Specifications for Supply of High Temperature High Vacuum Annealing Furnace

1. Scope

This specification defines the requirements for a vacuum furnace which is to be fabricated and delivered to Raja Ramanna Centre for Advanced Technology (RRCAT), Indore, India. The vacuum furnace will be used for heat treatment of Niobium accelerator cavity.

2. General Description

The accelerator cavity assembly is approximately 1250mm long and 250mm in diameter (See Figure 1). The cavity is an assembly of niobium cells and niobium-titanium flanges. The cavities will be baked under full vacuum in order to reduce the hydrogen concentration (Hydrogen degassing) and will relieve stresses induced at various stages of fabrication.

The vacuum furnace will hold the cavity horizontally. Two process schemes are planned for annealing of the cavities in the above furnace. As a first scheme (Option-1), cavities will be baked for 5 to 10 hours at 600 to 800°C, and, for 2 hours at 1300°C as a second scheme (Option-2). The manufacturer has to submit offers for both the options separately. The vacuum vessel will have a vacuum pressure of 1 x 10^{-7} mbar or better at 600°C and in the range of 10^{-6} mbar above 1000°C.

3. Note for the Furnace Manufacturer

a. The manufacturer of this vacuum furnace ***should be*** a Company regularly engaged in the design and manufacture of vacuum furnaces of the required size, temperature & vacuum range, and should be capable of designing and fabricating the furnace in accordance with the requirements of the latest available edition of all relevant safety codes, at the time of fabrication.

b. The manufacturer should enclose the list of clients in India/ abroad to whom he has supplied furnaces of similar size, temperature & vacuum range along with the contact details (name of the contact person, phone number, email address etc).

c. The manufacturer must submit a detailed quality assurance programme (QAP) indicating quality checks applicable at various stages of fabrication starting from raw material to final testing.

In case of order placement a detailed QAP with necessary drawings, documentation and calculations for obtaining necessary approval shall have to be submitted to RRCAT, before taking up the furnace fabrication

d. A comparative statement of the technical specifications of the furnace indented versus the furnace being offered by must be furnished by bidders., ***without this comparative statement the offer is liable to be rejected.***

e. Foreign manufacturers shall also be considered, however manufacturers having authorized sales/ service support in India shall be preferred..

f. The manufacturer shall complete the questionnaire (Annexure-A) and submit it along with their offer. **Without the completed questionnaire the offer is liable to be rejected.**

g. All the bought out items like pumps, gauges, valves, electronics etc should have a service facility in India.

4. Safety

The vacuum furnace should meet requirements of all applicable codes and standards such as OSHA, NEPA, ANSI, ASME etc. The furnace should be in conformance with all applicable electrical, fire and safety standards.

a. All the operation modes; manual & automatic and maintenance, shall guarantee that the furnace and the pumping unit are not damaged by a power interruption or an emergency stop operation. A key lock is required for the maintenance mode. The suitable isolation valves leading to the vacuum pumps shall fail shut during a power failure or any unexpected interruption. After such an interruption, the gate valves will remain in closed condition until the operator resets the valves with the controller.

b. Design and fabrication of the main shell and doors of the furnace shall be as per the ASME Boiler and Pressure Vessel Code, Section VIII, Div. 1 and the ASME Boiler and Pressure Vessel Code, Section IX. Inspection during fabrication of the main shell assembly thus fabricated will be inspected as per ASME Pressure Vessel Code Section V or any other relevant code. The vessel need not be code stamped.

c. Welding shall be done using qualified weld procedures and welders under the rules of the most current version of the ASME Boiler and Pressure Vessel Code, Section IX. The Weld Procedure Specification (WPS), Procedure Qualification Record (PQR), and Welder Performance Qualification (WPQ) shall be included in the documents provided by the manufacturer. If required, third party certificate shall be provided by the manufacturer.

d. Details of suitable interlocks for smooth functioning of the furnace and its sub systems and protection of equipment as well as job, against conceivable malfunctioning (e.g for thermal cycle, vacuum pumps' operation etc) shall be provided by the manufacturer.

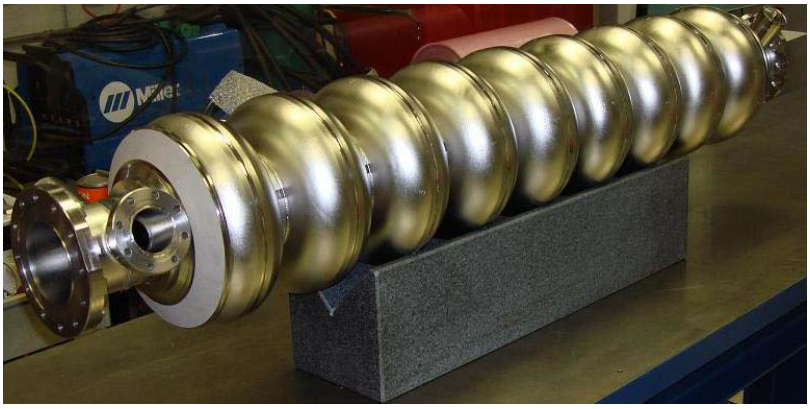

Figure 1: Accelerator Cavity

5. Manufacturer's responsibilities

a. The manufacturer is required to furnish design calculations that demonstrate the vessel design is in accordance with the ASME Codes as mentioned above for both internal and external pressures. The vessel need not be Code-stamped.

