Operation and Fueling (O/F) Workgroup Meeting Notes from October 6, 2016 Teleconference

(Note: Voting Members are in bold-face)

Meeting led by **John Crouch** (HPBA, Co-Chair of O/F Workgroup), **Marc Cohen** (Massachusetts DEP, Co-Chair of O/F Workgroup), **Lisa Rector** (NESCAUM, Co-Chair of Steering Committee)

Meeting Invitees (not necessarily all present): Bob Lebens (WESTAR, Co-Chair of Steering Committee), **Rod Tinnemore** (Washington) **& Phil Swartzendruber** (Puget Sound Clean Air Agency), **Cindy Heil** (Alaska), John Wakefield (Vermont), **Lisa Herschberger** (Minnesota), Ann Jackson (Minnesota), **Randy Orr** (New York) **& John Barnes** (New York), Adam Baumgart-Getz (EPA OAQPS, Wood Heater NSPS Group Leader), Amanda Aldridge (EPA OAQPS, Wood Heater NSPS Lead), Stef Johnson (EPA OAQPS, Measurement Group Leader), Mike Toney (EPA OAQPS, Measurement Group), Bob Ferguson (Consultant to HPBA, President of Ferguson, Andors & Company), **Tom Butcher** (Brookhaven National Lab, BNL), Rebecca Trojanowski (BNL), Adam Bennett (BNL), **Gregg Achman** (Hearth & Home Technologies), **Allen Carroll** (Applied Ceramics), Rick Curkeet (Intertek), **Ben Myren** (Myren Labs), **John Voorhees** (US Stove), **Tom Morrissey** (Woodstock Soapstone), Dan Henry (5G3 Consulting), Mark Champion (Hearth Lab Solutions), John Steinert (Dirigo lab), Doug Towne (Dirigo lab), Gaetan Piedalue (Polytests lab), Jared Sorenson (OMNI lab), Sebastian Button (OMNI lab), Alex Tiegs (OMNI lab), Kelli O'Brien (ClearStak), Jeff Hallowell (Biomass Controls), Lee Mitchell (Applied Catalysts), Martin Morrill (Applied Catalysts), Jill Mozier (EPA contractor, meeting note taker)

Primary Conclusions from Meeting:

- The next two O/F Workgroup meetings will be held on October 13th at 11 am EST (Christoph Schmidl's beReal presentation) and October 20th at noon EST (Rick Curkeet's specific gravity/density presentation).

- The details of today's presentation are noted below in the meeting highlights as well as in Bob Ferguson's presentation slides posted to Basecamp. This is background material to educate the group; no official conclusions have yet been drawn by the group.

- Regarding measuring moisture content in cordwood, the ASTM Task Group (TG) working on ASTM's cordwood method has not seen data comparing (a) the ASTM draft, (b) the SUNY ESF method, and (c) the ASTM oven dry methods directly to each other on well-equilibrated fuel pieces. The ASTM TG would like to see data collected from all three methods on the same fuel pieces at the same time.

To-Do List:

- The group should post any questions based on Bob Ferguson's presentation, regarding the ASTM cordwood method, to Basecamp.

Highlights from Meeting:

- John Crouch and Lisa Rector opened the meeting, introducing Bob Ferguson as today's presenter. [Lisa Rector could not stay on the line for the rest of the meeting.] John thanked everyone for joining the O/F meeting and webcast and noted that Rick Curkeet's presentation regarding density will be held on October 20th. There were no process/administrative questions from the group.

- John turned the meeting over to Bob Ferguson, noting that Bob had uploaded a lot of material regarding the ASTM process to Basecamp, which the group could download to view at any time.

<u>Bob Ferguson's ASTM Cordwood Test Method Development Discussion (continued from last week)</u>:

- Regarding the volume of ASTM material uploaded, Bob noted that the ASTM process was long and some issues were wrestled with for years, only to be re-visited again. Bob noted that the ASTM process is a consensus process that is not afraid to address issues again, as needed. Bob further explained that this presentation was given to EPA in February and took 5 hours, but he was trying to cover the material as quickly as possible.

- Bob picked up with where he left off last time, beginning with Slide 9.4.1.2 *Test Fuel Sub-load Concept*, slide #20. Bob noted that determining the composition of the test fuel loads also consumed a big part of the Task Group (TG) interactions. The starting point for defining the load composition was CSA B415.1-10. The CSA technical committee debated this issue throughout their standards development effort. CSA came up with a table, which divided up firebox volumes into several categories based on firebox volume and cross-section, weight and number of cordwood pieces (see table on slide #20 in ASTM Cordwood TM Presentation Part 1, on Basecamp). This fuel load composition was adopted for the Cordwood Annex in ASTM E2780, but unfortunately there was little or no use of the Cordwood Annex. So it really wasn't tested on woodstoves.

