SECTION - C

TECHNICAL SPECIFICATIONS OF STORES AND DRAWINGS.

Technical Specifications for DESIGN, FABRICATION AND SUPPLY OF THERMO-MECHANICAL EXPERIMENTAL SETUP FOR PEBBLE BED YOUNGS MODULUS AND CREEP BY USING UNI-DIRECTIONAL COMPRESSION TEST

BRIEF DESCRIPTION:

The machine should have the capability of high temperate thermo-mechanical experiment mainly for Cyclic Compression and creep of the pebble bed (lithium based ceramic of approximately 0.8 to 1.2 mm pebbles). The test facility should have variable loading rate as mentioned below up to 50 kN. The testing system should have high data capture and sampling rate.

Scope of Work:

The experimental facility is planned to perform cyclic compression and creep experiment of lithium titanate ceramic pebbles of ~ 1 mm. The strain developed in terms of continuous cyclic loading and strain in terms of time during high temperature were recorded with the help of LVDT for both experiment and used for further calculation of Young's modulus and creep rate. The experiment will be carried out at high temperature and vacuum.

The present experimental facility can be divided in to two parts, one is the main machine which is used for the precise loading for cyclic compression and creep experiment and the second part is an integrated portion with the machine and it consists of (top and bottom piston, sample holder, LVDT for the strain measurement of the sample (pebble bed region), vacuum assembly for the sample region and an external furnace). The schematic of second part (integrated portion with the main machine) is shown in Fig 1 & 2.

a. Details of the main machine is provided in section 1 of the specification part.
b. Integrated setup for pebble bed experiment schematic is shown in Fig. 1 & 2.
c. For the measurement of precise load and to maintain the accuracy, details are provided in section 2.
d. Sample holder and piston details are provided in section 3.
e. Dimension of the sample holder is mentioned in section 3.6 & 3.7. It should be noticed that the dimension can vary as mentioned in section 3.6 & 3.7 so that the drawing has to be made accordingly as per the future extension plan.
f. The experiment is planned to perform at high temperature (1000 deg C) and the details of furnace is provided in section 4.

g. Both cyclic compression and creep will be performed in vacuum of 10^{-4} mbar as mentioned in section 5, the components should have the ability to withstand at this high temperature as mentioned in section 4.
h. The strain measurement of the pebble bed (ceramic material) has to be recorded using LVDT probe positioned internally as shown in Fig 1 & 2 and the details are given in section 6.
i. The data should be recorded with high accuracy as mentioned in section 7.1 and output format and required output data are mentioned in 7.5 & 7.6.
j. Water cooling requirements are mentioned in section 8.
k. The vendor should study the IPR inputs and submit the design details along with drawings to IPR. The design detail should contain material information, positioning of each items in the whole experimental setup like LVDT, thermocouple, sample holder locking with the bottom piston, additional feed through for the additional thermocouple in the vacuum region, vacuum sealing, dimension of each items, section wise temperature distribution with in the test area, water cooling arrangement etc.
l. After acceptance of drawings, the vendor may start the fabrication work.

Specification:

1. Machine:

1. Load cell Capacity	:	50 kN
2. Application	:	Cyclic Compression and Creep
3. Test area-height	:	max. 1350 mm
4. Test area-width between drive Screws	:	610 mm
5. Rate of loading	:	variable from 0.1 to 5 MPa/min
6. Test speed range	:	≤ 0.1 mm/h to ≥ 100 mm/min
7. Crosshead speed accuracy	:	± 0.1 % or better of set value
8. Position control resolution	:	0.1 μm or better
9. Control parameter	:	Force and displacement control
10. Loading arrangement	:	Servo controlled motorized loading system.
11. Duration of the experiment	:	100 hrs. (in case of creep); 200 cycle (in case of Young's modulus)
12. Mode of Operations	:	a.) Auto Mode b.) Manual Mode
13. Safety	:	a.) Emergency Switch b.) Limit switch for Up/Down
14. Power supply	:	230 volts, ± 10 volts

15. Water Cooler : Inlet and outlet connector dimension should be mentioned.

2. Load Cell:

2.1. Load Cell along with indicator – To display the load applied (Preferable make: Syscon, Strainsert, Tecsis LP, ATI industrial automation, etc.).

2.2. Rotational symmetrical design with precise axial alignment should have the option of interchanging with other load cell.