b. Detailed drawings of the vacuum furnace vessel design based on the above design shall be provided.

c. Under the rules of the ASME Boiler and Pressure Vessel Code, Section IX, the Weld Procedure Specification (WPS), Procedure Qualification Record (PQR), and Welder Performance Qualification (WPQ) shall be provided. If required, third party certificate shall be provided by the manufacturer.

d. The manufacturer shall also provide emergency backup scheme for cooling of furnace in case of power failure. **The supplier shall clearly specify his scope for emergency backup cooling of furnace.**

e. The furnace manufacturer should submit design calculations for power requirements and radiation shield requirements such as appropriate thickness of radiation shields and their location indicating clearly number of shields for both the options. There should be adequate provision for free expansion/contraction of shields during the heating cycle.

6. Main Parameters of the Furnace

Sr. No	Parameter	Value
1.	Purpose	To vacuum degas hydrogen from niobium accelerator cavities
2.	Working volume (Clear Hot Zone Size)	Diameter 400mm x Depth 1500mm with temperature control as specified in this document
3.	Configuration	Horizontal, Front Loading with demountable dished end doors at both ends.
4.	Material of construction for Vacuum Chamber	SA 240 Grade 304L/316L Stainless Steel, double wall with water cooling and provision for drain.
5.	Material for support structure	SA 240 Grade 304L/316L Stainless Steel
6.	Heaters	***Option-1 : Pure Molybdenum elements*** ***Option-2 : Lanthanated Molybdenum (ML) elements***
7.	Heating Zones	The furnace shall have multiple heating zones with independent Power Supply controls (at least three).

Sr. No	Parameter	Value
8.	Heat Shields	5 layers (minimum) of Molybdenum Thicknesses of Molybdenum layers shall be – 1st layer - 0.50mm minimum 2nd layer onwards - 0.25mm minimum ***The supplier shall provide a conceptual design & scheme for number of shields for both options & mounting of shield to provide no deformation during operation along with the offer.*** *Use of Stainless Steel for shields is not permitted*
9.	Temperature in the Working Volume	<u>Option-1</u> 1000°C maximum, 600 – 800°C, standard process temperature range <u>Option-2</u> 1400 °C maximum 600 – 800 °C and 1300 °C, standard process temperature range ***Separate technical & commercial offer shall be submitted for both the options***
10.	Heat up ramping	1 to 10 °C / minute
11.	Temp. Uniformity	± 5 °C in the working volume *(for both the options)*
12.	Partial pressure clean-up system	The furnace shall have Hydrogen purging capability at (500 micron ±50 micron) for **partial pressure clean-up system** (for cleaning heating elements, in case they are oxidized)
13.	Inert gas Purge	Partial pressure (500 micron ±50 micron) boiled-off argon gas purge capability during heat cycle (purge valve on/off, rough valve on/off)
14.	Working Vacuum	1×10^{-7} mbar or better at 600 °C 1×10^{-6} mbar or better at > 1000 °C *(in the vessel, measured by a suitable gauge located diametrically & longitudinally opposite to the pumping port)*

Sr. No	Parameter	Value
15.	Ultimate Vacuum	5 x 10^{-8} mbar or better (empty, clean, cold furnace) *(in the vessel, measured by a suitable gauge located diametrically & longitudinally opposite to the pumping port)*
16.	Vacuum System	<u>For Obtaining Roughing and Holding Vacuum in the chamber–</u> • Dry Vacuum pump, Scroll, roots and/or claw combination or screw type and not of diaphragm type, swept volume free from any oil, grease, hydrocarbon etc. of *Edwards/ Leybold/ Alcatel/ Kinney* make of adequate pumping speed. • Noise suppressing silencer. • SS Bellow of Suitable length, connecting adopters/flanges, clamps, Viton O-rings etc. <u>For obtaining High Vacuum</u> – Cryo Pump On-Board type *CTI/Leybold* make with automatic operation of the pump with manual override facility, having heaters and temperature sensors at both the stages inside of the pump, 25 meters system cables for remote operation with automatic mode regeneration of the pump. Helium compressor shall be water cooled. Installation kit should include Helium charging/ transfer lines, maintenance manifold and two adsorbers. ***<u>Extra Spares</u> for five years duration trouble free operation of both Cryopump and Dry pump.*** <u>Valves</u> Electro-pneumatically actuated gate valves in between vacuum chamber and cryo pump and all other valves should also be electro-pneumatically actuated gate valves of suitable size. <u>Gauges & Controller</u>: Convectron and Ion gauges to monitor the vacuum level inside the vessel. Cold-cathode gauge to monitor pressure on the cryopump side of the gate valve. For display and control of vacuum of the entire

