

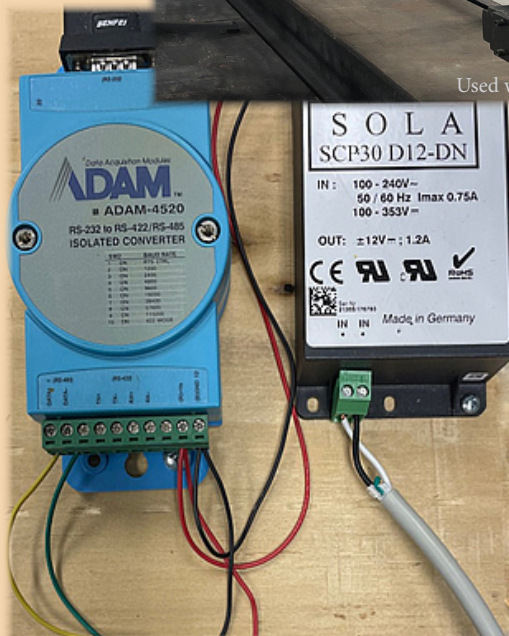


Development of a Test Method to Monitor Creep Behavior of Structural Insulated Panels under Load

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Abstract

Structural insulated panels (SIPs) are an important construction material that has been developed through many years of research at the USDA Forest Service, Forest Products Laboratory. There are concerns, however, related to the in-service performance of this important construction material. More data are needed to determine creep performance of these panels to help the industry address these concerns. This report describes a test method that was developed to measure the creep performance of SIPs. Topics covered in this report include a summary of the development of sandwich-type structural products for use in wood-frame housing, the method used to establish load levels for creep testing, and the creep test setup and data acquisition system. This test system was used to collect creep behavior for a long-term study of SIPs that will be reported on at a later date, but information about the test design and system itself will be useful for researchers conducting other studies.

Keywords: sandwich construction, wood, structural insulated panels, creep, test setup, data acquisition

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Conversion table

English unit	Conversion factor	SI unit
foot (ft)	3.048×10^{-1}	meter (m)
inch (in.)	2.54×10^1	millimeter (mm)
pound, mass (lb)	4.535924×10^{-1}	kilogram (kg)
square foot (ft ²)	9.2903×10^{-2}	square meter (m ²)
$T^{\circ}\text{F}$	$T^{\circ}\text{C} = (T^{\circ}\text{F} - 32)/1.8$	$T^{\circ}\text{C}$
		Standard lumber size
Nominal lumber size (in.)		(mm)
2 by 4 (actual 1.5 by 3.5)		38 by 89
2 by 12 (actual 1.5 by 11.25)		38 by 286

May 2024

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Introduction

The USDA Forest Service, Forest Products Laboratory (FPL) and cooperators have a long history of researching the properties and performance characteristics of sandwich-type products. Structural insulated panels (SIPs) are a commercially available product that has evolved from early FPL sandwich material research. SIPs are now in wide use throughout both the residential and nonresidential construction industries, with more than 70 million ft² produced on a yearly basis. Several in-service concerns have arisen related to the use of SIPs, and solutions for these concerns would greatly enhance the growth of the SIP industry. For example, limited data are available for the creep performance of SIPs while under load. This paper summarizes a testing method developed to monitor the creep of SIPs under load. Please note that the descriptions of the components and software in this report are for those used in this particular study. Many comparable components and software packages are available, but these would need to be configured and programmed differently.

Background

For many years, FPL has conducted research on structural sandwich composite materials. Early work focused on the development, testing, and analysis of materials for use by the aircraft industry in support of the U.S. Department of Defense. For example, a series of reports (Heebink and Mohaupt 1947; Heebink and others 1947, 1949, 1950) examined the bond performance and durability of core materials and sandwich composites. The widespread application of sandwich-type construction in high-speed

aircraft escalated the need for research in this area. The work was done at FPL under the joint direction of the Army Air Forces, the Bureau of Aeronautics, the Navy Department, and the Civil Aeronautics Authority. Boller (1946) investigated the impact resistance of three core materials—balsa wood, hard synthetic sponge rubber, and cellular cellulose acetate. Each was tested individually and in combination with two facing materials—aluminum and resin-impregnated glass cloth.

In the 1950s and 1960s, FPL began to apply the knowledge gained in the sandwich panel research to residential housing applications. At least five different housing developments were constructed during that time period using the sandwich panel concept, including the Alden Dow Homes in Midland, Michigan (Fig. 1). Complete technical data and sandwich

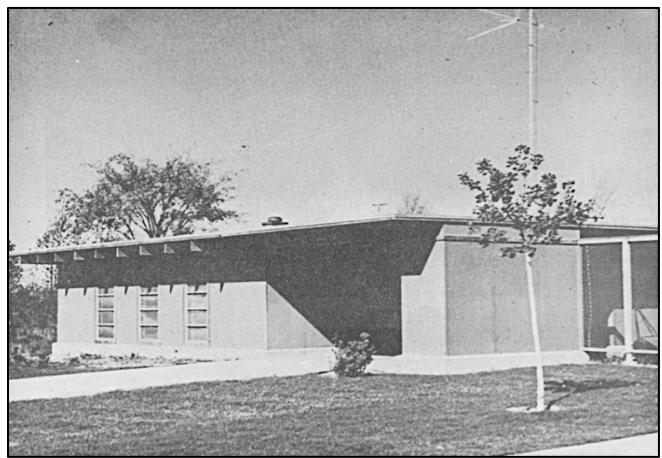


Figure 1—Alden Dow panel house, Midland, Michigan.

panel design criteria were not generally available for these homes. Markwardt and Wood (1959) provided a summary of four modular houses built in the 1950s that used sandwich panel construction materials and techniques. Their report on the livability, serviceability, and performance of these houses was important in evaluating the potential of using sandwich panel construction for houses.

Anderson (1964) presented a summary of FPL research on experimental structural units conducted up to that time. Anderson and Wood (1964) presented a history of the performance of a sandwich-panel unit between the time of its installation in 1947 and the time of the publication, including stiffness and strength data of many wall panels exposed for periods up to 15 years.

Structural insulated panels used in today's wood construction industry are composite building materials that consist of a sandwich of two layers of structural faces with an insulating layer adhered between. The faces are usually oriented strandboard (OSB), although a wide array of materials can be used as face layers, such as plywood, steel, aluminum, cementitious panels, and even exotic materials such as stainless steel, fiber-reinforced plastic, and magnesium oxide. The insulating layer is usually foam plastic insulation, such as expanded polystyrene (EPS), extruded polystyrene (XPS), or polyurethane foam, although sometimes agricultural fiber, such as wheat straw, is used for the core.

Structural insulated panels have structural properties similar to those of an I-beam or I-column. The rigid insulation core of the SIP performs as a web, and the faces perform as flanges. Structural insulated panels replace several components of conventional wood-framed buildings, such as studs and joists, insulation, vapor barrier, and air barrier. As such they can be used for many different applications, including exterior wall and roof systems.

Recently, FPL has cooperated with other organizations (APA—The Engineered Wood Association, Home Innovations, Structural Insulated Panel Association (SIPA), and SIP producers) to address several performance characteristics of SIPs. Kochkin and others (2015) investigated the cyclic performance of SIP wall systems. Several papers summarized research to investigate lateral load performance (Yeh and others 2018, 2019). Rammer and Williamson (2020) studied the performance of SIPs subjected to seismic loading.

Creep is the tendency of a solid material to deform slowly under the influence of sustained load. It occurs because of long-term exposure to levels of stress that are below the yield strength of the material. The rate of creep deformation is a function of material properties, exposure time, exposure temperature, moisture, and applied structural load. Depending on the magnitude of the applied load and its

duration, deformation may become so large that a component can no longer perform its intended function.

Structural insulated panels are frequently used in roof applications. Historically, determination of transverse load capacities of SIPs for these applications has been conducted using ASTM E72, which is a short-term load duration test. Limited data are available describing the creep performance of SIPs under the long-term loading conditions that are likely to occur during in-service use (Taylor and others 1997; McDonald and others 2014, 2018).

FPL, in cooperation with Mississippi State University and SIPA, conducted a testing program to investigate the long-term creep performance characteristics of SIPs used in horizontal loading applications. This report describes the test methods and procedures developed. It includes a description of the methodology to establish creep load levels, the test setup, and the data acquisition system that was developed.

Establishing Creep Load Levels and Test Setup

Short-term bending (beam) tests were conducted in a laboratory on a universal testing machine. Specimens were moisture-conditioned prior to testing. The environmental conditions were approximately 70 to 75 °F with approximately 50% relative humidity. Therein, full-scale matched specimens were tested in third-point bending. Time to failure was approximately 1 minute. The purpose of this testing was to establish 5%-point estimates for use in computing load levels for the long-term duration of load tests in accordance with ASTM D6815 (ASTM 2015).

Creep specimens were side-matched to short-term bending specimens. That is, each master panel (4 ft wide) was ripped into four test specimens. From each master panel, two adjacent side-matched specimens were assigned to either creep test or short-term bending test. Each 6.5-in. class specimen was approximately 6.5 in. thick, 11.75 in. wide, and 120 in. long. Each 12-in. class specimen was approximately 12.25 in. thick, 11.75 in. wide, and 222 in. long.

Creep load levels were based on the 5% nonparametric point estimates from the short-term laboratory tests. To determine these creep load levels, a minimum of 28 specimens were required to be tested in the lab (ASTM D2915 (ASTM 2017)). In this case, for the 6.5- and 12.25-in. thick specimens, 31 and 32 pieces were tested, respectively. Next, in each case, the data were rank-sorted, lowest to highest. Next, the rank value i for each specimen was calculated as $1/(n + 1)$. Then the 5th percentile values were interpolated between the rank sort 1 and rank sort 2 values. These calculations are shown in Table 1. The creep test load, w_t , was then determined based on ASTM D6815 as shown in Table 1.

