LABORATORY PROCEDURE
STP-2.1, COMBUSTION RETARDING EFFECTIVENESS

CONTENTS

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STP 2 Combsution Retarding Effectiveness (Burn Test)
REVISED BURN TESTING – Alternate Evaluation using only 2 GPC coverage levels (2019)
Evaluation of Forest Fire Retardants-A Test of Chemicals on Laboratory Fires (1962).
LF-2.1.0 Burn Test Sprayer and Residue Spreadsheet
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1. Abstract

1.1. This procedure outlines the entire combustion retarding effectiveness testing process, referred to hereafter as the *Burn Test*. All instruction is for WFCS laboratory personnel and is based upon Standard Test Procedure (STP) 2, Combustion Retarding Effectiveness.

2. Overview

2.1. Wildland Fire Chemical Systems performs combustion retarding effectiveness testing on all Long-term retardants. This test evaluates the chemical after it has been conditioned to dry in an environmental chamber so it is not applicable to class A foams or water enhancers. The acceptance limits of this procedure are provided by the comparable performance of the 10.6% (w/w) diammonium phosphate (DAP) standard solution.

2.2. The wind tunnel and combustion chamber of the Missoula Fire Science Lab is used to conduct all testing. Two different fuel types are evaluated. Pine needles are evaluated as the waxy, resinous fuel and aspen excelsior is used as the fine woody cellulose fuel. The developmental product is applied at one coverage level of 2 gallons per 100 sqft (GPC). 2 GPC is also used for the DAP standard to a second bed for direct comparison of performance. Finally, an untreated bed is prepared to evaluate flame spread and weight loss across the untreated fuels. Both the developmental product and DAP are analyzed in the wind tunnel at set conditions of 5 miles per hour, 90°F, and 20%RH. The rate of spread and weight loss are recorded for each burn as a part of data collection. This data is then used to directly compare performance with reduction in weight loss and reduction in rate of spread from the baseline of untreated fuel.

2.3. Historically Wildland Fire Chemicals evaluated a second coverage level at 1 GPC, but the findings of: 2019 REVISED BURN TESTING – Alternate Evaluation using only 2 GPC coverage levels, demonstrated a modification to only 2 GPC was an accepted reduction in scope. This improved reproducibility of the test and reduced expenses. This testing was first developed in 1962 using the work of Hardy, Rothermel, and Davis with the Intermountain Forest and Range Experiment Station (1962).

2.4. The data collected are averaged using a minimum of 5 burns on each fuel type. Developmental product burns are directly compared to DAP burns from the same day to reduce variables in wind tunnel conditions. A spreadsheet is used to compile all data and then a letter is sent to the company informing them of how their product performed.

2.5. All long-term retardants are evaluated using this test and must either meet the minimum salt concentration or the acceptable performance outlined in this test procedure.

2.6. Spot checks of alternative formulations may also be conducted using this testing. A minimum of 2 replicates on each fuel type are used to confirm performance. Additional replicates may be needed if non-conforming results are observed. All testing is at the expense of the submitter.

3. Procedure

This procedure is outlined chronologically for each task performed. Some sections may be performed in an alternative order or concurrently for efficiency. Scheduling of the combustion chamber and wind tunnel should be done approximately 1 year in advance. Ideally shoulder seasons are used for scheduling, avoiding months where outdoor temperatures are below 35°F, which is found to be the lowest temperature the wind tunnel can operate and hold conditions of 20%RH and 90°F. Due to reduced available space in the combustion chamber, operations have been reduced to preparation and burning of approximately 4 beds each day. A typical burn day would consist of:

- 1 Fuel type
    - 1 untreated bed
    - 1 DAP bed
    - 2 replicates of developmental products

BE SURE to wear all appropriate Personal Protection Equipment as deemed necessary by the task being performed (i.e. gloves, goggles, ear protection, nomex, etc.)

Prior to requiring a burn test, products may be deemed acceptable (without burn testing) based on the underlying salt content. The lab forms LF-2.1.6 and LF-2.1.7 can be used to determine if burn testing can be waived. Some salts do not have the historical data to waive testing, so for new, non-validated salt formulations a burn test will be required. Refer to the specification for guidance.

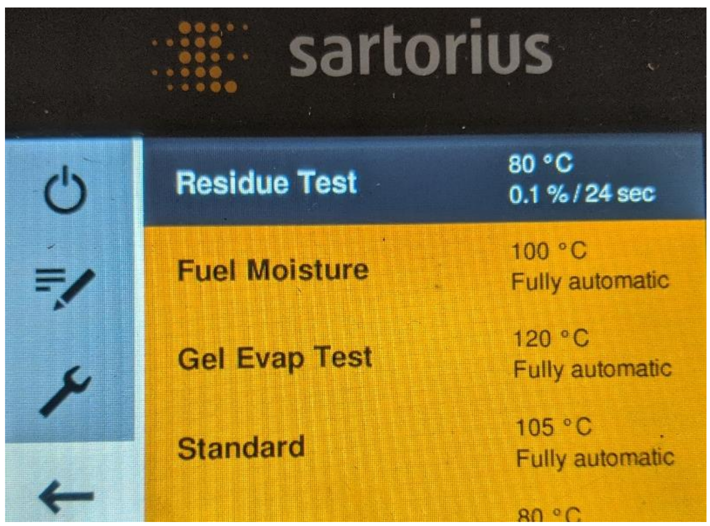
3.1. RESIDUE DETERMINATION

Prior to time in the combustion chamber developmental products and DAP are mixed for use. Samples are collected to submit for chemical analysis and the rest is transferred to carboys for transportation. A separate sample is collected to perform % solids residue testing. This is done to determine the expected water content that should be evaporated to be within drying tolerances.

