Operation and Fueling (O/F) Workgroup Meeting Notes from September 29, 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), **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 Town (Dirigo lab), Gaetan Piedalue (Polytests lab), Jared Sorenson (OMNI lab), Sebastian Button (OMNI lab), Kelli O'brien (ClearStak), Jeff Hallowell (Biomass Controls), Jill Mozier (EPA contractor, meeting note taker)

Primary Conclusions from Meeting:

- O/F Workgroup meetings will be held on October 6, 13 and 20, 2016 with the beReal presentation by Christoph Schmidl happening from 11am until noon on October 13th.

- The details of today's presentations are noted below in the meeting highlights as well as in the presentations posted to Basecamp. This is background material to educate the group; no official conclusions have yet been drawn by the group (except for the next bullet).

- It would be very useful to research the typical degree of variation in cordwood piece length and weight (before getting outside the norm), burned across the nation.

To-Do List:

- Lisa will set up the October 13, 2016 presentation by Christoph Schmidl of beReal.
- Lisa will upload Tom Butcher's presentation regarding wood species to Basecamp.
- Anyone in the group who has additional suggested citations regarding wood species studies should e-mail those suggestions to Tom Butcher of BNL.
- Anyone in the group with questions for Bob or Tom should post their questions to Basecamp.

Highlights from Meeting:

- Marc Cohen, John Crouch and Lisa Rector opened the meeting. Marc reviewed the agenda (attached) and Lisa did the roll call. Note that the attached agenda reflects revisions decided upon in this meeting and includes the agenda for today (September 29), October 6, October 13 and October 20, 2016.

- Regarding scheduling, Lisa noted that she had tentatively blocked 11 to noon on October 20th with Christoph Schmidl of BeReal. That would mean a 2.5 hour call on October 20th (due to the other agenda items for that call) which may be too long. Lisa noted that there are 3 options: do the BeReal call on October 13th; do the marathon call on October 20th; or push the BeReal call to November 3rd. Marc suggested doing 11 on October 13th, as this is the most manageable and the presentation would be helpful sooner rather than later. John Crouch noted concern that since Bob Ferguson's presentation is spread out over 3 calls, interrupting those calls may lose the thread (of understanding). Marc noted that the BeReal effort looks at how homeowners really operate their stoves and this was also an important consideration during the ASTM test method deliberations. Therefore looking at the outcome of the BeReal survey will aid the group's understanding rather than interrupting the flow of information. Bob Ferguson agreed, noting it made sense to have the call on October 13th from 11 to 12.

- Lisa noted that the calls are every week starting today for 4 weeks. No one noted a problem with this. Lisa will e-mail Chris Schmidl and set up his presentation on October 13, 2016. Lisa further noted that these 4 calls are background calls with the calls in November starting to focus on discussion items. Marc and John agreed.

Tom Butcher's Wood Species Impact Discussion:

- Marc introduced Dr. Tom Butcher from BNL who began presenting slides entitled "Summary of Literature Review for Wood Species Impact on Emissions" by R. Trojanowski and T. Butcher of BNL. [Note: These slides are posted to Basecamp.]

- Tom noted that he would go over some things that BNL has looked at in the literature regarding wood species and go over what's already known, starting out with a primer on wood species that many in the group may already know. Tom further noted that he's sure that there's literature out there he has missed and therefore asked everyone in the group to send him additional literature (or citations) that should be reviewed. Tom also noted that the BNL work is admittedly slanted toward red oak and Douglas fir, as that pertains most to the research BNL is currently doing.

- Regarding the primer on species, Tom noted that hardwood (deciduous) trees generally have broad leaves which are shed in the fall, usually (not always) are of higher density than softwoods, and have vessels/elements that transport water similar to "pores". Softwoods (conifers) have needles all year, medullary rays and tracheids transport water and produce sap, faster growing than hardwoods and generally lower in value. Note that tracheids are long, thin longitudinal cells in softwoods that act as pores, take up 90% of the volume of the tree and serve to carry sap. Sap gets secreted into the tracheids when the tree is injured.