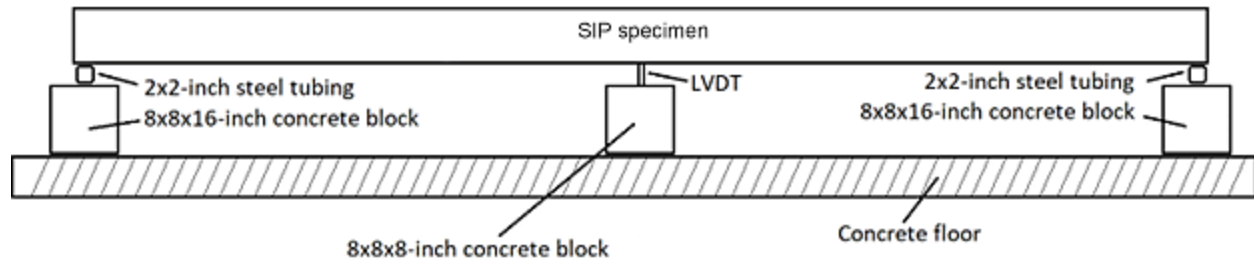


Figure 3—Structural insulated panel (SIP) specimen on the concrete block and steel tubing foundation (LVDT, linear variable differential transformer).

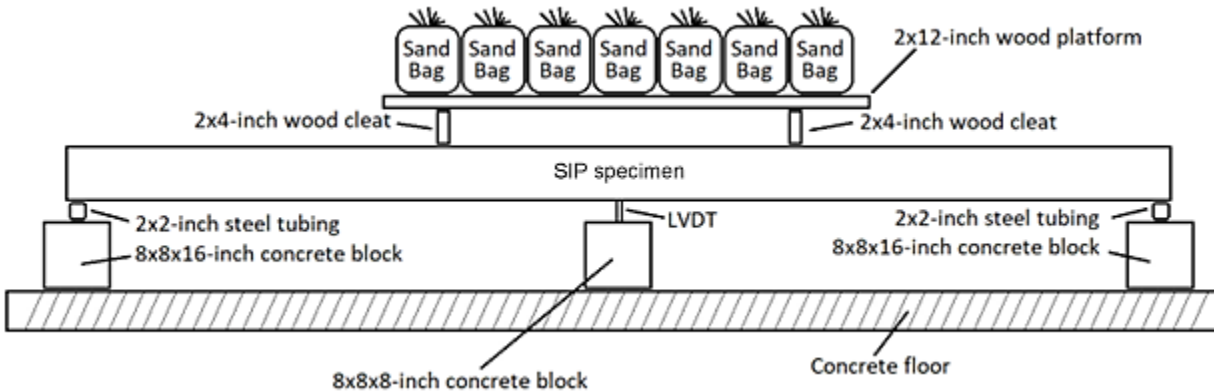


Figure 4—The load platforms and deadweight (sandbags) applied to each structural insulated panel (SIP) specimen (LVDT, linear variable differential transformer).

those were chosen as a critical part of the interface between a computer to store the data and the sensors measuring deflection of each specimen during the creep test. One Adam 4520 and enough Adam 4017+ modules to read the output or beam deflection from each PZ12-F-0075-L were needed. The Adam 4017 modules come in two configurations: the 4017 only communicates using Advantech's proprietary protocol, whereas the 4017+ has options to run Advantech's protocol and, more importantly, it can also run Modbus protocol, which is used in this system. Each 4017+ can acquire data from eight LPs; therefore to acquire data from 60 specimens, eight 4017+ modules were needed. A converter that translates computer USB serial communications to RS485 communications was also needed. An Adam 4520 module was used in this study, but a cheaper converter can also be purchased online. The system also tracks temperature and relative humidity during testing using a NOVUS (NOVUS Automation Inc., Canoas, Brazil) RHT transmitter <https://www.novusautomation.com/en/product/humidity-temperature/rht-climate>. The transmitter is compatible with RS485, and the environmental conditions can be included in each data recording. Also, the interface software SpecView (Burlington, Ontario, Canada <https://www.specview.com/>) was needed to acquire the data from each LP and the

NOVUS RHT at specified time intervals and to write those data to a comma-delimited file, which is easy to import into Microsoft Excel (Microsoft Corporation, Redmond, Washington, USA) for analysis. Each Adam Module needed a 12-V power supply, and the ones used in this study were SOLA SCP30 D12-DN. Because the Adam 4017+ modules read ± 10 V, DC converters were also purchased to convert 12 V to the correct 10 V to provide power for the LP instruments. Additionally, some basic hand tools such as screwdrivers, wire strippers, heat gun, soldering iron, voltmeter, small screws, wire, terminal strips, shrink wrap, and plywood were needed to construct the system.

After the Adam 4017+ modules were procured, the address of each 4017+ was set for the project. We recommend setting the Adam modules with sequential addresses. To set the addresses of the Adam modules, download the Adam 4000-5000 utility program at <https://www.advantech.com/support/details/utility?id=1-9VJDY>.

This report describes the materials and methods used to construct a duration of load (creep) data system. Figure 5 shows the finished product, and the following text and figures give the instructions for building the data system.

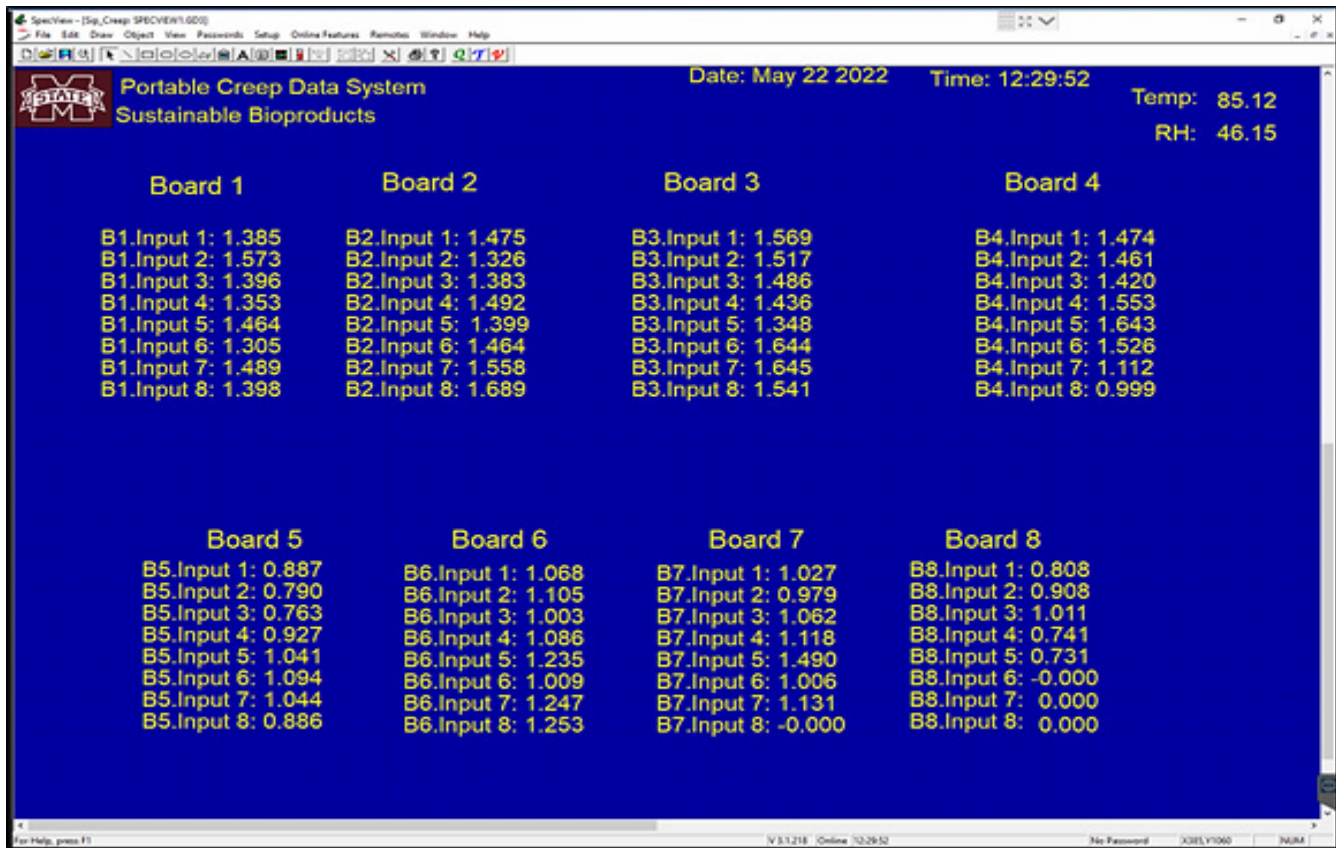


Figure 5—Creep data system main menu.

To set the RS485 network addresses, each Adam module needs to undergo the following procedure (Fig. 6):

- Connect the 12V+ to the (R)+Vs terminal and the 12V- to the (B)GND on the Adam 4520 and the Adam 4017+.
- Connect the Data+ on the 4520 to the Data+ on the 4017+, and connect the Data- on the 4520 to the Data- terminal on the 4017+.
- Use a USB to RS232 9-pin connector to connect the Adam 4520 to a computer that has the Adam 4000-5000 software. (Speed note: The green terminal strips on each Adam module are removable by using a small screwdriver to apply pressure in the gap between the green terminal strip and the Adam module. After the setup is wired, simply swap the green terminal strips to accelerate the wiring process for setting network addresses.)
- With the power supply unplugged, look on the side of the 4017+ (Fig. 7) and move the slider switch to “init”. Reconnect the power and start the Adam 4000-5000 utility software. Select the appropriate COM port and then press the binocular button and let the software search for the connected 4017+.

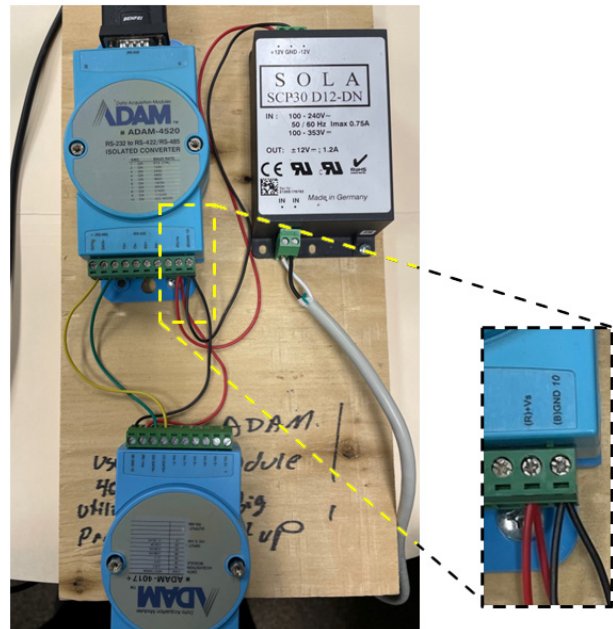


Figure 6—Wiring to set Adam module RS485 network addresses.