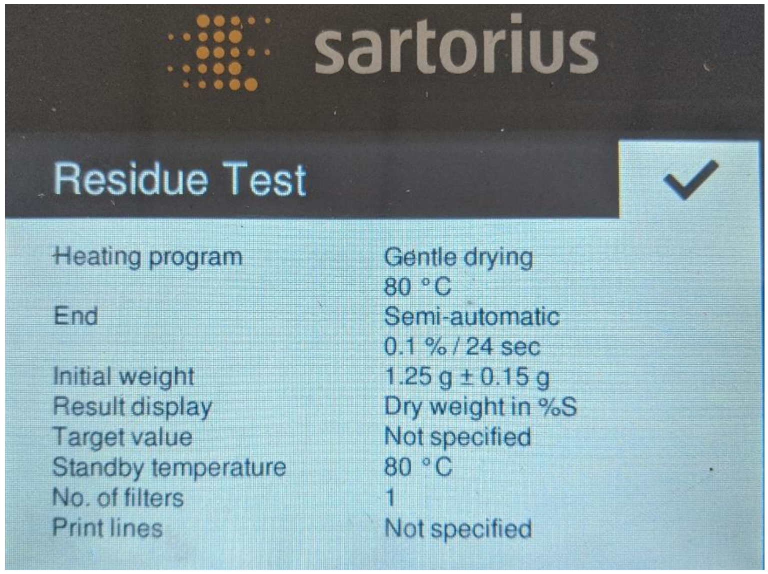
3.1.1. Use the current version of Lab Form (LF) LF-2.1.0 to record all data. The "residue" tab is needed for this section. Prior to any testing, you will need to use the DMA 35 density meter to determine the density of the solution. Record each density in g/mL on the LF. There are also directions embedded in the LF to help explain use of the form.

3.1.2. Power on the MA-160 Moisture Analyzer. Locate the calibration sticker and verify it is within its calibration date.

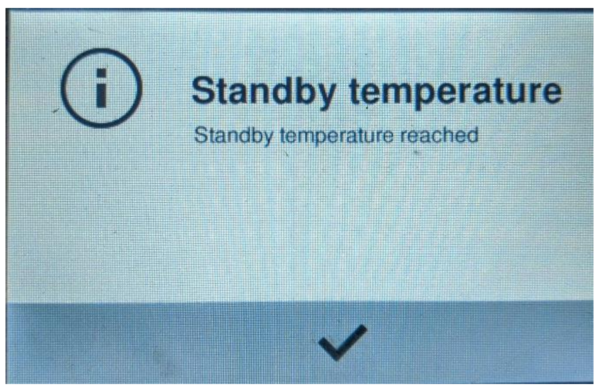
3.1.3. Navigate the home panel and use the touch screen to select the method Residue Test as shown.



3.1.4. This program uses the following settings to analyze the sample. These settings should not be changed unless properly validated. Wildland Fire Chemicals validated use of this method through the work documented in *MA-160 Method Justification (2016)*. Previously the method used an oven-drying approach that was labor intensive and had a higher standard deviation in measurement.

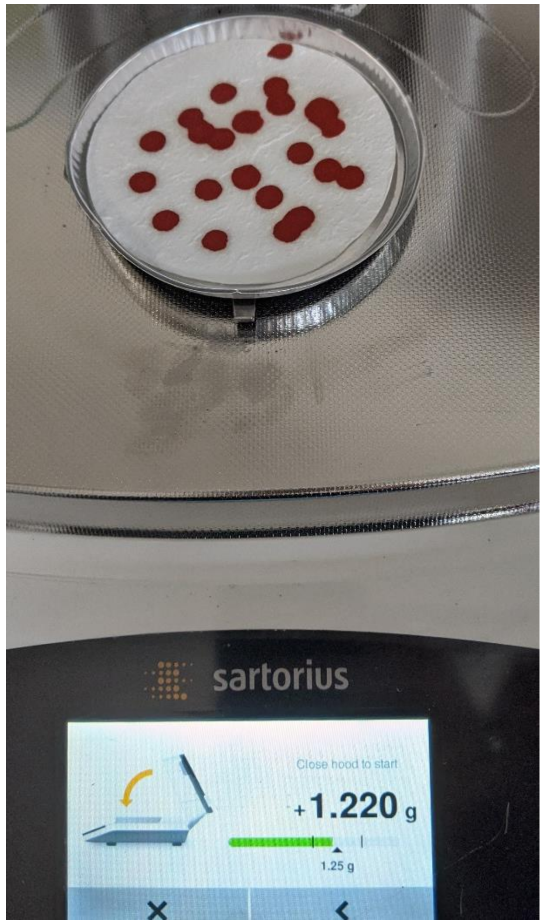


3.1.5. Once selected, press the START button in the lower right-hand corner of the touch screen. This method utilizes a Standby temperature, so it is best practice to wait until the screen designates that you may proceed.