Sr. No	Parameter	Value
		process cycle and interlocking purpose, gauges of Alcatel/Pfiffer /Edwards/Varian make with dark color LCD display shall be used.
17.	Vacuum Pump Down Time in the Vacuum Chamber in cold condition	Atmosphere to $5x10^{-2}$ mbar ~ 15 minutes Atmosphere to $5x10^{-5}$ mbar ~ 45 minutes Atmosphere to $5x10^{-7}$ mbar ~ 90 minutes Atmosphere to ultimate vacuum ~ 300 minutes After achieving 12K temperature in the Cryopump and connecting the pump to the vacuum chamber
18.	RGA System	A Residual Gas Analyzer (RGA), range 0-100 amu, with RS232 port, shall be provided and the partial pressures shall be data logged. The RGA shall be installed at a specific location in order to allow an accurate monitoring of the partial pressures. Make – Pfeiffer/ Hiden
19.	Cool-down of work piece (job)	Under vacuum - When the job cools down to a temperature between 30 and 50 °C, the chamber should be backfilled to atmosphere with boiled-off argon gas (automatic backfill gas shut-off when atmospheric pressure is reached) Forced Cooling – Cooling rate shall be ~40°C/min from 1000 to 200°C by forced circulation of Argon Gas from multiple nozzles located along the circumference of the furnace. The gas circulation shall be effected by blower of suitable capacity (~ 25 HP/ 30000 lpm or above). The re-circulated gas shall be cooled by Stainless Steel Heat exchanger of suitable capacity (~ 150 kW). The pumps used with the heat exchanger should be of Stainless Steel material. A conceptual design document shall be made available with the offer & detail design at the time of order

Sr. No	Parameter	Value
20.	Temperature Control	Automatic and manual temperature control with PID temperature control unit, separate temperature units for each zone for control and over temperature with Red color LCD display so as to read values easily. Eurotherm/ Honeywell/Yokogawa make. Total of 30 numbers of thermocouples should be used in the furnace. Control and Over-temperature thermocouples for each heating zone for a total of 20 thermocouples. 10 thermocouples need to be attached to monitor work piece temperature.
21.	Data logging of process parameters	All the temperature, pressure, vacuum and key diagnostics of the process shall be data logged for at least 100 hours with adequate PC memory. A desktop computer with high quality printer of suitable configuration should be supplied along with the furnace.
22.	Furnace Cooling	Vessel including the doors, power feed throughs, shall be water cooled. vacuum pumps shall also be water cooled, but independently. **The furnace manufacturer shall provide the total water cooling requirements of the furnace** and offer a closed loop water cooling system for the furnace. **The manufacturer shall submit the scheme for emergency backup for cooling in case of power failure during operation clearly mentioning his scope of supply.**
23.	Power Requirements	The power should be 415 ± 10% VAC three phase 50 Hz on primary side and low voltage high amperage on secondary side(heating element side), and should be thyristor controlled either in primary or in secondary side. Sufficient margin/allowance for voltage fluctuations, spikes etc shall be considered while selecting thyristor ratings and other electrical components. The thyristors should not be loaded more than 75% of their rated capacity for drawing the maximum power at any point of time during

Sr. No	Parameter	Value
		heating cycle of the system. Step-down transformers shall be oil-cooled type with temperature indicating device at the top of the unit, provision for delta/star connections and to be oil cooled. Provision for measuring currents/votages at primary and secondary of the power supply. Make of transformers should be reputed with ISO certification. Make of thyristor : Eurotherm/Seimens or euivqlent ***Vendor shall specify the actual requirements with support of design calculations*.**
24.	Maximum Weight of Work Piece	700 kgs (1500 lbs), work-piece to be loaded on the bottom hearth. (Details specified later in the document) **The manufacturer shall submit the scheme giving details of support & material handling in his offer i.e for smooth loading & unloading of the job.**
25.	Max allowable floor Load	*Manufacturer shall specify* same will be provided by RRCAT
26.	Available floor space for installation of the furnace	The Furnace Layout shall be built as compact as possible without comprising on ease of maintenance and manufacturer shall mention the footprint for the furnace including adequate space for maintenance and repairs in their offer.
27.	Painting	The furnace along with its structural supports should be epoxy painted before dispatch.

7. Vacuum Chamber

a. The double walled vessel shall have a cylindrical center part where the usable work hot zone is accommodated.

b. It is preferable that, the vessel shall have access from both ends of the center part. The front end shall have a demountable type hinged door for regular access. The back end shall also be a demountable dished end for maintenance purposes.

c. All of the parts shall be double walled for water-cooling with suitable baffles and made of stainless steel SA240 Grade 304L/316L (inner and outer jacket). The design of the water cooling jacket shall assure that there are no hot spots above 30°C on the vessel.

