

THERMAL PROFILING EQUIPMENT FOR BITUMINOUS MATERIAL

**\*\*From Stockbridge-Bethel STP 2910(1)**

- xx. DESCRIPTION. This specification contains requirements to determine the placement uniformity of asphalt mixture construction through continuous thermal profiling.

The equipment uses infrared temperature measurement technology to measure a longitudinal thermal profile across the pavement width and displays these data as a surface contour plot of asphalt mixture placement temperatures. The equipment shall be able to calculate real-time indices including the number and percentage of profiles with moderate and severe thermal segregation and the temperature differential of each profile. Post-process software shall be able to calculate summary indices, which include the real-time indices plus the distribution of placement temperatures and the location and duration of paver stops exceeding one minute. This specification is designed to apply to both hot and warm asphalt mixtures.

- xx. TERMINOLOGY.

*contour plot* – a graphic display of data using contour lines. These plots may employ varying degrees of smoothing.

*index* – measure or standard. Within the context of this test method, several suitably chosen indices quantify the uniformity of a hot or warm-mix asphalt construction operation.

*moderate thermal segregation* – temperature differentials exceeding 25°F and not exceeding 50°F, unless otherwise defined by the owner-agency.

*real-time indices* – the number and percentage of thermal profiles with moderate and severe thermal segregation and each thermal profile's actual temperature differential.

*sample interval* – the longitudinal distance between data capture points.

*severe thermal segregation* – temperature differentials exceeding 50°F, unless otherwise defined by the owner-agency.

*summary indices* – the combination of real-time indices plus the distribution of placement temperatures and the location and duration of paver stops exceeding one minute.

*temperature differential* – the difference between the statistical 98.5 percentile and the statistical 1 percentile within a thermal profile, unless otherwise specified by the owner-agency.

*thermal profile* – the geospatial makeup of hot or warm-mix asphalt placement temperatures over a paving distance of 150 feet.

*thermal profiler* – the combination of equipment and host vehicle to measure the thermal profile. In context of this test method, the paving machine typically will serve as the host vehicle.

- xx. GENERAL REQUIREMENTS. The equipment shall function independently from the paving crew during normal paving operations and may operate either on its own or the paver's on-board power supply.

The equipment shall be equipped with various sensors, interface hardware, computer hardware, and software that, working together, perform the measurement, recording, and summary display of the thermal profile. The data shall be stored both internally and onto suitable high-density removable storage during the test. The equipment computer shall have the capability to process the collected data for display of the thermal profile and the percentage of the project with moderate or severe thermal segregation. Supplier-provided post-process software shall be capable of displaying the thermal profile along with stationing, GPS coordinates, and annotations. The post-process software shall also be capable of automatically processing the profile and generating a PDF report output to include the summary indices.

The equipment shall mount on the paver catwalk or other suitable location with minimum disturbance to the paver and in a fashion that the paving crew can conveniently and safely perform their duties.

- (a) Measuring Thermal Profile. The thermal profile shall be measured in a manner to obtain at least 12 measurement points across the mat width. Distance traveled during collection of the thermal profile shall be measured using a distance sensor and/or GPS receiver. The run-time software and post-processing software shall be used to combine these measurements to develop a thermal-profile result with distance or stationing and GPS location. The equipment shall be capable of obtaining and storing profile measurement data at selected longitudinal distance intervals. The equipment shall be capable of a sample interval every 6 inches or less at the maximum sustained paving speed.

- (b) Calculating Temperature Differential. The temperature differential of each thermal profile shall be computed automatically in both real-time and post-processing using the data collected and stored on either internal or external storage media. The temperature differential shall be calculated as follows:

$$\text{Temperature Differential} = \text{statistical 98.5 percentile} - \text{statistical 1 percentile}$$

The computer shall also be capable of calculating the temperature differential based on a filtered data set, whereby either the operator indicates which temperatures or sensor(s) to ignore, or a supplier-supplied algorithm determines whether specific temperature or sensor data is valid or not. Any supplier-supplied filtering algorithm must be approved by the owner-agency prior to use.

- (c) Calibration. The equipment shall have built-in provisions to facilitate the calibration and verification of each infrared temperature sensor(s) signal. These sensor(s) shall be calibrated at intervals not to exceed 12 months in conjunction with a calibration protocol specified and carried out by the

supplier or the supplier's authorized designee. These recurrent calibrations shall ensure the accuracy of the data.

xx. EQUIPMENT.