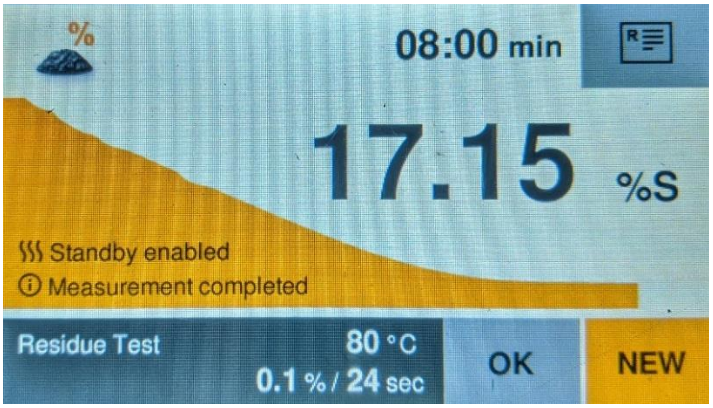
3.1.6. If you are analyzing the first sample of the day, you will want to use an independent calibration verification (ICV) as a daily check. Typically this is a 10% (w/w) solution of sodium chloride, but any standard salt solution is acceptable.

3.1.7. Open the hood and follow the on screen instructions. When applying the chemical to the filter paper, attempt to apply it evenly across the surface to assure the most uniform drying. See the photo below for reference.



3.1.8. When the screen shows that the applied amount is correct, the data bar will turn green. Follow the on screen directions and close the hood. You will note that the program starts as soon as the hood is closed and a real-time graph appears on the screen.

3.1.9. The program runs until it has completed. It uses criteria of less that 0.1% change over 24 seconds to determine constant weight and calculate results in % solid.



3.1.10. Record the % solid measurement in LF-2.1.0 and remove the old sample. Repeat the process for all replicates and products needed. Typically 5 replicates are used to determine the residue, but 3 may be acceptable if the Relative standard deviation (%RSD) is below 5.0%. The average % solid measurement is used later in the process, so make sure to save the file in a known location. If analyzing more than 2 different products, several copies of LF-2.1.0 can be saved in the appropriate file.

3.1.11. When you are completed with the measurements for the day, power down the MA-160.

3.2. SPRAYER CALIBRATION

3.2.1. This step in the process can be either completed prior to entering the chamber or prior to applying the first coverage level to a fuel bed. Each product requires a 3 point calibration to account for different flow characteristics.

3.2.2. Required items for this section:

- Density measurements for each of the test products, and the mixed product
- Sprayer and cart or tray
- Balance capable of weighing entire fuel bed
- Stop watch
- Different T-jet tips (8010, 8020, 8030, etc.)
- Splash guards and PPE
- Calibration tray

3.2.3. If not already completed from Section 3.1.1., enter the densities of each of the products into LF-2.1.0. Then assure these densities appear correctly within the *Sprayer Calibration* tab. Then take the calibration tray and place it on the test balance, tare the balance.

3.2.4. Setup the spray apparatus, prime the pump with water and assure it is operating optimally before introducing mixed products. It is useful to introduce air pockets into the suction line to remove any in-line bubbles. It is useful to setup the splash guards at this time as well to protect equipment and clothing.

3.2.5. Once all air bubbles have been removed, move the suction line into a well-mixed test product container. Repeat the introduction of air bubbles as needed for the mixed product to remove any new air bubbles. Attach a T-jet tip (historical data suggest using the T-jet 8030 for the DAP standard) to test out the sprayer pattern.

3.2.6. Inspect the sprayer during operation and assure uniformity of the pattern across the width of the bed. Try out different T-jet tips as needed to get the most uniform pattern applied.

Figure 1- Sprayer Calibration Setup

3.2.7. Once the spray pattern appears uniform, setup the sprayer, cart, and calibration tray as shown in Figure 1. Assure that the fuel bed can properly move through the setup with the rails guarded by the splash guard.

3.2.8. With the tared calibration tray on the cart, use the stop watch to record application times. With the pump on, but the spray nozzle closed, simultaneously fully open the spray nozzle and start the stop watch. Stop both at the same time after approximately 10 seconds. Move the calibration tray to the balance and record the weight and time into LF-2.1.0 under the "*Sprayer Calibration*" tab and the correct product. Tare the calibration tray once again and repeat the process using an approximate 20 second interval. Record the new weight in the same lab form and repeat a third time at either a higher or lower time interval as deemed necessary.

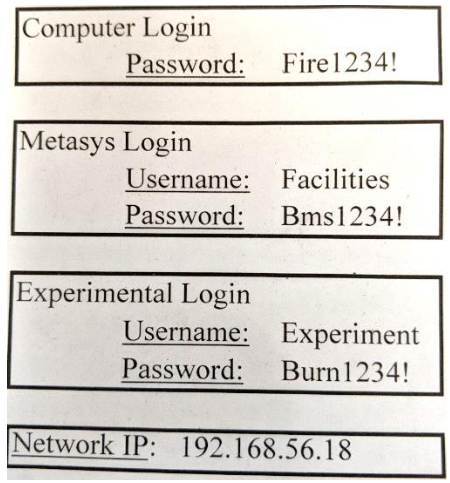
3.2.9. Once a minimum of 3 times have been recorded in the lab form, review the associated equation for the linear fit curve. If the R^2 value is greater than 0.995 no additional times are needed, otherwise repeat a fourth and fifth replicate to determine if a better fit can be calculated or if an outlier was recorded. Once the R^2 value is greater than 0.995, update the green boxes *Equation, m, and b* fields to reflect the new equation.

NOTE: These green boxes are used by the lab form to calculate the specific times for 2 GPC coverage levels of each product. These calculations are then used in the *Bed Weight Calculator* tab for when products are applied.

