# Revised Specifications for

# High Temperature Vacuum Furnace

# with

# High Pressure Gas Quenching System

# Index

## 1. Scope of work

The scope of work comprises of supplying a **High Temperature Vacuum Furnace with High Pressure Gas Quenching System**, which involves design and preparation of manufacturing drawings, manufacturing of system, pre despatch inspection, supply, Installation & commissioning of the system at FCIPT premises. The system shall confirm to the technical specifications, drawings, standards listed, notes attached and tests/quality standards to the satisfaction of the purchaser. Both factory acceptance tests (FAT) and site acceptance tests (SAT) will be conducted before despatch and after dispatch respectively for the acceptance of the entire system.

Detail technical write up of the system is supplied to the bidder. ASME section VIII division-1 shall be used for the design of the system. Bidder shall design the system and send the design for approval within 30 days from the receipt of PO. After approval of design, bidder shall prepare detailed fabrication drawings within 2 months after the approval of design, wherever required giving all dimensions and tolerances based on the assembly requirements. These drawings (hard copy and soft copy in PDF format) shall be submitted to the FCIPT/IPR/engineer/ in-charge for approval. No modifications in the drawings are permitted except in case where it is necessary to facilitate manufacturing, assembly, testing or erection provided such changes don't impair the functional accuracy and strength of the components. Such modifications backed up by calculations and drawings wherever necessary shall be submitted to the purchaser for approval, before implementation.

Any additions or revisions in the scope of work due to revision in the requirement of functions, designing and interface with other system; also form the part of the scope of work mentioned herein. (Minor revisions required at the time of manufacturing are considered in it and its financial implication wills not be more than 1% of the total cost).

The available space for the system in the lab is 7 m length, 6 m width and height 10 m. The shutter used for unloading the system has the dimensions of 7 feet height and 7 feet width. The bidder has to manufacture the system such that it can be placed in the above mentioned area and can easily go inside the lab. We will provide the required power on the wall mounted DB which is around 25 meter away from the lab (DB is in the same building but 25 meter away from the location of the system), so necessary input cables having sufficient capacity and length need to be provided by the bidder. We will also provide water for cooling but the capacity has to be mentioned by the bidder. The bidder also has to specify the ratings of the compressor for functioning of all the valves of the system. The bidder has to make his own arrangements for unloading the system at FCIPT, IPR. It is in the scope of the bidder to place the required components at their respective places.

**Detail technical write up of the system:**

The **high temperature vacuum furnace with high pressure gas quenching system** consists of sub-systems/equipments which are listed in Table 1. This system as shown in Fig. 1 and 2 will have a vacuum furnace which will be cylindrical in shape and horizontal mounting. The furnace will also have double wall configuration with guiding baffles along with water cooling provision. The

vacuum furnace must have longitudinally welded three 40KF threaded coupler at its bottom. The vacuum furnace should have several ports for heater electrodes, heat exchanger, thermocouples, etc. and they shall be water cooled. The vacuum furnace shall be provided with supports and necessary ducts.

Table 1: Sub-systems of High temperature vacuum furnace with high pressure gas quenching system

| **Sr. No.** | **Sub-system/Equipment** |
|---|---|
| 1 | Vacuum Furnace with ports |
| 2 | Vacuum Pumps (Rotary Piston/Vane & Booster pump in combination) |
| 3 | Conductance Valve |
| 4 | Process gas feeding system<br>(system consist of three Mass Flow controllers) |
| 5 | Hot zone support cage |
| 6 | Radiation shield, |
| 7 | Heater (heating elements) |
| 8 | Hearth/ Job holder plate |
| 9 | Heater Power supply |
| 10 | DATA acquisition system |
| 11. | Water cooling system (water cooling tower, water pump) |
| 12. | High pressure gas quenching system ( nitrogen gas chamber, heat exchanger and blower fan motor) |

A vacuum furnace will be connected to the combination of rotary piston/vane and booster pump to evacuate the furnace up to base pressure and to maintain the set total pressure during process. Both the pumps shall operate at variable speeds. In between furnace and pumps an isolation valve followed by conductance valve shall be connected. Conductance valve must have variable openings which will be useful to reduce the gas consumption during process. This conductance can be pneumatic or motorised throttling valve with controller and selectable opening from 10 to 100%. Isolation valve will isolate the conductance valve and vacuum pumps from furnace during high pressure gas quenching process.

For measurement of low pressure one pirani (from atmosphere to base pressure) and one capacitance mano-meter gauge (from base pressure to operating pressure) shall be provided. Pirani gauge will be used for base pressure measurement while capacitance mano-meter gauge for operating pressure measurement. Both the pressure gauges shall have individual isolation valve to avoid exposure to high pressure of gas quenching process.

Inside the furnace a cylindrical metal cage will be mounted to the inner wall of the furnace. The cage must have longitudinal three holes at its bottom and those shall be matched coaxially with

40KF coupler welded at bottom of vacuum furnace. The radiation shield to reduce the heat loss will be fixed on entire inner surface of the cage, front dish end and rear side of the furnace. The heating elements shall be affixed on the inner side of the radiation shielding of cage, front dish end and on rear side (before the heat exchanger). The heating element shall be distributed equally over the entire cylindrical side of cage, front and on the rear side of the hot zone. The heating elements shall be electrically insulated. The remaining empty cylindrical volume surrounded by heating element is referred here as the hot zone of the system. The entire heating elements shall be divided equally in three heating zones. The electric power will be supplied to heating elements of each heating zone with separate electrodes from a single heater power supply. A hearth plate/ job holder plate is required to hold the charge/job inside the hot zone. The support for the hearth plate shall be welded with inner wall of vacuum furnace. The hearth plate shall be electrically isolated with these supports and also from other parts of the hot zone. It shall be apart by ~ 70 mm from all the side for more kindly see the figure 3 for schematic front and side view of the hot zone. Provision of thermocouples shall be made available in the furnace to measure the temperatures.

The vacuum furnace also requires a process gas feeding system. The process gas feeding system comprises of three mass flow controllers for different gases. At the process gas inlet an isolation valve must be provided to avoid exposure to high pressure gas quenching.

A nitrogen gas chamber is required for gas storage and it should be designed such that it can fill nitrogen gas in to the entire vacuum furnace up to 11 bar pressure for quenching pressure. The nitrogen chamber must have flow regulator, valve to allow /stop the gas flow inside the vacuum furnace. For quenching process the vacuum furnace must have a heat exchanger and blower fan motor. The heat exchanger must be at placed behind the rear radiation shielding. The blower fan motor must be placed behind the heat exchanger. Heat exchanger must have inlet/outlet for water supply. The blower fan motor shall have variable speed. The blower will suck the hot nitrogen gas from the hot zone and will pass it through water cooled heat exchanger and again it will send the cooled nitrogen gas to hot zone to cool the charge/job with desired quenching rate. A pressure release valve is also required to release the high pressure on completion of process.

A water cooling system also must be provided to cool the furnace and heat exchanger. All the ports welded with the furnace shall be water cooled. The water cooling system must have cooling tower, water pump, manifolds for water distribution, valves etc. Cooling tower must be efficient to supply the water with temperature not more than room temperature.

Moreover, the radiation shielding of front dish end and rear side of furnace must have provision to pass hot/cooled nitrogen gas during the high pressure gas quenching process. All the devices and equipment will be operated through PLC based SCADA program. A mimic diagram for entire system and process flow chart shall be provided. All the set parameters and measured parameters shall be displayed through mimic diagram. SCADA programme will check for the set parameters as per the flow chart and accordingly it will set the variable parameter.