(a) General. The thermal profiler shall meet the following requirements:

- (1) The thermal profiler shall use any infrared temperature sensor or combination of infrared temperature sensors to measure a minimum of 12 points across the mat width, with each measurement point at most 13 inches apart.
- (2) The thermal profiler shall use infrared sensor(s) capable of measuring a range of at least from 40 to 475°F with an accuracy meeting  $\pm 1.5$  percent of reading or  $\pm 2.7^\circ\text{F}$ , whichever is greater, when the object temperature exceeds  $32^\circ\text{F}$  and the ambient temperature is  $73 \pm 9^\circ\text{F}$ . The sensor(s) repeatability shall meet  $\pm 0.75$  percent of reading or  $\pm 1.4^\circ\text{F}$ , whichever is greater.
- (3) The thermal profiler shall measure distance and location using a distance sensor and/or GPS, such that longitudinal distance can be measured with sufficient accuracy and resolution to maintain a 6 inch sample interval. The thermal profiler shall support both English and SI units for distance data in incrementing or decrementing mode from a selected starting point and relate the longitudinal distance to any test point. Optionally, the equipment may also report in station format.
- (4) The thermal profiler shall determine the low and high temperatures within each profile using the statistical 1 percentile and 98.5 percentile, respectively, unless otherwise specified by the owner-agency. The thermal profiler shall use 150 feet as the default length for each profile.
- (5) The thermal profiler shall provide real-time and post-process software capable of developing and analyzing thermal profiles for the entire project.

(b) Functional Hardware Modules. The following minimum specifications shall apply to the thermal profiler:

- (1) Operating ambient temperature range shall be  $-22$  to  $158^\circ\text{F}$ ; nonoperating temperature range shall be  $-40$  to  $158^\circ\text{F}$ .
- (2) Power consumption of all installed equipment shall not exceed the capacity of the equipment providing operating power. Complete discharge of this system shall not impact the vehicle's regular electrical system.

- (c) Functional Software Modules. The equipment computer shall contain the necessary software modules to perform all tasks required. These functions include:
- (1) Auto execution
  - (2) Program initialization
  - (3) Operation selection
  - (4) Data collection and management
  - (5) Data save
  - (6) Direct data entry
  - (7) Data retrieve
  - (8) Data output
  - (9) Data transfer
  - (10) Data display
  - (11) Equipment calibration
- (d) Auto Execution. The equipment computer shall provide an automatic execution function that shall configure equipment components, load the main control program of the computer, and start up all required operations.
- (e) Program Initialization. The software shall provide a central program initialization function that shall be loaded by the operating software following all other drivers and reserved memory. The initialization program shall perform start-up initialization, activate the data acquisition system, initialize program control parameters and system self-check, and activate a start-up that requires no operator input.
- (f) Operation Selection. The operation selection function shall display a main menu of computer operation functions that can be performed when selected by the operator. The main menu selections shall be displayed to the operator in a manner clearly indicating their functions. The selection shall be provided via a touchscreen, keypad, computer keyboard, or other input device.
- (g) Equipment Operation Functions. The equipment computer shall provide a set of operation functions selected by the operator main menu. The equipment operation functions shall provide everything necessary for the operator to perform data collection in a user-friendly manner. It shall not be necessary for the operator to use operating commands directly to perform any of the required functions. The equipment operations as a minimum shall:
- (1) Create projects including identification (ID) and data collection properties necessary for adequate documentation and proper data collection.

- (2) Allow editing of project headers.
  - (3) Allow deletion of projects from the main menu list of projects. Deletion of projects from the main menu list shall only remove those projects from the display and shall not delete the projects from the internal storage media.
  - (4) Display software version information.
  - (5) Restore data backup files. This function shall copy all project files on the internal storage media to the removable storage media.
  - (6) Support operator-activated initiation of data collection for the selected project.
- (h) ID and Data Collection Properties. The user shall be able to change and save ID and data collection properties for each created project. The equipment shall contain properties similar to those in the table below:

Project Property	Description
Operator	The name of the person/operator who creates the project.
Roadway ID	The name of the route where the project is located.
Start Location	The description of the section of road where the project is located.
Comment	Additional information of interest to the user.
Lift	The lift number or identification of lift being placed for the mat.
Lift Thickness	The thickness of the lift being placed.
Paving Width	The width of the mat width behind the paver.
Sample Interval	The longitudinal distance between data capture points.
Min Temp Display	The minimum temperature of the color scale during data collection.
Max Temp Display	The maximum temperature of the color scale during data collection.
Ignore Sensors	Set to YES or NO. In case of YES, the sensor omission dialog is displayed before data collection begins.
Rolling Radius	The distance between the center of the paver wheel where the distance sensor is mounted to the ground. The operator can use the Calculation Program to automatically determine the rolling radius.
Distance Sensor Rotation	Can be set to left or right to indicate which side of the paver the distance center is mounted.
Start Station	The number of the nearest station. Select "none" if unknown
Start Offset	The distance from the paving start point to the nearest station identified as the Start Station. If the Start

	Station is the front of the paver, the offset must be positive. If the Start Station is behind the paver, the offset must be negative.
Station Distance	The distance between two stations.
Station Sequence	Set to Ascending or Descending to indicate whether stations are increasing or decreasing with the direction of paving.
Unit Type	Determines the units of the project.