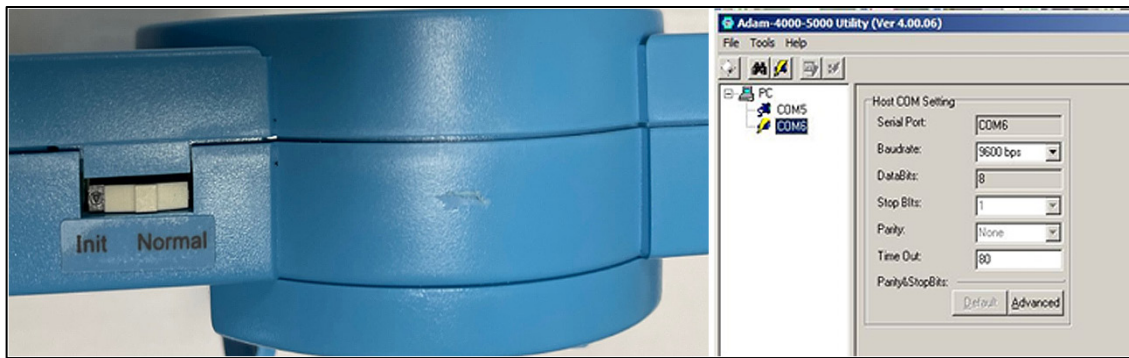


Figure 7—Adam module initial switch setting for setting RS485 network addresses.

- The left picture in Figure 8 shows that a 4017P or plus + was found, and it is in Advantac protocol mode. Click on the 4017P and the screen shown on the right side of Figure 8 will appear. Set the DEC number for each board. For example, a 4-board system would use 1, 2, 3, or 4 as Adam module addresses for the boards. Also, on the protocol line, set the protocol to MODBUS and leave the Baud Rate as 9600. Exit the software, unplug the power supply, and then slide the switch on the side of the 4017+ to normal mode. Plug in the power supply and restart the Adam 4000-5000 software.
- Again, search for the 4017+ module and the system should find it on the same COM port, but notice the red M on the Adam device indicating it is running “MODBUS” mode (Fig. 9 left panel). Click on the 4017P and the menu shown on the right side of Figure 9 will appear. The DEC number should match what you set above, the protocol should be MODBUS and each channel setup should be set to ±10 V. Each Adam 4017+ module must be programmed in this manner, and they will each be identical except for the address or the DEC number. Remember the settings of 9600 Baud Rate, 8 data bits, 1 stop bit, and “None” parity. It will be needed later.

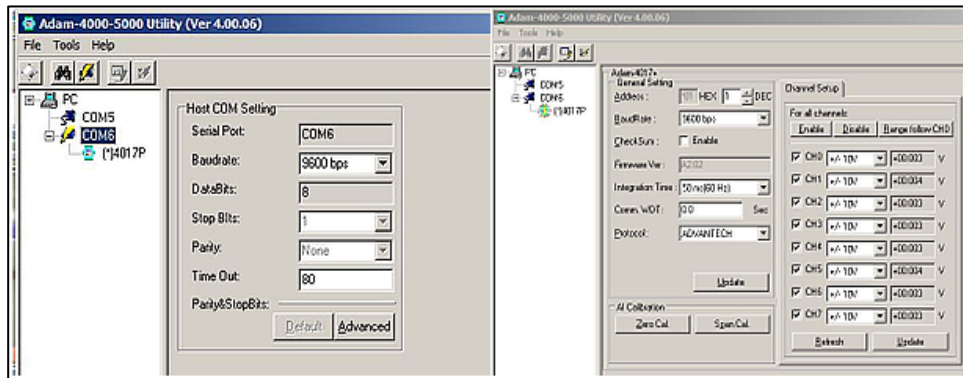


Figure 8—Navigating Adam software to find Adam modules.

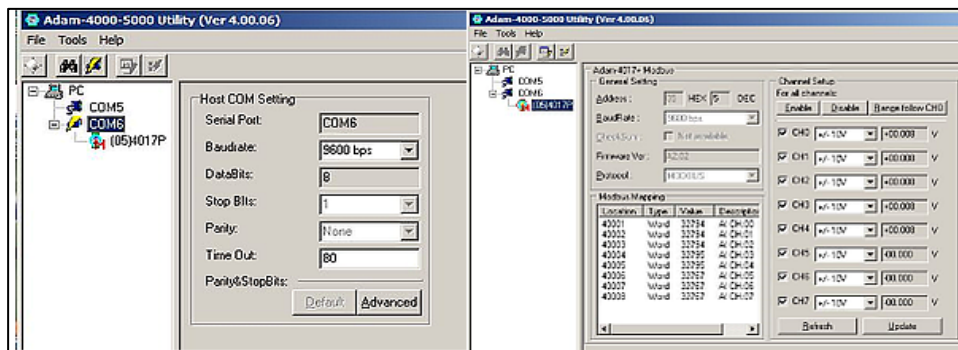


Figure 9—Adam 4017+ modules correctly configured for the creep data system.

To begin the project assembly, a sheet of 3/4-in. plywood was purchased and cut into eight 24- by 24-in. boards. Next, 16 terminal strips, each with 12 taps, were purchased and secured to each board. It is important to understand the complete layout before affixing terminal strips to the plywood. The Adam modules come with a flat mounting plate, which was attached to each plywood board before the terminal strips were attached.

Terminal strips can be thought as having an LP side and a response side. Each LP requires 3 taps on the terminal strips, one for positive power to the LP, one for negative power to the LP, and one for the response from the LP for the Adam 4017+ to measure the voltage. On the LP side, a red wire was looped through each third terminal starting from 1 and a black wire was looped through each third terminal starting with 2. That left 8 terminals open (every third terminal starting with 3).

On the response side of the terminal strips, blue and yellow wires were chosen to feed responses to the Adam module. The Adam Data Module had eight pairs of terminals to read the ± 10 -V output from the LP. The data pairs were numbered from 0 to 7. Yellow wires were connected to the terminal strips on the response side starting with terminal 3 connected to Vin0-. The next yellow wire connected terminal 6 to Vin1-, and so on, resulting in every third terminal having a yellow wire. Blue wires were connected to response-side terminals starting with terminal 1 connected to Vin0+. Then terminal 4 was connected to Vin1+, and so on. These were matched pairs across the terminal strips to the Adam modules. Stranded project wire was used for these connections. The wiring diagram discussed here is illustrated in Figure 10.

As previously mentioned, the Adam 4017+ channels were set to read ± 10 V but the Adam module runs on 12 to 24 V. This created the necessity to feed 10 V to each LP; therefore, 12- to 10-V converters were purchased for this situation. A quick search yielded many options, but for this project, a converter with a pot or screw to adjust the voltage was chosen. The wiring diagram shown in Figure 10 shows that 12 V were applied to the converter and the stepped down 10 V were then connected to the red and black wires that were looped through the LP side of the terminal strips.

The left side of Figure 11 shows the 12- to 10-V converter that was powered by the 12-V power supply when the input and the output were attached to the LP side of the terminal strips for positive and negative voltage. After the voltage converter was connected to the power supply and the terminal strips, a voltmeter and a small screwdriver were used to adjust the DC voltage to 10 V for the LP power (Fig. 11).

At this point in the build process, each piece of plywood or board should have the power supply, voltage converter, terminal strips, and Adam 4017+ mounted and wired

according to the diagram in Figure 10. At this point, the LPs were connected to each board. In the system built for 64 specimens, approximately 1,800 ft of Belden 9533 wire (Belden Inc., St. Louis, Missouri, USA) were used. Each LP was connected to the terminal strips with 33 ft of wire to allow for spacing of the test specimens. It should be noted that the Belden wire was essentially a patch or extension cable for the PZ12 measuring instruments, and the wire colors in the two cables did not match; therefore, this set of instructions will indicate each color crossover.

Figure 12 shows the diagram from the Gefran documentation that comes with each PZ12-F-0075-L and the connecting and shrink wrapping of the PZ12 to the Belden cable. Figure 12b shows that the blue LP wire was connected via solder to the red wire in the Belden 9533 cable, the brown wire from the PZ12 was connected to the black wire of the Belden 9533 cable, and the yellow wire from the PZ12 was connected to the white wire of the Belden 9533 cable. Each connection was soldered and then individually shrink wrapped as shown in Figure 12c. Finally, the entire connection set of three wires was shrink-wrapped to make a relatively smooth secure connection (Fig. 12d).

Figure 13 shows an example RS485 network with one Adam 4520 (converts RS232 to RS485) and three Adam 4017+ modules each with a unique RS485 network address.

The Adam 4520 used to set the addresses was now repurposed and attached to a board in the system. Figure 13 shows the connections to connect the boards together. Because each board has a unique RS485 address, the architecture allows more than 240 boards to be connected. This capability far exceeds the requirements of this application. The length of the RS485 network can be up to 4,000 ft. Therefore, the distance between boards is not significant. A USB to 9-pin RS232 cable was used to attach the system to a computer.

Data were collected using the previously mentioned software SpecView, which can be downloaded and purchased online. SpecView will send a hardware USB key after the software is purchased. With the RS485 network powered up, start SpecView, create a new project, and give it a name. Figure 14 outlines the steps necessary to make the logical connections between SpecView and each 4017+. The three steps shown in Figure 14 are as follows:

Step 1. At the top right of the Specmenu, press the red v (for variables).

Step 2. Click new and the new instruments list will appear. Click on the arrow next to Adam+ MB and the list will expand to show Adam 4017+, which is the MODBUS version of the instrument that has been wired into the system. Remember that it must be a 4017+ to use the MODBUS protocol.

