Item: 10 kN Servo Hydraulic Universal Testing Machine.

**Detailed Specifications**

1. **General**: The test machine should be capable of performing following tests confirming to respective indicated standards or their ISO equivalent:
   a) Tensile tests as per ASTM E8,
   b) Compression tests as per ASTM E9,
   c) Fracture toughness tests as per ASTM E1820,
   d) Fatigue crack growth rate tests under cyclic loading as per ASTM E647 and
   e) Low cycle fatigue test as per ASTM E606.

2. **Test Materials**: Specimens in the form of sheet, plate, rods and blocks made up of metallic solids, porous materials, weld metals and ceramics.

3. **Scope**: Supply, installation, user training and test demonstration of complete testing capabilities of the machine at RRCAT site. The machine should comprise of load frame assembly, servo-hydraulic actuator assembly with linear encoder, hydraulic power pack, servo valve manifold, load transducer, digital controller interfaced with a computer and the necessary hardware and software for single channel and single station servo-hydraulic test system. It should have digital controller for command waveform generation, data acquisition, transducer signal conditioning, test monitoring, event detection, and other relevant closed loop servo-control capabilities. This digital controller should have a PC based windows interface and all the necessary licensed software, through which tests and applications can be assigned, performed, monitored and data be acquired. The test machine should have a local control panel mounted on the load frame to facilitate manual loading, unloading of samples, positioning of the actuator along with emergency stop switch. Windows-7 or later version and other application software compatible with the digital controller and testing software should be included in the scope of the supply. Requisite accessories including grips, fixtures and strain measuring devices, like extensometers should also be included in the scope of the supply. There should be provision for testing the materials immersed in Simulated Body Fluid environment.

4. **Construction of Test Machine and Detailed Specifications**:
   a) **Load Frame Assembly**:
      i. The load frame assembly should comprise of two columns with smooth moveable top crosshead and actuator mounted on it. The load frame assembly of the machine should be mounted on Castor/Isolator pads to damp external vibrations.
      ii. The bottom should be with T-slot base table facilitating ease mounting of fixtures/specimens.
      iii. Column spacing should be 350 mm or more.
      iv. The vertical test space should be 900 mm or more.
      v. Load frame should be self-reacting type and free from self-induced shocks and vibrations. The stiffness of the load frame should be more than 400 MN/m at a crosshead separation of 350 mm.
      vi. The column should be chrome plated for corrosion resistance.
      vii. Emergency stop button should be provided on load frame for pressure release. The cables connecting the load frame, load cell, extensometer etc. to the control console should be of adequate length (maximum radial distance up to 3 meters) for easy handling.
      viii. There should be provision for the supply of hydraulic lines at the test station for conducting tensile/fatigue tests by operating the hydraulic grips.
      ix. Load assembly should have a PLC based touch screen operating control panel for power pack, top cross head movement and emergency stop.
      x. Overall dimensions (max.): 1000 mm x 700 mm x 2200 mm.
   b) **Load Cell**:
      i. Fatigue rated load cell with rated dynamic load capacity of ±10 kN should be mounted on base plate. An additional load cell of rated dynamic capacity ±1 kN for precise measurement at low loads should be provided. This additional load cell may be coupled with main load cell in “Piggyback” type arrangement. The load cells should have overload protection up to 125% of rated capacity with built-in shunt resistors for shunt calibration.
The load cells should have provision and mountings for stacking of force transducers in series for testing small/large specimens in the same load frame. The load cell should have electronic controls for smooth functioning of load cell during automatic/manual mode.

ii. Load measuring system including load cells should confirm to the requirements of ASTM E4 or equivalent ISO specifications.

