

## TECHNICAL SPECIFICATIONS

### AMBIENT AND HIGH TEMPERATURE DYNAMIC MODULUS MEASUREMENT SYSTEM USING IMPULSE EXCITATION TECHNIQUE

Supply, erection, installation, commissioning, demonstration and imparting training on an ambient and high temperature dynamic modulus measurement system using impulse excitation technique, as per the specifications given below.

The test system shall be capable of determining dynamic elastic modulus, dynamic shear modulus, Poisson's ratio and damping characteristics of metallic materials, ceramic materials and composite materials. The test system shall support specimens in the form of bars, cylinders and discs. The test system shall have a furnace to heat the sample to any temperature between ambient temperature and 1200°C or above in air and inert gas environment (Nitrogen, Argon), mechanism for impulse excitation, non-contact microphone sensor and software to control the furnace, excitation device, data capturing, analysis and result generation.

#### II. SYSTEM HARDWARE

##### 1. FUNCTIONAL CAPABILITY

S.No.	Feature
1.1.	Equipment shall be capable of measuring dynamic elastic modulus (E), dynamic shear Modulus (G), Poisson's ratio and damping characteristics in homogeneous, isotropic materials at any desired temperature between ambient and 1200°C or above, using the principle of impulse excitation technique and procedures outlined in standard ASTM E1876 both in air as well as in inert gas environment and shall facilitate measurements in both torsional and flexural modes.

##### 2. HEATING MODULE

S.No.	Feature
2.1.	Cylindrical/box type furnace possessing a uniform hot zone of length 150 mm, 110 mm width and 50 mm depth. The uniform hot zone shall be able to accommodate the sample sizes as mentioned in ASTM E1876. The furnace shall be able to accommodate the holding mechanisms. Uniform hot zone is centered about the specimen. During pre-delivery inspection and installation, temperature uniformity shall be demonstrated as per the

	procedure enclosed with the purchase order. Temperature uniformity of within $\pm 5^{\circ}\text{C}$ is required within the uniform hot zone.
2.2.	The furnace shall work with an AC input supply of 220-240 V/50 -60 Hz.
2.3.	Furnace outer wall temperature shall not exceed $50^{\circ}\text{C}$ under any circumstances and shall be controlled using appropriate water cooling system.
2.4.	Furnace temperature shall be controlled and maintained using a programmable controller of reputed brand like Eurotherm. Accuracy of the controller shall be within $\pm 1^{\circ}\text{C}$ . It shall be interfaced with the test software such that varying rates of heating and varying hold times can be pre programmed and adopted for different intermediate temperature ranges before attaining the maximum test temperatures.  Valid Calibration certificates of Eurotherm controller traceable to National/International standard issued by accredited laboratories of country of origin shall be provided.
2.5.	The furnace shall possess durable resistance heating elements capable of achieving maximum temperature of $1200^{\circ}\text{C}$ or above on the test specimen.
2.6.	At any desired temperature, the set up shall permit purging with inert gases to keep the test environment lean in oxygen. It shall also permit continuous flow of inert gases during testing at desired flow rates. The set up shall also contain traps for moisture in gases.
2.7.	Thermocouple(s) of S type (with accuracy $\leq \pm 0.25\%$ ) meant for repeated use in the capable temperature range under both air and inert gas environment shall be supplied. The furnace thermocouples shall be placed as close to the specimen as possible in order to acquire specimen temperature. Test certificate of the thermocouple for the mentioned accuracy shall be submitted.  Valid Calibration certificates of thermocouple traceable to National/International standard issued by accredited laboratories of country of origin shall be provided.
2.8.	In addition to job thermocouple, a separate control/ safety thermocouple (S type) shall also be available with the system to control/ prevent accidental temperature overheating of the furnace.
2.9.	Construction of the furnace and test platform shall ensure clear visibility of sample, supports and location of excitation system with respect to sample. It shall be possible to place the sample in different orientations with respect to the

	excitation system for facilitating torsional and flexural modes.
2.10.	The system shall be provided with a wave guide along with microphone having suitable cooling arrangement.
2.11.	The test set up shall be isolated from external vibrations; suitable mechanism shall be provided for the same.
2.12.	Appropriate safety interlocks and option to consciously overrule them, if needed, shall be provided both in the hardware and software so as to ensure safe operation of the test system (e.g., (a) furnace shall not start unless water chiller is on (b) shall not start /shall switch off if temperature of cooling water is not within acceptable limits, 20-30°C etc.)