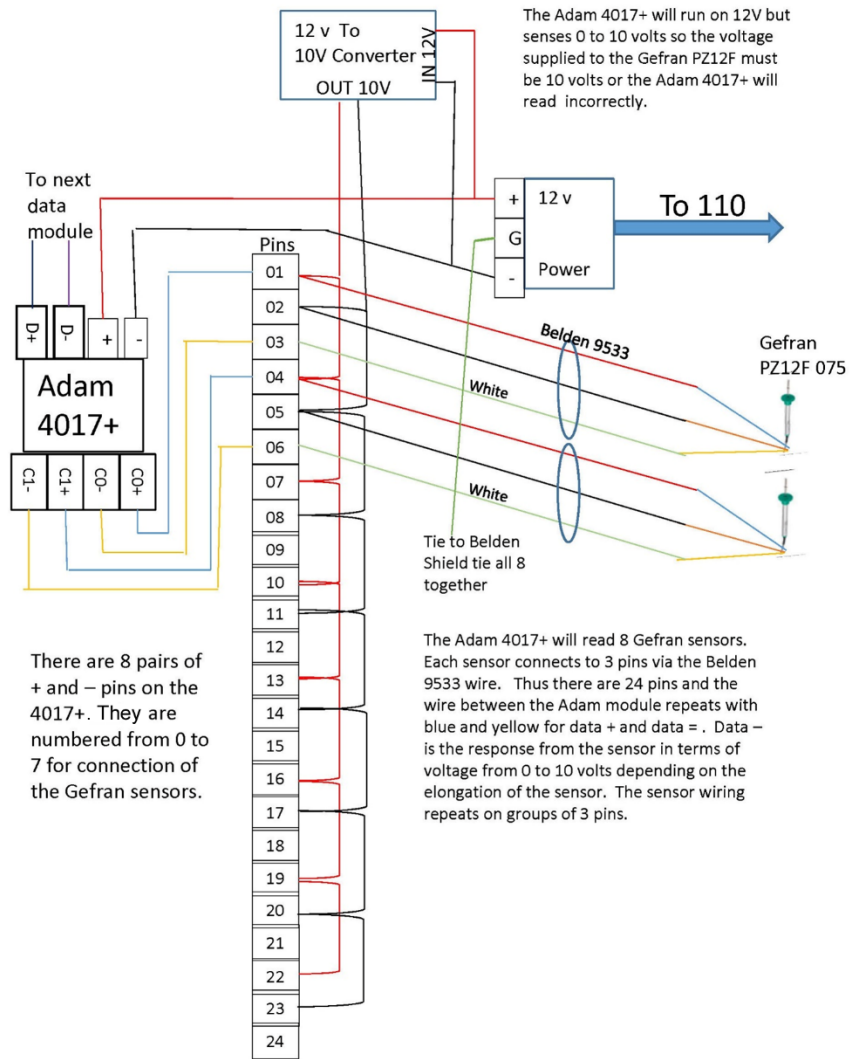


Figure 10—Wiring diagram showing setup for collecting creep deflection data from 8 LP sensors.

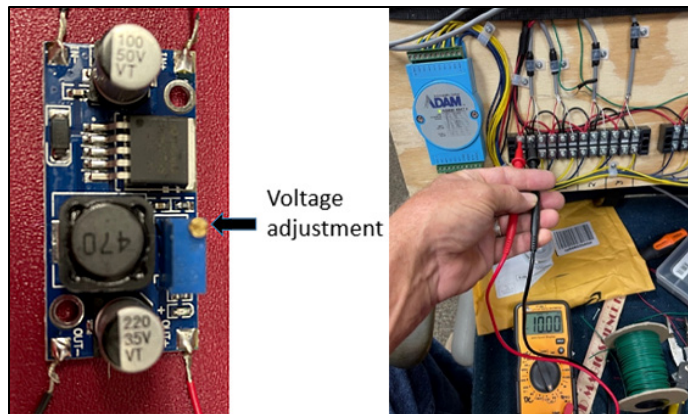


Figure 11—Voltage converter (left) and terminals that feed the LPs being measured with a voltage meter (right).

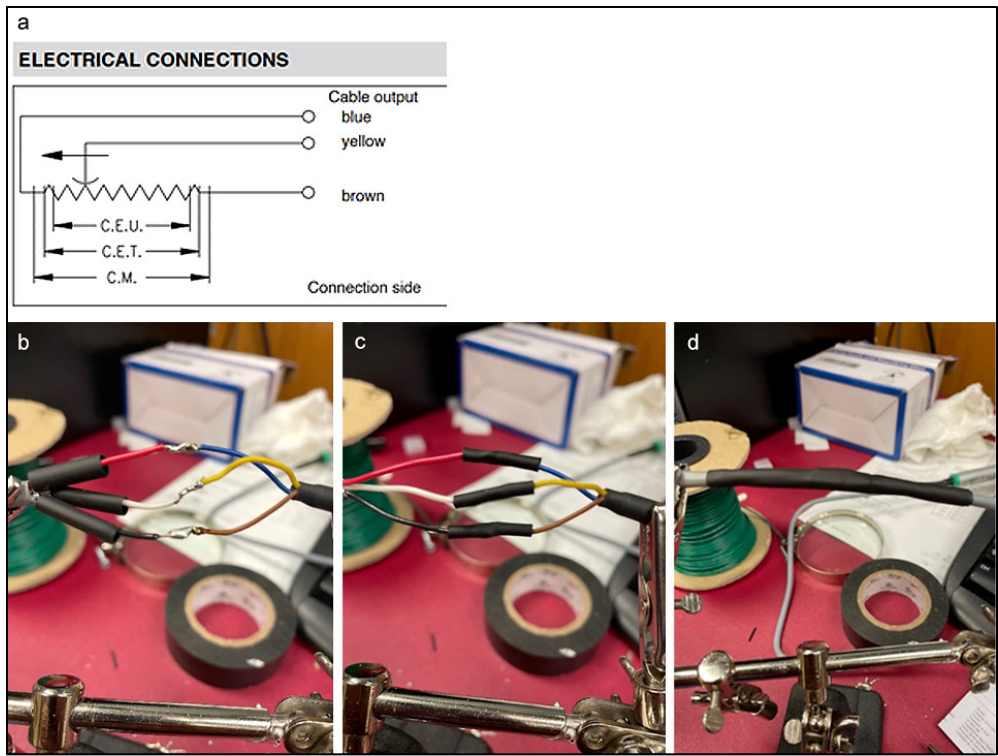


Figure 12—Diagram from Gefran documentation (a) and wires being connected from the PZ12-F-0075-L to the Belden 9533 cable (b-d).

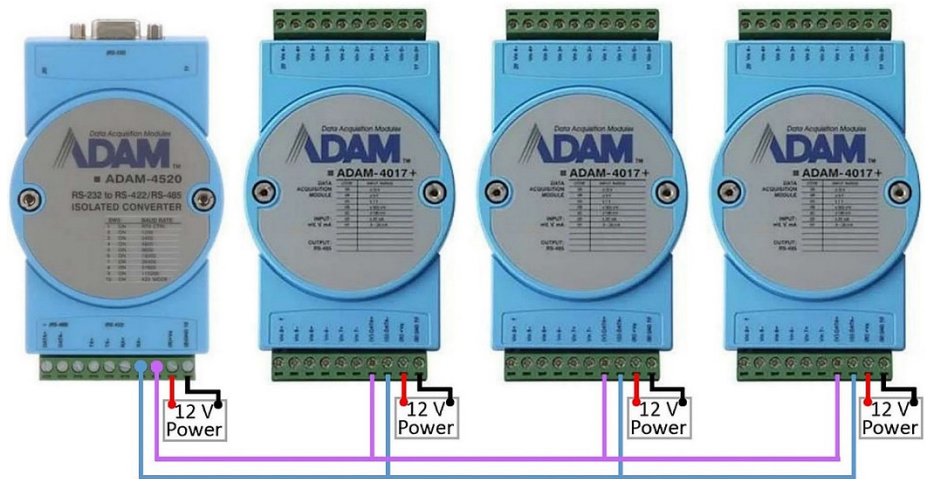


Figure 13—An example RS485 network with one Adam 4520 (with RS232 to connect to computer USB) and three Adam 4017+ modules, each with a unique address.

Step 3. Clicking the Adam 4017+ instrument will make the Add/Rename Instrument Adam 4017+ configuration menu appear. Select the com port that was set up in the address-setting phase of this project. The address that was set in the Adam 4017+ module is referred to here as slave address. For example, if you had a board with address 1, the software would capture data from that board if the slave address is set at 1. The Baud Rate and Parity should match the settings in

each 4017+. Enter 3 for the decimal places, and give each board a unique name. This project used B1 through B8 as shown in the variable list in the screen image for Step 2. Repeat this process for each board connected in the system. After all the boards are configured, the individual LP data can be displayed on the SpecView run or main menu. Click on the red v for a list of the variables, and the list of boards should appear. Click the little “+” box beside the one to be

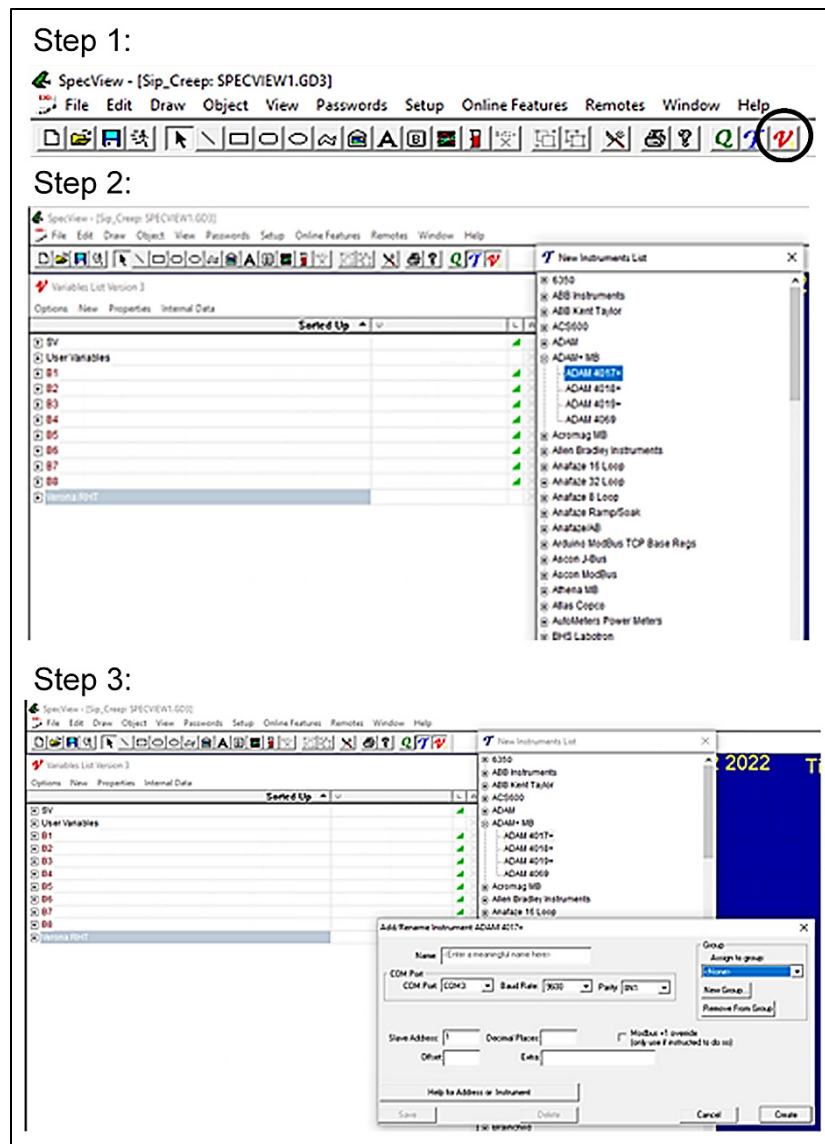


Figure 14—Steps necessary to configure SpecView to read the data boards and the individual LP sensors.