2.3. High accuracy (Linearity, Repeatability, Hysteresis, Resolution) according to ASTM E 4 and ISO 7500-1.

2.4. The accuracy should be effective in the lowest level of operation even if 100 N load is applied.

3. Sample holder and Piston:

3.1. Material of Construction for both sample holder and piston (upper and lower) should be Inconel 718

3.2. The upper piston should be dynamic for the experiment and lower piston should be in static condition.

3.3. The axial alignment of the piston should be in accordance with ASTM E 292.

3.4. The upper and lower piston fixed/clamped in a way that one can easily replace and assemble with other fixture/piston easily.

3.5. The sample holder is also to be made up of Inconel 718.

3.6. Inner dia of the sample holder is 50 mm which can be extendable with 60 and 70 mm.

3.7. The inner depth of the sample holder is 25 mm which can be extendable up to 50 mm.

3.8. The sample holder should be easily fixed on the top of lower piston and the clearance should be minimum so that it will not move here and there during operation while applying load as well as the condition of expansion and contraction must be focused at elevated temperature.

3.9. The position of the thermocouple at the nearest point of the sample is mentioned in the Fig. 2 which is kept internally through sample holder.

3.10. The minimum possible gap which can be maintained between the inner wall of sample holder and outer wall of upper piston during operation at elevated temperature should not be higher than 0.5 mm.

4. High Temperature Furnace and Controller:

4.1. A cylindrical three zone vertical split furnace which can go up to maximum temperature of 1200 °C (Independent power connection for zones to operate separately).

4.2. Heating zone should be in the range of 120-130 mm dia x 360 mm height

4.3. 3 Thermocouples for furnace controller, up to 3 additional Thermocouples provision for temperature control at the specimen

4.4. PID Controller with thyristor drive which can program at-least 10 segment with variable ramp and dwell time.

4.5. Heating rate of the furnace should be in the range of 1 to 10 °C/min.

4.6. The expected accuracy is ± 5°C or better.

4.7. Proper insulation should be maintained to keep the outer temperature of the furnace below 60 °C and should not affect the frames of the machine.

4.8. The furnace should be positioned vertically at the center of the specimen during test and should have the option of moving (up and down) without changing anything in the main machine.

4.9. Digital display of temperatures.

4.10. Furnace should be able to control through PC.

<u>5. Vacuum Chamber:</u>

5.1. The test area should be covered by vacuum as shown in the schematic drawing.

5.2. The level of vacuum should be in $1x10^{-4}$ mbar

5.3. Vacuum chamber material should be made of transparent Quartz.

5.4. The stability of quartz at higher temperature should be above 1000 °C.

5.5. The wall thickness of the quartz should be selected in a way sample should get temp. of 1000 °C and during vacuum it should not get broken as well.

5.6. The vacuum O-rings should be selected in a way, it will sustain high temperature whichever is the possible temperature to reach during high temperature test at the top and bottom portion of the piston where ever O-rings are placed.

5.7. The outer dia of the quartz should be selected by keeping in view of inner dia of furnace 120-130 mm dia so that it could be around 90 to 110 mm (OD)

<u>6. LVDT (to measure strain):</u>

6.1. LVDT (preferable make **-** Messotron, Trans-Tek, Singer Instruments and Control, TE connectivity or better)

6.2. 0-5mm range with resolution of 1micron.

6.3. 2-LVDT should be placed inside the vacuum chamber to access the strain developed in the sample (pebbles) within the sample holder (please see the location in the schematic fig. 1 & 2).

6.4. Position of the strain measurement probe can be discussed during the drawing submission by vendor to IPR.

7. Data Acquisition and Output:

7.1. 2 kHz or better

7.2. Sampling must be configurable with discrete steps

7.3. The software should have the facility of different method of testing for cyclic compression and creep experiment.

7.4. The software should have user programmable loading pattern with different wave form.

7.5. The data output will be GUI and ASCHII format

7.6. The required output is Test time, travel sensor, standard travel, standard force, temperature, vacuum, Sample Strain and stress.

8. Water Cooler and Accessories: ***(Optional)***

8.1. Water chilling unit: A chiller unit to chill the water and to circulate the fittings to avoid the LVDT sensor damage due to heat.