- When the interest in cordwood testing for room heaters was reinitiated, it soon became obvious that the CSA wood load table did not have adequate resolution for the firebox volumes associated with woodstoves. The CSA load table was focused primarily on much larger central heater fireboxes (up to 20 ft^3). Most woodstoves fall within the lowest delineation (<4 ft^3). The piece size gradations were simply too course. Therefore, an initial proposal was made to simply increase the resolution for firebox volumes in the range of interest, to make the table more granular (see table on slide #21). However, the TG concluded that there was too much potential variation in the load composition using the simplest table concept. The TG determined that what was needed was a means to allow some of the randomness associated with cordwood, along with some control over how far the wood pieces and load configuration could stray from the middle of any typical distribution (of piece size, geometry and number of pieces). In other words - to account for the randomness but still have some control over the load. Thus, a number of fuel load and wood piece sizing criteria were evaluated, in attempt to keep a simple table.

- Bob discussed the table on slide #23. In this case, the table approach was expanded to be more granular in terms of defining piece weight and composition of the overall test fuel load across the full range of woodstove sizes. Tables relating load volume to firebox volume were also proposed. (See table on slide#24). The concept was that the test fuel loads, in term of the number of pieces and volume occupied in the firebox, would be the same regardless of the specific gravity (SG)/species of the fuel used. However, it could result in widely different fuel load weights and the TG still needed to define the fuel load composition and fuel piece specs.

- Thus "GO-NO GO" gauges were proposed as a way to better control individual fuel piece cross-sectional dimensions. (See diagrams of circular and square portals on slide #25.) However, weaknesses were ultimately uncovered for each of the initial options. For example, slabs fit through.

- Therefore, the *Test Fuel Sub-load Concept* was attempted. Thus was born the concept of separating the test fuel load into two parts, strictly for the purposes of defining the overall load composition. A single fuel load still results. The first part, or core sub-load, represents the more typically sized fuel pieces in any cordwood pile. There are somewhat tighter limits on the range of individual piece weight that can be used. It always consists of three fuel pieces. It comprises 45 – 65% of the total load weight. This was done to eliminate a totally homogeneous sub-load (all the pieces nearly the same), some piece weight variation is required but still controlled. The smallest piece in the sub-load cannot exceed 67% (two-thirds) of the weight of the largest piece. Bob noted that much of this may not make sense initially, but Bob will take questions and it may make sense after progressing through the presentation material more.

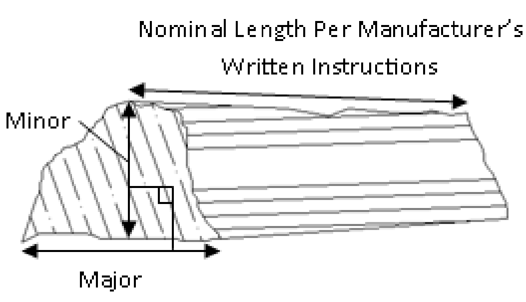
- The second part of the fuel load, or remainder sub-load, comprises the rest of the test fuel load. This can vary from 35 – 55% of the total fuel load weight. The number of pieces in this sub-load varies depending on the firebox volume and/or test run category. In each case, however, there is a range in the number of pieces allowed (so as to not over-specify this):

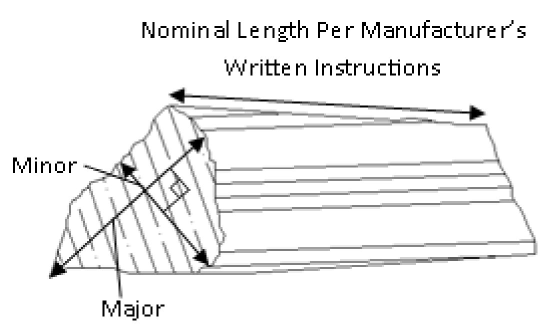
  Low & Medium Fire Tests:
    - ≤ 3 ft^3 – 2 or 3 fuel pieces
    - >3 ft^3 – 3 or 4 fuel pieces

  All High Fire Tests
    - 1 – 3 fuel pieces

  The weight range for each individual fuel piece is also broader than for the core sub-load.

- In all cases, there is a required minimum ratio of the minor and major fuel piece cross-sectional dimensions (to eliminate fuel pieces that don't look like typical cordwood).





