United States
Department of
Agriculture

Forest Service

Forest
Products
Laboratory

General
Technical
Report
FPL–GTR–200

Heat Treatment of Firewood—Meeting the Phytosanitary Requirements

Xiping Wang
Richard Bergman
Brian K. Brashaw
Scott Meyers
Marc Joyal

Abstract

The movement of firewood within emerald ash borer- (EAB-) infested states and into adjoining states has been a major contributor to the spread of EAB throughout the United States and Canada. In an effort to stop the further spread of EAB from infested areas and to facilitate interstate commerce, USDA Animal and Plant Health Inspection Service (APHIS) has required and are enforcing a heat-treatment process in the firewood industry to heat sterilize firewood before it can be shipped out of infested areas. States and firewood producers are now faced with challenges implementing heat-treatment processes and meeting the heat-treating standard. The purpose of this project was to transfer background knowledge and advanced heat-treating technology to field application through field heat-treatment demonstrations, on-site workshops and web-based training seminars (webinars). We evaluated a series of temperature sensors/probes and data loggers for their applicability in heat-treating process and constructed easy-to-install temperature monitoring systems suitable for field heat-treatment operations of different scales. Successful on-site heat-treatment demonstrations were conducted at four firewood heat-treating facilities. Two training workshops were developed and presented to regulatory field staff and firewood producers. The content of training included certification of treatment facilities, recommended heat-treating strategies, and temperature monitoring and thermal verification.

Keywords: Demonstration, emerald ash borer (EAB), firewood, heat treatment, kiln, temperature monitoring

Acknowledgment

This project was funded in part through a grant awarded by the Wood Education and Resource Center, Northeastern Area State and Private Forestry, Forest Service, U.S. Department of Agriculture (08-DG-11420004-100). We thank JoAnn Cruse of USDA APHIS PPQ, Terry Mace of Wisconsin DNR, Jeff Settle of Indiana DNR, Anthony Weatherspoon of Michigan DNR, David Hutton (Indiana) and Brent Wachholder (Illinois) of USDA APHIS EAB PHSS, for providing assistance to the field demonstration projects.

Contents

July 2011

Wang, Xiping; Bergman, Richard; Brashaw, Brian K.; Myers, Scott; Joyal, Marc. 2011. Heat treatment of firewood—meeting the phytosanitary requirements. General Technical Report FPL-GTR-200. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 34 p.

A limited number of free copies of this publication are available to the public from the Forest Products Laboratory, One Gifford Pinchot Drive, Madison, WI 53726–2398. This publication is also available online at www.fpl.fs.fed.us. Laboratory publications are sent to hundreds of libraries in the United States and elsewhere.

The Forest Products Laboratory is maintained in cooperation with the University of Wisconsin.

English unit	Conversion factor	SI unit
BTU	$1.055\,056 \times 10^3$	Joule (J)
Inch (in.)	25.4	Millimeter (mm)
Temperature (°F)	(T °F –32)/1.8	Temperature (°C)
Temperature increment (°F)	0.556	Temperature increment (°C)
Cubic feet (ft^3)	0.0283	Cubic meter (m^3)
Pound	453.6	Gram (g)
Cord	3.6224	Cubic meter (m^3)
Board feet	2.35849×10^{-3}	Cubic meter (m^3)

Heat Treatment of Firewood—Meeting the Phytosanitary Requirements

Xiping Wang, Research Forest Products Technologist
Richard Bergman, Research Forest Products Technologist
Forest Products Laboratory, Madison, Wisconsin

Brian K. Brashaw, Program Director
Natural Resources Research Institute, University of Minnesota–Duluth

Scott Myers, Entomologist
USDA APHIS, Center for Plant Health Science and Technology, Buzzards Bay, Massachusetts

Marc Joyal, Electronics Technician
Forest Products Laboratory, Madison, Wisconsin

Executive Summary

The interstate movement of all hardwood firewood is currently restricted under the Federal Quarantine (68 FR 59088, October 8, 2003, as amended at 72 FR 30460, June 1, 2007 (7CFR301 2011)) because of the potential risk associated with moving emerald ash borer- (EAB-) infested firewood. Heat treatment is an approved method to kill EAB in firewood and prevent its transport between regions and states. However, states and firewood producers are faced with challenges implementing heat-treating processes and safely treating firewood for interstate commerce. United States Department of Agriculture (USDA) Animal and Plant Health Inspection Service (APHIS) Plant Protection and Quarantine (PPQ) officers and regulatory field staff have had little training to bring their knowledge of heat-treatment operations to the level desired for program integrity. The purpose of this demonstration project was to transfer background knowledge and advanced heat-treating technology to field application through field heat-treatment demonstrations, onsite workshops and web-based training seminars (webinars).

A multidisciplinary team that included university and federal laboratory researchers, USDA APHIS PPQ officers, state wood utilization and marketing specialists, and regulatory field staff from several states participated in this demonstration project. We evaluated a series of temperature sensors/probes and data loggers for their applicability in the heat-treating process and constructed easy-to-install temperature monitoring systems suitable for field heat-treatment operations of different scales. Successful onsite heat-treatment demonstrations were conducted at four firewood heat-treating facilities: two in Wisconsin, one in Illinois, and one in Indiana. Two training workshops were developed and presented to regulatory field staff and firewood producers. One was an onsite workshop and hands-on field demonstration (February 25, 2009) and one was presented as a web-based seminar (December 17, 2009). The content of training included 1) certification of treatment facilities, 2) recommended heat-treating strategies, and 3) temperature monitoring and thermal verification.

> The current heat-treatment schedule for EAB in firewood requires the core temperature to reach a minimum of 60 °C (140 °F) for 60 min (USDA APHIS PPQ 2011). Prior to January 2011, a more stringent schedule (71 °C (160 °F) for 75 min) was used (USDA APHIS PPQ 2010). The heat-treatment standard for EAB exceeds the ISPM-15 standards because of the higher thermal tolerance of EAB.
>
> This project was conducted between July 2008 and November 2010. The heat-treatment demonstrations documented in this report were primarily based on the previous heat treatment schedule for EAB (71 °C (160 °F) for 75 min).

Background

Emerald ash borer (*Agrilus planipennis*) (EAB) has emerged as a devastating killer of ash trees in the United States and Canada. As of May, 2011, EAB-infested areas include 15 U.S. states and two Canadian provinces (Michigan State University 2011). Extensive survey programs have been established to detect emerging populations in other areas. USDA estimates that if EAB is not contained or eradicated, it will cost local government and homeowners approximately $7 billion over the next 25 years to remove and replace dead and dying ash trees (FS 2008). This scenario would also result in extensive environmental damage and long-term changes in the North American forest structure.

The movement of firewood within EAB-infested states and into adjoining states has been a major contributor to the spread of EAB throughout the United States and Canada. In an effort to stop the further spread of EAB from infested areas and to facilitate interstate commerce, USDA Animal and Plant Health Inspection Service (APHIS) has required and are enforcing a heat-treatment process in the firewood industry to heat sterilize firewood before it can be shipped out of infested areas.

The keys to the success of this heat treatment of firewood are to 1) increase the kiln/chamber temperature high enough to meet the EAB heat-treatment standard where the firewood core temperature reaches the kill temperature for an extended period of time, and 2) monitor the core temperatures of the largest firewood pieces to ensure that the temperature-time requirement is met before the heat-treating cycle is completed. However, many firewood producers have difficulty meeting these key requirements because of lack of knowledge of heat-treating operations, insufficient heating facilities, and inadequate temperature monitoring equipment.

In a previous project funded through the USDA Forest Service Wood Education and Resources Center (WERC), we addressed technical issues related to heat-treatment options and heating times for ash firewood (Wang and others 2009). The project resulted in practical heat-treating strategies for various firewood operations. The heating time tables developed benefit the firewood producers in planning and executing effective firewood heat treating as required by the new USDA phytosanitary regulations.

The other concern with heat treating firewood is the practical challenge to implement federal regulations and meet the new heating standards. Standard procedures in heat-treatment operations are lacking. In federal and state management, APHIS Plant Protection and Quarantine (PPQ) officers and regulatory field staff have had little training and few available internal resources to enhance their knowledge of heat-treating operations to provide the safeguarding required in the agency mission. In field operations, managers and operators of heat-treatment facilities lack the necessary knowledge and expertise to implement temperature measuring systems, conduct heat-treatment operations with appropriate heat-treating schedules, and monitor heat-treatment processes to ensure that requirements are met.

Objectives

The goal of this project was to transfer information and knowledge of heat-treating technology to field operations through onsite demonstration projects and training workshops. The specific objectives were to accomplish the following:

1. Evaluate commercially available temperature sensors/probes and data logging systems and use this information to design and build temperature measurement systems suitable for monitoring chamber/kiln conditions and the core temperatures of firewood for heat-treatment operations.
2. Conduct heat-treatment demonstration projects at four selected heat-treating facilities in Wisconsin, Illinois, and Indiana and train kiln operators and regulatory staff on fundamentals of the heat-treatment process and the proper procedures for monitoring firewood core temperatures.
3. Develop a generic operating manual for firewood companies incorporating the knowledge gained through the demonstration projects to be used by field operators to successfully treat firewood materials.
4. Develop training workshops for regulatory field staff and firewood producers on certifying treatment facilities and conducting and monitoring heat treatment.

APHIS PPQ Enforcement Regulations for Heat Treatment of Firewood

The heat treatment of firewood must be performed at an approved facility that maintains a current compliance agreement. APHIS PPQ enforcement regulations stipulate that a heat-treating facility be inspected and certified by a PPQ official for initial qualification. The official certification test has three main components: 1) calibrating the temperature sensors, 2) thermal mapping (cold spot mapping), and 3) conducting an actual test treatment.

Certified heat-treatment facilities are required to monitor the core temperatures of several firewood pieces during the heating process and provide a temperature history record of each heat treatment run to verify that the conditions of the schedule have been met. The firewood samples monitored are required to be placed in the coldest areas of the kiln/chamber. The internal wood temperature should be collected at least once every 5 min and stored in a data file. The sensors used to monitor firewood temperatures need to be calibrated annually and read within ± 0.5 °C (0.9 °F) of the treatment temperature.

Temperature Monitoring System

Monitoring Air Temperature Inside a Kiln/Chamber

Typically, commercial dry kilns and heating chambers designed for heat treatment are equipped with one or two temperature sensors or temperature gauges that display the dry-bulb temperature of the heating medium. Most kilns/chambers used to heat treat or dry firewood do not have a wet-bulb temperature sensor installed (Note: wet-bulb temperature usage allows for greater control of kiln conditions necessary for drying lumber). The dry-bulb temperature of the heating medium is normally called kiln temperature or chamber temperature and is used for real-time checks of kiln condition and as guidance for kiln control. In facilities without computer monitoring or a control program, kiln temperature information is often not recorded. To meet the heat treatment monitoring requirement, a firewood producer may need to install a temperature recording device to obtain a record of temperature history of the kiln/chamber.

Figure 1. Temperature sensors installed inside the kiln for measuring dry-bulb temperature of air inside the kiln.

Table 1—Accuracy of standard Omega RTDs[a]

Temperature (°C)	Temperature (°F)	Ohms (Ω)	Deviation (degrees) (°C)	Deviation (degrees) (°F)
–200	–328	± 0.56	± 1.3	± 2.34
–100	–148	± 0.32	± 0.8	± 1.44
0	32	± 0.12	± 0.3	± 0.54
100	212	± 0.30	± 0.8	± 1.44
200	392	± 0.48	± 1.3	± 2.34
300	572	± 0.64	± 1.8	± 3.24
400	752	± 0.79	± 2.3	± 4.14
500	932	± 0.93	± 2.8	± 5.04
600	1,112	± 1.06	± 3.3	± 5.94
700	1,292	± 1.17	± 3.8	± 6.84
800	1,472	± 1.28	± 4.3	± 7.74
900	1,562	± 1.34	± 4.6	± 8.28

[a]Omega Engineering, Inc., Stamford, Connecticut (2011a).

Figure 1 shows temperature sensors used to measure the dry-bulb temperature of air inside a heat-treatment kiln. Figure 2 shows a typical temperature gauge installed on the exterior wall for real-time monitoring of the kiln temperature.

Monitoring Core Temperatures of Firewood

Monitoring core temperatures of firewood requires having temperature sensors properly inserted into the largest firewood pieces during a treatment run. The sensor should reach the center of the cross section if inserted from a side face or reach more than 4 in. deep if inserted from the end-grain of the piece. Two types of temperature sensors that can be used for this application are resistance temperature detectors (RTD) and thermocouples (TC).

Resistance Temperature Detector

Resistance temperature detectors operate on the principle of changes in the electrical resistance of pure metals and are characterized by a linear positive change in resistance with temperature. Most RTD elements consist of a length of fine coiled wire wrapped around a ceramic or glass core. The element is usually quite fragile, so it is often placed inside a sheathed probe to protect it. RTD is one of the most accurate temperature sensors in industrial applications, but it is generally more expensive than alternatives because of the careful construction and use of platinum. As an example, Table 1 illustrates the accuracy of Omega standard RTDs.

Figure 3 shows two examples of RTD probes in different lengths. To measure the core temperature of firewood, the probe should be inserted into the center of the firewood piece from an end through a pre-drilled hole. Using RTD probes to measure internal wood temperatures poses some challenges:

1. The sheath that houses the RTD element requires drilling a relatively big hole (1/4 in.) either from the end or at the midsection of the firewood. Any gap between the probe and hole is difficult to seal, thus causing heated air to enter into the hole and affect the RTD's readings during the treatment.
2. APHIS PPQ Heat-Treatment Manual requires that the pre-drilled hole needs to be a minimum of 4 in. deep if the sensor is inserted into the firewood end. Therefore, a RTD probe should be at least 4 in. long.
3. The typical RTD probes used in commercial kilns are somewhat fragile and can be damaged during the firewood handling process.