### 3. EXCITATION AND SENSING MODULE

S.No.	Feature
3.1.	The test system shall be provided with suitable automatic impulse excitation system during measurements from ambient temperature to 1200°C or above in air as well as in inert gas environment. The excitation force and timing shall be controllable through the computer software. Force used in impacting shall be consistent in multiple readings and it shall be user selectable.
3.2.	Facility for manual excitation at room temperature shall also be provided and accessories required for manual excitation shall be explicitly quoted.
3.3.	Tips of appropriate sizes and geometry shall be provided for the automatic excitation tool so that appropriate tips can be chosen suitable for materials ranging from low density to high density metals (Range of density values=2400-9500 kg/m <sup>3</sup> ). Such tips shall be compatible for use at ambient and high temperatures up to 1200°C or above.
3.4.	Facility to position automatic excitation device at different locations in the furnace as well as at room temperature shall be provided. There shall be a provision to change the height of excitation system with respect to sample height.
3.5.	Microphone used for sensing the vibrations both at ambient and high temperatures should have a frequency range of 20 Hz (or below) - 90 kHz (or above).
3.6.	Leak-proof water cooling arrangement shall be provided for the microphone for high temperature use.
3.7.	Both at ambient and high temperatures, there shall be a provision to adjust the

	height of the microphone to position it close to the specimen.
3.8.	Before starting any high temperature testing it shall be possible to carry out in-situ checking of the high temperature test set up at ambient temperature with sample loaded on supports without closing furnace and initiation of other processes that precede high temperature testing.

#### 4. SOFTWARE AND ELECTRONIC HARDWARE

S.No.	Feature
4.1.	The system shall be provided with software which would (a) control and monitor all the functions of furnace, (b) activate and control automatic impulse excitation device, (c) permit pre-programmed setting up of experimentation (d) carry out data acquisition, data analysis and report generation.
4.2.	The software shall permit programming the desired heating cycle and temperature profiles involving varying heating and cooling rates and hold times. It shall have the capability to log and store temperature data as a function of time at a default or user defined data capturing rate.
4.3.	The software shall have provision for selecting excitation force for samples.
4.4.	The software shall permit carrying out of experiments at high temperatures with programmed test parameter settings and automatic excitation wherein excitation, data acquisition and analysis shall be possible at an interval of every 10°C or higher.
4.5.	The software shall have features to automatically repeat excitations, if need be, till consecutive readings falling within limits stipulated by ASTM E1876 or as desired by user are achieved.
4.6.	The software shall have provision for calculation of dynamic Young's modulus , Shear-modulus, Poisson's ratio for homogeneous, elastic and isotropic materials in the form of bar, cylinder and disc as per the latest version of ASTM E 1876 at ambient temperature and the software shall also have provision for calculation of dynamic Young's modulus and Shear-modulus, Poisson's ratio for homogeneous, elastic and isotropic materials in the form of bar as per the latest version of ASTM E 1876 at high temperatures.
4.7.	The software shall provide real-time updates of frequency/damping plotted as a function of test temperature.