   The furnace will be installed such that the front opens in class 10000 clean room (where loading & unloading of job will be carried out). The remaining portion of the furnace will be positioned in an air conditioned area outside the clean room.

d. The surface finish of the vessel's inner surfaces shall be Ra <1.6 micron. The manufacturer shall propose the process to achieve the above mentioned surface finish for approval of RRCAT. The finish will be inspected at intermediate stage by representatives of RRCAT.

e. The vacuum sealing between parts shall be made with VITON O- ring seals. The O-ring shall be a single piece, free from any inclusion, crack, line or projection. The temperature of the door flanges should not rise more than 50°C to avoid damage to the seals.

f. The furnace shall be made with a front door for easy access to the hot zone allowing the operator to reach the hot zone entirely when he will load the workpiece. Pneumatic closing & opening of front dished end is required. The molybdenum heaters on the door have to be protected against any accidental bumps during loading of the workpiece with some caging or shielding.

g. Two view ports with shutter are required , one each on the front & back doors to allow viewing of the hot zone during heat cycle.

h. Ports : The manufacturers shall define the location and the configuration of the ports for vacuum gauges, electrical feed through, cooling etc. Extra pumping port suitable for the pump offered and feedthroughs shall be provided on the main shell (one each).

i. Design and fabrication of the main shell and doors of the furnace shall be as per the ASME Boiler and Pressure Vessel Code, Section VIII, Div. 1 and the ASME Boiler and Pressure Vessel Code, Section IX. Inspection during fabrication of the main shell assembly thus fabricated will be inspected as per ASME Pressure Vessel Code Section V or any other relevant code.

j. The manufacturer shall provide the Weld Procedure Specification (WPS), Procedure Qualification Record (PQR), and Welder Performance Qualification (WPQ) as defined in the most current version of the ASME Boiler and Pressure Code, Section IX. If required, third party certificate shall be provided by the manufacturer.

8. <u>Heating System and Shields:</u>

a. The heating system shall be made of pure molybdenum (99.95% purity) elements for *Option-1* & Lanthanated Molybdenum (ML) for *Option-2*. The furnace shall contain at least three heating zones with independent control.

b. The hotbox cage should be of stainless steel and should support heating elements and radiation shields of molybdenum.

c. ***No carbon steel material shall be used for the hotbox***

d. The heating elements of a flat, strip-type design are desirable. The heating elements shall be sized by the manufacturer in order to provide the specified temperature limits and temperature uniformity with the proper heating rate and power density. The manufacturer shall provide the size of the heating elements and the spacing between them, the power density calculations for the heating elements and expected temperature of the heating element when the furnace is operating at the process temperature. It is preferred that the manufacturer should provide a Paschen curve of the heating element design. The operating voltage shall be low enough, such that there is no arcing.

   Heating elements are to be connected in delta/star configuration whichever is the most suitable and ends of the elements should be connected to feedthroughs in such a way that there is no over heating or cooling at joints. **The surface of the elements should be free from any scratch, crack, dent etc.**

e. The ramp rate of the heaters shall be between 1 to 10 °C per minute. The manufacturer shall calculate the power requirements for the heaters. The heating system shall be designed such as to minimize the distortion of the heating elements during operation.

   A conceptual design document shall be made available with the offer & detail design after the placement of order.

f. The ceramic insulation that will be used to support the heating elements shall be properly designed to eliminate any cracks during heating and cool down operations. **Conduits and spacers of Alumina ceramics with purity 96% or higher shall be used in the hotbox for electrical and thermal insulation.** These conduits and spacers should support dead weight of heating elements, radiation shields and thermal loads during heating process and loads due to un-even expansion and contraction of heating elements. The alumina ceramics should have zero porosity.

   The sublimation can cause some material to coat these ceramic insulation parts (they become conductive); the manufacturer shall assure that there is no potential of any electrical short circuit during any heat process.

   A conceptual design document shall be made available with the offer & detail design after the placement of order

g. The hot zone assembly shall contain a minimum of 5 Molybdenum Heat Shields. The heat shields shall be made by pure molybdenum, no stainless steel allowed. Thickness of Molybdenum layers shall be minimum 0.5mm for 1st layer & minimum 0.25 mm for subsequent layers. The spacers placed between each panel shall ensure the correct clearance and avoid

deformation leading to a mechanical contact between shields during operation.

h. It is preferable that the heat shield at the front and back ends be attached to the doors.