- (i) Distance Calibration. If the system uses a distance sensor, the operational computer software shall allow the operator to perform a distance sensor calibration and use the calculated factor to perform the operational distance measurements. The operator shall only need to enter the distance traveled in feet, meters, kilometers, or miles and not make any calculations to determine the calibration factor. The calibration software shall also allow the operator to save the factor calculated or change the calibration factor to other than the calculated value.
- (j) Infrared Temperature Sensor Calibration. The operational computer software shall allow for calibration of the infrared temperature sensor(s). This calibration shall not be accessible or editable through the main menu, and this calibration shall only be performed by the supplier or their authorized designee. The infrared temperature sensor(s) shall be calibrated on an annual basis.
- (k) Roadway Testing. The operational computer software shall provide all necessary functions for the operator to select and perform roadway testing as required for a specific location. The test software shall activate the testing using the data collection properties stored by the selected project. The position points of each measurement shall be automatically determined using the project property inputs, distance sensor, and/or GPS. The software shall detect abnormal conditions in the status of sensors and report the condition to the operator. The testing software shall as a minimum save temperature values measured by the infrared temperature sensor(s), the position information from the distance and/or GPS sensors, and the time stamp from each recorded measurement. These results must also be automatically transferred to removable media during testing for redundancy of data recording.
- (l) Equipment Shutdown. The operational software shall stay active unless the supply of power to the system is removed. The computer shall continuously save project data to minimize data loss in the case of an accidental loss of power during testing.

xx. MOUNTING/INSTALLATION OF EQUIPMENT AND TRAINING REQUIREMENTS.

- (a) Mounting/Installation of Equipment. The supplier shall provide all parts and training necessary for the proper installation and use of the equipment. Installation of the new equipment shall include a mounting arrangement that can be easily used by the operator as designated.

Careful consideration shall be given to the mounting and location of equipment. Mounting of equipment shall be made in a manner to withstand normal vibrations that occur while traveling at the normal operating speeds for the equipment utilized. The location of equipment shall be accessible to the operator and not impede safety.

Electronic components shall be restrained where possible with tie-downs or other applicable methods.

- (b) Training Requirements. The Engineer and/or their representative(s) shall be provided, during the first month of the Contract, with a minimum of two separate 8 hour minimum training sessions on the use and operation of the thermal profiling unit and its software. One of the two sessions shall occur within one week of delivery of the unit to the site. The second of the two sessions shall occur at the request of the Engineer. If a Contract has multiple years of work, an additional 8 hour minimum training shall be provided at the request of the Engineer.

All training shall be performed by a manufacturer - verified trainer who is approved by the Engineer. The training shall occur at the Engineer's Field Office or at a location agreed to by the Engineer.

Upon delivery of the thermal profiler, the following shall be required:

- (1) One DVD containing all necessary software and user manuals for operational software.
- (2) Two complete parts lists detailing the components of all equipment used.

xx. METHOD OF MEASUREMENT. The quantity of Special Provision (Thermal Profiling Equipment for Bituminous Material) to be measured for payment will be on a lump sum basis in the complete and accepted work.

xx. BASIS OF PAYMENT. The accepted quantity of Special Provision (Thermal Profiling Equipment for Bituminous Material) will be paid for at the Contract lump sum price. Payment will be full compensation for preparing and installing the equipment including software, providing support, maintenance, and training, and for furnishing all labor, tools, equipment, and incidentals necessary to complete the work.

Partial payments will be made as follows:

- (a) The first payment of 50 percent of the bid price for Special Provision (Thermal Profiling Equipment for Bituminous Material) or five percent of the adjusted Contract price, whichever is less, will be made with the first biweekly estimate upon the completion of the first training session as determined acceptable by the Engineer.

- (b) The second payment of 40 percent of the bid price for Special Provision (Thermal Profiling Equipment for Bituminous Material) or five percent of the adjusted Contract price, whichever is less, will be made on the first estimate upon completion of 75 percent of the Contract price.
- (c) Payment of any remaining amount bid for Special Provision (Thermal Profiling Equipment for Bituminous Material) will be made after the Contract Substantial Completion Date as determined by the Engineer.

Delays due to satellite reception of signals to operate the thermal profiling system will not result in adjustment to the Contract unit price for any construction items or be justification for granting Contract extensions.

Payment will be made under:

<u>Pay Item</u>	<u>Pay Unit</u>
900.645 Special Provision (Thermal Profiling Equipment for Bituminous Material)	Lump Sum