The minor dimension must be at least 40% of the major dimension. The full test fuel load ends up looking like a reasonable representation of what a stove user might load into the stove. A mix of pieces of similar size plus some larger and smaller pieces. Bob noted that when people started using it, this was found to be workable. The allowable ranges were identified by experimentation.

- This protocol might seem complex at first look or to the uninitiated. However, the concept was fully exercised across a range of firebox volumes and configurations by test labs and manufacturers alike and as each issue was uncovered it was worked through by the TG. For example, the allowable weight ranges for the two sub-loads were determined by experimentation which identified the need for some flexibility (weight ranges) when working with cordwood. Using this methodology allows overall test fuel load weight range to be tightened to ±5% of the nominal. Previous tolerances have been ±10%.

- The ASTM TG developed the *Test Fuel Load Calculator* to de-mystify the procedure AND, equally as importantly, to ensure consistent application of the fuel loading requirements across all testing entities. The calculators standardize the application of the test load parameters from the method into Excel spreadsheets. The Excel spreadsheets have been made available to the TG and all other interested parties for "beta" testing and review since the earliest versions. The early versions were used as part of Mark Champion's extensive test program and were put to the test by his very experienced lab technician. The feedback was always very positive and the conclusion was that this system worked well.

- The spreadsheets continued to evolve and now include more information than just the test load composition. They are now interactive. Input the key data and the spreadsheet calculates and then evaluates whether the test load requirements have been achieved. Problematic fuel pieces are identified. Adjustment to individual fuel pieces can then be made until a fully compliant load is achieved. There is a learning curve to using the calculator spreadsheets, but they are quickly mastered. Subsequent test runs for a given model may use the first run as a template to very quickly reproduce a valid test load. So the calculator expedites the process, Bob explained, especially on subsequent loads.

- Based on the method requirements, there are three separate calculators:
    - Low & Medium Fire Tests with ≤ 3 ft^3 useable firebox volume (UFV)
    - Low & Medium Fire Tests with > 3 ft^3 UFV
    - High Fire Test with all UFV

  The load calculator workbook will be available from ASTM as an adjunct to the method. It is password protected to prevent tampering.

- Bob demonstrated the Load Calculator on the webcast (See slide #33 on Basecamp). Data is entered in yellow boxes (e.g., usable firebox volume, the weights of the core load pieces, the weights of the remainder pieces, the kindling weight, the start-up fuel weight, the residual start-up fuel weight and the fuel load ending weight). Other colors are outputs. The calculator will give allowable piece load weight for core load. If any piece is out of range, it will immediately tell you that in red. This holds true for all the parameters. If there is any red on the calculator that means your load is not in compliance with the standard. (Otherwise, it's "In Range".) There are also requirements for kindling amount and start-up fuel load. The calculator will also ensure these are within the allowable ranges. On the other side of the calculator, Bob noted that the calculator will give you the dry load basis. All calculations are done automatically, which ensures people don't have to attempt to interpret [or misinterpret] the standard.

- Bob showed photos from Mark Champion's testing, showing newspaper, kindling, start-up fuel, core loads and remainder loads for several different size UFV (1.42, 1.80, 2.10, and 3.1 ft^3 UFV). Bob noted that these loads looked reasonable for the stoves. Bob asked the group if there were any questions.

- Lisa Herschberger asked about the balance between reproducibility/controlling variability versus allowing for some real-world variability and how that balance was addressed by the ASTM TG. Bob explained that the TG realized the method couldn't be all things to all people in the field. There couldn't be infinite variability. Therefore, the TG talked about trying to stay more towards the middle of loading. Bob noted that it was not super scientific, but it was based on many people with decades of design, testing and wood stove use experience. It was a meeting of the minds to allow some of the randomness, while cutting off extreme ends of possibilities. The TG didn't do specific testing of a no control option versus some X level of control. Rather, the TG relied on the best judgements of experts to come up with a fuel load that has some randomness in order to be representative, while controlling to the extent the TG could/felt reasonable.

- Lisa Herschberger asked what the method might look like if someone wanted to make it more variable. Bob explained that the method (in that hypothetical case) wouldn't put any constraints on piece length or weight, or the method might prescribe a certain weight but allow infinite variations to achieve that test load weight. That would allow infinite variation, but it wouldn't ensure any consistency regarding the load type in the lab. The TG wanted a balance of difference and similarity.