<table>
<thead>
<tr>
<th>Setup</th>
<th>Load Cell - 1</th>
<th>Load Cell - 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated Capacity</td>
<td>10 kN load cell</td>
<td>1 kN load cell</td>
</tr>
<tr>
<td>Minimum measurable force</td>
<td>± 50 N</td>
<td>± 5 N</td>
</tr>
<tr>
<td>Maximum measurable force</td>
<td>± 10 kN</td>
<td>± 1 kN</td>
</tr>
</tbody>
</table>

The load measurement accuracy should be better than ±0.002% of load cell capacity or 0.5% of indicated load; as per ISO7500-1 Class 0.5, ASTM E 4, EN10002-2 Class 0.5, JIS (B7721, B7733) down to 1/250° of full scale.

iii. The instrument should have electronic calibration of the load cell which will do away with the conventional manual calibration of the load cell with standard weights.

c) **Servo Hydraulic Actuator**: 10 kN fatigue rated double acting, double ended, equal area actuator with an integrated manifold and monolithic piston design having total stroke of ± 50 mm or more with cushion of 5 mm on both the ends should be crosshead mounted. The actuator should have co-axially mounted digital linear encoder for stroke measurement with 0.1 micron resolution. The actuator should have closely coupled servo-valve for Fatigue (both low cycle and high cycle) and Fracture toughness testing. Pressure gauge for pressure sensing should be provided. Machine should be able to perform fatigue testing at a frequency of 50 Hz or more with a displacement of at least ± 0.05 mm at 90% of rated capacity. Performance curves of the actuator under full loading and partial loading with corresponding displacement range versus frequency should be provided. The speed of the actuator should be in the range of 10 – 3000 microns/second for carrying out various tests.

d) **Hydraulic Power Pack**: Servo hydraulic power pack with sufficient rating and capable of generating line pressure of at least 200 bar should be supplied. There should be provision for pressure adjustment, so that the power pack can be operated in the range 60 – 200 bar or better in the steps of at least 10 bar. The gear pump should be of reputed make preferably of M/s Bosch/Parker make. The power pack should comprise of oil pressure indicator, temperature transducers, hydraulic oil level indicator, in-built micro filter (10 micron or smaller), connecting hoses of sufficient length, pressure gauge, accumulators, relief valve to limit system pressure and electronically adjustable pressure regulation for setting pressure from minimum value to maximum value. The power pack should have different interlocks for over temperature, low oil level, filter clogging, electrical phase failure, pressure transducers and motor overload protections. The power pack should be operable locally and remotely by control system and should have feature of condition monitoring in the event of over-temperature, low oil level, filter clogging, electrical phase failure and motor overload. Hydraulic power pack should be supplied with oil-filled for smooth operation of the machine for at least 100 hours of continuous operation with its technical specification. If any cooling arrangement/system for continuous operation is required, it should be included in the scope of supply. During operation, the noise level of power pack should not exceed 70 dB at the distance of 1 m.

5. **Input Electrical Supply**: 415 V ± 10%, 50 ± 5% Hz 3 phase.

6. **Ambient Condition**: 45 ºC Maximum with RH > 90%.

7. **Electronic Controller**:
   a) **General**
      i) The servo hydraulic test system should be controlled by a fully digital, closed-loop control system based on 32-bit architecture. The system should feature a digital control system capable of controlling the actuator in position, load, and strain modes.
      
      ii) The control loop should feature waveform generation of 32-bit resolution, with a minimum loop closure rate of 10kHz or higher across all control axes regardless of how many axes are being used.
      
      iii) The controller should feature a facility for automatically updating the control loop terms in order to compensate for changes in specimen stiffness during a cycle. This facility should run at a minimum of 1kHz.
      
      iv) Channels for linear position and axial load should be included and should feature 19-bit or better resolution, with a minimum of 1 kHz bandwidth or 24-bit or better resolution at 1Hz bandwidth, across the full range of the transducer.
v) The linear position, axial load, and two optional sensor conditioning channels (e.g. strain) should be available for control and data acquisition.

vi) Up to eight channels should be available as optional sensor conditioning channels of data acquisition for future upgrade.

vii) Data from all control and acquisition channels should be recorded simultaneously and synchronously and should be capable of being logged at sample rates up to and including 10 kHz across all channels, irrespective of how many channels are used.

viii) The controller should have at least one analogue input for an external analogue waveform drive signal, and at least four assignable analogue outputs.

ix) All supplied transducers should be automatically recognised and calibrated by the controller.

x) The controller should prevent any test proceeding with an uncalibrated transducer to prevent incorrect data being gathered.