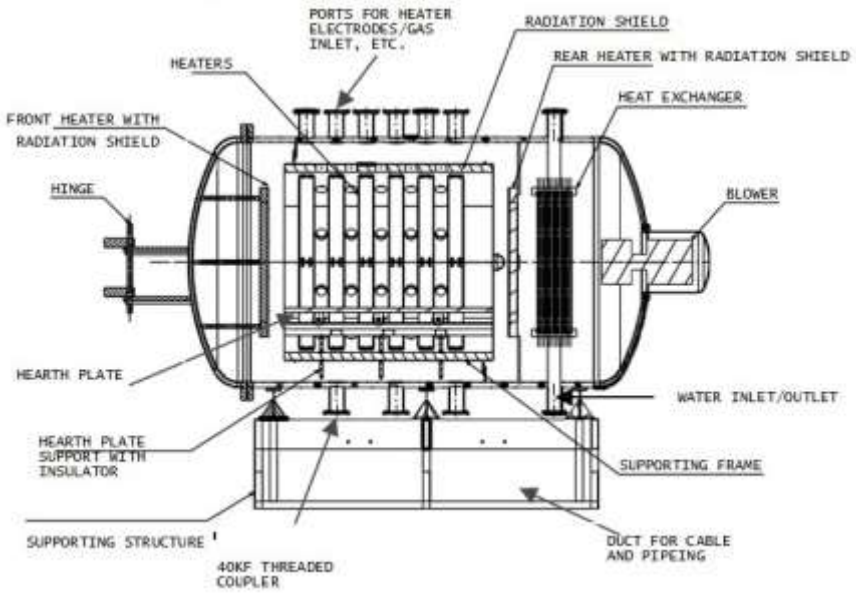


**Figure 1: Schematic picture of side view of vacuum furnace configuration**

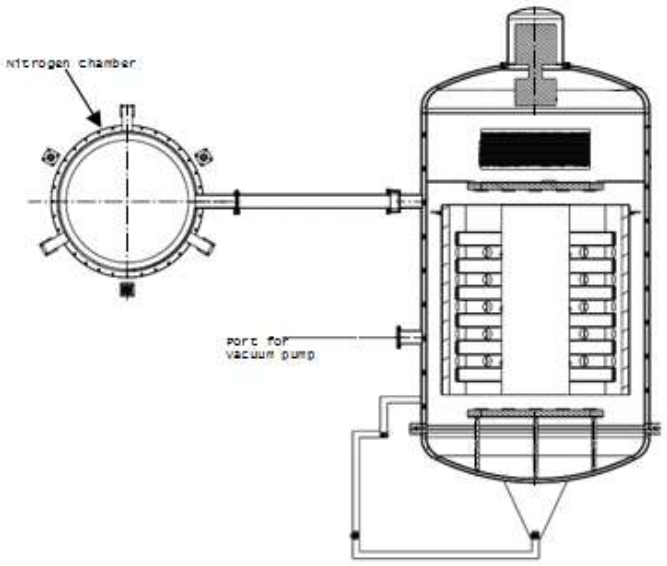


**Figure 2. Schematic picture of top view of vacuum furnace configuration**

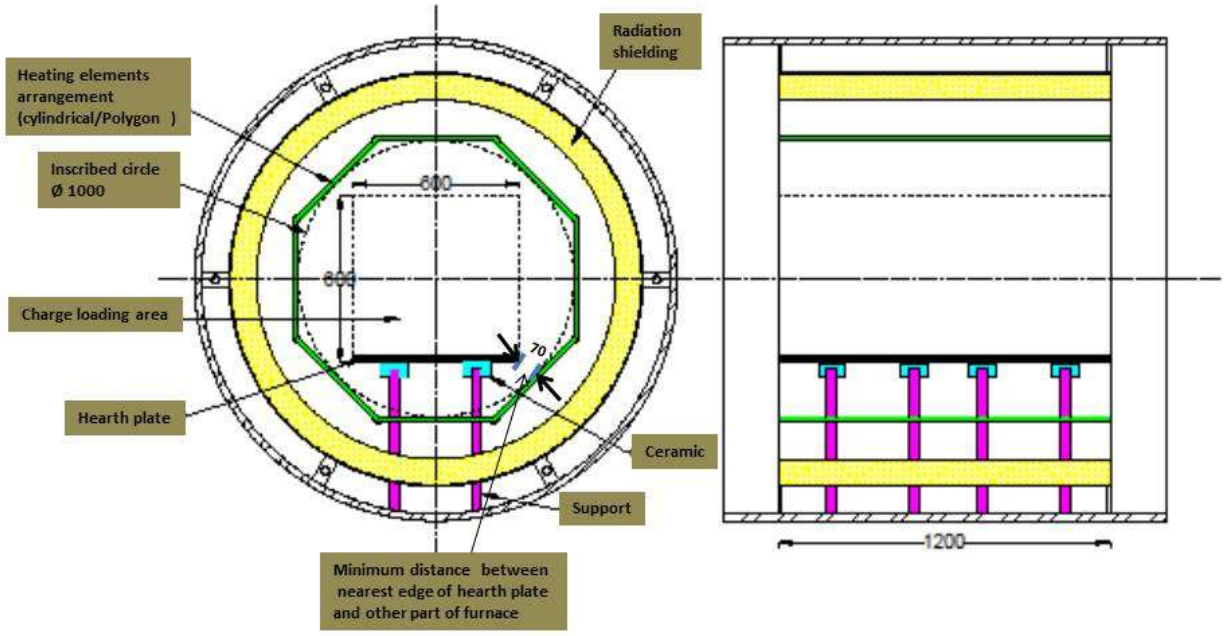


**Figure 3. Schematic of front and side view of the hot zone**

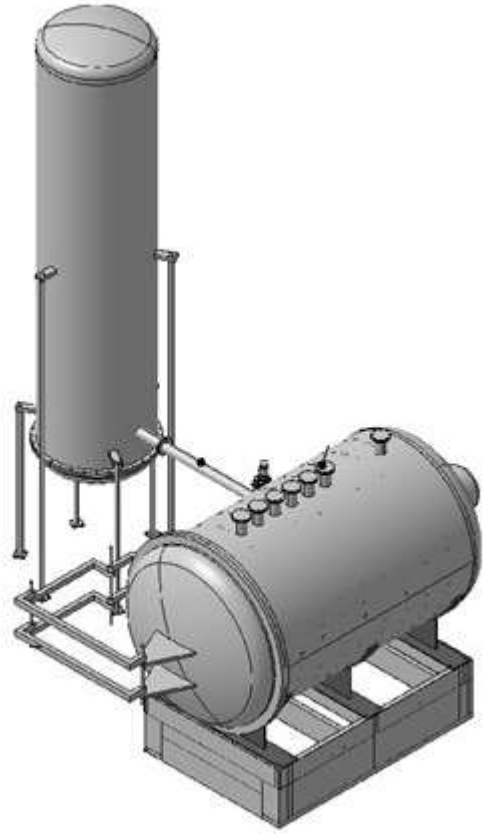

**Figure 4. 3D Isometric view of High temperature high quenching vacuum furnace configuration**

## 2. Introduction

The High Temperature Vacuum Furnace with High Pressure Gas Quenching system is meant for diffusion heat treatment process of steels & their alloys under vacuum and high pressure for enhancing the life of the component. This system comprises of, vacuum pumping system, hot zone, radiation shield, hearth plate, heat exchanger, blower fan motor, cooling system and nitrogen chamber.

The vacuum pumping system of the furnace evacuates the entire furnace to the set base pressure. The Gas feeding system allows all the three MFCs to flow the respective gases in to the furnace at user defined gas composition ratio to achieve pre-defined partial pressure. To achieve the pre-defined partial pressure conductance control valve and variable pumping speed also can be utilized. Opening of the conductance valve can be increased/decreased as per the requirement and also speed of the vacuum pump can be varied as well.