Figure 2. Temperature gauge for real-time monitoring of kiln temperature.

Thermocouple

A thermocouple is a junction between two different metals that produces a voltage related to a temperature difference (Fig. 4). Thermocouples are widely used temperature sensors suitable for measuring over a large temperature range. They are inexpensive, interchangeable, and come fitted with standard connectors. A thermocouple is available in different

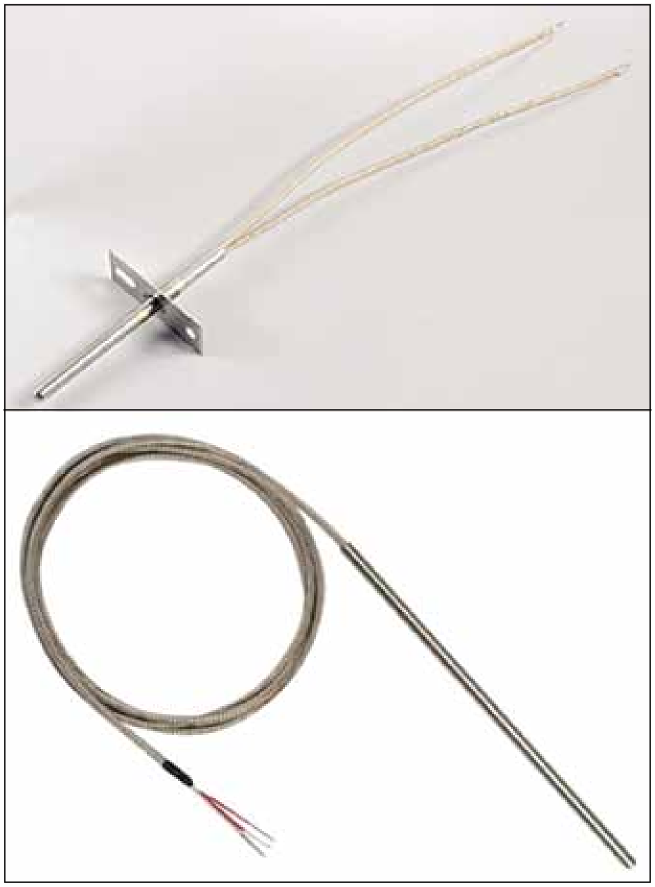


Figure 3. Two typical resistance temperature detectors (RTD) probes in different lengths (Omega Engineering, Inc., Stamford, Connecticut).

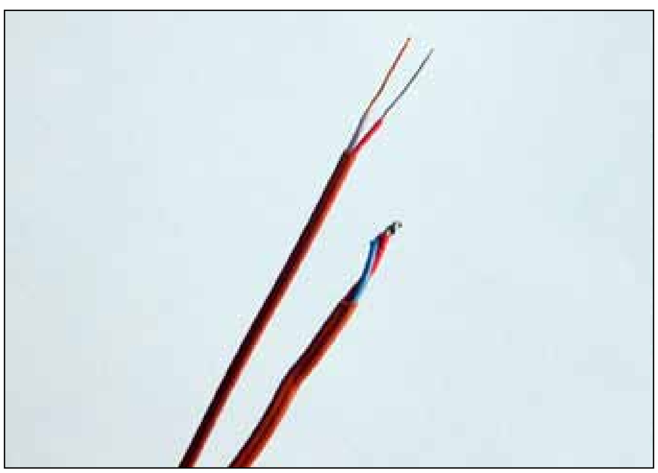


Figure 4. Typical insulated thermocouple (Omega Engineering, Inc., Stamford, Connecticut).

combinations of metals or calibrations. The four most common calibrations are J, K, T, and E. Table 2 shows the temperature range and standard limits of error of these types of thermocouples. Type T (copper-constantan) thermocouples operate in the −200 to 350 °C (–328 to 662 °F) temperature range (Omega Engineering, Inc. 2011b) and are thus best suited for heat-treatment applications.

Temperature Data Logger

Temperature data loggers are stand-alone data collecting devices that can read and store temperature data in internal memory for later download to a computer. Some also provide an option for real-time monitoring. The advantage of data loggers is that they can operate independently of a computer, unlike many other types of data acquisition devices. Data loggers are also cheaper than chart recorders and are available in various shapes and sizes. The range includes simple economical single channel fixed function loggers to more powerful programmable devices capable of handling hundreds of inputs. When choosing a temperature data logger, the following parameters should be considered:

1. Number of inputs
2. Size
3. Speed/memory
4. Real-time operation (option)

A variety of thermocouple data loggers are available for monitoring and recording temperature data during a firewood heat-treatment operation. Following are five types of data loggers we evaluated and used in field demonstration projects.

1. USB TC-08 Thermocouple data logger (Pico Technology, Ltd., St Neots, Cambridgeshire, UK)
2. OM-SP1700-500 4-channel compact portable data logger (Omega Engineering, Inc., Stamford, Connecticut)
3. OM-CP-OCTTEMP 8-channel temperature data logger (Omega Engineering, Inc., Stamford, Connecticut)
4. USB-502 RH/temperature data logger (Measurement Computing, Inc., Norton, Massachusetts)
5. HOBO U12 Stainless steel temperature data logger (Onset Computer Corporation, Pocasset, Massachusetts)

Development of a Heat-Treatment Monitoring System

The temperature monitoring system for a heat-treatment operation can vary depending on the configuration and capacity of the heating chamber or kiln and the availability of the monitoring equipment. In general, a monitoring system for a heat-treating operation should include multiple temperature sensors (thermocouples or RTD probes), a data acquisition and recording device, and a personal computer. In this study, we custom-built one temperature monitoring system for each participating company based on the type and needs of the facility. The goal was to select appropriate temperature equipment and build reliable and cost-effective temperature measurement systems that typical firewood producers can afford and are easy to use and capable of providing

Table 2—Common thermocouple temperature ranges[a]

Thermocouple (TC) type	Temperature range (°C)	Temperature range (°F)	Standard limits of error (°C)	Standard limits of error (°F)	Standard limits of error (%)	Specific limits of error (°C)	Specific limits of error (°F)	Specific limits of error (%)
J	0 to 750	32 to 1,382	Greater of 2.2	(3.96)	or 0.75	Greater of 1.1	(1.98)	or 0.4
K	–200 to 1,250	–328 to 2,282	Greater of 2.2	(3.96)	or 0.75	Greater of 1.1	(1.98)	or 0.4
E	–200 to 900	–328 to 1,652	Greater of 1.7	(3.06)	or 0.75	Greater of 1.0	(1.80)	or 0.4
T	–200 to 350	–328 to 662	Greater of 1.0	(1.80)	or 0.75	Greater of 0.5	(0.90)	or 0.4

[a]Omega Engineering, Inc. (Stamford, Connecticut) (2011b).

satisfactory temperature information (heating condition and firewood core temperature) required by federal and state regulations. Detailed information of the monitoring systems built and evaluated in this study is given in the "Onsite Heat-Treatment Demonstrations" section. The typical cost for a basic monitoring system that includes thermocouple sensors and a data logger ranges from $1,000 to $2,000 depending on the number of data inputs. A desktop computer or a laptop computer is essential for initiating the data logger, downloading temperature data, and for real-time monitoring.

Heat Treatment Operating Procedure

Based on previous experience gained during laboratory heat treatment and field kiln certification processes, we developed a step-by-step procedure for conducting heat-treatment runs and monitoring the temperatures of both kiln and firewood samples during the heating process. This operating procedure has been demonstrated and improved through field demonstration projects.

Basic Operating Procedure

1. Initiate temperature monitoring system.
2. Select monitoring samples (largest firewood pieces).
3. Determine the center of the firewood.
4. Drill a small-diameter hole into the center of the firewood to accommodate the temperature sensor and ensure a minimal gap between wood and sensor.
5. Insert a temperature sensor into the hole and ensure that the tip of the sensor reaches the center of a firewood sample.
6. Use silicon sealant and a round toothpick to seal the hole and secure the sensor in position.
7. Place the firewood samples into the firewood bins or baskets, ensuring that all firewood monitoring samples are buried deep within each bin, about halfway down. Place the bins containing monitoring samples in the cold spot areas that were determined by APHIS PPQ staff through kiln certification.
8. Complete loading and close the kiln.
9. Check the temperature monitoring system and start heating. We recommend that the kiln operator record in a kiln operation journal the initial kiln temperature, initial firewood core temperatures, and time that the heating starts.
10. Periodically monitor the kiln temperatures and the core temperatures of the firewood samples.
11. Determine the completion of the heat-treatment cycle once the requirements are met.

Onsite Heat-Treatment Demonstrations

Onsite heat-treatment demonstrations were conducted at four firewood heat-treating facilities, including two in Wisconsin, one in Illinois, and one in Indiana. Michigan was originally included in the field demonstration plan; however, we learned after the project started that the Michigan cooperator was no longer heat-treating firewood. We also learned from USDA APHIS PPQ staff that no firewood producers in Michigan have been certified to conduct heat treatment because ash trees have been heavily infested in Michigan, and the felled ash trees are primarily disposed of and utilized locally. Also, the entire lower peninsula of Michigan is now considered a quarantine zone, removing requirements for heat treating. Therefore, a second heat-treating facility in Wisconsin was identified to conduct the field demonstration.

The selected heat-treating facilities varied in size and type of energy source. Different heat-treating strategies were employed in these facilities to meet the particular needs of each facility. During the onsite demonstration phase, we custom-designed and built a temperature monitoring system for the participating facility and permanently installed the system in the kilns. USDA APHIS PPQ officers and state field regulatory staff participated in the demonstration projects. Each demonstration project included the following technical aspects:

- Evaluate accuracy and reliability of the temperature sensors and data loggers selected for the heat-treatment applications;
- Evaluate compatibility of the temperature monitoring system in firewood heat-treatment operations;
- Demonstrate the monitoring process through heat-treatment runs and show how to generate a record of the temperature history;

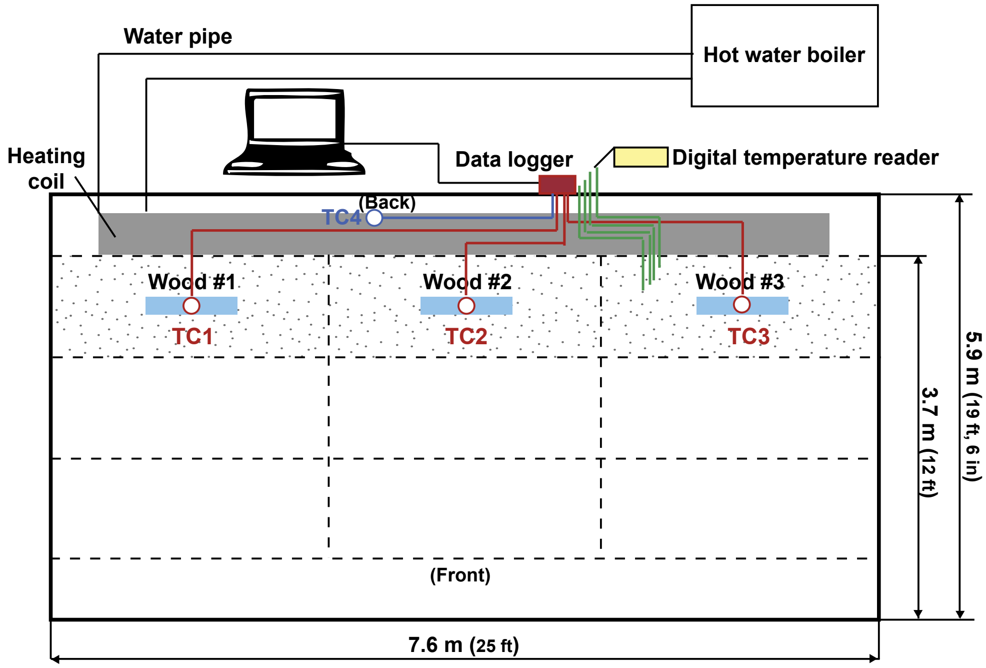


Figure 5. Layout of the kiln and temperature monitoring system at Facility A.

- Train facility managers and kiln operators on the entire heat-treating process by demonstrating heat-treatment procedures.

Demonstration 1—Heat-Treating Facility A (Wisconsin)

This heat-treating facility included a commercial dry kiln (Koetter Dry Kiln, Inc., Borden, Indiana) that measures 25- by 19.5- by 12-ft, and a hot water boiler (Mahoning Outdoor Furnace, Mahaffey, Pennsylvania) with a heating capacity of 550,000 British thermal units (BTU) per hour (Appendix A). The kiln holds 27 baskets (4- by 4- by 8-ft) of firewood in a full load (approximately 14 cords). The boiler is fueled manually with the facility's waste wood during the kiln drying and heat-treatment operation. The facility previously had difficulty raising the kiln temperature sufficiently in winter to levels required to meet the EAB heat-treatment standard. Through participation in a previous field demonstration project (Wang and others 2009), the owner made the following improvements to the kiln:

- Added extra fin pipes to the heat exchanger inside the kiln to increase heating area;
- Added baffles to improve air circulation inside the kiln;
- Insulated the exposed hot water pipes between the hot water boiler and the kiln.

After the kiln improvements, the kiln was able to reach 76 °C (170 °F) during the winter months and 82 °C (180 °F) in summer, which was proved sufficient to meet the EAB heat-treatment standard (Wang and others 2009).