- Regarding softwood structure, Tom noted that medullary rays are sheets extending through the tree perpendicular to the growth rings, consisting of parenchyma cells that allow sap to flow outward to heal injury. Tracheids are an element of the plant's vascular tissue and consist of elongated narrow tube like cells with cell walls composed of lignin. Tracheids help transport water from the roots to the rest of the plant.

- Tom noted that Barbara Cole from the University of Maine did research on the extractive components of wood. Wood extractives are non-cell wall components that can be removed using solvents (e.g., pet. ether, acetone, ethanol, water). These are relatively small molecules ($<C_{40}$) and usually comprise 1-5% of the wood. Wood extractives are under genetic control and therefore vary by species. Softwoods have more extractives than hardwoods. Barbara Cole's research also notes that softwoods have resin acids (40-45% of extractives), fatty acids (40-60%), monoterpenes (turpentine) and phenolics. Hardwoods, on the other hand, have no resin acids or monoterpenes, but do contain fatty acids (60-90%) and phenolics. Tom noted that the point is the structure and composition vary significantly between softwoods and hardwoods.

- Regarding wood densities, Tom showed a slide that indicates that densities/specific gravities of tree species don't necessarily differentiate well between soft and hardwoods. For example, the densities of hardwoods on this slide vary from 0.60 (black maple) to 0.71 (white oak) while the softwood on this slide has a density right in the middle of that range at 0.64 (southern longleaf pine).

- Regarding wood side hardness, Tom pointed out that hardwoods do have higher Side Hardness (N) values than softwoods. On Tom's slide, hardwoods vary in hardness from 3,800 for black ash to 6,500 for some birch, while softwoods vary from 1,600 for spruce to 3,200 for Doug-fir. Marc asked if these values are derived from something similar to the Rockwell hardness test and Tom confirmed they were.

- Regarding an overview of the literature, many European studies (on different wood species/types such as cordwood, pellets and "garden biomass" on modern stoves and boilers) have collected PM_{10}, $PM_{2.5}$, PM_1, EC, OC and odor data. Tom noted that these European studies show high inter-species variability dependent on the location of the tree and growth conditions as well as the combustion environment.

- Tom discussed the 2009 Kinsey et.al. study ("Evaluation of methods for the physical characterization of the fine particulate emissions from two residential wood combustion appliances") which looked at 3 burn phases of a non-catalytic woodstove burning northern red oak and Douglas fir cordwood at two different moisture levels. On the slide showing results, Tom compared Stove-Dry Oak to Stove-Dry Fir and noted that from this particular study one could conclude that the oak is worse (higher emitting/"dirtier") than the Douglas fir, although the error bars are large.

- Next, Tom discussed the study by Fine, Cass and Simoneit ("Chemical Characterization of Fine Particulate Emissions from Fireplace Combustion of Woods Grown in: Northeast, Midwest & Southern US") that identified the top 21 wood species in the US, selected 18 for testing and divided them into four groups based on geographical location. BNL looked most closely at the study results pertaining to Northern red oak (moisture content of 14%, DB) and Paper Birch (MC of 9%, DB) from the Northeast and, from the Midwest and West, American beech (MC of 13%, DB) and Douglas fir (MC of 19%, DB). The study's methodology included oven-drying the cord

wood and burning it in a conventional masonry heater while sampling 4 meters above the fire using a dilution source sampler (with cyclone separators).

- Tom further noted that results showed a mixed bag which made it hard to conclude much regarding hardwood versus softwood: American Beech at 9.3 ± 1.0 g/kg; Northern Red Oak at 5.7 ± 0.6 g/kg; Douglas Fir at 4.0 ± 0.8 g/kg; and Paper Birch at 2.7 ± 0.3 g/kg. In addition to fine particulate emission rates, results provided EC & OC, ion species and elemental species. There were a series of 6 sampling trains operating in parallel: 2 for EC/OC; 2 for gravimetric mass determination (1 L/min, Teflon filter); and 2 for gravimetric mass, IC and XRF analyses (15 L/min, Teflon filter). Uncertainties were based solely on analytical & measurement errors. Interestingly, there was no observed correlation between wood moisture content & fine PM rate. The authors believed increased emissions were a result of sap inclusions within wood. The average particle size distribution showed little variation from wood to wood (with the peak at 100- 200 nm).