- Lisa Herschberger wondered if, in an extreme case, a tester could follow ASTM and then use one giant load and see how the stove responded. Lisa continued that she imagined, if the stove met the emissions limit in both cases, it would be a very good stove. Bob noted that a manufacturer/tester could also go to the other extreme of loading a stove with 20 small pieces. Bob explained that both of those extremes (one large piece or many small) will present challenges for the stove designer, in terms of actually being able to design a stove that could control emissions from very small pieces to very large. Ideally that would be the case/possible, but a consumer controlled product doesn't make for an ideal world. If there were lots of research money, we could test at the extremes [of fuel load] to see what happens, Bob noted. But the ASTM TG attempted to get to a starting point so people [manufacturers] would start burning with cordwood. Bob again noted however that the ASTM process allows re-opening when new information is available.

- Rick Curkeet noted that the ASTM TG also approached it from the other direction. That is, the TG didn't want the method to be so open or unregulated that manufacturers would hunt for the best load to give the lowest emissions. Rick explained that the TG didn't want to allow, for example, putting 2 big pieces in at a low fire for a long burn, resulting in low emissions [with time in the denominator]. Rick noted that that's not what consumers would do. Bob agreed, noting it was the balance between randomness and control/consistency. Bob explained that the TG did take a tremendous amount of input regarding this issue; the TG spent a huge amount of time on this over a few years, along with a couple other issues. How the TG defined the load took a lot of discussion. Lisa Herschberger thanked both Bob and Rick.

- Bob started going through Part 2 of the ASTM Cordwood Test Method for Room Heaters: *Highlights of the Proposed Method*, including Section 9 Procedure pertaining to Test Fuel Load Requirements (Test Fuel Properties) and the High Fire Test Category. Bob noted that Rick was supposed to give his presentation on specific gravity/density which would have been helpful for this, but Rick will give that presentation on Oct 20th.

- Section 9.4.2.1 of the ASTM CTM regards *Fuel Species and Properties*. Based on the work done during the development of CSA B415.1-10, fuel specific gravity was chosen over fuel species as the more reliable way to define and differentiate key properties. Fuel species within the allowable Specific Gravity (SG) range are generally available throughout the country. This solves a number of regional fuel availability problems. There are tight restrictions on shipping cordwood between and even within states. Cordwood has to be locally sourced (as it can't be shipped more than 50 miles in most places). Split cordwood can be difficult to identify in terms of exact species, and cordwood loads are often a mixture of species.

- The CSA B415.1 SG range of 0.60 – 0.73 was ultimately expanded to 0.48 – 0.73 to allow the use of some softwood species (including Douglas fir). This was requested by Rod Tinnemore with support from the West Coast manufacturers. It was commented that lower specific gravity species are less likely to be used anywhere hardwood species are available. And, in general, given the chance, stove users are more likely burn the highest specific gravity fuel they can find in their location (because of economics - $$ per BTU). This included a range of hardwood species in at least the mid-west and northeast. Some higher SG fuels are burned in all regions. An article by Dr. Houck summarized his findings regarding the split between hardwood and softwood use across the country. It must be noted that Pacific Northwest and some mountain states are not included in his table of survey results. The table published in Hearth and Home in 2007. See slide #5 from the ASTM Cordwood TM Presentation Part 2 on Basecamp.

- Test fuel moisture determination evolved over the course of the test method development before finally reaching the current requirements. Options considered included: Continuing with EPA M28 and ASTM E2780 procedure (a minimum of three readings per test fuel piece); Using the moisture meter manufacturer's electrode penetration guidelines which are based on extensive research including the USDA Forest Products Lab; Increasing to a minimum of five readings with two probe penetration depths following the HH test procedure; Tightening the location and depth accuracy requirements for probe penetrations; Evaluating the BNL/SUNY procedure [This was done during the initial method development and again after receiving a negative regarding moisture determination during the last ballot cycle (Jan. 2016)].

- The State University of New York College of Environmental Science and Forestry (SUNY ESF) method is intended to provide a solution to the consequences of forced drying of high moisture wood to be used for testing without significant additional conditioning. The TG felt that forced drying without additional conditioning is not an acceptable process as it creates potentially large moisture gradients within fuel pieces which is likely to produce combustion patterns that are not representative of real-world seasoned cordwood. Experience with forced drying has shown that core moisture content (MC) can be above 40% while the outer layers are below 10%. If it is necessary to force dry wood to obtain an adequate supply, the proper process is to dry cut and split pieces at a moderate temperature (<140°F) and then allow for a minimum period of 3 to 4 weeks of conditioning at ambient temperature and humidity to allow the moisture gradient to re-equilibrate and stabilize. Samples can be checked to verify that the gradient is not too large.