3.2.10. This calibration will be retained in the form and saved for timing purposes of programming the controller.

3.3. CHAMBER CONTROLS

3.3.1. The chamber is controlled using a software interface developed by Johnson Controls. The details of this operation are outlined in *Burn Chamber Controls Walk Thru* (2018). This document references login in information, set points, safety, and overall operations. A copy of this is also located in Appendix C.


Computer Login
Password: Fire1234!

Metasys Login
Username: Facilities
Password: Bms1234!

Experimental Login
Username: Experiment
Password: Burn1234!

Network IP: 192.168.56.18

3.4. FUEL CONDITIONING AND BED PREPARATION

3.4.1. Time scheduled within the burn chamber vary according to other research and products, but whenever possible it is helpful to move the fuels into the chamber the weekend before use. By breaking apart a bale of excelsior and removing pine needles from their boxed containers, the open air flow helps get the fuels to a constant moisture content more quickly.


NOTE 1: There are two different ways to operate the chamber, OPEN LOOP and CLOSED LOOP. In the mornings, during conditioning, the CLOSED LOOP setting is used to recycle the conditioned air rather than pull in outside air. This is discussed in the Burn Chamber Controls Walk Thru from the CHAMBER CONTROLS section.

NOTE 2: Do NOT operate OPEN LOOP when outdoor conditions are below 35°F.

NOTE 3: If space in the burn chamber is unavailable, it can be helpful to store fuels in the back lab the weekend before moving into the chamber to help reduce acclimation time to the indoor conditions.

3.4.2. Taking a fuel moisture content reading discussed in Section 3.7. Can help assure that the fuels are ready for preparation. When time is critical, “wet” beds can be prepared by filling fuel buckets toward the upper end of the weight limits.

3.4.3. After a weekend of conditioning, the fuels should be ready for weighing and bed building. Fuel beds are 8 feet long and 1.5 feet wide with a guard rail that measures approximately 3-4 inches high to help contain the fuel. The ends of each burn bed remain open (no guard rail). LF-2.1.8 includes a *Building Worksheet* tab that can be printed for recording data in the burn chamber. This printed form is used to record the empty weight of each bed and the day and time of the reading. Beds have assigned numbers on each end of the bed for traceability. These numbers and fuel types are also recorded on the lab form.

3.4.3.1. Excelsior bed building uses 4.0 lbs of fuel for each bed. Four buckets are used, with a target weight of 460 grams each to account for loss during preparation.

3.4.3.2. It is best practice to layer the bed using 2 pounds (or buckets) first to make sure the fuel is uniform, distributing the fuel evenly from side to side and end to end. Then the remaining 2 buckets are used to finish the bed with the second layer directly on top and integrated into the first layer. Using your fingers, loosen and shake the fuel to provide a uniform fuel bed. Finally, hedge trimmers are used to trim the fuel around the edges and along the top for consistency.

3.4.3.3. Starter beds are prepared the same way using a different weight of fuel per bucket. Starter beds are used to provide a natural introduction of the flame to the fuel burn bed.

3.4.3.4. Pine needle bed building uses a target weight of 6.0 pounds of fuel in the same dimension beds as described above. This uses 6 buckets with the target weight of 460 grams per bucket.

3.4.3.5. For pine needle beds it is best to start with 3 buckets and uniformly distribute the fuel from side to side and end to end. Then the remaining 3 buckets are distributed on top of the first layer. Again, use your fingers to loosen and shake the fuel so that it can better lay flat and integrate the two layers.

3.4.3.6. Lastly the trimmers are used to remove and trim layers that are out of the fuel bed dimensions.

3.4.3.7. As with the excelsior beds, starter beds for the pine needles are also prepared using the same starter bed dimensions but with a fuel bucket weight to match the fuel loading of excelsior.

3.4.4. After each fuel bed is prepared, a final weight and time is recorded on LF-2.1.8 and the bed is set aside to condition in the chamber. Weights are taken periodically to confirm that a constant weight has been achieved prior to applying chemicals to each bed. This same printed form is used to record the applied product weights in the next section.

3.5. CHEMICAL APPLICATION

3.5.1. Developmental products and the standard 10.6% DAP chemical are applied using the calibrated sprayer from earlier sections. This section uses LF-2.1.8 and LF-2.1.0.

3.5.2. After fuel beds have been prepared and reached a constant weight this section is to be completed. Note that not all fuel beds will have a chemical applied; 1 each of the pine needles and excelsior fuels will be untreated to provide the test with a “blank” or untreated measurement.

3.5.3. Setup of the spray apparatus is discussed in Section 3.2. Prior to chemical application on a conditioned fuel bed, you will need to do a couple of things:

- Refer to LF-2.1.0 for calibration times and T-jet nozzles that are appropriate for each chemical
- Assure the pump is primed and all air is removed from within the suction line

3.5.4. Place one of the untreated (conditioned) beds onto the spray cart. Next, using a stop watch, turn on the controller and use the stop watch to time how long it takes for the bed to entirely run under the spray apparatus. Use a reference point such as the tip of the sprayer or the end of the splash guard. Use this reference time to make adjustments to the controller.

3.5.5. Using the LF-2.1.0 under the *Bed Weight Calculator* tab you will see a drop down menu that allows for the selection of which chemical you are applying and the coverage level as shown in the figure below.

Figure 2- Bed Weight Calculator, Product Selection

Product	Target GPC	density
10.6% DAP	2	1.064
	Add (grams)	
minimum (grams)	target (grams)	maximum (grams)
942	**967**	**991**

3.5.6. The lab form will update the density from the *Residue* tab which the data was collected from instruction of section 3.1. If this section was not yet completed, stop here and complete that section first.