- Next, Tom discussed the 2015 Gullet et.al. NYSERDA study entitled "Environmental, Energy Market, and Health Characterization of Wood-Fired Hydronic Heater Technologies" which looked at Red Oak versus White Pine cordwood as well as pellets. Tom noted that since efficiencies were very low due to cycling, it was best to examine the Heat Input graphs, rather than the Heat Output graphs. In this study, White Pine is higher emitting/dirtier than Red Oak. Species-wise, this is the opposite of what the earlier studies concluded, Tom pointed out.

- Next, Tom discussed the OMNI/Fairbanks study which looked at Birch (hardwood) versus Spruce (softwood) burned in both an EPA certified woodstove and a conventional woodstove. In both types of stoves, emissions were higher from the Birch than from the Spruce.

- Marc noted that these studies are showing different results from woodstoves versus hydronic heaters when comparing hardwoods to softwoods. Tom agreed, although noted there were also the differences in the testing methodology, researchers, etc – so there could be many reasons for the differences. Tom noted that the bottom line is that BNL didn't see a clear case that one species is always worse or better (higher or lower emitting) than another species. Marc noted that this meant there really wasn't anything to conclude. Tom agreed, noting that he wished the situation were different, but there is not a clear picture regarding species and emissions.

- Tom proceeded to discuss the next slide regarding the OMNI/Fairbanks study which looked at EPA qualified outdoor hydronic heaters and Non-qualified outdoor hydronic heaters when burning Birch and Spruce. For the EPA qualified HH, again the hardwood (Birch) is higher emitting than the softwood (Spruce). But for the conventional non-qualified HH, the picture is not so clear and it suggests the Spruce is higher emitting than the Birch, especially at the low burn rate.

- Lisa noted that this OMNI study looked at Birch, not red oak, as the hardwood, but in one of the previous studies Tom discussed, Beech had higher emissions. Marc noted that's what he recalled as well.

- Next, Tom discussed a European study authored in part by Christoph Schmidl entitled "Odor, gaseous and PM10 emissions from small scale combustion of wood types indigenous to Central Europe." The authors looked at many different species, using two different stoves. Tom noted that, for the purposes of discussion, he'd focus on Stove A and look only at actual cordwood fuels (not wood pellets, wood briquetts, dry leaves, pine cones and pine needles which were also examined in the European study in addition to 12 cordwood species). Tom noted this was a careful study which produced good data, based on a scripted operating procedure which was the same for all species examined. Nonetheless, Tom noted that the results are all over the place – for example, when looking at the PM10 results (in mg/MJ). The bar chart shows that oak is worst in this study.

- Tom concluded that, based on BNL's literature survey, there is not a clear case on species trend based on the data. Marc and Lisa thanked Tom and Lisa noted that she would post Tom's slides to Basecamp.

- Lisa noted she understood the trends are all over the place, but asked if it were still likely true that species impacts emissions and the impact on emissions is as yet unknown, or even this is not the case. Tom replied that was a great question and explained that, all things considered, if you want good repeatability, the same species should be used in testing. Tom further noted that the softwood versus hardwood structure differences alone are a good reason to suspect different results. Tom again asked the group, that if BNL missed any major studies, he'd appreciate group members letting him know.

- Lisa Herschberger asked if any of studies looked at the composition of the PM to see why the results are different to help explain them. Tom replied "not really" and noted that the Fine, Cass and Simoneit study on masonry heaters looked at organics in the PM, but didn't link those results back to the species involved.

- Marc asked, in terms of the fuel loading in each study, if that information was available (e.g., weight of wood fuel over volume in meters^3 of firebox). Tom replied that such data is available for most of the studies, but he didn't prepare that in the summary format.

