

## **SPECIFICATIONS**

### **THERMAL CHARACTERIZATION SYSTEM REQUIREMENTS**

#### **SECTION 1.0 SCOPE.**

The Naval Research Laboratory (NRL), Washington, D.C. has a requirement for an integrated thermal characterization system (TCS) capable of experimentally determining: thermal diffusivity, thermal conductivity, and specific heat over the temperature range: -125 deg C to 1100 deg C for a variety of material compositions, geometries, and states (solid, powder, liquid). The system must be fully integrated with single-computer automated control, data acquisition, and software analysis capabilities. This system must provide high precision, high accuracy thermal property measurement capabilities on a variety of materials over a wide range of temperatures.

The TCS must be suitable for the purposes of research and development of advanced material systems and must have wide-ranging capabilities for user control over the measurement process. The TCS will be placed in a multiple user facility and must provide ease of operation and safety to those in the facility.

#### **SECTION 2.0 PRIMARY SYSTEM COMPONENTS.**

- 2.1** Computer-controlled laser-flash apparatus for measurement of thermal diffusivity of solid, powder, and liquid samples over a -125 deg C to 1100 deg C temperature range in vacuum or user-selected gaseous environments.
- 2.2** Computer-controlled heat-flow or guarded hot-plate apparatus for measurement of thermal conductivity of insulator-like (low conductivity) materials in thin or thick sheet configurations over a -20 deg C to 80 deg C temperature range in an ambient air environment.
- 2.3** Computer-controlled differential scanning calorimeter for measurement of specific heat of solid, powder, and liquid samples over a -125 deg C to 1100 deg C temperature range in vacuum or user-selected gaseous environments.
- 2.4** Appropriate computer hardware and software for instrument control, data acquisition, and data analysis of all three of the above components that electronically integrates them into a turn-key thermal characterization system package. All three instruments shall be capable of being operated simultaneously by one single computer.
- 2.5** The data generated by the three TCS instruments shall be compatible with and capable of being analyzed in a single thermal data analysis software package.

### SECTION 3.0: INTEGRATED THERMAL CHARACTERIZATION SYSTEM (CLIN 0001)

#### 3.1 LASER-FLASH EQUIPMENT (FOR THERMAL DIFFUSIVITY MEASUREMENTS)

The Laser-Flash equipment shall:

- have a thermal diffusivity measurement range, accuracy, and repeatability equal to or better than, respectively: 0.01 to 1000 mm<sup>2</sup>/s, +/- 3.0% accuracy; +/- 2.0% repeatability.
- be capable of testing material samples over a temperature range: -125 deg C to 1100 deg C.
- be capable of measuring thermal diffusivity on a variety of materials and sample configurations, with all necessary sample mounting hardware to be provided by the vendor:
  - solids, powders, or liquids.
  - through thickness measurements.
  - in-plane measurements (e.g., thin samples, anisotropic material samples).
  - large samples (e.g., ~25 mm planar dimensions, ~6 mm thickness).
  - multi-layer (3 or more layers) samples
  - multiple samples in a given run.
  - fiber material samples.
- be capable of testing material samples in the following test environments:
  - vacuum at 10<sup>-2</sup> mbar or lower with all appropriate pump, plumbing, connection, and valve hardware to be provided by vendor.
  - one or more user-selected gases with all appropriate metered gas flow control and mass flow measurement/regulation hardware to be provided by vendor.
- provide electric positioning and safety interlocks of the refrigeration/furnace chamber(s).
- be capable of interactive (manual) or fully automatic (following pre-selected parameters) test control.
- allow for conditioning the various test signals: amplifier output gains and filtering, temperature calibration corrections, etc.
- be capable of testing in conformance with ASTM E1461.
- use IR sensing for specimen temperature measurements with all necessary/appropriate auxiliary hardware for up to 24 hours of unattended operation (e.g., LN2 Dewar's with caster dollies for easy movement) to be provided by the vendor. ***Thermocouple attachment to specimen for temperature measurement is not acceptable.***
- provide all appropriate IR sensors to cover measurements over the temperature range (e.g., individual sub-ambient and high temperature IR sensors).
- meet Laser Safety Class I with all appropriate interlocks for safety.
- provide a co-linear alignment laser feature for easy equipment adjustment/calibration after system repair or replacement of major components.