3.5.7. Once the drop down menus are selected, data fills the worksheet and provides estimated target times to use. These are referencing the *Sprayer Calibration* tab. Again, assure that section is completed before this section.

Figure 3-Bed Weight Calculator, Target time

Low weight	High weight	Low time	Target time	High time
942	**991**	27.17	27.86	28.55

3.5.8. After the initial run (as completed in Section 3.5.4), you will likely need to adjust the controller to either speed up or slow down the cart. As seen in Figure 3, the target time is the mid-range time that should be used to apply the target of 2 gallons per 100 square feet (2 GPC). To be on the safe side it is best practice to adjust the controlled to just below this target time to guard against an overspray which requires rebuilding a new bed for application.

3.5.9. The controller currently uses an analog dial setting (Figure 4), where the higher the number the faster the motor. So as this dial is turned “up” the cart moves faster which reduces the time it takes for the cart to run beneath the sprayer. This can be a point of confusion when optimizing the controller to match the target time (or a little bit faster than the target time) to prevent an overspray. If in doubt after making adjustments to the controller, use the stop watch to time the cart.

Figure 4-Motor Controller

3.5.10. Once the timing of the cart closely matches the target time (or slightly faster) you can begin the application.

3.5.11. Prior to application a dry or untreated weight of the bed is taken and recorded on LF-2.1.8. and entered into the electronic LF-2.1.0 under the *Bed weight calculator* tab in the field called "Pre-Spray Bed weight" as shown in Figure 5.

Figure 5-Bed Weight Calculator, Pre-Spray weight

	BED SPRAY CALCULATOR			
	RED = TOO MUCH *DAMNIT	GREEN = GOOD SPRAY	BLUE = ADD MORE	
Bed ID		Data	Product	Target GPC
10	Pre-Spray Bed weight	18531	10.6% DAP	2
	Weight after Spray	0		Add (grams)
		-18531	minimum (grams)	target (grams)
	2nd Spray		19473	19498
	Pre-Spray Bed weight	18531		
	Weight after Spray			
		-18531	Add (grams)	target (grams)

3.5.12. When this is all setup and looks good, start the first application under the sprayer. First start the cart and as it approaches, turn the spray nozzle on before the cart has reached the application area. Once the cart has entirely cleared the spray area, turn off the spray nozzle and turn off the cart motor controller. Take the bed to the balance and take a "Weight after Spray reading and enter it into LF-2.1.0.

3.5.13. The weight applied will appear below in either a color blue, green, or red indicating what needs to be done next. Figure 6 shows when the application is within the weight tolerances (green text and fill). Application tolerances are 1.95 GPC – 2.05 GPC.

Figure 6-Bed Weight Calculator, Applied chemical weight

	BED SPRAY CALCULATOR				
	RED = TOO MUCH *DAMNIT	GREEN = GOOD SPRAY	BLUE = ADD MORE		
Bed ID		Data	Product	Target GPC	density
10	Pre-Spray Bed weight	18531	10.6% DAP	2	1.064
	Weight after Spray	19498		Add (grams)	
		967	minimum (grams)	target (grams)	maximum (grams)
	2nd Spray		-25	0	24

3.5.14. If the chemical was over weight (too much added) the only way to correct this is to prepare a new fuel bed. Often times this is done by using the "untreated" bed and then building a new untreated bed later to replace it. All data should be recorded on the associated lab forms.

3.5.15. If the chemical was under weight (designated by a blue text and fill), then the cart will need to run under the sprayer again to apply more product. Figure 7 shows that when an under spray happens, how much more weight is needed to meet tolerances, and the minimum calibration time.

Figure 7-Bed Weight Calculator, Under-weight

	BED SPRAY CALCULATOR					
	RED = TOO MUCH *DAMNIT	GREEN = GOOD SPRAY	BLUE = ADD MORE			Password to Unlock shee
Bed ID		Data	Product	Target GPC	density	Low weight
10	Pre-Spray Bed weight	18531	10.6% DAP	2	1.064	942
	Weight after Spray	19398		Add (grams)		
		867	minimum (grams)	target (grams)	maximum (grams)	minimum time needed (sec)
	2nd Spray		75	100	124	2.17
	Pre-Spray Bed weight	18531				

3.5.16. When underweight applications occur, you will have to reprogram the controller to meet that time or manually run the cart below the sprayer at a constant speed. After a reapplication, weigh the bed a final time to assure you are within the tolerances. There is a "2nd Spray" field that appears below the first application to account for this weight change.

3.5.17. Beds should appear uniform in appearance after application. Repeat this section for each product being tested, being sure to change T-jet tips, flush the chemical, and reset the controller to match the associated calibrations for each chemical. All products are compared to DAP and untreated on both fuel types. All fuel beds are allowed to dry overnight and will be burned the following day once they have reached a minimum of 95% dry (as calculated within the lab forms.


3.6. WIND TUNNEL SETUP – The wind tunnel has several different tables, a test scale, burn coil, bed holder, 8 foot marker, and ash bin.

3.6.1. Setup all components and use a 4 foot level to make sure all stands and tables are level. Some connections are made below the wind tunnel floor so, be sure to lower the lift during these attachments and assure all safety practices are followed.

3.6.2. After the burn bed holder is placed on the scale, make sure to tare the scale and make all connections to your computer for communication to the LabVIEW program. When everything is setup and a bed is set on the stand it should appear as shown in Figure 8.