Temperature Monitoring System

Figure 5 shows the layout of the kiln, temperature monitoring system installed, and the locations of temperature sensors. The temperature monitoring system consists of four Type T thermocouple wires, a 4-channel temperature data logger (OM-SP1700-500 Compact Portable Data Logger, Omega Engineering, Inc., Stamford, Connecticut), and a laptop computer. One thermocouple (TC-4) was mounted on the interior rear wall of the kiln (next to the RTD probe originally installed) to measure the temperature of return air (after circulating through firewood). Three thermocouples (TC-1, TC-2, and TC-3) were used to measure the core temperatures of the firewood samples that were placed in each of three baskets located in the bottom layer of the back row. Based on the thermal mapping through kiln certification conducted by AHPHIS PPQ staff, these locations were identified as the cold spots within the dry kiln. At the time of the demonstration project, the heat-treating facility did not have a control room on site to house a computer. Therefore, real-time monitoring was not available. The temperature data stored in the data logger was downloaded and viewed after the completion of each heat treatment run by bringing a laptop to the site or taking the data logger back to the office. To allow the kiln operator to monitor the core temperatures of the firewood samples, we provided four additional thermocouple wires and a digital thermometer as a secondary temperature monitoring system. Each of the three firewood samples had an additional TC wire installed so that the core temperatures of the firewood could be checked real-time periodically using a digital thermometer during the heat-treating process.

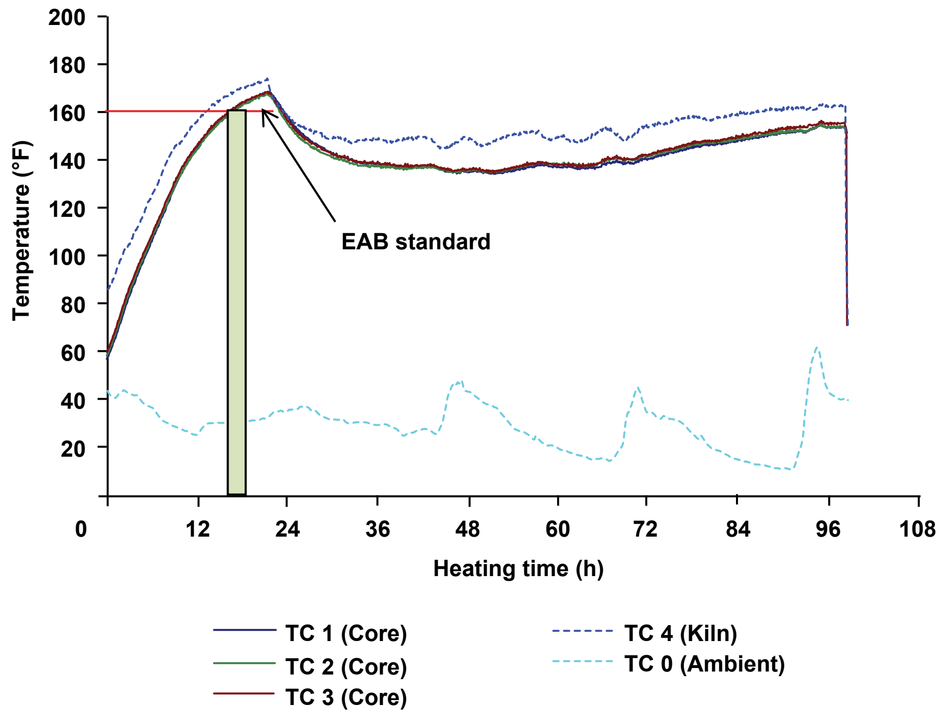


Figure 6. Temperature record of heat-treatment run No. 1 at Facility A.

Heat-Treatment Run

The facility has been kiln drying firewood for interstate commerce for several years. Firewood loads were typically kiln dried weekly throughout the year. In this case, a dry-heat schedule would best fit the production needs of the facility by integrating a heat-treatment procedure with a kiln drying process. The heat-treatment demonstration runs were set to meet the heating standard for EAB. The kiln first heated the firewood pieces to the target core temperature of 71 °C (160 °F) and held for at least 75 min. After meeting the heating standard, the firewood loads were continuously heated and kiln dried until the moisture content of the firewood reached 20% or below.

Three field heat-treatment runs were conducted in the winter of 2009 (February 12–16, February 19–25, and February 25–March 2) using the established step-by-step operating procedure. In each treatment run, the kiln was fully loaded with 27 baskets of fresh split firewood. Baskets were arranged in three levels (bottom, middle, and upper), with nine baskets on each level. The monitoring firewood samples were placed in three baskets in the back row of the lower level, one in the middle of each basket. The data logger was programmed to start temperature measurement before the heat treating started.

This kiln has limited heating capacity because the heat energy comes from a wood-fueled hot water boiler. To raise kiln temperatures as high as possible, the vents on the back wall of the kiln were closed during the heat-treatment phase. The vents were then opened to release moisture after the heating standard was met to start drying the firewood. This procedure proved effective in all three heat-treatment runs. Figures 6, 7, and 8 show the temperature data recorded during each treatment run, demonstrating that the cycle met the heating standard for EAB.

In the demonstration runs, the kiln temperature reached 78–81 °C (174–178 °F). The monitoring firewood samples reached the core temperature of 71 °C (160 °F) in 17, 27, and 31 h respectively. This large variation of heating time was associated with differences in initial wood temperature and ambient air temperature. But most importantly, heating time was found to be affected by how frequently the water boiler was fueled. This result indicates that both the kiln temperature and the firewood core temperature should be closely monitored and used as a verification of the heat-treatment process.

Table 3 shows a portion of the temperature data recorded by the data logger. The dates, recording time (time stamp), and temperature of each channel are shown. Channel 0 shows the ambient temperature outside the kiln. Channels 1 to 3 correspond to the core temperatures of the firewood samples. Channel 4 corresponds to the kiln temerature (temperature of return air). A complete record of temperature history should be provided to APHIS PPQ staff as a thermal verification of the heat-treatment process.

Demonstration 2—Heat-Treating Facility B (Wisconsin)

Facility B is a family-owned welding repair and fabrication business. It produces kiln-dried firewood and sells to parks and local businesses within the state. This facility has

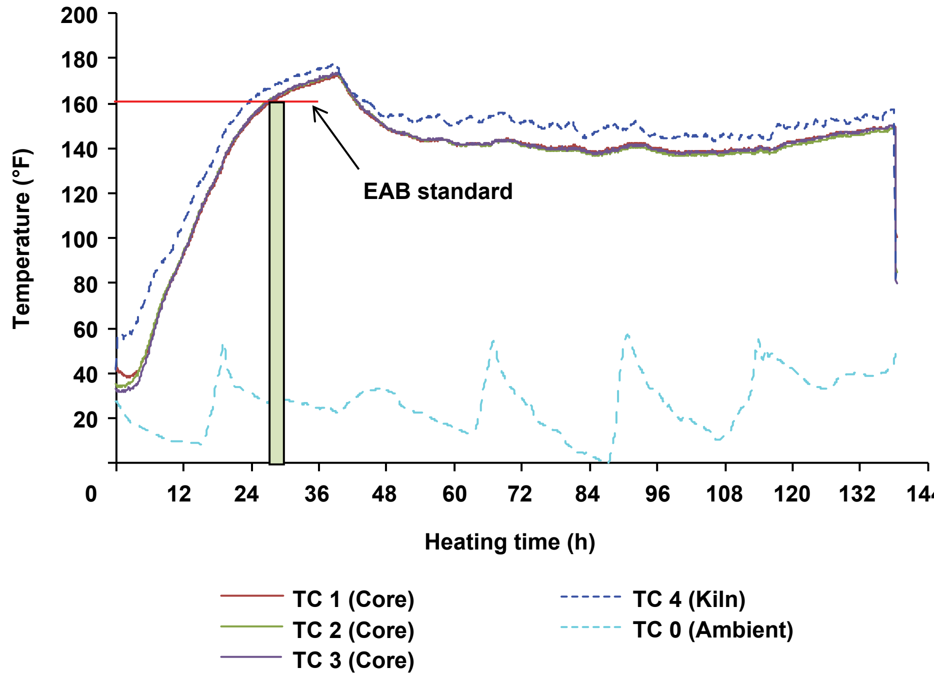


Figure 7. Temperature record of heat-treatment run No. 2 at Facility A.

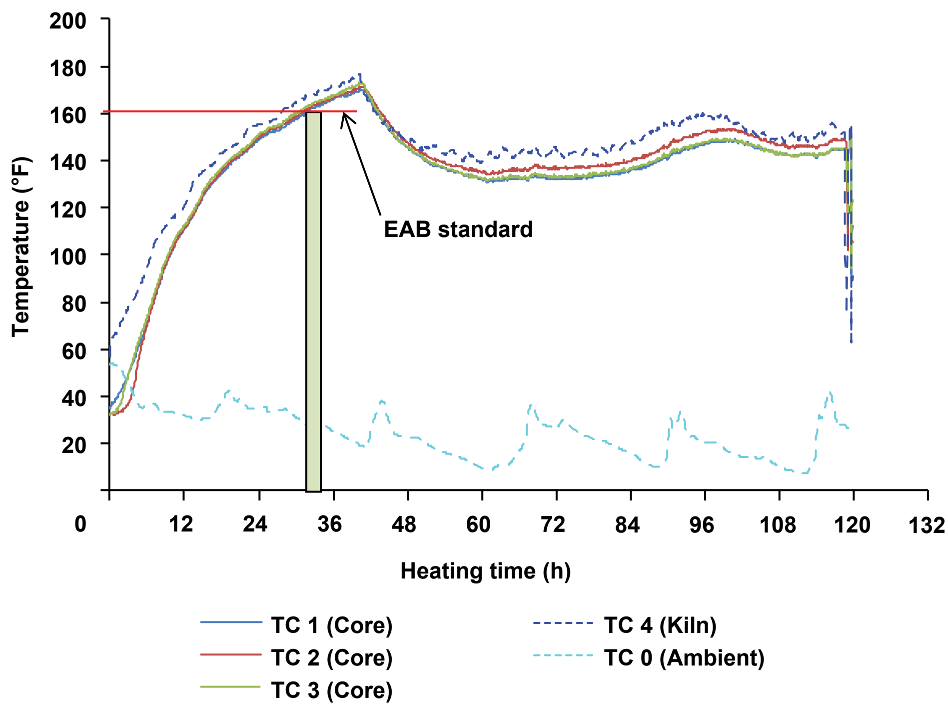


Figure 8. Temperature record of heat-treatment run No. 3 at Facility A.

two custom-modified kilns for kiln drying and heat treating firewood (Appendix B). At the time of this demonstration project, the facility had only Kiln No. 1 fully operational and had no temperature monitoring capability for either kiln. Because it was located outside of the EAB quarantine area, the facility was only required to heat treat firewood for gypsy moth standard, which requires the core temperature to reach a minimum of 56 °C (133 °F) for 30 min (USDA APHIS PPQ 2010).

Kiln No. 1 is a modified Northland dry kiln which measures 31- by 13- by 11-ft. The kiln holds 44 bins (3- by 3- by 3-ft) of firewood in a full load (approximately 5 cords). During kiln drying and heat-treatment runs, a manually fed Model CL7260 Central Wood boiler (Central Boiler, Greenbush,

Table 3—Portion of the temperature data recorded during heat-treatment run No. 1 at Facility A

Date (mm/dd/yy)	Time hh:mm:ss (a.m.)	CH-0 ambient (°F)	CH-1 sample 1 (°F)	CH-2 sample 2 (°F)	CH-3 sample 3 (°F)	CH-4 kiln temp (°F)
2/13/2009	4:00:00	30.70	159.30	158.50	159.70	166.80
2/13/2009	4:05:00	30.70	159.30	158.50	159.70	166.80
2/13/2009	4:10:00	30.79	159.30	159.20	159.80	167.50
2/13/2009	4:15:00	30.79	159.30	159.20	159.80	167.50
2/13/2009	4:20:00	30.88	159.40	159.30	160.50	167.60
2/13/2009	4:25:00	30.88	160.10	159.30	160.50	168.30
2/13/2009	4:30:00	30.88	160.10	160.00	160.50	168.30
2/13/2009	4:35:00	30.88	160.10	160.00	161.20	167.60
2/13/2009	4:40:00	30.88	160.70	160.00	161.20	168.30
2/13/2009	4:45:00	30.88	160.70	160.00	161.20	168.30
2/13/2009	4:50:00	30.88	160.70	160.60	161.90	168.30
2/13/2009	4:55:00	30.88	161.30	160.60	161.90	168.30
2/13/2009	5:00:00	30.88	161.30	161.20	161.90	168.90
2/13/2009	5:05:00	30.88	161.30	161.20	161.90	168.90
2/13/2009	5:10:00	30.88	161.30	161.20	161.90	168.90
2/13/2009	5:15:00	30.99	162.10	161.30	162.60	169.60
2/13/2009	5:20:00	30.99	162.10	161.30	162.60	169.60
2/13/2009	5:25:00	30.99	162.10	162.00	162.60	169.60
2/13/2009	5:30:00	30.99	162.70	162.00	163.20	169.60
2/13/2009	5:35:00	30.99	162.70	162.00	163.20	169.60
2/13/2009	5:40:00	30.88	163.20	162.50	163.10	170.20
2/13/2009	5:45:00	30.88	163.20	162.50	163.80	170.20
2/13/2009	5:50:00	30.74	163.10	162.40	163.70	170.10
2/13/2009	5:55:00	30.74	163.10	163.00	163.70	170.10
2/13/2009	6:00:00	30.74	163.80	163.00	164.30	170.10
2/13/2009	6:05:00	30.74	163.80	163.00	164.30	170.70
2/13/2009	6:10:00	30.74	163.80	163.70	164.30	170.70
2/13/2009	6:15:00	30.74	163.80	163.70	164.30	170.70
2/13/2009	6:20:00	30.74	163.80	163.70	164.30	170.10
2/13/2009	6:25:00	30.74	164.40	163.70	164.30	170.70
2/13/2009	6:30:00	30.85	164.50	163.80	165.00	170.80
2/13/2009	6:35:00	30.99	164.60	163.90	164.50	170.90
2/13/2009	6:40:00	31.14	164.80	163.90	165.20	171.10
2/13/2009	6:45:00	31.23	164.80	164.00	165.30	171.10
2/13/2009	6:50:00	31.23	164.80	164.00	165.30	170.40
2/13/2009	6:55:00	31.32	164.80	164.10	165.40	171.10
2/13/2009	7:00:00	31.32	164.80	164.80	165.40	171.10
2/13/2009	7:05:00	31.46	165.00	164.30	165.60	171.30
2/13/2009	7:10:00	31.46	165.00	164.90	165.60	171.30
2/13/2009	7:15:00	31.55	165.70	165.00	165.60	171.40
2/13/2009	7:20:00	31.55	165.70	165.00	166.30	171.40
2/13/2009	7:25:00	31.55	165.70	165.00	166.30	171.40
2/13/2009	7:30:00	31.55	165.70	165.70	166.30	172.00
2/13/2009	7:35:00	31.55	165.70	165.70	166.30	172.00
2/13/2009	7:40:00	31.55	165.70	165.70	166.30	171.40
2/13/2009	7:45:00	31.55	166.40	165.70	166.30	171.40
2/13/2009	7:50:00	31.55	166.40	165.70	166.30	172.00
2/13/2009	7:55:00	31.55	166.40	166.30	166.90	172.00
2/13/2009	8:00:00	31.55	166.40	166.30	166.90	172.70

Note: Data within the box indicates that the treatment has met temperature-time requirement for EAB.