The hot zone consists of several heating zones having individual power connections which makes them enable to heat the component at different rate of heating as per the requirement. Each heating zone consists of individual temperature measurement facility and according to the feedback of the temperature, PID controller will automatically define the rate of heating for each heating zone individually to get the specified temperature in a given time duration. After achieving a user defined temperature power of each heating zone will be controlled to make the temperature constant for a complete duration of given soaking time. The SCADA program will

consist of the provision to repeat the heating process at different temperatures for different time durations.

At the final stage of the process, high pressure gas quenching process will start and before that all the vacuum devices like, vacuum pump, vacuum pressure gauges, gas feeding system shall be isolated. The nitrogen gas shall be filled in the chamber up to required pressure and with help of heat exchanger and blower fan the charge /jobs shall be cooled down in the system itself up to required temperature with desired quenching rate.

Finally the cooled charge/jobs will be taken out from the furnace and will be utilized as per the application for what they are designed for.

## 3. Process Description and Design Basis

### 3.1 Process Description

The high temperature vacuum furnace with high pressure gas quenching system shall be complete with all necessary mechanical & electrical system, instruments & controls, including thermal radiation shields, heating elements & supports, guided loading fixture, vacuum systems and all other accessories required for safe, smooth & efficient operation of the furnace.

In this system, industrial charge/job (~500 kg.) to be processed will be kept on electrically isolated hearth plate and front door will be closed. Air from the system will be removed using vacuum pump up to base pressure of the order of $5 \times 10^{-2}$ mbar. Later necessary gases like hydrogen and acetylene will be introduced at partial pressure (1 to 10 mbar) to create a clean environment for diffusion process. Sometimes nitrogen gas will also be used. With help of heater, temperature of entire charge/job will be increased (from room temperature to 1100$^{o}$C). This diffusion process may have more than one soaking period at different temperature between 100 to 1100$^{o}$C and time duration for soaking may be between 0.5 to 8 hours therefore system must be designed accordingly. At the end of the process entire charge will be cooled down in the system with high pressure gas quenching (pressure between 3 to 10 bars) with maximum quenching rate 40$^{o}$C/min.

Bidder has to provide suitable PLC based SCADA programme for automatic data acquisition for various process parameters and control for process parameter and process operation. Charge/Job will be arranged on a hearth plate (Job holder) with help of transfer mechanism plate and charge will be transferred inside the vacuum chamber at its respective place. The entire process will be then operated through the SCADA programme as per given process flow charts.

#### 3.1.1 **Process Flow Chart** (see Annexure-1)

### 3.2 Design basis

| Para of technical specifications | Clause heading | IPR's Specifications |
|---|---|---|
| **1.0** | **Vacuum Chamber** (See Drawing No. 1 & 2) | |
| 1.1 | Working Volume (equal to hot zone) | Diameter: 1000 ±50 mm. |
| | | Depth: 1200 ±50 mm. |
| 1.2 | Internal & External pressure | |

| Para of technical specifications | Clause heading | IPR's Specifications |
|---|---|---|
| 1.2.1 | Base vacuum pressure | 5 x $10^{-2}$ mbar. |
| 1.2.3 | Operating vacuum pressure | 1 to 10 mbar |
| 1.2.4 | Operating Quenching Internal pressure | 11 bar (abs). system should be designed for 16 bar pressure and expected operating quenching pressure could be up to 11 bar (abs). |
| 1.2.5 | Design Internal pressure | 16 bar (abs). The design intenal pressure should be 16 bar (abs) of high temperature vacuum furnace. |
| 1.3 | Material of construction | Carbon steel SA 516 Gr70. |
| 1.4 | Furnace Configuration | |
| 1.4.1 | Loading & Unloading | Front loading. |
| 1.4.2 | Configuration (see Drawing No. 2 ) | Cylindrical and horizontally mounted furnace. |
| 1.4.3 | Wall type | Double wall. |
| 1.4.4 | Furnace water cooling | Water cooling with guiding baffles. |
| 1.5 | Support structure | |
| 1.5.1 | Material | Mild Steel of IS 2062 GRADE E300 Quality A or BR |
| 1.5.2 | Duct at bottom of the support | With Cable and piping duct at bottom of the support structure. |
| 1.5.3 | Painting/Coatings | Powder coating. |
| 1.6 | Dish-ends | |
| | | **Front Dish-end:** |
| 1.6.1 | Material of construction | carbon steel SA 516 Gr 70 |
| 1.6.2 | Front dish end support | A hinge supported |
| 1.6.3 | Front dish end locking system | Autoclave locking ring closure. |
| 1.6.4 | Front dish end 'O' ring groove | Double 'O' ring groove. |
| 1.6.5 | Front dish end wall type | Double wall with water cooling |
| 1.6.6 | Space for loading/ unloading | Maximum open space for loading and unloading of job. |
| | | **Rear dish-end:** |
| 1.6.7 | Material of construction for rear | carbon steel SA 516 Gr 70 |

<table>
<tr><th>Para of technical specifications</th><th>Clause heading</th><th>IPR's Specifications</th></tr>
<tr><td></td><td>dish end</td><td></td></tr>
<tr><td>1.6.8</td><td>Blower fan housing<br>(see drawing No. 2 )</td><td>Consist of housing for blower fan.</td></tr>
<tr><td>1.6.9</td><td>Rear dish end wall type</td><td>Double wall with water cooling</td></tr>
<tr><td rowspan="3">1.7</td><td rowspan="3">Ports</td><td>Material of construction: Seamless pipe carbon steel SA 516 gr 70.</td></tr>
<tr><td>All the port shall be water cooled.</td></tr>
<tr><td>Ports required for
<table>
<tr><th>Purpose</th><th>Quantity</th></tr>
<tr><td>Vacuum pump</td><td>01 No.</td></tr>
<tr><td>Pirani gauge</td><td rowspan="2">01 No. each</td></tr>
<tr><td>Capacitance Manometer</td></tr>
<tr><td>Hydrogen gas</td><td rowspan="3">01 No. each</td></tr>
<tr><td>Nitrogen gas</td></tr>
<tr><td>Acetylene gas</td></tr>
<tr><td>Quenching gas inlet</td><td>01 No.</td></tr>
<tr><td>Pressure release</td><td>01 No.</td></tr>
<tr><td>Thermocouples</td><td>Bidder has to decide</td></tr>
<tr><td>Electrodes for heater power</td><td>Bidder has to decide</td></tr>
<tr><td>40 KF threaded coupler welded at equal distance at bottom of the furnace.</td><td>03 Nos.</td></tr>
</table></td></tr>
<tr><td>1.8</td><td>Conductance control valve</td><td></td></tr>
<tr><td>1.8.1</td><td>Conductance control valve</td><td>Vendors can provide pneumatic /motorized throttling valve with controller in front of isolation valve to control the gas consumption.</td></tr>
<tr><td>1.8.2</td><td>Different opening positions of conductance control valve</td><td>The valve shall be provided with controller having selectable opening from 10 to 100%.</td></tr>
<tr><td>1.8.3</td><td>Control of opening positions</td><td>Opening shall be variable through PLC & PID controller to maintain the set total pressure.</td></tr>
<tr><td>1.9</td><td>Cooling for entire vacuum furnace</td><td></td></tr>
</table>