9. Work Piece Cool-down :

- Under vacuum - When the job cools down to a temperature between 30 and 50 °C, the vessel shall be backfilled to atmosphere with boiled-off argon gas (automatic backfill gas shut-off when atmospheric pressure is reached).
- Forced Cooling – Cooling rate shall be 40°C/min from 1000 to 200°C by forced circulation of Argon Gas from multiple nozzles located along the circumference of the furnace. The gas circulation shall be effected by **externally mounted** heat exchanger & blower of suitable capacity (~ 25 HP/ 30000 lpm or above). Calculations to support the capacity should be enclosed with the offer. The re-circulated gas shall be cooled by Stainless Steel Heat exchanger of suitable capacity (~ 150 kW). The pumps used with the heat exchanger should be of Stainless Steel material.

  A conceptual design document shall be made available with the offer & detail design after the placement of order

10 High current feed-throughs

a. All the high current feed-throughs shall be equipped with flanges and double radial seals. For each feed-through, the central electrical conductor shall be made of copper, water cooled and electrically insulated from the flange with a brazed ceramic. A conceptual design document shall be made available with the offer & detail design after the placement of order.

b. On the vacuum side, the connections shall be designed to minimize the cooled zone on the copper conductor of feedthroughs.

c. The mechanical orientation of the feedthroughs shall be vertical relative to heating elements.

d. During the heat ramp and cool down, the hot zone will expand and contract. The design of the feed-through penetration shall assure that there is no bending force (due to hot zone thermal expansion or contraction) on the power feed-throughs that might cause a vacuum leak to the furnace.

11 Water-cooling system

a. The manufacturer shall offer the best, safest and most cost effective cooling scheme for the furnace. The furnace manufacturer shall specify the cooling requirements for the furnace during normal operation and shall provide dedicated adequate capacity water chillers of reputed make. The water chillers should be made from rust proof stainless steel construction to avoid any rusting in water pipe line. The water cooling lines/piping between the cooling system and the furnace should be of stainless steel construction for

avoiding water discoloration due to rusting. All the water circulation pump used shall be of Stainless Steel material. Cooling towers are not acceptable.

b. All water-cooling lines shall be fitted with flow meters, pressure switches, filters and flow guards that can switch off the power supply in case of lack of cooling water. The cooling system shall be designed to allow cool-down of the furnace from the maximum temperature in a stand-alone mode without any risk of overheating of the vessel including all the flanges (especially the door seal flange). **Appropriate air bleed points shall be provided in order to remove all trapped air from the water system**.

c. Emergency Backup Scheme - The manufacture shall propose the scheme for emergency backup system for cooling of furnace in case of power failure. The supplier shall clearly indicate his scope of work in the emergency backup system.

12 Thermocouples

a. 30 number of thermocouples shall be used in the furnace.

b. 20 number of thermocouples used for measuring and controlling the resistor temperatures shall be of “S” or “K” type with protective alumina tubes.

c. 10 number of thermocouples used to monitor work-piece shall be of “K” type (Chromel /Alumel) with Inconel 600 sheath.

d. A temperature gauge on the cryopump side of the gate valve shall also be installed.

13 Vacuum System

- For Obtaining Roughing and Holding Vacuumin the chamber –

  Dry Vacuum pump, Scroll, roots and/or claw combination or screw type and not of diaphragm type, swept volume free from any oil, grease, hydrocarbon etc. of Edwards/ Leybold/ Alcatel/ Kinney make of adequate pumping speed to obtain vacuum of 5×10^{-2} mbar.

  The pumps shall be provided with noise suppressing silencer. SS Bellow of Suitable length, connecting adopters/flanges, clamps, Viton O-rings of etc shall be used for the vacuum connections.

- For obtaining High Vacuum –

  Cryo Pump On-Board type CTI/Leybold make with automatic operation of the pump with manual override facility, having heaters and temperature sensors at both the stages inside of the pump, 25 meters system cables for remote operation with automatic mode regeneration of the pump. Helium compressor shall be water cooled. Installation kit should include Helium charging/ transfer lines, maintenance manifold and two adsorbers.

  Hydrogen pumping speed shall be 500 liter / second minimum

  Extra Spares for five years duration trouble free operation of both Cryopump & Dry pump.

- Pump Down Rate :

  Atmosphere to $5x10^{-2}$ mbar ~ 15 minutes

  Atmosphere to $5x10^{-5}$ mbar ~ 45 minutes

  Atmosphere to $5x10^{-7}$ mbar ~ 90 minutes

  Atmosphere to ultimate vacuum ~ 300 minutes

  After achieving 12K temperature in the Cryopump and connecting the pump to the vacuum chamber

- Residual Gas Analyzer : 100 amu system from a standard manufacturer like Pfeiffer, VG etc with RS232 port for communication with a computer, make Pfeiffer/ Hiden
- Rough Vacuum Valve : Gate valve, VAT or equivalent make
- High Vacuum Valve : Gate valve, all metal with Conflat flanges, VAT or equivalent make
- No poppet valves are permitted.

Vacuum pump down calculations should be enclosed with the offer to support the vacuum pump selection.