Minnesota) provided 750,000 BTU per hour to the kiln. The wood boiler was also capable of burning oil as an alternative. The heating coils and fans are located just beneath the ceiling along the central line of the kiln. A tarp baffle is used to cover the top bins after the loading is completed and guide the hot air circulating through the firewood bins.

Kiln No. 2 was modified from a used freight container that measures 8- by 9- by 48-ft. It holds 48 bins (3- by 3- by 3-ft) of firewood in a full load (approximately 5.5 cords). The heating coils and fans were installed at the upper corner through the length of the kiln. Initially, a custom-built wood furnace system provided hot air through ductwork to the kiln for heating. In fall 2009, the wood furnace was replaced with a new manually fed Model CL 40 Central Wood Boiler, which provides 500,000 BTU per hour. This newly upgraded kiln had not been certified for heat treating

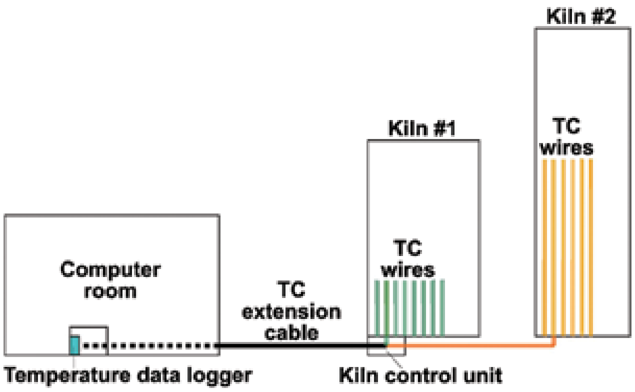


Figure 9. Layout of the temperature monitoring system at Facility B.

and the air circulation condition was unknown at the start of this project.

Our demonstration project at this facility was primarily focused on installing a temperature monitoring system at Kiln No. 1 and demonstrating the proper heat treating and temperature monitoring processes. At the owner's request, we expanded the monitoring system to include Kiln No. 2 also. Working with the state field regulatory staff, we conducted thermal mapping and kiln certification on Kiln No. 2 and installed six TC wires at appropriate locations for monitoring purposes.

Temperature Monitoring System

Figure 9 shows layout of the temperature monitoring system installed at this facility. The monitoring system was originally designed just for heat-treatment process of Kiln No. 1 and included 8 type-T TC wires, an 8-pair TC extension cable, and an 8-channel data logger (USB TC-08 Thermocouple Data Logger, Pico Tech, Cambridgeshire, United Kingdom). Later, when the second kiln was added next to Kiln No. 1, we expanded the system by adding six TC wires to Kiln No. 2. The heat-treatment operation of Kiln No. 2 can be monitored by connecting these six sensors into the monitoring system. Because the data logger has only eight channels, only one kiln can be fully monitored at a time.

A certification test had been completed on Kiln No. 1 before we installed the temperature monitoring system. The thermal mapping results indicated that the cold spots in Kiln No. 1 were located in the right side of the kiln near the two vents on the kiln wall (Fig. 10). Although the vents were completely closed during the heat-treating period, some heat loss seems to be occurring through the vents, causing the air temperature to drop in that area.

The computer and the data logger were both housed in a heated computer control room that was about 100 ft away from Kiln No. 1. The TC wires were connected to the data logger through an 8-pair TC extension cable. The data logger was connected to the USB port of a desktop computer. The USB connection allows the data logger to be powered directly by the USB bus, eliminating the need for an external power supply.

The location of the TC sensors in Kiln No. 1 is shown in Figure 10. TC wires 1 to 4 were placed at four different locations along the interior walls, with two on each side. These TC sensors are intended for measuring air temperatures or as a backup sensor. In the demonstration runs, TC-1 to TC-4 were all used to measure air temperatures in order to check the heat distribution. In a normal operation, two TC sensors should be sufficient for monitoring the kiln temperatures; the other two can be used as a replacement if any other TC sensors were broken. TC wires 5 to 8 were distributed in the cold areas (right side of the kiln) to measure the core temperatures of firewood samples in four different bins.

Heat-Treatment Runs (Kiln No. 1)

The facility produces split firewood and places firewood pieces into 3- by 3- by 3-ft steel-wired bins before loading the kiln. For a full load operation, firewood bins were arranged in 3 rows with 9 bins on each side row and 4 bins on the center row. The rows were stacked 2 bins high, for a total of 44 bins in each kiln run. The kiln operation of this facility included both heat treating and kiln drying. The firewood load was first heated to meet the heat-treatment standard (heat-treatment stage), then kiln dried to 20% or below (kiln-drying stage).

Two field heat-treatment runs were conducted in Kiln No. 1 on May 13–18 and May 27–June 1, 2009. Figures 11 and 12 show the temperature history of the two demonstration runs. The whole process of heat treatment and kiln drying took 5 days for both runs, which was a typical duration for drying green firewood at this facility.

In the first heat-treatment run, the kiln temperature was raised to 82 °C (180 °F) for the entering hot air and 76 °C (170 °F) for the return air (after circulating through firewood). The operation passed the heat-treatment standard for gypsy moth in 72 h and achieved the heat-treatment standard for EAB in 96 h. Although the facility was only required to meet the gypsy moth standard, this demonstration run indicated that Kiln No. 1 also had the capability to meet the EAB heat-treatment standard.

In the second heat-treatment run, the process was set only to meet the heat-treatment standard for gypsy moth and kiln dry the firewood as their normal operation. The highest kiln temperature during the treatment reached 76 °C (170 °F) for the entering air and 73 °C (165 °F) for the return air. The operation passed the gypsy moth standard in 16 h.

Thermal mapping of Kiln No. 2

Wisconsin state regulatory personnel conducted a certification test on Kiln No. 2 on December 3–11, 2009, for intrastate movement of firewood. The purpose was to certify the kiln for heat treating firewood per gypsy moth standard, which stipulates that the core temperature of the firewood be heated to 56 °C (133 °F) for 30 min. HOBO U12

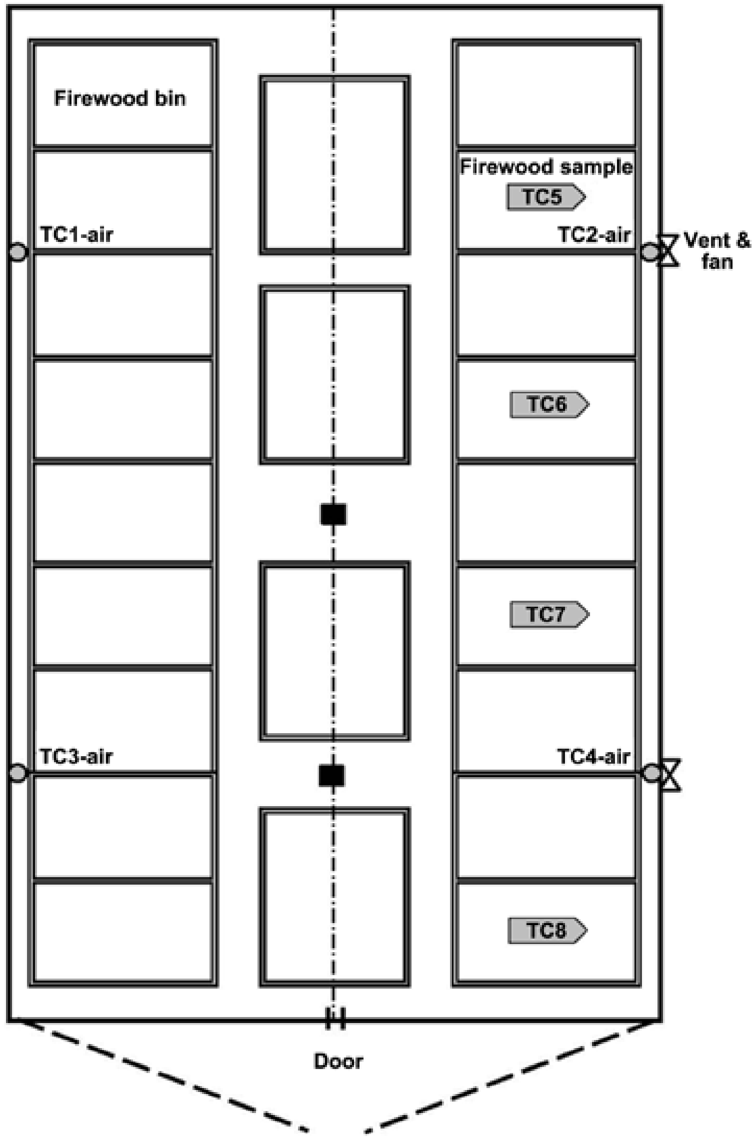


Figure 10. Arrangement of firewood bins and location of TC sensors in Kiln No. 1.

stainless steel temperature loggers (Onset Computer Corporation, Pocasset, Massachusetts) were used to separately measure the air temperature and core temperature of firewood. A total of 26 probes were placed into the kiln. Thirteen probes were inserted into firewood pieces located in the bottom layer of firewood bins to measure the core temperatures of the firewood, and 13 adjacent to them to measure air temperatures. Temperature data were recorded every 5 min and downloaded from the loggers following the heat treatment.

Figure 13 shows the recorded temperatures from 13 temperature probes that were used to map the air temperature distribution within the kiln. Figure 14 shows the recorded temperatures from 13 data loggers that were monitoring core temperatures of the firewood samples. All the probes measured temperatures above the gypsy moth standard.

Thermal mapping results indicate that the air was not well circulated in this modified kiln. The temperature difference between the hot spots and cold spots was about 7 to 8 °C (12–15 °F). The bottom bins No. 1, 2, 5, and 11 were identified as cold spots that had the lowest air temperatures during the heating cycle (Fig. 15a). We recommended that Facility B place the TC sensors in these cold areas to monitor both kiln temperatures and firewood temperatures in future heat-treatment operations (Fig. 15b).

Demonstration 3—Heat-Treating Facility C (Illinois)

Facility C produces several different wood products including heat-treated firewood and pallets. In 2007, USDA APHIS certified its dry kiln for heat treatment to allow the company to move firewood outside the EAB quarantine area.

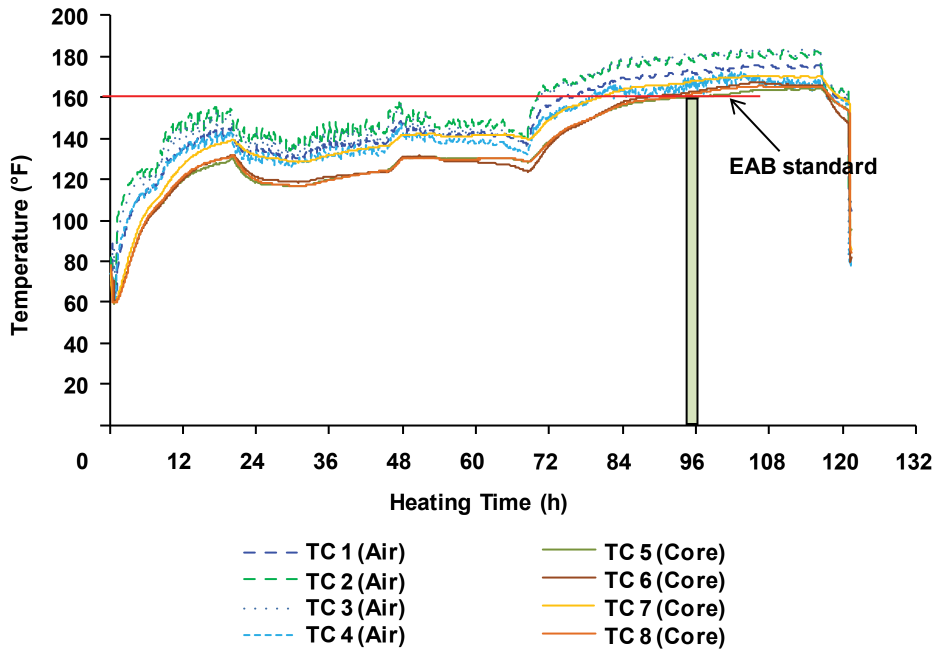


Figure 11. Temperature record of heat-treatment run No. 1 at Facility B.