xi) The controller should have a minimum of two limit detectors per connected transducer and should have a detection time of 1ms or better.

xii) The controller should incorporate a watchdog protocol to detect loss of communication with the personal computer. In the event of any communications loss, the controller should stop testing and revert to a safe state.

xiii) The control system should have a feature to ensure the load is kept within a predefined range during test set up and specimen loading.

xiv) The selectivity option to the user for running tests either by means of a manual hardware based control panel, or through application programs running on a PC should be available.

xv) The controller should provide control of the hydraulic power supply from the load-frame. Hydraulic power supply buttons should be provided on the load-frame. The controller will monitor the hydraulic power supply's (HPS) safety features and should shut down the machine in the event of a HPS fault

xvi) The hydraulic grip should be electronically controlled. The controller should prevent the operation of the grips either whilst a test is running or whilst the machine is NOT in position control.

xvii) Human Machine Interface (HMI) should be provided with separate icons for coarse and finer actuator positioning.

b) Waveform Generation

i) The controller should have internal waveform generator, should have the capability to generate sine, square, triangle, single ramp, dual ramp or trapezoid waveforms.

ii) The resolution of the internal waveform generator should be at least 32-bit.

iii) The frequency accuracy should be 0.01% of setting, or better.

iv) The frequency of the waveform generator should be in the range of 1 Hz to 1 kHz or better.

v) The controller should have the capability for sample data playback via the computer interface. The sampled data playback rate should be up to and including 10 kHz. Standard digital filters should be available for sampled data playback, with terms adjustable by the user.

vi) A cycle counter should be available. The cycle counter should display elapsed and total cycles.

c) Closed Loop Control

i) The controller should have a six-term control loop (featuring P, I, D, Lag, Feed forward, and Notch Filter) in addition to an external compensation input (e.g. for acceleration or pressure feedback).

ii) Three control loop configurations should be available; serial (standard), parallel or cascade.

iii) The control loop update rate should be 5 kHz or better.

iv) The controller should allow full closed-loop control from any connected, calibrated transducer available for control i.e. position, load and strain control, as well as derivatives of these such as stress intensity and plastic strain.
v) The controller should feature a facility for automatically updating the control loop terms in order to compensate for changes in specimen stiffness during a cycle. This facility should run at a minimum of 1kHz. (Adaptive Control)

vi) A servo-valve dither facility should be provided with a variable frequency and amplitude up to 10% of the full-scale drive signal.

vii) Servo-valve null should be automatically adjusted.

viii) Servo-valve limits should be provided with independent settings for low and high-pressure modes.

d) Signal Conditioning

i) The controller should support a minimum of four signal conditioners per axis controller. The capability to add additional signal conditioners up to a maximum of 8 should be provided.

ii) Signal conditioners will be fully digital using advanced Digital Signal Processing (DSP) techniques (not conventional ADC) with 40 kHz sampling rate.

iii) Each signal conditioner should have a data acquisition and logging rate up to and including 10kHz, fully synchronous and continuous regardless of the number of signal conditioners or transducers connected.

iv) The resolution of each signal conditioner should be 19-bit at 1 kHz bandwidth or 24bit at 1Hz bandwidth, over the full range of the transducer.

v) Each signal conditioner should have an accuracy of 0.25% of reading or 0.005% of full scale or better.

vi) The controller should support dynamic inertia compensation with automatic set-up without use of external accelerometer (when used with compatible loadcells). This facility should have the capability to reduce the inertia errors to less than 0.5% at frequencies of up to 100Hz.

vii) Position (stroke) accuracy should be ±0.5% of transducer full scale, or better, with the vendor supplied transducer.

viii) Load accuracy should be ±0.005% of full scale, or 0.5% of reading or better. Calibration should meet or surpass ISO7500-1 Class 0.5; ASTM E4; EN10002-2 Class 0.5; JIS (B7721, B7733).

ix) Strain accuracy should be ±0.005% of full scale, or 0.25% of reading or better. Calibration should meet or surpass ISO9513 Class 0.5, 1, 2; ASTM E83 Class B1, B2, C, D; EN10002-4 Class 0.5, 1, 2; JIS7741 Grade 0.5, 1, 2.