| Para of technical specifications | Clause heading | IPR's Specifications |
|---|---|---|
| 1.9.1 | Type of cooling | Water cooling |
| 1.9.2 | Max. outer wall temperature | 35°C/ room temperature. |
| 1.10 | 'O' rings | |
| 1.10.1 | Type | Moulded (without joint) |
| 1.10.2 | Material | Viton 'O'-rings |
| 1.11 | Design standards | Design and Fabrication of the Furnace Chamber will be as per ASME code SEC. VIII, DIV- I. |
| 1.12 | Welding Standard | All The welding procedures will be as per ASME code SEC. IX. Hydro test of the chamber along with front dish door and water path shall be as per UG99 of ASME code. |
| 1.13 | Various drawings & approval from IPR | The bidder has to submit design drawing based on the design of the system and after approval of these drawings bidder needs to submit detail manufacturing drawings of the system. |
| **2.0** | **Vacuum Pumping system** | |
| 2.1 | Base pressure | Better than $5x10^{-2}$ mbar with charge of 500 kg. |
| 2.2 | Type of pump | Rotary vane/piston pump should be supplied in combination with booster pump . |
| 2.3 | Variable pumping speed | Pumping speed shall be variable (VFD). |
| 2.4 | Pump down time | Less than 20 min.<br>(to achieve the specified base pressure ($5 \times 10^{-2}$ mbar) with the 500 kg charge) |
| 2.5 | Isolation Valve-2<br>(for location see Schematic drawing of process flow chart (PFC)) | Electro pneumatic valve shall be provided to isolate the vacuum furnace and vacuum pump during quenching process. |
| 2.6 | Pirani gauge<br>(for location see Schematic drawing PFC) | High pressure Pirani gauge shall be provided to measure the pressure |

| Para of technical specifications | Clause heading | IPR's Specifications |
|---|---|---|
| | | from atmospheric pressure to $10^{-3}$ mbar. |
| 2.7 | Isolation valve-1<br>(for location see Schematic drawing of PFC) | Between pirani gauge head and vacuum furnace an electro pneumatic valve for isolation must be provided. |
| 2.8 | Bypass line with valve | A bypass line between the Vacuum furnace and the blower fan motor hood along with an electro pneumatically operated butterfly valve shall be provided. |
| **3.0** | **Process Gas feeding system (Mass Flow controllers)** | |
| 3.1 | A capacitance mano-meter gauge<br>(for location see Schematic drawing of PFC) | A capacitance mano-meter gauge shall be provided The gauge selection shall be on following criteria.<br>I. Pressure range: 1 x $10^{-2}$ mbar to 100 mbar.<br>II. Temperature: ~50°C.<br>Resolution: ~0.003% of full scale. |
| 3.2 | Isolation valve-4<br>(for location see Schematic drawing of PFC) | Between capacitance mano-meter gauge head and vacuum furnace an electro pneumatic valve for isolation must be provided. |
| 3.3 | Mass flow controllers for gases<br>(for location see Schematic drawing of PFC) | 1. Hydrogen<br>2. Nitrogen<br>3. Acetylene |
| 3.4 | Total pressure to be achieved/ maintained | 1 to 10 mbar. |
| 3.5 | Flow ranges of Hydrogen & Nitrogen gas MFCs | Suitable to fill the entire vacuum furnace up to 10 mbar pressure with single gas only. |
| 3.6 | Flow ranges of Acetylene gas MFC | Suitable to fill the entire vacuum furnace up to 0.5 mbar pressure with single gas only. |
| 3.7 | Solenoid valve positions | Each MFC must contain three position of solenoid valve,<br>I. Purge (fully opened)<br>II. Auto (opens as per set |

| Para of technical specifications | Clause heading | IPR's Specifications |
|---|---|---|
| | | pressure).<br>III. Close (fully closed) |
| 3.8 | Gas flow control through SCADA programme<br>(refer PFC) | Through SCADA programme the flow rate of each gas shall vary to achieve set total pressure with given gas mixing ratio. |
| 3.9 | Isolation valve-3<br>(for location see Schematic drawing PFC) | A suitable isolation valve shall be provided between vacuum furnace and gas flow path to isolate the MFCs during quenching process. |
| 3.10 | Uniform gas flow | Uniform gas distribution should be ensured by the bidder. |
| **4.0** | **Hot zone configuration**<br>(see Drawing No. 1 & 3 ) | |
| | Hot zone consist of | 4.1. Hot zone<br>4.2. support cage<br>4.3. Radiation shield<br>4.4. Heating Elements (heaters)<br>4.5. Hearth Plate (charge/ Job holder) |
| 4.1 | Hot zone | |
| 4.1.1 | Configuration of actual hot zone | Cylindrical/multisided polygon and horizontal |
| 4.1.2 | Hot zone diameter<br>(inscribed circle diameter in the case of multi sided polygon hot zone) | 1000±50 mm |
| 4.1.3 | Depth of hot zone | 1200 ±50mm |
| 4.1.4 | Max Design temperature | At least 200 $^{o}$C above the maximum operating temperature (1100$^{o}$C). The system design has to be done such that it shall work 15 hours a day without fail. |
| 4.1.5 | Operating temperature range | Room temperature to 1100$^{o}$C |
| 4.1.6 | Range of heating rate<br>(Time required to achieve operating temperature) | Heating rate 1 -10$^{o}$C/min.<br>(Minimum 120 & Maximum 1100 minutes) |
| 4.1.7 | Environment of process | Partial pressure of Hydrogen ($H_2$), Nitrogen ($N_2$) and Acetylene ($C_2H_2$) gases. |
| 4.1.8 | Range of Total vacuum pressure | 1 - 10 mbar |

| Para of technical specifications | Clause heading | IPR's Specifications |
|---|---|---|
| 4.1.9 | Temperature Uniformity | Uniformity of temperature at 1100°C and 800°C shall be ± 6°C as per AMS2750E pyrometry class II. |
| 4.1.10 | Temperature resolution | 1°C |
| 4.2 | Support cage | |
| 4.2.1 | Material of construction | SS310 |
| 4.2.2 | configuration | Horizontal and cylindrical |
| 4.2.3 | Size | Suitable for working volume |
| 4.2.4 | Mounting of hot zone support cage | On inner wall of furnace. |
| 4.2.5 | Extractable & insertable | It shall be easily extractable and insertable. |
| 4.2.6 | Coaxial holes at bottom | Three coaxial holes with the 40KF threaded coupler welded at bottom of the furnace shall be made at the bottom side of cage. |
| 4.2.7 | Load bearing capacity | The cage shall be capable to withstand the weight of<br>I. Radiation shield,<br>II. Heating elements with accessories of fitting.<br>(Thermal & structural load shall be considered while load bearing capacity is being calculated) |
| 4.3 | Radiation shields | |
| 4.3.1 | Material of construction | Graphite/Carbon board |
| 4.3.2 | Radiation shielding must be provided between | I. inner wall of cage and heating elements,<br>II. between front & rear dish ends of furnace and heating elements<br>III. Hot zone & heat exchange<br>Other places which are not mentioned here but shielding is required. |
| 4.3.3 | Ports in radiation shield | Radiation shielding of front & rear side of furnace must contain ports which will allow to flow hot & cooled gases for uniform quenching |
| 4.3.4 | Open & close condition of ports provided in radiation shielding | The port shall be closed during entire process of heat treatment and shall open during quenching stage of the process. |
| 4.3.5 | Material for covering of radiation | Shielding shall be covered with |