Figure 8-Wind Tunnel Setup

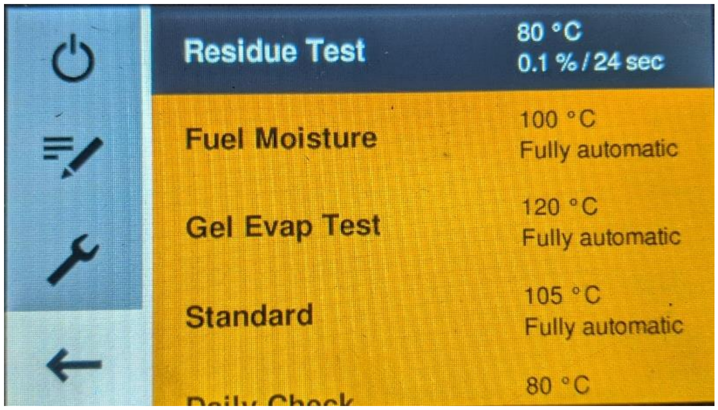
3.6.3. The wind tunnel is now ready for burning.

3.7. FUEL MOISTURE CONTENT AND BURN BED SETUP – After beds have been allowed to dry overnight, they are likely ready to be burned in the wind tunnel.

3.7.1. Fill in the data collected from previous sections into LF-2.1.8. The form will auto-calculate the % dry weights to reference and check prior to burning. If the weights meet the percent dry tolerance, record the chamber weight on the LF-2.1.8 printed form and load the bed (and same fuel starter bed) up onto the wind tunnel lift.

3.7.2. Once in the wind tunnel place the burn bed on the bed stand and move the tables around the bed. Record the weight from the tunnel scale to assure it is similar to that recorded in the burn chamber. Sometimes the fuel bed can be touching one of the side or end tables and lead to an artificially high or low reading. When it looks good, you can then incorporate some of the starter bed to touch and integrate the fuel into the burn bed and take a small sample of fuel from the end of the burn bed (at the 8 foot mark). Place the fuel in the fuel canister and exit the wind tunnel.

3.7.3. Use the MA-160 to measure the fuel moisture. Navigate the touch screen to the programmed tests. Select the "Fuel Moisture" cycle and follow the on screen prompts to set up the tray and sample the material.



3.7.4. The FMC method was developed using the same temperature conditions as the previous oven drying method (100°C). The stability of the analysis is determined by the program (fully automatic end-point). A 0.5 g sample weight is used due to the size of the instrument.

3.7.5. The MA-160 instrument will beep when the sample measurement is complete. Record the fuel moisture content on the printed LF-2.1.8. and in the electronic form. Fuel moisture for both fuel types should be below 10%, however there are no set tolerances prior to burning.

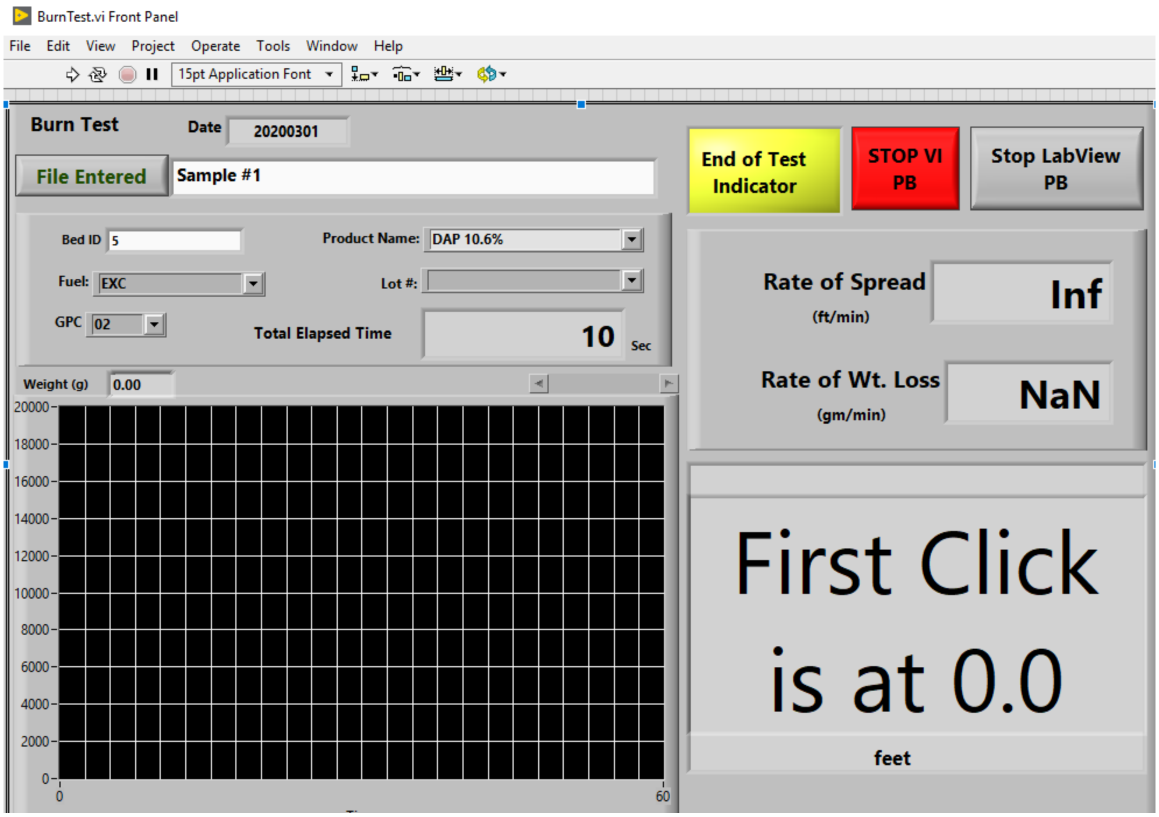
3.8. BURN TEST PROGRAM – LabVIEW is used to record each separate burn to measure rate of spread and weight loss. It is important to check the communication of the scale and LabVIEW using NI-Max prior to running any tests.