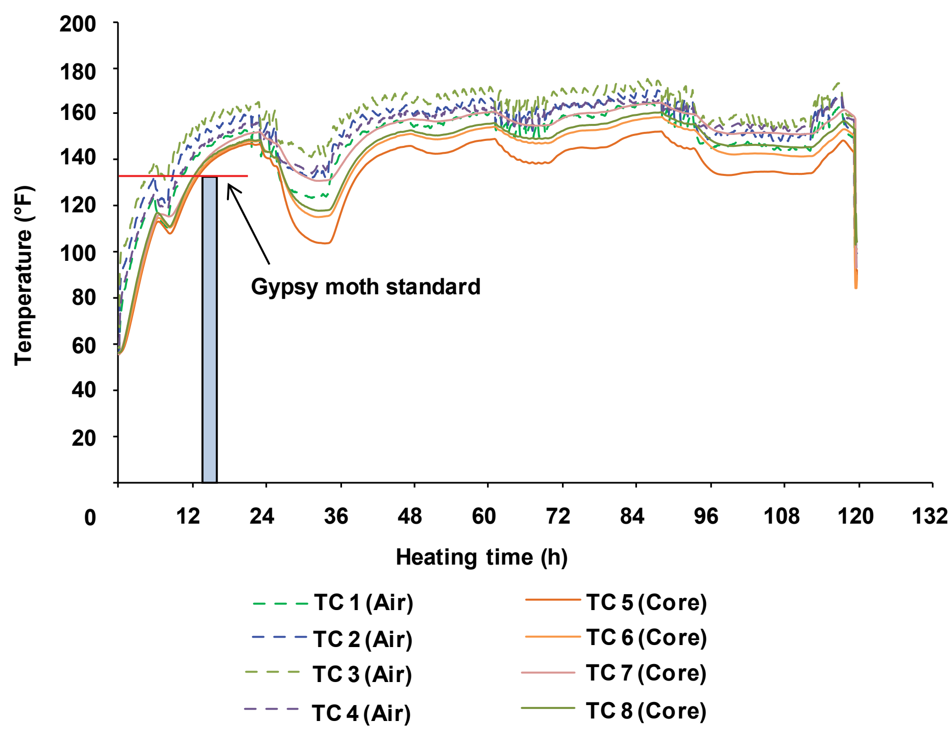


Figure 12. Temperature record of heat-treatment run No. 2 at Facility B.

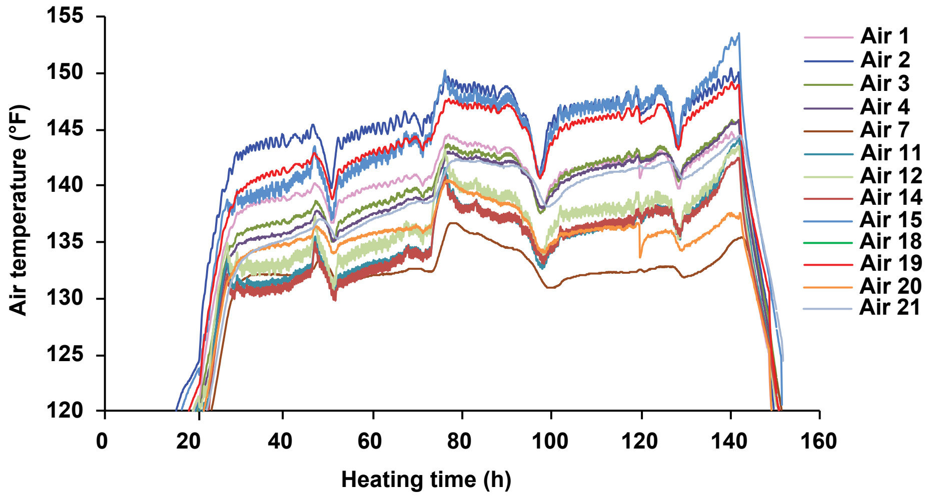


Figure 13. Air temperature recorded for thermal mapping in Kiln No. 2 at Facility B.

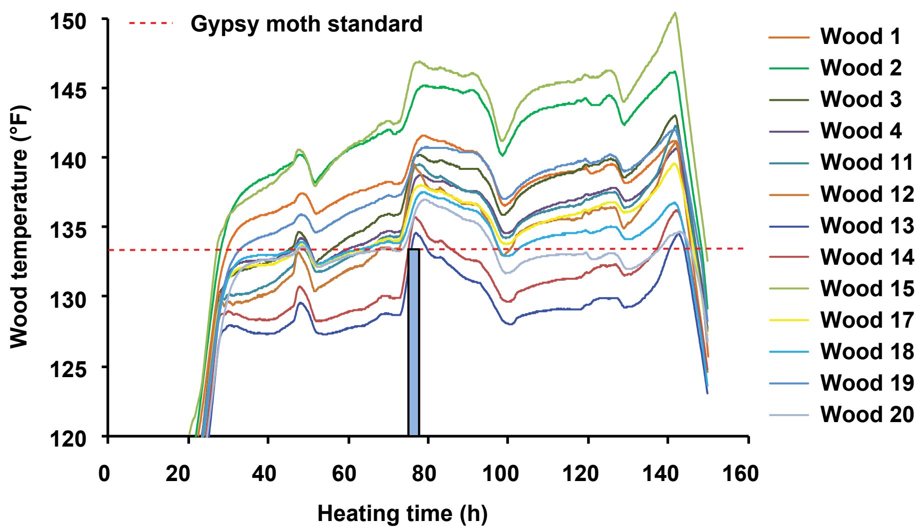


Figure 14. Internal wood temperature recorded during thermal mapping in Kiln No. 2 at Facility B.

The heat-treatment facility consists of a direct-fired dry kiln (Kiln-Direct, Burgaw, North Carolina), a gas burner, and a small computer control room next to the kiln (Appendix C). The kiln was originally designed to heat treat pallets per the International Standards for Phytosanitary Measures (ISPM) 15 standard. The facility burns natural gas as its heat source for heat treating both pallets and firewood. The kiln measures 48- by 15.5- by 11.5-ft, which holds 54 bins (4- by 4- by 4-ft) of firewood (approximately 11.5 cords). Heat-treated firewood is stored inside the main building and then packaged into 0.75 ft^3 (21 L) aerated plastic bags for their distributors. The dry kiln produces 24 pallets of packaged firewood per treatment run.

Temperature Monitoring System

The heat-treatment kiln at this facility has an existing temperature monitoring system that was included with the dry kiln. This existing system employed eight 2-in. long RTD probes for temperature measurements: two for air temperatures located at the rear wall, about 4 ft above ground and six for core temperatures of firewood samples that are placed in the center of bins at the rear, middle, and front of the kiln. A computer is used to monitor the sensors in real time. The kiln was programmed to complete the heat treatment after the lowest of these six probes had reached 71 °C (160 °F) for 75 min (EAB standard). In the past, the kiln operator had trouble with data collection under severe weather conditions. The owner agreed to install a second temperature monitoring system in the kiln as a backup system if the primary system was not operational. This situation provided us with an opportunity to test our custom-built system and compare the use of two different temperature sensors (RTD versus TC).

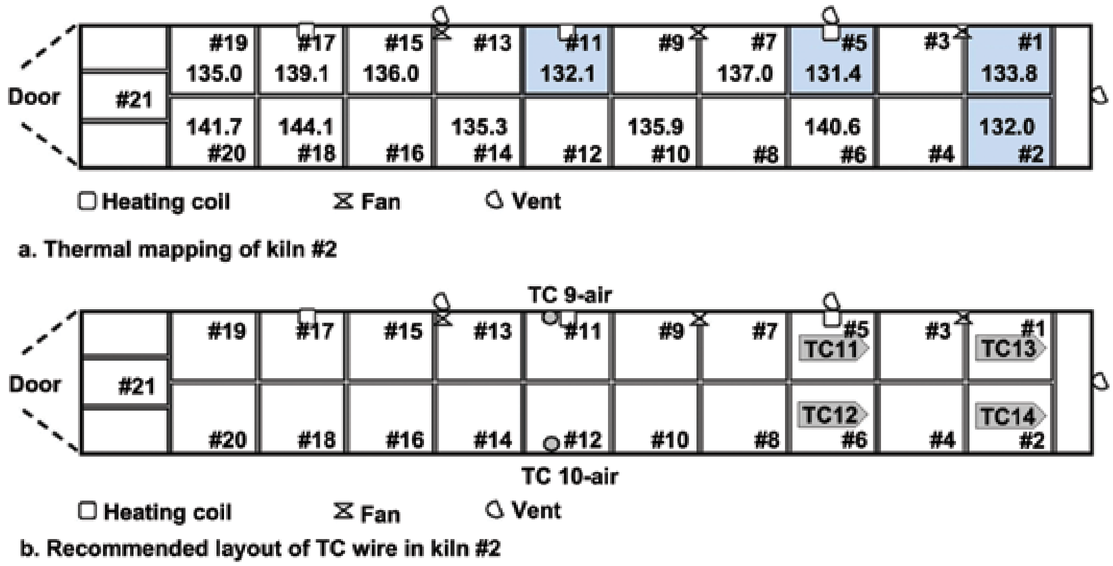


Figure 15. Thermal mapping and recommended layout of TC wires for Kiln No. 2 of Facility B.

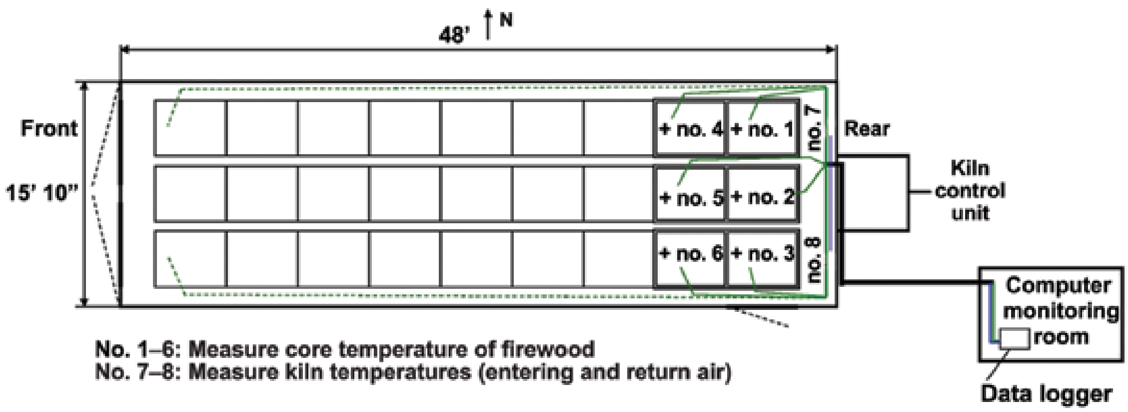


Figure 16. Layout of the kiln and temperature monitoring system at Facility C.

Figure 16 shows the layout of the heat-treatment kiln, the new temperature monitoring system, and the location of the TC temperature sensors. The new monitoring system consists of eight type-T thermocouple wires, an 8-channel temperature data logger and a desktop computer. The computer and the data logger are both housed in a small control room next to the kiln (Appendix C, demonstration photo C5 and C6). The 8-channel Omega data logger measures and records up to 14,563 temperature measurements per channel and includes a real-time clock that records the temperature data with a time stamp. The TC wires run from the data logger to the rear wall of the dry kiln, and then are distributed to the following locations as shown in Figure 16.

- TC-1, 2, and 3 are located in the first bin of each row in the bottom layer at the rear of the kiln;
- TC-4, 5, and 6 are located in the second bin of each row in the bottom layer;
- TC-7 is located at the rear of the kiln and next to the burner assembly (hot air);
- TC-8 is located along the rear wall of the kiln (return air).

TC No. 1 through No. 6 are used to measure the core temperatures of the firewood samples in the bottom six bins. These bins are located in the cold spot areas as identified through thermal mapping and kiln certification (previously conducted by APHIS PPQ staff). TC No. 7 is used to measure the temperature of hot air coming out of the burner assembly. TC No. 8 is used to measure the return air temperature.

Heat-Treatment Runs

Facility C heat treats split hardwood firewood that has been air dried in the wood yard. Kiln drying is not required in the heat-treating process. The firewood heat-treatment operation uses the dry heat produced through the gas burner. The facility normally conducts 16 to 18 firewood heat-treatment runs annually to produce certified firewood. To demonstrate the heat-treating process and test the new temperature monitoring system, we conducted three heat-treatment runs between September 2009 and April 2010. Split firewood was contained in 4- by 4- by 4-ft metal-tube bins. These bins were loaded into the kiln by a forklift and arranged in three rows. Each row was nine bins long and stacked two bins high for a total of 54 bins. Firewood bins were staggered to force heated air to make better contact with the firewood.

During the demonstration runs, both RTD probes (previous monitoring system) and TC wires (new monitoring system) were inserted into selected firewood samples. TC wires (TC No. 1 through No. 6) were inserted into the center of each firewood sample at the midsection according to the established procedure. The 2-in.-long RTD probes (RTD No. 1 through No. 6) were inserted into firewood samples from the end through a pre-drilled hole (1/4 in. diameter and 2 in. deep), and then plugged with a putty patch (Appendix C, demonstration photo C7). We noticed during installation that the putty patch attachment was not as secure as the TC wires. The installed RTD probes occasionally pulled out of the firewood during normal handling due to their loose attachment. The other disadvantage of using this short RTD probe is that it can only go into the firewood 2 in. deep from the end. Therefore, the temperature measured may not reflect the true core temperature for that piece of firewood.

In this case, the temperatures measured by RTD probes and TC wires were all monitored in real time and recorded through the desktop computer located in the control room. During a normal kiln operation, the Kiln-Direct program controlled the heating process. The kiln was programmed to stop the heat treatment after the lowest of the six RTD probes had reached 71 °C (160 °F) for 75 min.