| Para of technical specifications | Clause heading | IPR's Specifications |
|---|---|---|
| | shielding | carbon-carbon composite long fibre to reduce the erosion rate of the shielding material at high velocity of quenching gas. CFC faced graphite board also can be used. |
| 4.4 | Heating element (heaters) | |
| 4.4.1 | Material of construction of heating elements, electrodes and other connection accessories for heater | High density graphite. |
| 4.4.2 | Shape of elements | Rectangular bar. |
| 4.4.3 | Element distribution | Heating elements should be distributed uniformly over entire cylindrical side of hot zone and front and rear sided of hot zone as well. |
| 4.4.4 | No. of heating zones | Entire hot zone shall be divided in three heating zones along the axis of the cylinder or multisided polygon. |
| 4.4.5 | Electrodes for heater power | Must be passed through ports with proper electrical insulation. |
| 4.4.6 | Electrode dimensions | Electrode diameter and length shall be capable to draw sufficient current with minimal heating effect. |
| 4.4.7 | Water cooling of electrode | Shall be provided if required. |
| 4.5 | **Heating Power supply** | |
| 4.5.1 | Load to heat | 500 kg. |
| 4.5.2 | Operating temperature range | Room temperature to 1100$^{o}$C |
| 4.5.3 | Heating rate (to achieve operating temperature) | 0 -10$^{o}$C/min in all heating zones (Minimum 120 min & Maximum 1100 min) |
| 4.5.4 | Input Voltage | 415 VAC ±10%, 50$H_z$ |
| 4.5.6 | Output power | >160 kW |
| 4.5.7 | Output voltage range | 0 - 50V AC continuous variable |
| 4.5.8 | Voltage regulation | 0.5% or better |
| 4.5.9 | Voltage resolution | 0.1V or better |
| 4.5.10 | PLC based SCADA programme | Temperature & time duration (to achieve the temperature) will be set by user in SCADA programme and programme will automatically set the necessary parameters to achieve the set values for all the heating zones. |

| Para of technical specifications | Clause heading | IPR's Specifications |
|---|---|---|
| 4.5.11 | Voltage/power control | Voltage/Power control shall be through SCADA. |
| 4.5.12 | Protections | Over voltage & over current protection must be provided. |
| 4.5.13 | Emergency switch | Must be provided to cut the power in the case of emergency. |
| 4.5.14 | Temperature & Relative humidity | Supply must be efficient to work at 55$^{o}$C temperature and humidity 90% RH. |
| 4.5.15 | Cabinet coting | Close cabinet with powder coating. |
| 4.5.16 | Material of construction of cabinet | Mild Steel |
| 4.5.17 | Easy access of card & devices | All the circuit cards and light weight devices shall be mounted in such a way so that electrical input & output faces towards user for easy access. |
| 4.5.18 | Input/output cables accessibility | Main input & output shall be rear side of the power supply (but not at the bottom). |
| 4.5.19 | Nomenclature & tagging | All the cable shall be tagged on both ends. |
| 4.5.20 | Lifting | Lifting hooks must be provided at the top. |
| 4.5.21 | Movement on floor | Sufficient space must be provided to insert hydraulic pallet trolley at bottom of the power supply for movement on floor. |
| 4.6 | Hearth Plate (charge/ Job holder) | |
| 4.6.1 | General requirement & size | The size of the hearth plate shall be defined in such a way so that nearest edge of the hearth plate shall be apart about 70 mm from all sides from the heater. Kindly see the figure 3. |
| 4.6.2 | Material of construction | High Density Graphite/CFC<br>(Shall be fabricated such that it can withstand at 1100$^{o}$C with a charge/ job of 500 kg.) |
| 4.6.3 | Support for hearth plate | Shall be welded longitudinally with inner wall vacuum furnace. |
| 4.6.4 | Isolation of hearth plate | Hearth plate must be electrically isolated from all the side. |
| 4.6.7 | Suitable charge/job transfer mechanism | The bidder shall provide a suitable transfer mechanism which can |

| Para of technical specifications | Clause heading | IPR's Specifications |
|---|---|---|
| | | transfer 500kg. charge/job loaded hearth plate inside and outside the vacuum furnace |
| 4.6.8 | Material of insulator | Ceramic |
| 4.6.9 | Life of hearth plate | The hearth plate shall have a life of minimum one year. |
| 5.0 | **Heat Exchanger & High pressure gas quenching System** ( refer Drawing No. 1 & 2) | |
| 5.1 | Heat Exchanger | |
| 5.1.1 | Type | Finned and tube type |
| 5.1.2 | Material of fins & tubes | SS & copper |
| 5.1.3 | Inlet water temperature | ~35$^{o}$C/room temperature. |
| 5.1.4 | Temperature and time for cooling the charge | A Suitably designed Heat Exchanger shall be provided in front of the blower to cool the hot gas coming from the Hot Zone when sucked by the blower to achieve the desire cooling rate to decrease the temperature from 1100$^{o}$C to 100$^{o}$C in 25 min. |
| 5.1.5 | Rate of quenching | 5 – 40$^{o}$C/min. This rate of quenching should be variable. from 5 to 40$^{o}$C/min |
| 5.2 | Blower fan | |
| 5.2.1 | Blower fan motor | Blower fan motor shall be provided with suitable power capacity. |
| 5.2.2 | Variable speed (VFD) | Speed of blower fan motor shall be variable. |
| 5.3 | Nitrogen chamber (quenching gas storage tank) | |
| 5.3.1 | Material of construction | Carbon steel SA516 Gr 70 |
| 5.3.2 | painting | Epoxy painting on internal surface and outer surface powder coating. |
| 5.3.3 | Volume | Vendor has to design the nitrogen chamber such that it can fill entire vacuum furnace with nitrogen gas up to expected operating quenching pressure of 11 bar (abs). |
| 5.3.4 | Safety devices | Gas storage system must have necessary safety devices suitable valves and necessary pressure gauges to control and store the gas. |

| Para of technical specifications | Clause heading | IPR's Specifications |
|---|---|---|
| 5.3.5 | Gas refilling provision | Gas refilling provision in nitrogen chamber shall be provided. |
| 5.3.6 | Flow control valve | Electro-pneumatically operated valve to control the flow shall be provided. |
| 5.3.7 | Gas nozzles | Gas nozzles with flaps shall be provided for cross flow cooling. |
| 6.0 | **Data acquisitions system** | |
| 6.1 | Industrial PC | Industrial PC with<br>I. 19"TFT touch screen.<br>II. SCADA software for complete automation with operation of the system.<br>III. i7 processor,<br>IV. Windows 10 or above,<br>V. 8GB RAM,<br>VI. 2TB HDD,<br>Data analysis software for retrieving particular parameter for definite time duration and date. |
| 6.2 | Data logging & Plots | 1. SCADA Software must have data logging in convenient format like ASCII or excel table with real time value for<br>a) Voltage (each heating zone),<br>b) Current (each heating zone),<br>c) rate of heating (each heating zone),<br>d) power of heater (each heating zone)<br>e) temperature (each heating zone),<br>f) total pressure (chamber),<br>g) gas flow rates (three gases)<br>h) Proportionate ratio of all the three gases,<br>i) Inlet and outlet water temperature of furnace<br>j) Inlet and outlet water temperature of Heat exchanger.<br>k) Quenching pressure<br>2) Sampling rate shall be 1 sec.<br>3) Plots for all the above parameters (a to l) with respect |