- John Crouch noted that burn rates are typically higher in Europe [than in the US]. For example, the European study indicated burn rates of 2.7 and 2.8 – these are high burn rates. Tom agreed, noted they were consistently high although there was some variability. John noted that Americans need to look at that as Europeans often burn at higher burn rates - both in terms of testing conditions and in–home conditions, because Europeans use smaller appliances and burn them hotter. Lisa thanked John, noting she was wondering the same. John also noted that Europeans tend to test with hardwoods which will burn hotter (in g/kg) than softwoods, and asked Bob Ferguson to correct him if he was wrong. Bob agreed that was the case and explained that, generally for the same air setting, the softwood will burn faster. That is, one has to set the stove at a higher air setting to get the same burn rate on hardwoods as softwoods. Bob also noted however that the run on hardwoods is a lot longer than on softwoods.

- Lisa asked, regarding loading protocols, if the study authors loaded the same type of charge (i.e., were they normalized by weight) and did they measure emissions over the entire fuel charge or over just one period of time. Tom noted that the European/Schmidl study used a pretty rigorous/constant loading protocol, but Tom did not know if they measured emission over the entire fuel charge or over just one period of time. Tom also noted that the answer would only apply on study-by-study or researcher-by-researcher basis.

- Tom noted that he wished, for example, that the softwoods in the studies had consistently come out 25% higher than hardwoods, so we would know what was going on. But he didn't see that in the studies. Lisa thanked Tom and noted again that she'd put his slides on Basecamp.

Bob Ferguson's ASTM Cordwood Test Method Development Discussion:

- Bob Ferguson began presenting his slides entitled "A Discussion of the Development of the Proposed ASTM Cordwood Test Methods for Room Heaters – Part 1". [Note: These slides are posted to Basecamp.] Bob noted that this is a revisited presentation that he gave to EPA and some states back in February, which has been updated to include developments that occurred between February and September (now). He has broken up this large presentation into 3 parts and encouraged people to ask questions along the way, as needed.

- Bob noted that the presentation will cover the development timeline, background, highlights of proposed method (meaning Section 9 which is the meat of method). The Section 9 procedure includes the pre-conditioning (stove breaking in), test facility, usable firebox volume (UFV), and test fuel load requirements (including a test fuel load calculator, to make the determination easier for people following the method).

- Next, Bob reviewed the Cordwood Method Development Timeline, beginning in June 2009 through November 2010 when ASTM E2780 was developed and published. Bob explained that ASTM E2780 is an updated M28 with a cordwood annex attached to what was otherwise a crib standard. Then there was a lull in development from November 2010 until 2013. From February 2013 to July 2014, development of the current draft ASTM Cordwood Test Method began. This method initially used a hot-to-hot test cycle, like M28, but used cordwood instead of crib. There were at least 12 calls/meetings and 9 drafts of that method, including a task group (TG). Starting in August 2014, the method was changed to a cold start. Through August 2015, there were 23 calls/meetings and 10 drafts created. The key documents and method drafts were provided to the TG e-mail list and posted on ASTM's website. Bob noted that anyone can go there; one doesn't have to be an ASTM member to view these. It's an open process.

- Bob continued, explaining that the subcommittee ballot is the first level and there was a successful sub-committee ballot in September 2015 with only minor revisions. The revisions were addressed in a subsequent draft, followed by concurrent sub-committee/main committee balloting in January 2016. Substantive negatives and comments were received from NESCAUM and EPA. (Bob noted that negatives and comments are treated the same way in the ASTM process.) There were 6 additional meetings/calls to address those comments and negatives,

including reviewing all the references/supporting materials. A revised draft, including revisions based on those negatives and comments that were found to be persuasive, was released September 8, 2016. That revised draft went out for first round of balloting which closes October 17, 2016. Bob again noted that the process is open. If successful, the sub-committee ballot will move to main committee balloting. This is a second opportunity for comment. If main committee balloting is successful, it will move to ASTM review and then onto editors for form and style, and ultimately publication as a new ASTM Standard Test Method.