3.8.1. Startup whichever laptop is being used for the data collection and make all USB connections needed. One connection is to the test scale (RS-232, COM 3 or 4) and one connection is for the Burn Test clicker (NI USB-6008).

3.8.2. If all communications appear correct, open the BurnTest.vi program on the computer. Depending on which copy you use, the file paths may require update to properly save all the data.

3.8.2.1. If the communications do not appear correct, troubleshoot, and as necessary contact www.ni.com. Historically there have been issues with driver updates and software upgrades with the NI-Serial downloads. Consult a user manual as necessary. Appendix D also has a list of previously conducted troubleshooting approaches.

Figure 9-LabVIEW BurnTest.vi



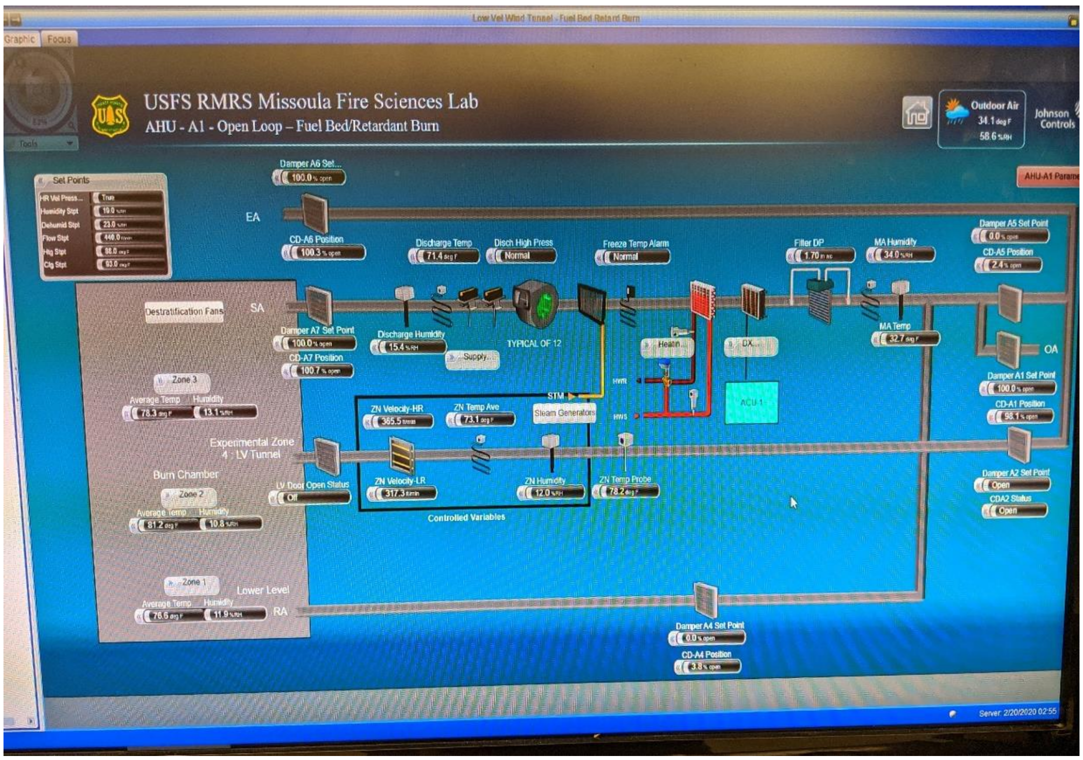
3.8.3. The program should be tested prior to any real burns. This can be done by entering "Sample #1" (or any suitable name) into the file name field and filling the other fields arbitrarily to confirm data collection. Press the check mark and press the run arrow at the top of the software. A pop-up box will prompt that you fill the file name field with a unique name and click the ***File Entered*** toggle button imbedded in the software. This will begin the burn test recording. Since it is a test, you can just click through using the burn test clicker as fast as you like until the 8.0 foot mark is displayed in the lower right hand corner. Then press and hold the *Stop VI PB* button until it designates a completed run. This is displayed by an update to the Rate of Spread and Weight Loss fields. You will want to confirm that the raw data was stored to the two locations (one on the flash drive and one on the C drive of the computer). Locations of these files may vary depending on which computer is used. Once confirmed that the data is saved you are ready for an actual test.

3.9. BURN TEST DATA COLLECTION

3.9.1. Approximately 1 to 2 hours before burning, you will need to switch the burn chamber controls from closed loop to an open loop. This is done easily by removing any overrides from the Open Loop – Fuel Bed/Retardant Burn test cycle. Overrides can be identified with a pale orange outline next to any of the dampers or other controls. All overrides shall be removed and time allowed for the system to optimize and equalize to the conditions of:

- 5 mph wind (or 440 ft/sec, ± 40 ft/sec)
- 90°F ± 5°F
- 20%RH ± 2%RH

For more detailed instructions, refer to the Burn Chamber Controls Walk thru guide or refer to Appendix C.



3.9.2. You are waiting until the black outline with the designation of *Controlled Variables* to be within these tolerances.