e) Data Logging

i) The data logging should be fully selectable at up to 10 kHz per connected transducer. This logging rate should be continuous as measured at the computer, regardless of the number of transducers connected. Data acquisition on all channels should be fully synchronous to avoid data skew. Logged data should include a time and cycle stamp for each logged point.

ii) The controller should have a minimum of two peak detectors per connected transducer, for measurement of minimum, maximum, mean and amplitude.

iii) The peak detectors should update at 5 kHz.

iv) Software capable of exporting data to MS-excel and text format, where report generation and graphing is available should be supplied. Data reduction options should be available in real time data logging and during data reporting.

f) Safety Limit Detectors

i) The controller should have a facility for limiting the load applied during specimen set-up. The load threshold should be user adjustable.

ii) The controller should have a minimum of two limit detectors per connected transducer.

iii) For systems with hydraulic crosshead clamping, the controller should detect unclamped state and the system should revert to a safe mode.

g) Computer & Interface

i) The controller should feature a high-speed, industry standard Ethernet computer interface, capable of handling all control signals and data acquisition.

ii) For controlling the system, a test workstation (Processor: Intel 4th generation Core i7 Processor with clock speed 3.20 GHz or higher; at least 4 GB RAM or more; HDD 1 TB or more; a standard UPS having power backup of 30 minutes or more; TFT Monitor 24" or more; DVD writer; network adapter card; at least 6 USB ports; keyboard and optical mouse) should be provided. It should be preloaded with original OS Window 7 Professional or later version with application hardware and software of the equipment. All software should be
8. **Application Software:** The application software for real-time control of the test system should be provided with a set of user-friendly panels for console operations, calibration, data acquisition, safety limit interlocks and servo-tuning. There should be provision to change the control mode depending on the application (example: specimen loading mode; run-test mode: stroke mode, load mode, COD mode and extensometer). In specimen loading mode, the actuator force and velocity will be restricted to pre-defined values to prevent any possible damage to the test specimens while loading. Changing from specimen mode to run-test mode should be a positive and deliberate action by the operator on the local control panel. The operation of hydraulic grips at the user interface should be disabled during run-test mode. There should be provision of various displays meters for current readouts, max-min read outs, peak-valley read outs, set point and cycle counters. There should be provision of display of various channels in multi-scope. It should have capability of recording data with time. Software should export to MS-excel and text format, where report generation and graphing is available. Data reduction options should be available in real time data logging and during data reporting.

9. **Safety Features:**
   a) The controller should have a facility for limiting the load applied during specimen set-up. The load threshold should be user adjustable.
   b) For crosshead clamping, the controller should detect the unclamped state and the system should revert to a safe mode and warn the operator.
   c) The controller should have minimum of two limit detector per connected transducer.
   d) The controller should feature a watchdog to detect loss of communication with the personal computer. If communication fails, the system should shut down in safe mode. Please specify the safe shut down procedure.
   e) The power pack should have feature of condition monitoring and warning at the user interface in the event of oil over-temperature, low oil level, filter clogging, electrical phase failure and motor overload.
   f) The system should revert to safe-mode with warning and trip down in event of any interlock failure.

10. **Grips and Fixtures**
    (Qty. :1 set Each)
    a) **Mechanical Wedge Grips for Tensile Testing of Specimens:** The size of proposed specimens in the grip region should be up to 25 mm width and up to 5 mm thickness for sheet specimen & 3-10 mm diameter for round specimen.
    b) **Fatigue Rated 3 point Bend Fixture** of at least 20 kN capacity with adjustable lower span of about 50 mm to test specimens up to 50 mm displacement. The test setup should consist of three sets of rollers and pins and corrosion resistant graduated scales on the base.
    c) **Compression Platen Rated for Maximum Capacity of 20 kN:** The maximum test specimen diameter should be 50 mm. The compression platen should preferably be made from hardened steel with corrosion resistant coating. The upper grip should have spherical seat for ease of alignment and smooth faced with etched concentric rings.
    d) **Hydraulic Lines:** Provision for hydraulic lines for mounting hydraulic wedge grips and their control switches for activating and de-activating them should be provided.