displayed (Fig. 15), and a list of inputs will appear for that particular 4017+. Remember that the Adam modules were numbered from 0 to 7 but SpecView numbered them from Input 1 to Input 8. Therefore, number 1 on the screen will actually be the 0 data channel on the physical Adam module. Highlight all 8 inputs and drag them to the blue screen menu, and the numbers will follow as shown on the left side of Figure 15.

The initial readings obtained when each board and LP are connected to SpecView show that the system works, but calibration of each LP is necessary before beginning a creep test. Press the red *v* to get a variable list, and then press the “+” in the box to the left of the instrument to calibrate (left side of Fig. 16). The 8 inputs will appear. Select the input to

calibrate and highlight it, then right click and select properties and then highlight Scaling settings. There are two values, Scale and Offset. Set Scale to 1 and Offset to 0. Then read the numbers for that input on the menu screen and enter those values into the scaling settings spreadsheet shown in Figure 17. There will be a Scale and Offset number for each LP. The scaling spreadsheet is used to calibrate each LP and calculate the parameters needed for SpecView.

The contents of the calibration spreadsheet (Fig. 17) are a mixture of labels, readings, and formulas. The spreadsheet was created to work in column B and then copied across the worksheet so each LP had a calibration column. The rows for Specimen, Board, and Data Channel are labels. In this

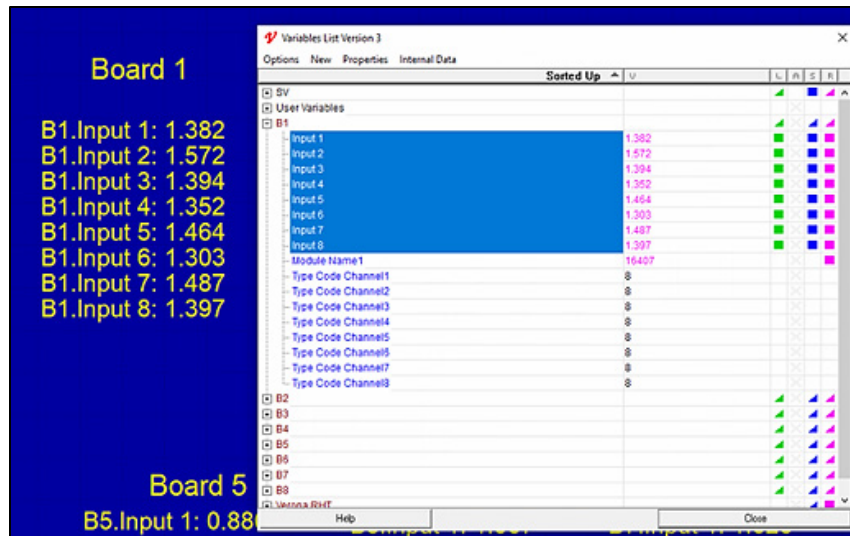


Figure 15—Creating the creep system display.

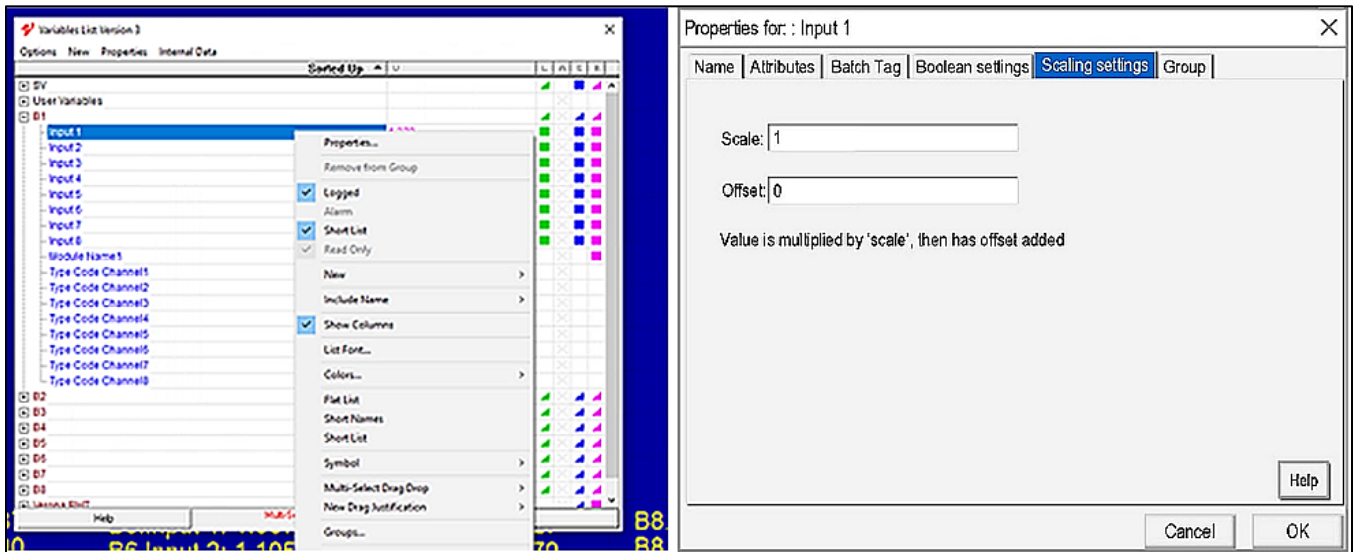


Figure 16—SpecView settings for LP calibration.

	A	B	C	D	E	F	G	H	I	J
1	Specimen	1	2	3	4	5	6	7	8	9
2	Board	1	1	1	1	1	1	1	1	2
3	Data Channel	0	1	2	3	4	5	6	7	1
4										
5	insthi	63.82	65.135	65.522	65.424	65.526	65.521	65.53	65.529	65.535
6	instlo	32.759	32.758	32.758	32.755	32.756	32.758	32.758	32.758	32.786
7										
8										
9										
10	Slope	0.095219085	0.091348797	0.090269808	0.090532309	0.090253280	0.090272564	0.090247772	0.090250526	0.090311155
11	Offset	-3.11928201	-2.99240389	-2.95705838	-2.96538578	-2.95633645	-2.95714864	-2.95633653	-2.95642674	-2.96094151
12										
13	user hi	2.9576								
14	userlo	0								

Figure 17—Spreadsheet for calculation of scaling settings.

case, Specimen ranges from 1 to 60, Board ranges from 1 to 8, and Data Channel ranges from 0 to 7 (consistent with the Adam modules).

In row 13, user hi is the full extension measurement of the LP (found in the LP documentation).

In row 14, user lo is the zero-extension measurement of the LP (found in the LP documentation).

Because all the LP instruments are the same make and model, user hi and user lo only need one value each that apply to all the LP instruments in the system.

In row 6, instlo (instrument low value) is the value on the screen when the LP is at minimum extension.

In row 5, insthi (instrument high value) is the value on the screen when the LP is at maximum extension.

These values are entered for each LP as they are moved to their respective positions.

In row 10, the Slope is calculated as $=(\$B13 - \$B14)/(B5 - B6)$.

In row 11, the Offset is calculated as $=(-B6/(B5 - B6)) \times (\$B13 - \$B14) + \$B14$.

These values are calculated based on the instlo and insthi instrument readings given above them in the spreadsheet.

After the spreadsheet has been created, input the number displayed on the SpecView screen while the LP is fully extended into row 5 for the insthi. Then move the LP to the minimum extension, read the number on the screen, and enter that number into row 6 (instlo). After these two numbers are entered, the spreadsheet will calculate row 10 and row 11. Copy the Offset number in row 11 and paste it into the SpecView Offset in the property scaling settings. Then copy the slope from row 10 and paste it into the Scale value of the property scaling settings as shown in Figure 18. This calibration procedure should be performed individually on each LP.

Temperature and Relative Humidity

If it is desirable to record temperature and relative humidity, there is an instrument made by NOVUS that is compatible with this system and can coexist on the same MODBUS network. The instrument is available in several configurations, but a wall mount works well in this application. The NOVUS RHT Climate is available from several vendors.

Figure 19 shows the basic wall mount unit configured for this system. To set the RS485 address, a USB cable was used to access the unit to configure some parameters and set the MODBUS address. One peculiar issue with the NOVUS was that not all USB cables that fit the connector worked to program it. When the unit was attached to a cable, the front screen illuminated but the programming software was not able to recognize the device. It may be necessary to try several cables. The cables that worked had a network symbol on the PC side of the USB cable.

Just as the ADAM 4017+ required software to set the RS485 network address, the NOVUS RHT also required software to set the MODBUS address. To find the software, go to www.novusautomation.com, select Downloads, select software, then select NXperience Installer. After being downloaded, the software must be installed before the NOVUS RHT RS485 address can be set. Use a USB cable to connect the small port on the side of the NOVUS RHT to the computer, and then start the NXperience software. After this, the main menu will appear. In the menu (Fig. 20), select configure and the Select Device prompt will appear. If the COM port with the device is not displayed, try again. If unsuccessful, a different USB cable may be required.