14 Partial Pressures

a. Partial pressure allowed at 600 °C:

Oxygen partial pressure: less than 1×10^{-8} mbar
Hydrocarbon amount: less than 1×10^{-13} mol

b. ***Option to control the furnace heating with the partial pressure of hydrogen for partial pressure clean-up system for removing oxide deposition on elements & boiled-off argon gas during heat cycle with partial pressure of 500 micron ±50 micron shall be provided in the furnace*****.**

15 Controller and Displays

a. A PC based PID controller (Eurotherm/ Honeywell make) shall be furnished with the furnace for the control of the temperature in multiple hot zones, vacuum and positive pressure levels. The PLC (Mitsubishi make) shall be used for interlocking self-control of the furnace in the PC along with control cards (temperature, vacuum, pressure etc.)

b. The PC shall have user-friendly Microsoft Windows based control software (preferably SCADA).The PC based controller shall be able to control the power fed to the multiple heaters individually. The PC shall have be state-of-the-art technology. The manufacturer should offer a PC with suitable configuration as part of the proposal.

c. The recorder capability shall be in the same PC based controller. The data acquisition shall be able to record data from various temperatures, pressures to monitor the furnace control and over-temperature, temperature

distribution of the work piece, vacuum and pressure gauges, RGA partial pressures throughout the heat cycle for at least 100 hours with adequate PC memory capability.

d. The controller, software and displays shall be user friendly for easy programming, monitoring and operation of the furnace.

e. A complete backup/recovery disk shall be supplied.

16 Workpiece Loading into the hot zone

The furnace shall have parallel **guide rails** inside the hot zone on which a **hearth** carrying the work piece (job) will slide & sit. This hearth with the job will be loaded in the furnace hot zone with the help of a **loading cart**.

The furnace shall have a frame of three parallel rails, **made from Titanium Zirconium doped molybdenum (TZM)** at the bottom of the hot zone. These rails will act as guides for the hearth. The height of the guide rails should be such that the job is located in the centre of the hot zone of the furnace.

The bottom hearth will be perforated type of suitable length having sufficient thickness to avoid any deformation during the process. The hearth shall be made from **Lanthanated molybdenum (ML)**.

The loading cart shall have a manually pumped hydraulic cylinder for raising and lowering the load, (fork lift type) with adjustable high & low limit stops and angle adjustment. The cart should be able to carry & load the hearth (with job) inside the furnace hot zone. This cart shall be engineered properly so that there is no risk of tip over, which can damage the job or cause safety hazards for personnel. A sample loading setup is shown in the below pictures for reference (Fig 2,3 and 4):

The loading cart , Hearth & guide rails shall be designed and provided with the furnace.

A conceptual design document for loading cart, hearth & guide rails shall be made available with the offer & detail design of the same after the placement of order

Figure 2: Cavity Loading Cart with Hearth & cavity

Figure 3 : Cavity loaded inside the furnace

Figure 4: Rails at the bottom of the hot zone to support the bottom hearth

17 Operation

a. In the automatic operation mode, the furnace shall carry out a pre-programmed thermal cycle. The controller shall control the vacuum pumping and heating start-up automatically. When the desired vacuum level is achieved, the controller should start the programmed heat cycle automatically. The operator shall be able to load the program to the furnace with ramp, soak and dwell heating profile to the PC based controller. From the PC based controller, the vacuum pumps should be controlled. After the vacuum level is achieved, the operator shall be able to read the vacuum level from the PC monitor. After each sequence of the operation, pumping, heat cycle start up, program, the operator shall be able to monitor the performance of each step and shall be able to stop the all operations with an emergency stop button.

b. In the manual mode, the operator should be able to manually control from the control panel. The operator should be able to control the pumping sequence for the evacuation of the furnace and shall have the possibility to close or open all the valves and start or stop all the pumps. In this mode, the thermal cycle shall only start if the necessary safety conditions are fulfilled.

c. For the furnace cool-down, the operator shall be able to select any one of the two modes, natural or inert gas cooling. The natural cooling mode shall correspond to the cool-down of the furnace under vacuum at the end of the thermal cycle. The inert gas cooling mode shall correspond to the cool-down of the furnace under controlled gas atmosphere at the end of the thermal cycle. The manufacturer shall provide the safest temperature and partial pressure (below 1 atm) at which the inert gas cooling may be carried out. The furnace shall be equipped with proper interlocks so that the introduction of inert gas at a temperature does not damage the hot zone or cause a vacuum leak due to hot gas circulation.

d. Safety Interlocks – Safety interlocks should be provided for safe operation of the furnace and to protect the system from un-authorized use/operation. List of interlocks proposed by the manufacturer must be furnished in their offer

18 Cleanliness issues

a. After fabrication, the vacuum vessel chamber shall be cleaned according to common **UHV practice**. The manufacturer shall specify the cleanliness method proposed by them in their offer.

b. Excessive dust or airborne particulate generation by any main or sub-components of the furnace should be eliminated, by replacing them with the ones that will have less probability to create excessive dust and particulates.