| Para of technical specifications | Clause heading | IPR's Specifications |
|---|---|---|
| | | to real time shall be display during entire process and entire plot shall be stored at the end of the process.<br>ASCII or excel file shall be saved with a unique title format like yyyy-mm-dd-hh-mm. |
| 6.3 | Remote control access | Remote control access from other network shall be enabled through licenced software like, team viewer. Entire recipe shall be controllable through remote control access (within LAN and also outside the LAN network) |
| 6.4 | Ethernet/LAN | Ethernet card shall be provided for LAN connection for internet. |
| 6.5 | Mimic diagram and flow chart | A mimic diagram with flow chart shall be displayed in the IPC for entire vacuum system, heating system and gas feeding system with indicators along with audio alarm for utility failure with integrated alarm management system. All the variable and set parameter given in flow chart shall be display in mimic diagram. |
| 6.6 | Vacuum & high pressure gauge communication with SCADA | All the gauges shall be communicated to PLC and SCADA. |
| **7.0** | **Utilities** | |
| 7.1 | Water cooling system | Cooling tower |
| 7.2 | Water temperature at cooling tower outlet | ~ 35$^{o}$C/ room temperature |
| 7.3 | Water pump | Water pump for cooled water circulation must be provided. |
| 7.4 | Accessories | Following accessories shall be supplied with water cooling system.<br>I. Pressure gauges,<br>II. Switches,<br>III. Manifolds for input and |

| Para of technical specifications | Clause heading | IPR's Specifications |
|---|---|---|
| | | output,<br>IV. Valves,<br>V. Pressure relief valve if required,<br>VI. Bypass line if required<br>VII. Hose connection,<br>VIII. Water flow controller. |
| 7.5 | | Supplier will inform IPR well in advance before dispatching the system to keep ready necessary quantity of water, air compressor with pressure details and other necessary arrangement. |
| 7.6 | UPS | UPS with sufficient capacity for power back up Control panel/Data acquisition system should be provided. Calculation to arrive at required UPS power for 20-30 min backup of data acquisition unit and related instrumentation should be submitted for approval along with the design calculation of the system. |
| Important Notes:<br>1. Bidder also has to provide all the safety devices, necessary equipment which are essential for completeness of the system but not mentioned here.<br>2. If there is any indifferences in the value mentioned in the documents and the design bases (i.e. ASME, AMS) then it shall be brought in the notice of IPR for further approval before implementation. | | |

**Preferred makes of major items:**

| SI. NO. | DESCRIPTION | MAKE |
|---|---|---|
| 1. | Graphite elements & thermal insulation | M/s. Shunk/Mersen/ Toyotanso or equivalent |
| 2. | Rotary vane pump | M/s. Indo Vacuum/ Leybold/Edwards/HHV or equivalent |
| 3. | Roots pump | M/s. Indo Vacuum/ Leybold/Edwards/HHV or equivalent |

| | | |
|---|---|---|
| **4.** | Isolation Vacuum Valve (Butterfly Type) | M/S. Bray/Omal or equivalent |
| **5.** | 19" IPC with same specifications as mentioned in RFQ | M/s. Scheider/ Exor/ Proface/Advantech Siemens or equivalent |
| **6.** | SCADA | M/s. GE/Siemens/Proface or equivalent |
| **7.** | Pirani gauge with cable | M/s. Pfeiffer/Leybold/Inficon/ Thyracont or equivalent |
| **8.** | Capacitance gauge with cable | M/s. Pfeiffer/Leybold/Inficon/ Thyracont or equivalent |
| **9.** | Digital Temperature Programmer Controller | M/s. Eurotherm/Gefran/ Delta or equivalent |
| **10.** | Over Temperature Controller | M/s. Eurotherm / Gefran / Autonics/ Delta or equivalent |
| **11.** | Thermocouples | M/s. GEO/Tempsen/ Techno or equivalent |
| **12.** | PLC | M/s. GE/Siemens or equivalent |
| **13.** | Switch gears | M/s. Siemens/Schneider/ABB/ Mitsubishi or equivalent |
| **14.** | Mass flow controllers | M/s. Bronkhost/ Aalboarg/ Dakota or equivalent |
| **15.** | Quenching motor | M/s. ABB/Crompton or equivalent |

### 3.3 **Bill of material (bidder has to supply)**

| **Sr. No.** | **Parts/Equipment/Consumable** | **Qty.** | **Unit** |
|---|---|---|---|
| 1. | High temperature vacuum furnace with support structure | 01 | No. |
| 2. | Vacuum Pumps like booster & rotary piston/vane pump combination. | 01 | No. |
| 3. | Absolute pressure gauge (capacitance manometer) | 01 | No. |
| 4. | Electro pneumatic valve (as per flow chart) | 05 | Nos. |
| 5. | High pressure gauge (atm. to 16 bars) | 01 | No |
| 6. | High pressure digital Pirani gauge | 01 | No. |
| 7. | Heaters power supply | 01 | No |
| 8. | Hearth plate | 01 | No |
| 9. | Insulators for hearth plate | 01 | Set |
| 10. | Blower system | 01 | set |
| 11. | Mass flow controller for $H_2$ gas | 01 | No |
| 12. | Mass flow controller for $N_2$ gas | 01 | No |
| 13. | Mass flow controller for $C_2H_2$ (acetylene) | 01 | No |
| 14. | Conductance control valve | 01 | No |
| 15. | Industrial PC | 01 | No. |
| 16. | PLC, SCADA software and PID controllers | 01 | Set |

| Sr. No. | Parts/Equipment/Consumable | Qty. | Unit |
|---|---|---|---|
| 17. | Thermocouples | 01 | Set |
| 18. | Quenching gas storage tank | 01 | No |
| 19 | Water cooling tower | 01 | No |
| 20 | Water circulation pump | 01 | No |
| 21 | Water pressure gauges, switches, valves for inlet and outlet, temperature sensors | 01 | Set |
| 22. | Manifolds | 01 | Set |
| 23 | Suitable charge/job transfer mechanism | 01 | No |
| 24 | Heat exchanger | 01 | No. |

All other components or accessories required for the smooth functioning of the system shall be provided by the bidder.

## 4. Spares

### 4.1 Commissioning Spares

Bidder shall supply adequate quantity of commissioning spares so as to ensure that commissioning of the system is not hampered. The bidder shall include the cost of the commissioning spares in the base price / lump sum quoted price. In case during commissioning any spare is used from recommended spares or mandatory spares, the same shall be replaced free of cost within a reasonable period of time as mutually agreed.

### 4.2 Mandatory Spares

Bidder shall quote the following mandatory spares. These prices will be considered for price evaluation. If is not quoting any one of them the maximum offered price for the same item quoted by others will be loaded for the price comparison.

| Sr No. | Item | Qty | Unit |
|---|---|---|---|
| 1. | Heater elements with other necessary accessories for entire assembly | 01 | Set. |
| 2. | Vacuum pump oils (for each pump if used in combination) | 01 | Charge. |
| 3. | Ceramic Insulators | 02 | Sets. |
| 4. | Viton ‘O’ ring (all sizes used in vacuum chamber) | 02 | Set |
| 5. | Heater electrodes | 01 | Set |
| 6. | Feed through (one for each different size and design) | 01 | No. |
| 7. | Temperature sensors & thermocouples for heating zone, inlet and outlet water of furnace and heat exchanger. | 01 | Set. |
| 8. | Hearth plate | 01 | No. |
| 9. | Insulators for hearth plate | 01 | Set. |

### 4.3 Recommended Spares

Bidder shall furnish quotation for spares in addition to mandatory spares for two (2) years trouble free operation and maintenance of the equipment with itemized price list along with the Price Bid (uploaded online). These spares will not be considered for price evaluation of the bid. These spares will be ordered by purchaser separately. The un-priced price bid copy of these spares shall be attached with technical offer also. Price offer of recommended spares shall be valid for a minimum period of 2 years from the date of opening of commercial bid.

## 5. Safety & interlocks

The vacuum furnace shall meet requirements of all latest codes and applicable standards including electrical, fire and safety standards.

a. In all modes of operation; automatic, manual & maintenance, safety of the furnace along with vacuum systems shall be ensured during power interruption or in case of emergency stop. A key lock shall be provided for the maintenance mode. During any unexpected interruption all isolation valves 1, 2, 3, and 4 to the vacuum devices shall automatically close during a power failure if process was in the stage up to 4 as per the recipe and if process was in the stage 5 (quenching) than vent valve shall open to reduce the pressure inside the chamber till 3 bar and thereafter vent valve will close again. After such an interruption, the valves will remain in closed condition until the operator resets.