- Next, Bob moved onto the Background slide, noting that the primary driver for the new cordwood fuel and operating test method has always been to have a method that more closely represents the way stoves are used in homes. With crib fuel, there is no consistency, a lack of correlation between lab versus field performance. Dr. Jim Houck published a paper in February 2012 which demonstrated that cribs don't predict cordwood performance. Specifically, Houck found that (1) stoves with low crib certification results can perform less well on cordwood than stoves with higher crib scores, and vice versa; and (2) the average emission rates for certified stoves are much higher when tested under real-world conditions with cordwood. Bob noted that, for the past thirty years, by necessity, the engineering mission for manufacturers has been to optimize performance for the fuel and test conditions specified in Method 28, and not necessarily to optimize performance under real world conditions.

- Bob further noted that the original decision to use cribs (in the early 1980s based on Oregon's work) assumed there would be better test method precision but we know that the inherent variability when burning wood, even cribs, overpowers other sources of imprecision. Bob also noted that tightening test parameters in an attempt to improve precision in the lab will only increase the lack of real world representativeness. In light of this, everyone agrees that moving to cordwood and specifying O/F procedures that better represent in-home use is where we want to get to.

- Bob noted that Houck's paper pointed out cold starts by homeowners occur commonly. Therefore, the lack of a cold start in the lab is key problem regarding why lab performance is not lining up with field performance.

- Bob explained that the ASTM TG felt that using cordwood for the test fuel, with the possibility of some additional variability in results, is a good trade-off that should have positive benefits for the homeowner and the environment. Stoves will have to be designed to have good performance even with variation between test fuel loads. Accordingly, in terms of defining the test fuel loads, ASTM has attempted to recognize the inherent variability that can be expected with cordwood (every fuel piece is different) and then add some controls regarding how the test loads are assembled to help ensure that the test loads are generally toward the middle half of the distribution of possibilities.

- Lisa asked Bob how ASTM defines an outlier piece of cordwood. Bob explained that the TG recognized the fact that anything from sawdust to half a tree could be in a woodpile, but tried to reduce the width of the variability in piece sizes that went in. There was lots of discussion, but

no scientific way was developed. The piece sizes are not based on the middle 50% of a bell curve, for example. So there was no official method [for determining allowable piece size], the TG just recognized that we wanted as much variability as we could, without getting too far afield.

- John Crouch noted that everyone would welcome a survey [regarding typical piece sizes used in the field], if someone wants to fund that study. But the TG didn't want pieces to be specific to any states; rather the draft ASTM method attempts to represent the national average in terms of piece sizing.

- Lisa noted that the beReal process did put out a survey, which might be interesting to contemplate. John noted that the beReal process was not random. Lisa agreed, noting that no one will ever have the funds to do a nationwide random sample. Everyone agreed.

- Bob noted that in the past Skip Arnett and OMNI monitored woodpiles and some of those studies provided fuel weight. Bob explained that somewhat uniform pieces can vary by 100% in weight, meaning some pieces can weigh twice as much as other pieces of similar size. Bob again explained that the ASTM members merely attempted to stay in the middle of what we perceived typical piece size to be.

- Lisa noted that it should be recorded in the notes that useful research would regard how much variation in piece length and weight is typical in the field, before getting too far out of the norm. Everyone agreed this was important to research.

- Bob continued his presentation, noting the slide that showed photos of cordwood versus the dimensional crib wood lumber. It was also recognized by the ASTM TG that the manufacturers must provide concise information to consumers about how to achieve the best in-home performance. This includes information about the fuel itself plus kindling and start-up instructions, loading and reloading, etc., that will help achieve the best possible results. Bob further noted that EPA recognized the importance of these instructions, both during the ASTM test method development process and also in the new NSPS, where use of improperly seasoned fuel and failure to follow manufacturer's instructions are considered violations of federal law.

- In summary, the ASTM TG concluded that the move to cordwood and the specification of other operating conditions that better reflect homeowner use patterns including adding a cold start, should significantly improve the representativeness of lab test results when compared to in-home performance. The TG also recognized the importance of providing concise operational information to the stove user. This will become even more important as the stove technologies evolve in response to the challenges presented when testing with cordwood using this new protocol.