4.8.	The software shall have facility for signal analysis in time and frequency domain. It shall also have the facility for noise suppression of high temperature signals. There shall be provision to overrule noise suppression option.
4.9.	Signal thresholds and microphone gain shall be controllable through the software.
4.10.	The electronic system shall have an accuracy and precision to measure the frequencies of interest to an accuracy of 0.1%.
4.11.	Frequency resolution shall be within $\pm 0.1\%$ of the measured frequency and not less than 1 Hz for signals of length $\geq 20$ msec. For signals with length of $< 20$ msec, a resolution not less than 50 Hz is mandatory.  The technical bid shall contain a report on the frequency analysis performed using the software of a known frequency signal with signal length $< 20$ msec as well as signal of length $\geq 20$ msec.
4.12.	The software shall have features for automatic identification of peaks in frequency spectrum.
4.13.	The software shall provide complete frequency spectrum response after the data analysis.
4.14.	Algorithms used in software shall be robust enough to analyze signals under severe conditions (noise, low vibration amplitude, etc.)
4.15.	The software shall be capable of generating reports or outputting the results to a spreadsheet file.
4.16.	The software shall have features to carry out measurement of dynamic Young's modulus and dynamic shear modulus on the same test specimen in a single thermal cycle.
4.17.	The software shall also have provision to access raw data in text format/spreadsheet format for data analysis separately.

## 5. COMPUTING HARDWARE

S.No.	Feature
5.1.	The testing system shall be supplied together with a computer of the following specifications.: Intel latest generation Quad-Core Processor, minimum 3 GHz, , 8 GB RAMDDR-4, DVD-Writer (optional), Multimedia USB Keyboard, USB Mouse, 21" LED backlit IPS display, 2 x 1 TB Hard Drive SATA 7200 RPM, Windows 10, 2x USB 3.0, HP Color Laser Jet Printer or latest available in

	market. Resolution of monitor shall be compatible with the latest version of the software for better visualization of results. Preferably Indian make.
5.2.	Proven hardware and software available in the market at the time of supply will be acceptable, provided its compatibility with the test system has been fully checked and ensured.
5.3.	The computing system has to be equipped with all necessary drivers, DAQ cards and software.
5.4.	Latest version of the testing and analysis software shall be supplied together with the test system. Upgrades and updates to the testing software shall be provided free of cost for a period of ten years from the date of completion of installation. Original licensed version of the software together with unlocking keys shall be supplied in Compact Discs.

## 6. GENERAL GUIDELINES

- 6.1. If the bidder is quoting for an imported system, the bidder will have to attach the authorized representative certificate from OEM. Ink signed authorized dealership certificate for the system as well as the software from the principals shall be provided.
- 6.2. Supplier shall have the heritage in manufacturing and supply of similar systems and only proven systems are acceptable.
- 6.3. Calibration certificates of thermocouple and Eurotherm controller traceable to National/International standard shall be provided.
- 6.4. Flexible hoses, clamps, connectors, fasteners, cir-clips, pipes etc. required for installation and commissioning shall be within the scope of supply by the party.
- 6.5. Any special requirements at the site such as water availability, special foundation, electricity, earthing, UPS etc. shall be specified in the offer. It may be noted that the UPS is not under the scope of supply but requirements related to UPS shall be mentioned.
- 6.6. All the assembly related activities such as welding, riveting, bolting etc. required at the site shall be taken care of by the party.
- 6.7. The OEM shall have manufactured and supplied at least 3 high temperature dynamic modulus measurement systems to reputed organizations in India working on the principle of impulse excitation technique. Details (telephone number with address and contact person) pertaining to these organizations shall be given to LPSC, ISRO. Customer satisfaction certificate in this regard is preferred.

6.8. Table of compliance statement against this specification sheet, giving exact numerical values with tolerances or range of values shall be supplied along with the quote without which the quote will not be considered. Merely stating, “comply” does not constitute sufficient technical data.

**7. ESSENTIAL ACCESSORIES -**

S.No.	Feature
	<b>Following spares and accessories shall be supplied</b>
7.1.	Sample supports shall be made of platinum and Rhodium wires which do not react with test specimens at high temperatures during the test.
7.2.	Sample supports at both room and high temperature shall facilitate accurate placement of samples at nodal positions. The supports shall be smoothly sliding / moving and shall be amenable for fixing at any point to facilitate accurate placement of specimens at its nodal points.
7.3.	Certified reference samples (one metal and one non-metal) along with their measured values and relevant references
7.4.	<p>Water Chiller: A water chiller of appropriate type and capacity suitable for the test system shall be supplied together with the test system. Preferably Indian make.</p> <p>Medium : Cooling water at RT</p> <p>Pressure : 4-6 bar</p> <p>Flow : 3-5 litres /min</p> <p>Cooling capacity : 3.5 kW</p>