Figures 17–19 are the temperature plots of both TC wires and RTD probes for three kiln runs conducted on September 1, 2009 (run No. 1), October 28, 2009 (run No. 2), and April 28, 2010 (run No. 3). Data from the RTD probes indicated that the firewood samples reached 71 °C (160 °F) in 5 h 20 min in run No. 1; 15 h and 35 min in run No. 2; and 5 h and10 min in run No. 3. Data from the TC wires show that the firewood samples reached 71 °C (160 °F) in 7 h for run No. 1 and 16 h 20 min for run No. 2. The firewood samples of run No. 3 did not reach 71 °C (160 °F) based on the TC readings. There were significant differences between the TC readings and the RTD readings. Considering that both RTD probes and TC wires have been calibrated, we projected that the possible causes of this difference were 1) poor installation of RTD probes from the end of firewood; 2) possible falling out of the RTD probes from some firewood samples; and 3) insufficient depth of RTD probes placed into the firewood samples.

TC wires No. 1 to No. 6 (that measured firewood core temperatures) worked well during all three runs. No wire damage or wire falling out of firewood was observed. However, the plastic conduit used to guide, protect, and anchor the TC wires on the kiln walls was not high-temperature resistant and consequently became deformed and fell off the wall during the first kiln run. This did not affect the readings of TC No. 1 to No. 6, as they were still securely inserted into the firewood. But TC No. 7 and No. 8, which were originally installed up near the burner assembly (No. 7) and on the rear wall (No. 8) through the plastic conduits, fell off from the anchor and dropped onto the ground because of conduit deformation. This explained why temperature readings of TC No. 7 and No. 8 in run No. 1 were much lower than the RTD readings 2 h into the treating process. All the TC wires were reinstalled through steel conduits prior to the second kiln run.

From TC temperature charts, we observed that the temperature of hot air entering into the kiln fluctuated dramatically during the heat-treating process. This could have been related to the heating cycle of the burner and the strong turbulence of the hot air near the burner assembly. Thermocouple readings of the return air also showed slightly larger variation as compared with the RTD readings in run No. 2. This may be related to the movement of the TC wire under the turbulence of the return air.

Demonstration 4—Heat-Treating Facility D (Indiana)

This facility was certified on May 13, 2009, to heat treat firewood for movement outside of an EAB quarantine zone. The dry kiln (Nova Dry Kiln, formerly Koetter Dry Kiln, New Albany, Indiana) measures 18- by 18- by 10-ft, which holds approximately 7.5 cords of firewood (Appendix D). A wood boiler is manually fed wood scraps to supply hot water for heating the dry kiln during heat treatments. This facility does not produce firewood but heat treats firewood for other producers. The firewood is brought to the facility in small bundles stacked on pallets. Before arriving onsite, the producer wraps the bundles in a mesh to keep the bundles from moving. The firewood is heat treated in stacked and palletized bundles. Pallets are arranged in four rows, each five pallets long and stacked two pallets high for a total of 40 pallets per treatment run.

Before the installation of our system, the facility inserted single temperature probe into firewood placed in the center of a pallet at the rear of the kiln to monitor real-time temperature during the heat-treatment run. A circular chart recorder (Dickson No. KT803, Addison, Illinois) recorded temperature data from this probe. The run was completed when the chart recorder read 71 °C (160 °F) for 75 min. Hard copies of the circular charts were sent to the USDA APHIS personnel as verification. Typical heat-treatment runs last 24 to 48 h depending on the season and feeding of the boiler.

New Temperature Monitoring System

To help create a more efficient heat-treating operation, a new temperature monitoring system was installed at this facility on September 28, 2009, to electronically collect the kiln temperature and firewood temperature data. Figure 20 shows the layout of the kiln and the new temperature monitoring system. It consists of three 4-in.-long thermocouple probes (for measuring firewood temperature), one

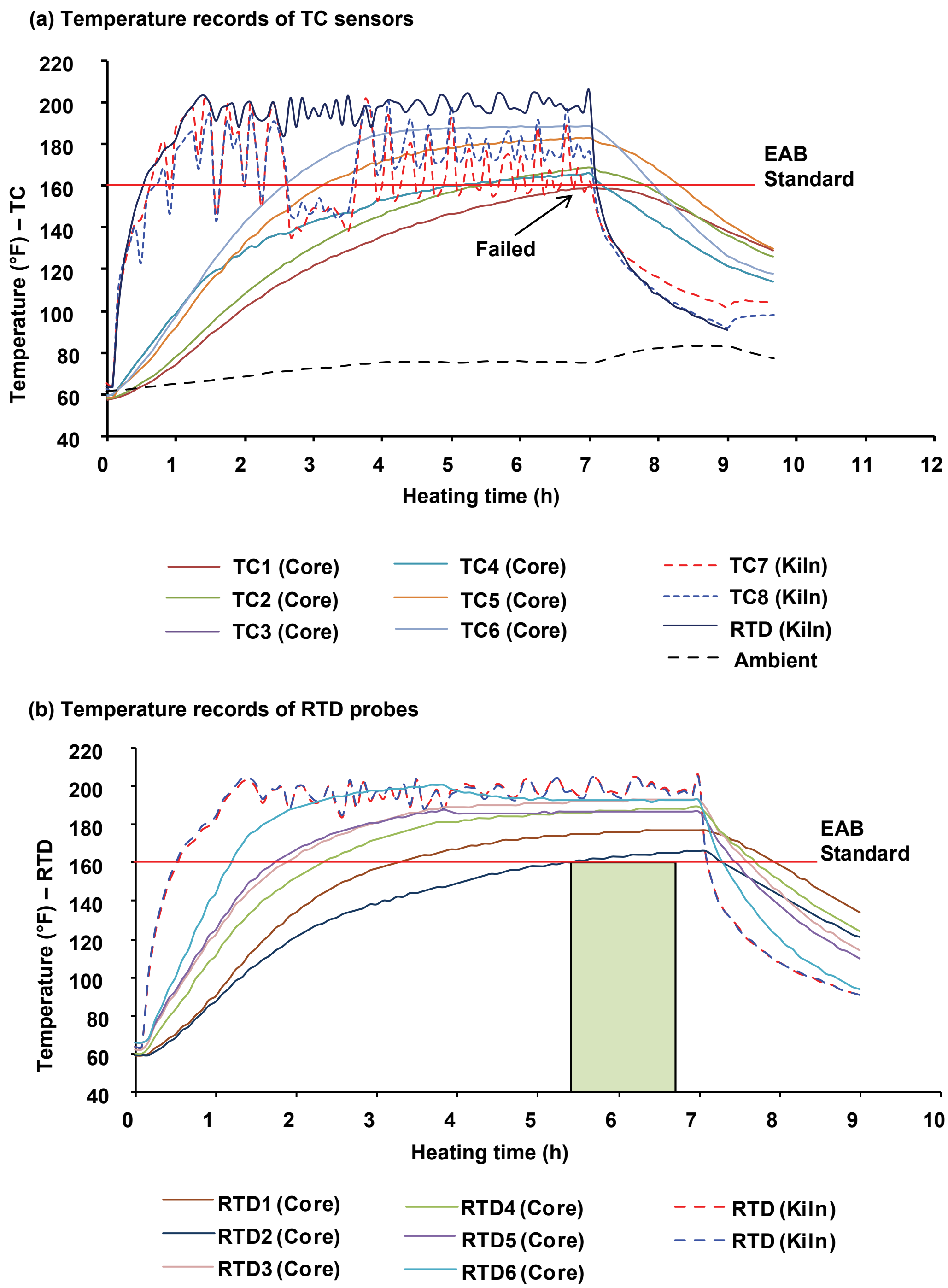


Figure 17. Temperature records of heat-treatment run No. 1 at Facility C.

thermocouple wire (Type T) (for kiln temperature), and a 4-channel temperature data logger. The Omega data logger was installed on the outside kiln wall in an adjacent storage room. The TC wires run from the data logger to the rear interior wall of the kiln. The TC No. 1 (wire) was mounted next to the RTD probe originally installed to measure the temperature of return air (RTD measurement is only read real-time, not recorded, through a temperature meter on the control panel attached to the outside kiln wall), and TC No. 2 through No. 4 were placed in three palletized firewood bundles on the back row. The back row was identified as the kiln cold spot through thermal mapping and kiln certification.

Heat-Treatment Runs

Three heat-treatment runs were conducted on September 28, 2009 (run No. 1), October 30, 2009 (run No. 2), and April 29, 2010 (run No. 3) (Appendix D). During the heat-treatment runs, three of the five lower pallets closest to the rear wall had a sensor located in the center of the bundle to

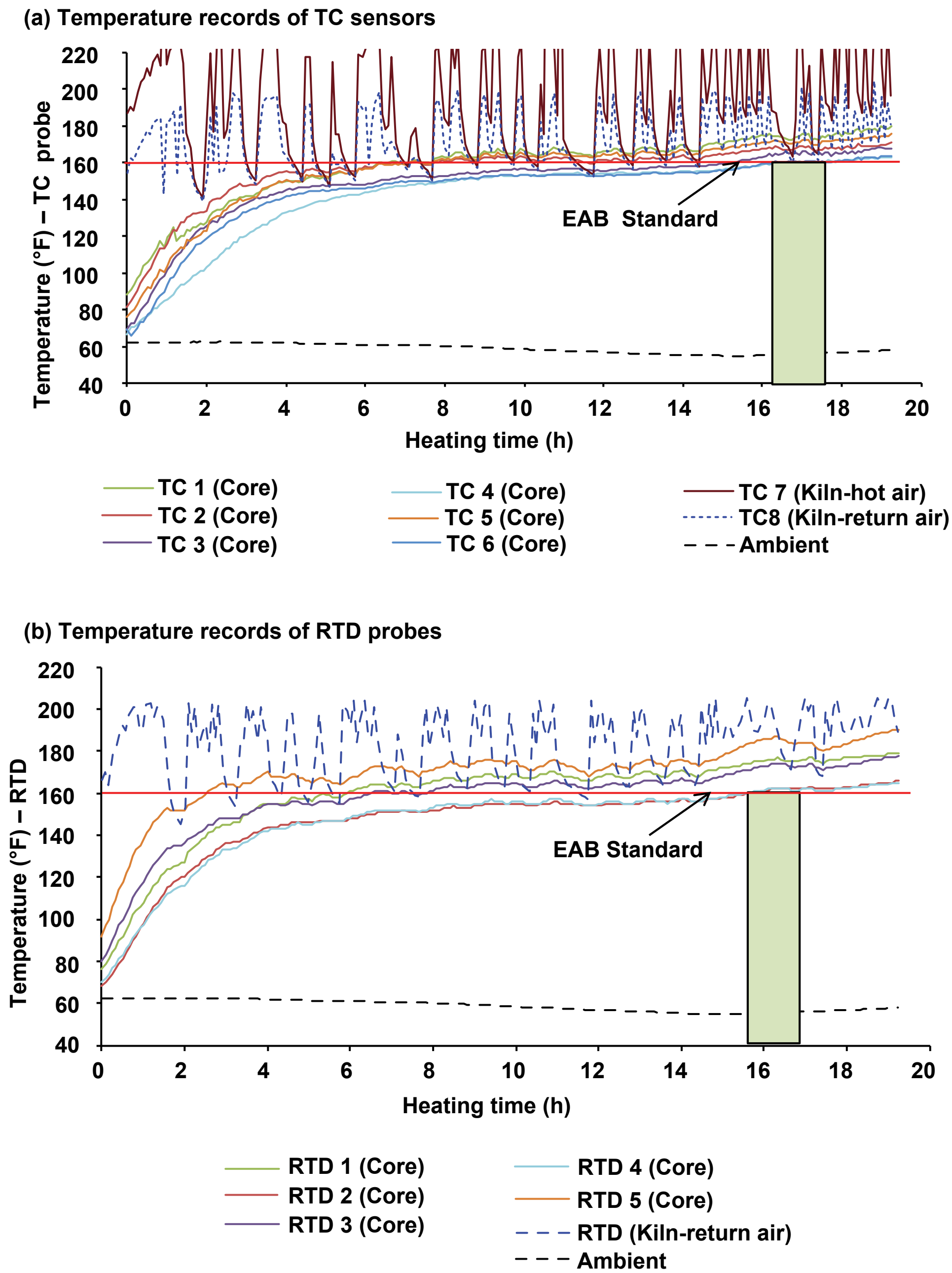


Figure 18. Temperature records of heat-treatment run No. 2 at Facility C.

monitor firewood temperature. To install the temperature sensors, the mesh on the pallet was partially removed to access the bundles located in the center of the bins. Three TC probes were inserted into the firewood samples 4 in. deep from the end and the gap was sealed using silicon sealant.

The Omega monitoring system showed that all three runs passed the firewood heat treatment requirement for EAB. As for the original Dickson monitoring system, the facility owner ran it once and decided not to use it again based on the ease of the Omega monitoring system.

For run No. 1, only 20 pallets were heat treated (one-half of a total load) due to insufficient firewood supply. Both the Dickson circular chart recorder and the Omega monitoring system measured core temperatures of firewood above the current heat-treatment standard for EAB (Figs. 21 and 22). The heat treatment lasted roughly 48 h. Insufficient fueling of the wood boiler resulted in the system not maintaining kiln temperatures at night, prolonging the heat-treatment cycle.