- provide software control of the laser energy and filter system for precise control of thermal energy input to the test samples.
- provide laser-pulse characterization features for accurate quantification of heat input to the test samples.
- be capable of data acquisitions rates at 500 Hz (500 Sa/s) or faster.
- be capable of automated testing of multiple samples (three or more) of varying materials/geometries within a single experimental run.
- provide fixture/holders for:
  - round material samples: 25 mm, 10 mm, 8 mm, and 6 mm.
  - square material samples: 8 mm x 8 mm, 10 mm x 10 mm.
  - multiple material samples: (3 or more).
  - liquid material samples: for general organic and inorganic liquids, liquid metals, etc.
  - in-plane thermal diffusivity measurements.
  - laminate material samples (~25 mm x 25 mm).
  - fiber material samples.
- provide appropriate software for instrument control, data acquisition, and data analysis with:
  - the capability for handling: pulse-width correction, multi-layer models, in-plane diffusivity calculations, data-base storage of test results, etc.
  - calculation of thermal diffusivity for different marginal conditions/models with pulse width correction: adiabatic, Cowan, radiation correction, Cape-Lehman, 2-/3-layer models, in-plane anisotropic analysis, approximate specific heat analysis.
  - plotting: temperature rise, theoretical model curve (adiabatic case, heat loss correction curve, 2-/3-layer model or contact resistance model), temperature/thermal diffusivity curve.
  - storage of the measuring data and measuring results in a data base.
- be capable of interfacing with the other two instruments as appropriate (compatible data forms, single computer control and data acquisition, etc.).
- provide appropriate reference samples to cover the entire thermal diffusivity measurement range.
- provide all necessary hardware/software and consumables needed for making thermal diffusivity measurements on the materials and over the range of conditions described above.

### **3.2 HEAT-FLOW METER OR GUARDED HOT-PLATE APPARATUS.**

The Heat-Flow Meter or Guarded Hot-Plate equipment shall:

- have a thermal conductivity measurement range, accuracy, and repeatability equal to or better than: 0.005 to 0.5 W/m-K, +/-2% accuracy; +/-0.5% repeatability.
- be capable of testing over the temperature range: -20 deg C to 80 deg C.
- be capable of providing thermal conductivity measurements within ~30 minutes of test start.

- be capable of automated thermal conductivity measurements at 10 or more pre-programmed sample temperature levels.
- provide dual heat-flux transducers (both sides of the test specimen) with separate signal measurement for measurement accuracy and validation purposes.
- provide a sealed test chamber to prevent external air exchange.
- use solid-state (Peltier) modules for sub-ambient cooling of the test samples.
- be capable of testing solid materials in plate form: monolithic panels, laminate plates, woven layers, etc.
- be capable of testing panels of size: 300 mm x 300 mm x 100 mm (thick) or larger.
- be capable of testing in conformance with: ASTM C-518 and ISO 8301.
- be capable of automated sample thickness measurement.
- provide appropriate software for instrument control, data acquisition, and data analysis with:
  - the capability for controlling direction of heat flow.
  - interactive or fully automatic (following pre-selected parameters) test control with variable plate temperatures.
  - appropriate instrument calibration routines.
  - calculation of thermal conductivity for various specimen configurations/models (e.g., insulations, wovens, multilayer models, etc.).
  - real-time monitoring of test signals versus time.
  - plotting of the various test parameters versus time and or temperature.
  - storage of the measuring data and measuring results in a data base.
- provide appropriate reference calibration samples to cover the entire thermal diffusivity measurement range.
- be capable of interfacing with the other two instruments as appropriate (compatible data forms, single computer control and data acquisition, etc.).
- provide all necessary hardware/software and consumables needed for making thermal conductivity measurements on the materials and over the range of conditions described above.

### **3.3 DIFFERENTIAL SCANNING CALORIMETER.**

The Differential Scanning Calorimeter equipment shall:

- have a specific heat (cp) measurement accuracy better than or equal to +/-2.5% over the temperature range: -125 to 1100 deg C.
- be capable of testing material samples over the temperature range: -150 to 1400 deg C.
- be capable of testing material samples in the following test environments:
  - vacuum at  $10^{-4}$  mbar or lower with all appropriate pump, plumbing, connection, and valve hardware to be provided by vendor.
  - three or more user-selected gases with all appropriate metered gas flow control and mass flow measurement/regulation hardware to be provided by vendor.