- It is preferable for labs to use wood fuel that has been naturally seasoned and stored under controlled conditions for at least several months before measurement and use. This, after all, best reflects homeowner use practices, which is the one of the core design principles that has guided the development of this method. Wood fuel that has been handled in this manner does not require special procedures to accurately determine MC. It may also be necessary for the labs to store test fuel in a temperature and humidity controlled environment to prevent the fuel from drying below the prescribed MC range (as Bob explained wood can dry out to below what homeowners typically use). Wood pieces that have been conditioned for a substantial period of time under reasonably controlled conditions develop a moisture content gradient, from center to surface, with a parabolic distribution. Hence, measurement of MC at the 1/4th to 1/5th of the piece depth, as recommended by the meter manufacturer, provides a good measurement of the average MC across the gradient. The accuracy of the available moisture meters is claimed to be +/- 2% MC above 20% MC (that is, a 20% can be an 18% or a 22%). If it is assumed that the error is random and averaging the many readings taken under the proposed procedure reduces the uncertainty of the average to a small value. For a typical fuel load in the draft ASTM method, the average fuel moisture of the test fuel load will be determined by at least 12 total readings and often 15 or more.

- The accuracy of the MC determination has no significant influence on the appliance test results as it is only used to determine the actual dry weight of the fuel. This weight is used to calculate dry burn rates and total heat input in efficiency determinations. In both cases an error on the order of +/- 2% in the MC determination results in a negligible effect on the key results. Note that the effect on B415.1 stack loss efficiency calculation is small since any error in the dry weight determination and thus the total heat input is present in both the numerator (Heat Input – Heat Loss) and the denominator (Heat Input). The net effect is that a 2% error in MC results in less than a 0.5% error in efficiency (because errors essentially cancel each other out, Bob clarified). The critical determination is really whether the MC of the individual fuel pieces and the average MC of the test fuel load fall within the allowable ranges.

- Experiments comparing the moisture determination protocol in the ASTM draft to oven-dry moisture determination have been undertaken by several labs and companies. Mark Champion did a comparison study as part of the previously mentioned cordwood method development testing he conducted. (See table from slide #10, below)

		Pin readings, 1/5 to 1/4 depth				Into Kiln, 212 deg F, 12/26 1400, drying weights, lbs						
Sample	Wet Weight, lb	Left	Center	Rgt	Pin Avg	12/27			12/28	Min Weight	Calc MC, dry	Pin Error, MC %
1	4.20	18.8	20.6	22.7	20.7	3.55	3.53	5.13	3.52	3.52	19.3	1.4
2	6.49	18.5	19.6	21.1	19.7	5.52	5.44	5.42	5.42	5.42	19.7	0.0
3	5.98	15.1	17	23.2	18.4	5.13	5.08	5.07	5.06	5.06	18.2	0.3
4	4.42	15.5	15.3	18.2	16.3	3.8	3.78	3.78	3.77	3.77	17.2	-0.9
5	4.54	17.8	20.6	22.7	20.4	3.79	3.76	3.75	3.74	3.74	21.4	-1.0
6	7.15	24.2	23.8	26.1	24.7	5.94	5.82	5.81	5.8	5.8	23.3	1.4
7	6.24	13.9	9.3	19.1	14.1	5.51	5.47	5.46	5.45	5.45	14.5	-0.4
8	6.14	23.2	23.7	26.1	24.3	5.08	4.98	4.98	4.97	4.97	23.5	0.8
				Load Straight Average	19.8						19.6	0.2

- So far, the TG has not seen data comparing the ASTM draft, SUNY ESF method and ASTM oven dry methods directly to each other for well-equilibrated fuel pieces. In other words, the TG has never all three methods on the same fuel pieces at the same time. Bob noted that ASTM would like to see such research.

- The Current Proposal Requirements include: A minimum of three readings per piece – two ~3" from ends, one at the center, all on different sides of the fuel piece; Electrode penetration 1/5 to 1/4 of the piece thickness at the measurement location (to give the approximate average moisture across the gradient); An expanded allowable average moisture range for each fuel piece to 18 - 28%, recognizing the need for more flexibility since managing cordwood on a frequent testing basis can be challenging; An average MC requirement for the full test fuel load of 19-25% Dry Basis (which is consistent with other test methods). Accelerated drying was added by the TG with conditions on maximum temperature and the requirement for a minimum of three weeks before using fuel, to allow fuel MC to re-equilibrate. Moisture content requirements were added for kindling and start-up fuel after the cold start requirement was added to the method.

- Regarding Section 9.4.2.6 *Test Fuel Piece Length*, Bob noted that the method is per the manufacturer's recommendations for nominal fuel piece length. All fuel pieces in test fuel load must be ±1" of the nominal length.