19 Safety devices

a. The furnace shall be fitted with alarm devices for over-temperature for every heating zone. From the control cabinet, the operator should be able to adjust the maximum temperatures corresponding to these alarms, up to the maximum working temperature of the furnace.

b. **Interlocks** :

The furnace control shall have all the possible interlocks for thermal cycle, cooling system, vacuum system etc. for protection of equipment, its sub systems as well as the loaded job. The manufacturer shall provide the complete list of interlocks in the offer. Typical interlocks required are –

- Over-heating of the vacuum vessel
- Over-heating of one of the high current feed-throughs
- Over-heating of workpiece thermo-couple(s)
- Lack of vacuum level
- Lack of water flow
- Lack of water pressure
- Lack of compressed air pressure (for pneumatic components)
- Lack of inert gas pressure for purge & backfill.
- Vacuum interlock for vacuum pump operation.
- Vacuum & temperature check before the flange is opened.
- Misbehavior of any component/sub-system

etc

c. The control cabinet shall be fitted with a flashing light for all of the security devices.

d. The total number of alarm devices and the levels of the alarms listed above shall be defined by the manufacturer in order to ensure safe conditions for the furnace.

e. In addition to the alarms, the furnace shall be equipped with safety interlocks to protect the hot zone from any vacuum leaks arising from the hot zone or the rest of furnace components due to any mechanical, electrical damage.

The manufacturer shall design and implement the safety interlocks for safe operation of the furnace in manual and automatic modes. A conceptual design document shall be made available with the offer & detail design at the time of order.

f. A vacuum safety relief device will be installed on the vessel. The set pressure of the relief device shall be 1-atm.

20 On-site Inspections (witness and hold points)

a. RRCAT reserves the right to perform visit manufacturer to assess their QA program prior to the start of fabrication. This will include physical inspection of raw material before starting fabrication, review of material test certificates etc.

b. RRCAT reserves the right to make on-site inspections of the manufacturer's facility at any time ***during fabrication*** of the vacuum furnace with particular interest at the following manufacturing stages:

   i. Fabrication and welder qualification

   ii. Final assembly

   iii. Inter-stage Inspection including vacuum and leak testing of double walled main shell and double walled door ends individually and in assembled condition at fabrication stage.

   iv. Packaging for shipping

21 Services provided by RRCAT

RRCAT will provide the following necessary utilities for the furnace :

- Power
- De-mineralized (DM) water
- Compressed air
- Furnace site preparation
- Inert Gas delivery lines

22 Testing

Two sets of tests will be performed on the completed vacuum furnace.

Ist Test - Tests to be carried out at the Manufacturer's premises*:*

The furnace shall be completely assembled with systems as indicated in the purchase order and made available for acceptance tests at the Manufacturer's premises. The entire furnace shall be subjected to:

- A leak check based on the static pressure increase method
- A leak check based on the mass spectrometry (Helium leak detector), the acceptance criteria will be $1x10^{-9}$ mbar.liter/s Helium leak

- A control of the ultimate vacuum pressure
- A hot test with the temperature at 600 and 1000 °C (for option 1 or 600,1300 and 1400 °C (for option 2) with measurement of the working vacuum pressure. **Without this test, clearance for shipment will not be provided.**
- A mechanical and electrical function test
- A test of the pumping sequence in automatic and manual mode
- The temperature uniformity shall also be evaluated at the process temperatures according to a procedure that will be defined by RRCAT and agreed by the manufacturer.
- After cool-down, open chamber and inspect hot zone for thermal shorts, warped heat shields or other signs of heat related failure.

a. RRCAT reserves the right to be present or to be represented by an organization of its choice, to witness the tests carried out at the Manufacturer's premises. The manufacturer shall give at least 10 working days advance notice of the proposed date of any such tests.

IInd Test - <u>Tests to be carried out at RRCAT :</u>

a. The furnace shall be supplied and installed at RRCAT.

b. The furnace shall be completely assembled with systems as indicated in the purchase order at RRCAT by the manufacturer.

c. The entire furnace system shall be subjected to the same tests as those performed at the manufacturer's premises.