For runs No. 2 and No. 3, 40 pallets were heat treated (a full load). Results from the Omega monitoring system showed that all core wood temperatures passed the 71 °C (160 °F) for 75 min mark at about 37 and 30 h after starting the runs (Figs. 23 and 24). All three bins met the temperature/time

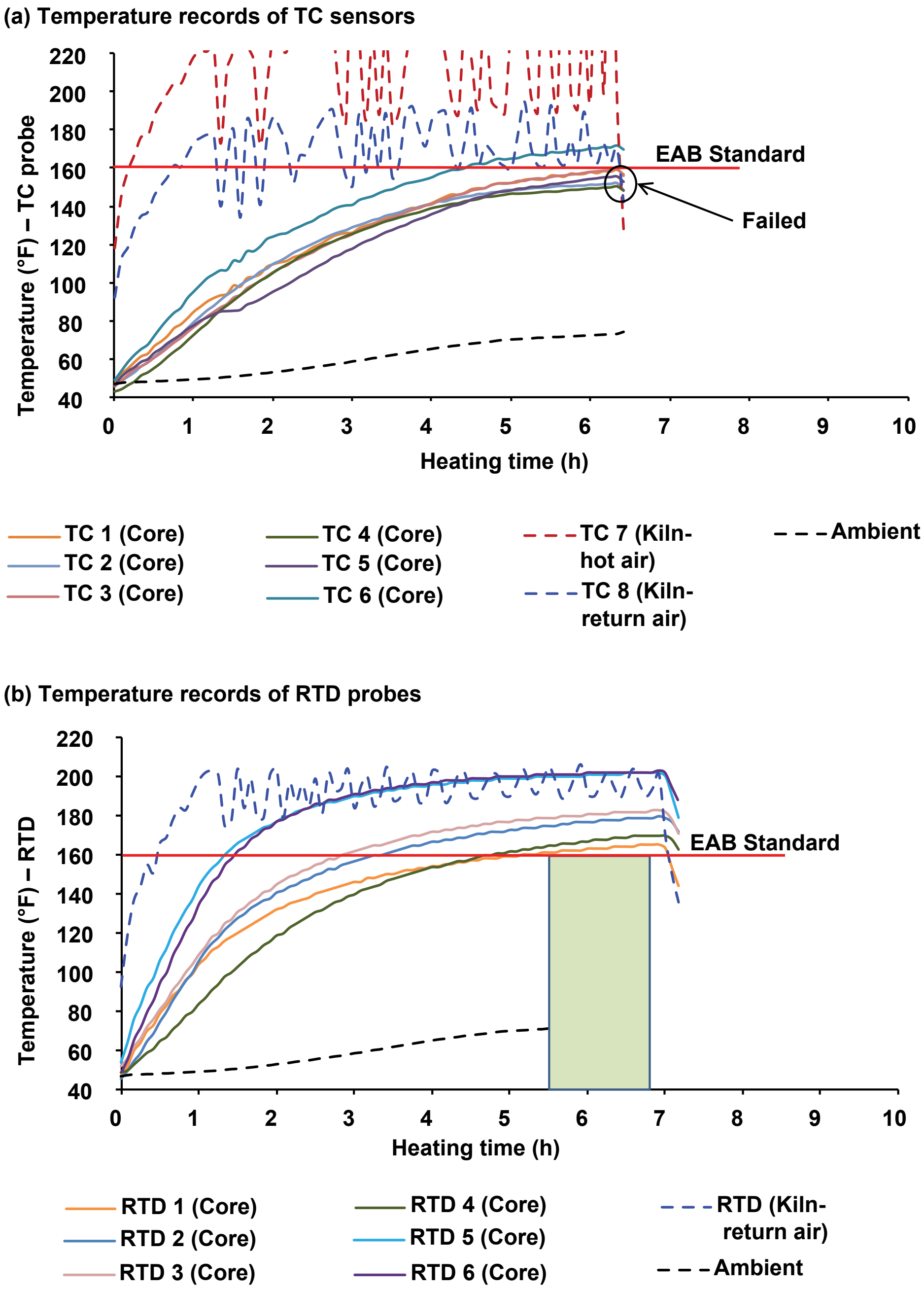


Figure 19. Temperature records of heat-treatment run No. 3 at Facility C.

mark almost simultaneously, indicating good air movement through the palletized firewood.

For a hot water heated kiln facility, the heat-treatment process greatly depends on the heating capacity of the system and how well the hot water boiler is operated during the heating process. Kiln certification is necessary for any heat-treatment facility to test its heating capacity for meeting the heat-treatment standards. If a kiln operation is intended for both heat treatment and kiln drying, the heating times for the core temperature to meet the heat-treatment standard are usually not critical as long as the heating standard is met before the kiln drying process is completed.

Training Workshops

Based on the baseline information developed through a previous WERC project and by incorporating what we learned through field demonstration projects, we developed two technical workshops to educate and train field operators and regulatory staff in states affected by EAB infestation or where commerce of hardwood firewood is under federal quarantine. These workshops outlined the fundamentals of heat treatment of firewood, the use of temperature monitoring systems, and the certification and verification of heat-treatment operations.

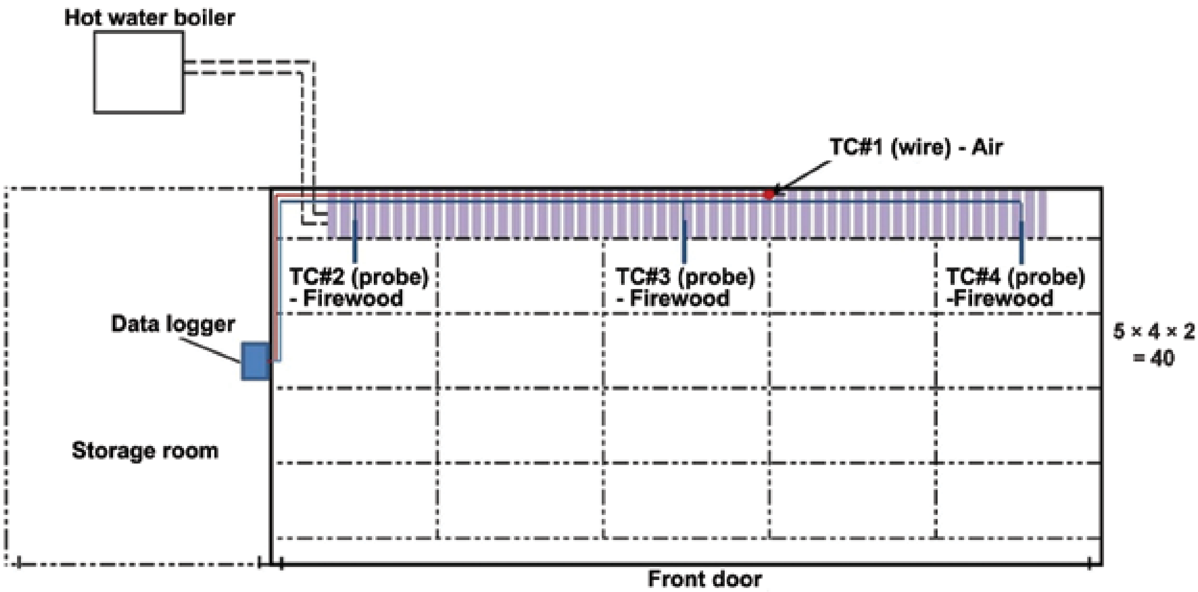


Figure 20. Layout of the kiln and new temperature monitoring system for Facility D.

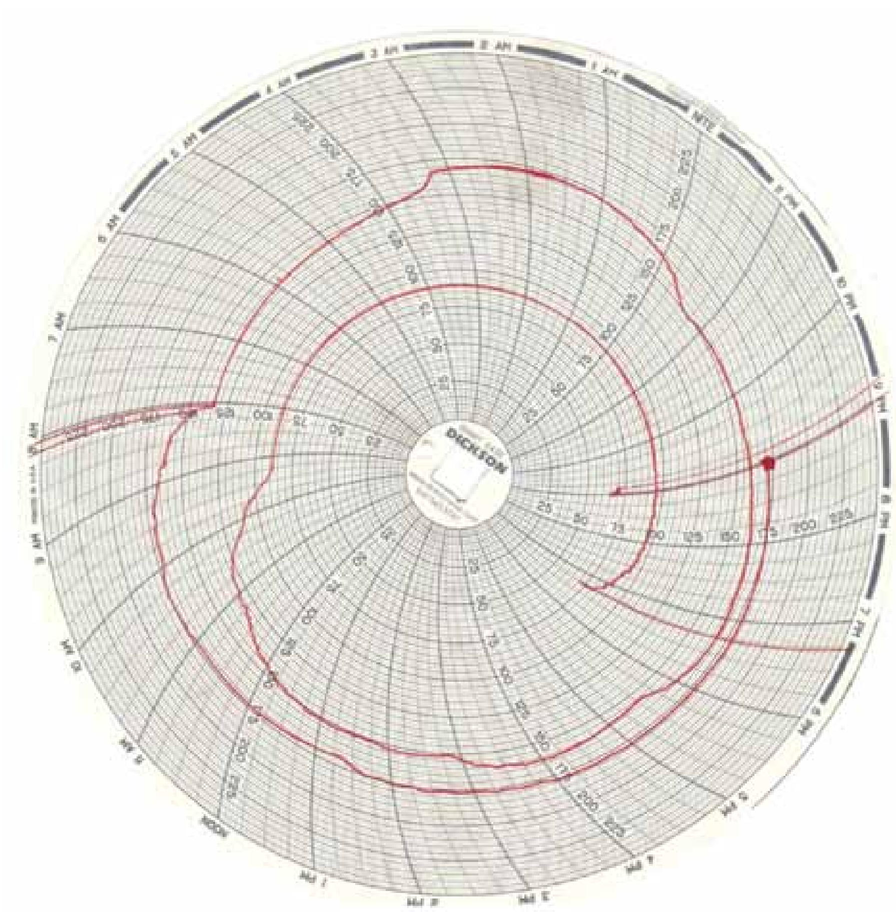


Figure 21. Temperature record of heat-treatment run No. 1 at Facility D produced by a circular chart recorder.

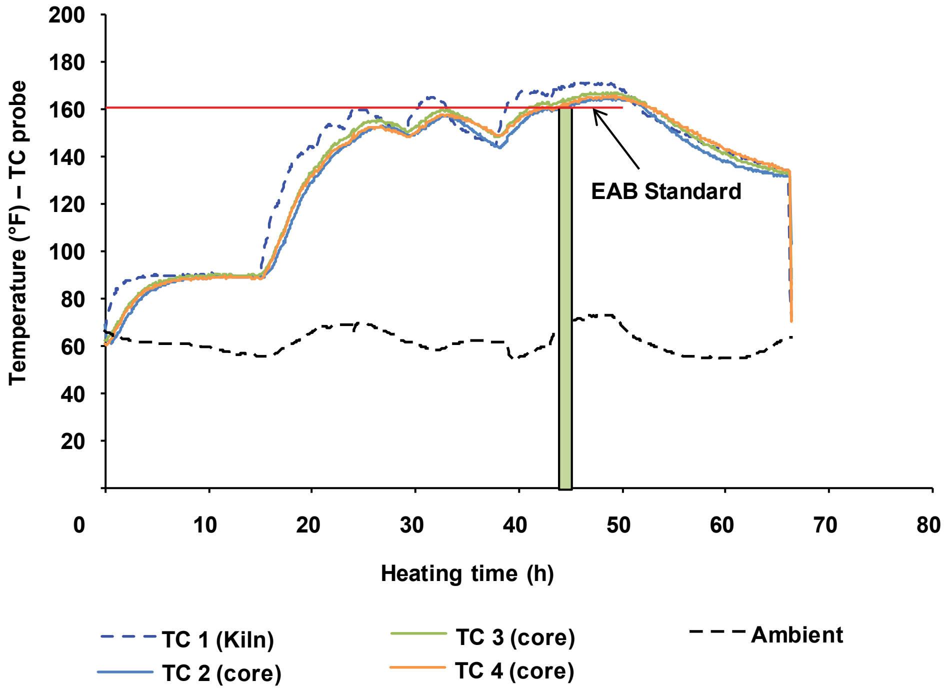


Figure 22. Temperature record of TC proves heat-treatment run No. 1 at Facility D.

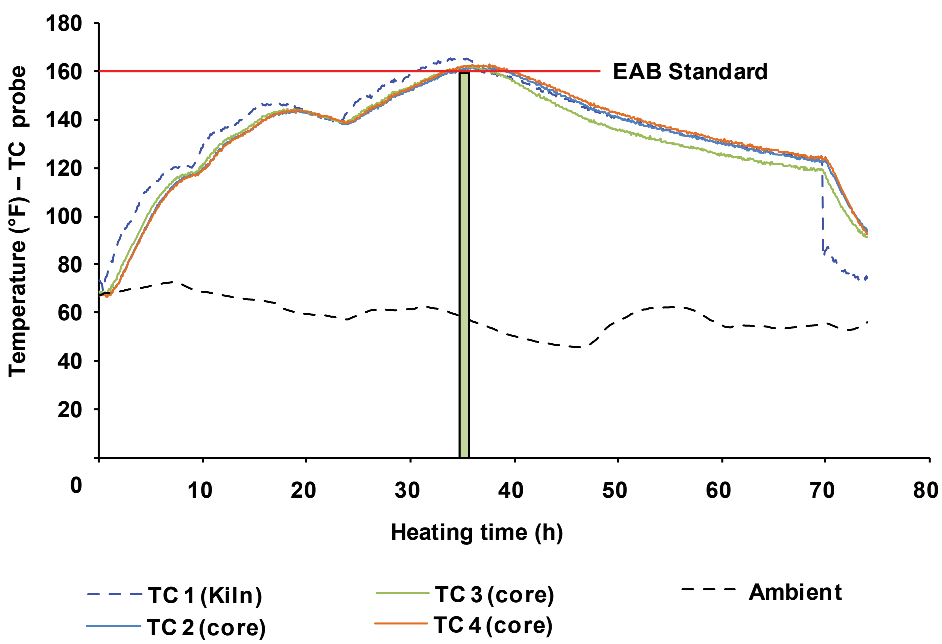


Figure 23. Temperature record of heat-treatment run No. 2 at Facility D.