8.2. Capacity : 50 liters tank capacity

8.3. Temp controller : Automatic on/off Digital temperature controller with set temperature

8.4. Cooling : Automatic cooling on/off facility

8.5. Working temp range: water inlet temp. 25 °C ± 2°C

8.6. Water circulation : 20 lit/min

8.7. The water chilling plant is constructed with the wheel to move the equipment easily

8.8. Switches : independent control for chilling plant and water circulation pump

8.9. Dimension of the Input and output connector from the water cooler/hose to the machine should be mentioned.

Vendor should provide the following:

1. Calibration Certificates:
   a. LVDT along with signal conditioner
   b. Load cell along with signal conditioner
   c. Thermocouples
   d. Cross-head movement of the machine
2. Utility (power, water, space) requirements
3. Detail of Shell Construction (Furnace)

4. Details of heating element and their locations
5. Provision of having additional thermocouples in the vacuum region
6. Details of water cooler and accessories
7. Detailed design drawing should include the following:
    - Information of material used for construction of machine
    - Dimension details of the machine with each individual items
    - Dimension details of the piston and sample holder
    - Positioning of each item in the machine including the controllers
    - LVDT
    - Thermocouple placement
    - Sample holder locking with the bottom piston
    - Additional feed through for extra thermocouple in vacuum region
    - Vacuum sealing details
    - Section wise temperature distribution in the test area and how the distribution is getting reduced above and below of the furnace region to the maximum temperature.
    - Stability of the machine for 50 kN load stress analysis report
    - Temperature stability of the material with thermal properties
    - Total space required for the machine
    - Electrical connection and its drawing for the machine, furnace, water cooler etc.
8. Details of the vacuum pump (make, model, pumping speed etc.)
9. LVDT position has to be mentioned in the drawing. Vendor should also provide its working temperature (the expected working temp. for LVDT is 200 °C).
10. Vendor should mention about the warranty/guaranty
11. Vendor should quote separately the following additional items along with their price:
    a. 100 N load cell – 1 no.
    b. LVDT as per point 6 – 2 nos.
    c. Transparent quarts tube as per point 5.5 – 3 nos.
    d. O-rings as per point no 5.6 – 10 nos.
    e. List of any other spares and consumables
12. Vendor should quote separately for the water cooler and its accessories.
13. Vendor should arrange their own water cooler facility as per point no. 8 in the specification during the factory acceptance test at vendor site.

Scope of supply:

Complete unit (including vacuum pump, furnace, water cooler (Optional), diagnostics system, data acquisition system)

Schedule:

1. Vendor should submit the design details along with drawing within 15 days from PO received.
2. IPR will give the comments/acceptance of the drawing within in 7 days after receiving it from the vendor.
3. After the acceptance of drawing from IPR, vendor can start the fabrication.
4. Vendor should inform IPR for the Factory acceptance test/PDI at the vendor/factory site well in advance preferably 15 days before.
5. The delivery of the machine should be within 3 month from the date of acceptance of drawing.
6. After Factory acceptance/PDI, the inspection report will be reviewed by IPR expert committee for its acceptance, after completing the acceptance procedure IPR purchase section will issue the dispatch clearance.
7. Proper packing should be done for the shifting of instrument from vendor/factory site to IPR.

Factory Acceptance Test: (Vendor need to submit the following documents/test reports for the approval before dispatch)

i.) Temperature, vacuum, cross head speed and accuracy, load cell accuracy, LVDT accuracy and data acquisition will be tested at Vendor's place.

ii.) At least 1 hour of holding at 1000 deg will be done to check the temperature accuracy mentioned and heating rate as well during this experiment.

iii.) Cyclic Compression and Creep expt. will be done with Li_2TiO_3 Pebbles (IPR will provide Li_2TiO_3 Pebbles for the experiment)

Acceptance Test at IPR:

i.) The instrument along with its all components should be installed and commissioned at IPR.

ii.) Vendor should provide proper training of the instrument to IPR personnel for its operation.

iii.) The following experiments will be carried out at IPR:

- a) Temperature, vacuum, cross head speed and accuracy, load accuracy, LVDT accuracy and data acquisition will be tested after installation.
- b) Temperature accuracy, heating rate etc. will be tested.

c) Cyclic Compression and Creep expt. will be carried out with Li_2TiO_3 Pebbles (IPR will provide Li_2TiO_3 Pebbles)

d) Continuous expt. of creep and Young's modulus will be carried out during this test.