11. **Extensometers/ displacement/ strain measuring devices:** The extensometers for direct strain measurement and close loop strain should be provided. The construction of extensometers should be full stain bridge type. It should be operational in tensile, compression and fatigue testing with protection for over travel. It should be easily mounted on to the specimen with internal shunt reference for easy calibration. Axial extensometer for tensile and fatigue tests. The details of extensometers are as follows:
    a) Gauge length 12.5 mm with travel range ± 0.5 mm  
    b) Gauge length 25 mm with travel range ± 0.5 mm  
    c) Gauge length 25 mm with travel range ± 5 mm with de-extender for changing GL to 25 mm.

The above extensometer should be provided with mechanical over-travel stops and should have non-linearity of less than 0.15% of the full range. The position accuracy should be better than ± 0.2% of full travel. Provision should be there to use these extensometers on both round and rectangular shaped specimens. All extensometers should comply with Class B-1 of ASTM E83 or equivalent ISO standard.

12. **Inspection and Acceptance**
    a) The supplier should furnish performance test certificate of standard bought out items from the original manufacturer.
b) RRCAT representative will witness the dimensions and the accuracy check of the system and it will be accepted after his certification.

c) RRCAT reserves the right to inspect the items any time during fabrication/assembly to ensure the material and workmanship are in accordance with the specification and quality assurance plan.

d) All work covered by the specification should be subject to quality surveillance by the purchaser or his authorized representative for which purpose the fabricator should allow access during manufacturing of the machine.

e) The vendor should not subcontract any or all the work without written consent from the purchaser. The fabricator should be responsible to the purchaser for all work of the sub-contractor of the fabricator, if allowed by the purchaser.

f) The vendor or his representative should demonstrate the performance of the machine at the vendor’s works to RRCAT representative by carrying out all the tests mentioned in the specification. All requisite items for the testing and demonstration of tests should be arranged by the vendor. The machine will be cleared for despatch to RRCAT only after successful testing of one set of tensile, compression, fracture toughness test, low cycle fatigue test and fatigue crack growth rate tests.

g) At least two sets of tests called in the specification should be demonstrated at RRCAT after the commissioning of the machine. The vendor should also supply 5 sets of specimens for tensile, compression, fracture toughness test, low cycle fatigue test and fatigue crack growth rate tests under cyclic condition for demonstration and training purpose.

h) The supplier should impart minimum two weeks training to three RRCAT personnel for the operation and maintenance of the machine in two phases: 1st phase will be of at least one week after the commissioning of the machine at RRCAT site; 2nd phase of one week after a gap of 6 weeks from the date of commissioning of the machine so as allow RRCAT personnel to gain some working experience.

13. Three sets of the machine’s operation and maintenance manuals (two sets hardcopy and one e-set in CD/DVD) should be supplied along with the supply of the machines.

14. The relevant technical literature/catalogs should be provided with the offer.

15. The supplier should also furnish the list and offer for necessary grips, fixtures, accessories. The list and offer of spares for five year trouble free operation should also be included.

16. Performance Guarantee: The system should be guaranteed for the performance at the rated specification at least for a period of 12 months from the date of installation at the user’s site.

17. Details of site preparation, utilities required etc. should be mentioned clearly in the offer for timely installation and testing of the supplied items.

18. The vendor should submit a separate offer for Annual Maintenance Contract of the machine for a period of at least two years after the expiry of guarantee/warranty period.

19. Delivery Period: The delivery period should not be more than twenty weeks from the date of release of purchase order.