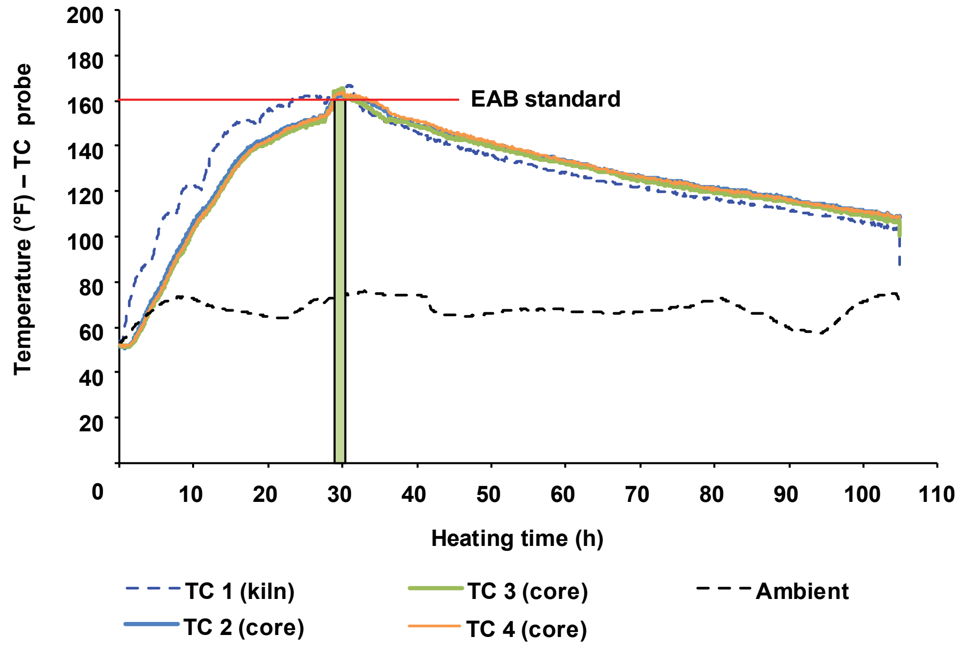


Figure 24. Temperature record of heat-treatment run No. 3 at Facility D.

The first workshop was held on February 25, 2009, in Madison, Wisconsin, in conjunction with one of the demonstration projects. Fifty-four people representing both private and public organizations attended. The second workshop was conducted on December 17, 2009, through an interactive webinar, with over 60 attendees representing at least 15 states and federal agencies. The webinar sessions have been recorded and archived for viewing in the future. The workshop covered the following content:

1. Federal and state regulations on EAB-infested firewood;
2. Current heat-treatment standards for firewood and treating facility certification processes;
3. Fundamentals of heat-treating processes; and
4. Heat-treating options, temperature monitoring, and thermal verification.

The archived webinar containing the PowerPoint slides and presenter audio can be accessed at the following web location: https://umconnect.umn.edu/p89465540/.

Literature Cited

CFR. 2011. Title 7, Volume 5, Revised as of January 1, 2011, Washington, D.C.: U.S. Code of Federal Regulations, U.S. Government Printing Office. pp. 62–67.

FS. 2008. Emerald ash borer: Control may be on the horizon. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. Research Review Vol. 2, Winter 2008. 5 p.

Michigan State University. 2011. Emerald ash borer, a multinational effort in Michigan, Illinois, Indiana, Iowa, Kentucky, Maryland, Minnesota, Missouri, New York, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia, Wisconsin, Ontario, and Quebec. http://www.emeraldashborer.info/. Accessed on July 13, 2011.

Omega Engineering, Inc. 2011a. Technical reference—RTDs. Stamford, CT: http://www.omega.com/rtd.html. Accessed on April 18, 2011.

Omega Engineering, Inc. 2011b. Technical reference—Thermocouples. Stamford, CT: http://www.omega.com/thermocouples.html. Accessed on April 18, 2011.

U.S. Department of Agriculture, APHIS. 2011. USDA revises heat-treatment schedule for Emerald Ash Borer. [News release]. January 19, 2011. Washington, DC: Animal and Plant Health Inspection Service.

U.S. Department of Agriculture, APHIS PPQ. 2010. Treatment schedules T300—Schedules for miscellaneous plant products. T314—Logs and Firewood P.5-4–5-38. Washington, DC: Animal and Plant Health Inspection Service, Plant Protection and Quarantine.

U.S. Department of Agriculture, APHIS PPQ. 2011. Treatment schedules T300—Schedules for miscellaneous plant products. T314—Logs and Firewood P.5-4-38. Washington, DC: Animal and Plant Health Inspection Service, Plant Protection and Quarantine.

Wang, X.; Bergman, R.; Simpson, W.T.; Verrill, S.; Mace, T. 2009. Heat-treatment options and heating times for ash firewood. Gen. Tech. Rep. FPL–GTR–187. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 29 p.

Appendix A Demonstration Photos—Heat-Treating Facility A

A1. The dry kiln of Facility A measures 25 ft by 19.5 ft by 12 ft and holds approximately 14 cords of firewood (42 face cords, 1,792 ft^3) in a full load.

A2. The hot water boiler is fueled with the facility's waste wood to provide heat for heat treating and kiln drying firewood.

A3. Freshly split firewood pieces are loaded into 4-ft by 4-ft by 4-ft steel baskets prior to loading into the kiln.

A4. Firewood baskets are loaded into the kiln and arranged in three levels (bottom, middle, and upper), with nine baskets in each level. The monitoring firewood samples were placed in the three baskets of the back row in the lower level. One instrumented piece was placed into each basket.

A5. Thermocouple wires were inserted into the center of firewood samples at the midsection.

A6. Firewood samples were placed in the center of a basket.

A7. A 4-channel temperature data logger was installed on the back wall outside of the kiln and housed in a steel case.

A8. The kiln and firewood temperature data were downloaded using computer software after a heat-treatment cycle was completed.

A9. During heat treatment, a digital thermometer is used to periodically check the core temperature of the firewood.

Appendix B Demonstration Photos—Heat-Treating Facility B

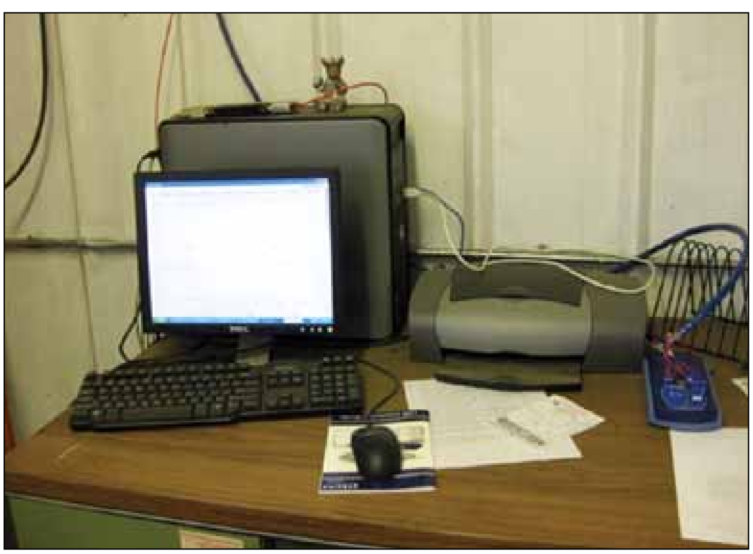
B1. Heat-treating facility with two custom-modified kilns for kiln drying and heat treating firewood.

B2. Kiln No. 1, a modified Northland dry kiln (Northland Kilns, Inc., Bagley, Minnesota), measures 31 ft by 13 ft by 11 ft with a capacity of 8,000 board feet.

B3. Kiln No. 2 was modified from a used freight container and measures 8 ft by 9 ft by 48 ft with a capacity of 10,000 board feet.

B4. The temperature monitoring system was installed at Facility B.

B5. Thermocouple wire layout in Kiln No. 1.



B6. Real-time temperature monitoring was conducted using a desktop computer and a data logger housed in a control room.

B7. Kiln No. 1 is fully loaded with 44 bins of firewood.

B8. Firewood is loaded into Kiln No. 2

B9. Thermal mapping test is conducted at Kiln No. 2.

Appendix C Demonstration Photos—Heat-Treating Facility C

C1. Direct-fired dry kiln (Kiln-Direct, Burgaw, North Carolina) measures 48 ft by 15.5 ft by 11.5 ft with a capacity of about 10,000 board feet.

C2. Interior of the heat-treatment kiln.

C3. A gas burner provides heat into the kiln for heat treating pallets and firewood.

C4. Thermocouple wires are installed inside the kiln.

C5. An 8-channel temperature data logger (OM-CP-OCT-TEMP, Omega Engineering, Inc., Stamford, Connecticut) was installed in the computer control room. All the TC wires ran from the data logger to the rear wall of the dry kiln and were then distributed to the designated location.

C6. The computer and the data logger are both housed in a small control room next to the kiln.

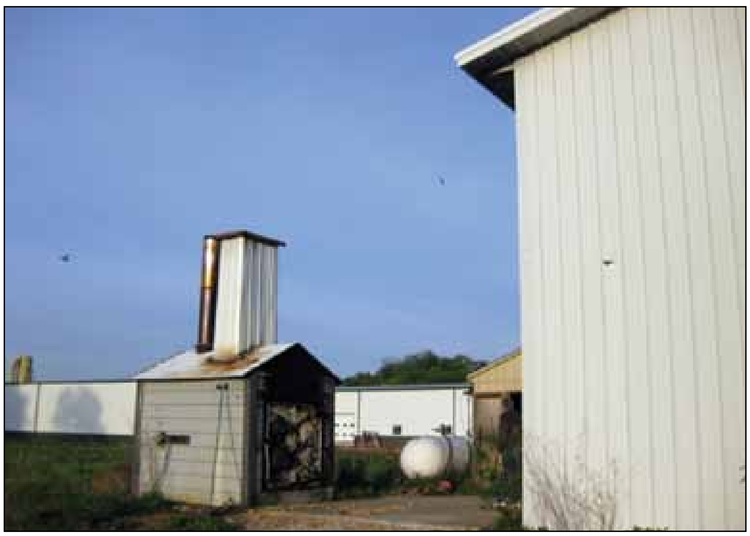
C7. A thermocouple wire was inserted into the center of the firewood at the mid-section. A RTD probe from the old monitoring system was also inserted into the firewood sample about 1-1/2 in. deep from the end.

C8. Firewood bins were loaded into the kiln by a forklift and arranged in three rows; each was nine bins long and stacked two bins high for a total of 54 bins. Bins were staggered to force heated air to make better contact with the fire-wood.

C9. The heat-treated fire-wood is packaged into 0.75 ft^3 aerated plastic bags now ready for shipment.

Appendix D Demonstration Photos—Heat-Treating Facility D

D1. Dry kiln facility certified to heat treat firewood for movement outside of EAB quarantine zone. The kiln measures 18 ft by 18 ft by 10 ft with a capacity of 10,000 board feet. The firewood to be treated is brought to the facility in bundles wrapped in mesh and stacked on pallets.



D2. A wood boiler is manually fed wood scraps to supply hot water for heating the dry kiln during heat-treatment operation.

D3. The heating coil is mounted between the rear wall and a separation frame. The thermocouple wires and temperature probes are installed through the kiln wall and put in designated locations.

D4. Facility D's old temperature monitoring system used a circular chart recorder (Dickson No. KT803, Addison, Illinois) to record temperature data. The hard copies of the circular charts are used as verification.

D5. During the heat-treatment runs, three of the five lower pallets closest to the rear wall had a sensor located in the center of the bundle to monitor firewood temperature.

D6. A 4-channel temperature data logger (Omega OM-SP1700-500, Omega Engineering, Inc., Stamford, Connecticut) was installed on the outside kiln wall in a storage room.

D7. A thermocouple probe was inserted into a firewood sample 4 in. deep from the end and the gap was sealed using silicon sealant.

D8. For a full load, firewood pallets are arranged in the kiln four rows by five pallets long and stacked two high for a total of 40 pallets.

D9. The data logger was initiated using a laptop before heat-treatment operation started.

Appendix E—Temperature conversion table (°F–°C)[a]

°F	°C	°F	°C	°F	°C	°F	°C	°F	°C
31	–1	71	22	111	44	151	66	191	88
32	0	72	22	112	44	152	67	192	89
33	1	73	23	113	45	153	67	193	89
34	1	74	23	114	46	154	68	194	90
35	2	75	24	115	46	155	68	195	91
36	2	76	24	116	47	156	69	196	91
37	3	77	25	117	47	157	69	197	92
38	3	78	26	118	48	158	70	198	92
39	4	79	26	119	48	159	71	199	93
40	4	80	27	120	49	**160**	**71**	200	93
41	5	81	27	121	49	161	72	201	94
42	6	82	28	122	50	162	72	202	94
43	6	83	28	123	51	163	73	203	95
44	7	84	29	124	51	164	73	204	96
45	7	85	29	125	52	165	74	205	96
46	8	86	30	126	52	166	74	206	97
47	8	87	31	127	53	167	75	207	97
48	9	88	31	128	53	168	76	208	98
49	9	89	32	129	54	169	76	209	98
50	10	90	32	130	54	170	77	210	99
51	11	91	33	131	55	171	77	211	99
52	11	92	33	132	56	172	78	212	100
53	12	93	34	**133**	**56**	173	78	213	101
54	12	94	34	134	57	174	79	214	101
55	13	95	35	135	57	175	79	215	102
56	13	96	36	136	58	176	80	216	102
57	14	97	36	137	58	177	81	217	103
58	14	98	37	138	59	178	81	218	103
59	15	99	37	139	59	179	82	219	104
60	16	100	38	**140**	**60**	180	82	220	104
61	16	101	38	141	61	181	83	221	105
62	17	102	39	142	61	182	83	222	106
63	17	103	39	143	62	183	84	223	106
64	18	104	40	144	62	184	84	224	107
65	18	105	41	145	63	185	85	225	107
66	19	106	41	146	63	186	86	226	108
67	19	107	42	147	64	187	86	227	108
68	20	108	42	148	64	188	87	228	109
69	21	109	43	149	65	189	87	229	109
70	21	110	43	150	66	190	88	230	110

[a]Conversion formula: $T_{°C} = (T_{°F} - 32)/1.8$