<u>Fig. 1. Schematic of the Experimental set-up</u>

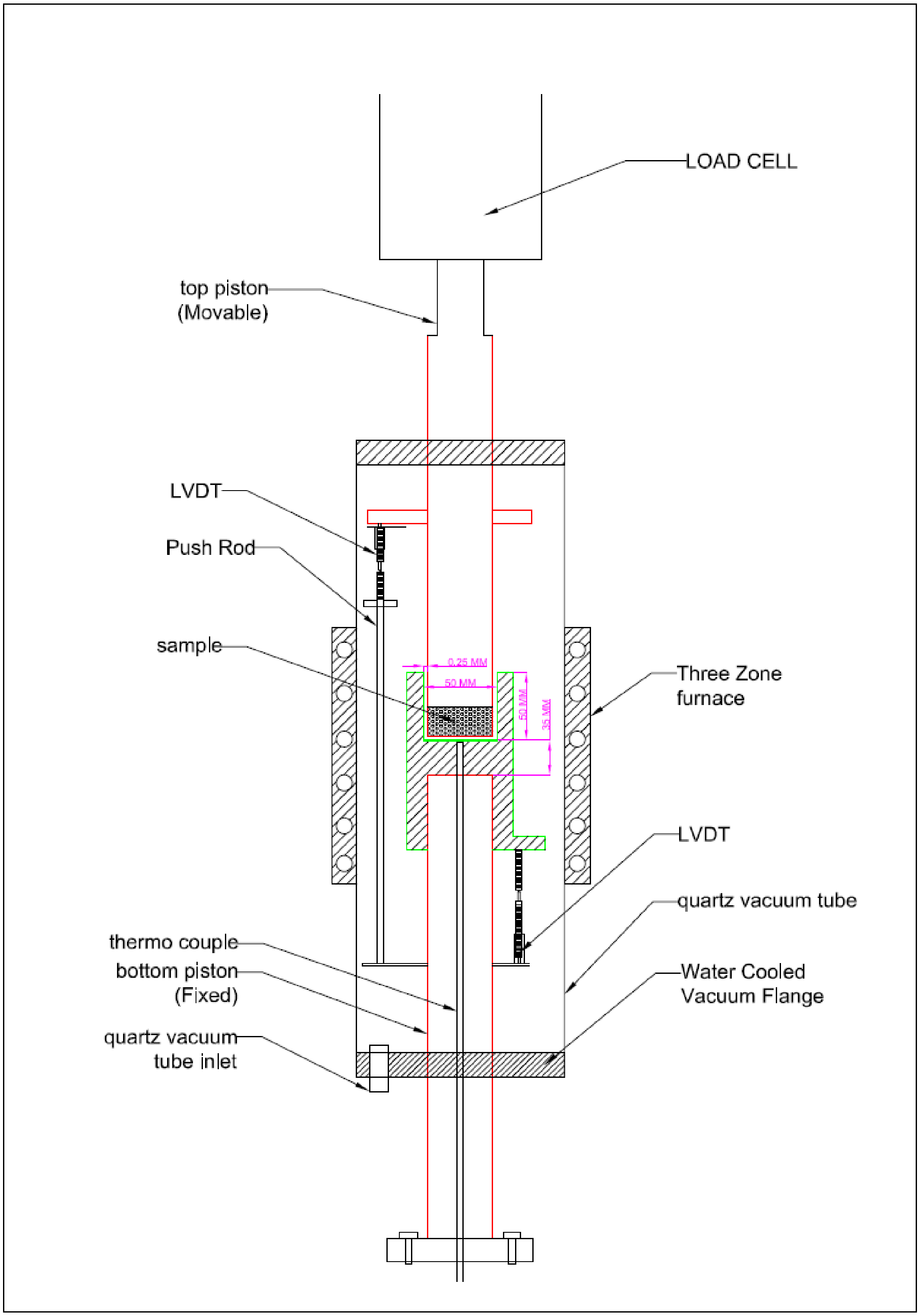
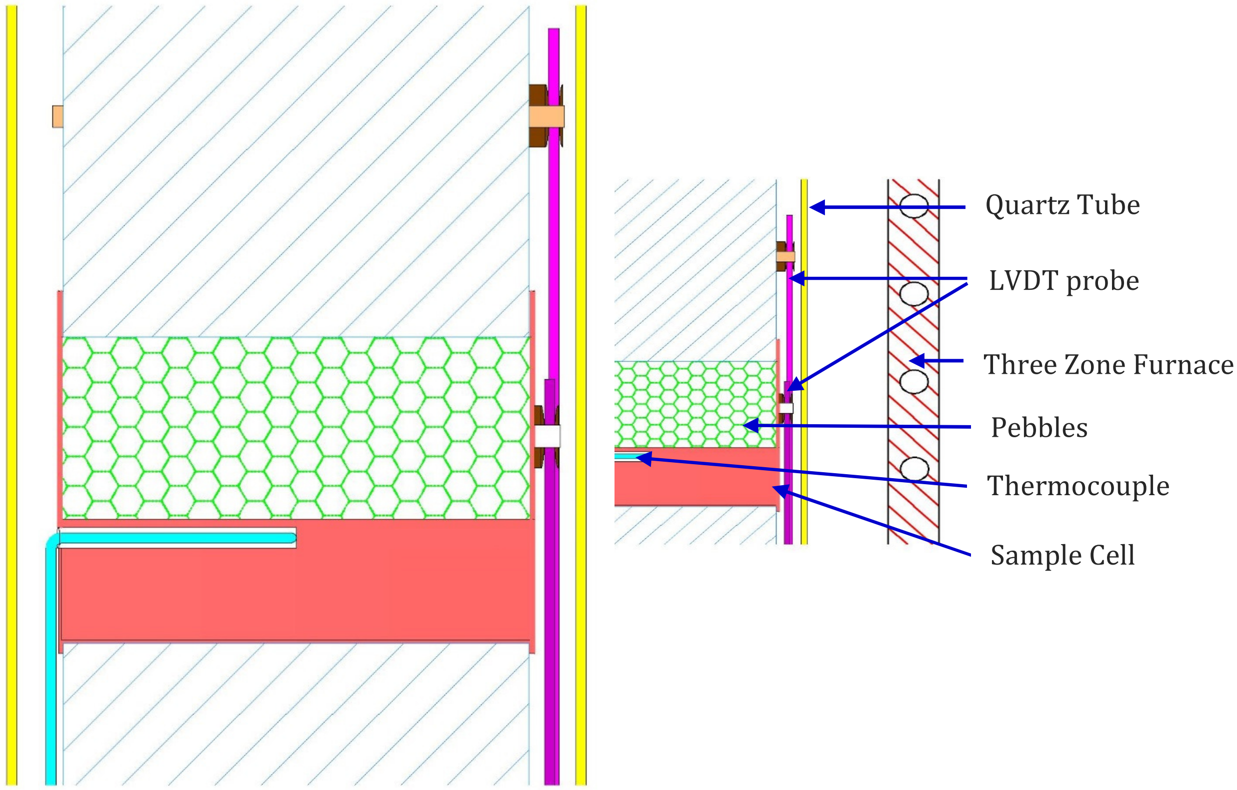