- Regarding the *High Fire Test Category* (ASTM CTM Section 9.5), Bob noted that when the current ASTM cordwood test method development process began in 2013, all test runs were hot-to-hot test cycles, following the precedent from EPA M28, ASTM E2780 and CSA B415.1-10. Much of the method development activity was focused on defining the test load parameters as described earlier in this presentation. However, beginning in July 2014 the importance of adding a cold start to the test protocol was brought to the TG (thanks to James Houck's work).

- Dr. James Houck had pointed out, based on his research, that a key difference in lab testing results compared to in-home performance, beyond the obvious use of cribs versus cordwood as the test fuel, was the fact that homeowners start their stoves from a “cold” condition with some significant frequency. Although this was not actually new information in 2014, it finally attracted the attention of the ASTM TG with the realization that moving to cordwood without including a cold start was only achieving part of the stated goal – development of a new cordwood test method that more closely represents the way stoves are used in homes. This opened a gigantic can of worms and the TG discussed it for months, Bob noted.

- Adding the cold start to the test method would become the dominant subject before the TG for many meetings. At the beginning of the process, we looked at the only ASTM solid fuel method that includes a cold start: ASTM E2618-13, Annex A2 for testing hydronic heaters that employ partial thermal storage was examined. Although many of the issues addressed in the PTS HH Annex are similar in nature to those for a room heater method, the specific differences in the appliances and how they operate obviously implicates many differences in many of the details.

- One place there was similarity that carried over was in the definition of the conditions that defined a cold start. In a PTS HH, they run the heater and then allow the system to cool until the thermal storage is 125±5°F. They then shovel all remaining fuel and ash out and start the test run. The TG Proposed that for a wood stove/room heater the average surface temperature and the flue gas temperature must be less than 40°F above ambient (which means a maximum of 130°F if the lab is at the maximum allowed 90°F). Two factors drove the TG to the current limit: the amount of heat stored in the test unit at the 40° ΔT limit represents a fraction of 1% of the total heat input during a high fire test run. This was not felt to have a measurable impact on the test results. The other factor which drove the TG to the current limit is the practical consideration for “production” testing situations, where waiting for the last few hundred BTU to dissipate wastes expensive lab time.

- However, during the most recent round of balloting, a negative and comment were received regarding the 40°F limit over ambient for the average surface temperature and the flue gas temperature. The TG eventually agreed to reduce the starting temperatures to 10°F over ambient after recognizing that a fan could be used to remove residual heat from the stove and lower the temperatures without causing significant delays in the lab.

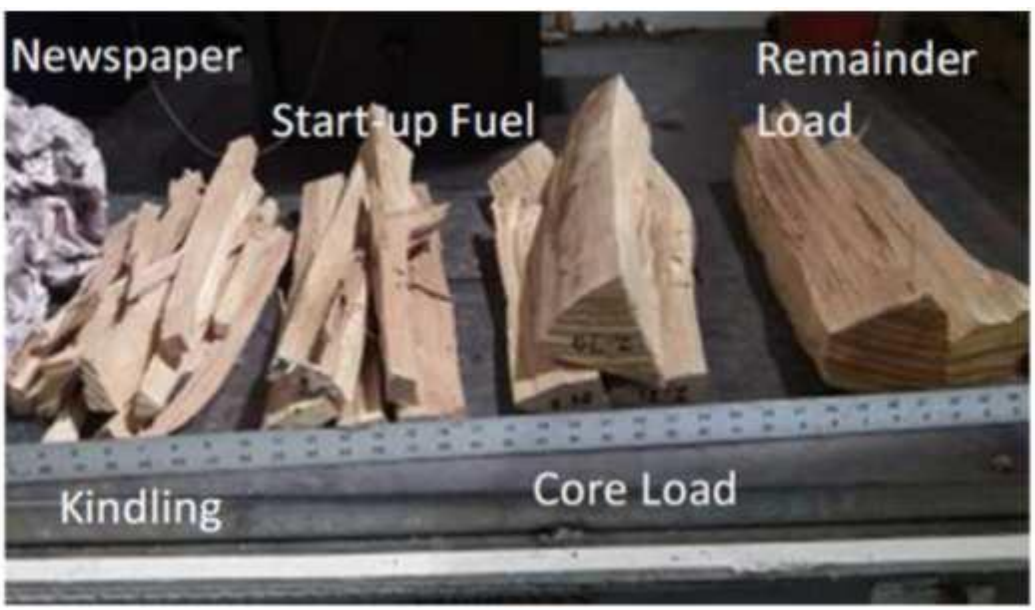
- Regarding *General High Fire Test Requirement Highlights*, Bob explained that the primary air control(s) are always at their maximum setting. The nominal load density requirement is 10 lb/ft^3 because the initially proposed 7 lb/ft^3 resulted in a volume of fuel in the stove that looked too small (Bob noted he didn’t have photos, but Ben Myron did a lot of research into this). An exception to this load density requirement was also added. Rather than adopt an unproven sliding scale to accommodate small or atypical fireboxes, the following exception was added: if it is physically impossible to achieve the minimum 9.5 lb/ft^3 (the low end of the tolerance) despite exercising all of the piece size and other fueling flexibility allowed in the method, the stove must be operated with the actually achievable maximum load density. This exception must be fully documented and the load density that is achieved reported. It must also be confirmed that the average stove body and flue gas temperature are below the required limit as part of the data recording requirements.