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. Inspection of the main shell shall be as per ASME Pressure Vessel Code Section V. The vessel need not be code stamped.

c. Welding shall be carried out by welders qualified in accordance with latest 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.

d. Details of interlocks for safe & smooth functioning of the furnace & its sub systems shall be provided. During normal operation, the protection of equipment as well as job, against malfunctioning shall be ensured by the manufacturer.

**Interlocks**:

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

- Over-shooting of temperature in the furnace.
- Over-heating of feed-through
- Low vacuum level
- Inadequate water flow
- Inadequate compressed air pressure
- Interlocks for vacuum pumps
- Interlock for isolation valves
- Front door shall not open while process is going on.
- In the beginning, cooling of the vacuum chamber and heat exchanger shall be checked and if it fails heater power must not turned ON.
- If cooling fails during process heater power shall be turned OFF.

- In the case of mains power failure, data acquisition system must be powered by UPS immediately.
- In the beginning of the quenching process closed condition for isolation valves-1, 2, 3 and 4 must be ensured if it fails quenching gas shall not be filled in the vacuum chamber.
- Provision shall be provided to
- the interlock whenever required.

All the instruments required obtaining the above signals to PLCs such as level switch, pressure switch, flowing switches, thermocouples etc. shall be included in the scope of supply.

e. Audio-visual alarm and the levels of the alarms shall be defined by the manufacturer in order to ensure safe operation of the furnace.

**6. Note to the Manufacturer**

a. The manufacturer shall be a reputed Company, engaged in the design and manufacture of high vacuum cold wall heat treatment furnaces and shall be capable of design and fabrication of the furnace in accordance with the requirements of the latest edition of all relevant codes and practices at the time of fabrication.

b. The manufacturer shall enclose the list of clients to whom he has supplied similar furnaces along with order details, certificate of performance and contact details.

d. The manufacturer shall submit the following schematics without which the offer shall not be considered

i. Furnace elevation with dimension
ii. Furnace cross section with dimension
iii. Vacuum system with dimension

e. The manufacturer shall submit a detailed quality assurance plan (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 approval shall have to be submitted to IPR, before taking up the fabrication.

*f.* The manufacturer shall submit completed questionnaire as per Annexure-A along with the offer.

*g.* A comparative statement of the technical specifications of the furnace tendered versus the furnace being offered shall be furnished by the manufacturer**.** Deviations, if any, from the tender specification shall be explicitly specified in the offer, failing which it will be construed that the party is concurring with the tender specifications.

*h.* All the bought out items like pumps, gauges, valves, electronic items etc. shall be of reputed make & preferably shall have service facility in India. The manufacturer shall

provide all the details with make, model & catalogue etc. and submit original documents / test certificates for the bought out / imported items.

*i.* Before starting the manufacturing of the system the design calculations for double walled chamber thickness, heater power calculations, thermal radiation shield, hearth plate and its supporting structure, heat exchanger and blower design, chamber stand and nitrogen gas chamber design, rear and front dish end along with thermal and structural analysis shall be submitted to IPR by bidder to get them approved.

j. Industrial PC based operator station along with licensed software loaded for OS, PLC and SCADA.

k. Vacuum seals shall be Viton and of circular cross section. Chord is not acceptable. List of all the O-rings and sizes shall be furnished.

## 7. Inspection, testing & Performance Trial

### 7.1. Inspection and testing at Manufacturer's premises (FAT)

Stage wise on-site inspections shall be carried out at any point of time by IPR appointed TPI along with IPR representative at manufacture's premises.

Manufacturer shall offer the furnace to be inspected at their works before dispatch.

All required tests including the following shall be carried out as per ASME Pressure Vessel Code Section V:

Checking of Material test certificate for IGC, Chemical composition test for all materials, dye penetration test reports, radiography of all welds exposed to vacuum.

Leak check of all components & joints based on the mass spectrometry (Helium leak detector), the acceptance criteria shall be $1x10^{-4}$ mbar x liter per second Helium leak.

Demonstration of the vacuum pump capacity & leak rate.

Demonstration of ultimate vacuum, pump down time and leak rate.

Checking of calibration certificate of vacuum gauges & gauge heads.

Hydro test of annular space of cooling chambers.

Internal surface finish as rolled from the plate.

Inspection of main shell as per ASME pressure vessel code Section-VIII.

Individual Chambers shall be demonstrated for

- Sequence of operation
- Ultimate vacuum in cold and hot condition.
- Leak rate
- Interlocks and alarm systems
- Heating system calculation & power calculation by resistance measurement

IPR reserves the right to be present or to be represented by an organization of its choice, to witness the above tests. The manufacturer shall give at least 15 working days advance notice of the proposed date of any such tests.

# Factory acceptance tests for the performance of high temperature vacuum furnace.

One complete cycle will be performed at bidder's site and following tests will be carried out during this cycle. The cycle duration will be 15 hours with 500Kg load at 1100°C under environment of partial pressure of hydrogen, nitrogen and acetylene gases at 10 mbar pressure. Quenching will be performed with nitrogen gas at 10 bar pressure with quenching rate ~40°C/min. All the necessary arrangement is in the scope of bidder.

| Sr. No. | Parameters to be tested | Expected test result |
|---|---|---|
| **1.00** | **Vacuum Chamber** | |
| 1.01 | Working Volume (equal to hot zone) | 1000 ±50 mm diameter x 1200 ±50 mm depth. |
| 1.02 | Base Vacuum Pressure (in 20 min) | 5 x $10^{-2}$ mbar. |
| 1.03 | Quenching Pressure | 10 +1 bar (abs). |
| 1.04 | Temperature of inlet water (After soaking at 1100°C temperature for 1 hour) | 35°C/room temperature |
| 1.05 | Temperature of outer wall of the vacuum furnace (After soaking at 1100°C temperature for 1 hour) | ~50°C |
| 1.06 | Load capacity of hearth plate | ~500 kg. Charge/Job will be distributed on entire hearth plate. Bidder has to prepare the two type of charge/job. First type of job shall have multiple jobs with similar size and weight while second type of job will be single job having weight about 250 kg. |
| **2.00** | **Hot Zone - All Metal Hot Zone** | |
| 2.01 | hot zone dimensions | 1000±50mm diameter & 1200 ±50mm (depth). |
| 2.02 | Operating temperature | 1100°C in 120 min |
| 2.03 | Temperature Uniformity | Uniformity of temperature at 1100°C and 800°C shall be ± 6°C as per AMS2750E Pyrometry class II. (Note: weight distribution shall be non-uniform and rate of heating shall be automatically adjusted as per the load for entire hot zone.) |
| 2.04 | Heating rate | 0 – 10°C/min. variable |
| **3.00** | **Heating Power supply** | |