- Bob further noted that the TG relied both on the members' extensive experience in woodstove design and testing, but also on test data, some of which were developed expressly to inform TG's consensus based decision-making. For example, the test program undertaken by Mark

Champion (starting in November 2014 and continuing into summer 2015) is the poster child in this regard, but other data development was also undertaken (e.g., by Myren Consulting, Polytest and several manufacturers). The extensive data and observations used to formulate the proposed cordwood method were made available for review by all TG members and any other interested parties. Bob noted that every effort is made to achieve the widest exposure and stimulate the most feedback possible.

- Bob further explained that concerns, comments and suggestions from all sources, including EPA and the participating states, were considered on the merits during the method development process. Based on the data-driven approach, some were supported or accommodated in the method drafts while others couldn't be supported and were dropped. No comments, suggestions or feedback were dismissed without consideration by the TG. There are over 100 names on the TG e-mail list, including a number of state and federal regulators. While some didn't participate in conference calls, everyone on the distribution received all TG e-mails including drafts, proposals, data or supporting materials and meeting reports. Everyone also had access to the ASTM Collaboration Area where those materials were also made available on-line.

- Bob noted that the next part of the presentation went over Section 9. Section 9, in every ASTM method, is always the test procedure. Section 9.1 regards the Pre-conditioning of the wood heater. Bob explained that each heater is burned for a certain amount of time to break it in. The conditioning time changed during the development of ASTM 2780. (Bob noted that ASTM E2780 is the successor to EPA M28 and is also the predecessor to the current ASTM draft cordwood test method.) With E2780, the pre-conditioning time was changed to 48 hours for all appliances, based on 8-hour day shifts. This leveled the playing field for everyone. ASTM did get comment from EPA that EPA wanted to go to 50 hours. So ASTM added the extra 2 hours, as it was not worth further discussion.

- Section 9.2 regarding installing the wood heater in the test facility. The ASTM draft cordwood method uses the same flue gas and surface temperature requirements as in M28 and E2780. The flue gas temperature is needed for CSA B415.1-10 Efficiency Determination AND to demonstrate cold start conditions are met. (Marc asked if the Canadian method is a stack loss method and Bob confirmed that it was.) The stove surface temperature is needed only to demonstrate that cold start conditions have been met. Bob further noted that there are no Stove Body ΔT or ΔQ requirements in this method. As background, Bob explained that Stove Body ΔT was an EPA M28 requirement that the average stove body temperature at the end of a test run must be within 125°F of the average stove body temperature at the end to the test run. This was intended to prevent overly hot starts on lower burn rate test runs. However, it does not account for difference in stove mass for any given size stove. For example, a soapstone stove has much higher mass than a steel stove of the same size. (John explained that it was also very difficult for large catalytic fireboxes. Bob agreed and noted that for some stoves it worked fine, while for others it didn't.) Stove ΔQ was added to ASTM E2780 as way to account for the differences in stove mass in terms of the amount of heat stored in the stove relative to the total amount of heat input from the fuel. Bob explained that 100 lb stoves versus 600 lb stoves present a huge difference in the amount of energy stored in the stove for any given increase in

burn rate. So the ΔQ was a way of leveling the playing field for low mass versus high mass stoves. But, there is no ΔT or ΔQ requirement in the ASTM draft cordwood method, because Mark Champion's data showed no need to retain either. In an effort to mimic realistic operation in the lab, stove temperatures are allowed to be where they may be, based entirely on the realistic fueling and operating protocol.

- Bob noted that the ASTM draft method also started requiring photographic records of the test, to eliminate any concerns/questions of what's going on. Photos of the complete test set-up are required. This is a theme throughout the method where photographic or video documentation is required in addition to the typical data gathering. Any interaction with the stove requires photos. This is evidence that the test method is done appropriately. Bob noted that ASTM and industry doesn't like the idea of people taking advantage of the test method any more than a regulator does; we want a level playing field too.

- Bob began going over Section 9.3 the usable firebox volume (UVF) determination. The UVF determination relies in large part on Manufacturer's Written Instructions. The prior language (M28/E2780), in which nearly every open space was included in the usable volume, raised many concerns as the test fuel loading density was increased from 7 lb/ft^3 to 10 and 12 lb/ft^3 for cordwood testing. In some cases, it was shown that it was difficult or impossible to get the last fuel piece into the stove or with a fuel piece in a location that could interfere with the functionality of the combustion process.