20. The vendor should submit a point-wise confirmation to the specification in tabular format and any deviation has to be specified clearly in the offer. The vendor should also fill and submit the Check list of compliance in the attached format (Refer Annexure-A).
# Check list of Compliance

<table>
<thead>
<tr>
<th>S.No</th>
<th>Description</th>
<th>Indent Value</th>
<th>Offered Value</th>
<th>Remarks/Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>General compliance</td>
<td>ASTM E-4/ ISO 7500-1 Class 0.5</td>
<td></td>
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<tr>
<td><strong>Load Frame Assembly</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>2.</td>
<td>Machine Configuration</td>
<td>Top mounted actuator with T-slotted base plate</td>
<td></td>
<td></td>
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<tr>
<td>3.</td>
<td>Column spacing</td>
<td>350 mm or more</td>
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<tr>
<td>4.</td>
<td>Vertical test space</td>
<td>900 mm or more</td>
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<tr>
<td>5.</td>
<td>Load frame stiffness</td>
<td>400 MN/m @ 350 mm or more</td>
<td></td>
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<tr>
<td>6.</td>
<td>Maximum load frame dimensions (Length x Width x Height)</td>
<td>1.0 m x 0.7 m x 2.2 m</td>
<td></td>
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<tr>
<td>7.</td>
<td>Input Electrical Power Available &amp; Ambient Conditions</td>
<td>3 phase, 415 V ± 10%, 50 ± 5% Hz &amp; 45 ºC maximum with RH &gt;90%</td>
<td></td>
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<tr>
<td><strong>Load Cell -1 (Rated capacity 10 kN)</strong></td>
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<tr>
<td>8.</td>
<td>Minimum measurable force</td>
<td>± 50 N</td>
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<tr>
<td>9.</td>
<td>Maximum measurable force</td>
<td>± 10 kN</td>
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<tr>
<td><strong>Load Cell -2 (Rated capacity 1 kN)</strong></td>
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<tr>
<td>10.</td>
<td>Minimum measurable force</td>
<td>± 5 N</td>
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<tr>
<td>11.</td>
<td>Maximum measurable force</td>
<td>± 1 kN</td>
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<tr>
<td><strong>Servo-hydraulic actuator</strong></td>
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<td>12.</td>
<td>Total stroke</td>
<td>± 50 mm or better</td>
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<tr>
<td>13.</td>
<td>Linear encoder resolution</td>
<td>0.1 µm or better</td>
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<td>14.</td>
<td>Actuator speed range</td>
<td>10 – 3000 µm/second or better</td>
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<tr>
<td>15.</td>
<td>Pressure setting range of hydraulic power pack</td>
<td>60 – 200 bar in step of 10 bar or better</td>
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<tr>
<td><strong>Electronic Controller</strong></td>
<td></td>
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<tr>
<td>16.</td>
<td>General</td>
<td>32-bit architecture, with a minimum loop closure rate of 10kHz</td>
<td></td>
<td></td>
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<tr>
<td>17.</td>
<td>Signal conditioning</td>
<td>Fully digital using advanced Digital Signal Processing technique with an accuracy of 0.25% of reading or 0.005% of FSR or better.</td>
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<tr>
<td>18.</td>
<td>Wave form generation</td>
<td>Sine, cosine, square, triangle, dual ramp &amp; trapezoid</td>
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<tr>
<td>19.</td>
<td>Data logging frequency</td>
<td>Up to 5 kHz</td>
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<tr>
<td><strong>Grips &amp; fixture</strong></td>
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<td>20.</td>
<td>Mechanical wedge grip</td>
<td></td>
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<tr>
<td>a.</td>
<td>Rectangular specimen</td>
<td>Upto 25 mm (W) x 5 mm (t)</td>
<td></td>
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<tr>
<td>b.</td>
<td>Round specimen</td>
<td>3 -10 mm diameter</td>
<td></td>
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<tr>
<td>21.</td>
<td>3-point bend test fixture</td>
<td></td>
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<tr>
<td>a.</td>
<td>Adjustable lower span</td>
<td>About 50 mm</td>
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<tr>
<td>b.</td>
<td>Vertical displacement</td>
<td>Upto 50 mm</td>
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<tr>
<td>22.</td>
<td>Extensometers (gauge length x travel)</td>
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<tr>
<td>a.</td>
<td>12.5 mm x ± 0.5 mm</td>
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<td></td>
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<tr>
<td>b.</td>
<td>12.5 mm x ± 5 mm</td>
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<tr>
<td>23.</td>
<td>Position accuracy</td>
<td>± 0.2 % of full travel</td>
<td></td>
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