| Sr. No. | Parameters to be tested | Expected test result |
|---|---|---|
| 3.01 | Output Power: | Power offered by bidder will be tested and necessary arrangement has to be done by bidder. |
| 3.02 | Output voltage: | 0 - 50 VAC continuous variable |
| 3.03 | Voltage regulation | 0.5% |
| 3.04 | Voltage resolution | 0.1V |
| 3.05 | PLC based SCADA programme: | Automatic adjustment of rate of heating in individual heating zones will be tested by non-uniform distribution of weight (as per given weight in parameter 1.06) |
| 3.06 | Nomenclature & tagging | Nomenclature and tagging will be checked. |
| 3.07 | High current electrode temperature | Temperature of electrode will be measured and that shall not be more than 50$^{o}$C. |
| 3.08 | Protections | Over voltage & current protection will be tested. |
| 3.09 | Plotting | All the plot will be verified as per the para of technical specification point no. 6.2 of given design basis. |
| 3.10 | Type of file saving | File type will be checked.<br>That shall be ASCII or Excel table. |
| 3.11 | File name format | yyyy-mm-dd-hh-mm |
| **4.00** | **Operating Gas pressure with different gas combinations** | 10 mbar pressure in vacuum chamber with following gas combinations:<br>1) Hydrogen 98% + Acetylene gas 2%<br>2) Nitrogen 98% + Acetylene gas 2%<br>Note: During FAT hydrogen and acetylene gas combination will be used and nitrogen and acetylene combination will be tested at FCIPT, IPR premises. |
| **5.00** | **Conductance valve operation** | Various opening positions will be checked. |
| **6.00** | **Quenching System** | |
| 6.01 | Gas quenching | Quenching with rate of 40$^{o}$C/min will be tested at quenching pressure |

| Sr. No. | Parameters to be tested | Expected test result |
|---|---|---|
| | | 10 bar of nitrogen gas. |
| 6.02 | High pressure testing | Bidder has to demonstrate pressure of nitrogen as per ASME recommendation (~ 16 bars) bar in vacuum system. |
| 6.03 | Variable speed of blower | Variable speed of blower will be tested at 10 bar pressure. |
| 6.04 | Isolation valves operation | Operations of All the 5 isolation valves will be tested as per the flow chart. |
| 6.05 | Nitrogen Chamber (gas storage tank) | Capacity to fill the vacuum chamber with nitrogen gas up to 16 bars pressure. |
| **7.00** | **Cooling system** | |
| 7.01 | Outer Wall temperature of vacuum chamber | ~50$^{o}$C after getting 1100$^{o}$C on charge |
| 7.02 | Heat exchanger inlet water temperature | ~35$^{o}$C/room temperature |
| **8.00** | **Data Aquisition** | |
| 8.01 | Industrial PC | Specification will be checked for<br>1) i7 processor<br>2) operating system windows 10 or above,<br>3) 8GB RAM,<br>4) 2 TB HDD,19" TFT,<br>5) Supervisory control and data acquisition (SCADA) |
| 8.02 | Remote control access | Remote control access from other network through team viewer (if provided) and remote desktop will be checked. |

### 7.2. Inspection and testing at purchaser's site (SAT).

All required tests carried out at vendor's premises will be repeated at purchaser's site once again.

### 8. Utilities available

The purchaser will ensure that all the utilities shall be available at one point and distribution to the required location shall be in the purchasers's scope. Each of the utilities shall be made available at single point within 25 m distance from the Furnace.

### 8.1 Cooling water

Supply temperature : 35˚C (max.)/room temperature

The bidder has to indicate the cooling water requirement ($m^3$/hr) for the furnace.

**8.2 Electrical power**

3 phase 415± 10% V, 50 Hz Power shall be provided by the purchaser up to the power panel at single point. Supplier shall have to distribute the power wherever required from this point. The bidder shall indicate the power requirement in extreme case.

(Note: In addition to above emergency power will also be provided for operating of vacuum pumping systems and control systems.)

**9. Documentation**

The manufacturer shall submit four hardcopies & soft copy of operation, maintenance & safety manual of the furnace along with the following.

a. Design Basis, heating system details with calculations & 3D model.

b. P&IDs along with control system and interlocks.

c. General arrangement drawing of the furnace.

d. Requirement of utilities.

e. Details of thermal radiation shields.

f. Material of construction of various components.

g. As built drawings of

-Assembly (including bought out items complete with make, model, manufacturers Part no, voltage, current etc.)

- Sub-systems

- Electrical circuit diagram

- Control circuit diagram

- PLC wiring diagram

- PLC program

- Pneumatic circuit diagram

- Cooling water circuit diagram

- List and location of 'O' rings/seals

- Vacuum line diagram

h. Manuals & drawings of all bought out items & spares.

i. Technical specification of all major items such as shell, radiation shields, power panel, control panel, transformers, thyristors, PLC, SCADA, Vacuum pumping system, vacuum valves, vacuum gauges etc.

j. Weld Procedure Specification (WPS), Procedure Qualification Record (PQR), and Welder Performance Qualification (WPQ)

k. Complete list of spares with manufacturer's part number, make, model, quantity & dimension.

**Annexure – A Questionnaire**

| Sr. No | Comments | Response from supplier |
|---|---|---|
| 1. | Whether supplier is an original manufacturer If No, whether certificate of dealership from the principle manufacturer is provided. | |
| 2. | Whether supplier has manufactured similar multiple chamber horizontal vacuum furnace with minimum hot zone size of 1000 mm. If Yes, whether list of client with contact details attached with the offer. If Yes, whether technical details & copy of purchase order has been submitted. | |
| 3. | Whether calculations for vessel design is in accordance with the ASME Code for externally and internally pressurized vessels. | |
| 4. | Whether Weld Procedure Specification (WPS), Procedure Qualification Record (PQR), and Welder Performance Qualification (WPQ) are provided. | |
| 5. | Whether a conceptual design & schematic for mounting of radiation shield are provided. | |
| 6. | Whether supplier has provided details of<br>• Power & Cooling water requirement<br>• Job loading system<br>• Floor load<br>• Foot print of furnace including space for maintenance & operation. | |
| 7. | Whether make and model number for all the bought out items like pumps, gauges, valves, PIDs, PLCs, transformer etc. are mentioned in the offer. | |
| 8. | Whether inner surface finish of the chamber indicated in the offer. | |
| 9. | Whether details of sealing material are provided. | |
| 10. | Whether conceptual scheme for Power Supply is provided. | |
| 11. | Whether Vacuum Pump down time calculations are provided. | |
| 12. | Whether details of safety devices incorporated are provided with the offer. | |
| 13. | Whether the supplier shall hot test of the furnace at his premises to its full operating temperature. | |
| 14. | Whether onsite warranty is provided in the offer. | |
| 15. | Whether point by point compliance for the technical specification is provided along with the offer. | |

## Annexure- B (Un-priced Price bid)

### Price Schedule

Un-priced price-bid shall be submitted with the offer as per the format given below. All the item/rows are to be filled as "Q" indicating quoted and submitted with technical offer, and the same shall be submitted as Price-bid in part-II. Item wise cost of all the items shall be clearly offered as per the price bid for cost evaluation, failing which the cost of the same item offered by highest bidder for that same item will be loaded and then compared.

| Sr No. | Description | Qty | Unit | Remark |
|---|---|---|---|---|
| 1. | Basic equipment: Design, Manufacture, Supply, Installation, Commissioning and Performance Demonstration of horizontal (Resistance heating & cold wall) high temperature vacuum furnace with high pressure gas quenching system as per technical specification/Scope of supply &Services. | 01 | No | |
| **Mandatory spares** | | | | |
| 2. | Heater elements with other necessary accessories for entire assembly | 01 | Set. | |
| 3. | Vacuum pump oils (for each pump if used in combination) | 01 | Charge. | |
| 4. | Ceramic Insulators | 02 | Sets. | |
| 5. | Viton 'O' ring (all sizes used in vacuum chamber) | 02 | Set | |
| 6. | Heater electrodes | 01 | Set | |
| 7. | Feed through (one for each different size and design) | 01 | No. | |
| 8. | Temperature sensors of heating zone, inlet and outlet water of furnace and heat exchanger as well. | 01 | Set. | |
| 9. | Hearth Plate (job holder) | 01 | No. | |