring of the test chamber with display of relevant messages and automatic shutdown when exceeding critical limits
6. Signaling system for display of status, fault and system messages
7. Extensive mathematical functions
8. Numerical and graphical report generation in accordance with mentioned standards
9. Security concept with user and administrator levels
10. U-Value Report Generation after satisfactory Test completion.

**Computer:** 1 nos, The computer shall be integrated inside the Instrumentation Panel and shall consist of Processor, 8 Cores/16 Threads, base frequency >3 GHz, Turbo frequency > 4.5 GHz, 32 GB Ram having speed >2666 MHz (with matching FSB speed), 256 GB SSD Harddisk, 1.0 TB SATA 7200 rpm Harddisk, 8GB Graphics Card, A 23-24 inch LED Backlit IPS monitor with HDMI and Display port connectors and video cables, Integrated internal speakers, Integrated network controller card, Genuine Windows 10 Professional 64-bit Operating System, Wireless USB optical scroll mouse and wireless standard keyboard, 2 hr. Backup UPS, Multifunctional Colour Printer

**Human Machine Interface specifications :** 2 nos. of programmable and controllable HMI with specifications as follows

display size  $\geq$  15 inches, CPU: Cortex A8 Dual Core, TFT widescreen display, LED backlighting, No. of colours : 65,536, Resistive touch screen, Numeric and Alphanumeric onscreen keyboard Ethernet port, USB, RS232/422/485 communication port

**Laptop Specifications:** 1 nos., Display  $\geq$ 14", Resolution : 2560x1600 pixels or better, Touch Screen, RAM 16GB, OS : Windows 11, SSD : 1TB or better, Battery capacity : 75WHR or better, Refresh Rate  $\geq$  120Hz or better, web camera, pointer device, touchpad, internal mic, speakers, headphone and mic combo jack, HDMI port

**Power Requirement:**

415V, 3 Phase, 50 Hz., Inverter Backup for entire electronic and control systems of the U Value apparatus for 24 hours and in addition backup needed for safe shutdown of entire system in case of power failure.

## Other Accessories

1. 3 calibration panels of different sizes which are most common like one for general window size, general door size and one for maximum possible sample size (W X H): 3.0 m X 2.5 m with factory calibration certificate
2. 3 test masks of different sizes which are most common like one for general window size, general door size and one for maximum possible sample size (W X H): 3.0 m X 2.5 m with factory calibration certificate
3. Reference sample: At least 1 reference with calibrated from recognized national / international lab shall be provided for calibration of U value facility.

**Warranty:** 3 year on the entire system including Instrumentation panel, controls and software with 2 years extended warranty option.

## Additional Qualification Criteria:

1. The quotation shall consist of the 3D drawings and design of the U Value apparatus quoted showing various views including plan, sectional views, top and front view and isometric view of the all the three chambers of the system in open chamber condition as well as closed chamber including AHU devices and Instrumentation panels. These 3D drawings shall meet the specifications of the U value apparatus described.
2. The quotation shall consist of brochures and model no.s of all the equipment including sensors and measurement devices to be installed in this hot box apparatus where the required specifications as per this document are clearly mentioned in those brochures.