Fig. 2. Schematic of Alternate locations of LVDT



Compliance Sheet

No.	IPR Requirement		Vendor
1.	Machine	Load cell Capacity: 50 kN	
		Application: Cyclic Compression and Creep	
		Test area-height: max. 1350 mm	
		Test area-width between drive: 610 mm Screws	
		Rate of loading: variable from 0.1 to 5 MPa/min	
		Test speed range: ≤ 0.1 mm/h to ≥ 100 mm/min	
		Crosshead speed accuracy: ± 0.1 % or better of set value	
		Position control resolution: 0.1 μm or better	
		Control parameter: Force and displacement control	
		Loading arrangement: Servo controlled motorized loading system.	
		Duration of the experiment: 100 hrs. (in case of creep); 200 cycle (in case of Young's modulus)	
		Mode of Operations: a.) Auto Mode, b.) Manual Mode	
		Safety: a.) Emergency Switch, b.) Limit switch for Up/Down	
		n) Power supply: 230 volts, ± 10 volts	
		o) Water Cooler: Inlet and outlet connector dimension should be mentioned.	
2.	Load Cell	Load Cell along with indicator – To display the load applied (Preferable make: Syscon, Strainsert, Tecsis LP, ATI industrial automation, etc.).	
		Rotational symmetrical design with precise axial alignment should have the option of interchanging with other load cell.	
		High accuracy (Linearity, Repeatability, Hysteresis, Resolution) according to ASTM E 4 and ISO 7500-1.	
		The accuracy should be effective in the lowest level of operation even if 100 N load is applied.	
3.	Sample holder and Piston	Material of Construction for both sample holder and piston (upper and lower) should be Inconel 718	
		The upper piston should be dynamic for the experiment and lower piston should be in static condition.	
		The axial alignment of the piston should be in accordance with ASTM E 292.	
		The upper and lower piston fixed/clamped in a way that one can easily replace and assemble with other fixture/piston easily. The sample holder is also to be made up of Inconel 718.	