**8. ACCEPTANCE CRITERIA :PRE-DISPATCH INSPECTION CRITERIA**

For acceptance of the item, the following criteria shall be met:

- 8.1. Specific application training for at least two LPSC personnel at manufacture’s site shall be provided for free of cost.
- 8.2. All specifications of the equipment mentioned in technical data shall be demonstrated.
- 8.3. Demonstration of the general operation of the equipment as well as the software.
- 8.4. Ambient and high temperature modulus measurements on specimens supplied by LPSC, as per Section 12 shall be carried out. As an optional, reference test bars (metal and non-metal) shall be provided with valid international calibration certificates.

- 8.5. During pre-delivery inspection and installation, temperature uniformity shall be demonstrated as per the procedure enclosed with the purchase order.
- 8.6. E, G measurements on reference standards samples (from RT to 1200°C or above) and comparison of results available in literature.
- 8.7. Valid Calibration certificates of thermocouples and Eurotherm controller traceable to National/International standard issued by accredited laboratories of country of origin shall be provided.

## **9. ACCEPTANCE CRITERIA : POST INSTALLATION AND COMMISSIONING**

For acceptance of the item, the following criteria must be met:

- 9.1. Completion of the installation, training, maintenance training and commissioning of the systems- Room temperature and high temperature modulus measurement system using impulse excitation technique at LPSC, Valiamala, Trivandrum, Kerala, India.
- 9.2. All specifications of the equipment mentioned in technical data shall be demonstrated. For parameters which are not possible to demonstrate shall be supported by certificate of performance issued by a competent authority.
- 9.3. Demonstration of the general operation of the equipment as well as the software.
- 9.4. Submission of the detailed technical, maintenance and operating manuals (2 copies) in English.
- 9.5. Complete capabilities of the system including software and hardware are to be fully demonstrated.
- 9.6. E,G, measurements on reference standards samples (from RT to 1200°C or above) and comparison of results available in literature,
- 9.7. During installation, temperature uniformity shall be demonstrated as per the procedure enclosed with the purchase order.
- 9.8. Testing and demonstration of modulus results on samples provided by LPSC during pre-dispatch inspection, as mentioned in Section 12 provided by LPSC.

## **10. WARRANTY**

- 10.1. The equipment must be under warranty for a period of one year from date of successful commissioning.
- 10.2. Cost of extended warranty for 2 years shall be quoted separately over and above 10.1.

## **11. ANNUAL MAINTENANCE CONTRACT (AMC)**

- 11.1. Non-comprehensive AMC charges for the next 7 years after the expiry of warranty shall be indicated in the quotation separately. Scope of the AMC shall include 1 preventive

maintenance visit in a year and any number of breakdown visits.

11.2. List of essential spares and consumables required for trouble free operation of 5 years shall be provided. The price for these spare parts shall be quoted separately. This will be also included in bid estimation.

11.3. Supplier shall be in a position to undertake AMC or provide service support for the instrument supplied, after the expiry of the warranty period either directly or through an authorized, trained service representative stationed in India. Details in this regard (company profile, year of establishment and number of factory trained engineers) shall be provided.

## 12. TEST MATRIX

<b>Sl.no.</b>	<b>Material</b>	<b>Temperature in °C</b>	<b>Parameters to be measured</b>
1.	Nickel based super alloy	Room Temperature&900 (INERT ATMOSPHERE)	Young's modulus, shear modulus and Poisson's ratio
2.	Columbium	Room Temperature&1200 (INERT ATMOSPHERE)	Young's modulus, shear modulus and Poisson's ratio
3.	Stainless steel	Room Temperature&1000 (INERT ATMOSPHERE)	Young's modulus, shear modulus and Poisson's ratio