- Regarding Section 9.4 Test Fuel Load Requirements, Bob noted that this issue required many phone calls/meetings and the more random the fuel the more important it is to have good documentation. Codifying a more random fuel load became very complicated. All stoves are capable of holding more cordwood than crib due to the lack of spacers. There was discussion of a sliding scale based on firebox volume, recognizing that smaller stoves can be harder to load. Ben Myron did a bunch of loading and photos to put visual on the different loading densities. So there was a lot of discussion on this topic, and concerns were resolved with a later proposal. There were several discussions of a volume-to-volume ratio concept, that is maintaining a ratio of firebox volume to wood volume. This removed the fuel specific gravity (or species) from the test fuel load determination. But, it introduces the potential for big differences in test fuel load weight which can, in turn, impact emissions. Going back to the 1970s, Bob explained there are studies on fuel loading densities. This variability was problematic. After much deliberation, it was determined that using test fuel load density was the most straightforward approach. In other words, mass of fuel based on usable firebox volume – lb. of wood/ft^3 of firebox volume.

- Bob next explained the concept of attended vs unattended fires. Attended versus unattended fires implicates how much fuel is placed in the stove per load. Low Fire falls into the unattended category, while High fire is attended. Medium Fire could go either way but TG classified it as unattended.

- Bob explained that the ASTM discussion then moved to load density requirements. It was generally agreed that the high fire load density (attended fire) should be lower than the load

density for the low and medium fire test runs. Homeowners will place less fuel in the stove when trying to achieve a high heat output, especially from a cold start. During high fires, the homeowner is not looking for a packed stove to achieve an overnight burn. The fire is likely to be attended and if more heat is needed, extra fuel pieces will be added. The High Fire Load Density was increased from an initially proposed value of 7 lb/ft^3 to 10 lb/ft^3 based on the visual appearance of the test fuel load in actual fireboxes. For Low Fire, load densities from 12 – 15 lb/ft^3 were considered. Based on trial loading conducted by Ben Myren and others, it was realized that loading above 12 lb/ft^3 would be problematic for many stove models. The loads simply wouldn't fit due to the typical obstructions and inaccessible volume in many models. For example, space above bricks might be counted in UFV determination but wood in the test fuel load won't necessarily occupy that space. The final conclusion based on all the TG input, is the following:

    - Nominal High Fire Test Load Density – 10 lb/ft^3;
    - Nominal Low and Medium Fire Test Load Density – 12 lb/ft^3;
    - It should be noted that these represent 43% and 71% increases over M28.

- Since many had to leave the call at this point (the scheduled ending time), it was decided to pause Bob's presentation here. [Note: The presentation ended on Slide 19; Bob's next presentation should resume on Slide 20.]

- Everyone should post their questions for Bob (or Tom) to Basecamp.

- Lisa and Marc thanked Bob for the great presentation.

- **Meeting adjourned**.

September 29, 2016 Agenda
Cord Wood FRM
Operation and Fueling (O/F)
Technical Workgroup

1. Call to order, Announcements, Roll call,
2. Review agenda for next three calls
    a. Sept 29:
        i. Brookhaven Wood Species Literature Review, Dr. Tom Butcher
        ii. Intro to the ASTM test method, test fuel load concepts, Bob Ferguson
    b. October 6:
        i. Wood density as possible solution to the species issue, Rick Curkeet
        ii. ASTM part 2 - Test fuel properties, and moisture content, high fire test category, cold starts etc, Bob Ferguson
    c. October 13:
        i. BeReal's Christoph Schmidl
    d. October 20:
        i. EPA Research Efforts, Adam Baumgart-Getz
        ii. ASTM part 3, low and medium fire, overall efficiency, test method outputs, weighted averages, Bob Ferguson
        iii. General Questions and discussion of ASTM
3. Presentation: Brookhaven Review of Literature on Wood Species Impact – Dr. Tom Butcher, BNL
    a. Q/A & Review
4. Presentation: Intro to the ASTM test method, Test fuel load concepts, Bob Ferguson
    a. Q/A & Review
5. Final Questions, comments, items