- John Crouch explained that the reasoning behind this is that the method might inadvertently disqualify some small woodstove (e.g,. stoves from Europe, some of which have firebox volumes less than 1 ft^3). ASTM's intent is a 9.5 ft^3 load, but if that is not possible, then the manufacturer/tester should load the firebox as fully as possible. This exception allows smaller stoves not to be disqualified. The ASTM TG wanted to work around the exceptions, which would immediately crop up.

- Regarding Section 9.5.6 *Kindling*, Bob noted that kindling may be up to 20% of the test fuel load weight, with a moisture content between 6 and 12% DB.

- Regarding Section 9.5.7 *Start-up Fuel*, Bob explained these are slightly larger pieces than kindling and can be up to 30% of the test fuel load weight, with a moisture content the same as test fuel load (between 19 and 25% DB).

- Both the amount of kindling and start-up fuel were based on testing and observation. Higher amounts were proposed at various points but ultimately rejected. Visual appearance of the quantities played a role in the decision (i.e. does it look right?). Simply asked, did the amounts look reasonable from a homeowner's perspective AND is there enough fuel to consistently get the stove going before the main test fuel load is added and keep the test fuel load burning after it loaded.? See photos on slide #20 including –



- Emission sampling begins immediately before the kindling is ignited. Both the kindling and start-up fuel are placed and ignited in accordance with the manufacturer's instructions. This allows possible innovations in the way the stove is started to minimize emissions (e.g., top-down burn). Bob noted that the ASTM TG didn't want to stifle innovation.

- Kindling and start-up fuel are burned until 10-20% of the test fuel load weight is reached. This remaining fuel is referred to as "residual start-up fuel" but could contain some partially burned kindling. This range was based on testing by Mark Champion and others. It was observed that the 20-25% "charcoal bed" range from EPA M28/ASTM E2780 was too high, due to the increase in the nominal loading density. With the increase in the nominal loading density from 7 to 10 lb/ft^3, the charcoal bed weight increases proportionally. Thus it was difficult to get the test fuel load in with that much residual fuel in the stove. There can be too much raw wood and flaming.

- Bob showed photos of various size fireboxes with the newspaper, kindling and start-up fuel all in together and the significant flaming and raw fuel that results with 25%, 20%, 15%, and 10% residual start-up fuel load remaining, and finally photos of the test fuel added when 10% of the residual start-up fuel is left. See slides #23 to #28 on Basecamp. These photos are from the stoves that Mark Champion tested.

- Bob noted the following conclusions regarding the residual start-up fuel weight range:
    - Lowering the residual start-up fuel weight range appears to make sense based on available data and observations. The originally proposed 25% upper limit (and maybe even a 20% upper limit) could result in start-up conditions at the point the test fuel load is added that are not very representative of conditions when a homeowner might actually add the first fuel load after a cold start. There is also some thought that loading at the high end of the currently proposed range could contribute to increased variability of results.
    - Lowering the range to 10 – 15% may be warranted.
    - It was ultimately agreed by the ASTM TG that 10 - 20 % would be the best option.

- Other high fire test requirements include:
    - Residual fuel bed must be documented by photo or video before and after any adjustments and before test fuel load added.
    - Test fuel must be loaded in accordance with the manufacturer's instructions. The test fuel load must be documented by photo or video before and after loading.
    - Maximum load time is 30 seconds per cubic foot (ft^3) UFV with a minimum of 60 seconds (that is, the least amount of time is 60 seconds – Bob noted this isn't much time, as maneuvering is needed for small stoves and more pieces are needed for large stoves). Bigger fireboxes can take longer to load than smaller ones. To be clear, the entire fuel load (core and remainder portions) must be loaded within the maximum loading time. So, for example, a 3 cubic foot stove would have 90 seconds to load.
    - Emissions are sampled during this time, so no PM are being missed.