3.9.3. Once all conditions have been met, you can start the burn test program (after entering all associated data into the fields), and ignite the starter bed. Ignition of the starter bed is done with the heating coil that has a two button controller. Press down both buttons until ignition is clear across the width of the coil.

3.9.4. Use the burn test clicker and walk perpendicular to the line of sight of the flame front. Press the clicker every time it moves to the next 0.5 ft mark. The first click is at the 0.0 foot mark which correlates to the start of the burn bed (treated or untreated). Proceed to click through as the flame front progresses, keeping an eye on where the flame front meets the fuel and not necessarily the tip of the flame. Once you have proceeded through to the 8.0 marker, end the test and record the data.

3.10. DATA MANAGEMENT – Electronic and hard copies of each of the burns are retained and stored in the associated product folders. The electronic copies are retained in the Burn Test file repository.

3.10.1. When working with LF-2.1.8. It is important that data is correctly tabulated for each of the experimental products. Within the spreadsheet there are *Untreated* and *DAP* "Summary" tabs which are referenced to pull the comparable data from.

3.10.2. Each day that products are burned, an untreated and 10.6% DAP treated bed must also be burned on the identical fuel type. When completing the lab form, you will need to double check that the formulas are selecting the same dates that the products were burned to remain consistent. The calculated values of the reduction index rely on accurate data and calculations from the summary pages.

Figure 10-Burn Test Product Summary

	Excelsior				Needles			
	2 GPC				2 GPC			
	Date	GPC	R/S	R/WL	Date	GPC	R/S	R/WL
Product A	2/26/20	2.03	0.998	189	2/26/20	2.00	2.243	256
	2/26/20	2.03	1.412	245	2/26/20	1.98	2.202	236
Average		2.03	1.21	217.00		1.99	2.22	246
% Reduction			87%	67%			53%	46%
	Reduction Index (Exc) = 0.77				Reduction Index (P.Pine) = 0.50			
	Reduction Index =			**0.63**				
DAP 10.6%	2/26/20	1.98	1.116	171	2/26/20	1.98	3.582	294
Average		1.98	1.12	171.00		1.98	3.58	294
% Reduction			88%	74%			24%	36%
	Reduction Index (Exc) = 0.81				Reduction Index (P.Pine) = 0.30			
	Reduction Index =			**0.55**				
Untreated	2/26/20	0.00	9.231	660	2/26/20	0.00	4.706	459
Average			9.231	660.000			4.706	459.000

3.10.3. Figure 10 shows that each of the *Untreated* and *10.6% DAP* burns were conducted on the same days as each of the product burns. This is an easy example since all burns were from the same day, but when multiple days are used, it is important to confirm the correct dates and data are being tabulated.

3.10.4. Once the values and equations have been confirmed correct and complete, proceed to the section about report generation, Section 3.11.

3.11. REPORT GENERATION

When all previous steps are done, the report is ready to be completed.

3.11.1. An example report is generated as shown in Appendix B. The language of the letter can be adjusted to meet the intent of the work.

3.11.2. The data can be copied directly from LF-2.1.8 and pasted as a picture into the summary letter. It is important to only issue results relevant to the company and not to include any experimental burns from other competing companies in the summary letter.

3.11.3. Once final, print and review the summary letter. Using peer-review, have a second party sign using a wet signature and date to authenticate the review. Then scan the signed copy and issue the scanned copy as a peer-reviewed report to the company.

4. CALCULATIONS

Calculations used in LF-2.1.8 are explained in this section. Simple arithmetic equations such as weight loss and conversions are not included.

4.1. GALLONS PER 100 SQUARE FEET (GPC)

4.1.1. $1\ GPC = 1\ gallon\ of\ product\ \div 100\ sqft$. It is important to note that the density of the product needs to be taken into account when performing these calculations. Density is typically recorded in grams/mL and needs to be converted to gallons to determine proper weights and weight ranges of use.

4.2. RATE OF SPREAD

4.2.1. This is calculated between the 3 foot and 7 foot markers unless noted otherwise.

$$Rate\ of\ Spread\ (feet/minute) = \frac{4\ feet}{time\ (in\ minutes\ between\ the\ 3'\ and\ 7'\ markers)}.$$

This calculation is imbedded in the LabVIEW software but can be calculated manually from the raw data.

4.3. RATE OF WEIGHT LOSS

4.3.1. Measurement in grams; this is calculated between the 3 foot and 7 foot markers unless noted otherwise.

$$Weight\ Loss\ (grams/minute) = \frac{(total\ weight\ loss\ (between\ 3'\ and\ 7'\ markers)}{time\ (in\ minutes\ between\ the\ 3'\ and\ 7'\ markers)}.$$

This calculation is imbedded in the LabVIEW software but can be calculated manually from the raw data.

4.4. REDUCTION INDEX

4.4.1. The reduction index (RI) is used to compare the performance of the experimental product to that of an untreated fuel bed of the same fuel type.

$$R.I.(excelsior, pine\ needles)\ =$$
$$\left(\frac{Average\ Rate\ of\ Spread\ of\ Untreated - Average\ Rate\ of\ Spread\ for\ the\ 2\ GPC\ product}{Average\ Rate\ of\ Spread\ of\ Untreated}\right)$$

The calculation for each fuel type is conducted separately and the RI of the product is then averaged for both fuel types and compared to the average RI of 10.6% DAP. For a product to pass the test, the following shall be true:

$RI_{product} > RI_{10.6\%\ DAP}$.

5. Training

5.1. Training is provided and supervised by a qualified analyst.