		Inner dia of the sample holder is 50 mm which can be extendable with 60 and 70 mm.	
		The inner depth of the sample holder is 25 mm which can be extendable up to 50 mm.	
		The sample holder should be easily fixed on the top of lower piston and the clearance should be minimum so that it will not move here and there during operation while applying load as well as the condition of expansion and contraction must be focused at elevated temperature.	
		The position of the thermocouple at the nearest point of the sample is mentioned in the Fig. 2 which is kept internally through sample holder.	
		The minimum possible gap which can be maintained between the inner wall of sample holder and outer wall of upper piston during operation at elevated temperature should not be higher than 0.5 mm	
4.	High Temperature Furnace and Controller	A cylindrical three zone vertical split furnace which can go up to maximum temperature of 1200 °C (Independent power connection for zones to operate separately). Heating zone should be in the range of 120-130 mm dia x 360 mm height 3 Thermocouples for furnace controller, up to 3 additional Thermocouples provision for temperature control at the specimen PID Controller with thyristor drive which can program at-least 10 segment with variable ramp and dwell time. Heating rate of the furnace should be in the range of 1 to 10 °C/min. The expected accuracy is ± 5°C or better. Proper insulation should be maintained to keep the outer temperature of the furnace below 60 °C and should not affect the frames of the machine. The furnace should be positioned vertically at the center of the specimen during test and should have the option of moving (up and down) without changing anything in the main machine. Digital display of temperatures. Furnace should be able to control through PC.	
5.	Vacuum Chamber	The test area should be covered by vacuum as shown in the schematic drawing. The level of vacuum should be in 1×10^{-4} mbar Vacuum chamber material should be made of transparent Quartz. The stability of quartz at higher temperature should be above 1000 °C. The wall thickness of the quartz should be selected in a way sample should get temp. of 1000 °C and during vacuum it should not get broken as well. The vacuum O-rings should be selected in a way, it will sustain high	

		temperature whichever is the possible temperature to reach during high temperature test at the top and bottom portion of the piston where ever O-rings are placed. The outer dia of the quartz should be selected by keeping in view of inner dia of furnace 120-130 mm dia so that it could be around 90 to 110 mm (OD)	
6.	LVDT (to measure strain)	LVDT (preferable make **-** Messotron, Trans-Tek, Singer Instruments and Control, TE connectivity or better) 0-5mm range with resolution of 1micron. 2-LVDT should be placed inside the vacuum chamber to access the strain developed in the sample (pebbles) within the sample holder (please see the location in the schematic fig. 1 & 2). Position of the strain measurement probe can be discussed during the drawing submission by vendor to IPR.	
7.	Data Acquisition and Output	2 kHz or better Sampling must be configurable with discrete steps The software should have the facility of different method of testing for cyclic compression and creep experiment. The software should have user programmable loading pattern with different wave form. The data output will be GUI and ASCHII format The required output is Test time, travel sensor, standard travel, standard force, temperature, vacuum, Sample Strain and stress.	
8.	Water Cooler and Accessories: ***(Optional)***	Water chilling unit: A chiller unit to chill the water and to circulate the fittings to avoid the LVDT sensor damage due to heat. Capacity : 50 liters tank capacity Temp controller : Automatic on/off Digital temperature controller with set temperature Cooling : Automatic cooling on/off facility Working temp range: water inlet temp. 25 °C ± 2°C Water circulation : 20 lit/min The water chilling plant is constructed with the wheel to move the equipment easily Switches : independent control for chilling plant and water circulation pump Dimension of the Input and output connector from the water cooler/hose to the machine should be mentioned.	

Authorized Singatory

Official Seal

Date