- There are provisions for: Using a portable propane torch (in accordance with the manufacturer's written instructions and limited to 60 seconds). There are also provisions for automatic ignition systems, so that the stoves are allowed to operate as designed. Likewise, there are provisions for supplemental energy input. Any supplemental energy that is added (other than the 60 seconds of propane torch use) must be accounted for in the overall energy efficiency determination. ASTM is trying not to stifle innovation, but at the same time, is also accounting for all energy when determining efficiency.

- The fuel load door can be in any position per the manufacturer's written instructions during the first five minutes after the test fuel load is added. Fuel adjustments may also be made during this time.

- Test fuel pieces may also be adjusted once, until 15 minutes after the maximum load time has lapsed or until 15% of the test fuel load weight is consumed, whichever is less. This might be done if a fuel piece fell forward onto the glass – a situation that a homeowner would correct in order to keep the glass clean. (Bob noted that the ASTM TG was trying to replicate homeowner behavior.) Any fuel adjustments need to be less than 30 seconds in duration and fully documented with before and after photos or video (so people can't game the system).

- The test fuel load may be adjusted one additional time after 60% of the test fuel load weight is consumed AND only if there is no measurable weight loss in a 10-minute period. This adjustment also must be documented with before and after photos or video.

- Regarding Section 9.5.9.8 *High Fire Test Run Completion*, Bob noted that the proposed 90% ±1% of test fuel load weight burned was based on the testing conducted by Mark Champion. What stood out in the majority of the high fire test runs was that even at maximum primary air settings, the stoves still "tailed" for long periods of time. The charcoal is generally in a somewhat compact configuration with the bottom of the pile not engaged to any great degree in the fuel combustion that is occurring.

- Bob explained that waiting for the last 10% of the fuel weight to be consumed was in some cases almost doubling the test run duration. The consequence that emission rates (g/h) and heat outputs (Btu/h) were reduced in ways that it was agreed were misleading on the low side. This might lead to consumers oversizing stoves, Bob noted.

- After all volatiles in the test fuel have been consumed (all yellow flaming has ceased) essentially 100% of the PM emissions have already been captured by the 90% cut-off point. The other reason was the visual appearance of the fire—in other words, when did the stove look like it was ready to be reloaded? Mark Champion used his judgment, having been a wood burner at home, a stove designer and a stove tester for many years to make that visual determination and then looked at the corresponding data. The 90% test load weight cut-off was very consistent across the stove models. It was also noted that real world stove users rely on the same type of visual cue since they have no way of knowing the remaining fuel weight.

- Bob showed two photos from a 3.1 ft^3 non-catalytic stove depicting all yellow flaming ceasing at 2.8 pounds and also depicting that the stove looks ready to be re-loaded at 2.6 pounds (see slide #36 on Basecamp). All yellow flaming has ceased after 244 minutes from adding the test fuel load. The remaining load weight at that point was 2.8 lb. At this point, 91% of the test fuel load weight has been consumed. It is projected that the remaining 2.8 lb of charcoal could take 3 hours or more before it is consumed. This would result in a high fire test run over 7 hours in duration and an average high fire burn rate (and corresponding heat output rating) well below the true capability of the stove. This could lead to oversizing stoves in homes and more smoldering burns.

- Bob noted that the ASTM's final determination reflects an elegant solution which is practical in a laboratory environment and a realistic reflection of homeowner behavior (since heat output and visual cues likely trigger a reloading point, especially if high heat output is desired). A more realistic high heat output rating for consumers is thus produced. And this solution addresses concerns of EPA and many state regulators who have repeatedly voiced concerns over "long tails" of tests potentially skewing test results (on a g/hour basis). Finally, Bob noted that in almost all cases, the 90% cut-off allows a low or medium fire test run to be conducted using the remaining high fire test charcoal bed.

- Bob noted that this concluded the second portion of his ASTM cordwood test method presentation, although there is a third section. Bob explained that the presentation represents 3 years of work and apologized for how fast he went through it, noting that going fast was the only way to get through it.

- John Crouch encouraged people to make notes of their questions and perhaps post their questions to Basecamp.

- John noted that the O/F workgroup call will start next week at 11am EST, in order to allow Christoph Schmidl from Germany to present on the beReal method. After next week, the group is back to regular time (noon EST) the week after that. There were no questions and John thanked everyone for their attention and participation.

- **Meeting adjourned.**