After the device can be seen in the software, press the Read Device button (left side of Fig. 21) and the screen shown on the right side of Figure 21 will appear. To match the Adam modules operating on the same network, set the MODBUS address (usually 1 higher than the last board address), Baud

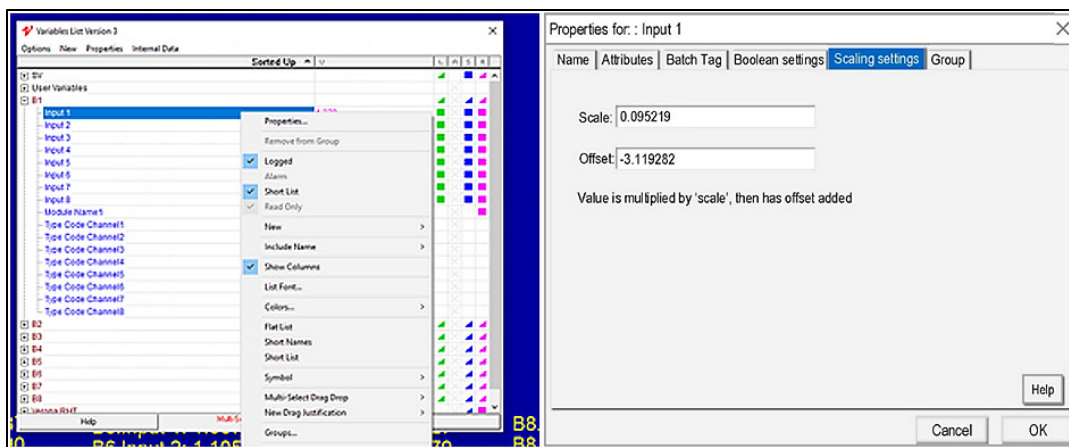


Figure 18—SpecView settings for LP calibration.



Figure 19—NOVUS RHT climate instrument: Left, basic display; Right, side view with clips that open and the USB programming port.



Figure 20—NXperience main menu (left) and Select Device prompt (right).

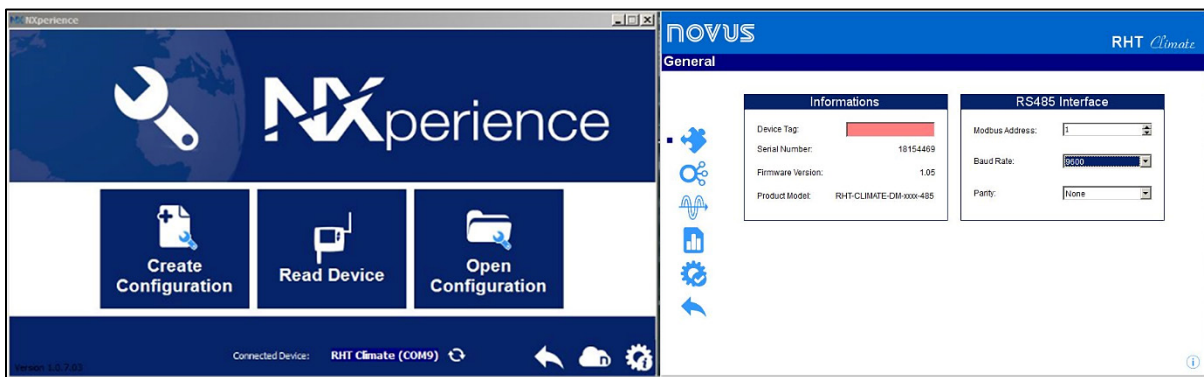


Figure 21—Reading the NOVUS RHT device and setting the MODBUS address.

Rate to 9600, and Parity to None. In the red box, give the device a name, such as RH_Temp.

On the left side of the NXperience screen, there are some symbols. The second symbol down looks like a set of connected circles. Click on that symbol and the General menu will appear as shown in the left side of Figure 22. Set the units to SI or US and enter the pressure for the test location in terms of feet above sea level. Now find the symbol on the left side of the screen that looks like a bar chart. Click on that and the Diagnostics menu will appear (right side of Fig. 22). Check to see if the temperature and relative humidity are correct for your location.

After the NOVUS RHT device is configured, click on the gear with the check mark on the left side of the screen and the Finalization screen will appear. From here, update the device configuration. Then the message shown in Figure 23

will appear, which indicates success. The RHT is now configured for the network.

After being configured, the RHT needs to be wired to allow information to be exchanged with SpecView.

On the bottom of the RHT, there is a removable wiring port to connect MODBUS wiring. Remove the screw on this port and take out the rubber stopper. Then, carefully using a small screwdriver, slightly lift the four tabs on each side of the device, and the face will separate from the body. Inside, there is a control board (Fig. 24) along with the connection points that are germane to this application. In this project, a common thermostat cable was used that had at least four wires in the cable. We used red to connect 12 V+ from the power supply on a board to the 12+ pin illustrated in Figure 24 and black to connect to 12 V-. Another pair of colors was selected to connect Data+ to Data+ and Data- to Data- terminals between the RHT and the Adam 4017+ module.

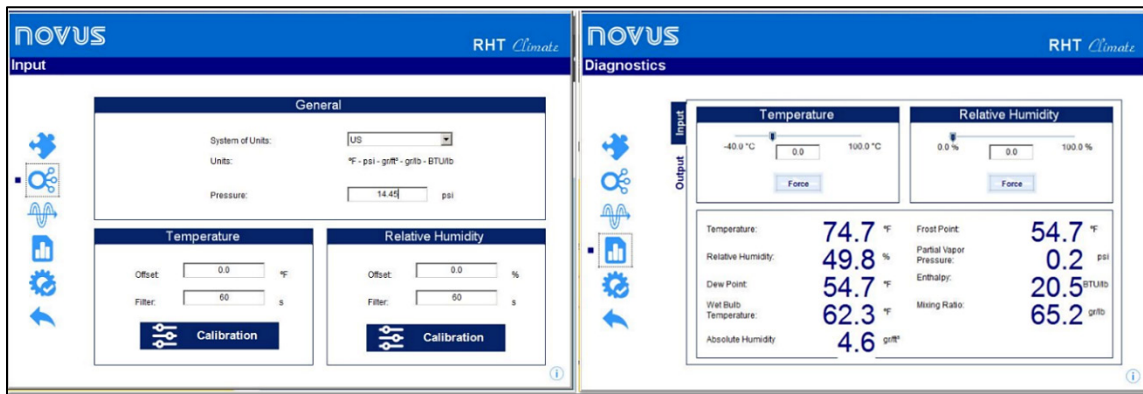


Figure 22—General menu (left) and Diagnostics menu (right) of the NXperience software.

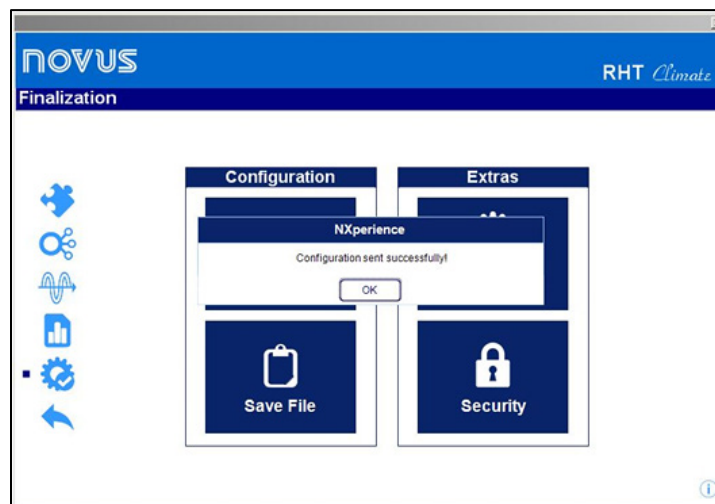


Figure 23—Finalizing the Novus RHT configuration.

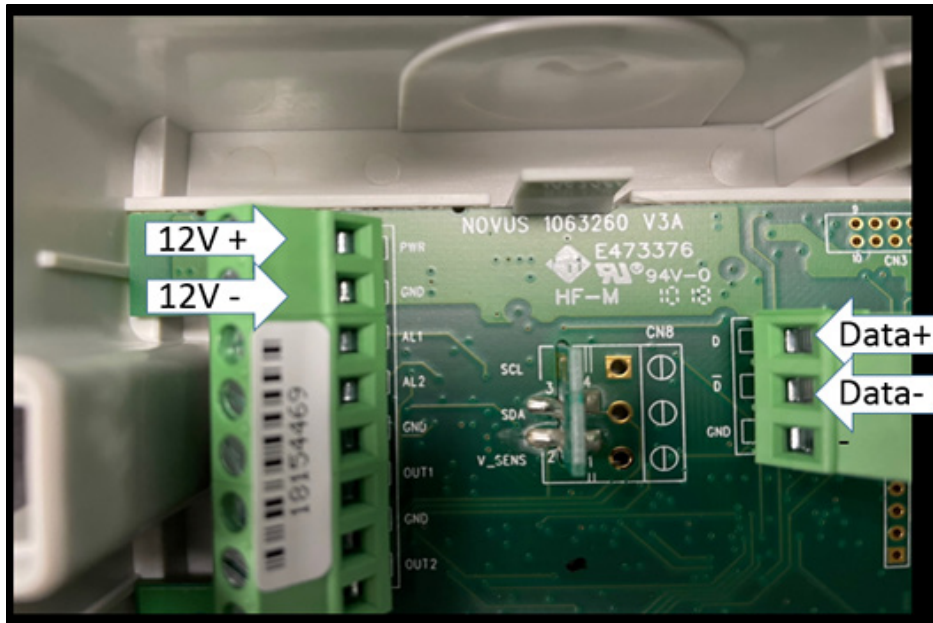


Figure 24—RS 485 control board wiring connections for the NOVUS RHT climate instrument.

Now return to SpecView and select the red ν and then the new instrument. If NOVUS is not on your instrument list, email support@specview.com and ask for the NOVUS RHT instrument driver that was supplied to Mississippi State University. Alternatively, email rds9@msstate.edu for the instrument driver. After receiving the zip file, simply copy the file into the SV3 directory on the computer, unzip the instrument, and it will appear in the variables list.