23 <u>Installation</u>

a. The vacuum furnace installation shall be made at RRCAT by the manufacturer.

b. <u>Training</u> :

i. **One week** Training program shall be conducted by manufacturer at their premises for two of purchaser's representatives, covering assembly and dismantling procedures, safe mode of operation and maintenance of subsystems involved and software related to RGA, PLC based control and SCADA incorporated in the equipment including diagnostics and modification/up-gradation capabilities. **The to and fro air fare (traveling expenses), local hospitality including lodging & boarding shall be to Manufacturer's account.**

ii. The manufacturer shall conduct **one week** hands on training on operation & maintenance of the furnace at RRCAT immediately after the installation & commissioning of furnace at RRCAT. **The travelling, lodging & boarding expenses for the manufacturer's personnel shall be borne by the manufacturer.**

24 Information and documentation management

The manufacturer shall deliver **three hardcopies** of complete sets of technical documentation, which provide for safe operation and proper maintenance of the furnace system. The documents shall contain:

a. The operating instruction manual of the furnace

b. The manuals of all the equipment used such as pumps, RGA, valves, recorder, controller etc.

c. A complete set of drawings of all parts of the furnace

d. Schematic of the vacuum relief system and the inert gas system

e. Detailed descriptions of each components and sub-components. For the components shown in the schematic, there should be manufacturer's part number, which should match the drawing.

f. Detailed drawings of the vessel, the vacuum system and the inert gas system

g. Detailed design calculations of the vacuum vessel

h. Weld Procedure Specification (WPS), Procedure Qualification Record (PQR), and Welder Performance Qualification (WPQ) for the vacuum vessel

i. A detailed list of spare parts showing the number of elements installed and making reference to the drawings in the technical documentation.

j. List of necessary spares for 5 years of trouble free operation should be submitted along with the offer

k. The electrical wiring diagrams for all the electrical & electronics including PID controller, thermocouple layout, power supply etc.

l. Test results from the tests that are specified at serial No 22.

25 Packing and Transportion to RRCAT

a. The manufacturer is responsible for packing and the transportion of the furnace to RRCAT. He shall ensure that the equipment is delivered to RRCAT without damage and any possible deterioration in performance due to transport conditions.

b. Before the installation at RRCAT, there will be complete visual inspection of furnace with panels removed to check for shipping damage: misalignments of doors, twisted framework or other structural defects.

26 Warranty Details

The manufacturer shall provide Two year warranty with parts and labor from the date of commissioning at RRCAT. In case of long time delay in rectifying the machine fault (servicing downtime more than 4 weeks) the period lost in servicing would be added to the warranty period

Optional - : The manufacturer shall provide an option for 5-year Warranty (including above two years).

27 Technical Milestones

The manufacturer shall provide a fabrication and testing schedule. The following technical milestones shall be highlighted:

1	Completion of design phase
2	Completion of fabrication of vacuum chamber
3	Completion of fabrication of vacuum system
4	Completion of hot zone fabrication and installation
5	Completion of inert gas system
6	Completion of electrical system

6	Completion of controller + program
7	Completion of the water-cooling lines
8	Final assembly
9	Manufacturer testing
10	Packaging for shipping

Annexure – A

Questionnaire

Sr.No	Comment	Response from Supplier	
1.	Whether supplier is a original manufacturer	Yes	No
	If No, whether certificate of dealership from the principle is provided	Yes	No
2.	Whether supplier has manufactured furnace of similar size & temperature range.	Yes	No
	If Yes, whether list of client with contact details attached with the offer	Yes	No
3.	Whether calculations for vessel design in accordance with the ASME Code for externally pressurized vessels provided with the offer	Yes	No
4.	Whether drawings of the vacuum vessel based on the above design provided with offer	Yes	No
5.	Whether Weld Procedure Specification (WPS), Procedure Qualification Record (PQR), and Welder Performance Qualification (WPQ) be provided	Yes	No
6.	Whether a conceptual design & scheme for mounting of shield to provide no deformation during operation provided with offer	Yes	No
7.	Whether Hydrogen purging capability for partial pressure clean-up system provided in the furnace	Yes	No
8.	Whether supplier has provided details of		
	• Power requirement	Yes	No
	• Cooling requirement	Yes	No
	• Argon gas required	Yes	No
	• Floor load	Yes	No
	• Foot print of furnace including space for maintenance & operation.	Yes	No
9.	Whether make and model number for all the bought out items like pumps, gauges, PIDs, PLCs etc mentioned in the offer	Yes	No
10.	Whether Surface finish of the vessel inner surface indicated in the offer	Yes	No
11.	Whether details of sealing material provided	Yes	No
12.	Whether conceptual scheme for Power Supply provided	Yes	No
13.	Whether power density calculations provided	Yes	No

Sr.No	Comment	Response from Supplier	
14.	Whether vacuum pump down calculations provided	Yes	No
15.	Whether scheme for emergency backup system for furnace cooling provided in the offer	Yes	No
16.	Whether offered water cooling system is externally mounted type	Yes	No
17.	Whether capacity of Heat exchanger & blower are mentioned along with supporting calculations	Yes	No
18.	Whether conceptual design of loading cart with lifting arrangement provided with the offer	Yes	No
19.	Whether details of safety devices incorporated provided with the offer	Yes	No
20.	Whether point by point compliance for the technical specification provided along with offer	Yes	No
21.	Whether the supplier shall hot test the furnace at his premises.	Yes	No
22.	Whether offer for five years provided in the offer	Yes	No