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- be capable of testing materials in the following forms: solids, powders, or liquids.
- provide electric positioning and safety interlocks of the refrigeration/furnace chamber(s).
- be capable of testing in conformance with ASTM E1269.
- have a temperature measurement precision of better than +/- 0.5 deg C.
- be capable of testing with linear heating/cooling rates from 0.0 to 50 deg C/min or higher.
- not use carbon in the heating elements and furnace components that are exposed to the sample chamber to avoid sample contamination.
- be capable of having the temperature sensors changed by the user in less than 5 minutes.
- provide sensitive adjustment feature (e.g., micrometer) of the temperature sensor for optimal control/adjustment of the baseline signal.
- allow for the use of various other temperature sensors, depending on testing needs.
- provide appropriate software for instrument control, data acquisition, and data analysis with:
  - interactive or fully automatic (following pre-selected parameters) test control.
  - appropriate instrument calibration routines.
  - automatic baseline correction capability.
  - calculation of specific heat and other thermal properties (e.g., enthalpy, T<sub>g</sub>, etc.).
  - real-time monitoring of the test signals
  - plotting of the various test parameters versus time and or temperature.
  - storage of the measuring data and measuring results in a data base.
- provide an assortment of sample holders with appropriate thermocouples, radiation shields, crucibles and covers for solid and liquid material samples being tested over the range of temperatures (sub-ambient and high temperatures).
- provide appropriate reference calibration samples to cover the specific heat measurements over the range of temperatures.
- provide appropriate reference calibration samples to cover the enthalpy and temperature measurements over the range of temperatures.
- provide accessories for removal of trace oxygen in environment (e.g., getter system).
- be capable of interfacing with the other two instruments as appropriate (compatible data forms, single computer control and data acquisition, etc.).
- provide all necessary hardware/software and consumables needed for making specific heat measurements on the materials and range of conditions described above.

**3.4 COMPUTER AND PERIPHERALS FOR CONTROL, DATA ACQUISITION, AND DATA ANALYSIS**

The computer and peripherals shall:

- include all appropriate hardware/software for the Thermal Characterization System control, data acquisition, and data analysis.
- include at a minimum: 2GB RAM, 250 GB hard drive, DVD + RW drive, 19" flat screen LCD monitor, gigabit ethernet network connection, appropriate number of communications ports for interfacing with all three instruments.
- include MS Window 7 (business) or Vista (business) OS.
- include all necessary instrument communications cabling.
- include a color printer.

**SECTION 4.0: DELIVERY**

The Contractor shall deliver all components for a complete, ready to be installed system, to NRL-DC, no later than 60 days after receipt of contract award.

**SECTION 5.0: INSTALLATION (CLIN 0002)**

The contractor shall install the TCS in Bldg. 28 at NRL-DC in a location specified by the authorized government representative. The TCS will be co-located with existing NRL thermal analysis equipment. The available floor space in this laboratory is limited to approximately 36 sq.ft. All TCS equipment (primary, support, and auxiliaries), except for any portable LN2 tank storage casks, shall be capable of fitting and operating within this space.

NRL will provide all necessary site preparations for system installation. The contractor shall provide a pre-installation guide with their offer. The pre-installation guide shall indicate, in detail, all of the site requirements including but not limited to: environment (e.g. temperature, vibration, air flow, etc.); utility hook-ups (e.g. electrical, air, water, vacuum, etc.); required space (e.g., doorway passage, floor, operating, maintenance access, etc.); procedures for receiving the equipment and placing it in its laboratory location; communication hook-ups (e.g. Ethernet). The TCS shall be ready for immediate use following installation by the contractor (turnkey installation).

The contractor shall calibrate, as is periodically required, all relevant components of the TCS. The Contractor shall provide all applicable calibration records.

**SECTION 6.0: TRAINING (CLIN 0003)**

The contractor shall provide a minimum of 1 day of training for up to six people at NRL-DC. The training shall be conducted immediately following contractor installation and calibration of the system and prior to acceptance of the system. The contractor shall demonstrate all aspects of the TCS's measurement capabilities and functions, and the equipment upkeep and maintenance procedures. Other topics to be covered in the training session shall include at a minimum: TCS functionality, operation, testing procedures, and software. NRL-DC will supply a variety of materials for use in demonstrating the thermal characterization process with the system during the training.

**SECTION 7.0: WARRANTY (CLIN 0004)**

The contractor shall provide a standard commercial warranty covering all system components, for a minimum of twelve (12) months beginning the day after government acceptance.

**SECTION 8.0: DOCUMENTATION (CLIN 0005)**

The contractor shall provide all documentation, drawings, calibration records, and schematics for full site preparation, operation, troubleshooting, servicing and repair of the system and its components.

**SECTION 9.0: OPTIONAL ITEMS**

Vendors should offer specific items of possible utility for each of the proposed instruments. If required, the Government may exercise any of the options at time of contract award or no later than 60 days after acceptance of CLIN 0001.

**9.1 Option I – Laser-Flash (CLIN 0006):** consumables, additional sample holders, spare parts, optional sensors, calibration standards.

**9.2 Option II – Heat-Flow or Guarded Plate (CLIN 0007):** consumables, spare parts, calibration standards.

**9.3 Option III – Differential Scanning Calorimeter (CLIN 0008):** consumables, additional sample crucibles, spare parts, optional sensors, calibration standards.