Follow the same procedure to create a variable but use NOVUS RHT rather than the Adam 4017+. In Figure 25, the NOVUS has been named Verona RHT, the COM port is port 3, the Baud rate is 9600, and parity is 8N1 meaning 8 data bits, no parity, and 1 stop bit, just like the Adam modules. The Slave Address is 10 in this system, and the Decimal Places are 2. We used one computer to configure MODBUS addresses for the devices and it used COM 9, but SpecView was running on a “production computer” and it was connected to the 4520 using COM3.

After the NOVUS RHT has been successfully configured and added to SpecView, clicking on the variable name will reveal the individual data series available to the program (Fig. 26). Then the dry bulb temperature value and the relative humidity value and be highlighted and dragged to the SpecView menu.

Periodically Recording Data

The final thing left to complete the creep system is to periodically write the data to a file. In the SpecView menu shown in Figure 27, click Setup then Strategy Controller then Add and give this strategy a name such as Morning Print and select Time Based Event. Set the name of the

event and in this case print every time the minute is zero. That will set the event to run every hour.

After the event is scheduled on the action side of the menu, click the Add button. Give the action a name, in this case, Variable List, to write to file (Fig. 28, top). Then use the drop-down menu to select “SpecView Write Line to file/printer”. The file name is the location where the file is to be stored. In this case, the file was stored on Drive C as a CSV file, which is a comma delimited file that excel can read. Now click Visual Editor to configure the specific information to print on the Line Writer Menu. The write mode will be Append because the data will write each hour and keep a running value of each LP by day and time. Finally, drag the information you want to print from the variable list. In this case, SpecView was writing the Date, Time, B1.Input1, B1.Input2 ... B8.Input8, Verona RHT.Dry bulb temperature value, and Verona RHT.Relative humidity value (Fig. 28, bottom).

The format of these data was two percent signs, the variable name followed by two percent signs and a comma to begin the next variable in the string (%%B1.variable1 name%%,%%B1.variable2name%%). The variable name includes the LP name, in this case B1.variable name for Board 1 of the data system and variable 1 on the B1 4017+. Remember, SpecView numbers were 1 to 8 whereas the 4017+ numbers for the data channels were 0 to 7. In this example, the data can be quite long because it was writing date, time, 64 LP positions, temperature, and relative humidity for a total of 68 numbers separated by the %% and comma.

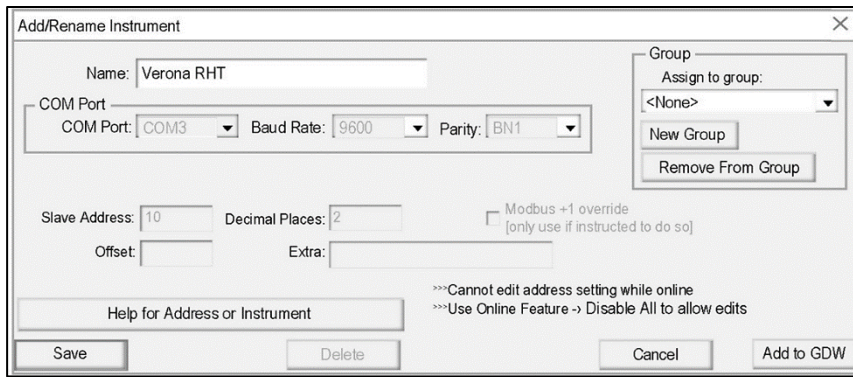


Figure 25—Configuration for the NOVUS RHT climate instrument.

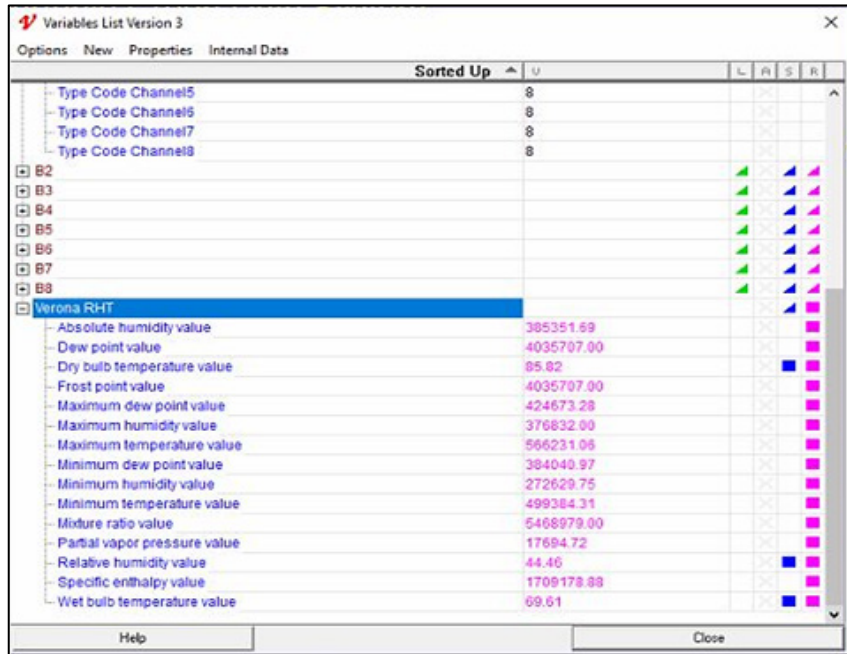


Figure 26—NOVUS RHT variable list.

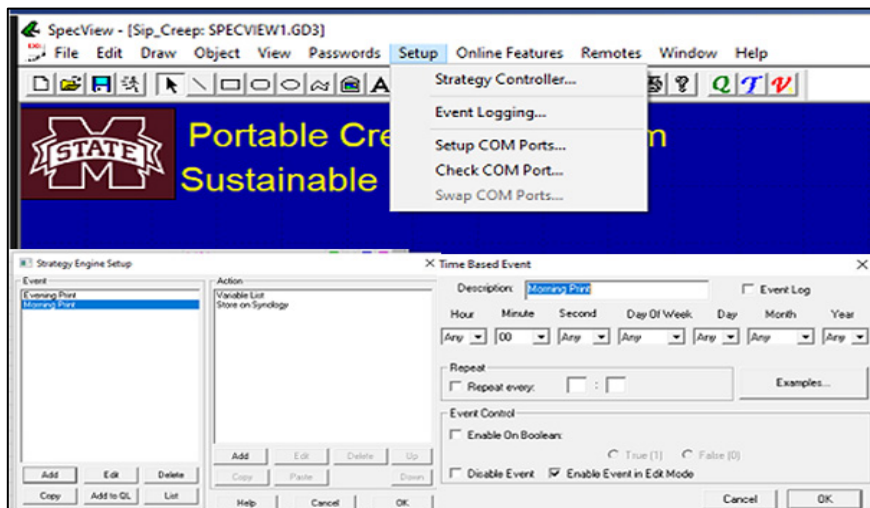


Figure 27—Using SpecView to write data to a file at specified times.

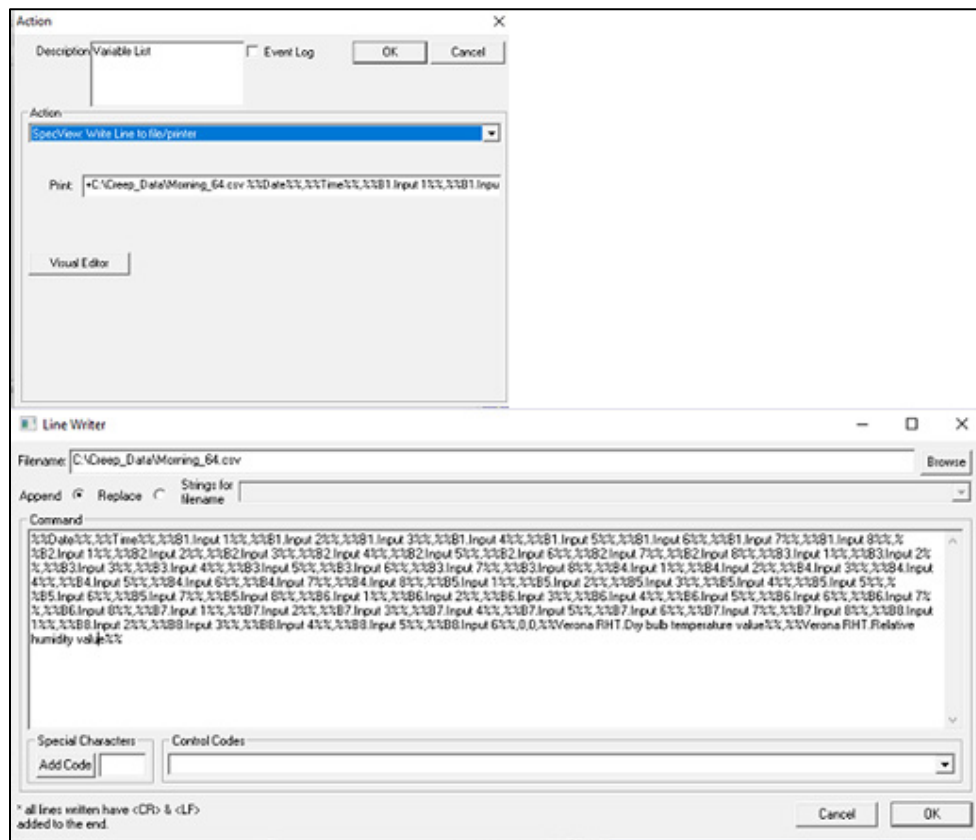


Figure 28—Creating a variable list for archiving data.

In the system described here, the Morning Print prints on every even hour and the Evening Print is set to print when the minute = 30 or every half hour. Early in the data collection, the seconds were set to print on 0; therefore, the system output the data every minute for about 3 days.

Conclusion

If you have successfully followed the instructions in this report, then you have learned how MODBUS, SpecView, and instruments work together, but this is just the beginning of what can be accomplished. The testing shown in the screenshot in Figure 29 runs constantly in the Department of Sustainable Bioproducts at Mississippi State University and writes data to file every 15 minutes. It is a mix of Adam modules, NOVUS RHT, and Watlow controllers. It tracks 40 creep samples in one laboratory and stores values from eight conditioning chambers monitoring temperature and relative humidity, 13 NOVUS RHT units monitoring building conditions, and four Adam 4017+ modules that monitor temperatures in ovens and freezers with alarms that are sent to email and text messages if certain parameters are exceeded. Finally, it monitors water flow in some outbuildings and applications. The authors hope that this information and knowledge can be applied to research projects in other organizations.

Literature Cited

- ASTM. 2015. D6815-09. Standard specification for evaluation of duration of load and creep effects of wood and wood-based products. West Conshohocken, PA: American Society for Testing and Materials
<https://cdn.standards.iteh.ai/samples/73001/e9b4bc9e763845e0af2783b9fe70aabb/ASTM-D6815-09.pdf>
- ASTM. 2017. D2915-17. Standard practice for sampling and data-analysis for structural and wood-based products. West Conshohocken, PA: American Society for Testing and Materials.
<https://cdn.standards.iteh.ai/samples/98337/794880280f35415d89ef6370c05e302f/ASTM-D2915-17.pdf>
- Anderson, L.O. 1964. A review of FPL studies on...stressed-skin and sandwich-panel units. Forest Products Journal. May. 192-194.
<https://www.fpl.fs.usda.gov/documnts/pdf1964/ander64a.pdf>
- Anderson, L.O.; Wood, L.W. 1964. Performance of sandwich panels in FPL experimental unit. Research Paper FPL-RP-12. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory.
<https://www.fpl.fs.usda.gov/documnts/fplrp/fplrp12.pdf>

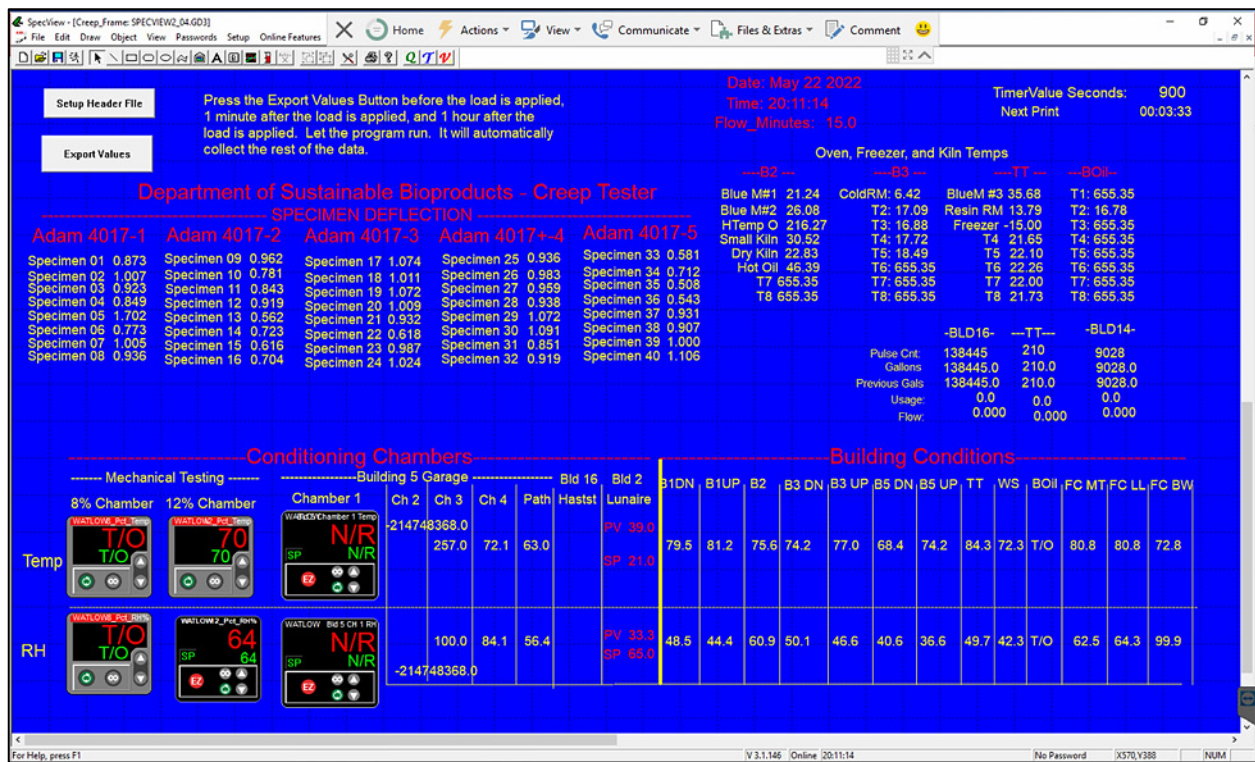


Figure 29—Example of mixed data acquisition using SpecView.

Boller, K.H. 1946. Impact resistance of three core materials and six sandwich constructions as measured by falling-ball tests. Report no. 1543. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. <https://www.fpl.fs.usda.gov/documnts/fplr/fplr1543.pdf>

Heebink, B.G.; Mohaupt, A.A. 1947. Investigation of methods of inspecting bonds between cores and faces of sandwich panels of the aircraft type. Report no. 1569. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 29 p. <https://www.fpl.fs.usda.gov/documnts/fplr/fplr1569.pdf>

Heebink, B.G.; Kommers, W.J.; Kunzweiler, J.J. 1947. Durability of low-density core materials; and sandwich panels of the aircraft type as determined by laboratory tests and exposure to the weather. Part I. Report no. 1573. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 55 p. <https://www.fpl.fs.usda.gov/documnts/fplr/fplr1573.pdf>

Heebink, B.G.; Kommers, W.J.; Mohaupt, A.A. 1949. Durability of low-density core materials; and sandwich panels of the aircraft type as determined by laboratory tests and exposure to the weather. Part II. Report no. 1573-A. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 31 p. https://www.fpl.fs.usda.gov/documnts/fplr/fplr1573_A.pdf

Heebink, B.G.; Kommers, W.J.; Mohaupt, A.A. 1950. Durability of low-density core materials and sandwich panels of the aircraft type as determined by laboratory tests and exposure to the weather. Part III. Report no. 1573-B. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 55 p. https://www.fpl.fs.usda.gov/documnts/fplr/fplr1573_B.pdf

Kochkin, V.; Rammer, D.R.; Kaufman, K.; Williamson, T.; Ross, R.J. 2015. SIP shear walls: cyclic performance of high-aspect-ratio segments and perforated walls. Research Paper FPL-RP-682. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 19 p. <https://doi.org/10.2737/FPL-RP-682>

Markwardt, L.J.; Wood, L.W. 1959. Case studies of four sandwich panel houses. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 7 p. <https://www.fpl.fs.usda.gov/documnts/pdf1959/markw59a.pdf>

McDonald, D.; Begel, M.; Senalik, C.A.; Ross, R.J.; Skaggs, T.D.; Yeh, B.; Williamson, T. 2014. Creep behavior of structural insulated panels (SIPs): results from a pilot study. Research Note FPL-RN-0332. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 12 p. <https://doi.org/10.2737/FPL-RN-332>

McDonald, D.; Begel, M.; Senalik, C.A.; Williamson, T. 2018. Evaluation of creep performance of structural insulated panels (SIPs): phase 2. Research Paper FPL-RP-697. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 12 p.

<https://doi.org/10.2737/FPL-RP-697>

Rammer, D.R.; Williamson, T. 2020. Performance of structural insulated panel walls under seismic loading. Research Paper FPL-RP-704. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 60 p.

<https://www.fs.usda.gov/research/treesearch/61118>

Taylor, S.B.; Manbeck, H.B.; Janowiak, J.J.; Hiltunum, D.R. 1997. Modeling structural insulated panel (SIP) flexural creep deflection. Journal of Structural Engineering. 123(12): 1658. [https://doi.org/10.1061/\(ASCE\)0733-9445\(1997\)123:12\(1658\)](https://doi.org/10.1061/(ASCE)0733-9445(1997)123:12(1658))

Yeh, B.; Skaggs, T.; Wang, X.; Williamson, T. 2018. Lateral load performance of SIP walls with full bearing. General Technical Report FPL-GTR-251. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 25 p.

<https://doi.org/10.2737/FPL-GTR-251>

Yeh, B.; Skaggs, T.; Wang, X.; Williamson, T. 2019. Lateral load performance of structural insulated panel (SIP) diaphragms. Research Paper FPL-RP-700. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 17 p.

<https://doi.org/10.2737/FPL-RP-700>

Additional References

Boller, K.H. 1947. Preliminary report on the strength of flat sandwich plates in edgewise compression. Report no. 1561. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory.

<https://www.fpl.fs.usda.gov/documnts/fplr/fplr1561.pdf>

Ericksen, W.S. 1951. Supplement to effects of shear deformation in the core of a flat rectangular sandwich panel: deflection under uniform load of sandwich panels having facings of moderate thickness. Report no. 1583-D. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 40 p.

https://www.fpl.fs.usda.gov/documnts/fplr/fplr1583_D.pdf

Ericksen, W.S.; March, H.W. 1968. The core of a flat rectangular sandwich panel: compressive buckling of sandwich panels having dissimilar facings of unequal thickness. Report no. 1583-B. 49 p.

https://www.fpl.fs.usda.gov/documnts/fplr/fplr1583_B.pdf

Kuenzi, E.W. 1970. Minimum weight structural sandwich. Research Note FPL-RN-086. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory.

<https://www.fs.usda.gov/research/treesearch/30508>

Kuenzi, E.W.; Norris, C.B.; Jenkinson, P.M. 1964. Buckling coefficients for simply supported and clamped flat, rectangular sandwich panels under edgewise compression. Research Note FPL-RN-070. Madison, WI: U.S.

Department of Agriculture, Forest Service, Forest Products Laboratory. 136 p.

<https://www.fpl.fs.usda.gov/documnts/fplrn/fplrn070.pdf>

Norris, C.B. 1964. Short-column compressive strength of sandwich constructions as affected by size of cells of honeycomb core materials. Research Note FPL-RN-026. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 16 p.

<https://www.fpl.fs.usda.gov/documnts/fplrn/fplrn026.pdf>

Norris, C.B.; Ericksen, W.S.; March, H.W.; Smith, C.B.; Boller, K.H. 1961. Wrinkling of the facings of sandwich construction subjected to edgewise compression. Report no. 1810. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 131 p.

<https://www.fpl.fs.usda.gov/documnts/fplr/fplr1810.pdf>